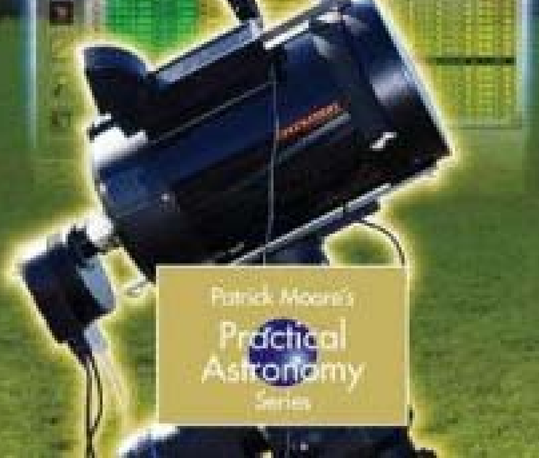
Rod Mollise

Choosing and Using a New CAT

Getting the Most from Your Schmidt Cassegrain or Any Catadioptric Telescope



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About the Author

Rod Mollise is an engineer by profession. He is also the author of numerous books and magazine articles on every aspect of amateur astronomy. Known to his fans as "Uncle" Rod Mollise, he is most well known for his books about catadioptric telescopes (CATs), which aim to help new CAT owners get past the inexperience and anxiety that often accompanies their entry into this wonderful hobby. In addition to his books and Internet sites, Rod's writings can frequently be found in *Sky & Telescope, Night Sky Magazine, Astronomy Technology Today*, and many other publications.

Rod also finds time to teach astronomy to undergraduates at the University of South Alabama in Mobile. When he is not on the road attending and speaking at star parties, he shares a rambling old Victorian home in Mobile's Garden District with his wife, Dorothy, two (four-legged) cats, and, at last count, 11 telescopes.

Acknowledgements

Thirty-five years of using and loving Schmidt Cassegrain telescopes (SCTs) has taught me a few things about these wonderful telescopes, but I hardly know everything. This book would not have been possible without the assistance of many kind and generous members of the amateur astronomy community.

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CHAPTER ONE

Why a CAT?

Since you're reading this, I'm guessing you have made an exciting decision: *You want a telescope.* Specifically, you want a telescope for looking at the sky, a telescope that will open the depths of space to your gaze and allow you to visit the Moon, the planets, and all the strange and distant wonders of our magnificent universe. And you are not looking for just any telescope, either, but for a Schmidt Cassegrain telescope (SCT), whose full-color advertisements fill the pages of astronomy magazines.

In our consumer culture, most of us have become wary of high-pressure ads from manufacturers who promise the Moon and deliver little. Luckily, that is not the case when it comes to SCTs. Sometimes, the advertising does contain hyperbole, but Schmidt Cassegrains really *can* deliver the Moon—and the stars, too.

SCTs, like anything else, are not perfect, but when all is said and done, the Schmidt Cassegrain may be the most versatile, technologically advanced, and easy-to-use telescope ever sold to amateur astronomers. Since SCTs were first offered at prices the average person could afford way back in 1970, they have dominated the amateur astronomy telescope market. Don't believe that? Take a stroll around the observing field of a local astronomy club during the next star party. Chances are a majority of the telescopes there will be SCTs. Fancy advertisements alone simply could not account for the enduring popularity of Schmidt Cassegrains. Something good is going on.

Not that an SCT (Plate 1) *looks* much like a telescope of any kind to novice astronomers. Catadioptric telescopes (CATs, for short), which are telescopes that use both lenses and mirrors, do not much resemble the telescopes we are used to seeing in the movies or on television. The eyepiece is where it "ought" to be, at the end of the tube, and that tube is perched on a tripod, but that is where the similarity ends. The tube is short and fat, looking more like a beer keg than a respectable

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Plate 1. (SCT) An 8-inch Schmidt Cassegrain telescope set up at a dark site and ready for an evening of deep space voyaging." Credit: Author

telescope. It is not just attached to a tripod, either. It is sitting on a complicated-looking "mount" festooned with myriad lights and switches.

The SCT looks different enough in beginners' eyes to be positively frightening, maybe scary enough to make a new astronomer who just wants a good look at the craters of the Moon turn tail and run. Appearances can deceive, however. The SCT is at heart an uncomplicated telescope. Despite its looks, its basic operation is easy to understand, and it is actually one of the most user-friendly scopes ever made.

And, it is not just user friendly. A beginning amateur astronomer may start out just wanting a look at the good old Moon but will soon find the faithful SCT can take even a novice observer way beyond our cosmic neighborhood—maybe even as far as the daunting depths of the universe inhabited by the mysterious quasars. Although nothing in the design of the SCT is astoundingly innovative, its basic layout is extremely sound and features good optics in sizes sufficient to take even a tyro a long, long way from home.

Capability is just the beginning of the SCT story, though. What also sets these CATs apart is their versatility. Other telescope types—Dobsonian reflectors and apochromatic refractors, for example—may do some things better than the SCT, but no telescope is as capable of doing so *many* things as well as the Schmidt Cassegrain. One of the reasons is that, like the personal computer, the SCT is a *system*. Much as the personal computer (PC) industry has done, the world's two SCT makers, Meade and Celestron, have standardized their products. A camera adapter sold by Meade will usually work just as well on a Celestron. Also, as in the computer industry, there are numerous third-party manufacturers making accessories for the telescopes. Actually, some of the best accessories for Meade and Celestron SCTs do not come from either company but from the hordes of aftermarket vendors large and small. SCTs have been in production and basically unchanged for nearly 40 years, and that means any accessory imaginable—focus motors, digital setting circle computers, electronic cameras, spectrographs, and much more—has probably already been made by somebody and will work on any Schmidt Cassegrain, old or new. As astronomy interests change over the years, an SCT can also change.

Does the SCT's ability to do so many things in astronomy have a downside? An old aphorism that is often all too true is "jack of all trades, master of none." In some ways, that *is* the case when it comes to CATs. As good as an 8-inch SCT is for planetary observing, for example, it will never be able to do quite as well as a high-priced apochromatic refracting (lens-type) telescope. As far as it may be able to voyage out into deep space, it will never show as many objects as a Dobsonian reflecting telescope with a 20-inch diameter mirror.

The SCT really does not fall far behind any other telescope in doing anything however. The differences in the planetary images of an SCT and a refractor are small and subtle. New observers may not be able to detect this difference for years. When observing deep space objects, the SCT has some features that help it keep up with the largest Dobsonians. Following is a discussion of a few of the many things a Schmidt Cassegrain can do well.

Deep Sky Visual Observing:

There are lots of cool things out there in deep space for you and your friendly CAT to look at and admire: star clusters, nebulas, and galaxies. The SCT is not only capable of showing these deep sky objects (DSOs), it **is** able to deliver remarkably detailed visual images of them under good sky conditions. It can do that because of its generous *aperture* (the diameter of the main mirror). To see an inherently faint object like a galaxy well, what **is** needed is plenty of light. Not all telescope designs are created equal in this regard. A very large refracting telescope, for example, will have an objective lens 6-inches in diameter. An *average* SCT has a main mirror 8-inches in diameter, which will collect nearly twice as much light as the 6-inch lens (objective *area*, not diameter, is what counts). Also, a fine 6-inch refractor is a fairly heavy and very expensive instrument. An 8-inch SCT, in contrast, is light, easily transported, and inexpensive enough to be within the financial reach of just about anybody.

It is not just optics that have allowed the SCT to pull ahead in the contest for the hearts and minds of amateur astronomers who are interested in deep sky observing. Almost all SCTs currently available have easy-to-use go-to computers. What's "go-to"? Select the object of interest on a little TV remote control-like "hand controller," push a button, and a pair of motors automatically points the scope at the target and tracks it as it moves across the sky. This is a boon for people more interested in looking *at* objects rather than looking *for* objects. Big Dobsonian telescopes, which are often recommended for deep sky observing, usually do not have go-to, and finding objects to observe often involves squinting at star charts and peering though dim finder scopes. Some Dobsonians can be adapted for go-to and can use other computerized pointing aids, but in general they are still not as accurate or easy to use as a go-to SCT.

Another Schmidt Cassegrain advantage for visual workers is the *comfort* inherent in CATs. An SCT allows its user to observe anything in the sky while comfortably seated. A big Dobsonian telescope can deliver a lot of that prized light, sure, but to see anything, the observer will often be swaying at the top of the tall ladder required to reach the eyepiece observing position of a large scope. A DSO may be brighter in the Dobsonian, but if it can be viewed in comfort while seated, almost as much—or more—may be seen in an SCT with a considerably smaller aperture. Nearly all Schmidt Cassegrains can track stars and other objects across the sky via built-in motor drives, allowing an observer to sit and stare at a galaxy for as long as desired, until the object sets or the Sun rises, anyway. Most Dobsonians lack any kind of motor system to make up for Earth's rotation. "Dob" users must continually nudge the scope along to follow objects, which can be distracting. Push a button to find an object. Sit comfortably to view it. Stare at it for as long as desired as it sits centered in the eyepiece. What could be better for visual deep sky observing?

Solar System Observing

There is a lot to view in the "great out there" of deep space, but there are also myriad wonders closer to home in our cozy little solar system: comets, asteroids, and most of all, the planets. When it comes to visual observing of the planets, as mentioned, the SCT cannot claim to be "the best." The refractor really is tops here. The SCT *can* deliver excellent solar system images, though. When the atmosphere is steady, you can bump up the magnification on a C8 SCT to over 400× and not only see the rings of Saturn but also detect subtle *detail* in the rings—detail that may escape a smaller-aperture refractor. Light, you see, is also important in planetary observation. Sharp is good, but if the image is so dim the eye has difficulty picking out details, the refractor's razor sharpness does not do much good.

The other pluses the SCT brings to the deep sky help it master the solar system as well. These telescopes' excellent, accurate drive systems are even more of an advantage in the realm of the Sun than they are in deep space. Imagine trying to nudge a telescope along to keep Jupiter in view at a magnification of 500×. Sitting relaxed on an observing stool while looking through the eyepiece helps even more when viewing the planets than it does viewing deep space objects. The planets—especially Jupiter and Mars—offer a wealth of detail, but it is subtle. When trying to see these details, being comfortable and relaxed really helps.

Imaging

In my earlier book, *Choosing and Using a Schmidt Cassegrain Telescope*, this section was titled "Photography." Oh, how things have changed over the last 8 years! These days it is hard to find good film to use to photograph terrestrial objects, much less celestial ones. CATs are still taking pictures of the universe, but they are now doing it with sophisticated CCD (charge-coupled device) cameras. The digital picture-taking revolution has hit amateur astronomy with a vengeance, and SCTs are at the forefront.

There is no doubt that digital picture-taking techniques have made the difficult art of astrophotography a little easier; at least you do not have to wait until film is developed to find out whether any of your shots turned out. Taking long-exposure pictures of the deep sky is still a difficult and sometimes maddening pursuit, however. Is an SCT a good telescope to use for digital astrophotography? You betcha.

Although almost any telescope can be adapted for imaging, the SCT is one of the few instruments that will not require sometimes-extensive modifications before picture taking can begin. Newtonian reflecting telescopes, for example, may require their primary mirrors be moved up the tube before a camera can even be focused. The SCT may need the addition of a few accessories before it is ready to take pictures of the sky, but it does not require any major alterations. Tom Johnson, Celestron's founder, designed his Schmidt Cassegrains for astrophotography from the beginning, and Meade and Celestron have continued to pay due attention to astronomical picture taking. Attach a modern CCD camera such as Meade's color DSI (Deep Space Imager) to an SCT, and even a novice can start capturing pleasing shots of the universe's distant wonders almost immediately.

"Deep space pictures of galaxies, nebulas, and star clusters from your first night out!" That may sound like a late-night TV commercial pitch, but anyone who has taken a little time to familiarize themselves with the basic operation of the SCT can get impressive astroimages from night one with modern digital cameras. There is very little to do beyond pushing a couple of buttons to get the scope pointed at your targets and focusing the telescope carefully. Meade's DSI software—like most imaging programs—is full featured but can be operated on a very basic, automated level. You can set up the program to take short images so you will not have to guide out drive errors, stack these images into the equivalent of one long exposure, and keep doing that until you tell it to stop. Just push the "go" button and wander around the field looking through friends' telescopes and scanning the sky with your binoculars while your scope and camera do their thing. After 15 minutes, wander back to the telescope and computer. Staring back at you from the monitor might be the Whirlpool Galaxy in all its glory (Plate 2). No, this image may not be as spectacular as the magnificent pictures in *Astronomy* or *Sky & Telescope*, but it will excite you.

Now, this may not say much about your skills as an astrophotographer. What it does say worlds about is the ease of astronomical picture taking offered by the SCT and modern CCD cameras.

Plate 2. (Whirlpool Galaxy) M51, a beautiful face-on spiral galaxy in the constellation Canes Venatici, is a prime target for CAT users. Credit: Author.

Advanced Applications

The capabilities of the SCT do not stop with visual observing or astroimaging. The Schmidt Cassegrain's versatility means it is a telescope that can handle "advanced" pursuits as well as simple ones. There is nothing wrong with "just" having fun looking at the Moon or showing off the wonders of the deep sky to friends and family. The new SCT owner does not have to take even one picture to be a real amateur astronomer, and nothing says *any* amateur has to contribute to science. One of the great things about amateur astronomy is that there are no rules to dictate how someone should view the night sky or use a telescope. Some amateur astronomers do eventually find they are interested in contributing to our store of astronomical knowledge, however, and undertake some pretty serious research and discovery programs. Many—if not most—of these amateurs are using SCTs for their endeavors.

What can the average CAT user contribute science-wise? How would you like to discover a new world? Amateurs are using SCTs and sensitive CCD cameras to find new asteroids almost every clear night. What else is there? Double-star measurement is a time-honored way for amateurs to contribute to astronomy, and the combination of the SCT with its long focal length and inexpensive high-resolution digital camera is stimulating a rebirth of amateur interest in this important pursuit.

Amateurs have long been engaged in the esoteric but scientifically important task of measuring the changing light output of variable stars. In the past, this had to be done by estimating brightness by eye or, if the amateur had the financial resources, measuring it with an expensive "photometer," a special light meter. That has all changed. The exact brightness of these fascinating stars is now easy to pin down with a CAT and an inexpensive CCD camera. The SCT's reliable and accurate go-to is proving to be a real plus for variable-star observers. In the bad old days, considerable time had to be spent just locating stars of interest.

Do these scientific pursuits sound interesting except for the fact that they require spending hour after hour in a dark, cold backyard? Then, you will be pleased to learn that most current go-to SCTs are easy to control remotely from the warmth and comfort of your house.

SCT Liabilities

Yes, I am enthusiastic about Schmidt Cassegrains and other CAT designs. That is why I have come to be known as "Mr. SCT" by fellow amateur astronomers. However, they are far from perfect. The SCT design, like that of any other telescope, is a compromise. SCTs and other CATs have some minuses to go along with the pluses I have been gushing about. Do not think these minuses outweigh the pluses, but prospective buyers should be aware of them.

Contrast Problems

SCTs are obstructed telescopes. What that means is that there is an obstruction—a "secondary" mirror—placed in front of the main (primary) mirror. Optical experts say obstructing the primary mirror of a telescope in this fashion will inevitably degrade the contrast of its images because light is scattered by the secondary into places where it should not go. Any reduction in contrast is potentially harmful for planetary observers. When straining to make out an almost-invisible cloud band on Jupiter, the last thing that is wanted is reduced contrast. Any telescope that uses a secondary mirror to divert light to an eyepiece will be affected by this problem, but the SCT is particularly troubled by this effect due to the size of its secondary mirror. To keep a Schmidt Cassegrain's tube short and easy to mount, the secondary mirror's diameter must be relatively large, often as much as 30% the size of the primary mirror.

That is pretty big, true, but the simple fact of the matter is that an obstruction of any size in a telescope's light path, no matter how small, will damage contrast. Even a Newtonian reflector with an obstruction of less than 20% will have lost out when compared to an unobstructed design like that of a refracting telescope. The question is, does the larger secondary of the SCT make things much worse? Based on my 43 years of observing experience with telescopes of all types, the answer is, "No"—or at least, "Not much."

Listening to scope "experts" down at the local astronomy club or on the Internet go on and on about this issue, the novice will get the idea that a C8 must produce planetary images not much better than those of a 60-mm junk-o-scope from a discount store. This beginner will then be amazed at his or her first look at, say, Jupiter, through a Schmidt CAT. The job an SCT can do on Jupiter or any other planet is simply astounding. There are plenty of belts to see, and subtle colors are easily discernible on Jove's huge globe. The Great Red Spot will not just be visible; there may be detail *within* it. Maybe this image will not be quite as high in contrast as one in a refractor, but as mentioned, the SCT at least delivers more light than all but the most horrendously expensive lens scopes (priced an 8-inch refractor lately?), and in my opinion, this extra light does a lot to make up for the Schmidt Cassegrain's contrast faux pas.

Collimation

A Schmidt Cassegrain can only produce beautiful images if it is properly collimated. If the primary and secondary mirrors are not properly aligned with respect to each other, expect Jupiter to look more like a custard pie than a planet. Because the SCT uses a convex-shaped secondary mirror that magnifies images five times, it is particularly sensitive to miscollimation—errors are magnified. The good news is that the Meade and Celestron SCTs are the easiest of all telescopes to collimate, and once adjusted they may remain in good collimation for years. Do check the collimation occasionally, but you might find you do not have to change anything—despite some bumpy trips over back roads—for at least several years.

Small Aperture

An 8-inch SCT's mirror looks positively huge to a novice amateur astronomer—until the first time the scope is set up next to a 20-inch Dobsonian at a star party, that is. Suddenly, the "big" SCT will seem pretty puny and not very capable of delivering decent images of DSOs or anything else. It Is true that an 8-inch SCT's visual images will never be able to compete with those of a 20-inch scope, but an 8-inch is nevertheless more than large enough to show plenty of good stuff, especially under a dark sky. An 8-inch CAT will reveal thousands of clusters, galaxies, and nebulas, more than most amateurs will ever get around to observing. Many of these objects, the brighter ones, will also show off plenty of detail. M13 will be revealed as a massive ball of tiny stars, M51 will pirouette its graceful spiral arms across the field, and the veil-like folds of M42, the Great Orion Nebula, will seem to stretch on forever. Remember also that if 8-inches is "not enough," SCTs are available in apertures up to 20-inches.

Portability

Are SCTs really portable? Well, sort of. Above 8-inches, the SCT enters the realm of "transportable" rather than "portable." Even with an 8-incher, expect to spend considerable time loading and unloading and preparing the telescope for the night's observing run. An 8-inch CAT, especially a fork-mounted model, may not exactly be lightweight either and may require a lift of as much as 50 pounds to place the telescope and fork on the tripod. What is the setup of a Schmidt Cassegrain like? When transporting a scope to a dark site where it can really rock and roll, the routine goes something like this:

I drive onto my club's observing field and start looking around for a good place to setup. While I'm hunting for a reasonably level spot for the tripod, the Dobsonian owner next to me has pulled her scope's simple wooden mount out of the backseat of her car, plunked the 10-inch scope's tube down in this "rocker box," inserted an eyepiece, and is ready to go. Not me. Not by a long shot.

With the tripod set up and adjusted to the proper height, I manhandle my NexStar 11 SCT's case out of the trunk. I'm glad it's got wheels since the scope and case combo approaches 100 pounds. I position the case as close to the tripod as I can so I don't have to move the 66 pound tube and fork mount far. After gingerly lifting the scope onto the tripod, I hunt around for the three bolts that attach the CAT to the tripod and insert and tighten them.

The CAT is on the tripod with just a little cussing from me, but it's far from ready to observe anything. Not without power. I return to the car for two 12-volt battery packs, one for the telescope and one for the dew heater that keeps the 11-inch SCT's big corrector lens dry. Luckily, for once, I've remembered to bring power cords for both batteries. Ready yet? Not yet.

Not only will I need eyepieces to look through, I'll need a little optical device called a star diagonal so I don't strain my neck while looking. I gather these items, remove and store their covers, screw the diagonal onto the rear port of the telescope, and insert an eyepiece. I can't start viewing yet, though. Not until I get the NS11's go-to computer aligned on the sky by sighting a couple of bright stars. Before I can do that, the "finder" telescope will need to be attached to the main telescope's tube and maybe aligned on a bright star so I can get those initial alignment stars in the field of view of the CAT without a struggle.

If I'm going to be doing any imaging on this evening, I need to set up a table for the laptop, haul its battery out, and connect the PC to the telescope. Next to me, my Dob-using neighbor is happily observing Saturn.

This is an accurate depiction of what is involved in setting up the average SCT. Remember, though: once the CAT is assembled, it can do a whole lot more than any Dob. It is virtually a portable observatory. The average SCT does not dictate its owner's choice of vehicle, either. I have seen 14-inch CATs transported in subcompact autos—including a tiny Geo Metro. A Dobsonian that size may *demand* an SUV or pickup truck.

Is a CAT for Me?

SCTs are good. They can do a lot and do it easily. But, is one the right scope for *you*? You Are the only person who can answer that question, but the following should help.

The SCT may be your scope if

- You have not specialized in a particular "branch" of amateur astronomy and do not intend to. You are an amateur astronomy dilettante. One night it is lunar observing, the next galaxy hunting, the following evening you are taking pictures of Jupiter. If this is you, then *you are a prime candidate for an 8-inch or larger SCT.*
- "Just looking" is okay, but what you *really* want to do is take pictures of distant, beautiful, DSOs. You do not want to or cannot spend a lot of money to do that, either. An SCT, especially one mounted on a GEM (a German equatorial mount), will allow you to play celestial Ansel Adams without breaking the bank.
- You do most of your observing from the backyard, but you like to travel to dark sky sites occasionally. You do not want to give up computerized pointing and other niceties, though. You also want to be able to pack a feature-laden scope into the family's Japanese sedan. An 8-inch or 10-inch SCT is just right for you.
- Your long-held dream is a personal observatory. You want to place a powerful scope in a dome, and you intend to leave it there. The SCT's compact tube in

12-, 14-, or even16-inch apertures allow the size of an observatory to be kept relatively small and helps the dream become an affordable reality.

- You are a geek. You love gadgets and electronics and computers and would no more buy a telescope without go-to than you would an automobile without satellite radio. The top-of-the-line telescopes from Meade and Celestron are not just techno-heavy; they sport features even you will probably never get around to trying.
- You are physically challenged. A 6-inch Dobsonian is too much to move around, even into the backyard. You need a scope that can be broken down into small, easily manageable pieces. Not having to contort your body around a tube to find objects would also be a big help, and sitting while observing is a must. Go-to-equipped CATs are available in ultraportable 6-, 5-, and 3.5-inch apertures.

An SCT may not be for you if

- All you care about is looking. You do not want to take pictures. You do not want to measure stars. You just want to see DSOs the best they can be seen without any technology getting in the way. You do not care if you need a huge truck or trailer to transport the telescope; you just want to see as much as possible. *You want a large Dobsonian, not a CAT of any kind.*
- You are an advanced CCD imager, and you are particularly interested in wide-field shots. You want perfection—and have the money to pay for it. You could still be happy with a top-of-the-line SCT equipped with a focal reducer or perhaps an SCT on a large third-party GEM mount, but you will probably be happier with a big, short focal length refractor.
- You do not like computers, and they do not like you. In fact, you are not fond of electronic gizmos of any kind, and the thought of hauling batteries and computers onto damp observing fields gives you the willies. Your motto? "Simpler is better." You will be happier with a 6- to 10-inch Dobsonian than with a microchip-infested SCT.

Still having trouble deciding whether a Schmidt Cassegrain is the telescope of your dreams? Even if you are pretty sure you do want a CAT, you should get out and see (and use) some in person. Most cities and towns in the United States and Europe have active astronomy clubs. If not, there is likely one within driving distance. Find the local club and join immediately. You will be able to look through members' SCTs at club star parties—group observing sessions—and just as important, you will be able to ask your fellow amateurs questions that will help in your decision. In fact, most amateurs will consider it their personal mission to help you select the right scope. There probably will not be any lack of SCT owners at your club, and you can bet they will be willing to offer their opinions on their instruments—and maybe even offer to let you play "copilot" during the next observing run.

No club? There is always the Internet. True, the Internet is renowned as a source of misinformation as well as information. There are, however, some reliable and friendly venues on the Internet for amateur astronomers. Some of these gathering spots devoted entirely to CATs and SCTs are listed in Appendix 2 of this book. Just like nonvirtual astronomy clubs, these online groups are inhabited by knowledgeable amateur astronomers who are eager to help.

What is next? The following couple of chapters present some history about SCTs and other CATs and how they perform the optical magic that brings the distant universe home.

CHAPTER TWO

What's a CAT?

What allows a Schmidt Cassegrain telescope (SCT) to make distant objects bigger and brighter? Optics: Lenses or mirrors or a combination of the two are the heart of any scope. Everything about a telescope, including its capabilities and its price, is determined by its optical design. Before we find out what makes SCTs tick, let us go back to basics with the simple instruments of Galileo and Newton, the refracting and reflecting telescopes, respectively. The SCT—and the other members of the catadioptric telescope (CAT) tribe—are optical hybrids that combine aspects of these two simple designs, so understanding them is the key to understanding the catadioptric.

The Refracting Telescope

In the beginning, there was the simple refractor, the lens-type scope that was probably first turned on the heavens by Galileo Galilei on a mythic Italian evening in 1609. Galileo did not invent the telescope and may not even have been the first person to use it for viewing the night sky. He *was* the first real astronomer to wield a telescope, however, recording his observations and trying to understand what they meant. The puzzling thing is not that Galileo turned his scope to the Moon, planets, and stars or that he did it in 1609. What is mystifying is that it took so long for someone to stumble onto the idea of the telescope itself since it is such a laughably simple thing.

The secret of Galileo's telescope or any refracting telescope is at the end of its tube, where a large lens is found (Figure 1), the refractor's *objective*. This objective may be, as it was in Galileo's telescope, a single lens or element, or, as in today's refractors, it may be composed of two or more elements. The purpose of the objective

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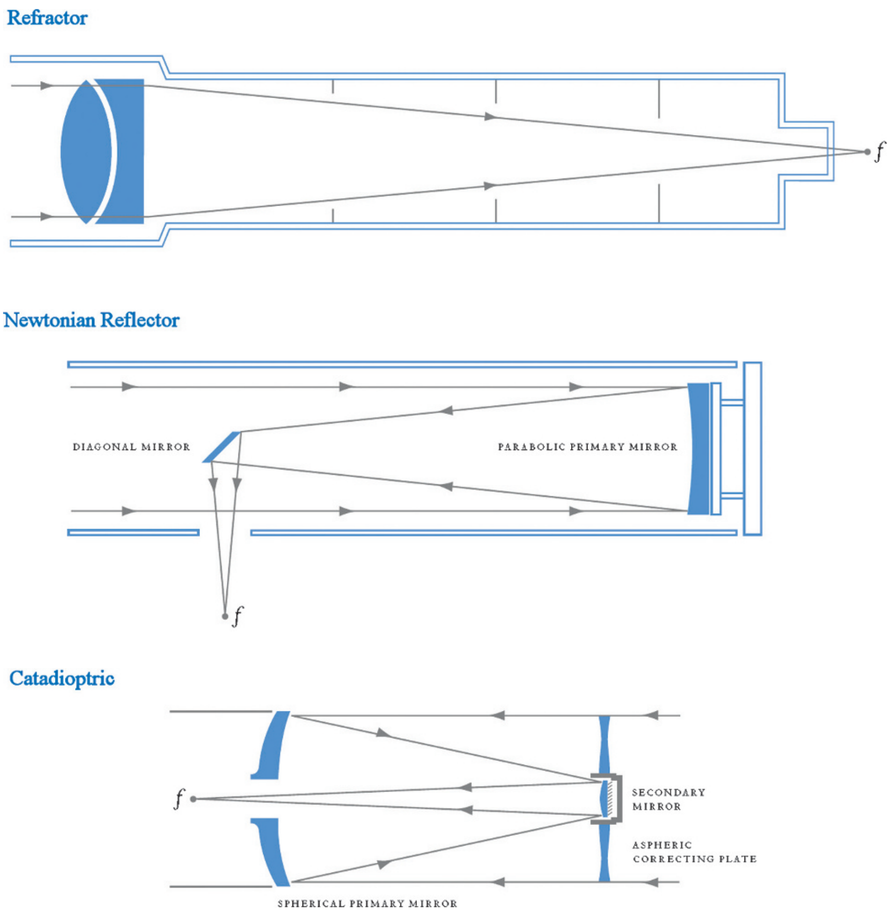

Figure 1. (Telescope Types) The three most common telescope types: the refractor, the (Newtonian) reflector, and the catadioptric (CAT). Credit: Image courtesy of Meade Instruments Corporation.

is easy to understand. Its job is to collect light, lots of light, much more than the tiny lens of the human eye can gather.

The objective not only gathers light, it also brings it to a focus at the opposite end of the telescope's tube. The image formed at this focus is bright but small. In order for the human eye to make out details in this telescopic image, a magnifying glass is placed just past the focus point. This magnifying glass, like the telescope's objective, may be made from one lens element or many and is commonly referred to as an "eyepiece" or "ocular." In modern telescopes the eyepiece can be removed and replaced by one with differently shaped lenses that delivers a different magnification ("power"). A refracting telescope's images are focused, brought to best sharpness, by moving the eyepiece in and out, placing it closer or farther away from the objective. That's all there was to Galileo's telescope and all there was to any astronomer's telescope for many years: a lens to collect and focus light and a lens to magnify this image for human inspection.

Simple as these first telescopes were, astronomers in the seventeenth and eighteenth centuries used them to take humankind's first steps towards unlocking the mysteries of the cosmos. It soon became clear, however, that Galileo's version of the telescope, with its single element objective lens, had some debilitating defects. The most severe of these was *chromatic aberration*. The Galilean telescope's simple lens could not bring all rays of light to the same focus. Red rays, for example, focus at a slightly different position than blue rays. No matter how the focus of the telescope was adjusted by moving the eyepiece, the image remained slightly blurry and deviled by (usually) purple-colored halos around bright objects. Eventually, a means of making refractors "color free" would be found, but lens-type telescopes completely free of this "spurious" color would not be possible for a long time, not until the twentieth century.

Fortunately, it wasn't too long after Galileo's time that a genius turned his attention to the telescope problem. Isaac Newton, perhaps the greatest scientific mind the human race has yet produced, came up with an elegant solution for chromatic aberration. It was obvious the spurious color was due to the basic properties of the telescope's objective. The lens brought images to a focus by bending, by *refracting*, light; that's where the color came from. Why not use something other than a lens, then? A mirror can collect light as well as a lens, and a concave mirror can bring this light to a focus.

In Newton's reflecting telescope (Figure 1), a large concave primary mirror does just that. It gathers light from the sky like a lens. The "Newtonian's" primary mirror then reflects this light back up the tube, where it is intercepted by a small, flat, secondary mirror tilted 45°. This secondary diverts light rays out the side of the tube to an eyepiece for viewing. Since there is no refraction going on, there is no chromatic aberration. Reflecting telescopes have optical problems of their own, but colored halos around bright stars is not one of them.

The refractor and the reflector sound like very different animals, but in some ways they are quite similar. Their basic characteristics are measured and stated in the same ways. The diameter of a telescope's lens or mirror is its *aperture* and is expressed in inches or millimeters. The point at which the lens or mirror brings the light to a focus is the *focal point*. The distance from lens or mirror to this focal point is the telescope's *focal length*. The ratio of the telescope's aperture to its focal length is its *focal ratio* ("speed"). For example, a 6-inch (150-mm) diameter mirror with a focal length of 48-inches (1,200-mm) has a focal ratio of "f/8" (48/6). Telescopes with low ("fast") focal ratios deliver smaller, brighter images and wider fields, eyepiece for eyepiece, than telescopes with high, slow focal ratios. An f/4 telescope with a 12-inch (300-mm) aperture mirror produces a magnification of 48× with a 25-mm eyepiece (300 × 4/25 mm = 48×). A 12-inch mirror with a focal ratio of f/6 gives 72× (300 × 6/25 = 72×).

Birth of the CAT

Isaac Newton's idea for a reflecting telescope was a brilliant one, but it was not long before other scientists and optical tinkerers began to find ways to improve on it. The reflecting telescope designs that have appeared over the last 400 years since Sir Isaac's "Newt" was born are often so different from his original concept that the only thing they seem to have in common with it is that they use mirrors instead of lenses to produce images. Two of these alternate designs, one that appeared shortly after Newton brought forth his telescope, and one that did not come around until the twentieth century, are the direct ancestors of today's Schmidt Cassegrains. These scopes are, as you might have guessed, the Cassegrain telescope and the Schmidt camera.

The Cassegrain Telescope

A Frenchman named Cassegrain came up with a clever design for a reflecting telescope in 1672, only a few months after Sir Isaac wowed the members of London's Royal Society with his Newtonian. What is surprising about Cassegrain is that, considering the impact his idea has had on astronomy over the last four centuries, we know so little about him. Historians are not even sure of the man's first name. Maybe it was "Jacques," or, perhaps, "Guillaume" or "Giovanni." Some historians think his first name was "Laurent." All we know for sure is that his telescope design was so innovative that it, rather than the Newtonian, is the basis for almost all professional telescopes in use today, including the Hubble space telescope. Unlike Isaac Newton, though, it seems Cassegrain never actually *built* one of his scopes. The Cassegrain existed only on paper for many years, perhaps because it took optical skills a while to catch up with Cassegrain's brilliant conception.

Cassegrain's idea, like Newton's, is simple and seems intuitive once you have heard it. Make a concave mirror with a shape identical to that used in Newtonians. Cut a hole in the center of this mirror. As in the Newtonian, place a secondary mirror at the opposite end of the tube, which will direct light to an eyepiece. Unlike the Newt's secondary, which is flat, the Cassegrain's secondary is convex in shape and is parallel to the primary and positioned so it reflects light back down the tube and through the hole in the primary mirror, as shown in the CAT diagram (Figure 1).

Cassegrain's arrangement has a number of advantages over the Newtonian design. Since viewing is done at the rear of the telescope, as in a refractor, the eyepiece is almost always in a comfortable position. The Newtonian's ocular, in contrast, is fixed at the top of a long tube and may be placed in inconvenient positions as the telescope moves across the sky. The Cassegrain's secondary design offers another advantage: It can reduce the length of the telescope's tube. Since the mirror is a convex shape, it does not just redirect light down the tube of the Cassegrain; it magnifies the image. Because of that, a Cassegrain can pack a long focal length into a short tube. A 6-inch (150-mm) Newtonian with a focal length of 60-inches (1,500-mm) will be nearly 60-inches long. A 6-inch Cassegrain of the same focal length may have a tube half that long or even less, and the shorter the tube, the better. Short telescope tubes dramatically reduce problems involved in designing and building solid yet light mountings.

Is the Cassegrain the perfect telescope? Not exactly. The design is brilliant, but it has some serious failings. One is that, since it usually uses a relatively short focal length parabolic-shaped primary mirror, it suffers from severe coma. What that means to the observer is that objects in the center of a Cassegrain's eyepiece field are sharp, but those on the edge appear out of focus. Stars may look more like comets than pinpoints at the field periphery. Astigmatism, another optical fault common to Cassegrains, may reduce sharpness at both the center and the edges of the field of view. Because of these inherent problems, it is rare to see a pure "classical" Cassegrain telescope today.

The Schmidt Camera

In 1930, a brilliant but eccentric Estonian optician, Bernhard Schmidt, had a conversation about telescopes with Walter Baade, an astronomer at Mount Wilson Observatory, home of the 100-inch Hooker reflector, then the largest telescope in the world. It was clear telescopes were just going to keep getting bigger. George Ellery Hale was already hard at work on a 200-inch giant. It was not all gravy, though. Bigger mirrors naturally meant longer focal lengths and resultant smaller fields of view. Astronomers needed some kind of a supplementary telescope or camera, a "scout," to survey large areas of sky and pick out interesting objects for the big scopes to view and photograph. The seed planted by this conversation led Schmidt to develop the camera design that bears his name.

Schmidt's camera was simple to explain but difficult to produce. He began with a sphere-shaped primary mirror since spherical mirrors are easy to make, even in large apertures. Although they are easy to produce, spherical mirrors have a serious problem that limits their use in telescopes: *spherical aberration*. This is a defect that is very similar to chromatic aberration in refractors. When light is reflected from a spherical mirror, not all the rays come to focus at the same point. Those at the edge come to a focus closer in than those reflected from the mirror's center. The end product is not colored halos, as in chromatic aberration, but even worse, images that are badly blurred. This is the exact same problem that afflicted the Hubble Space Telescope when it was first launched. Schmidt was well aware of the effects of this aberration and knew he had to do something to "correct" for it if he were to use a spherical mirror in his astro-camera.

His great idea, the thing for which he is most remembered, was a special lens, a *corrector plate*, that he placed at the opposite end of his camera's tube from the primary mirror. This thin glass lens, which in Schmidt's camera is somewhat smaller in diameter than the primary mirror, bends incoming rays of light very slightly, just enough so rays at the edge of the corrector are at a different focus than those passing through its center. This different focus distance is identical to that of the mirror's edge and center, but reversed. Rays from the corrector edge focus at a longer distance than those passing through its center. The corrector introduces *negative* spherical aberration. This lens's negative spherical aberration and the mirror's positive spherical aberration cancel out, and, theoretically, result in an image that is perfectly sharp.

As mentioned, the Schmidt camera design was easier to describe than make. The corrector was the problem. Generating the complex ("fourth-order") curve that would produce negative spherical aberration was very difficult. Finally, Schmidt devised a trick that made grinding the lens a little easier. He placed a glass lens blank in a special cylindrical jig with the blank forming one end of the cylinder. A precise amount of vacuum was then applied to the cylinder to pull the glass blank inward slightly. The optician ground and polished the exposed side of the lens blank into a sphere shape, and when the vacuum was released and the blank sprang back, it almost magically assumed the required shape. The problem was that applying the exact amount of vacuum required and maintaining this pressure was maddeningly difficult. This method did work, however, and allowed Schmidt to successfully complete working cameras.

The Schmidt, which uses both lenses and mirrors to produce images, was the first catadioptric instrument in wide use by astronomers. It was not a catadioptric *telescope*, however. Its focus point is at an inconvenient position halfway between the corrector and the primary mirror. That makes it difficult to position an eyepiece for viewing. Schmidt was not concerned. He did not imagine his instrument would be used visually; it was to be a giant camera that did not have and did not need a secondary mirror or an eyepiece. Instead, he placed a film plate holder at the focus position. Astronomers accessed this "focal plane" through a door on the side of the tube. Schmidt's camera was very successful in professional astronomy, and one of the instruments built shortly after his untimely death in 1935, the 48-inch Oschin Schmidt at Mount Palomar, continues to do cutting-edge research today.

Putting it All Together: The Schmidt Cassegrain

By the middle of the twentieth century, the two pieces of the Schmidt Cassegrain puzzle, the classical Cassegrain telescope and the Schmidt camera, were lying around waiting for someone to assemble. It was also at about this time that amateur astronomers began to be in need of a telescope of a new type.

Two things were changing the amateur's world as the 1960s arrived: light pollution and an interest in picture taking. The unchecked growth of the suburbs and the brightening of most astronomers' home skies meant more and more observers had to travel to get good views of the night sky. Also, quite a few of the more serious amateurs were trying to take pictures of what they saw. The average amateur's traditional instrument, the long-tubed Newtonian reflector, did not fit in well with either of these new realities. Long Newts were not easy to haul around to dark sites and often had to be rebuilt if not redesigned before they could be used for astrophotography.

It was becoming more and more obvious that something like a Cassegrain with its short tube and convenient eyepiece (or camera) position would be an ideal telescope for amateur astronomers. Many amateurs did build or buy classical Cassegrains at this time. Unfortunately, home-built Cassegrains were often a bust. The convex secondary mirror was considerably harder to make than it seemed. Store-bought

Casses? Even if made perfectly, the optical problems inherent in the design discouraged even the most forgiving amateurs.

A few brilliant amateur telescope makers thought they had a better idea. They had been experimenting with a design that combined the Schmidt camera and the classical Cassegrain. This "Schmidt Cassegrain" took the Schmidt camera's spherical primary mirror and corrector plate and added the Cassegrain's convex secondary and behind-the-primary eyepiece arrangement (Figure 1). In most designs, the secondary, like the primary, was spherical in shape. These mirrors' curves were figured so the secondary could be placed in a holder suspended near the corrector end of the tube or even attached to the corrector itself. This SCT design would be easy enough to make—two spherical mirrors are easy for even a novice "glass pusher"—if only a way could be found to produce that nasty corrector easily.

The stumbling block for amateur telescope makers was the same thing that gave Bernhard Schmidt fits (literally) 30 years before: the corrector lens. Some advanced and enterprising amateurs tried their hand at SCTs nevertheless. A few of the most talented workers were able to grind and polish correctors by hand. Most, however, tried Schmidt's vacuum trick. Some were successful, but most found the Schmidt trick hard to execute without a well-equipped optical shop at their disposal. There things remained for a while. An SCT would occasionally show up at Stellafane, the big U.S. amateur telescope-making yearly convention, but these CATs were curiosities. The SCT's impact on the average amateur was nil. Correctors would never be practical for most people to produce at home, and commercially made telescopes that required these labor-intensive lenses would, it seemed, be far too expensive for the average amateur to afford.

That's what everybody thought, anyway.

CHAPTER THREE

Inside a CAT

Tom Johnson was a man with a mission, but that mission had nothing to do with telescopes, at least not at first. Johnson had formed a small company in the early 1960s in southern California, Valor Electronics, to produce power supplies and other items for the burgeoning hi-tech industries of the area, and he was focused on making his firm a success. There things would have stayed if he had not bought a small Newtonian reflector for himself and his children. That was the spark. Johnson became one of those rare people who discover their true calling, and he was soon a full-fledged amateur telescope maker. By 1963, he had finished building an innovative 18.75-inch Cassegrain telescope, a huge amateur instrument for the time, and was showing it off at area clubs and star parties. Tom Johnson and his absurdly big, portable, and advanced telescope were featured in a *Sky & Telescope* magazine cover story that year.

Johnson soon set his sights higher than just occasionally contributing to astronomy magazines, however. Seeing the tremendous response his big Cassegrain got at amateur gatherings, he began to wonder if he could sell telescopes like it to amateurs or maybe sell telescopes that were even *more* advanced and easier to use and transport. He was well aware of the Schmidt Cassegrain design and its potential advantages for the amateur astronomer. He was also aware of the problems involved in fabricating corrector lenses. While considering the problem, he ordered a 20-inch corrector plate from optics giant Perkin-Elmer, but by the time this massive, expensive piece of glass arrived he had already thought of an elegant and inexpensive way to make Schmidt Cassegrain telescope correctors.

It was obvious that hand grinding and figuring correctors would not be practical in a mass production setting. Schmidt's vacuum trick was the way to go, but something needed to be done to make the process easier. What he came up with was his "master block" process. In this method a master corrector "form" is first

R. Mollise, *Choosing and Using a New CAT*,
DOI: 10.1007/978-0-387-09772-5_3,

ground and polished into a Pyrex glass blank somewhat larger than the desired size of a finished corrector. The figure ground into this master is the exact *inverse* of the shape needed for the finished corrector, which is thick in the center, thinner between center and edge, and thick again at the edge (Figure 1). The master block's shape is the exact opposite.

When the painstaking process of making the master block is complete, a glass blank that is to become a corrector is placed on the master and pulled against it with a vacuum. The exposed surface of the blank is then ground and polished flat. When the vacuum is released, the blank springs back and assumes the opposite curve of the master, just as in Schmidt's original process.

The master block system is actually considerably more difficult and complex than described. In addition to the basic challenge of making a master block (luckily, a single master can produce many corrector plates), it is hard, for example, to pull the blank evenly against the master so the two pieces of glass are in perfect contact. The interface between the blank and the block also must be nearly clean-room clean as any dust between the master block and the corrector blank will show up as light-scattering depressions on the finished corrector plate. These problems are manageable, however, and the master block technique allowed Johnson to start cranking out SCTs.

The Commercial SCT

That is just what Johnson did. Not long after he cracked the corrector "code," he renamed Valor "Celestron Pacific" and turned it into a telescope company. It was not quite the Celestron today's amateurs know. Johnson thought the SCTs he was producing in apertures of 6, 8, 10, 12, 16, and 22-inches would be perfect for amateur astronomers, but his scopes were not marketed to amateurs at the beginning. The first Celestrons were beautiful instruments with striking blue-and-white paint schemes and excellent optics (Plate 3). Unfortunately, they were expensive—*very*

Plate 3. (Blue and White Celestron) One of the Celestron's legendary 1960s Blue and White SCTs, the C10. Credit: Image courtesy of Bob Piekiel.

expensive. A C10 10-inch SCT, which was the Celestron most often purchased by amateur astronomers, cost almost as much as a brand-new Volkswagen Beetle. Celestron did sell quite a few of the blue-and-white Schmidt Cassegrains to small colleges and universities eager for good telescopes that did not cost as much as custom professional instruments.

Celestron could easily have stayed on this path, selling a few scopes to educators and even fewer to wealthy amateurs, but Tom Johnson wanted more. As Robert Piekiel says in his excellent history of the company, *Celestron: The Early Years*, "In the late 1960s, Celestron was realizing that the Vintage, blue-white scopes they were producing were not selling to a fair share of the market due to their cost, as well as their bulk and weight." Tom Johnson knew amateur astronomy was changing ever more rapidly as the 1970s dawned, and he decided he was going to furnish this new breed of amateurs who traveled to dark sites and dabbled in astrophotography with the telescope they needed.

The breakthrough was the original C8, the "Orange Tube" (Plate 4), so called because of the orange paint job Johnson settled on—maybe in an effort to stand out from the crowds of white-tube scopes advertised in *Sky & Telescope*. The paint scheme was not the only thing that made the C8 different from earlier Celestron scopes (most of which remained available through the early 1970s). The design of the Orange Tube was almost identical optically and mechanically to the earlier Celestrons, but the company had to cut some corners to lighten and cheapen the massive and complex white-and-blue Celestron Pacifics.

In the Orange Tube C8, the focusing mechanism was simplified, the heavy piers furnished with the original scopes were replaced by light but sturdy tripods, and the telescope drive systems were equipped with simpler and cheaper gears and a minimum of electronics. The optics were still as good as ever, though, and the telescope was so far in advance of the simple Newtonians and refractors amateurs were used to buying that the C8 caused a real revolution in amateur astronomy. Almost immediately, old-time companies, amateur traditions such as Cave and Unitron, began to wither. Johnson was soon selling every C8 his dramatically enlarged

Plate 4. (Orange Tube Celestron) Celestron's first mass produced Schmidt Cassegrain, the ground-breaking Orange Tube C8. Credit: Image courtesy of Bob Piekiel.

company could produce, even though the C8 was not exactly cheap. The Orange Tube commanded a whopping $1,000 (a lot of money in 1970) once the customer stocked up on all the "optional" accessories, such as a tripod.

What happened to Tom Johnson's little company, Celestron? The 1980s and 1990s brought plenty of changes. After the success of the C8, the product line was expanded to include a C5, a C11, a C14, and other catadioptric telescopes. The company continued to grow and prosper under Johnson, but after he sold out to a Swiss holding company in the 1980s, Celestron began to suffer some setbacks. These culminated in the 1990s with the sale of the company to notorious junk-scope importer Tasco. Thankfully for Celestron fans, that state of affairs did not last. By the early years of the new century, Celestron had been purchased by Taiwanese optical/telescope giant Synta, under whose guidance the company appears to be flourishing again. Whatever happens to Celestron in the future, it and its founder, Tom Johnson, have certainly earned a mention in the astronomy history books for finally bringing the amateur astronomer a modern, high-quality, affordable telescope.

Meade

Changes in ownership were not the only challenges Celestron had to face as the years rolled on. For the first decade after the introduction of the Orange Tube C8, it had no competition when it came to SCTs. One company, Criterion, formerly known for producing cheap but good Newtonians, had introduced a Schmidt Cassegrain of their own, the Dynamax. However, this telescope was never a serious contender for a number of reasons. What mostly kept Criterion down was poor optics. Some of their SCTs could be described as having "acceptable" optical quality, but very few were better than that. Most were worse, and most amateurs stuck with Celestron.

Then, in 1980, it was a whole new ball game for Celestron. A little company called Meade, which had been started by another southern California electronics engineer, John Diebel, introduced an 8-inch SCT that some amateurs thought was not just as good as the C8, but better.

The rise of Meade Instruments is one of those old-fashioned success stories Americans love. The world's number one telescope company began as John Diebel's one-person "garage" business in the early 1970s, selling small imported telescopes and accessories through tiny ads in the astronomy magazines. Meade did not exactly take amateur astronomy by storm, but Diebel kept plugging away at it, continuing to add to and broaden his product line. After a couple of years this steady plodding started to pay off. Amateurs noticed Meade was offering some pretty good eyepieces for bargain prices, something that was rare in the early 1970s. Meade's prospects advanced even further in 1978 when they began selling serious telescopes—6- and 8-inch Newtonian reflectors.

It was clear to Diebel that Meade had potential, but it was also clear that the market for the accessories, Newtonian telescopes, and old-fashioned achromatic refractors (another big product for the young company) was strictly limited. One thing appeared certain: The Schmidt Cassegrain was the wave of the future, and the only way to really get ahead was to take on Celestron by producing a CAT. Meade, it was

Plate 5. Meade 2080 20 Celestron's first serious competitor, the Meade 2080 8-inch SCT, which featured an improved worm gear drive system.Credit: Image courtesy of John Clothier.

decided, would give it a try, even though the other popular Newtonian maker of the time, Criterion, was in the process of failing due to its SCT woes. After 2 years of development, Meade released its first SCT, the 2080, in 1980 (Plate **5**).

Lucky for John Diebel and his employees, the 2080 was not another Dynamax. The design was similar to that of the C8, but in some regards the Meade was clearly superior to Celestron's famous orange CAT. Diebel and his Meade colleagues had done their homework, taking those 2 years to painstakingly design a telescope and a manufacturing process to produce it. The all-important corrector was made using a method similar to Schmidt's original vacuum process. Early Meade correctors were maybe not as good as those produced by Celestron's proprietary master block system, but before long Meade had its act down, and its SCT optics were close in quality to those of Celestron. One thing astrophotographers liked about the 2080 was that it used a high-quality worm gear in its drive system that was at least perceived to be more accurate than the cheaper spur gear of the C8.

In the nearly 30 years since the arrival of the 2080, Meade has continued to grow and prosper. There have been a few bumps on the road of late, but Diebel's kitchen table company has become established as *the* innovator in technology for the amateur astronomy market. This approach culminated in the introduction in 1992 of the LX-200 series of SCTs, the first practical and affordable go-to Schmidt Cassegrain.

Which Is Better, Celestron or Meade?

It is a cliché, I know, but if I had a dime for every time I've been asked the question which is better, Celestron or Meade by a novice amateur astronomer, I would be rich. It's not that I don't want to answer this question; it is just that it is a hard one to answer. There are differences in the Schmidt Cassegrains sold by Meade and Celestron, but they are minor differences. When it comes to the all important optics, it is close to impossible to tell the difference between the two companies' scopes. Mechanically, Meade and Celestron SCTs are also very similar.

How to choose, then? It used to be simple: look for the features you want. Want permanent periodic error correction (PPEC)? Buy Meade. Want StarBright optical coatings? Celestron. Truth is, though, that today the feature sets of the two firms' go-to scopes are just about as indistinguishable as their optics. If there is a clear difference in the two SCT brands, it might be in company philosophies. Meade tends to be on the cutting edge of electronics and computers. Celestron tends to focus more on optics and mechanics. That **i**s not as true as it used to be, though. Meade, for example, has recently pulled ahead in the optics race with its "advanced coma free" SCTs. Celestron, meanwhile, has worked to close the electronics technology gap and was the first telescope maker to include onboard global positioning system (GPS) receivers in its Schmidt Cassegrains.

How, then, to decide on "orange" or "blue" (the companies' traditional color schemes)? There are still differences. Meade's telescopes still tend to be possessed of more computer features and frills. Meade CATs are also available in larger sizes than the Celestrons, including 16- and 20-inch models. Scope for scope, Meades are noticeably heavier than the Celestrons. The larger-aperture SCTs—and this includes even the 12-inch models—cry out for permanent mountings. Celestron's CATs tend to be less feature laden and perhaps a tad more user friendly. They are also lighter in weight. The largest -aperture Celestron, the 14-inch C14, is surprisingly easy for one person set up, both because its tube is lighter than the equivalent Meade and because it is furnished on a German equatorial mount rather than a huge fork, like the Meade 14-inch.

Anatomy of an SCT

To now we have been talking about the Schmidt Cassegrains in general terms. Next is a detailed tour of a Meade/Celestron SCT tube (optical tube assembly, or OTA). An 8-inch telescope is dissected, but smaller and larger CATs are almost identical. When done poking around in the tube, we move on to take a look at the mounts on which these tubes ride.

Optical Tube Assembly

As mentioned in Chapter 1, a new user's first impression of a Schmidt Cassegrain tube is that it is short and fat, like a little beer keg. The SCT is very compact due to its "folded" optical system. Seen in Figure 1, light enters the corrector end of the tube, passes through the all-important corrector lens, strikes the primary mirror, and is reflected back up the tube to the secondary mirror. The secondary sends this light down the tube again and out through a 1.5-inch diameter hole for viewing. The SCT's convex, magnifying secondary mirror allows the Schmidt Cassegrain to pack a lot of focal length into its short tube, which is only about 17-inches long. Standard Meade and Celestron Schmidt Cassegrains have focal lengths of approximately 2,000 mm, and if not for these SCT tricks—the folded optics and the magnifying secondary—the tube would need to be approximately that long, about 80-inches, or over 6.5 feet.

Almost all the SCTs Meade and Celestron produce today have focal ratios of f/10 (for an 8-inch SCT, 2,000/200 mm [focal length/mirror diameter] = 10 or f/10). Meade sold an f/6.3 focal ratio version for a while, but it was never very popular with consumers despite the wider fields of view its shorter focal length yielded, and it was phased out a few years ago. Recently, however, Meade has begun to offer an alternative to f/10 again. Its top-of-the-line LX400ACFs feature the slightly faster focal ratio of f/8.

Physically, most of Meade's and Celestron's SCT tubes are made of thin-walled aluminum. Both companies have also used carbon fiber for some of their top-of-the-line telescopes at times. The tubes' interiors, whether made of carbon fiber or aluminum, are painted a flat black to reduce unwanted reflections. At one end of the tube is the "corrector assembly," and at the other end is a "rear cell." The corrector assembly is designed to, naturally, hold the corrector and secondary mirror securely and maintain proper alignment. The rear cell contains the primary mirror, focusing mechanism, and the "rear port," a hole onto which eyepieces, star diagonals, cameras, and other accessories can be mounted.

Probably the most striking part of the SCT OTA is its big glass corrector lens (Plate 6). This lens does not look much like a lens, and some beginners mistakenly assume it is just a flat piece of glass designed to hold the secondary mirror in place and keep dust out of the tube. The corrector is thin (about 5 mm thick) and very gently curved, but it is a lens, all right. At least one person we know of broke a corrector and replaced it with a piece of nice, flat window glass. This person was mightily flummoxed when he looked through his "repaired" scope and found its images were a blurry mess. As we know from our discussion of the Schmidt camera, the corrector plate has the important job of removing image-destroying spherical aberration. In the center of the corrector and extending through it is the mounting for the secondary mirror.

This secondary holder both supports the CAT's small convex mirror and provides a means for adjusting its tilt so that the telescope's optics can be aligned, or collimated. Look closely at the secondary holder, and three screw heads equally spaced around its circumference in a triangular pattern will usually be obvious (Plate 6). These screws, Allen screws on Meade scopes and Phillips screws on Celestrons, are used to adjust the telescope's collimation.

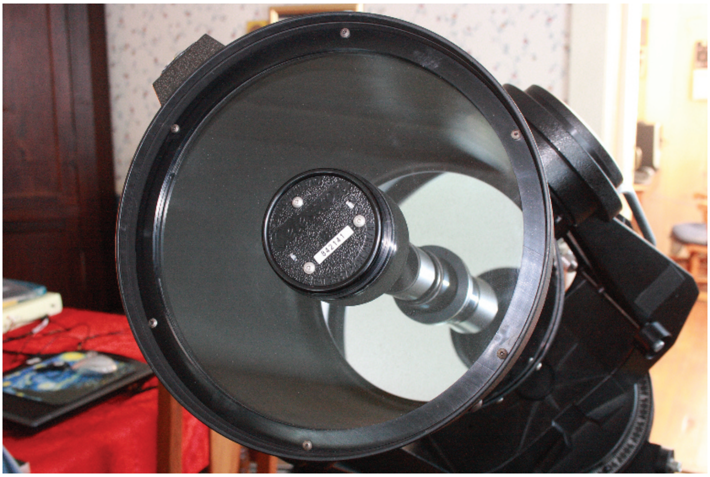

Plate 6. (Corrector and Secondary Holder) The business (corrector) end of a Celestron Schmidt CAT.Credit: Author.

Moving around to the CAT's back end, take a look at the rear (or "mirror") cell. In addition to the central hole, the rear port, there is usually at least one knob, the focus control, that moves the telescope's primary mirror forward and back in the tube to focus the telescope. If the CAT in question is one of Meade's LX200ACF's, there will also be a second knob, which is used to lock the primary mirror in place during picture taking. If the scope is an LX400 ACF, neither knob will be present. The 400's primary mirror is permanently fixed, and the scope is focused by moving a (motorized) secondary mount.

The rear port is surrounded by a raised and threaded metal lip. The size and threading on 8-inch rear ports is the same on all modern Meades and Celestrons (2-inches, 24 threads per-inch). Some equipment, such as camera adapters, threads directly onto the port. Other items, mainly diagonals and eyepieces, require the use of a "visual back" (Plate 7). This is an adapter that is composed of a threaded ring and a barrel. The ring screws onto the rear port and snugs the barrel up against the rear cell. The visual back's barrel has an inside diameter of 1.25-inches, allowing "American standard" eyepieces, star diagonals, and other small accessories to be inserted into it and secured with a set screw.

Look through the rear port and into the OTA interior, and the first thing that you will notice is an eye staring back, reflected by the secondary mirror at the corrector end of the OTA. The other thing is that the rear port does not look out onto the surface of the primary mirror; instead, it opens into a metal tube that is the same diameter as the rear port and extends about halfway into the telescope. This is the SCT's "baffle tube," which serves two purposes. First, it prevents the contrast destroying "sky flood" that would happen if light passing through the corrector at oblique angles were allowed to bypass the telescope's mirror system and "flood" the

Plate 7. (Rear Cell) SCT rear cell assembly showing rear port, visual back, and focus knob." Credit: Author.

eyepiece with unwanted light. The baffle tube blocks the eyepiece from these contrast-spoiling light rays. The other important job the baffle tube does is to provide something for the primary mirror to slide up and down on during focusing.

Other telescope designs focus by moving the eyepiece in and out, just like Galileo's little refractor did—but not Schmidt Cassegrains. Meade's and Celestron's standard SCTs focus by moving the primary mirror back and forth. The focus knob on an SCT's rear cell is attached to a threaded rod that screws into the scope's primary mirror holder. This simple system allows the mirror to be moved up and down on the baffle tube in small, fine increments. Turning the control clockwise moves the mirror down the tube. Counterclockwise moves it up the tube. Note that in most SCTs the mirror is not riding directly on the baffle tube. Instead, a sleeve/hub is inserted into the primary's central hole, and that is what actually moves up and down on the baffle. Also, note that turning the focus control to both ends of its range does not move the mirror very far. It does not have to move very far; a small amount of movement has a large effect on focus due to the magnifying effect of the secondary.

Why don't Schmidt Cassegrains focus by moving the eyepiece, like other telescopes? Moving mirror focusing has some advantages. Not having to move the rear port and visual back in and out to focus makes for a more stable mounting for heavy items such as cameras. The moving mirror system also gives the SCT a large focus range. Almost any eyepiece, even insanely long focal length or homemade oculars, will come to focus in a Schmidt Cassegrain. Remember how we said that a Newtonian will sometimes need to be modified by moving its mirror up the tube before a camera will focus? The reason that is not necessary with SCTs is because of the moving mirror-focusing system and its huge amount of focus travel, or "back focus."

Alas, the moving mirror focus system is not all to the good. Meade and Celestron SCTs are pretty well put together, but they are not Swiss watches. There is generally a small amount of space between mirror and baffle, and the mirror rides just a little loosely on the tube. That causes the primary to tilt slightly when the focus control is turned since the threaded rod is on one side of the mirror and is pushing up or pulling down. When that happens, images move slightly in the field, which is annoying but not debilitating. Most new SCTs display a "focus shift" of only about 45 arc seconds, about the diameter of the planet Jupiter as seen from Earth.

A more serious problem with moving mirror focusing (for astrophotographers) is mirror *flop*. Unfortunately, a CAT's primary mirror may move slightly even when it is not being focused. When the scope's attitude changes significantly, when it tracks across the local meridian (the imaginary line that divides the sky in half from north to south), for example, the primary may shift a little bit. If an image is being exposed when the mirror flops in this fashion, the picture may be ruined; stars in the frame will come out as little lines rather than dots. Fortunately, there are several simple means of eliminating or at least reducing flop and shift, which are covered later.

SCTs larger than 10-inches are very similar to the 8-inchers, but one way in which they differ is the size of their rear ports and baffle tubes, which are larger in diameter, almost 3-inches rather than 1.5-inches. That allows big CATs to use long focal length wide-field eyepieces without suffering the "vignetting" that cuts off the edge of the field of view in some long focal length eyepieces when they are used on 8-inch scopes. Unfortunately, not many accessories can be used with the larger rear port. One reason is that, unlike the 8-inch scope ports, Meade and Celestron use different-size big backs (3.25-inch 16 tpi [threads per inch] for Meade, 3.3-inch 16 tpi for Celestron), do not ask why. Luckily for big CAT owners, standard SCT accessories of all types can be used on the larger scopes with the aid of a "rear port reducer." This item is supplied as standard equipment with all Schmidt Cassegrains bigger than 10-inches.

What else does the rear cell do? It provides a place to mount a finder. Even if the SCT has go-to, as most do these days, a finder scope will be needed to help locate two or three go-to alignment stars. An f/10 2000-mm focal length 8-inch SCT has a narrow field of view, even when long focal length (low-magnification) eyepieces are used. This field of view is so narrow that it is surprisingly difficult to get even the Moon centered in an eyepiece without a finder. Finders are of two basic types. One is a small, low-power telescope with a magnification of about 6× to 12×. Some recent CATs use nonmagnifying zero-power ("unit power") finders instead. These employ a red light-emitting diode (LED) and an optical window to "project" a dot or bullseye reticle on the night sky for aiming.

Back at the front of the CAT, take another peep down the tube, this time focusing on the primary mirror. Looks pretty, doesn't it? All bright and shiny? Due to the semi-sealed nature of the SCT's tube (it is not exactly airtight), dust and dirt on the mirror are not usually a problem. Theoretically, an aluminum-coated first-surface mirror will need recoating every 10 to 15 years. Maybe that is the case with Newtonians, but luckily it is not the case with SCTs. I have a 1973 Orange Tube C8 at the university where I teach astronomy labs, and its mirror at least *looks* as shiny as it did the day it rolled off the line at Celestron's Torrance, California, plant. That is good because getting SCT mirrors recoated normally requires the scope to travel back home to Celestron or Meade.

Mountings

What good is a telescope without a sturdy mounting? Absolutely no good at all. Without an adequate mount, a telescope becomes a source of frustration rather than a pleasure. This is especially true in the case of the Schmidt Cassegrain since its relatively long focal length produces a fairly high magnification with any eyepiece. It is at higher magnifications that "the shakes" become most obvious and serious. In addition to supporting the scope, an SCT's mount contains the motors and electronics that allow it to point at objects and, once pointed, track these objects as they move across the sky due to Earth's rotation.

Meade's and Celestron's SCTs are currently available in two flavors of mount, fork and GEM. The GEM, the German equatorial mount, must be properly aligned on the North Celestial Pole (or just Polaris) before it can track the stars. The fork, on the other hand, can be used in either of two modes. In equatorial mode, it is aligned on the Celestial Pole, just like a GEM, and also like a GEM, tracks objects by countering Earth's rotation. Today's go-to-equipped fork mounts can also be set up in alt-azimuth mode. This does not require any kind of polar alignment for the scope to track. In "alt-az," a fork needs the services of two motors to counteract the Earth's rotation, one for altitude (up/down) and one for azimuth (right/left). Alt-az tracking is a complicated business only made possible by the computers contained in go-to mounts, which can accurately "stair-step" a telescope across the sky.

FORK MOUNTS

Most of the SCTs Meade and Celestron sell are equipped with fork mounts. The reason is that the fork is easy to produce, is easy to use, and provides a reasonably stable mounting for a short-tubed Schmidt Cassegrain. The fork, which has not changed much since the days of the Orange Tube C8 seen in Plate 4, is just that, a large metal fork attached to the SCT's OTA on either side by means of declination (altitude) bearings. Today's forks contain some electronics and a motor in one of the fork arms that drive the telescope in declination/altitude during go-tos. In the past, almost all SCTs also featured mechanical slow-motion declination controls. These were knobs located on a fork arm and were designed to allow a user to manually move the telescope slowly and precisely in declination (north-south)/altitude. Some Meade telescopes still feature declination "slo-mo." Most Celestrons do not. With the move to motorized go-to forks, there is less need for mechanical slow motion. Another common feature before go-to was a graduated dial, an analog declination "setting circle," to assist in finding objects. The tube is held stationary in declination with a lock lever or knob.

The fork sits on the telescope's drive base, which contains most of the electronics and controls needed to run the telescope. The fork can swivel 360° in azimuth (or right ascension, RA [east-west], in equatorial mode). Before go-to, most SCTs had manual RA slow-motion controls as well as declination slow-motion controls. As with declination slow-mo, this feature is disappearing. Having an RA slow motion is still handy, though, since it can be used to track objects across the sky when power is unavailable. Even if the scope does not have a right ascension slow motion control, it will have a right ascension lock to secure the tube during go-to and tracking. Like declination setting circles, RA setting circles have disappeared from many telescopes with the advent of go-to.

Look at all those switches, lights, and connectors! The fork-mount Schmidt Cassegrain's control panel (Plate 8) is usually located either on the top or the side of the drive base, but some models, including Celestron's NexStars and CPCs, place some connectors on the top of the drive base and switches and power indicators on the side.

Wherever they are, these complex-looking panels are intimidating for a beginner. They become less scary when they are boiled down to a few important indicators, sockets, and switches. First, there will be a receptacle for a power cable. The type of current required is usually 12 volts direct current (DC) and may be supplied either

Plate 8. (RCX Control Panel) The drive control panel of a modern SCT, the Meade LX400-ACF. Credit: Image courtesy of Meade Instruments Corporation.

by a DC source like a battery or by some kind of alternating current (AC)-powered DC supply. Somewhere in the area of the power connector, there will be an on-off switch—usually one that is way too small for convenient use by gloved hands in the wintertime. There may also be a little red (to preserve night vision) power-on indicator, usually an LED.

Next up is an RJ ("telephone-style") connector for the hand control (HC). There are several styles/sizes of RJ connector—RJ-11, RJ-12, RJ-45, and more—which is good, since it allows telescope makers to use different sizes of connectors for different purposes, ensuring SCT users do not plug the telescope's HC into the wrong socket, which could be disastrous. The usual plug style used for an HC is RJ-12, which can handle as many as eight wires, enough for all HC signals and power.

On many scopes, there will be yet another RJ jack labeled "autoguide" (or similar). This allows a telescope's aim to be automatically fine-tuned, "guided," during picture taking using Santa Barbara Instrument Group's relay-switch-closure autoguider format, which has become a standard in the telescope industry. Plug a cable from an autoguiding-capable camera into this RJ-12 port, and the camera will detect and correct any small drive gear errors that would otherwise spoil long-exposure images.

On some fork-mount go-to scopes, there will also be an RS-232 (serial) jack on the control panel. If present, this will usually be an RJ-11-style connector. Recently, however, Meade and Celestron have migrated this RS-232 port to the hand control for most models. RS-232 serial data are used for a variety of functions on a fork-mount SCT, including sending the telescope on go-tos using an astronomy program running on a laptop personal computer (PC), autoguiding the telescope serially if a dedicated autoguide port is not available, and updating telescope firmware.

If the CAT in question is a Celestron, there will be another RJ port on the drive base, one labeled "PC." You'd *think* that would be the place to connect a laptop computer to control the scope via "planetarium" software. Makes sense, right? But, the Celestron engineers had other ideas apparently. This port, which uses an RJ-45 connector, is instead used for two very different purposes. One use is for upgrading the telescope's motor control firmware. Celestron go-to scopes use two separate computers, one in the HC and one in the mount (the motor control board). The PC port is also used when operating the telescope via the *NexRemote* software program rather than a hand control (see Chapter 10).

Finally, both Meade and Celestron fork-mount telescopes feature "auxiliary" ports. These are used for a variety of functions, most often for operating accessories such as motorized focusers. Beware of plugging anything into these ports that should not go there since these receptacles are "hot." They supply power to devices that need it and can damage anything that does not.

That is the control panel. But, what is *inside* the drive base? We do not recommend opening the base of a modern telescope. It is generally a maze of easily pinched and disconnected wires. It is also full of circuit boards that can be damaged by static electricity. Also in there, however, are the same things that have been in there since the days of the Orange Tube C8: a drive motor and drive gears (Plate 9). The motors on today's telescopes are of two types: steppers or servos. These motors differ in one respect; steppers, as their name implies, move in distinct steps, while servos move continuously. Stepper motors were originally developed for use in computer print-

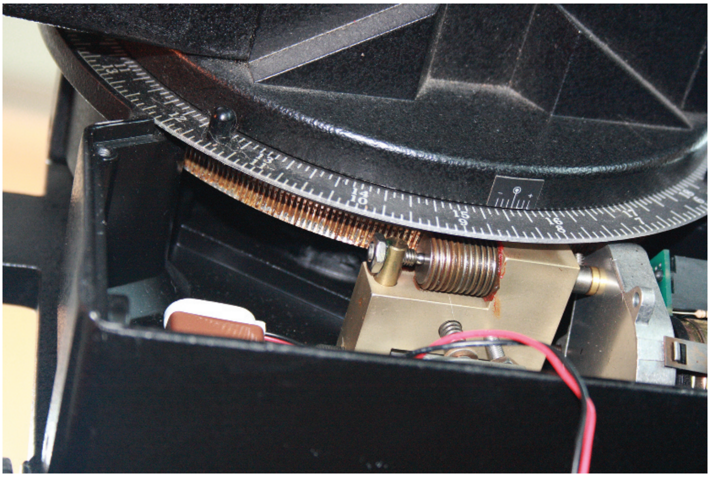

Plate 9. (Worm Gear Assembly) A fork mount SCT's worm gear right ascension drive. Credit: Author.

ers and are therefore easy to control with computers. Servo motors, on the other hand, feature smoother operation since they do not "step along." In practice, both types work well for fork-mounted CATs.

These motors are coupled to the telescope's main drive gears, either directly or through a gear train. However they are linked to it, their purpose is to drive a smaller gear that turns a large gear that is attached to the fork. In older fork-mount SCTs and some current less-expensive telescopes, the gears used for the telescope drive were both *spur gears*. In spur gear systems, a small gear with straight teeth is attached to the motor and drives a larger gear of the same type coupled to the fork. Spur gear systems work fairly well, are inexpensive, and can be highly accurate. Their drawback is that the gears' teeth cause tiny random variations in the telescope's tracking speed. This is not a problem for the visual observer, but it means imagers guiding manually must monitor the scope's aim very carefully and be ready to push a HC direction button when these random variations show up. An autoguider may have trouble with the sudden, random errors introduced by spur gears.

In all but today's least expensive Meade and Celestron telescopes, the smaller gear in the drive system is now a worm-type gear. A *worm gear* is a cylindrical, helically cut (slanted) gear renowned for smooth precision. The helical nature of the worm ensures good contact with the gear it is meshed to and delivers an accurate drive rate. More important, much of the spur gear system's randomness is eliminated. Like any mechanical gear system, worm gear drives still show some error, but this is usually *periodic error*, a slow and regular variation that is easy for an astrophotographer to "guide out" using the scope's HC or an autoguider. One thing to remember when talking about Meade and Celestron SCTs' worm gear drives is they are only really *half* a worm system. In these scopes, the larger gear the worm drives is actually a big spur gear. In a true worm system, this larger gear would be the "wheel" and would have helically cut teeth, like the smaller gear.

Although the half-worm system works decently, the very nature of Meade and Celestron forks tends to limit their drive accuracy. They have to be designed both to track at an accurate "sidereal" rate and, when called on, zip the scope across the sky for go-tos at speeds as high as 8° per second—much faster than the tracking rate of 15° per *hour*. Unfortunately, they must do that without relying on high-cost gears, motors, and couplings. For that reason, it is common to find some looseness and backlash in the companies' fork drives that limit them during demanding applications like long-exposure imaging.

If a fork-mount telescope is to be used in equatorial mode—which is a requirement for serious imaging—it requires one additional component, a "wedge." The wedge, shown in Plate 5, is a simple wedge-shaped metal affair that has a single purpose: It tips the telescope over so it can be aligned on the North Celestial Pole. When tipped in this fashion, the up-and-down movement of the tube in the fork tines becomes movement in declination (north/south). When swiveling on the drive base, the scope moves in RA (east/west) rather than left/right.

What makes a fork mount a good choice for an amateur astronomer? Comfort. Forks are incredibly comfortable to use for visual observing when set up in alt-az mode. Nothing is more pleasant for just looking than an alt-azimuth SCT. When mounted on a wedge for equatorial use, a Schmidt Cassegrain's eyepiece can be placed in some odd positions. When pointing to far northern targets (or far southern ones south of the equator), for example, the eyepiece will be nestled up against the fork arms and difficult to get at. In alt-az mode, the worst it gets is when the telescope is pointed at the zenith. In that position, the ocular will be up against the drive base, but still not as difficult to access as the eyepiece on a north-pointing wedge-mounted scope.

Should your Schmidt Cassegrain be a fork-mounted Schmidt Cassegrain? If you want ease of use and want to keep the price down without sacrificing strength or features, the answer is "yes." There are some reasons to consider an alternative to a fork, however. In addition to gearing/drive deficiencies, forks are not as stable as other mounts. One look tells the story: The thing is a big metal fork, like a big tuning fork. The fork mount is naturally prone to vibration. Need to set a fork mount scope up in equatorial mode? That makes the vibration problem even worse. Tipped over on its base, the fork is off balance, and the whole shebang, and not just the fork, is prone to a right good case of the shakes. Finally, have you seen large-aperture fork-mount telescopes like a 12 or 14-inch? In person? To support large OTAs, these forks must be *huge*—and heavy. Modern go-to SCT OTAs cannot be easily separated from their forks, either, so the whole, heavy thing has to be lifted onto a tripod in one big piece.

So, maybe fork-mount Meade or Celestron SCTs, as pretty and appealing as they appear in the ads, are not quite the thing for all amateur astronomers. What then? Do not worry. There is an alternative: the GEM seen in **Plate 10**. The GEM has a lot of fans, especially among photographers and other serious amateurs. Although it has been overshadowed by the fork mount for Schmidt Cassegrains, the German mount has been offered as an option since shortly after the first Orange Tubes began rolling out of California. Although it has not and probably will not displace the fork

Plate 10. (German mount) A C8 CAT mounted on Orion's Atlas EQG German equatorial mount. Credit: Author.

mount as the most popular support for the SCT, it has some advantages that make it worthy of consideration.

The German Equatorial Mount

What's "German" about a GEM? It was invented by a German priest, Christoph Grienberger, in the seventeenth century, not long after Galileo did his refractor thing. Perhaps it should have been called the Grienberger equatorial mount, but "German" does have a nicer ring.

Whatever you call it, the GEM is a simple if complicated-looking device. In Plate 10, you can see that it is composed of two axes connected to form a "T" shape. The "vertical" bar of this T forms the RA axis, while the "cross" bar of the T is the declination axis. The telescope is attached to the crossbar, and the vertical bar is tilted to point at the North Celestial Pole. Arranged in this fashion, the GEM can track the stars by turning on its RA axis. Add a single motor, and it can track automatically. Hook up a computer and add a declination motor to the German mount, and it can go-to as well as any fork mount can.

The details are a little more complicated, but not much. A shaft runs through the vertical bar of the T, rotates on bearings, and forms the actual RA axis. The RA axis is physically attached to a strut or housing that allows it to tilt to point at the pole, and there are usually fine-adjustment knobs that allow this tilt to be precisely set for exact polar alignment. The RA axis can also be adjusted finely in azimuth. There is a lock to secure the scope in RA during tracking and go-to.

The crossbar of the T houses the declination axis shaft and its bearings. There is a lock on the declination axis just like the one on the RA axis that must also be tightened down for go-to. The declination shaft extends through and out of its housing, and "counterweights" are mounted on this extension to *counter*balance the scope that is attached to the opposite end of the axis. The counterweight end of the declination shaft is usually equipped with a safety bolt that prevents the heavy weights from accidentally sliding off the end of the declination shaft. That is a very good thing. As a very young man, I had a bad experience with a counterweight on a GEM-mounted 4-inch reflector that did not have this feature. In the course of adjusting the scope's declination balance, I let go of the 10 pound counterweight, which I had loosened, and it slid right off the shaft and onto my big toe. Ouch!

Drives on GEMs are not much different from those on fork mounts. There is a separate servo or stepper motor for each axis, and these motors are controlled by a computer in a hand control. One advantage GEMs, even low-cost imported ones, have over less-expensive fork mounts is that almost invariably the smaller and larger gears on both axes are both worms. One drawback to GEMs is that the RA gear is usually smaller than those gears used in the fork mounts. A fork usually has an RA drive gear as large as the drive base—6-inches in diameter or larger. RA gears on all but the largest GEMs are typically half that diameter or smaller. That does not seem to affect GEM tracking, however. A GEM's declination gear is typically identical to its RA gear.

Unlike forks, German mounts are still available without go-to, mostly from third-party manufacturers. Non-go-to GEMs typically feature manual slow-motion controls on both axes, while go-to models do not. Often, manufacturers, especially of cheaper mounts, use the same basic mount for go-to and non-go-to models, with the slow-motion controls removed to allow go-to motors to operate without the addition of the clutches that would be needed if the slow-motion controls were retained. Even without slow-motion controls, most GEMs are easy to point and hand track without power. They are considerably easier to balance than fork-mount scopes, and that helps a lot when pushing the scope along after the battery dies.

Is a German mount *better* than a fork? In some ways, it is. Despite the aforementioned smaller RA gears on some GEMs, most of the German mounts seem to track better than similar-quality forks. In large part, this is because they are easier to balance. Unlike a fork, a telescope on a German mount is easily balanced in RA by moving the counterweight up and down its shaft. Declination balancing is also easy and is accomplished by the simple expedient of moving the scope back and forth in the dovetail/cradle that is used to attach tube to mount. A fork may need the addition of weights to the fork and to the OTA to achieve balance in both RA and declination—assuming the telescope *can* be properly balanced in both axes, something that is not always possible with fork-mount Schmidt Cassegrains.

One tremendous advantage for the GEM is that, unlike most fork-mount scopes, the tube can be removed from the mount easily. That makes the scope/mount combo much easier to transport since it can be broken down into several easy-to-handle pieces. Being able to remove the scope from the GEM also allows the same mount to be used for a number of different telescopes. Most GEMs use one of two standardized and easily available dovetail/cradle-mounting systems to attach scopes to the mounts.

Who is the GEM for? The GEM is for two groups. The first is those folks, beginners or just the budget conscious, who want a mount that does everything a fork can do, including go-to and computer control, but for a less-expensive price. Meade and Celestron offer medium-size imported (Chinese) GEMs for their SCTs that work well and are as full featured as more expensive forks.

Since, as we all know, “there ain’t no such thing as a free lunch” (TANSTAAFL), there must be a penalty of some kind. There is: GEMs are harder for beginners to learn to use than forks. Since the GEM cannot be set up in alt-az mode, the novice must learn to at least roughly polar align if the mount is to track the stars accurately. A halfway decent polar alignment is also needed for good go-to performance on some models. Go-to alignment is also a bit more complicated with GEMs, with many models requiring the user to sight as many as six or seven stars for optimum accuracy rather than the fork’s two or three.

The biggest fans of German mounts, however, are serious imagers. They often eschew the GEMs offered by Meade or Celestron and place their SCT tubes on large (and expensive) third-party mounts sold by companies such as Losmandy, Asro-Physics, Software Bisque, and Mountain Instruments. These *big guns* are often in the $10,000 price range.

Hand Controls

Meade’s (Autostar) and Celestron’s (NexStar) HCs look a little different (Plate 11) but are similar in function. They include both numeric keypads and an array of dedicated buttons to allow users to input information. Both flavors of hand control feature relatively small LCD displays that give feedback on what is being entered into the HC (date, time, and location, for example) and display various types of output—object data, telescope position, etc. The major difference between Meade and Celestron HCs is that Meade uses a red-on-black display, while Celestron uses black on red. Meade’s HC display is much easier to read at 3:00 in the morning. Otherwise, the NexStar and the Autostar are nearly indistinguishable. The Nexstar offers nine user-selectable slewing/centering/guiding speeds: 6°/second; 3°/second; 1.5°/second; and 128×, 64×, 16×, 8×, 2×, and 1× sidereal. There are also three selectable drive rates: sidereal, solar, and lunar. The Autostar features 6.5°/second, 3°/second, 1.5°/second, 128×, 64×, 16×, 8×, 2×, and 1× sidereal and the

Plate 11. (Hand controllers) The Meade Autostar and Celestron NexStar hand controllers are very similar. Credit: Author.

same user-selectable tracking rates as the NexStar. The HCs' features and slewing speeds can vary a bit, depending on the model of scope with which they are used. Meade also makes an Autostar II HC for its top-of-the-line models that offers further features and refinements.

TRIPODS

If a telescope is not any good without a good mounting, a mount is not any good without a good tripod. What is a good tripod? In my opinion, the baseline is still Celestron's original Orange Tube tripod. It provides the best combination of lightness and stability ever seen in a Schmidt Cassegrain tripod. This famous "triangle-tripod's" legs and braces were a series of triangles forming, from an engineering standpoint, the perfect design for a tripod. A similar arrangement is often found in the expensive tripods used by professional photographers for large-format cameras or by surveyors for their instruments. This tripod provided excellent support for the C8, but users did not like the fact that it was not adjustable or collapsible. Most owners described loading it into a small sedan as akin to wrestling with an octopus.

Today, all Meade and Celestron telescopes feature collapsible tripods. The usual one found on a CAT is a tubular affair with legs that can be extended to bring the height of the tripod head up to about 4.5 feet. Most also have a "spreader," a metal or plastic bracket that fits beneath the tripod head and pushes against the legs. A threaded knob-and-rod arrangement allows the spreader to be tightened against the legs, ensuring they are held firmly apart. Both Meade and Celestron have done a considerable amount of work to upgrade their tripods in recent years, but it must be said that most of the companies' tripods, while adequate, are hardly oversize.

One thing that can help is leaving the tripod legs unextended. Since most CAT users like to sit while observing, that does not usually create a problem.

Who Makes SCTs?

The question of who makes SCTs is easy to answer: Meade and Celestron. That is it. In the past, a few other telescope manufacturers have tried their hand at the Schmidt Cassegrain, but usually not for long. Renowned Japanese telescope manufacturer Takahashi, for example, produced only approximately 100 of its legendary TSC225 9-inch SCTs in the late 1980s. Belgium's Lichtenknecker Optics has also made a few SCTs. Their 8-inch models are renowned for their optical quality, or so it seems. They are rarely seen.

Why are no companies other than Meade and Celestron making SCTs today? Maybe this is because the other makers who have entered the SCT arena have been, like Takahashi and Lichtenknecker, focused on making the best SCTs it is humanly possible to make. That does not come cheaply in any scope design. The Lichtenknecker 8-inch, for example, cost nearly 5,000 German marks in the mid-1980s. The big problem, though? It is hard to best Meade and Celestron when it comes to SCTs, whether you want to produce an expensive scope or just something similar to what comes out of California. They have the process down, and their products, while not on the Takahashi level, perhaps, are very good nevertheless. As a matter of fact, the few Tak TSC225 SCTs that I have used have been very good, yes, but only somewhat better than a good Meade or Celestron.

Other Members of the CAT Tribe

Thus far, except for an occasional aside, the terms CAT and SCT have been used interchangeably. The SCT is far from being the only CAT in use by amateurs. A visit to any club observing field will also reveal SNTs (Schmidt Newtonian telescopes) MCTs (Maksutov Cassegrain telescopes), MNTs (Maksutov Newtonian telescopes), and maybe even KCTs (Klevtzov Cassegrain telescopes). All these variants are described in the next chapter, but a few words about the Maksutov family are in order here.

The Maksutov Cassegrain telescope, the MCT or "Mak," is without doubt the non-SCT CAT most beloved of amateurs. The SCT and MCT are such similar scopes that beginners often have a hard time telling one breed of CAT from the other. The principal difference, visible in Plate 12, is the MCT's corrector. Unlike the thin, complex-curved Schmidt Cassegrain lens, the Mak has a corrector plate that is thicker, deeper, and simpler. It is often called a "salad bowl" corrector because of its appearance. While it looks different, the Mak corrector's function is the same as that of the SCT corrector: remove spherical aberration. One other striking difference between these two types of CATs is that the MCT often does not have a separate secondary mirror. In Gregory design MCTs, the secondary is a silvered (aluminized) spot on the inside surface of the corrector plate.

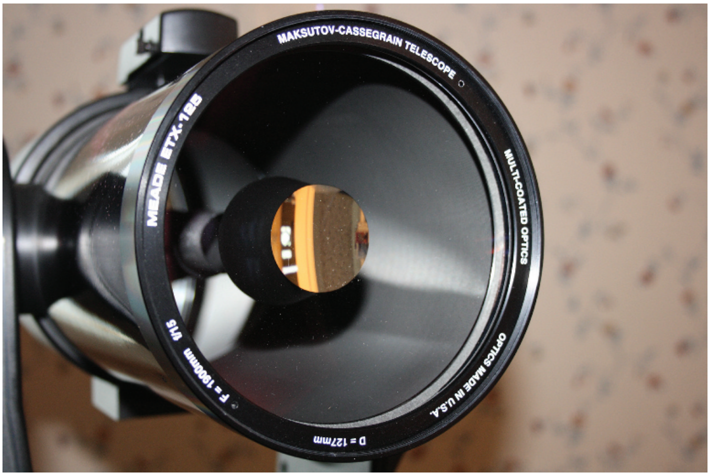

Plate 12. (MCT Corrector) The deep-dish corrector plate of a Gregory-style Maksutov Cassegrain telescope, the Meade ETX125PE. Credit: Author.

Why would somebody want an MCT instead of an SCT? because—some amateurs think—MCTs have better optics. Although SCTs are good, the MCT does usually pull ahead of the SCT in image sharpness. This is due in part to the nature of the corrector. In the MCT, it is usually figured in an easy-to-make spherical shape, which is less demanding to make than the SCT's corrector, and for that reason is often of better quality. Also, the MCT's primary mirror (which is sometimes a sphere, just like an SCT mirror) usually has a higher focal ratio (and thus a shallower curve) than a comparable SCT (often f/3 instead of f/2). Higher focal ratio mirrors are usually more optically forgiving than lower focal ratio ones. The final focal ratio of the MCT's primary/secondary mirror combination is usually considerably higher than that of most SCTs (f/15 is common). The longer Mak focal length and longer tube that result from this design difference mean the MCT's secondary mirror can be smaller than that of an SCT, allowing the Mak to possibly deliver slightly higher contrast images.

Everything does not come up roses with the Mak, however. Problem number one is expense. Thick Maksutov correctors require expensive glass blanks that drive MCT prices up. The (usually) higher focal ratio of the MCT means there is lot of focal length, which delivers higher magnifications eyepiece for eyepiece and narrower fields of view. Do not buy an MCT to scan the vast star fields of Sagittarius. Buy one if you value optical quality above all else (and do not like superexpensive apochromatic refractors) and do not mind focusing on small and medium-size targets. If you are a planetary observer, a Mak may be just the CAT for you.

Our tour of a generic SCT is now at its end. I have already mentioned a few specifics of the two SCT makers' telescopes, but in the next chapter we get down to brass tacks and survey each company's scopes model by model and in detail. The MCTs, MNTs, and SNTs are also not ignored, and a few of the CAT zoo's even more exotic beasts are introduced.

CHAPTER FOUR

Which CAT?

Telescope Buyer's Guide

What is so difficult about choosing a new Schmidt Cassegrain telescope? There are just so darned many of them, and the manufacturers' ads in the astronomy magazines and on the Web tend to confuse more than they enlighten. Is a fork mount best? Or, is a German mount better? Are ultra high contrast coatings (UHTC and XLT) optical coatings necessary (whatever they are)? Is any kind of Schmidt Cassegrain the "right" catadioptric telescope? Might a Maksutov Cassegrain or a Schmidt Newtonian be better? Yes, all those models, all those options—it is enough to confuse anybody.

Choice is good, however, and picking a first serious telescope is not as hard as it seems if the prospective buyer has at least some idea of what the telescope will be used for and how much money can be spent on it. The different CAT designs, SCT, MCT, SNT, and MNT have different strengths as far as what they are best suited for viewing or imaging, and that will help when choosing a model. When it comes to price, the SCTs, at least, sort into three categories: bargain, medium priced, and top of line.

One thing *not* to do is skimp on a telescope, even if spending more than was initially planned means putting off buying for a while. The worst thing for a novice amateur astronomer to do is choose an unsatisfying scope that will be rapidly outgrown and soon need to be replaced. That does not mean a top-of-the-line telescope is necessary the first time around. Today's less-expensive SCTs sport features at least as advanced as those of the most advanced telescopes on the market 10 years ago. The critical thing is not to choose an aperture that is too small to show good detail in objects. Hold out for at least an 8-inch if possible. A question I am often asked

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by beginners is whether buying a particular manufacturer's most expensive model ensures better optics than those in one of their less-expensive telescopes. In general, the answer is "no," not if the scope in question is an SCT. Celestron and Meade use identical optics in all their standard design telescopes.

Are there any other caveats before we start kicking the tires of telescopes? There are a couple. First, if at all possible, try to examine the scope of interest—or at least a similar model—in person before committing to buying it. SCTs look a lot smaller in the magazine ads than they do in person, and all too many novices wind up buying more scope than they can handle weightwise. There is a lot to ponder beyond the general information given here that is best experienced in person. Is a particular telescope's control layout easy for *you* to use? Do the images it produces impress *you*?

A Few Words about GPS

When Celestron and Meade first began integrating global positioning system (GPS) receivers into their SCT mounts about 10 years ago, amateurs were plenty excited. We imagined GPS would take the last of the drudgery out of telescope setup: no more sighting go-to alignment stars, no more polar alignment headaches. Reality turned out to be a little different. Onboard GPS receivers did and do help some but not to the extent we thought they would.

GPS can be a considerable labor saver with fork-mounted telescopes set up in alt-azimuth mode, but it does not work alone. Yes, Meade and some Celestron forks can find north, level themselves, and head for go-to alignment stars without much user intervention. The observer still has to center the alignment stars, however. And, GPS alone could not even do this much. A GPS-enabled fork-mount scope must also be equipped with level sensors and an electronic compass to do its roboscope thing.

In equatorial mode on a fork or when used with a German equatorial mount (GEM), supplying accurate time, date, and position information is *all* a GPS receiver does. It does not polar align the scope, and it does not help the mount when slewing to alignment stars. Look on GPS as a timesaver for equatorial mode and nothing more. Paying extra for the minor convenience of not having to manually input time and position does not really seem worthwhile, but the manufacturers must believe amateurs want that since almost every GEM mount has GPS available at least as an option.

Some amateurs wonder if the go-to alignments produced by GPS scopes are more accurate than those produced by non-GPS scopes. The answer is "no." Accurate time, date, and location *may* help the scope come closer to go-to alignment stars during its initial slews, but it will be no more accurate than a scope with date, time, and location entered manually with reasonable care. Amateur-grade mounts are simply not able to take advantage of the precision time and location data offered by GPS.

SCT Buyer's Guide

This guide to new SCTs is current as of the writing of this book, but CAT manufacturers tend to change models, prices, and features every year or two. Celestron and Meade are especially prone to this since they sell nearly identical telescopes and are locked in fierce competition for a relatively small number of potential customers. Often, these "new" Meades and Celestrons are only superficially different from previous models, however, so even if a particular telescope is not here, there is probably one that is very similar to it. Finally, Meade's scope offerings are somewhat in flux due to the company's decision to move production offshore. Some models are not available at the time of this writing (including the LX200-ACF 14-inch and the entire LX400-ACF series) but may be on sale again by the time this book is published.

Okay, now let us find you a telescope.

Entry-Level 8-Inch SCTs

Traditionally, the entry-level 8-inch SCT was the realm of the "manual" fork-mount telescope. Turn on a switch, and the telescope tracked the stars. Turn it off, it stopped. "High tech" was powering the scope drive with an internal battery rather than plugging it into an alternating current outlet.

Bargain scopes have changed a lot. The biggest change is that non-go-to SCTs have almost vanished. Meade and Celestron believe CAT buyers want computer drives, and that is almost all they offer at all price levels. One other recent development is that Meade and Celestron (remember, they are the only mass-production SCT makers) have had to abandon traditional double-tine fork mountings for their loss-leader scopes. Old-style forks are now too expensive to produce to be sold at the critical $1,000 to $1,500 price point amateur astronomers have come to expect to pay for an introductory SCT.

Continuing to (profitably) market 8-inch SCTs at beginner-friendly prices has meant switching to German mounts or "half forks." Meade offers a GEM-equipped introductory scope, while Celestron offers both single-fork arm and GEM-equipped models for cost-conscious buyers. The medium-weight German mounts used by both companies are imported from China, and the tubes can either be imported or made in the company's California factories. As mentioned, Meade has recently moved all production to Mexico and China, and Celestron is heading in the same direction. Both the mountings and optical tube assemblies (OTAs) for Celestron's single fork-arm models are imported.

Bargain-basement SCTs are just right for some observers, but prospective CAT owners whose main interest is astronomical imaging, or astrophotography, should think long and hard before buying an entry-level telescope. The cheap scopes *can* take pleasing pictures of deep sky objects (DSOs), but the difficult art of astronomical picture taking is made even harder by an inexpensive telescope.

Meade LXD75 Schmidt Cassegrain

Meade's LXD75 (Plate 13) is a standard 8-inch aperture SCT optical tube mounted on an imported (Chinese) GEM. Although this model is hardly in the high-priced league, it is an attractive and fairly reliable scope whose mounting offers a surprising number of high-tech features thanks to its Autostar computer hand control.

Plate 13. (LXD 75 SCT) Meade LXD75 8-inch Schmidt Cassegrain. Credit: Image courtesy of Meade Instruments Corporation.

This mount is very similar to Japanese scope maker Vixen's renowned Great Polaris GEM, if not as sturdy or well finished. Most imported GEMs in this payload class (20 pounds) are "clones" of the Vixen. The LXD75 tube itself does not feature frills, like the mirror locks and motorized Crayford-style focusers found in the high-end Meade telescope, but the optics are the same as those used in the company's other standard SCT OTAs and come equipped with Meade's UHTC, on the primary mirror, secondary mirror, and corrector plate.

A frequent question is whether UHTC make a difference. The answer is "yes." When comparing a Meade OTA equipped with these coatings to one without, the UHTC telescope clearly shines as the winner. Images of DSOs are noticeably brighter due to the higher transmission of the UHTC corrector and the higher reflectivity of the primary and secondary mirrors. Though the difference is not overwhelming, it is there, and sometimes it makes the difference between seeing and not seeing difficult DSOs.

Mechanically, there are no surprises in store for the LXD75 owner. The moving mirror focuser is smooth and focus shift is minimal, about 45 to 60 arc seconds in the examples tested. The 75's tube is finished a gleaming white, a color that is extremely attractive and that matches the similarly finished mount. White is an unusual color for CAT tubes these days, but it may be a plus. A white finish may aid in the thermal cooldown that is necessary when an SCT is taken from a warm house and into the cold night air. The white tube may radiate heat away from the tube interior more quickly than a dark color.

The mount this tube rides on, although not fancy, is workmanlike and workable. Operationally, its German mount is more complicated for beginners to learn to use than a fork. The major difference is that, as discussed in Chapter 3, the GEM must be at least roughly polar aligned if it is to accurately go-to and track sky objects. That involves pointing the right ascension (RA) axis of the mount at the North (or South) Celestial Pole, which lies about half a degree from bright Polaris, the North Star. This polar alignment process can be somewhat confusing for a beginner but is not overly difficult since perfection is not required for most observing tasks. For visual use or casual picture taking, it is only necessary to get the RA axis pointed *close* to the pole, and Meade has made that fairly simple with the LXD75's polar alignment telescope (polar alignment viewfinder), which is inserted through the mount's hollow RA (polar) axis. Place Polaris on the correct spot on this small refractor's reticle using the mount head's altitude and azimuth adjusters, and the LXD75 is more than ready for go-to and visual observing.

Once the LXD75 mount is polar aligned, the user switches on the power and uses the Autostar computer to do a go-to alignment. In its most basic form, that involves entering current date, time, latitude, and longitude into the HC and centering two alignment stars. Normally, the Autostar picks a pair of stars and moves the telescope to the positions where it thinks they should be. The observer uses the hand control's direction buttons to center these stars in the finder and then in the eyepiece. Once that is done, the scope should theoretically be able to find any of the 30,000 stars, planets, and DSOs in the Autostar's memory—theoretically.

Beyond the obvious fact that at least some of those thousands of galaxies, clusters, and nebulas (the Autostar includes the entire Messier, NGC, and IC catalogs) are going to be beyond the reach of an 8-inch telescope, the LXD75 will need a careful go-to alignment to perform well. Even centering the two stars precisely with a high-power crosshair reticle eyepiece usually did not ensure good accuracy. For that, you may need to forgo the two-star "Easy Alignment" and use the more accurate "Three Star Alignment" instead. In Three Star mode, the Autostar chooses an additional alignment star on the opposite side of the sky from the other two (on the other side of the local meridian). That allows the Autostar computer to take into account any misalignment caused by less-than-perfect mechanical alignment of the mount's axes, something that is common on all but the most expensive German mounts.

Featurewise, the LXD75 hardly seems an inexpensive telescope. Thanks to the Autostar, it has more features than you can shake a Nagler eyepiece at. Not only does the HC contain a library of 30,000 objects, it provides descriptive data for many of these wonders. Center the Great Orion Nebula, press a button, and the computer scrolls a message across the display telling all about M42: how big, how far away, and more. Some of the Autostar's other capabilities, which frankly are amazing to find in an introductory telescope, include guided tours, periodic error correction (PEC) for long-exposure imaging, and computer control via a laptop. Stumped about what to look at on a given evening? Take a guided tour. The "Tonight's Best" excursion will send the LXD75 to the "best" astronomical objects visible on a given date. The Autostar contains a number of other similar expeditions, and it is even possible for the LXD75 owner to write personalized tours with the aid of a personal computer (PC).

Do you fancy taking long-exposure deep sky images? The LXD75's mount may be a little light for that demanding task, but the Autostar can help achieve success with its PEC feature. As mentioned in the discussion of mounts in Chapter 3, all gears contain slight imperfections that cause small tracking errors that spoil long-exposure photos if not "guided out." PEC allows the HC button presses made to keep a star centered in a high-power crosshair eyepiece during guiding to be "recorded." The finished PEC recording can be played back for the rest of the evening, automatically making corrections. PEC is not perfect, and a guide star will still need to be closely monitored during exposures, but corrections will be fewer and smaller with PEC than without.

A telescope is more than just a mount and a tube; a few accessories are needed before any observing can be done. How does the LXD75 stack up there? It is a little Spartan but not overly so compared to other SCTs, including considerably more expensive ones. In the box, in addition to the tube, mount, and Autostar hand control, there's a 26-mm Plössl eyepiece, an imported ocular that, while not a world beater, is of decent quality. There is also a 1.25-inch format prism star diagonal that, like the eyepiece, is usable if not exactly impressive in its build quality or performance. Even though this is a go-to scope, a decent finder is needed to help locate go-to alignment stars (or objects the computer misses). Meade's 7 × 50 is a good one, providing prominent crosshairs, a wide field, and enough aperture to pull stars out of light-polluted suburban skies. Finally, there is a battery pack that holds eight D cells for powering the mount. Unfortunately, the D cells will not power the telescope for long, especially in cold weather. Forget this battery pack and purchase the optional 12-volt power cable so you can run this surprisingly power-hungry mount off a hefty 12-volt direct current battery.

How good *is* the LXD75 SCT? What are the negatives? There are not many. The LXD75's predecessor, the LXD55 had a poor reputation, but Meade seems to have worked most of the bugs out of the new mount. Some users have found they have needed to do some tightening and tune-up of the GEM after it has been used for a while (as with the LXD55, the declination drive gears tend to suffer from loose setscrews over time). Mostly, the mount seems reliable and fairly accurate. The LXD75 GEM is not heavy duty, of course. "Medium duty" might even be stretching it, but it is at least sufficient for the short SCT tube. The mount *could* use a little sound suppression. When it is slewing to an object at high speed, it sounds as if it is grinding a pound or two of coffee in the process.

What is there to like? A lot, beginning with very good 8-inch optics. Under a dark sky, this CAT is going to impress. It is more than capable of showing all the basic wonders of the universe. Brighter DSOs—like the Messiers—will display considerable detail, as will the Moon, Mars, Jupiter, and Saturn when they are well placed. No, the mount is not rock solid, but part of this scope's appeal is its light weight and the fact that it can be disassembled into mount and tube, making it easy to waltz around a dark backyard. Its eminently reasonable $1,500 price tag does not hurt, either. With its long list of features and its big library of objects, this scope could keep even a fairly demanding astronomer happy for years.

Celestron Advanced Series C8-SGT

At first blush, the Celestron C8-SGT (Plate 14) does not appear much—if any—different from the LXD75. Ah, but appearances can be deceiving. At nearly the same price, $1,515, the Celestron is arguably a more capable telescope. It does not look that way at first glance, certainly, with its subdued gray tube and black GEM, but some of its characteristics make it more suited for advanced pursuits, such as imaging, than the Meade.

My C8-SGT story starts with a lingering backache. The SGT's CG5 GEM did not cause this complaint; the culprit was my Celestron Ultima C8, an optically splendid old-school manual fork-mount SCT. I had always loved the U8 for its wonderful

Plate 14. (C8 SGT) Celestron C8-SGT German mount SCT. Credit: Image courtesy of Celestron.

views, and when it came time for a recent star party, I decided I would take the Ultima with me rather than my go-to CAT, a large and heavy Celestron NexStar 11 GPS. The images delivered by the U8 are, to put it mildly, as good as any I have seen in *any* 8-inch telescope of *any* design over 40 years of observing.

Unfortunately, good images are not everything. It had been a while since I had used the Ultima or any noncomputerized fork scope (I do subject my freshman astronomy students to them), and I had forgotten what using an SCT on a wedge meant. It meant that all too frequently I was contorting my body into a pretzel shape, both to find objects and to view them. That was okay when I was 30. It was still okay when I was 40. But at 50? I was laid up for a solid week.

After I returned from the star party, I determined that I still had a place in my telescope stable for an 8-inch CAT, which is superportable but with plenty of viewing horsepower for all types of sky objects. I decided no more crouching behind the non-go-to Ultima. What to do? Pony up for a new Meade or Celestron 8-inch? It seemed a waste to let those wonderful Ultima optics go idle. What if I removed the tube, the OTA, from the Ultima's fork mount (a simple operation involving removing four screws) and put it on the Advanced Series' CG5 GEM (which was available without an optical tube)? I would make my own C8-SGT and see what the mount would do.

Three years later, I am still happily using my "custom" C8-SGT. When I received the mount and placed my Ultima 8 OTA on it (via a third-party dovetail rail), I was given an education in what is possible go-to mountwise for relatively few dollars in this new century. I had expected a flimsy aluminum tripod. What I received was a hefty tubular steel affair with 2-inch diameter legs. The mount head itself was fairly well finished and seemed larger and sturdier than it looked in the pictures. The computer? The mount was equipped with the same HC used on my much more expensive NS11 GPS (albeit loaded with the different software required to run a GEM).

The proof is on the observing field, however, and I soon had the scope running through its alignment. The go-to alignment is similar to that of the LXD75 in that it defaults to a two-star alignment. When the alignment is complete, though, the mount gives the option of adding up to four cone-alignment stars, which makes the C8-SGT's CG5 mount surprisingly accurate. I was amazed, in fact, at how good the GEM's go-to accuracy was. On my first evening with the SGT, I punched galaxy M63 into the HC without expecting much. The mount began moving, appearing to position itself in the correct general area of the Sunflower Galaxy. Still, I expected nothing more than an anonymous field star or two when I put my eye to the eyepiece. Surprise! There was the dim ghost of a spiral galaxy staring back at me. Okay, Mr. Smarty Pants, give me M64. Boom! The Blackeye Galaxy was centered. M53! That glittering star ball was almost perfectly positioned. I was so excited I ran into the house, grabbed my wife, and literally dragged her into the backyard for a look. I would have thought that after my many years of observing with lots of fancy equipment it would be impossible for a sub-thousand-dollar mount to excite me, but it did. The CG5 just worked well and simply.

I later found out that the CG5 was even better than I thought. I could even take pictures with it. I am not exactly an advanced astrophotographer, even after 40 years of trying, but I do like to take the occasional deep sky snapshot. The CG5 has more than enabled me to do that. I have taken scads of attractive (to me) color charge-coupled device images with the Meade DSI (Deep Space Imager) color imager and my homemade C8-SGT. All these have been unguided 30-second to 1-minute exposures. The gears on the CG5 are good enough to usually deliver nice round stars when the scope is well balanced. It is also not difficult to achieve a polar alignment good enough for imaging. The hand control includes a polar alignment utility that actually makes that task easy.

But, this was with my Ultima 8 OTA riding on the CG5. What will images be like in a genuine Celestron SGT-8? Probably, they will be better than in the Ultima 8/CG5 combination. The Ultima is a fine OTA, but it is unlikely the nice old CAT would be able to compete with a just-produced C8 with Celestron's high-performance XLT coatings, their analog of Meade's UHTC. The new OTA correctors pass more light, and their mirrors reflect more. Images in a current C8 are noticeably brighter than those in an old Ultima. What one thing is better with the older OTA? The focus action on current Celestrons is smooth but not quite as buttery smooth and easy as on the old scope. On the other hand, some users have commented that the focus on the Ultima OTA is "too easy." Maybe it depends on what you are used to. The glossy black Ultima OTA is certainly classier looking than the gray finishes of the new C8 OTAs. Of course, all CATs are black in the dark.

What is there not to like about the Celestron? Sure, there is always *something* not to like with any telescope. The Celestron NexStar HC is very similar to the Meade Autostar but has one big strike against it for imagers: It lacks PEC. There is no way of recording a guiding run to minimize periodic error. That is not a fatal lack for astroimagers, however. The periodic error on the CG5 is smooth and regular and easily guided out manually with button pushes or automatically with a guide camera. The mount features an ST4-compatible autoguider port, and autoguiding programs are able to deliver round stars in exposures as long as 15 minutes at f/6.3 or f/3.3 (via focal reducers and reducer/correctors described in Chapter 6), which are the longest exposures you will probably need to do.

Are there other complaints? Let us face it, the CG5 GEM is not the rock of Gibraltar, and while slightly heftier than the LXD75, it is not in another class. It *is* very stable with the C8 OTA except on windy nights, and even then visual observing is not much affected. Imaging *is* affected and is simply not practical under windy conditions. A set of Celestron's vibration reduction pads (Chapter 6) can at least reduce vibrations caused by wind, if not completely eliminate them. The noise produced by the CG5 mount while moving to targets at its maximum go-to rate is slightly less than that of the LXD75, but not much. If the neighbors are easily awakened, do not do too much go-to slewing in the backyard late at night.

The accessories included with the C8-SGT include a 12-volt DC power cable (there is no option for onboard batteries; this mount needs lots of current to operate reliably), a too-small 6 × 30 mm finder, a decent 25-mm Plössl eyepiece, and a CD containing TheSky home planetarium software. For observers strapped for cash, the C8-SGT is available without XLT coatings for a slightly lower price (not recommended).

All in all, the quality and utility of the Celestron C8-SGT and its CG5 mount are excellent. Yes, there are some nits to pick, but the mount is adequate. A more expensive, heavier GEM might do things a little better or more easily, but the C8-SGT gets the job done.

Celestron NexStar 8 SE

When the forerunner of the Celestron NexStar SE, the NexStar 8, appeared in 1998, it was not just a striking-looking new telescope; it was the telescope CAT fans thought might be the savior of Celestron. The company had spent much of the previous decade in the doldrums. It had offered a few interesting products, but mostly it seemed to be playing catchup with Meade. To add insult to injury, the venerable Torrance, California, company had just been bought out. The new owner, Tasco, despite what we feared, did not turn Celestron into a purveyor of junk-o-scopes. In fact, their cash allowed Celestron to release a genuinely innovative instrument, the aforementioned NexStar 8.

Today's NexStar SE 8-inch (Plate 15) builds on that success with refinement. Its sleek design is not *quite* as striking as it was in 1998, but it still looks as if it would

Plate 15. (NexStar 8 SE) The half-fork mounted Celestron NexStar 8 SE. Credit: Image courtesy of Celestron.

be right at home on the bridge of Captain Kirk's *Enterprise*. "Streamlined" is a good word for the SE. Its snazzy lines are further enhanced by the fact that the NexStar HC nestles in a recess in the single-fork arm. What is the first thing you notice about the SE, though? It is the color of the OTA, a brash orange, homage to the original Orange Tube Celestron C8 of 1970.

It is what is under the hood that counts, of course, and despite its fairly modest price, the SE does not scrimp. At first, there seems to be a lot of plastic involved in its construction, but that is deceptive. The plastic on the single-fork arm is just a covering; the arm itself is aluminum. The SE feels considerably more solid than competing telescopes in its price class.

Some amateurs have expressed doubts about the SE's country of origin. This SCT was the first Celestron scope to be made entirely in China. In the past, the company has placed tubes on imported GEMs, but the fork-mount scopes have been entirely American made. What impact did this change have on the NexStar's quality? Absolutely none it seems. The SE is almost indistinguishable from the last American-made version of the scope, the NexStar 8i. "Almost" because there have been some minor cosmetic changes to the OTA's rear cell and corrector assembly. The SEs are very good optically when compared to other SCTs and are mechanically as good as or better than the NexStar 8 or 8i.

Who will like the NexStar 8 SE? Anyone who wants a light, visual-use telescope and does not want to spend a lot of money. At a street price of $1,400, the SE is slightly more than $100 less expensive than the C8-SGT, and it is about as close to the traditional "$1,000 for an 8-inch SCT" price that amateurs have grown accustomed to over the last couple of decades. This little CAT will be particularly attractive for beginners because of its incredibly easy setup.

An SE user does not need to perform any kind of polar alignment. Being a fork-mount SCT, the NexStar SE can operate in alt-azimuth mode. Plunk the scope down in the backyard, level the tripod, perform Celestron's SkyAlign procedure—point the scope at three stars using the hand control—and it is ready to observe any of the 40,000 objects in its database that are visible in an 8-inch telescope.

The SkyAlign go-to alignment routine is one of *the* biggest advances in computerized scopes to come around in the 20 years since go-to scopes appeared on the amateur astronomy scene. This new alignment method is largely the result of a legal tussle with Meade. Formerly, during alignment, Celestron's go-to telescopes pointed themselves north, leveled their tubes, and chose two alignment stars. The scopes would then slew to the general vicinity of these stars, and the user would fine-tune centering. That worked well and yielded good go-to alignments. Unfortunately for Celestron, Meade claimed they had a valid patent for this "north-and-level" alignment system. The courts agreed. What was Celestron to do, other than pay royalties? They designed a new and noninfringing routine.

This new alignment method, SkyAlign, is almost the complete opposite of the earlier north-and-level procedure. With SkyAlign, the *telescope* does not choose the alignment stars, the *user* chooses them. But, here's the kicker: The user does not have to know which stars are which; all the user must do is point the scope at any three bright objects—yes, *objects*. These three targets do not have to be stars; Jupiter, Saturn, Mars, or Venus will do. Even the Moon will work. Once the three objects have been centered, the telescope figures out their identities and generates an internal model of the sky. The user can ask the scope to give the names of the three objects following the alignment, but that is not necessary.

Can it really be that simple? Yes. Testing both the new SkyAlign routine and the old north-and-level system on the same telescope, my NexStar 11GPS, showed that SkyAlign yielded go-tos that were every bit as good as—if not better than—north and level. It seemed that SkyAlign tended to almost always place requested objects nearer the center of the eyepiece than a north-and-level setup.

The bargain-basement SE is not loaded with accessories, but it does hold its own in this area. Celestron ships the scopes with the advanced XLT coatings standard. That is somewhat remarkable since these coatings are a fairly costly option on more expensive Celestron SCTs. Like the previous two scopes, the SE is equipped with an inexpensive 1.25-inch format star diagonal and a minimalist 25-mm Chinese-made Plössl eyepiece. As for the finder scope, there isn't one. Instead, the NexStar SEs use a zero-power red-dot "BB gunsight." Some astronomers may prefer a real finder telescope, but since the average SE user will only need a finder for initial go-to alignment, the red-dot job is not a huge handicap. Other than the HC and a decent steel-legged tripod, that is almost all there is in the box other than the scope itself.

Celestron does throw in a couple of CDs. One is unremarkable, a copy of the basic edition of *TheSky* computer software home planetarium, which can be used to send the scope to targets with a PC connected to the scope with an optional serial communications cable. The other CD contains the remarkable *NexRemote* software, which can really make this *sing* (see Chapter 10). As shipped, the SE does not sport GPS capability, but that can be added at any time with the purchase of the optional CN-16 GPS receiver module.

The SE can be powered by internal batteries—eight AA cells in this case. Like other CATs that can use small batteries, it will eat AAs in a hurry, though, and works best with an optional DC power cord and a strong 12-volt DC battery. Do not waste time with the AC power supply Celestron sells for use with this telescope; it tends to send the scope off into never-never land rather than to sky targets.

Is the NexStar 8 SE really that good? Yes! That does not mean the scope does not have a few liabilities. The biggest aggravation is the SE's fork-mount gears. Like Meade's and Celestron's inexpensive GEM-mounted SCTs, the SE's gear train tends to be a little sloppy. When the scope is tracking, that is not a problem, but slew the scope with the HC, especially at slower speeds, and then reverse directions with the opposite button, and there will be a considerable time lag—often as much as 15 seconds—before the scope begins moving while the motors take up the gear slack. This is not an insurmountable difficulty as there is a software routine in the hand control to reduce "backlash" that helps some, probably more than enough for the visual observing for which this telescope is best suited.

Can the SE take pictures? Yes. Imaging the Moon and planets with this scope is fairly easy despite the aggravation backlash causes when centering these objects at high power. Can deep sky images be taken? Maybe. Some fairly impressive long-exposure shots have been done with this telescope, and it is certainly more capable in this area than the earlier NS8s due to a somewhat improved drive system. This is still not a deep sky imaging powerhouse, however. Also, if the SE is to be used for deep sky exposures longer than about a minute, it will require an optional wedge.

One thing a lot of prospective SE buyers worry about is its half-fork nature. Does the fact that it uses only one fork tine instead of two to support the OTA make the SE shaky? The answer is "no." A dual-tine fork would be steadier, but for the relatively light 8-inch OTA a single arm does fine, especially for just viewing. The SE mount does have one excellent feature. Unlike just about every other fork-mounted telescope that has been sold by Meade and Celestron over the last 40 years, the SE features a removable optical tube. The OTA is mounted to the single-arm fork via a dovetail bracket. The tube can slide back and forth in this bracket to balance, which will do a lot to improve tracking and backlash characteristics. It can also be completely removed from the arm for easy transport and storage—or to mount to another scope (maybe a small wide-field refractor, for example) on the fork via the standard "Vixen-compatible" dovetail bar.

The C8 SE is at least impressive, if not overwhelming. If you are a beginner, you will probably be even more impressed. The scope is a great choice for the visual observer or even for the astrophotography dabbler. It is also light and highly portable and may change the minds of those people who do not think they can handle an 8-inch SCT. The SE is a cute and wonderful beginner's scope.

Midlevel 8-Inch SCTs

Celestron's and Meade's midgrade SCTs, the LX90 and the C8 CPC, are a definite step up from the basic telescopes. They are not much better accessorized than the low-cost models (Why is it that an imported Dobsonian is often equipped with two or three eyepieces, while much more expensive SCTs come with only one?), but the ills that plague the price-buster scopes have been at least partially cured. Most notably, the gear systems on these SCTs are much better; they exhibit far less annoying backlash than the LXD75, C8-SGT, and especially the NexStar 8 SE. The midgrade mounts are also less shaky, and both brands are equipped with PEC to make imaging easier. All this goodness comes at a penalty, however. These telescopes are heavier, if still transportable by any healthy adult. They are also more expensive. At the midlevel, plan to pay about $2,000 for a scope. Still, this seems very reasonable considering the capabilities of these CATs. One of them could very well be the scope of a lifetime ("aperture fever" notwithstanding).

Meade LX90 8-Inch SCT

When Meade announced the LX90 SCT toward the end of the 1990s, amateur astronomers were a little skeptical. The fact that that this telescope, which would replace the company's non-go-to LX50 model, was to be equipped with the Autostar computer, the same HC that was introduced with the company's go-to ETX telescopes, seemed a recipe for disaster. What Meade would do, it seemed likely, was scale up the tiny ETX 90 MCT to 8-inch size. It would have all the plastic of its little brother, but since it would have 8-inches of telescope aperture onboard, it would be as shaky as a leaf in a Gulf of Mexico hurricane. Nobody in their right mind would buy the thing. Wrong!

The LX90 was an immediate and continuing hit with amateur astronomers and for good reason: its outstanding design. The telescope simply does what it is supposed to do, simply and reliably. The Autostar computer—variations of which are now used on all Meade's go-to telescopes—means it is full featured. In fact, most observers will never get around to making use of all its capabilities.

The LX90 is currently priced at $2,000, putting it squarely in the midprice pack. As seen in Plate 16, it has that classic SCT look. Unlike the Celestron SE, it has a double-tine fork mount. There are no fancy paint jobs; the LX90 is finished in the same good old Meade blue-and-black color scheme the company has been using for the last 30 years. A look at the base of the right fork arm reveals a group of telephone-style RJ-11 connectors and that spells "go-to"—and does it go-to. The LX90 features a built-in library of 30,000 DSOs, planets, and stars, just like the LXD75. Worried about exhausting those 30,000 objects In that unlikely event, the scope

Plate 16. (8-inch LX90) Meade's mid-price 8-inch SCT, the LX90-ACF. Credit: Image courtesy of Meade Instruments Corporation.

can be hooked up to a computer via an RS-232 connector in the Autostar's base and utilize an astronomy software program's library of hundreds of thousands or millions of objects. If you do not want to spend money on astronomy software needed to control a telescope, that is okay. Meade throws in a copy of its *Autostar Suite* software with every LX90.

If long-exposure deep sky imaging with the LX90 is a goal, be prepared to spend more money, and not just for a camera. Meade's optional LX90 wedge is a must buy for versatile imaging use of the scope. As delivered, this CAT, like other fork-mount telescopes, can only be set up in alt-azimuth fashion directly onto the head of its tripod. The LX90 cannot use just any Meade wedge; it requires the Meade wedge designed specifically for the 90 (the LX90 has only one bolt hole in its base rather than the normal three) or Meade's "wedge adapter plate," which will allow the LX90 to be mounted on a standard Meade wedge. It is not known why Meade did not just put three holes in the drive base.

When it comes to included accessories, the LX90 is not much advanced from the el cheapo brigade. Other than the aforementioned software CD, there is a 1.25-inch, 26-mm Plössl eyepiece (good enough) and a star diagonal. One nice touch is that the telescope ships with a high-quality 50-mm finder telescope in addition to the red-dot LNT finder/module that Is used for initial go-to alignment. As is the case with most other Meade CATs, the enhanced UHTC optics are standard.

Other than relatively minor software changes, the LX90 remained the same for quite a few years. Then, beginning in 2005, Meade piled on the new stuff. In addition to introducing larger-aperture LX90s, a 10-inch and a 12-inch, it added GPS to the 8-inch LX90. Coupled with the scope's north-and-level alignment routine, the GPS makes go-to alignment a true no brainer: Turn on the telescope, and it listens for GPS satellites, gets a "fix"—determines time and the scope's current location—and does a little dance. The tube levels itself, finds north, determines the tilt of the scope tripod/mount, chooses two alignment stars, and heads for the first one. All the user must do is center the alignment stars in the finder (either the red-dot LNT finder or the real finder scope), hit enter, and the telescope is ready for an evening's sky voyaging.

The LNT red-dot finder is a pleasure to use for alignment. Since there is no magnification, the field of view is wide, making it easy to get the alignment star centered. One other nice thing about the LNT: When the alignment begins, the Autostar HC automatically turns on the red dot. When alignment is done, it turns it off. Many times a red-dot finder's small batteries have been burned out by forgetting to shut the thing off in the excitement of starting to observe.

One other feature that makes LX90 go-to alignment easy is that the user does not have to set the mount or tube in a special "home position" before beginning. Unlike most of Meade's other go-to telescopes, the LX90's receptacles for the hand control, power, and other cords are in a fork arm and not in the base, so there are no cables running up from the drive base to the fork to twist if the scope is rotated too far in one direction. There are no "hard stops" needed in the base to prevent this rotation, and the scope does not need to be made aware of its rotational position in reference to these stops at startup by placing the tube in a particular starting position. Plunk the LX90 down with the tube facing anywhere, hit the power, let it do its dance, and it is good to go.

The LX90 is a remarkably well-designed scope. However, your Old Uncle Rod can *always* find nits to pick with any SCT, and the LX90 is no exception. One negative thing about this telescope is its elevation/declination lock knob. It always feels too loose, but the user may be reluctant to tighten it down too much for fear of breaking something. In the scope's defense, while the knob *felt* too loose, it always seemed to hold the scope firmly in place in declination. The problem was merely "feel." Then, there is the fork. The LX90's fork mount is hefty enough for extensive visual use and some imaging, but it could not be called rock solid. Do not expect to do 2-hour CCD exposures in the middle of a windstorm.

Astrophotographers will be pleased to learn that, like the LXD75, the LX90 Autostar includes PEC. It is unfortunate, though, that this is PEC and not PPEC, *permanent* periodic error correction. Meade's more expensive models allow guide corrections to be recorded and stored permanently. As is the case with the entry-level LXD75, unfortunately, an LX90 PEC recording is erased at power down and has to be redone for every imaging session. That is a shame since the LX90 is otherwise nicely suited for astrophotography. A shame, but not a show-stopper. One other feature of interest to astrophotographers the scope lacks is a dedicated autoguide port. That can be fixed with the addition of the Meade 909 accessory port module (about $50), or the scope can be guided through its serial port with the proper software.

Another quibble concerns, as usual, the telescope's power arrangement. As with the Celestron SE, the telescope can be powered by internal batteries, eight C cells this time. Although that might be a minor step up from AAs, Cs will not last long, either. Get the optional DC cable and run the LX90 with a reliable lawn tractor or automotive "jump start" battery. Meade really should face the realities of the power situation and begin including the necessary DC power cable instead of making new buyers pay extra for it.

Do not take the foregoing to mean that we do not like the LX90. Its pluses *far* outweigh its minuses. This is a well-thought-out, sweet little scope sure to please both beginners and advanced amateurs. In fact, there may not be another SCT that is both as easy to use and as capable of carrying out demanding observing programs.

Just as this book was being finished, Meade announced yet another version of the venerable LX90, the LX90-ACF. This new edition is identical to the previous LX90-GPS, but the standard SCT optics have been replaced by Meade's f/10 Advanced Coma Free optics package. For more details, see the entries on the LX200-ACF and the LX400-ACF, but in a nutshell, these aplantic SCT optics can produce flatter fields and sharper stars.

Celestron CPC 800 GPS

When Celestron began to put itself back together following its economic problems of the late 1990s, the SCT that re-won the company the hearts and minds of amateur astronomers was the NexStar GPS. These heftily mounted fork scopes equipped with built-in GPS receivers took the amateur community by storm. Alas, nothing lasts forever, and we knew Celestron would eventually have to retire these classic CATs. The question was Celestron would do for an encore. The GPS was a tough scope to follow.

What Celestron did was introduce a fork-mount CAT that was a lot like the NexStar GPS, but with some hardware and software refinements. The CPC 800 8-inch ($2,000) model, shown in Plate 17, features a larger drive base and RA gear system, an improved tripod, and updated firmware that includes the new SkyAlign routine (see the entry for the NexStar 8 SE). In fact, one of the main reasons Celestron may have introduced the CPC when it did was to make a clean break with the old north-and-level GPS scopes. Every GPS scope sold meant a royalty payment to Meade for the use of the north-and-level routine.

Plate 17. (CPC 800) Celestron's mid-price entry, the CPC 800 8-inch SCT. Credit: Image courtesy of Celestron.

What is a CPC like? To be honest, it is not as attractive as the GPS models. The base is absolutely huge in comparison to the 8-inch OTA. That may be good for tracking, but it looks kind of funky. Then, there is the color scheme, silver-gray base, black fork arms, and gray aluminum tube. Something just does not work there. By the way, CPC supposedly stands for "Celestron Professional Computerized", whatever that means. Like cats, all CATs look alike in the dark anyhow, and you can call your scope anything you want. What matters is how a CAT performs on the observing field.

Optically, there were no surprises. Celestron seems to have been on a roll in that regard over the last 10 years or so. There does not seem to have been an optically inferior Celestron OTA produced in a long time. Equipped with the (standard) Star-Bright XLT optics, this OTA should whip—at least slightly—even the Ultima 8 OTA. Other than that, there is not a lot to say about the tube. The OTA has been slightly redesigned (all Celestron's OTAs have), but this seems to be for appearance only. Build quality, including focus action, is still very good.

The mounting, despite its wacky color scheme and *big* base, is very much like that of the NexStar GPS scopes. There are two sturdy aluminum (plastic-covered) fork arms. The base has RJ- (telephone) style inputs for the HC, PC (for NexRemote), and "Aux." What are the uses of Celestron's Aux inputs? Not much. Celestron promised us "numerous Smart Accessories" would "soon be available" to use these connectors, but it has been 6 years since these plugs appeared, and no Smart Accessories have appeared on the scene. One of the most wonderful things about this mount is that it is like a radar antenna. How so? It uses a *slip ring* to transfer power and data from the base to the fork. This arrangement, like that used for rotating radar antennas, means that there are no wires to get twisted. Signals are conveyed by two rings rotating against each other. For this reason, Celestron does not have to either put the connectors in a fork arm or use hard stops, as Meade does.

What makes that base so darned big? This is Celestron's take on an SCT RA drive. The tube is driven by a worm/spur gear set just like Meade's scopes. The CPCs differ in regard to what the mount moves *on*. Instead of a ball-bearing race, Celestron's CPC mount uses rollers riding in a large-diameter track. That makes for smooth azimuth/RA movement. The only real complaint about this system is that over time the NexStar GPS (which uses a similar but slightly smaller track) gets dirty, making movement a little rough and herky-jerky. The track is fairly easy to clean, however.

The CPC uses the same HC shipped with all Celestron's other current go-to scopes (programmed with CPC software). The NexStar hand control contains over 40,000 objects, tours, and space for 400 user-defined objects (like comets, etc.). Again, the main complaint about the HC is the black-on-red display, which is hard to read at 3 a.m. with middle-aged eyes.

One word sums up the drive system on this scope: solid. Celestron uses high-quality servomotors. You often hear long-time amateurs joke about the coffee grinder noise made by go-to scopes on a peaceful observing field—no java with this one. Even slewing at high speed (3° per second maximum), the sound is more like the purring of a big cat than a refugee from Starbucks.

In the area of included accessories, the scope is similar to the less-expensive Celestrons (and the Meades). Included is an inexpensive Plössl (a not-so-hot 40 mm) and a similarly inexpensive 1.25-inch star diagonal. Both these items work okay but are destined to be tossed in a drawer and forgotten as soon as something better can be purchased. There is also a good 50-mm finder and a CD containing the all-important *NexRemote* software. Way down in the Styrofoam peanuts is one last item: a DC power cable. It is unclear why Celestron does not include this cord with *all* its SCTs. Encouraging users to power the scope with a reliable 12-volt DC power source would prevent a lot of "tech support" calls to the company. The CPC tripod is Celestron's improved heavy-duty field model (chrome) with 2-inch steel legs. This is at least an incremental advance over the Celestron "heavy-duty" tripod of yore.

"Ain't nuthin' perfect on God's green Earth," as Rod's old granny used to say, and the CPC is not exempt, even if there is not *too* much bad we can think to say about this one. It was disappointing to see that this series of scopes uses aluminum tubes rather than the carbon fiber of the NexStar GPS series. Carbon fiber was both elegantly attractive and a boon for imagers. It does not expand or contract very much with temperature changes, meaning astrophotographers do not have to refocus NexStar GPS telescopes very often. Aluminum-tubed scopes do have the benefit of reaching thermal equilibrium faster than carbon fiber ones, though, and being able to get the scope settled down for viewing quicker is probably of more interest to most observers than avoiding tiny changes in focus.

The only other criticism is not really a criticism per se. The CPC is a very good fork-mount telescope, but it *is* a fork-mount telescope, and a comparably priced GEM seems a better investment if astrophotography is a major interest. The CPC is certainly as imaging capable as any other fork scope and has an advantage over the LX90 in that it is equipped with PPEC. Like other current fork-mount scopes from both Meade and Celestron, a wedge, required for long exposure photography, is optional for the CPC. Like the SE, the entire CPC is now apparently being produced offshore in China. Also, as with the SE, quality does not seem to have been affected.

Despite its odd looks, it must be admitted that the CPC is a worthy successor to the GPS scopes. It is at heart very similar to those classic instruments and can certainly give a lot of pleasure as a general-use or even an advanced-use CAT.

Top-of-the-Line 8-Inch SCTs

The top-of-the-line 8-inch SCT is the best of the best for mass-produced Schmidt Cassegrains, and it is where Meade's and Celestron's offerings diverge. At one time, Meade was saying its top scopes, the LX200-ACF and LX400-ACF, were not really SCTs at all, but CATs of an "advanced Ritchey Chrétien design." Most optically knowledgeable amateurs called the ACF telescopes "optimized/aplantic SCTs" instead, and in a recent settlement between Meade and makers of *true* Ritchey-Chrétien telescopes, Meade has agreed not to refer to its telescopes as Ritcheys any more.

Optics aside the Meade ACFs are similar to other Meade fork-mount SCTs in most ways. Celestron takes a different path here. Rather than producing a fork scope with more features or a new optical design, they abandon the fork altogether and place a standard C8 SCT OTA on a high-quality GEM mount, the CGE.

Celestron CGE 800

Celestron's premier 8-inch SCT, the CGE 800 (Plate 18), uses the same optical tube as the C8-SGT, a standard f/10 Schmidt Cassegrain OTA equipped with enhanced XLT coatings. The 800's CGE GEM is the product of an evolutionary process that started over 10 years ago. Initially, Celestron did not make heavy-duty GEMs, but instead sold scopes on mounts obtained from Losmandy, famous for their G11 German mount. Unfortunately, Losmandy could not produce GEMs in the numbers Celestron required, and that resulted in Celestron phasing out the Losmandy GEMs in favor of a similar mount produced in-house, the CI700. The 700 was not a bad mount, but it was one with a few rough edges, especially in the electronics department. And, it had one huge strike against it: no go-to at a time when computerized mounts were becoming the norm.

Plate 18. (CGE 800) The top-of-the-line Celestron 8-inch SCT, the German mount CGE 800. Credit: Image Courtesy of Celestron.

As soon as possible, Celestron brought forth the CGE, which was a near-complete redesign of the CI700. In addition to adding go-to via the NexStar computer HC, Celestron cleaned up the electronic/electrical issues that plagued the CI700. The CGE is a very clean-looking mount, with all cables being internal to the mount head and nothing to get tangled up. The CGE 800's price, about $3,600—almost two and a half times the price of the C8-SGT GEM SCT—takes some scope shoppers aback. What makes the CGE cost so much more?

It is not apparent in magazine ads, but set the SGT next to the CGE in person, and the reason becomes clear. The CGE is a far heavier-duty mount than the C8-SGT's CG5. Couple this mount with an 8-inch OTA, and the result is that elusive goal of astrophotographers, a scope that is truly steady as a rock.

The CGE mount is capable of supporting a payload of 65 pounds, according to Celestron, enabling an imager, for example, to load a C8 OTA down with all kinds of accessories and piggyback scopes and cameras and not even make this big dog flinch. And, it is not just in payload capacity that the CGE pulls ahead of less-expensive Meade and Celestron scopes. The gears are high quality, as are the motors, strong Pittman servos. Unlike its smaller sister, the CG5, the CGE uses a considerably heftier Losmandy-compatible dovetail to attach scope to mount, which further aids stability.

Is a CGE overkill for a C8? As any astroimager will say, there is no such thing as too much mount.

The NexStar hand control shipped with the CGE 800 is identical to the C8-SGT model and features the same tours, utilities, and library of objects (40,000 targets). Other CGE 800 accessories include, surprisingly, a way-too-small 6 × 30 finder scope, a DC power cord, an okay 1.25-inch, 25-mm Plössl eyepiece and star diagonal, and the NexRemote software CD.

Then, there are those inevitable downsides. The foremost of these for many of us is probably price. The CGE 800 costs over twice as much as the C8-SGT, but does it deliver twice the performance? For the visual observer, probably not. For the astrophotographer, most definitely yes. Do not get the idea that this is really a top-of-the-line GEM, though. Top of the line for truly serious astronomy picture takers means paying three times what the complete CGE 800 costs for just a mount. The CGE *is* a very capable GEM mount similar to the much-loved Losmandy G11, and all but the most experienced and demanding imagers will find the CGE 800 more than sufficient.

The steadiness and sturdiness of the CGE comes at a weight penalty. The CGE 800 package—mount, tripod, and OTA—weighs in at a frightening 100 plus pounds. That is not quite as bad as it sounds since the 800 can be broken into its components. The tripod, the biggest Celestron sells, weighs about 40 pounds when combined with the short pier on which the mount head is placed. The CGE equatorial head without counterweights is another 40 pounds, and that is 40 pounds that will have to be lifted fairly high to place it on the (extendable) tripod. That is well within the ability of most healthy adults but do not kid yourself: The CGE 800 is *not* a scope to grab in one piece and carry into the backyard for a quick look at the Moon.

The CGE 800 is heartily recommended for the experienced amateur, especially the experienced amateur devoted to imaging. For the beginner who *might* want to pursue astrophotography, it may be. But, the novice or the casual visual observer might be better served with an easier-to-use fork mount. Again, nothing is more comfortable and user friendly for the visual observer than a fork-mounted go-to scope set up in alt-azimuth fashion. Like the CG5 mount, the CGE requires a polar alignment each time it is used.

Meade LX200-ACF 8-Inch

By the middle of the first decade of the twenty-first century SCT-using amateurs were getting a mite antsy. What would Meade do next? Celestron was playing things fairly safe with the CPC. Would Meade up the ante as far as technical innovation, something they have been known to do frequently? Indeed, they did, with the LX400-ACF (initially called the RCX400). This innovative CAT, unfortunately, was a little too much for most amateurs—too much money and too many radically new features. Meade did not forget the rank and file, however, and soon replaced their former top-kick scope LX200GPS with the $2,700 LX200-ACF (Plate 19).

"Replaced" is probably too strong a word. All Meade did to update its LX200GPS SCT into an LX200-ACF (originally sold as the LX200R) was change the optics in the OTA. Meade's Advanced Coma Free optics are different, but not tremendously different, from those used in the company's other and earlier SCTs. The focal ratio is still f/10, and the coatings are Meade's advanced UHTC recipe (standard). What is changed is the secondary mirror and the corrector. The "traditional" Meade (or Celestron) SCT has heretofore been equipped with a spherical convex secondary. The ACF-type SCT replaces this with a secondary mirror that is figured as a hyperbola (or a parabola, depending on which optics guru you listen to), a deeper curve, instead. The primary remains a sphere. The corrector may be slightly altered in figure for the new optical prescription but is much the same.

What benefits do these "optimized" optics confer on the amateur? Not many, not for the visual observer, anyway. Their main benefit is that they flatten the naturally curved SCT field, making stars look "tighter" away from the center of the field, delivering sharper stars and less "coma" (although field curvature is a far more serious problem for SCTs, and that is mainly what the ACF fixes rather than true coma) than normal SCT optical sets. Amateurs have been achieving this same effect for a long time, however, by using one of Meade's or Celestron's inexpensive f/6.3 reducer/correctors, which have the added advantage of making the scope's field wider.

One group of amateurs *will* benefit from the new optics: astrophotographers using digital single-lens reflex cameras (DSLRs) or astronomical CCD cameras with large chips. While reducer/correctors can be useful for cameras with smaller imaging chips, using a reducer/corrector with a DSLR tends to result in *vignetting*. The entire frame is not evenly illuminated; the resulting picture gives the appearance of looking through a porthole. That can be cured or at least improved with flat-field frames and other processing tricks, but it is always best to work with an image that does not require much cleaning up. ACF-type images are flatter, mostly free from vignetting, and require less postprocessing.

Other than the optics, what is the LX200-ACF like? There is a built-in GPS receiver like the one on the LX90 that makes alignment in alt-azimuth mode a joy. The fork? It is sturdy, if not overkill. The LX200-ACF replaces the standard 497 Autostar with the Autostar II, which amazingly adds even *more* computer-

Plate 19. (LX200-ACF 8-inch) Meade's latest LX200 features the company's "Advanced Coma-free" ACF optics. Credit: Image courtesy of Meade Instruments Corporation.

ized features, including an overwhelmingly huge library of 147,541 objects (if you cannot *see* many of these, you can at least image some of them). One of the more important features of the LX200-ACF for imagers is the mirror lock. Once focus is achieved, the mirror is locked down with a rear cell knob to prevent mirror "flop" during long exposures. What if a focus touch-up is needed after the lock is engaged? Meade provides an Autostar-controlled motorized Crayford-style focuser that attaches to the rear port.

What accessories are included with the ACF? In addition to UHTC coatings, there is the standard Meade field tripod, which is both heavy enough to hold the scope fairly steady but still light enough to spare middle-aged astronomers' backs. Power is provided via eight C cells that are as useless with this scope as they are with the LX90 (optional AC supplies and DC cords are readily available). The finder is the same good 8 × 50 shipped with the LX90. The included eyepiece is Meade's 25-mm Series 5000 Plössl and is paired with a better-than-average 1.25-inch diagonal. Meade usually also throws in a copy of the *Autostar Suite* planetarium software.

The drive system on the ACF is Meade's good worm-spur gear set, which, unlike the LX90 drive, features PPEC. Record a guiding run, striving to carefully guide out the occasional fluctuations the LX200-ACF's drive—like any telescope drive—displays, and periodic error will be drastically reduced.

Unlike the PEC system used in the LX90, this PPEC recording is not lost when power is turned off at the end of the evening. The ACF's drive is also blessed with a feature called "Smart Mount." This is a software utility accessed from the Autostar II HC that allows the scope's go-to pointing accuracy to be refined by sighting multiple alignment stars (more than 40) following a "normal" go-to alignment. This procedure is probably mainly of interest to observers with permanently mounted telescopes since those 40 stars must resighted if the telescope is moved. Frankly, Meade's normal go-to accuracy is good enough that visual observers and most imagers will not need to bother with Smart Mount.

The bring-downs associated with the LX200-ACF are few but need to be mentioned. While reasonably priced, this is not a cheap scope at $2,700. It has a lot of features and frills, but many amateurs would be just as happy with the similar and cheaper LX90-ACF. Also, while LX200-ACF's go-to accuracy is very good, its tracking accuracy is average at best. At the scope's native focal length of f/10, do not expect unguided exposures longer than 30 seconds even with a careful polar alignment. The scope can be autoguided with CCD cameras, but it may take considerable tinkering with autoguide software settings and PPEC "training" before the LX200-ACF's mount behaves well enough for long exposures. The addition of a reducer/corrector can help, but Meade has not released a reducer/corrector designed for the ACF's slightly different optics. A "stock" f/6.3 reducer/corrector can be used, but it may not provide results as good as those on a standard SCT.

The altitude lock on this SCT, like the one on the LX90, does not have a firm feel when tightened. This has driven some users to invest in the aftermarket mod kits sold by Peterson Engineering, which makes several interesting accessories and mod kits for these scopes, that allows the declination axis to lock firmly without requiring the knob to be cranked down hard. As is the case with the LX90, this is probably not needed; the scope is usually held firmly enough with the standard lock finger tight. Finally, small hardware—nuts and bolts on the OTA and tripod—is another minor issue. As with its other CATs, Meade does not use high-quality stainless steel hardware, so screwheads may begin rusting after several dew baths. Some users replace these bolts and screws with a better grade of hardware, but a little rust does not do harm beyond the cosmetic.

There are a few negatives, true, but not enough to steer CAT buyers away from the LX200-ACF. This is a sophisticated scope with very good optics, perhaps the finest optics available in a production SCT. If you are after a fork-mounted SCT for general use, a top-of-the-line model with tons of features, you should give strong consideration to the ACF. Although many folks look on this as a scope for imagers, its real strength may be for visual observing. Mounted in alt-azimuth fashion, the scope is extremely solid and a joy to use.

Meade LX400-ACF 10-Inch

The LX400 (Plate 20) does not come in an 8-inch version, so I have chosen to place the smallest model, the 10-inch, with the 8-inch SCTs rather than with the big CATs. That is because this is a remarkable scope in many ways, one that is worthy of consideration by anyone in the market for an SCT of any size, not just something for folks suffering from the dreaded aperture fever.

What makes the LX400-ACF "remarkable"? There are a number of things, but basically this was the first new idea in SCTs to come down the pike in a long time when it was introduced in 2005. It still stands alone today. For mass-produced SCT buyers, this is as advanced as it gets. To start with the optics, like the Meade LX200-ACF, the LX400 features the optimized "aplantic" SCT design. Meade did not stop there, however. The LX400 optics set has a focal ratio of f/8 rather than what has

Plate 20. (LX400-ACF 10-inch) The smallest member of the LX400 family, a 10-inch LX400-ACF. Credit: Image courtesy of Meade Instruments Corporation.

been the standard for SCTs over the years, f/10, so its field of view is wider eyepiece for eyepiece, and imaging exposures can be shorter and will deliver wider fields than those taken with a standard SCT at f/10 without the need for reducer/correctors. It has been the norm for SCT-using imagers to have to fool around with these and other "focal-reducing" lenses to achieve shorter exposures and wider fields in the past. With the LX400, the telescope can often be used at its "native" focal ratio, eliminating problems such as vignetting caused by focal reducers.

The LX400-ACF optics are at least incrementally better than the previous SCT standard, but it is really the "everything" else that is the draw here. Let us look at the optical tube first. The question that comes to mind when you see your first LX400 in person would probably be, "Where is the focuser?" There is no focus control on the back of the LX400 OTA. There is no mirror lock, and none is needed. As mentioned, rather than focusing by moving the primary mirror, the LX400 focuses by moving the *secondary* mirror. Actually, the entire corrector assembly at the front of the scope moves back and forth as the telescope is focused. This is done with small motors and is controlled with a couple of buttons on the Autostar II HC. The primary mirror is firmly and permanently locked in place. This system finally eliminates the focus shift and mirror flop that have disturbed SCT users since the scopes were first introduced.

The focus motors do not just focus the LX400, however; they can also be used to collimate it. By activating combinations of the focus motors, the telescope can be optically aligned by pressing buttons on the Autostar. What if a new user starts playing around with this motorized collimation and gets things so far out of whack it is difficult to get a decent alignment back? A push of a button will restore default factory collimation.

One thing that has always been irritating about Celestron's more expensive fork-mount telescopes is that while they have the wonderful slip ring arrangement on the drive base to eliminate cable wrap, a dew heater (with cable) must usually be installed on the corrector to keep the lens dry—and back comes cable wrap. Why does an SCT not feature a *built-in* corrector heater? Meade listened. The LX400 includes an integral corrector plate dew heater that is controlled by the Autostar II.

What else could Meade pack into an SCT OTA? I have just begun to describe the features of this amazing scope. On the rear of the tube, there is an advanced control panel that features an additional port for the hand control, a Meade "auxiliary" port, an ST-4-style autoguider input, and most important, three USB (universal serial bus) ports for external computer control. Why is this most important? Computer manufacturers have eliminated serial (RS-232) ports on almost all laptop PCs. Unfortunately, until the LX400 came along, scope makers still insisted on using RS-232 serial data for computer control. That meant paying extra for a PCMCIA serial adapter card or trying to make a USB-to-serial converter cable work (often an impossibility). Meade includes special driver software with the LX400 that should allow off-the-shelf astronomy software to use the scope's USB ports.

As if all the above were not enough, the LX400's tube is made of low-expansion carbon fiber, material similar to what Celestron used on its now-discontinued GPS series. LX400-ACF-equipped astroimagers will not have to keep refocusing all night long as the temperature changes. Carbon fiber is also slightly lighter than aluminum and keeps the weight of these hefty scopes down. Carbon fiber tubes do take longer than aluminum OTAs to acclimate to outdoor temperatures, and the RCX addresses this problem handily with the addition of a built-in (filtered) cooling fan on the rear cell.

The fork mount and base of the telescope are a little less innovative than the tube. The mount is really not much different from that found on the LX200-ACF scopes. The drive base control panel does contain another USB port at least. The drive/gear system has been somewhat improved over that found in the LX200-ACF 8- to 12-inch telescopes, but performance is fairly similar. The LX400 includes both PPEC and the Smart Mount pointing accuracy improvement feature, just like the less-expensive scopes.

As befits Meade's top scope, the LX400's accessory lineup is impressive, if not as lavish as might be supposed. The scope comes standard with a UHTC-enhanced 2-inch star diagonal. The eyepiece shipped with a scope is a long way from the 25-mm Plössls I have been accustomed to finding in the boxes with the other SCTs. The LX400's single included eyepiece is a 24-mm 2-inch Meade Series 5000 Ultrawide with an 82° apparent field of view. The tripod is also something of an advance. It is heftier than Meade's standard field tripod and features an innovative "trigger release" mechanism that makes extending and collapsing the tripod legs easy.

All the above sounds good, but what is an LX400 like in the field under the stars? Thanks to the kindness of a Meade representative, I had the opportunity to give the 10-inch a hands-on tryout at the 2006 Cherry Springs star party where I was speaking. My first impression was that it was *big*. I could not believe I was looking at a 10-inch CAT. The LX400 OTA is larger than the "normal" 10-inch to accommodate all the motorized gizmos needed to handle focus and collimation. Combine that with the extra-heavy-duty tripod, and I thought I was looking at a 12-inch.

Getting the telescope going was simplicity itself. Like all Meade's GPS-equipped north-and-level scopes, when setup in alt-azimuth mode, the LX400 practically aligns itself. Turn it on, the scope gets a GPS position, date, and time fix, finds north and level, and heads for the first of two alignment stars. Center these two stars in the eyepiece, hit Enter, and an evening of productive observing can be enjoyed with the aid of deadly accurate go-to. Like the LX200-ACF, the RCX400-ACF does not have to be placed in home position before beginning alignment—the scope does that itself.

How good were the images the LX400 presented once the go-to had been aligned? They were very good indeed. Stars *did* seem sharper out at the edge of the field than they do in a "normal" SCT. But, as with the LX200-ACF scopes, the images were really only *slightly* better. They might make a great deal of difference for an imager, but most visual observers spend their time looking at the center of the field, not the edges, so the improved flatness of the ACF field would not be as big a factor.

What were the drawbacks? One was the noise level of the motors. No, they were not any louder than those of the LX90 or LX200, but they were not any quieter, either. At a price almost twice that of the LX200-ACF, you would expect something that sounded better. Now, admittedly, this was mainly an aesthetic consideration. The scope tracked well (visually), and the go-tos were great.

How about the motorized focusing? It is good, once you figure out how to use it. The Autostar does not have a dedicated focus control key; instead, the number 4 key is used to activate the focuser. Pressing this key while "focus speed" is displayed on the Autostar will adjust focuser movement from fast to slow. A second press of the 4 key after the focus speed display is gone (after 2 seconds) allows the user to access focuser "presets," user-defined focus positions for a particular camera or eyepiece. Focusing itself is done by pressing the up/down arrow keys. All this sounded reasonable enough when reading about it in a brightly lit motel room. Out on the dark Cherry Springs observing field, it was difficult to remember which button to mash to focus the thing. Once the correct button is pushed, focusing is easy and precise. The focus motor emits the usual Meade coffee grinder noise, just like the drive motors.

In fit and finish, the scope was fairly impressive. The tube is a thing of beauty. Its distinctive shape and the carbon fiber's elegant grayish finish stand out. The tripod was also very professionally put together and attractive. The fork mount was another matter. It was not much different from those on any of Meade's other scopes—workmanlike, but not exactly beautifully done. As a matter of fact, the castings on the RCX fork were somewhat the opposite; in a couple of places, they had the look of being "sand-cast in someone's backyard." Admittedly, this was an early example, and the mount did perform well. Last, the LX400 is a big, heavy scope, even for a fork SCT. The tube/fork combo weighs in at 84 pounds, so be sure you can handle it. There also is a fairly heavy price tag: $5,600.

Regarding overall quality, that is impossible to judge from one example. The scope I used worked flawlessly despite having been dropped at another star party (the fork had the scars to prove it). A bit disturbingly, however, input from LX400 owners over the last couple of years indicates the scope has not been completely problem free. Quite a few buyers have had to return their LX400s to Meade for various problems, many involving the focus/collimation motors. Over the last year, Meade has been working hard to resolve the telescope's problems, stopping production for a while, and perhaps by the time this book goes to press the last bug will have been exterminated. Some owners have also expressed concern about the LX400's unsealed optical tube. Due to the fact that the corrector must move to focus, there is a gap between the tube and the lens, and dust, dirt, and insects can conceivably gain entry. While no serious problems have surfaced in this regard, it is clear that if something gets inside the tube, it will be hard to get it out. The corrector cannot be removed as easily by the user as that of a standard SCT.

Some astrophotographers have raised questions about the RCX drive's tracking quality. However, the scope's periodic error and general tracking accuracy appear to be at least as good as that of the LX200-ACF and perhaps somewhat better. That is, not as good as a GEM mount costing two or three times as much as the whole 10-inch RCX, but very good nevertheless. The LX200 in its various incarnations over the years has taken thousands of excellent deep sky images.

Should you buy an LX400-ACF? If you want a fork-mount telescope, the LX400 would be impossible to ignore. Meade uses the word *advanced* a lot in this CAT's advertising, and in this case, it is not hyperbole. This telescope really is a *considerable* advance over what has been available to the fork-mount SCT user previously. Also, despite the usual Internet rumors, Meade has a good record of satisfying its customers. The biggest problem with the LX400? Getting one. As this book goes to press, it appears Meade has chosen to suspend production of the LX400 telescopes (except for the top of the line 16- and 20-inch instruments) indefinitely.

The Big CATs

How much telescope is too much? If the new baby is going to be installed in a permanent backyard observatory, the sky is literally the limit, and bigger usually *is* better. This is not so if the CAT must be set up and torn down for each observing run. A too-large first telescope can often bring a swift and bitter end to a budding amateur astronomy career.

The above being said, larger mirrors do enhance visual enjoyment; there is no denying that. Although an 8-inch or 5-inch telescope can do a good job from a dark site, it may be badly handicapped when used from a typically light-polluted suburban location. When light pollution is a factor, contrary to what you may have heard from some amateurs, more aperture is always better. As said in my book, *The Urban Astronomer's Guide*, skeptics should set up 5- and 12-inch SCTs side by side under light-polluted skies and point them at the great globular star cluster in Hercules, M13. In heavy light pollution, the star cluster is okay in the C5, a little on the smudge side with not too many—if any—cluster stars visible. In the 12-inch, M13 shows its true nature as a gigantic globe of distant suns.

Yes, aperture always wins, all things being equal. Fortunately or unfortunately, all things are not usually equal. Aside from the question of how to pay for a really big SCT, there is always the problem of how to move it. Unless the telescope is going into a permanent home, think long and hard before going bigger than 11-inches.

Celestron C9¼ and C11-SGT

If an 8-inch Advanced Series SGT is good, the 9¼- and 11-inch versions must be better, right? Perhaps. Going to the 11, especially, results in a significant performance boost for the visual observer. The trade-offs involved in moving up to the 9¼ or 11 SGT are a little more problematical than just weight or price. Price is not a huge obstacle as the 9¼ and 11 are "only" $485 and $765 more than the C8-SGT, respectively (the C11-SGT is currently $2,400, and the C9¼-SGT is $2,000). Setup is not overly difficult. At 20 and 27.5 pounds, respectively, these optical tubes, identical to those used with the CGE series, are fairly easy to place on their mounts. If the legs of the CG5 tripod are not extended; the mount head and saddle are low enough to make mounting the OTAs laughably easy. No, the problem is not set up; it is what happens when the tube is on the mount. When a larger-than-8 OTA is perched on this GEM, it gets the shakes in a hurry.

Certainly, the SGT's CG5 GEM performs well enough with the 9¼-inch, if not as well as with the 8-inch. At the 11-inch point, however, the blush is off the rose. That is *not* to say the C11-SGT is inadequate for the visual observer. It does a remarkably good job in that role, especially when the tripod is placed on Celestron's vibration suppression pads. Imaging is another story. If there is even a little wind or the telescope is the least bit unbalanced, picture taking is likely to be frustrating at best.

Let us not be too hard on the C11-SGT, however. It is, if nothing else, a tremendous bargain, an astonishing bargain, in fact. At this time, the C11-SGT package is only $100 more than just a C11 tube alone; the OTA currently retails for $2,300 without a mount. A hundred bucks is not a bad price for the computerized CG5, even if you have to bite your tongue on windy nights to keep from cussing the thing.

Leery of placing the C11 on the CG5 but still want more than 8-inches? Consider the 9¼; it has excellent optics and considerably more light-gathering power than an 8-inch for not much more money.

Accessories included with the larger SGT packages are identical to those that come with the 8-inch: 1.25-inch diagonal, TheSky software on CD-ROM, a 50-mm finder, and a DC power cable. The 11-inch is equipped with a somewhat "yucky" 40-mm NexStar Plössl rather than the better 25 mm that is shipped with the 8-inch. StarBright XLT coatings are an extra cost but recommended option for both larger SGT scopes.

Celestron CPC 925 and 1100

Celestron has long since discontinued its huge C14 fork-mounted SCT, but that does not mean the fork fan has to be satisfied with 5, 6, or 8-inches. Like its forerunner, the NexStar GPS, the CPC comes in 9¼- and 11-inch flavors. These telescopes are identical to the CPC 800 as far as accessories and fittings: same HC, same DC power cord, same decent 50-mm finder, same cheap 1.25-inch diagonal, same inferior 40-mm Plössl eyepiece. Why Celestron insists on including a 40-mm Plössl is a mystery. A 25 mm has nearly the same field of view and is much more comfortable to use. XLT coatings are optional on the CPC 925 and 1100, just as they are with the CPC 800. The CPC 1100 is equipped, like all C11s, with a rear port "reducer" that can be unscrewed to reveal the scope's larger 3-inch port for use with specialized accessories.

Like the CPC 800, these telescopes are wonderfully comfortable to use when set up in alt-azimuth mode. When they are used in this fashion, both the 9¼ and the 11-inch are also wonderfully steady (although a set of vibration suppression pads does not hurt). As with the other forks, an optional wedge is required for equatorial mode setup for picture taking. Equatorial setup is where the normally solid 11-inch begins to lose a little steam. As mentioned, tipping a fork-mount CAT over to point the mount's arms at the pole makes for an inherently flimsy telescope. The fairly heavy weight of the 11-inch fork and tube combination (65 pounds) makes the process of mounting the 1100 on a wedge dangerous for one person. In contrast, setting the CPC 1100 on its tripod for alt-azimuth observing is easy as pie for most adults. The telescope uses the same excellent, ergonomic handles as the 800 (and 925), which make it easy for most adults to get the telescope on the tripod head for alt-azimuth use. Still, 65 pounds is a fair amount of weight to be slinging around. If it sounds like "too much," there is always the 925. The CPC 925 is a *little* lighter, at 58 pounds. The 925 is also less awkward and bulky than the CPC 1100, though, and is therefore somewhat easier for one person to place on a tripod or a wedge.

So, which of these two scopes should you buy? Despite the outstanding optical reputation of the 9¼-inch OTA, it should probably be the CPC 1100. Its optics are easily as sharp as those of the 925, and its cost is only about $300 more. That $300 buys nearly two additional inches of aperture, which results in nearly a 70% increase in light (remember, area is the thing, not diameter). Under a dark sky, CPC

1100 images can be spectacular, and if the user must observe from light-polluted areas, DSOs are usually at least "pretty good" compared to the "barely there" the 800 and 925 sometimes offer. Let us say that an alt-azimuth mounted 11-inch go-to scope is pretty close to perfection for a visual observer, offering comfort, a manageable price, and a physical profile that is bearable for most of us.

Celestron CGE 925, CGE 1100, and CGE 1400

The mounting for these telescopes, Celestron's CGE GEM, is exactly the same as the unit shipped with the CGE 800, so see the entry for that scope in this guide for comments on the mount. The only major differences in these packages are the apertures of the OTAs and the number of RA counterweights included to balance the tubes. Accessories are similar to those shipped with the 8-inch: Plössl eyepieces (25 mm for the 9¼ and 40 mm for the 1100 and 1400), cheapo star diagonals (1.25-inch for the 9¼ and 11, and 2-inch for the 14), and the *NexRemote* software. As is the case with the CGE 800, the desirable XLT coatings are an extra-cost option for the 925, 1100, and 1400.

The Celestron 9¼-inch OTA definitely deserves a few lines of comment here. When this CAT was first introduced in 1996, it attracted a lot of notice from astronomers. For one thing, it was the first new aperture size Celestron had introduced in 16 years. For another, the 9¼ soon gained a reputation for optical excellence. The telescope was so good that some amateurs decided it simply *could not* be an SCT. No, the rumor went, this was not a "real" SCT. It did not have a spherical primary mirror, but a parabolic one. That was the reason for its exceptional performance.

Celestron's designers must have had a good laugh over that one. The 9¼ is a normal SCT with a spherical primary, a spherical or slightly aspheric secondary, and a corrector with a complex curve. The reason for its improved performance is that the primary mirror is slightly slower in focal ratio than that of other Celestron telescopes. Instead of the normal f/2, the 9¼ has an f/2.3 primary mirror. Because of that, the secondary mirror can be slightly smaller than would otherwise be required. The secondary's curve is a little less "steep" as well (its magnification is such that the final focal ratio of the system comes out to f/10). The smaller, less radically curved secondary is what is responsible for the slightly better performance of the 9¼ OTA.

Yes, I said "slightly." Rumors to the contrary, the performance of the 9 ¼-inch is right in line with that of the other Celestron telescopes. It is very good, and the image in an average 9¼ may be noticeably sharper or higher in contrast than that of the average C8, but the difference is minimal. Most of the improvement in image quality compared to an 8-inch actually comes from the 9¼'s superior light-gathering power, about 34% more.

One thing is sure, the 9¼ makes a nice set up when combined with the sturdy CGE mount. Although the scope has noticeably more deep sky reach than a C8, the still-light 9¼-inch tube (20 pounds), while slightly longer than a C8 OTA, does not even begin to stress out the CGE. Any drawbacks are mainly to do with the scope's higher price ($4,000 with XLT) and the fact that the next step up, the 11-inch CGE 1100, is still relatively easy to manage weightwise but provides an even greater performance increase.

Until the C9¼ came along, it was usually the C11 that folks pointed to when they talked about Celestron's "best." The company just seems to have done everything right with the C11 when it comes to optics. That is not to say that the C11 tube shipped with the 11-inch CGE setup, the CGE 1100, is exactly revolutionary. It uses the same optical prescription the C11 always has: an f/2 primary and 5× amplifying convex secondary that produce a focal ratio of f/10. Focus is via a standard moving-mirror system using the same rubber-covered knob and ball-bearing drive as seen on all modern Celestrons. The CGE 1100's OTA, which was carbon fiber back in the NexStar GPS days, is aluminum again, this time painted an inoffensive if not striking shade of gray.

The CGE 925 is an impressive scope, but the CGE 1100 may be the sweet spot in Celestron's GEM CAT lineup. The OTA is big enough to produce truly impressive visual performance, but it is lightweight enough to prevent setup from becoming an exercise in dangerous frustration. An imager or a visual observer who longs for wide-field views will find the 1100's focal length, while starting to creep up at 2,800 mm, is still usable via focal reducers and wide-field, low-power eyepieces. Wide-field imagers will be disappointed to learn that Celestron has stopped equipping the CGE 1100 with the Fastar-compatible secondary mirror mount. In the past, the telescope was available with this desirable option (Chapter 11), as were some of the company's 8-inch OTAs. Celestron has now phased out Fastar secondaries for all scopes except the C14. Custom C11 OTAs are still available with this option directly from the vendor Starizona (Appendix 1), however. Starizona also makes a corrective optics set for Fastar use, the Hyperstar. Celestron never got around to producing a Fastar corrector of its own for the 11-inch (Starizona can also retrofit a variety of other Celestron and Meade scopes for Hyperstar use). How good is the CGE 1100? Many CAT lovers find the views in the CGE 1100 so good that they never get around to buying a C14.

Nevertheless, the Celestron C14 (Plate 21) has always been and still is the Holy Grail for Celestron CAT fanciers. It is the biggest, the most impressive, and the most expensive Celestron—if it has not always been the best. Even today, when Meade offers considerably larger SCTs, the C14 still impresses. Actually, it is probably a more impressive and better telescope than it has ever been. The dirty little secret about the C14 OTA is that it has often possessed "rough" optics. A lack of smoothness on its mirrors caused light scatter and meant the scope did not live up to its potential, especially on solar system objects. Thankfully, Celestron dramatically improved the C14 OTA during the 1990s. Today, C14s seem almost invariably good; it has been a long time since I have seen an optical lemon.

Featurewise, the GGE 1400's C14 OTA is similar but not identical to the smaller Celestron tubes. Although all the other Celestron SCTs are f/10s, the C14 has stuck with the f/11 focal ratio its designers bestowed on it back in the 1970s. One other thing that is different is the presence of two "mirror stabilization" bolts on the rear cell. These are meant to be tightened against the primary assembly during shipment to prevent the heavy primary from being damaged. Some astroimagers have been able to use these bolts to lock the mirror down, preventing the dreaded mirror flop. Like the C11, the C14 features a 3-inch rear port and concomitantly a larger baffle tube. A rear-port reducer is included and allows the C14 to use all standard SCT accessories.

Plate 21. (CGE 1400) Celestron's largest aperture telescope, the CGE 1400 German mount C14 SCT. Credit: Image courtesy of Celestron.

What is it like to use a CGE 1400? This is an almost-overwhelming telescope. Its XLT coated optics and long focal length mean it can keep up with considerably larger telescopes when viewing medium-small DSOs. In the solar system it frankly leaves the big Dobs in the dust, presenting better views of Jupiter, Saturn, and Mars than a 24-inch Dobsonian. Visual users will love the CGE 1400. Its considerable light-gathering power allows it to deliver stars dimmer than magnitude 15. Unlike Dobsonian light buckets, however, it brings all those CAT niceties to the table—precision tracking, go-to, and comfortable seated observing.

Can anything bad be said about this legendary "portable observatory"? Once you get past the price—a reasonable if not inconsequential $6,600 (including the Fastar-compatible secondary mount and XLT optics options)—there comes the main argument against this big scope: *It is big*. If the C11 OTA is intimidating at first, an initial encounter with a C14 will be frightening. This thing is the size of a trash can—a 45 pound trash can that must be lifted onto the high saddle of the CGE mount. Over the years, Celestron has advertised the C14 as the world's largest one-person portable observatory telescope. That may be a little truer now that the company has discontinued the enormous fork-mount model, but setting up a CGE 1400, while it can be done by one person, is not for the faint of heart. On the other hand, the CGE 1400 assembly is amazingly easy for two people.

Once the tube is on the CGE mount, how does the package perform? It performs tolerably well. Actually, for the visual observer, it performs very well. The telescope/CGE combo is steady enough for visual use under most conditions. Imaging is another matter. Although good deep sky pictures can be taken with the CGE 1400, there is no doubt the CGE GEM is somewhat overwhelmed by the monster C14 OTA. A serious imager would be wise to think about a larger third-party mount—a Losmandy Titan, maybe, or an Astro-Physics 900.

If the thought of spending $10,000 for a telescope mount to do imaging does not appeal, order a CGE 1400 with the optional Fastar secondary. Equip it with one of Starizona's Hyperstar correctors, and astrophotography can be done at the more mount-forgiving focal ratio of f/2 (the higher the focal ratio and longer the focal length, the sturdier a mount must be). Be aware that Starizona does not exactly give Hyperstar lenses away; the C14 model is $1,500 (this *is* less than $10,000, of course).

Let us face it: If you love SCTs, somewhere deep down you want a C14. This telescope is a legend, and if you can deal with the realities that accompany the legend, you might be very happy with this granddaddy of a big CAT. For many of us, the practicalities of everyday life may mean we keep putting off getting one, but we can still dream of the day, perhaps in retirement, when we can build that long-dreamed-of and planned backyard observatory that will, naturally, house our very own C14.

Meade LX90-ACF 10 and 12-Inch

How good these larger LX90s are depends on what is done with them. A visual observer who wants more than what is delivered by an 8-inch and who does not habitually use high magnifications may find the Meade LX90-ACF 10- and 12-inch pair is worthy of consideration. The 10-inch and 12-inch LX90s have all the nice features of the 8-inch, including built in GPS receivers, no-extra-cost UHTC-enhanced coatings, and Meade's excellent ACF optics.

Although the 8-inch is a winner, the bigger LX90s are less exciting. The reason is obvious in a picture of the 12-inch member of the family (Plate 22). What Meade did to produce the two big sisters was merely upsize the 8-inch fork's length and width to accommodate the longer, larger-diameter tubes. The drive base is precisely the same. And it is not that big, folks, not even for the 8-inch. The drive base is undersize for the 10-inch and ridiculously small looking for the 12-inch. Now, looks are not everything, but the fact is that the small drive base, when combined with these too-light forks, does limit the telescopes' stability. The 10 and 12 are bearable for visual observers but inadequate for demanding imaging.

Plate 22. (LX90 12-inch) Meade has recently upsized and redesigned the LX90, adding a 12-inch ACF model to the series. Credit: Image courtesy of Meade Instruments Corporation.

That is the bad. Where is the good? At $2,700 and $3,300, the 10- and 12-inch LX90-ACFs are substantially cheaper than their LX200-ACF cousins. Going the cheap route does not mean sacrificing good optics, either. These f/10 telescopes use the same aplantic optics used in the LX200s. Weight is another consideration. At 60 pounds, the 12-inch is not exactly a lightweight, but it is a lot easier to place on the tripod than the equivalent LX200-ACF and is lighter than the smaller-aperture Celestron CPC 1100. The 10-inch is 10 pounds lighter still and will not be a huge problem for almost anyone to get on a tripod for alt-azimuth operation.

Like the 8-inch LX90, the 10 and 12 are competitive when it comes to accessories, which include 1.25-inch star diagonals, decent (imported) 26-mm Plössl eyepieces, and Meade's Autostar Suite telescope control and planetarium software.

Should a CAT buyer consider the LX90 10-inch and 12-inch? Keep this maxim in mind when deciding: The only enemy of good enough is more better. The 8-inch

LX90-ACF is such a good scope, it is a shame Meade tried to improve it by equipping its mount with too big OTAs.

Meade LX200-ACF 10, 12, and 14-Inch

Could a CAT user be happy with a 10-inch LX200? It is very likely. Everything that is good about the 8-inch is also good about the 10, and the larger-aperture tube, while increasing the scope's visual reach substantially (about 50% more light-gathering power), does not stress the hefty LX200 fork much. Yes, the longer focal lengths mean narrower fields of view than what is possible with the 8-inch, focal reducers or not, but the loss is not huge. The optics, like those on the 8-inch, are very sharp, with the optimized aplantic design making the edge of the field look noticeably better. Unlike the most comparable Celestron scope, the CPC 1100, the LX200-ACFs come standard with enhanced coatings (UHTC).

What are the bring downs? There are not many. Meade could have improved the action of the main focus control (as on the other Meade SCTs, it uses thrust bearings rather than ball bearings) instead of adding the motorized microfocuser. The hard stops the LX200 uses to keep the cables running from base to fork from tangling are irritating, and it would have been nice had they used all stainless steel hardware to prevent rusting for those of us whose scopes are often bathed in dew. The 10-inch is not *overly* heavy at 64 pounds for the tube/fork, but the poorly thought-out handles Meade puts on LX200s (and its other fork-mount scopes) make it an awkward and unpleasant—if not dangerous—task to get the scope on the tripod even in alt-azimuth mode. There are a couple of entrepreneurs selling much-improved replacement handles for the LX200 that make lifting the scope onto the tripod easier and safer.

All in all, the 10-inch LX200 is a good compromise weight- and performance-wise. Where it falls behind the power curve is price. At $3,700, it is nearly a thousand bucks more expensive than the larger-aperture Celestron CPC 1100. Why does Meade think they can charge such a premium for the scope? Its advanced optics perhaps may be the reason. Again, the performance increase, especially for visual observers, does not seem worth that much extra money.

The 12-inch LX200-ACF, like its predecessor the LX200GPS 12-inch, has thus far proven to be a somewhat problematical scope. That is not surprising since it is exactly the same as the earlier model except for the switch to the aplantic optics. Both scopes have had some problems with tracking, vibration, and reliability. Why? Maybe this is because Meade chose to take the easy way out with these scopes. How do you make a 12-inch LX200-ACF? The same way as a 12-inch LX90. Take the fork and drive base from the 8-inch and make the arms a little longer and more widely separated. That works after a fashion, but as with the larger LX90-ACFs, only after a fashion. At 12-inches of aperture, the OTA is getting long, wide, and heavy. What works for an 8-inch or 10-inch will not necessarily work well with a 12-inch. The added weight puts more stress on the motors (which are exactly the same as those used on the smaller scopes), gears, and drive electronics, and that may lead to reliability problems. This is not to say *all* Meade 12-inch LX200 scopes have problems. Most 12-inchers are reliable if somewhat shaky.

Before considering the 12-inch, remember that to see anything it will have to be mounted on its tripod. This is nearly 75 pounds of telescope at the 12-inch aperture level, which is more than many of us want to lift regularly, especially given the less-than-useful Meade handles. Heck, even this scope's Giant Field Tripod is difficult to move around. There is also no concealing the fact that this is where the price begins to climb away from the usually very reasonable SCT fare. At 12-inches of LX200, that fare is $4,700. Of course that is still very reasonable for a scope with all the myriad features of this one. This CAT has its attractions: the computerized Autostar II niceties and lovely ACF UHTC-coated optics in a really generous aperture.

Like the C14, the LX200-ACF 14-inch is not just a huge scope; it is a specialized one. This is not the SCT for slewing aimlessly through the Milky Way or imaging the North America Nebula. Its long focal length lends it to more esoteric and specialized pursuits, such as detailed studies of smaller objects: galaxies, planetary nebulae, and planets. A CAT this big can actually open up the world of serious astronomy since, with this much aperture horsepower, it is more than capable of undertaking honest-to-god research, including supernova hunting, asteroid discovery and photometry, systematic study of the planets, and other even more advanced activities.

The really good news about the 14-inch LX200 is that Meade did some thinking before they did the designing. Unlike the 12-inch LX200-ACF, steps were taken to make the fork/drive base more capable of supporting an instrument in this class. Meade also made some small but welcome improvements in the scope's gearing. The LX200 14's go-to accuracy is superb, its tracking is acceptable, and it is stable enough to stop you from saying bad words when a breeze is blowing—although it is still not built like a tank and is not much more stable than the Celestron CGE 1400.

There are really only a few strikes against the LX200-ACF 14. Other than price ($6,500), the big stop sign for many of us is the scope's size and weight. A C14 OTA can be a little scary, but an 82 pound LX200 in its enormous fork is downright terrifying. Some folks can lift the 14-inch onto its tripod by themselves, usually with the aid of a portable hoist of some kind, but that is not something anybody should consider lightly. Instead, be prepared to provide an observatory for this telescope and have a buddy handy to help heft the scope onto a good, solid pier, where it will remain. Who wants to haul a scope of this size around regularly to weekend star parties? There is maybe one exception to the "observatory rule." If there is a clean, dry area like a garage where the 14-inch can be stored that is adjacent to a paved viewing area/pad, the telescope could conceivably be put on "wheelie bars" (sold by JMI and other accessory vendors; see Appendix 1) and wheeled in and out for observing.

The accessories included with the 14-inch and other large LX200 scopes are nearly identical to those in the 8-incher's box and include the Autostar-controlled Crayford style microfocuser, a 26-mm Plössl, a star diagonal (a 2-inch model for the 12-inch and 14-inch), a 50-mm finder, the Autostar Suite software, and Meade's standard field tripod for the 10-inch and the Giant Field Tripod for the 12- and 14-inch telescopes. While it is possible to run the 10-, 12-, and 14-inch LX200s with a passel of C batteries, do not. As always, a 12-volt DC cable and good battery are much better.

Meade LX200-ACF 16-Inch

For many years, ever since Celestron discontinued its C16 in the early 1970s, the LX200 16-inch has been the king of the CATs. That has changed recently with the introduction of Meade's Max Mount 20-inch SCT, but the fork-mounted 16-inch LX200-ACF (Plate 23) is still a huge and impressive telescope. Think a C14 or Meade 14 is enormous? You ain't seen *nothin'* yet. Do I need to say this one belongs in an observatory? Everything concerning the 14 is doubly true here when it comes to this telescope's portability or the lack thereof. The 16-inch fork/OTA weighs in at 125 pounds, and the tripod is even heavier, at nearly 200. This CAT is, frankly, fairly painful for even two people to erect. Not that this is not done— I've seen one person setting up a 16-inch at the Texas Star Party using an engine hoist with only a little help from passersby. But, as with the 14-inch, one man setup is not something most of us will be willing to attempt.

The accessories included with this big, expensive telescope are, surprisingly, modest and similar to what is included with the smaller LX200s: a 26-mm Plössl, a 2-inch diagonal (UHTC coated), a 50-mm finder, a copy of the *Autostar Suite* program, and a (huge) Super Giant Field Tripod (Meade also sells the scope with alt-azimuth and equatorial piers rather than a tripod as an option). Do not even think about running this one off C batteries. The scope understandably has no

Plate 23. (LX200-ACF 16-inch) Meade's largest aperture LX200, the fork mount 16-inch model. Credit: Image courtesy of Meade Instruments Corporation.

provision for internal cells and is powered either by the included AC adapter or an optional 12-volt DC cord.

This scope *looks* awe inspiring and promises great things given its sterling ACF-type optics and all the countless computer frills provided by the Autostar II. The 16 might even deliver these good things—or not. Unfortunately, the 16-inch in its previous LX200GPS incarnation and in its initial configuration as the "classic" LX200 has been a problematical CAT. There have been problems with electronics, problems with optics, design problems regarding the support of the primary mirror, and other gremlins that have kept the scope in all its mutations from ever achieving "most wanted" status among amateur astronomers. Will the ACF version be different? Maybe it will.

Why the troubles? After all, even though it is very modestly priced compared to other scopes of similar aperture and capability, the LX200-ACF 16-inch is not exactly cheap at $13,000 (plus the cost of an equatorial pier instead of a tripod). Maybe it is that Meade does not make/sell enough of these to really get in a production groove with the 16-inch and get all the bugs worked out. Or maybe $13,000 just is not quite enough to produce a consistently good fork-mounted SCT in this aperture.

Despite these issues, it is also true that when the 16-inch is right, it is flat-out amazing. At least one of these scopes (which I saw at a professional observatory's visitors' center) seemed entirely problem free and produced truly mind-boggling views. Despite the long focal length (4,064 mm), the 16 was truly excellent visually. Wide-angle views were not missed at all. Small NGC globulars began to look like M13, and galaxies … oh my … it felt as if you were falling into M51. All in all, the experience of using the 16-inch LX200 was more similar to using a professional observatory instrument than to looking through an amateur's CAT. It is massive, and it is powerful. If you can get a good one or are willing to tinker and work with Meade until it is right (and Meade will help you get it right, eventually), there is no doubt the 16-inch LX200-ACF could be the scope of a lifetime.

Meade LX400-ACF 12, 14, and 16-Inch

For Meade fanciers, this is *almost* the end of the rainbow. Like the 10-inch LX400, the 12-, 14-, and 16-inch models boast features that make them some of the most advanced CATs on the planet. Not many custom observatory scopes are as loaded with advanced computer frippery as the LX400 SCTs. What the larger LX400s bring to the party is serious aperture in addition to the computer gee-whizzery. But, they are heavy. For someone living in a city and unable to build a permanent observatory, portability is a must, and that is something the big LX400-ACFs definitely do not offer.

In the discussion of the 10-inch scope, we mentioned it looked like a "normal" 12-inch. The *real* 12-inch is even bigger, the 14-inch is enormous, and the 16-inch—well, you get the idea. The 12-inch requires a lift of 96 pounds onto the tripod. The 14 comes in at 121 pounds. As for the 16-inch, try 250 back-breaking pounds. Making that even worse is the fact that many LX400 users are focused on imaging. To do serious picture taking, the CATs will have to be lifted and tilted to be placed on a wedge.

Might the large LX400s be the ultimate CATs for a permanent installation? Perhaps they will. As was the case with the 10-inch, this is a mighty impressive instrument, with all the features SCT users have for years been clamoring for: zero image shift focusing, motorized collimation, a built-in dew remover for the corrector plate, USB connectivity, and more. The optics are the same amazing f/8 aplantic SCT optics used on the 10-inch. Accessories, while not lavish considering the prices ($7,000, $9,600 and $17,000 for the 12-, 14-, and 16-inch, respectively) do include one of Meade's top Series 5000 Ultrawide eyepieces, a 2-inch UHTC-coated diagonal, and the Autostar Suite CD. The 10, 12, and 14-inch, like the 10-inch, are mounted on Meade's new heavy-duty tripod. The 16-inch, as is the LX200, is available with either the enormous Super Giant Field Tripod or a permanent pier.

What is the final verdict on the big LX400s? The 12 and 14, especially, have had their growing pains, maybe even more so than the 10-inch. The difficulties seem, as with the 10-inch, to center around focus/collimation motors and electronics at this time. As mentioned, Meade appears to have suspended production of these scopes– at least for now.

How about the 16-inch? Certainly, the pictures of this humongous CAT are impressive, although they *seem* to indicate Meade has mostly just scaled up the basic RCX design. Admittedly, it is hard to tell much from pictures, and there are not many around to look at. Unfortunately we may never see one, since, as with the smaller LX400s, Meade has stopped production on the 16-inch fork mount scope. Nobody seems to care much, though, since amateurs in the market for something in this class are now focused on what is undoubtedly *the* most impressive pair of SCTs ever produced by Meade—or Celestron—the Max Mount 16- and 20-inch LX400 SCTs.

Meade LX400-ACF 16 and 20-Inch with Max Mount

8-inches aperture does not excite? Is 12-inches still ho-hum? Even 16 is not *quite* enough inches? If you have the dollars, Meade has the SCT. Just when the dust had settled from Meade's introduction of its fork-mount LX400 SCTs, the company announced a pair of GEM-equipped scopes with similar optical tubes: a big 16-inch and a positively huge 20-inch (Plate 24). This Max Mount 20-inch is, in fact, the largest production SCT sold since Celestron stopped making its gargantuan C22 in the late 1960s.

Optically, the 16 and 20 are identical to the smaller LX400s and have all the bells and whistles Meade has bestowed on this series: electric focusing and collimation, a built-in cooling fan, USB ports—the works. The optics are done to the same prescription as those in the smaller models; they are a UHTC-coated f/8 optimized/ aplantic SCT design.

It was not the tubes that caught everybody's attention when this pair debuted, however. A 20-inch offers a sizable increase in light-gathering power over a 16, but it is still an incremental leap, big as it is (on the 20-inch OTA, the standard Meade 50-mm finder looks like a tiny red-dot peep sight). What surprised amateurs was the

Plate 24. (20-inch Max Mount) The world's biggest production SCT, the enormous Meade Max Mount 20-inch. Credit: Image courtesy of Meade Instruments Corporation.

huge GEM Meade built to carry these OTAs, the Max Mount. This towering thing weighs in at 329 pounds *without* counterweights and is probably the largest mass-production mount ever offered to amateur astronomers. Although Meade advertises the Max as having a payload capacity of 500 pounds, that includes counterweights. The actual maximum Optical Tube Assembly (OTA) weight the mount can handle is probably closer to about 250 pounds, but that is still a lot of pounds to play with, especially considering the fact that the titanic 20-inch OTA weighs in at a comparatively modest 190 pounds.

The weight and size of the Max are what grab you when you first lay eyes on it, but its capabilities are just as impressive. This GPS-enabled GEM can be controlled by an included Autostar II hand control or with a PC via furnished software. The large gears used on the Max lend it what is probably its most impressive statistic: a very low periodic error. Meade claims a before-PPEC-training periodic error of 5 arc seconds. After making a PPEC recording, typical error is about 2 arc seconds (they say). If so, the mount can be used for unguided imaging at all times, 2 arc seconds being below the scintillation threshold of atmospheric seeing.

So, will everybody at the next star party be setting up a Max Mount 16 or 20? Not likely. Beyond the fact that this is not by any means a portable or even transportable pair of scopes (the manual's assembly section has numerous notes that warn "death or serious injury may result" due to mishandling of the tremendously heavy OTA and GEM), they are quite expensive now. When first introduced, Meade was offering some real deals on both scopes, but just as they were going into production, prices rose precipitously. The 16-inch version is currently $40,000, and the 20-inch is $50,000. That is a lot of money to spend on a hobby—or even a "serious avocation." Still, some people who are not exactly millionaires have been known to spend that much or more on a bass boat.

Size and price aside, it is early in the life cycle for these two telescopes. As mentioned, the fork-mount LX400s have had some technical issues, and it would not be surprising if the big guns also had some teething problems. Still, who would not buy a Max Mount 20 if they could? It is the top CAT in every way at the moment and will probably remain unchallenged for the foreseeable future—if Meade can resolve its current difficulties and get Mad Max and the LX400 sisters operating without hiccups, that is.

Little Kitties: Smaller SCTs

Just as there are larger than 8-inch SCTs, there are smaller ones. At this time, purchasing a small SCT means buying a Celestron. Meade produced a 4-inch model for many years, the 2045, but that scope was discontinued over a decade ago when the company decided to use the Maksutov Cassegrain design for its smaller CATs. How good *is* a small SCT anyway? These are definitely kittens compared to big jungle CATs, like the C14 or Meade 16, but for an apartment dweller, a physically challenged person, or just someone who wants a telescope that can be set up and taken down at a moment's notice, it is hard to beat the portability combined with useful aperture found in the wee ones.

Celestron NexStar 5 SE, Omni XLT 127, and NexStar 6 SE

The Celestron C5 Schmidt Cassegrain has had a checkered career ever since it was introduced way back in the early 1970s. Celestron has discontinued the C5 three times over the last 30 years. The 5-inch scope's problems have had nothing to do with its f/10 optics, however—they are almost always outstanding. The problem for the C5 has been that it is nearly as expensive to produce as the C8, and that many people considering the C5 eventually turn to an 8-incher since it is "only a little more." At this time, an 8-inch SE scope is about $200 more expensive than her 5-inch sister, and there is no denying that a lot more can be seen with a C8. That is not the whole C5 story, though, and never has been; if it were, Celestron would not keep bringing the little scope back for one last bow.

The secret to the C5's longevity is that, in addition to fine optics, it is genuinely portable. At 27.6 pounds, including tripod and mount, the NexStar 5 SE ($800, Plate 25) is only somewhat lighter but is considerably less bulky than a NexStar 8 SE and is more practical for the apartment dweller—or anybody with limited space—to store and transport. For amateur astronomers without a backyard to use for observing and who must, instead, view from urban/suburban balconies, apartment roofs, and semipublic places, a telescope like the C5 may mean the difference between observing regularly and not observing at all. The 5-inch is not just for beginners, either. Many long-time amateurs have smaller CATs like the C5 in their stables for use when a big gun is not practical.

The little guy does not skimp on features. The NexStar 5 SE uses the same NexStar computer as the 8-inch telescope, and almost all the accessories developed for SCTs over the last three decades will work on the 5 because of its standard SCT rear port.

Plate 25. (NexStar 5SE) Celestron's highly portable C5 OTA on an SE half-fork mount, the NexStar 5SE. Credit: Image courtesy of Celestron.

The fork/drive base combo is identical to the one furnished with the 8-inch model. It is easy to set up and comfortable to use, if not the best mount for serious imaging tasks. The lighter OTA of the 5-inch SE may make for a somewhat more stable setup, allowing some long-exposure experimentation. The 5-inch OTA is capable of decent visual performance on the deep sky and the solar system but obviously has less oomph than an 8-inch (which will deliver more than 2.5 times more light). In the city or heavily light-polluted suburban areas, the NexStar 5 SE is somewhat handicapped, if still quite acceptable. Travel to a dark site, though, and prepare to be surprised at what this "little" telescope can show.

The "fixins" that come with the scope are not bad either. The NexStar 5 SE, like the NexStar 8, comes standard with Celestron's advanced XLT coating, the same usable 25-mm Plössl eyepiece, a 1.25-inch star diagonal, a red-dot finder, and a CD with the *NexRemote* and *TheSky* software on it. The telescope can be powered by AA cells—eight of them—or an optional DC power cable.

Is even the NexStar 5 SE too much? Want something even cheaper and easier to carry around? Do not like or do not need go-to computers? Celestron may have just the thing. The company has recently begun selling a C5 OTA on a CG4 GEM mount, which is similar to but slightly smaller than the CG5, for a measly $600 (or $700 with a motor drive). The Omni XLT 127 (Plate 26) does not come with a go-to computer, but the optional dual-axis drives and HC will allow the scope to track the stars and maybe even do a little beginning deep sky imaging.

Surprisingly, the Omni comes with nearly the same accessories as the more expensive SE: XLT optics, a 25-mm eyepiece, a 30-mm finder, a 1.25-inch star diagonal, and a software CD containing *TheSky*. The motor drive system for the CG4 operates off four D cell batteries, and since there is no computer to suck them down, they last a long time. The Omni is also a pretty little thing, sporting a blue-and-white color scheme that harks back to the classic 1960s Celestron Pacific SCTs.

What the Omni offers is simplicity and portability. While at 40 pounds the total weight of the package is considerably heavier than that of the NexStar 5 SE, this GEM scope breaks down into light components, with the heaviest piece weighing in at 20 pounds. The Omni XLT 127 is aimed at beginners, but its noncomputerized simplicity is refreshing, and this scope should appeal to grizzled veterans as well.

Care to give up a little portability in return for a little more horsepower? Celestron's got that base covered as well. The NexStar 6 SE is exactly the same package as the NexStar 5 SE but with a 6-inch f/10 OTA instead of a 5-inch one. There is no doubt the C6 OTA brings a little more of the deep sky home. The larger primary mirror delivers 50% more of what we all want—light. That may not seem a huge advance, but this extra inch is a real help with many DSOs, particularly globular star clusters. Under good conditions, the NexStar 6 SE has the ability to resolve quite a few of the Messier globs.

Celestron C6-SGT

Like the idea of a 6-inch OTA but do not like fork mounts? Consider the C6 SGT, then. This is the same f/10 6-inch tube used on the SE version but mounted on Celestron's go-to CG5 mount. Accessories are almost the same as those provided

Plate 26. (Omni XLT 5-inch) The bargain priced but very capable Omni XLT version of the venerable Celestron C5. Credit: Image courtesy of Celestron.

with the C8-SGT: 25-mm eyepiece, 1.25-inch diagonal, 30-mm optical finder, and TheSky CD.

This CAT is considerably cheaper than the C8-SGT ($1,000 for the 6-inch compared to $1,600 for the XLT 8-inch), but if you are going to pay the extra money for a CG5 mount instead of the SE fork and go to the trouble of hauling the GEM around, you might want a bit more of a "reward" in the form of an 8-inch tube. If you want a C6, it would be best to stick with the fork-mount SE version.

Schmidt Newtonians

The Schmidt Newtonian telescope (SNT) has always been an also-ran in the CAT popularity contest. Although the design has some real strengths, only Meade has offered serious SNTs to the amateur. Even there, the telescope's popularity has waxed and waned, with Meade discontinuing SNT production in the late 1980s. With the advent of the LXD55 and the follow-on LXD75, the SNT is back. That is not a bad thing, either. This somewhat un-CAT-like CAT does have some pluses. At this time, Meade is still the only non-custom producer of SNTs.

What the heck *is* an SNT? Think "mutant offspring of an SCT and a Newtonian." Like the SCT, the SNT uses a spherical primary mirror at one end of the tube and a corrector plate at the other. *Unlike* the SCT, it does not use a convex magnifying secondary. Light from the primary mirror is instead diverted out the side of the tube to a focuser by a Newtonian style flat mirror tilted at 45°. The secondary mirror's holder is mounted in the center of the corrector plate, just as in the SCT. Since this mirror does not magnify, the "final" focal ratio of the scope is identical to that of the primary mirror, which is usually f/4 to f/5. The benefit of this system is that it yields wide fields without the distorting coma that ruins Newtonian edge-of-field performance.

Meade SN-6AT, SN-8AT, and SN-10AT LXD75 Schmidt Newtonians

Since Meade reintroduced the SNT design with the SN-6AT, SN8-AT, and SN-10AT after a long hiatus as the LXD55 series, they have managed to improve the LXD GEM mount so that it is generally reliable electronically and mechanically. That does not mean LXD75 is optimum for a Schmidt Newtonian. The problem is not so much weight, at least not with the 6-inch and 8-inch SNTs, but length. Schmidt Newtonians necessarily have longer tubes than SCTs of the same aperture: 27-inches for the 6-inch SNT (13 pounds) and 30-inches for the 8-inch SNT (24 pounds). The longer tubes put more strain on the medium-weight LXD75 GEM and make it shakier than it is with an SCT OTA, if still usable. The 10-inch SNT increases both tube length (36-inches) and weight (30 pounds). What was bearable on the 6 and the 8 is just too much with the 10-inch in my opinion.

Optically, the SNT OTAs are similar, differing only in aperture and focal ratio. The 8-inch (Plate 27) and 10-inch are f/4s, and the 6-inch is an f/5. Although the mount these telescopes are shipped with is questionable, the optics are impressive. At a star party under the dark skies of Chiefland, Florida, an informal shootout was arranged between the 10-inch SNT and a 10-inch Dobsonian Newtonian (with a known "good" mirror). The results? The edge of the field in the SNT looked better, with the stars looking like stars instead of comets. DSOs seemed slightly brighter in the SNT, probably due to the LXD75's UHTC coatings.

The LXD75 SNT's features, in addition to UHTC (which is standard), include an 8 × 50 mm finder scope and a single 26-mm Plössl of good quality. The OTA sports a steel tube that is finished an attractive white. All three Schmidt Newtonians include 2-inch rack-and-pinion focusers. This focuser is workable for visual use, but if imaging is to be attempted, it should be replaced with a better unit. Luckily, several companies, including Jim's Mobile, offer vastly superior Crayford focusers that are near plug-and-play replacements for the SNT focuser.

How good are these SNTs? They are more than capable of producing quality images visually and photographically, but there are a couple of things the CAT

Plate 27. (LXD75 8-inch SNT) Meade's wide field Schmidt Newtonian OTA on a go-to GEM mount, the LXD75 8-inch SNT. Credit: Image courtesy of Meade Instruments Corporation.

shopper should know. First is that to deliver good images an SNT must be accurately collimated. The process of lining up the optical elements of a Schmidt Newtonian is decidedly more complicated than it is on a Schmidt Cassegrain. The SCT owner only needs to adjust the secondary mirror's tilt. The SNT may potentially require the secondary's rotation as well as tilt to be adjusted. The SNT primary must also be collimated, unlike the SCT primary. Users familiar with Newtonian alignment will be right at home, but SCT users may be in for some head scratching.

The bottom line on the SNTs also depends on their use. Dark skies that encourage wide-field viewing allow these OTAs to perform in world-class fashion, outdoing much more expensive telescopes. Lunar and planetary observers who frequently use high powers may be less enchanted by these short focal length OTAs and their undersize mounts. But, the Meade Schmidt Newtonian design is good. It provides a lot of potential for a little money ($1,000 for the 6-inch, $1,200 for the 8-inch, and $1,400 for the 10-inch). It would be ideal if the three were available in OTA-only configurations. On a sufficiently sturdy mount, these SNTs can really rock.

Here Come the Maks!

Many amateur astronomers say they love Maksutov Cassegrain telescopes (MCTs, Maks). What is not to love? As discussed in Chapter 3, the SCT-like MCT has the potential for producing better images than a Schmidt Cassegrain. The only thing most pre-1990s amateur astronomers did *not* like about MCTs was their prices. Until the advent of the Meade ETX, the only widely available astronomy-oriented Mak for amateurs was the very fine but very expensive Questar.

The Mak scene began to change for the better in the early 1990s when Meade added a 7-inch MCT to its LX200 line of go-to scopes. This Mak was somewhat more expensive than an 8-inch SCT but not horrendously so. The floodgates really opened in 1996 when the company began to sell the ETX, a 90-mm MCT. Since then, Maksutovs have multiplied like rabbits, at both the high and low ends of the price scale.

Meade ETX-90PE and ETX-125PE MCTs

I should preface this by saying I downright *love* the ETX. I own an ETX-125PE, and although I am sometimes accused of being a "Celestron man," I bow to no one in my appreciation of Meade's small wonder.

Be that as it may, there is no doubt the ETX has weaknesses as well as strengths. What does ETX stand for, anyway? When Meade was developing this little Mak (Plate 28), the letters were an abbreviation for the MCT project name, Everybody's Telescope. By the time the wee CAT was released, it was just called ETX, but it was still *meant* to be everybody's telescope. Is it?

That depends. The ETX, which is currently available in 90- and 125-mm apertures, has a lot going for it, most notably the optics. There are things that can be criticized about the ETX, but its optics are not one of them. The secondary obstruction on these scopes, the percentage of the aperture diameter obscured by the secondary mirror, is high at 40% for the 125 and 30% for the 90, but contrary to expectations, contrast does not seem to have been harmed much (the secondary mirrors are not overly large but are surrounded by big cone-shaped baffles to protect against stray light). The ETX-90 and ETX-125 produce outstanding, high-contrast images. Compare the 125 side by side with a C5, and you will have no doubt the Mak produces noticeably sharper, higher-contrast planetary images. Saturn in the ETX is chock full of detail, all that can be expected of any 5-inch telescope, and the visible disk and ring features compare very favorably with what can be detected in a C11. How about the 90-mm scope? If anything, this little wonder amazes even more. Tested against a Questar 3.5-inch MCT (which costs about five times as much as the Meade), there seemed to be no difference in the images.

Plate 28. (LX90 PE) The latest version of Everybody's Telescope, the ETX90 PE." Credit: Image courtesy of Meade Instruments Corporation.

That does not mean it is all gravy with the ETX. Face it—at these price points ($700 and $1,000 for the 90 and 125, respectively), there is going to be a lot of plastic. That does not seem to harm either telescope's performance, but they certainly do not have an heirloom feel. You will not be passing an ETX down to your grandchildren. Also, the 90-mm is a cute little CAT, but 3½-inches of aperture will severely limit views of the deep sky in or out of light pollution. Very few of the 30,000 galaxies, nebulae, and star clusters in the telescope's included Autostar HC's library will be visible no matter how good the observing site. The 125 fares better in this regard, but more aperture means more weight (28.5 pounds vs. 21 pounds for the 90-mm). The 125 is also quite bulky. You can waltz the 125 out into your backyard assembled on its tripod, but just barely. This telescope is not much more portable than a C8.

Optically, yes, the ETXs are fantastic, but do not expect wide-field views. Even the 90-mm needs long focal length eyepieces to take in medium-size vistas. That should not be a surprise since ETX focal ratios are high in typical Mak fashion: f/13.8 for the 90-mm and f/15 for the 125. The upside here is that the long focal ratios are well suited for urban observing, allowing for medium-high magnification with comfortable, long focal length eyepieces. The comfortable higher magnifications of these long focal length CATs tend to reduce the annoying background sky glow that is visible at lower powers in any telescope in light-polluted areas.

Despite a need to keep production costs down, Meade has spent the last 10 years continually upgrading both the software and hardware on its ETXs. The original 125, for example, was merely an upsized 90. The larger OTA was too heavy for the all-plastic fork mount. Today's 125PE still appears to have a plastic fork, but that is deceptive. The plastic is only an outer skin; inside, the 125PE fork is aluminum. Both the 90PE and the 125PE use the 497 Autostar for computer control. The 497 is user upgradable over the Internet, and Meade issues frequent software updates to fix ETX problems and add ever-more features.

Other than optically, what is 90PE and 125PE performance like? The go-to on both scopes is satisfyingly accurate. That does not mean every object you request from one side of the sky to the other is always in the center of the eyepiece, but even when the 125 misses, it is not by much. As long as due care is taken in centering the go-to alignment stars the scope chooses, the ETX mount and computer get the job done. Go-to accuracy seems to be as good as or slightly better than that of the Celestron NexStar SE SCTs. The go-to alignment procedure for the ETX Premier scopes is very similar to that of the GPS-equipped Meade SCTs, even though the ETXs do not come with GPS: Place the scope in its Home position and turn it on; it does all the alignment tasks except the fine-tuning of alignment star centering. Thanks to an internal battery, the ETX Premier models keep time and date current in memory, so these items normally will not have to be reentered for subsequent go-to alignments. What about tracking? The ETX drives provide OK tracking in alt-azimuth mode but are really not up to the task of anything more than casual lunar and planetary imaging due to small random tracking "jumps" that cannot be trained out with PEC (which the ETX Autostar does feature).

One thing not good about the ETX is its nonstandard rear cell. It would have been nice if it had used the normal SCT-style rear port like Meade's earlier MCT, the LX200 7-inch. Instead, the ETXs use a built-in diagonal that limits users to 1.25-inch eyepieces. This diagonal is equipped with a flip mirror. Flip the mirror up (via a knob), and light goes up to the eyepiece. Flip it down, and it is directed out a rear port (hole) to which cameras and other "external" accessories can be attached. The ETX's model 884 Field Tripod is more difficult to judge. It is fairly steady with the 90-mm, but due to the unwise use of plastic in a few critical areas, it is not quite as good with the heavier 125-mm. One other thing: There have been complaints about is the scope's tube. The Premier ETX are available either with an Astro Tube silk-screened with color astronomical images or a standard Meade-blue OTA. Some astronomers think the Astro Tube looks gaudy, but I think it gives the little telescope even more personality than it already has. Both ETXs are of the Gregory type and therefore do not have adjustable secondaries. How are they collimated? They cannot be easily collimated by end users, but they usually do not need to be.

Accessories shipped with the ETX are, not surprisingly, minimalist and, in addition to standard UHTC coatings, are limited to a Meade Series 4000 26-mm Plössl eyepiece (which is a cut above the average imported Plössl) and a CD containing the basic edition of Meade's *Autostar Suite* planetarium and telescope control software. The scope can be powered by (many) AA batteries. In this case, with these small telescopes, AA batteries can actually be a welcome option. It is nice to be able to throw the ETX in the trunk of the car for use during (nonastronomy) vacations without having to pack a large 12-V DC battery pack to power it.

What are my final words on Everybody's Telescope? It is not a thing of machined beauty. It is plastic and utilitarian. Nevertheless, it has delighted thousands of observers old and new and has probably done more to introduce more people to the wonders of the night sky and CATs than any telescope that has hit the market since the original Celestron C8 rolled out in 1970.

Questar 3.5

In 1956, the Questar Corporation of New Hope, Pennsylvania, begat a tiny telescope that has inspired 50 years of lustful amateur astronomer dreams, the Questar 3.5 MCT. The Questar 3.5 (inch) can best be described as "jewel-like." It is an incredibly attractive little instrument that is executed in gleaming stainless steel and beautiful anodizing. The most discriminating telescope connoisseur will search in vain for plastic here.

You "cannot judge a book by its cover," of course, and the Questar probably could not have hung on for 50 years if its optics could not deliver. They can and do, providing images as sharp and high in contrast as it is possible to achieve with any 3½-inch telescope. Quite a few Q3.5 fanciers are surprised to learn that the optics in the telescope are not made by Questar. They never have been. Instead, the company has always contracted them out to other manufacturers, with the firm of J. R. Cumberland having produced the lion's share over the years. No, the optics are not made in-house, but Questar's stringent testing and quality assurance program mean every scope that goes out the door possesses world-class optics.

If it were only that the telescope is "pretty" and has good optics, no one would likely pay the $4,250 that a Questar 3.5 sans tripod and with basic bottom-of-the-line coatings commands. What keeps the Qs coming, then? The Questar was an innovative design in 1956, and it is still innovative today, offering some unique features no other telescope can boast.

When an amateur astronomer finishes admiring the Questar's beauty, the first question that comes to mind is, "Where is the finder?" The Questar 3.5 does not appear to have one, which is surprising. This is a slow focal ratio, long focal length, Gregory-type Maksutov (f/14.6, 1,300 mm), so a good finder is mandatory. Actually, the Q3.5 does have a finder, just not a conventional one. When a finder is needed, the observer continues looking through the main scope's eyepiece and flips a little switch on the rear cell. This switches the ocular to a wide-field finder objective via a unique reflex optical system. The finder objective is mounted on the bottom of the rear cell and delivers a 4× image that takes in a full 12° of sky with the Questar's lowest-power eyepiece. The advantage of this somewhat complex arrangement is that the observer never has to move an eye from the eyepiece to find or center objects, a distraction when trying to pull in dim DSOs with the 3.5's limited aperture.

Need more magnification rather than less? With other telescopes, the user would change to a different eyepiece or insert an amplifying Barlow lens. Not with the Q3.5. Another rear-cell switch moves a built-in Barlow lens into the light path of the main optics. Again, the observer has not had to look away from the eyepiece. Not only is this Barlow convenient, it is a high-quality Dakin Barlow.

Like all other CATs, the Questar's corrector plate is prone to collecting dew. There is no need to spend money for a dew shield, however, as one is built into the Questar. Grasp the scope's lovely star-map-emblazoned tube and slide it forward, and this "tube" is revealed to be a dew shield. Extending it reveals the actual tube of the 3.5, which features an anodized Moon map. Like the star chart on the dew shield, it is not detailed enough to be very useful, but it sure is beautiful.

The Questar 3.5 is beautiful *and* legendary. Despite being in production and nearly unchanged for over 50 years, it is still sexy. Is it a good astronomical telescope, though? If there is one thing that prevents us from recommending the Questar wholeheartedly it is its aperture problem. Despite the beautiful tube and mount, this is still just a 3.5-inch telescope. It is an optimized 3.5-inch telescope, but it cannot violate the laws of physics. It will still be outperformed optically by the larger-aperture C5 and ETX-125.

It is remarkable that Questar has not had to change the 3.5 much over the last 50 years, but that is not necessarily a good thing for the amateur. While the rest of the telescope industry has moved on to computers and go-to, for example, the Questar still pokes along with an AC synchronous motor drive. Yes—polar align the scope and plug it into a wall socket (or inverter), and it tracks the stars. Unplug it, and it stops, which is not exactly high tech. A DC drive is available as an extra-cost option, but at over $4,000 for the basic scope, many purchasers will need to go easy on options.

Beautiful as it may be, the Questar mount is not overly pleasant to use. Since it does not have a computer, its drive base has to be tipped over to point at the Celestial Pole if it is to track the stars. Before it can be polar aligned, though, it will have to be mounted on a tripod of some kind. The three ridiculous little tabletop legs supplied with the scope are useless for much of anything; that means shelling out for Questar's tripod or an equivalent heavy-duty model from a third party. Despite its light weight (8 pounds), the Questar 3.5 needs a stable tripod due to its long focal length. Even on a good tripod or pier, however, the mount has limitations. Most seriously, its design prevents the scope from pointing at far southern objects (or far northern objects when observing from the Southern Hemisphere). Move too far south in declination, and the tube bumps into the base. Yes, the Questar 3.5's slow-motion controls are silky smooth, but they sometimes exhibit a surprising amount of backlash.

Like the Meade ETX, the Questar uses a built-in 1.25-inch star diagonal. This is necessary so eyepieces will be in the correct position to allow the switchable Barlow and finder to work properly. Unlike the Meade, however, the Questar diagonal is not set up to accept standard 1.25-inch eyepieces. It is formatted for the special pair of included Brandon oculars, which screw into the rear cell instead of sliding into a focuser tube. Although these are very good eyepieces, it is hard to imagine today's amateur not wanting to use other oculars, such as TeleVue Naglers. Luckily, TeleVue sells an adapter that will allow some of its eyepieces to be used in the Questar. They may not come to focus with the finder switched in, however.

Nevertheless, the Questar 3.5 is a "good" scope, maybe even a great one. Questar astronomy is astronomy with style. The little 3.5 is tremendously portable, and it is just about as well made and reliable as a telescope can be. In its case, with its included solar filter and pair of Brandons, it really is, as Questar has always advertised it, a "portable observatory." The ETX 90 may have optics nearly identical in quality, but unlike the Meade, the Questar *is* a telescope to pass down to grandchildren. That makes it almost seem like a bargain.

7-Inch Questar 7

The Q7, a scaled up 3.5, has always been a rare bird in the amateur community due to its astronomical price. We used the word jewel-like to describe the 3.5; for the 7, the word is "legendary." How does the Questar 7 perform? It works beautifully, under the right conditions. "Right conditions" mostly means allowing plenty of time for the tube to cool down so the optics adjust to outdoor temperatures and the nasty air currents inside the OTA to die away. You had best hope that temperatures do not continue falling throughout the evening. If that happens, this sizable MCT may never acclimate. For best results, the Questar 7 should also be used on objects appropriate for it. Large open clusters and nebulae are not its objects of choice. Its slow f/15 focal ratio delivers high magnifications, with even a 25-mm eyepiece producing over 100×.

Like the 3½-inch, the Questar 7 uses a built-in diagonal. This one is more "normal" than the 3.5 arrangement, however, and allows the use of standard 2-inch eyepieces as well as the pair of Brandon oculars supplied with the telescope. As an option, the user may choose to purchase an Astro model rather than the Classic 7. The Astro uses a standard 2-inch star diagonal and is more versatile but does not include the famous built-in finder and Barlow. Questar goes back and forth on the Q7, sometimes offering it in a fork-mount configuration similar to that of the 3.5 and at other times making the "big" scope available only as an OTA.

As with the 3.5-inch, price is the main barrier between most amateurs and the Questar 7 of their dreams. Do you think the 3.5 is expensive? The cost of a Classic Q7 with fork mount is $11,600. Admittedly, this model sports Questar's advanced (and lovely) titanium tube, which is lighter than the standard aluminum and has somewhat better cooldown characteristics. If $11,000 is too rich for your blood, Questar will sell the OTA alone for "only" $8,775. Back in the 1960s, the Q7 was often referred to as a "doctor's telescope." That was not just because the scope's gleaming stainless steel and aluminum body made it look at home in an operating theater, but because you would need to be a wealthy physician to afford one. That has not changed, but if you are lucky enough to get your hands on this scope, its Questar/Cumberland optics may astound.

Celestron NexStar 4 SE

Post-1960s, the only Maksutov Cassegrain Celestron marketed for many years was the little C90. This often-maligned but actually rather nice telescope was phased out in the late 1990s in favor of a succession of imported MCTs. Some of these have been okay, some of them have been marginal, and none of them in my opinion display the mechanical or optical quality of the C90. Until recently, Celestron offered two Maks, the C130 and the NS4 SE. The recent elimination of the 130 has left the company with, as in the C90 days, only a single Mak to sell. To be honest, the post-C90 MCTs have not inspired much excitement in amateur astronomers. The NexStar 4 SE seems more like a mere placeholder in the company's scope lineup than an important product. Not that the NS4 is a *bad* scope; it is not. It is just nothing new or special. There are dozens of amateur Web sites supporting the ETXs, but nary a one centered on the NexStar 4.

The NexStar 4 SE ($600; Plate 29) is a 102-mm aperture, f/13 Gregory-design Maksutov Cassegrain mounted on Celestron's SE single-arm fork mount. The NexStar computer is exactly the same as that shipped with the other SE telescopes and includes 40,000 objects for you to view (only a fraction of which will be visible in a 4-inch scope). The tube is ETX-like in that it uses a flip-mirror system similar to that on the Meade telescope. The usual use for the rear port is to mount a camera. However, this scope's small aperture and long focal length discourage imaging of any kind other than informal snapshots of the Moon and planets.

Plate 29. (NexStar 4SE) Celestron's MCT, the sometimes overlooked NexStar 4SE Maksutov Cassegrain. Credit: Image courtesy of Celestron.

The NexStar 4 SE is somewhat similar to the ETX-90 but without some of the "snap"—the sharpness—of the ETX images. Like many small MCTs sold to amateurs, this one has a sizable central obstruction—35% in this case—which may reduce some of the contrast advantage for which Maks are noted. In truth, the images in this scope look like what I used to see in 4-inch SCTs. Good, yes, but nothing to get excited about. One plus for the NS4 is that its build quality is a little more impressive than that of the ETX90; there is noticeably less plastic. Its tube, like that of the 8-inch and 5-inch SE SCTs, is a cool Celestron Orange and will not invoke chuckles from observing buddies like the astroimage emblazoned ETX tube will.

The accessories provided with the NS4 are about the same as those found with the other scopes in this series. There is a good, if not oversize, tripod, a zero-power red-dot SE finder, a 25-mm eyepiece, and the *NexRemote* and *TheSky* software CD. Yes, the scope can be powered with internal (eight AA) batteries; if you like buying batteries, go for it.

Overall, the NS4 SE is a nice enough telescope. What is the bottom line on it, though? If you want a *great* small MCT for a good price, do yourself a favor and think "ETX".

Synta (Orion) Maksutovs: 90, 102, 127, 150, and 180 mm

The label on the tube says "Orion StarMax," but these Maksutov Cassegrains are Synta through and through. That is, they are made in the Far East by Taiwanese optical giant Synta, Celestron's owner. That is not a bad thing. Unlike some imported MCTs, the telescopes offered by Orion strike a good balance between modest prices and quality. No, they are not Questars, but they are similar in optical quality to them and to the ETXs. In fact, some amateurs like these telescopes *better* than the ETX or the similar Celestron instrument because of their more standard rear cells. Unlike just about all the lower-priced, smaller-aperture MCTs on the market, the Orions eschew the flip mirror and built-in diagonal. Although they do not feature standard SCT-style rear ports and threads, it is possible to buy adapters that allow the use of at least some SCT accessories with these telescopes.

Orion's current MCT line is somewhat confusing, with at least 10 different models/configurations currently offered. This includes a bewildering array of mounts and tube colors. A close look, however, reveals that there are five different Synta MCT OTAs for sale: 90, 102, 127, 15, and 180-mm.

The 90 (Plate 30), 102, and 127-mm were the first Maksutovs offered by Orion and are all similar and good. These telescopes, with focal ratios of f/13.9, f/12.7, and f/12.1, respectively, did more than any other MCT to establish Synta in the Mak business. Optically, the only area for which they give ground to the much-loved Meade ETX is in baffling. Place a bright object like the Moon just out of the field, and there is a *tad* more scattered light visible in the fields of these scopes than in an ETX. Mechanically, the Orions seem a cut above the ETX in build quality. They are basically all metal, with only a little plastic used. Like all the Orion Maks, they move their primary mirrors to focus. The "focus shift" image movement in the field

Plate 30. (StarMax 90mm MCT) A basic 90mm Maksutov Cassegrain with excellent optics, Orion's StarMax 90. Credit: Image courtesy of Orion Telescopes & Binoculars.

inherent in this is small and is similar to—or a little less than—that found in the ETX or in most Meade and Celestron SCTs.

As for mounting the 90, 102, and 127-mm, there are several options. The least expensive are bare-bones Synta GEM mounts (small EQ-3s for the 90 and 102 and an EQ-4 for the 127-mm) available without motor drives for $320, $430, and $620, respectively, which includes the cost of the OTAs. The 127-mm model is also available on Orion's Skywatcher Pro GEM, a Synta mount that is nearly identical to the Celestron CG5 and that can be equipped with a similar go-to computer system. Be aware that while the HC looks similar to the Celestron NexStar, the software inside it is not quite as advanced.

The 90, 102, and 127-mm can also be purchased "OTA only" and can be placed on any 1 the user desires. The tubes come equipped with Vixen-compatible dovetail rails, but these can be removed and another style mounting bracket substituted, if necessary. The accessories included with these telescopes, whether as OTAs or as mount-scope packages, are few and include a better-than-average 25-mm Plössl eyepiece and a substandard finder. These finder scopes are the one really poor component in these Maks. They are far too small—6 × 20 for the 90 and 6 × 26 for the 102 and 127. Be prepared to replace these useless little things with something better.

The Orion/Synta 150-mm (f/12, 1,800-mm) MCT is a step up from the little guys. The 150 sells for $620, previously an almost-unheard-of price for an MCT OTA in this aperture. Build quality is similar to that of the smaller Orion MCTs, and although the scope is not exactly built like a tank, it has the benefit of being lightweight, at least, weighing in at a piddling (for a Mak) 12 pounds. The finder for the 150 is an 8 × 40 unit, better than finders of the smaller Orions, but still too small.

The king of the MCT hill at Orion is a Synta-made 180-mm MCT (Plate 31). This f/15 (2,700-mm) telescope, like the now-discontinued Meade 7-inch Mak, breaks the MCT price barrier that has kept many amateurs from owning larger than 6-inch Maks. Orion prices the 180 at an astounding $1,200 for the OTA. Not that there are not a few flies in that ointment. The foremost of these is cooldown time. Without some assistance (maybe a fan blowing into the rear port), this "big" MCT, like the Questar 7, may never cool off sufficiently for optimum viewing. If the temperature continues to fall through the evening, even blowing air into the OTA may not help.

Is this a scope to be seriously considered by the prospective CAT owner? It is a "quality" instrument, even if its construction is not *quite* up to Meade and Celestron standards. Remember, though, this is a very long focal length instrument; make sure that fact fits in with planned observing tasks. Despite the 180's low price when compared to other Maks in this aperture class, a larger-aperture, faster, more versatile

Plate 31. (SkyView Pro 180mm MCT) The largest MCT in the Orion CAT collection, a 180mm. Credit: Image courtesy of Orion Telescopes & Binoculars.

8-inch SCT OTA can be had for about $200 *less.* The biggest sore thumb with this scope, though, is that, like the smaller Orion MCTs, the dovetail for mounting the tube to a GEM is not attached to the corrector and rear cell; it is screwed right into the thin tube. This arrangement does not hurt the smaller CATs much due to their lighter weights, but it does make the 15.5 pound 180 shakier—on any mount—than it should be.

In addition to an OTA-only option, Orion offers the 180 on go-to and non-go-to versions of its Skyview Pro mount ($2,000 and $1,550) and on the considerably heftier Sirius mount (actually a Synta HEQ-5) for $2,000 for a non-go-to version or $2,350 for a go-to HC-equipped model. The Sirius would be a good choice for the 180. The scope is not much heavier than an SCT, but its tube is somewhat longer, which can stress out a mount every bit as much as weight can. Unfortunately, the poor dovetail attachment system limits how much the excellent Sirius mount can help.

All in all, we continue to be impressed by Synta's MCTs. If you want a Maksutov Cassegrain but cannot afford the high-priced spread represented by Questar, you could do worse. What if you do not live in the United States but want an Orion? Orion does sell some scopes in the United Kingdom and Europe, but nearly identical Synta MCTs badged as Skywatcher are easily available across the United Kingdom and the Continent.

INTES Micro M603 6-Inch and M809 8-Inch and Maksutov Cassegrains

Russian-produced Maksutov Cassegrains enjoyed a great deal of popularity among amateurs during the 1990s. With the coming of the Chinese MCTs, however, much of this interest fell off, and Russian MCT makers Intes and Lomo have now apparently quit the business. There are still some Russian Maks on the telescope market, however, in the form of high-quality instruments produced by Intes Micro of Moscow.

Intes Micro produces an extensive line of MCTs, ranging from a compact 5-inch to a gigantic 14-inch. The Intes Micro telescopes with the most appeal to amateurs, however, are the M815 8-inch and, especially, the M603 6-inch. The M603 features just about everything amateurs have wanted in a Mak OTA and that they have often found lacking in the Chinese imports: excellent build quality, top-grade optics, and a reasonable price (about $1,300 from the scopes' U.S. importers ITE and Teton Telescope (see Appendix 1).

Yes, this price is comparable to that of the 180-mm Synta, and yes, aperture *is* important, but in this case it might be wise to think about giving up that inch. Chinese optics can be very good, certainly, but they are probably not as consistent as those in these telescopes. A 1/8-wave accuracy is *usual* for the M603. The mirrors in the Intes Micro OTAs are not standard Pyrex, either, but Sital, a glass with better thermal characteristics, something that helps with the typically long Maksutov cooldown. Also, the M603's focal ratio is a comparatively low f/10, making the scope more versatile than most other MCTs. The primary obstruction in this CAT is somewhat large at 36% (necessary to get the focal ratio down to f/10), but this does not seem to hurt contrast much.

Tube mechanics are also noticeably better in the Intes Micros than they are in the Syntas. In addition to the normal primary and secondary mirror baffles, the inside surface of the M603 tube has a series of five knife-edge baffles that help further in reducing scattered light and increasing contrast. Intes Micro has also taken pains with the moving mirror-focusing system, nearly eliminating annoying focus shift. The Intes Micro Maks are of the "Rumak" design, which uses a secondary mirror that is separate from the corrector, not just a silvered spot (as has been the case with all the MCTs we have looked at so far). Like an SCT, and in contrast to Questar, Synta, Celestron, and Meade MCTs, an M603 is easily collimated by the user. The robustness of the M603 does come at a slight disadvantage: This 6-incher's 14-inch long tube weighs in at a hefty 12.5 pounds. That is well within the payload capabilities of modest mounts, such as the Celestron CG5 and the Meade LXD75, however. Finally, in a real coup for the M603, it features an SCT-style rear port and can use many of the accessories developed for Schmidt Cassegrains. Like other Intes Micro scopes, the M603 is sold as a "bare" OTA, with the only accessories included being lens caps and a 50-mm finder.

The M603 sounds good otherwise, but is it too small in aperture? Check out the M809, an 8-inch aperture Mak. The M809 is nearly identical to the M603, but the standard package includes a couple of nice features lacking in the 603. Most important, there is a cooling fan mounted on the rear cell to speed thermal equilibration. A big Maksutov like this one must have help in this area if it is to deliver as advertised on nights when the outside and inside temperature differential is large. Like the M603, the M809 has a fairly large central obstruction, necessitated by its fast f/10 focal ratio. This obstruction will not appeal to the Mak purists looking for "APO refractor performance." For these cognoscenti, there is the M815, which is the same as the M809 except for an f/15 focal ratio and a smaller secondary obstruction (24%).

How about price? The over-7-inches point is the point at which MCTs begin to demand serious bucks. At $3,200 without a mount or eyepieces (the M809/815 do usually come with a 2-inch star diagonal in addition to a 50-mm finder), price is a consideration here, but the scope is hardly in the Questar price zone. $3,200 is not bad for a Mak of this quality and aperture, but remember to also allow for the cost of a suitable mount. At a weight of 21 pounds and a length of 21-inches, the M810/815 will need something in at least the Orion Atlas class, so be prepared to spend another $1,500 to get fully set up.

Orion Optics UK OMC 140, 200, 250, 300, and 350 Maksutov Cassegrains

Orion optics in the United Kingdom (no relation to the U.S. company) has been turning out excellent Maksutov Cassegrains for quite a while. The company tested the waters 10 years ago with a 5½-inch model, the OMC140 (Plate 32) and then expanded MCT production to offer a whole line of Maks in apertures of 8-, 10-, 12-,

Plate 32. (Orion UK OMC140 MCT) Orion Optics UK's upscale but reasonably priced MCT, the 140mm OMC 140. Credit: Image courtesy of Orion Optics U.K.

and 14-inches: the OMC 200, 250, 300, and 350, respectively. The 140 and 200 scopes are similar in design and execution and incorporate fine optics and robust tubes. The 5½ and 8 are "traditional" high-focal-ratio MCTs (the 140 is an f/14, and the 200 is an f/20) of the Rumak configuration. The 140 and 200 are available as OTAs only or can be purchased with one of the Vixen GEM mounts Orion also sells.

Orion's three big guns are a very different breed of CAT. For one thing, all three, the 10, 12, and the 14, are, at f/9, considerably faster in focal ratio than their little sisters. Most notably, they are not traditional MCTs in the sense that they do not use full-aperture correctors. Instead, they use a subaperture corrector lens mounted on the secondary mirror to perform the same function. This is good since it helps keep the OTAs lighter (the OMC 250 is 20 pounds, the OMC 300 is 30 pounds, and the 350 is 48 pounds). At the time of this writing, the big 350 was, according to the company, temporarily unavailable "due to a large number of back orders." It is also probably the reason Orion can keep the prices for these large MCTs as low as they are.

The big OMCs are amazingly inexpensive compared to other MCTs in these large sizes despite the currently unfavorable (for U.S. consumers) U.S.–U.K. currency exchange rate. The 300 OTA, for example, costs "only" about $5,000, an excellent price for a Mak in this aperture range. Unfortunately for North American amateurs, none of the OMCs appear to be available from U.S. or Canadian dealers at this time. In this day of Internet commerce, there is probably a way to get an OMC nevertheless, a European or U.K. dealer who will sell one of these nice CATs over the Internet.

Maksutov Newtonians

Take a Schmidt Newtonian, replace the Schmidt corrector with a salad bowl Maksutov corrector plate, and the result is a Maksutov Newtonian. It is not *quite* that simple, but that is the basic idea. Back in the mid-1990s these MNTs were the darlings of the amateur astronomy chattering classes, the on-and offline astronomy pundits and writers. That was understandable. If any reflecting telescope approaches premium apochromatic refractors in image quality while beating them at the aperture/price game, it is the MNT. Why, then, has the popularity of MNTs waned?

Maybe this is because they are such specialized instruments. These are remarkable telescopes for looking, for visual use, especially for targets that benefit from high resolution such as the Moon and planets. On these subjects, MNTs may equal the best refractors. That comes at a price, however. One of the reasons MNTs are able to offer excellent images is by using very small secondary mirrors. The typical obstruction in these scopes is below 30%, and often below 25%. Although Maksutov Newtonians, which are available in relatively fast focal ratios like f/6 to f/7, are capable of producing great deep sky views, their tiny secondaries pretty much rule out any serious deep sky imaging. As this book goes to press, several new MNTs, including one by Orion (U.S.) have become available that are more suited for imaging. Unfortunately, their larger secondary mirrors reduce the MNT's legendary contrast advantage.

Intes Micro MN76 7-Inch Maksutov Newtonian and MN66 6-Inch f/6 Maksutov Newtonian OTAs

The Intes Micro 7-inch MN76, which, like the company's MCTs, is imported and sold by the U.S. dealers ITE and Teton, is a big, impressive CAT with a 42-inch long, 30 pound tube. It is an f/6, and that and the good edge-of-field performance MNTs, like SNTs, boast make it a powerful instrument for deep sky observing as well as planetary work—within the limits of its aperture. The 32-mm diameter secondary mirror gives the MN76 an amazing obstruction value of 20%, and it shows. When coupled with the telescope's way-above-average 1/8 wave peak-to-valley mirror figure, this scope can make its user forget it is only a 7-incher. It and its 6-inch sister feature tube interiors equipped with knife-edge baffles that help reduce scattered light and further improve the scope's already outstanding contrast characteristics.

At a price of approximately $2,350, the MN76 is not overly expensive. Of course, that is only for the OTA. A big GEM will be required to handle this puppy. Not only is it fairly heavy, but the long tube acts as a lever arm, giving CG5 class mounts a terminal case of the shakes. Do not consider anything less than the Orion Atlas for this mount, and the Losmandy G11 or Celestron CGE may be even more suitable (and more expensive).

Is the MN76 too much of a good thing? If so, look at a scope that many MNT enthusiasts have turned to, the MN66. The 6-inch optics are every bit as good as those on big sister, but come in a somewhat more manageable package. The 66 OTA is 35-inches long and 16 pounds. What will the MN66 stand mountwise? A Losmandy GM8 or a Synta HEQ5/Sirius is strongly recommended here. When the scope is properly mounted, expect great things contrast- and sharpnesswise; the MN66's central obstruction is a remarkable 19%. The asking price of $1,400 sounds a bit expensive for a 6-inch aperture CAT, but considering the fact that this 6-inch will do very well against an APO refractor of the same aperture costing eight times as much, it may actually be a bargain.

Both telescopes are sparingly equipped with accessories: a 2-inch focuser (a low-profile Crayford for the 66 and a helical unit for the 76), a set of tube rings for attaching the scope to the mount, and a 50-mm finder. The 6-inch includes a carrying case.

Is there anything to recommend *against* MNTs? Not really If it is understood up front that these are really visual-only instruments. If so, it makes sense to purchase one of these telescopes, which are among the most elegant members of the CAT tribe. Note also that if these two are too big or too small, Intes Micro also offers 5- and 8-inch apertures. Actually, although they apparently have not been offered for sale in the United States, Intes Micro can supply MNTs in apertures up to 14-inches. As might be expected, these are very heavy and very expensive CATs.

Subaperture CATs

With apologies to animal lovers, there is more than one way to skin a CAT (metaphorically speaking), and there is also more than one way to make one. Several variants on the standard MCT and SCT design have been appearing of late that attempt to capitalize on the strengths of the telescopes while avoiding the weight and expense of the 8-inch and larger MCTs' deep dish corrector plates or the fabrication difficulty inherent in the SCT's big lens. These telescopes do this, as the larger Orion MCTs do, by downsizing the corrector to a couple of inches and placing it in front of and often in contact with the secondary mirror or in the focuser assembly.

Vixen VMC200L

Out on the observing field, Vixen's 8-incher appears to be just another SCT. A close look shows several differences. First, rather than gray, blue, or orange, its OTA is a striking white. Also, it seems to be missing its corrector. It is not a classical

Cassegrain, however. Like the OMC MCTs, it is a subaperture corrector member of the MCT family. The Vixen's particular optical recipe is a little different from that of the Orions, being based on the Shafer-Maksutov design. Otherwise, we are in familiar territory. It has a focal ratio of f/9.75, close to the standard f/10 of the friendly neighborhood SCT. Unlike SCTs, however, the VMCs do not move the primary mirror to focus, and are equipped with a standard rack and pinion focuser on the rear cell. The rear port, though it *looks* like it should be SCT accessory compatible, is actually a T-mount affair. It should be fairly easy to find adapter rings to hang just about anything on this CAT's port, however.

The VMC is solidly built and quite good optically, something typical for this Japanese manufacturer's telescopes. The only question here is, "Why?" Its performance is nearly identical to the average SCT OTA, but at a price about $300 higher—the Vixen OTA is currently priced at $1,300. Why isn't the VMC better than the less-expensive SCTs? That may have something to do with the fact that the telescope's central obstruction is close to 30%. Or, it may be because it is harder to get the subaperture corrector "just right" than it is to do a good full-aperture lens. Unlike a full-aperture corrector, light must pass through the VMC's lens twice since it is mounted in front of the secondary. This small corrector does reduce the dew and weight problems of full-aperture MCT and SCT correctors. What is one thing some imagers do not like about this CAT? Since there is no corrector lens on the front to support a secondary mirror, the secondary/corrector assembly is held in place by "spider" vanes. These cause prominent diffraction spikes around stars in astrophotos.

In addition to the VMC200L 8-inch, Vixen also makes a 10-inch aperture version of this design, the f/11.5 VMC260L, and another subaperture scope, one intended primarily for imaging, the VC200L, an f/9 8-inch that uses an aspheric primary mirror and a three-element corrector mounted in front of and in contact with the secondary.

The TAL200K 8-inch Klevtzov Cassegrain

Tired of being just another member of the enormous pack of SCT and MCT users? Want something exotic? How about a KCT—Klevtzov Cassegrain telescope? This CAT, the TAL200K, now marketed by Russia's Novosibirsk, sounds exotic, but it is actually fairly similar to the Vixen subaperture corrector scopes. The TAL uses a spherical primary and a two-element meniscus corrector lens (a "Mangin" corrector) coupled to its secondary. It is also pretty similar to the Vixens in other ways, including an f/10.3 focal ratio.

Alas, the TAL got off on the wrong foot when it was introduced to U.S. amateurs a few years ago. To begin, the Russian seller at the time, TAL, insisted on packaging the OTA with a crude and shaky Russian-made GEM. More seriously, the original 200Ks were set up to be collimated by adjusting the secondary mirror. Collimation, it turned out, was frequently needed by new telescopes after their long voyage from the motherland, and users naturally attempted to put things right. The optical alignment of one of these telescopes via secondary mirror adjustment is a very difficult affair, however, one best suited for skilled hands and an optical bench. Because of this, many TALs wound up badly out of adjustment and delivered poor images. Recently, the design has been modified to allow collimation via the primary, a much simpler operation, but the damage to the scope's reputation had been done.

Like the Vixen, the main problem with the TAL200K is why someone would purchase it. When properly collimated, the KZT can deliver images very competitive with a modern SCT, not usually better than, however. The TALs are robust in construction, but rather crude looking as well. Finally, the 200K uses a standard rack-and-pinion focuser rather than a moving-mirror system, giving the CAT a very small focus range. Few cameras will come to focus with the TAL, and there may even be problems focusing some eyepieces. Due in part to these negatives, the 200K is no longer being sold in the United States. It does remain popular in Europe, where Meade and Celestron SCTs are quite (insanely) expensive and make the TAL200K an attractively priced alternative.

Novosibirsk must be selling some TAL200Ks somewhere, as they have recently introduced a 10-inch version. The company also has apparently wised up about the mount preferences of Western amateurs. Both the 8-inch and the 10-inch are now available as OTAs only.

Buying OTA Only and Rolling Your Own CAT with a Third-Party GEM

I have "test driven" a few CAT/GEM mount combos in this guide, but remember that it is not mandatory to settle for one of these packages. Meade and Celestron also sell their CATs as bare OTAs, and most of the other makers' scopes reviewed in this chapter are also available without mounts. Discriminating CAT fanciers can pick a combination of OTA and GEM that suits particular needs and goals. Often, beginners shy away from assembling OTA mount combinations themselves, but doing so often results in a better telescope. Putting together a telescope from an OTA/GEM combo usually means paying more, but the results yielded by high-quality third-party GEMs may more than justify the extra expenditure. One thing is certain: There is no shortage of excellent German mounts in all price ranges.

Synta

Celestron's parent corporation is well known for its light German mount, the CG5 (also known as Skyview Pro and EQ-4). This mount is excellent for visual use and light imaging, but it is really not heavy enough for demanding work with larger OTAs. Recognizing that fact, Synta is now selling a pair of much more robust GEMs, the Sirius EQ-G and the Atlas EQ-G. These mounts, which are sold in the United States by Orion, are also available elsewhere in the world, often under Synta's Skywatcher brand name (as the SkyScan HEQ-5 and SkyScan EQ-6, respectively).

The Sirius ($1,150) is an impressive mount able to easily handle payloads up to 30 pounds, at least 10 pounds more than the CG5. This capacity makes the mount just about perfect for a C8 and very good for a C11 but does not come at a huge weight penalty. The Sirius's equatorial head comes in at less than 30 pounds. Tracking accuracy is very good, the go-to HC features PEC (not PPEC), and the mount is fully capable of supporting a C8 loaded down with guide scopes and cameras.

The Sirius is great for dressed-out C8s and does fine with basic C11 OTAs, but it is not quite enough for the Meade 10-inch or heavily loaded 11-inch OTAs and is inadequate for a even a bare Meade 12-inch. The next step up, the Atlas EQ-G ($1,500) is able to support up to 40 pounds of scope, so 10- to 12-inch OTAs, even those weighted down with accessories and cameras, will do well on this GEM. That does come at the cost of a heavier mount; the Atlas equatorial head weighs 40 pounds (without counterweights), which may be pushing it for lightly built observers. The payload rating of the Atlas makes it seem the mount might even be enough to accommodate a C14, but the mount's counterweight system would be a problem for the large scope. The declination weight shaft is not long enough, and really not heavy-duty enough, to allow sufficient weight to be positioned on the shaft to balance that monster OTA. The Atlas features great tracking and excellent stability.

Both mounts come with respectable, if not perfect, tripods. The Atlas ships with a 2-inch leg diameter steel tripod identical to the one found on the CG5, and the Sirius features a slightly smaller 1¾-inch leg tripod that is sufficient, if not much more. Both mounts are available with or without the SynScan go-to controller. Interestingly, even the non-go-to version can be turned into a go-to by use of the innovative freeware computer program *EQMOD* (Appendix 1). This software driver works in similar fashion to the Celestron *NexRemote* program, allowing go-tos to be initiated from a laptop without the presence of an HC.

Vixen

Vixen has long been a much admired (and copied) player in the medium-weight GEM game. The company makes a wide variety of German mounts, ranging from the small to the impressively large. The Vixens of most interest to CAT-toting amateur astronomers, however, are the Great Polaris Deluxe 2, the Sphinx SXW, and the Sphinx SXD.

The Great Polaris Deluxe 2 (about $1,300 with tripod) is the latest edition of a mount that has been used by amateurs in the United States since the 1980s. The "GPD2" is a solid GEM that, despite its fairly low payload rating of 22 pounds, can do well in astroimaging with C8s or even 10-inch SCTs. It is not uncommon to see astrophotographers pushing this mount beyond its quoted "limit." That is possible due to excellent 144-tooth brass worm gears on both RA and declination. The only thing that lessens the GP's appeal is that currently drive motors and go-to controllers are optional. As shipped, the mount lacks any drives at all. Expect to pay about $500 more for a simple noncomputer dual-axis drive outfit, which brings the complete cost for the GP to around $1,800. If you want go-to, that is available in the form of the add-on Starbook S system—for $700.

The "next" Vixen certainly does not eschew go-to. The Sphinx SXW ($2,000) made quite a splash when it was introduced a few years ago. Not only did it modernize the looks of the Great Polaris with a snazzy white paint job and translucent plastic panels on the mount head, it offered Star Book, a go-to controller different from any other. How? Well, the display is large at 4¾-inches, and it is in color. The big deal, though, is that the Star Book displays a representation of the night sky via a built-in and fairly full-featured planetarium program. Click on an object on the Star Book's display and the mount goes there. Many amateurs think this is the wave of the future—having the features of laptop computer astronomy programs without the laptop.

The Star Book HC got most of the attention when the Sphinx debuted, but the specs of the mount itself are fairly impressive as well. The payload capacity is not overly large at 22 pounds, the same as the Great Polaris, but also like the GP, the Sphinx's high-quality construction means it is possible to exceed this limit and still achieve excellent results. The gears are 180-tooth hardened aluminum on both RA and declination and seem every bit as accurate as the brass gears of the Great Polaris.

So, why isn't the Sphinx more common on star party observing fields? The mount was plagued by small but irritating problems from the get-go. Some were minor oversights, like the failure of Sphinx designers to provide a way to dim the display to preserve users' night vision. Some were silly, like Vixen's original insistence that users pay extra to "unlock" the mount's software PPEC feature. Some, however, were serious and included poor electronic reliability and mechanical problems. To their credit, Vixen worked to fix these oversights and problems. One of the "fixes" has been the release of an upsize mount, the SXD ($2,700), which is similar to the original Sphinx but sports a payload rating of 50 pounds and incorporates the numerous electronic and mechanical fixes that Vixen has applied to the SXW over the last several years.

Losmandy

Losmandy, also known as Hollywood General Machining, is a name well known to the amateur community because it has been producing excellent GEMs since the 1980s. Today, Losmandy's reputation rests on three mounts: a medium, the GM8; a heavy, the G11; and a monster, the Titan.

It is probably misleading to refer to the GM8 ($2,495.00) as a medium mount since its stated payload capacity, 30 pounds, is considerably higher than that of the CG5s and Great Polarises. This is a beautiful mount finished in black anodizing and equipped with all stainless steel hardware. It is a step up in both capacity and in appearance, not just from the CG5 but also from the Vixens. Is the beauty skin deep? Not at all. The 180-tooth aluminum gearing system does a good if not perfect job, and coupled with the PPEC provided by the mount's Gemini go-to system, the GM8 makes an impressive imaging platform for a CCD-equipped C8.

The G11 ($3,200) provides 60 pounds of OTA handling at a relatively modest price increase over the GM8. Due to this payload rating and the mount's robust construction, it is able to handle a C14 without a problem, at least for visual use. This weight handling does not come at a huge cost in mount weight, either, with this

GEM's head, which weighs 36 pounds, actually slightly lighter than the Atlas. The G11 has been a long-time favorite of amateurs, and there is little to complain about. The only criticism of it is that Losmandy needs to consider updating the electronics. The Gemini go-to system, provided by a third party, works, but it is not overly user friendly—just the opposite. Performance-wise, the G11 is a good bet. Although its gear error is usually not worlds better than that of the Synta or Vixen mounts, it is more than good enough for imaging, and the build quality of the mount is noticeably better than that of the other makes.

A C14 will ride on a G11, but like the similar Celestron CGE, is borderline for imaging with that fat CAT. If a C14 or an even larger OTA is contemplated, the Titan ($7,000) is a very economical solution as big GEMs go and pushes the possible payload up to 100 pounds, more than enough for a fully tricked-out C14 or Meade 14. Construction-wise, the Titan is similar to its little brothers, black anodizing and stainless steel, but everything has been upsized, which accounts for the GEM head's considerable weight of 68 pounds. The drive gears are 270-tooth aluminum and provide good accuracy, similar to that of the G11. Like the G11 and the GM8, the Titan relies on the Gemini system, and that is the only facet of this mount that is less than "Titanic."

Astro-Physics

Astro-Physics (A-P) is almost legendary in the amateur astronomy community, mainly because of the outstanding apochromatic refractors this Illinois company produces. Surprisingly, A-P is also revered by CAT users due to its line of heavy-duty go-to GEMs, mounts with sterling reputations for quality and capability. A-P produces a full line of mounts, led by the newly introduced 3600GTO, the El Capitan, a monster of a GEM that is able to support scopes weighing up to 250 pounds. Not many SCT users outside those lucky folks who own vintage Celestron C22s or new Meade 20-inchers will need a mount in that weight (and price) class, but Astro-Physics sells three other mounts (the Mach1 GTO, the 900GTO, and the 1200GTO) well suited to the needs of 8- to 16-inch SCT owners.

The Mach1GTO ($5,950) is A-P's "light mount," but that is in relative terms. This GEM is more than able to accommodate CATs in the 8- to 12-inch aperture range, at least (Astro-Physics, unlike other GEM makers, tends to underrate the payload capacities of its mounts). One thing that is surprising about the Mach1 is that it is able to handle telescopes as heavy as it is without becoming heavy itself. The mount head is a positively puny sounding 28 pounds. When it comes to electronics, the Mach1, like other A-Ps, tends to take the tried-and-true rather than innovative route. The GEM is driven by heavy-duty servo motors under the direction of a computer HC. The hand control is nothing fancy, containing 17,000 objects and an array of features similar to those of other go-to HCs. Since the A-P go-to system "speaks" Meade LX200, it can be controlled by any PC program suitable for a Meade scope. The draw is not tons of features; it is build quality and precision, both for the computer and the mount itself. Out of the box, without PEC training, the Mach1 boasts a periodic error of 7 arc seconds, which is better than the best periodic error of many PEC-trained mounts.

Got a C14? Do not want to just look at pretty stuff with it, but instead want to undertake a serious program of imaging? Step up to the 900GTO ($8,250). Despite a still "reasonable" GEM head weight of 54 pounds, this thing packs a punch—a payload capacity of 70 pounds. Does 54 pounds of mount head sound like a lot to lift onto a tripod? Never fear—the GEM head breaks down into easily manageable pieces. The heaviest part is only 25 pounds. The 900 will not just accommodate the C14 or the heavier Meade 14-inch OTA; it will allow imagers to add considerable ancillary gear such as sizable guide scopes. Other than its much more noticeable beefiness, the 900 is much like the Mach1: high-quality servos, excellent build quality, and impressive accuracy. Its large brass worm gears deliver the same 7-arc-second tracking accuracy as the Mach1, good enough to allow many astrophotographers to take pictures without guiding.

Then, there is the 1200GTO ($9,400). The main descriptor for this mount is not "portable," but "transportable." Folks can be seen setting these up at star parties, but there is no denying the 81 pound equatorial head is big and heavy. This is not a mount to be carried out into the backyard on the spur of the moment, although one person *could* do that since the heaviest component is "only" 50 pounds. Naturally, this big gun is most at home in a permanent installation, and in that role it is hard to want for more than the 1200. It can handle an OTA of up to 140 pounds according to A-P, but users have pushed the 1200 past even that with great results.

So, who is the 1200GTO for? Perhaps it is for someone with a large OTA, a 16-inch, for example, who wants precision and build quality without leaving behind the comfortable punch-objects-into-an-HC-and-go-to-them paradigm. Accuracy? The 1200 is even better than her little sisters, with a stated error of an amazing 5 arc seconds or less.

Why should you not buy an A-P GEM? For many CAT fanciers, the stumbling block is money. The prices mentioned, by the way, are just for the GEM head. Prospective purchasers will need to invest more for a full-up system with a pier, a mounting plate for the OTA, and counterweights, and those three things will elevate the price tag another $1,000 on average. And yet, and yet, … plenty of folks think nothing of paying this much or more for a couple of jet skis that sit in the garage most of the year. For the person with the need and the means, it is hard not to say "go A-P." One thing that dissuaded some prospective A-P GEM purchasers in the past was the long wait times for mount deliveries, which approached the lengthy waiting periods required of buyer's of the company's refractors. In recent years, A-P has stepped up GEM production, and the GTOs are considerably easier to get than they once were. They are still not off-the-shelf items, however.

Bisque

Some CAT owners like the comforting computer setup of the A-P mounts with their normal HCs. Others want the capacity and quality of the A-Ps, but also the latest technology in the form of a mount that is ready out of the box for tasks such as remote control over the Internet—from 100 meters away or 10,000 kilometers away. These advanced amateurs naturally gravitate to the Software Bisque Paramount ME ($12,500). The ME is currently Bisque's only GEM, but it is a *mutha*. The company's magazine ads for the mount feature a picture of it emblazoned with the words, "They call it the red giant." That is a fair description. This 68 pound mount head can carry even more weight than the 1200GTO, up to 150 pounds. Although Bisque describes the ME as "field portable," its weight and its specialized power needs (48 volts DC) mean most of us will find carrying this GEM around to weekend star parties something less than practical.

What makes the ME different from the A-Ps or the GEMs sold by other manufacturers? Mainly, it is that this mount was designed for the digital age. Most GEMs can be controlled by an external PC, but the ME may be the only one that requires a PC. Much of the mount's "brains" are in the suite of Bisque software that accompanies the ME: *TheSky, CCDsoft, T-point*, and more. The Paramount is perfectly capable of producing an astounding visual observing experience, but CCD imaging is where it really sings. Not only is it designed with this in mind, featuring things such as internal cable routing for cameras and USB communications with the host computer, its mechanical precision makes image acquisition almost easy. With a periodic error of 7 arc seconds before PPEC, the mount, like the A-Ps, may not need guiding for most imaging tasks.

So, what is the downside? As with the A-Ps, it is partly the price. Like the A-Ps, the quoted price, as considerable as it is, is just for the equatorial head. Piers, counterweights, and dovetail mounting plates are extra. But it is also due to the nature of the mount, which is best suited for a permanent observatory. The ME is also a mount designed for serious imaging work, more so than for casual skylarking. The PC must be online whenever anything is done with this GEM. There are no clutches on the RA and declination axes, so the ME cannot even be moved without the help of the PC. Frankly, this is a GEM for CAT users engaged in much more serious amateur astronomy pursuits than most of us. For those folks, the Paramount is a genuine breakthrough.

Mounting CAT to GEM

How exactly is a Meade or Celestron attached to a non-Meade or -Celestron GEM? Most mounts use one of two standard dovetail mounting schemes, Vixen or Losmandy. There are a few oddities out there, like the proprietary system Takahashi uses, but almost all GEM makers have wisely stuck to one of the two most popular formats. Both systems consist of a dovetail bar that is attached to the underside of the CAT OTA, usually by means of the accessory screw holes found on the corrector and rear mirror cell assemblies. The telescope can then be placed in the corresponding bracket on the GEM head. Caveats? The Vixen system is adequate for tubes up to about 11-inches. Larger, and it is wise to go to the wider and sturdier Losmandy system. Both types of dovetail mounting bars are available from most scope dealers. Celestron ships some of its OTAs complete with preinstalled Vixen or Losmandy format dovetails, depending on the OTA size and model.

DEALING WITH DEALERS: Buying a New CAT

You have read this book from cover to cover, drooled over the Meade and Celestron advertisements in *Astronomy* and *Sky & Telescope* for months, and have asked endless questions of the CAT owners at the local astronomy club. You know which telescope you want, but you are not sure how to get it. Unfortunately, Meade and Celestron have not sold directly to the general public for a long time, which means finding a reliable dealer. A lot of people will advise you to patronize a local telescope merchant. You can at least look at a sample telescope in person even if you cannot always walk out the door with one (some models must be drop-shipped to customers from the manufacturer, even if they are paid for in a local store). Most important, if you have problems with that new scope, you have someone local to turn to for advice and help if you buy from a brick-and-mortar scope dealer.

The above might not be bad advice, but for most of us, it is not very practical. Telescope dealers are often few and far between. Amateur astronomers on the West Coast of the United States or in a major European metro area probably *do* have a telescope dealer within driving distance, but in the American Midwest or South, forget it. There, telescopes are usually bought on the Internet.

This is not always a bad thing. One strike against buying locally is that telescopes cost more that way. In addition to the price displayed in the magazine ads, there will be local sales taxes. Some telescopes (not usually Meade or Celestron) are also often "marked up" by local dealers. And, there are local dealers, and then there are local dealers. It is one thing to buy from the merchant down the street if that happens to be Anacortes, Astronomics, or another major astronomy seller. Often, however, buying locally means buying from a chain "nature store" or gift shop. Having a relationship with a local dealer will not help much if the people there do not know squat about scopes, if the response every time there is a question is, "I do not know. Guess you'd better call Celestron (or Meade)." Buying at these kinds of stores may work out if the scope is DOA (dead on arrival) right out of the box. In that case, it is usually possible to exchange it for a new one locally or at least get a refund, if needed.

DOA scopes are rare, but it does happen. Often, the unfortunates who receive these CATs are instructed by dealers (or the maker) to return them to Meade, Celestron, or whomever for repair, which often takes weeks. Insist on an immediate exchange from the dealer's or manufacturer's stock or a refund instead. If you brought a new television set home from a chain store and it was dead when you plugged it in, would you agree to ship it to Panasonic for repair? Not likely!

The best bet for most of us is to buy from a major national astroseller. Which one? I have listed some of the most prominent and reliable in Appendix 1, but a good way to decide on a dealer is to ask around at the astronomy club. Who do your buddies buy from? How have they been treated?

Buying a Used CAT

Prices for SCTs, MCTs, and, in fact, all amateur telescopes are currently as low as they have ever been. A shrinking dollar coupled with an influx of CATs from the East has seen to that. Still, for some novices and young people the $1,500 to $2,000 that a go-to 8-inch SCT commands can be prohibitive. That does not mean newcomers should have to give up on CAT ownership, however. Nothing says a new telescope must be new.

There are plenty of used SCTs, especially, available at very reasonable prices. The typical used scope will not have the whiz-bang computer features of a new model but will be more than capable of delivering good images and lots of enjoyment. One tremendous advantage of buying used is that if a telescope can be found locally, it may be possible to try it out under the stars.

Where can used scopes be found? The best and safest bet for a quality used SCT or other CAT is a fellow astronomy club member, so ask around there first. Newspaper want ads and local "swap-shop" papers are also possibilities. Some large, national telescope dealers also sell used telescopes, although these will probably be a little more expensive than a local CAT.

Is it safe to buy a used telescope from an individual through the mail or over the Internet? It may be. One way to eliminate a lot of potential lemons is to refuse to consider buying any Meade or Celestron SCT made from about 1987 to 1990. These "Halley scopes" were made at a time when both companies were wearing out their equipment and their workforces to produce as many scopes as possible to satisfy the comet craze. Halley-era CATs *can* be okay, but be wary of buying one you could not try first.

What is the key to successful used buying? If a scope is not to be found locally or in a reputable dealer's used inventory, stick with Astromart.com. This online classified service, run by a respected dealer, Anacortes Telescope and Wild Bird, is well policed. Scams can still happen, but the chance of being cheated on Astromart is far less than the chance of being cheated on most other online emporiums.

What is the secret to getting a good used telescope? Education: The best defense against being sold a punk CAT is to learn as much as possible about the model under consideration. Ideally, this book would have included a used CAT buyer's guide section. Unfortunately, Meade and Celestron alone have produced dozens of models over the last four decades, and including used CATs here would have added at least another hundred pages to this already long book. Instead, look for *Uncle Rod's Used CAT Buyer's Guide* on the Internet as a free Adobe Acrobat file. It includes a helpful checklist for used SCT buyers as well as extensive information on most of the SCTs and MCTs produced over the last 40 years. See Appendix 2 for more information.

What is next? Let us open the box and start assembling your beautiful new CAT.

CHAPTER FIVE

Making Friends with a CAT

Initial Telescope Assembly and Checkout

That wonderful, long-hoped-for day has arrived: The box containing a new catadioptric telescope (CAT) is on the doorstep. You are plenty excited. There is nothing like tearing into telescope boxes! Restrain yourself, however. The key to avoiding grief and confusion is being careful and methodical when unpacking, checking, and assembling a new telescope. Of course, you are anxious to get the new baby out under the stars and take "first light," but the experience will be more enjoyable if you take time to thoroughly check the telescope indoors first.

Initial Inspection

The first task is to make sure the telescope has arrived undamaged. You might even consider asking the delivery person to wait while the boxes are opened and the contents are given at least a cursory examination. The average delivery driver may balk at this prospect, but if there are signs of serious mishandling, you should insist on the driver waiting.

What if the boxes *are* damaged and an "open and inspect" reveals the telescope inside has been totaled? That does not happen often, but it does happen, and stories of smashed corrector plates and secondary mirrors that have been dislodged and deposited on primaries are unfortunately fairly common in the amateur community.

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In a case of obviously abused boxes, unpack the scope immediately and examine the contents in detail. Especially, remove the dust cover on the corrector end of the tube and check the optics for breakage or other damage. If the worst has happened, ask the driver the proper course of action. Whatever he or she says, call the dealer *immediately* and report what has happened.

Assuming the telescope has arrived intact, job number two is to take inventory of everything. There will probably be at least two boxes to poke around in. One will contain the telescope's tripod, the other will hold the optical tube assembly fork-mount combo. If the new baby is a German mount-equipped CAT, there will likely be three boxes, with a separate one for the GEM mount head.

What if there is only one box instead of two? The scope is there, but there is no tripod to mount it on? Or, worse, there is a shiny new tripod and no telescope to put on it. It is not uncommon for boxes in a multibox shipment to go their own ways. Go straight to the PC, bring up the delivery company's Web site, and plug in the tracking numbers (the dealer should have e-mailed these once the scope shipped). Likely, one package's Internet info will have "delivered" next to it, and the other one won't. It is painful not to have a complete telescope, but the remaining parts and pieces will probably arrive on the next day. What if the whole shipment is marked as delivered or the remaining items do not arrive in the next day or two? Call the dealer. It is possible something is back ordered or that something has gone astray.

If there are shipment problems, do not be too quick to blame the dealer or the guys with the big brown trucks. Many scopes are "drop shipped" from the manufacturer these days. This is particularly common with Meade. Often, a dealer does not have any inventory. When a telescope is purchased, the dealer sends the information to the manufacturer, who sends out the scope directly from the factory.

Now, the fun begins. Start unpacking. The first thing to look for is the instruction manual, which will be required for this initial inventory. It is pretty obvious that there should be a telescope and a tripod in the boxes, but what else? How about eyepieces? How many eyepieces? Does the telescope come with a direct current (DC) power cable? How about an alternating current (AC)/mains power supply? One thing you should do as soon as you purchase a scope is download a manual from the manufacturer's Web site. By the time the CAT actually arrives, you will have a pretty good idea exactly what should be in the boxes and how it will all go together.

Now, start removing items from the boxes and placing the items in an open, uncluttered area. If there are young children in the house, wait until they are in bed before beginning. Otherwise, that shiny and fascinating Plössl eyepiece may *never* be found. After removing a few small accessory containers perhaps, the beautiful new telescope will be revealed cradled in shipping foam. Grasping either fork arm, gently lift the telescope, remove it from the container, and set it up on its base (assuming it is a fork-mount telescope). Some fork models will have handles on the tines to make this easier. If this is a large or heavy-duty Schmidt Cassegrain telescope, take it easy. It will be heavy. Do not be afraid to ask for help if needed. Where should you put the scope? someplace where it will not be knocked over by passersby as the rest of the gear is unpacked. If there is a sturdy table at hand, that might be a good temporary home for the CAT.

Once everything is out of the boxes, try to bring some organization to a scene that will look a lot like Christmas morning with the kids (Plate 33). Group small items

Plate 33. (Unpacking a CAT) A new CAT: Christmas in July. Credit: Author.

such as eyepieces, the star diagonal, and the hand controller together and put them somewhere where they will not be misplaced. Do not throw anything away at this point. It is all too easy to accidentally dispose of small plastic bags containing critical mounting bolts and similar hardware.

How about all the packing stuff? Save everything for the moment in case something is wrong with the CAT and it has to go back. Actually, permanently retain at least the telescope's shipping box and the foam in which it was packed. Squirrel the box away in the attic for future use should the CAT ever need to be returned for repair. The box may also have to serve as a temporary telescope case until something better comes along. Keeping at least the foam the scope was packed in is vital. Some cases sold for SCTs—and a case *will* be needed—Meade's, for example, are just soft Cordura fabric meant to fit around this original shipping foam. The foam will also make building a custom case or adapting some other container as a scope case much easier. Foam padding suitable for a CAT case is hard to come by and harder to cut into a suitable shape.

Whew! Once the living room is in some semblance of order again, take a break and admire the new CAT. Remove any paper or plastic that protected the telescope during shipping, but don't do anything rash. Observe all caution and warning notes attached to the tube (often concerning moving a computerized scope in either axis with the locks tightened down). Resist the temptation to play with all those attractive knobs, switches, and levers at this time.

Assembly

Assembly of the telescope starts with the tripod, which is usually simple to put together and involves removing protective plastic from the tripod and attaching a tripod leg spreader and associated hardware. If the telescope is a Celestron, tighten the spreader against the tripod legs as instructed in the tripod assembly instructions but do not *overtighten*. The spindly design of some leg spreaders means they can and will break if too much tension is applied. Once the spreaderis snugged against the tripod legs, make sure these legs are all spread completely apart. If they are not, move them until they are as far apart as they will go and retighten the spreader. If the new scope is a Meade, assemble the threaded rod that extends through the tripod base and attach the spreader to it, but *do not* tighten anything down yet.

Place the now fully assembled tripod in an open area indoors. Leave the legs unextended if they are extendable. Then, stop! Before going further, there is—if you are like many people—a rather unpleasant task ahead. Sit down and read the manual. I know it is difficult. There is a brand new CAT that is just begging you to play with it. Resist the urge and *read the instruction manual cover to cover at least once.* The instructions that follow here are a good general guide, but they do not replace manufacturer's telescope-specific instructions. True, both Meade's and Celestron's manualsare written in something that resembles golden age Greek to most beginners, but the generic assembly and checkout directions that follow should help make the instructions in the manual clear—clearer, anyway.

The first step in assembling a fork-mount scope (German equatorial mount [GEM] instructions follow) is to get the scope/fork/drive base onto and secured to the tripod. Even if a wedge has been purchased for use in astrophotography, set the scope up in alt-azimuth fashion directly on the tripod for now.Before beginning, double-check the tripod. Make sure the legs are firmly spread apart and that they are completely unextended.

Before assembling a Celestron telescope, ensure that the bolts that attach telescope to tripod are close at hand. On some models, there actually will not *be* any separate bolts; they will be "captive," permanently attached to the tripod head. With bolts ready, carefully grasp the Celestron by the handles on its fork or if it does not have handles, just by grabbing each fork tine firmly and lift the scope onto the tripod head. A Celestron tripod will have a center "positioning" pin and a corresponding depressed area and hole on the underside of the drive base that will help guide the telescope into place. Work slowly and carefully and that ensure the drive base is properly centered on the tripod head. If the scope is difficult to seat properly, stop, set the CAT down on the floor, take a breather, and maybe get some help from a friend or family member. Getting the telescope on the tripod will be simple after a little practice, but it is much easier with help the first time.

When the base is properly positioned on the tripod, rotate the scope/drive base carefully until the holes on the tripod (or the captive bolts) line up with the holes in the drive base. There are usually distinctive markings of some kind on the base that will help line up holes and bolts. Then, carefully thread in the attachment bolts. If they do not want to screw in easily, stop and adjust the drive base. Be very careful not to "cross-thread" these bolts.

Meade scopes are both easier *and* more difficult to attach to their tripods in alt-azimuth fashion. They are easier in that there are not three bolts to tighten; all that must be done to secure scope to tripod is to screw the threaded rodthat protrudes through the tripod head into a single center hole on the underside of the scope drive base. They are harder in that there is no pin to guide the scope into place. It must be centered accurately on the tripod before the rod can be threaded into the hole.

Before lifting a Meade, adjust the tripod spreader so its three arms line up with the tripod legs, tightening the securing knob *slightly* to keep it in that position. Do not completely tighten the spreader at this time. Lift the scope onto the tripod and, as with a Celestron, center it on the head as accurately as possible. When the base is centered, reach below the tripod head, grasp the threaded rod, and screw it into the drive base. If it will not go, recenter the scope. The "C" clip that is placed on the scope end of the rod during assembly will prevent the rod from screwing in too far. After the rod is successfully threaded into the base, tighten the knob below the spreader to secure it against the tripod legs, but not too tightly.

If it is still difficult to get the CAT on the tripod after some practice, consider investing in one of the accessories several manufacturers produce to make mounting a fork-type telescope easier. Starizona (Appendix 1) makes a clever device, the Landing Pad, that makes attaching a fork-mount Meade or Celestron to a tripod simplicity itself. The Landing Pad attachment is bolted to the tripod head and features "arms" that guide the drive base accurately into position. This accessory or one of the competing products is handy for an 8-inch telescope but may be a necessity for larger, heavier CATs.

With the CAT safely on the tripod, following the instructions in the manual, unlock the scope's declination/altitude lock and move the tube until it is level, so that it is easier to work with. Relock the declination lock when the tube is in the desired position. Celestron has produced a few scopes that cannot be unlocked and moved by hand in declination. If the telescope requires a motor to move it in declination, go to the mount checkout section, get the scope powered up so it can be moved with the HC, and position the tube level using the hand control. Next? Proceed to install permanently mounted accessories such as finder scopes. Work carefully, keeping the manual at hand, and be careful not to cross-thread screws and bolts.

Assembling a German Mount

The GEM owner has a few more steps to perform than a fork-mount owner. The first task will be to install the "head" of the GEM, the mount on the already assembled tripod. How this will be done depends on the particular mount, but most use a variation of the threaded rod scheme used to attach Meade fork-mount scopes to their tripods. Follow the instructions in the manual and make sure the head is firmly attached since it will be supporting a fair amount of weight.

Once the GEM head is on the tripod, install the counterweightson the declination counterweight rod. *Never, ever, place a telescope on a GEM without first installing these weights*. Likewise, during disassembly, always remove a telescope from a GEM *before* removing the weights. Without weights to counterbalance the telescope load, even a firmly locked right ascension (RA) axis will come loose and slam the lovely new OTA into the tripod. That may cause the whole shebang to become unstable and come crashing to the ground. Attach the weights to the mount by unscrewing the "safety bolt" from the end of the counterweight shaft, sliding the weights up the rod and locking them in place with their setscrews. Be sure to screw the safety bolt back on after the weights are installed.

Once the mount is ready to go, the telescope tube can be installed. Most GEMs feature a dovetail-cradle arrangement. The tube will have a dovetail bar mounted on its underside that slides into the corresponding cradle/saddle on the mount. In some cases—the Vixen mounting system, for example—the dovetail can be "dropped" into the cradle; it will not have to slide in from an end. Before attempting to place the scope on the mount, be sure the cradle's retaining bolts (there should be at least two, often one large knob-headed bolt and one small safety screw) are loose. Then, holding the tube firmly, lower it onto the mount and into the saddle. Making sure it is completely seated, tighten the bolts while still holding the scope in place with one hand and cautiously let go. It might not be a bad idea to have a "spotter" assist the first time, especially if the scope uses the Losmandy dovetail system, which does require the scope to slide into the saddle from one end. When the OTA is firmly attached to the mount, proceed to install any permanently mounted accessories such as a finder scope or red-dot pointer.

Optical Inspection

Okay, good work. While resting up from these exertions, take a look at the telescope's optics. Remove the corrector's dust cover and look down the tube (Plate 34). The primary mirror at the bottom of the OTA should be bright and shiny, and there should not be any obvious dust, dirt, or packing debris on its surface. If there is any of that visible, call the dealer. A little dust will not hurt anything, but there have been reports recently of new scopes arriving with numerous pieces of Styrofoam packing on the mirror, and even of a case or two where there were human hairs inside the

Plate 34. (Corrector End of a CAT) Looking down the front of a Celestron NexStar11 GPS. Credit: Author.

optical tube. CATs are not assembled in clean rooms, but you should not accept one with an obviously dirty mirror.

On the other hand, beware of the “flashlight test.” Examining a mirror by the light of a flashlight or other bright-light source, especially one pointed at the mirror at an oblique angle, will make it look horrible. Don’t worry. The primary is not the welter of pits and dust it appears to be. Even the most reflective mirror coatings cannot reflect 100% of the light that strikes them, and any light that is not reflected, especially light striking the mirror at an angle, is scattered across the surface of the primary. That causes small particles of dust and other nearly microscopic flaws to stand out in dramatic and frightening relief. What is the solution? As the doctor said: Do not do that. Inspect the mirror in normal room light. If it looks reasonably clean, move on.

The corrector is almost as important as the primary mirror, and its exterior surface should be clean and free of blemishes and streaks of any kind. Do not fret over a few specks of dust. They will not hurt anything, so leave them alone. If there appears to be excessive dirt clinging to the corrector, follow the cleaning procedures in Chapter 9 of this book. Sure, you could call the dealer and complain and even demand a new scope, but the replacement telescope’s corrector would probably look the same. It is hard to assemble and ship an SCT without getting a little dust from somewhere onto the lens.

There may even be some specks of dust visible on the *inside* of the corrector plate. As with the outer surface, a little dust or a few tiny flecks of paint dislodged from the tube interior due to the tender mercies of delivery people will not hurt a thing. Naturally, if the interior surface is excessively dirty or scratched, get on the phone to the folks who sold the scope. If you are not sure what is “excessive,” the best advice I can offer is to call on a fellow CAT-owning astronomy club member for assistance. If there is no local club, try one of the Internet CAT groups, like the SCT user group listed in Appendix 2. There is also more information on optical cleanliness issues in Chapter 9.

What is visible looking down the front of the telescope tube? There is the secondary mirror holder mounted in the center of the corrector, and there is the reflection of the secondary mirror’s surface in the primary. What about the secondary? Its holder should be firmly attached. If this holder moves when gently turned, call the dealer immediately. If this is a C14, be aware that some of these telescopes are equipped with Fastar-compatible secondary mirrors that are removable for use with the Fastar optical system, and all that may be wrong is that the retaining ring that secures the secondary assembly in the holder is loose. Check the manual to see if the scope in question has a Faststar-compatible secondary mirror holder. Like the primary, the secondary’s surface should be reasonably clean and shiny bright. If it is hard to tell what its condition is from looking at its reflection in the primary, move around to the rear of the scope and take a look through the rear port(remove the plastic cap first, of course).

If the primary, secondary, and corrector receive a clean bill of health, move to the CAT’s rear and check the focus mechanism. Before doing that, however, check the manual. There may be “shipping bolts” that need to be released before focusing. Or, the scope may have a mirror lock that needs to be disengaged first. Failure to do either thing before fooling around with the focuser control can cause damage. The manual should have an illustration of the telescope's rear cell that identifies the focus knob and other controls. Exercise the focus knob by turning it several turns in either direction. Movement should be smooth (exactly how easy it is to turn will depend on the brand and model of the scope), and nothing should be obviously bent or out of alignment. If the focus control will not turn in one direction, gently turn the knob several turns in the opposite direction and see if it will then turn the opposite way. (There are, by the way, about 35 to 40 turns of the knob from one end of focus travel to the other.) If so, all is well. If not, get on the horn to the dealer.

If the focuser checks out, take a look up the rear port next. Do that by removing the plastic cap that should be present. Note that the cap that seals the rear port usually just snaps off. It is threaded into place on a few models, but in that case the cap will usually be aluminum rather than plastic. Take another look at the secondary mirror and also observe the interior of the baffle tube that extends from the rear port and up into the tube. It should be free of dirt and grease. Occasionally, a new SCT will have grease from outside the baffle tube (used to lubricate the mirror-tube interface) that has migrated into the interior. If there are globs of grease on the inside of the baffle tube, call the dealer.

Installing NonPermanent Accessories

Put the rear port cap aside for now (do not lose it) because it is time to install the remainder of the telescope's accessories, just as when preparing for an evening of observing. Go over to the pile of "stuff" and locate three items: the visual back, the star diagonal, and the eyepiece. One end of the visual back is equipped with a rotating threaded ring. Place that up against the lip of the rear port and screw it on. Don't cross-thread and do not force anything. It should go on smoothly. Hand tighten only, of course.

It is possible to insert an eyepiece directly into this visual back. It is just the right size for a 1.25-inch diameter ocular and is equipped with one or two setscrews to hold an eyepiece in place. That would not be a very comfortable way to observe. Imagine the neck bending involved in viewing an object near the zenith. Instead, most amateurs use a star diagonal, a simple device that takes incoming light from the scope, bends it at a 90° angle, and sends it to the eyepiece for comfortable observing. Remove (but save) the plastic caps that seal the diagonal's two barrels and insert the "telescope end" of the diagonal into the visual back (the scope end is usually chrome plated and will not have a setscrew). If it does not seem to want to go in, back off on the visual back's setscrews a bit. Avoid loosening these setscrews too much. They have a tendency to drop into grass or thick carpet and disappear forever. Note that the setscrews can be loosened and the diagonal rotated to various angles for even more comfortable viewing.

We will not be viewing anything yet, of course, but go ahead and insert an eyepiece into the diagonal; this will help balance the scope. Remove the eyepiece's lens caps, slide it into the diagonal, and tighten the setscrew. How is the eyepiece's optical condition? Like the scope corrector, both the eye end (eye lens) and scope end (field lens) should be free of dirt and blemishes, although a little dust is okay and is to be expected.

If this is a GEM-mounted scope, there may be one more item in the box, a polar alignment telescope. Some mounts will have this alignment aid already installed, and some mounts (the Celestron CG5) will not come with one at all (an extra-cost option). The polar scope fits into the hollow "bore" of the mount's RA axis and allows the mount to be accurately aligned on the Celestial Pole via the little telescope's special reticle. Install and align the polar scope as instructed in the manual.

Wow! It is really starting to look like a CAT now. The next item on the agenda is checking it out mechanically, electrically, and electronically. Before that can be done, the mount will, of course, have to be connected to a source of electricity. If, as recommended, the scope will be run off an external battery, go get that. Check to make sure the on-off switch is off and plug the DC power cord into both the telescope and the battery. If internal batteries will be used, install them. If an AC/mains adapter will power the telescope, plug it into the mount and, with the scope's power switch off, into a wall socket or extension cord. Locate the hand control next. Remove any protective plastic covering from the display or keyboard, and double-checking with the manual, plug the HC into the proper receptacle on the mount.

Balancing a GEM

If the CAT came with a GEM mount, balance the tube before proceeding further. The manual should have instructions for doing that, but it is pretty simple. To balance in RA, undo the RA lock, holding onto the tube so it does not slam into the tripod if it is way out of balance, and move the scope until the counterweight bar and the scope are horizontal (Plate 35). Note which way the scope tends to sink when it is released, tighten the RA lock again, partially loosen the setscrew on a counterweight, and move it up or down the shaft as appropriate to balance in RA. If there is more than one counterweight, both may have to be moved. When the weights are in position, tighten their setscrews firmly, unlock the right ascension lock again, move scope and weights back to horizontal, let go while keeping a hand close to the telescope, and see if it is now in balance. If not, lock the RA lock and do some more counterweight moving until RA balance is achieved.

To balance the telescope in declination, the OTA will be moved forward or back in the mount's cradle. Exercise extreme caution while doing this. Only loosen the cradle bolts a small amount, just enough to allow the OTA to slide forward and back. Before loosening these bolts, check the telescope's current declination balance. Return the counterweight bar to the horizontal position and lock it down, undo the declination lock, and move the tube in declination until it is level as shown in Plate 35. Then, carefully let go of the tube and see if it moves. Does the front end sink, or does the back end sink? If neither, the scope is in good declination balance. If it does move, tighten the declination lock again, undo the RA lock, and position the

Plate 35. (Balancing a GEM) Good balance is important for accurate GEM go-to and tracking, but is easy to achieve. Credit: Author.

telescope with the counterweights down. If the scope was front-end heavy, loosen the cradle bolts and move the tube back a little. If the back end was heavy, move it forward. Tighten the bolts securely, bring the RA axis back to horizontal, tighten the RA lock, undo the declination lock, and allow the scope to move freely. If it moves, repeat the process until the scope is balanced in declination.

Initial Mounting Checks (Go-to Mount)

The first step in checking out a go-to telescope's mount is to go back and at least review the manual one last time. Is it time to head outdoors? Nope. Most go-to scopes are pretty user friendly these days, but it is a lot easier to learn to operate them inside under normal lighting than it is out in a dark backyard. Indoors, it is easy to see the telescope is pointing to the ground instead of the sky or is about to crash into a tripod leg. Let's do a "fake" go-to alignment indoors before facing down the real heavens.

To perform a fake alignment, follow the CAT manual's directions exactly. Actually, Meade's and Celestron's HCs will scroll instructions across their displays that are adequate to get the scopes aligned and tracking. Keep the printed instructions close at hand the first few times, however, in case the HC's necessarily abbreviated instructions are confusing. Before beginning, ensure the HC is plugged into the appropriate socket and the scope is connected to its power source.

If the telescope tube needs to be placed in some kind of home position before beginning alignment (check the dad-gummed manual again), do that now. Home position for GEM-mounted telescopes usually has the tube pointing north in declination (parallel to the RA axis at 90° declination) and the counterweight bar "down." Home position for forks often has the tube level and pointed north. How exactly is the tube placed in home position? It can be moved either by using the direction keys on the hand control or by unlocking the mount's locks and moving it manually. If the scope is moved by hand, do not forget to relock the mount's locks. Use a compass to point the tube or mount north as required.

Okay, here we go: Flip the power switch to "on." If all is well, the HC display should light up, and its initial message (usually the computer brand, NexStar, Autostar, etc.) will be displayed. If there is a power-on light, that should illuminate. If this does not happen, check the power connection, cord, and power source. When the scope is successfully powered up, initial tests can begin. As a first check, try pushing the HC's direction buttons (be sure the mount's RA and declination locks are engaged). Normally, a go-to scope, even one that has not been aligned, will respond to direction buttons, but what if nothing happens when a direction key is pressed? Double-check that there is power going to the mount power by observing the telescope's light-emitting diode (LED) or HC display. If that is okay, the problem is likely that the scope is slewing at too slow a speed for its movement to be obvious. Reference the manual for instructions on increasing slew speed, increase the speed, and try again. There are some go-to mounts, mostly GEMs, that will not slew until the alignment process is started.

Follow the manual's instructions to begin a go-to alignment. Even if the CAT is equipped with GPS, it will probably be necessary to enter time, date, and position manually during a fake alignment since most GPS receivers cannot get a fix indoors. If the scope *is* allowed to try to get a GPS fix, it will sit there listening for satellites for a long time before it gives up. To prevent that, reference the manual; a push of an "Undo," "Escape," or "Mode" key will usually stop the GPS fix sequence and allow manual data entry.

The first piece of data the HC will request is time. Where do you get accurate time? easy: look at your watch. Even when doing a real alignment out under the stars, entering time within an accuracy of a minute or two is more than good enough. The scope will also need to know the local time zone, and that will probably be what it asks for next. Follow the HC or manual's instructions to scroll to and select the correct time zone. The next entry will almost always be daylight savings time(DST) status. Is DST off or on? If this is set incorrectly, the scope will stop 15° away from its alignment stars. Confused? Just remember: "Spring forward (on), fall back (off)."

The telescope will also need to know the date if it is to generate an accurate computer model of the sky, choose good alignment stars, and move close to those stars. Meade and Celestron generally expect date entries to be in the U.S. format, which is month/day/year. Some scopes do allow this to be changed to day/month/year if desired. Do not worry about complicated things like Universal Coordinated Time (UTC) dates or Julian days; just enter the current calendar date.

If the telescope is to stop near alignment stars, it also has to know where it is located on Earth's surface. Since GPS is not available indoors, tell the CAT where it is by entering the location's latitude and longitude. Perfect precision is not required. Simply enter the position of the nearest city. Not sure what that is? A list of latitudes/longitudes for major world cities is usually found in the back of the telescope's manual. If not, entering "find latitude and longitude of city" into the Google search engine will list numerous sites that will give latitude and longitude for towns and cities. Take care to enter north or south correctly for latitude and east or west correctly for longitude.

Most telescopes will ask for the alignment type next (one star, two stars, etc.). What do you choose when it does ask for "type"? This should be whichever method allows the telescope to pick its own alignment stars and move to them automatically. Do not choose "SkyAlign," as that requires the user to slew the tube to stars, and there will not be any visible stars indoors. Check the instruction book, choose the appropriate align method, and hit Enter (or whichever key or keys is called for). The HC will then usually display the name of the first alignment star it has chosen and begin slewing to it. Watch carefully and be prepared to stop the scope if it looks like it is going to do something crazy. A press of a direction key on a NexStar controller or any key *except* "Go-to" or a direction key on the Autostar will stop an errant slew, but be prepared to hit the power switch just in case. If nothing is wrong, the scope will move to point at the spot where it thinks the first alignment star should be.

To determine whether the scope has stopped in approximately the correct position indoors, use a star chart that shows where stars are for a particular date and time. A planisphere, a simple circular star chart that is often called a "star wheel," is perfect for this purpose. The round map portion of a planispherecan be rotated to set it for any date or time, day or night. If a planisphere is not available, virtual ones can be accessed online. A particularly good one can found at http://www.heavens-above.com. Once current date and time are set in the planisphere (just use the same date and time entered into the HC; do not worry about DST), it will show the positions of bright stars for that particular date and time. Even simple planispheres will show all the stars scope HCs will choose for alignment since these stars are always bright and prominent.

With the telescope stopped at its first go-to alignment star, take a look at the planisphere to see in which direction this star lies. If the scope chose Vega as the first alignment star and the planisphere shows Vega to be lying in the northeast, is the scope pointing roughly northeast? If it is, continue. If not? Make sure the planisphere is set up for the correct day and time (a.m. or p.m.). If the chart seems okay, check the HC to make sure date and time were entered correctly. Assuming the scope is pointed in roughly the correct direction, keep going. The HC will now ask for the star to be centered in the eyepiece or finder. Obviously, that is impossible inside. Do not worry about it. Just mash whichever buttons the manual's or HC's display specifies in order to proceed to the next alignment star.

When the telescope arrives at the place where it thinks the second star should be, check the planisphere again to make sure the CAT is pointing in the proper direction. Then, press the appropriate buttons to accept that star. The HC will then "think" for a moment and, if everything has gone as it should, will display an "Alignment Successful" message. A GEM may require more than two stars to complete an alignment; if so, allow it to pick and slew to these stars and accept them.

What if the hand control display says "Alignment Failed"? If the telescope appeared to point in roughly the correct directions for the stars it chose, don't worry about it. Indoors, the scope's exact pointing could not be fine-tuned, and that may have caused the alignment to fail. If, however, the telescope pointed in clearly the wrong direction or did something nutty, like pointing at the ground, something is obviously wrong. Reread the alignment section of the manual, power the scope off, and reenter the data in the HC, triple checking that the time, time zone, date, and latitude and longitude and their "signs" (E/W and N/S) are correct. If that does not help, the prime suspect (other than a defective scope) is power. Triple check the power cord, battery, and connections.

If the fake alignment was successful, try a fake go-to. With the aid of the manual, choose an object in the HC. It really does not matter much which object, just one that is above the horizon. A bright star is a good choice. How objects are selected for go-to depends on the scope model. Celestron NexStar controllers have a list of named stars in the menus available by pressing the HC's "List" button. Meades have a selection of prominent stars in the Objects menu, which is accessed using the Enter and Mode keys on the Autostar. Select a star that is shown on the planisphere and hit "Go-to" or "Enter" as appropriate to send the scope to it. If the telescope stops pointed in the proper direction, all is well. Power down the scope. If it does not, recheck the planisphere and try again.

Checkout for Non-Go-to Telescopes

There are only a few new CAT models available without computers, mostly GEM-mounted scopes like the Celestron Omni XLT, but these also will need to be checked. The usual first step in getting a manual GEM going is installing the RA and declination tracking motors. Since GEM mounts are often sold in both go-to and non-go-to configurations, the manufacturer often packages non-go-to motors separately and leaves it to the user to attach them (go-to motors are most often preinstalled since they are part of a more complex electronic assembly). Follow the manual's instructions for bolting the RA and declination motors in place. Take particular care to make sure the gears that mesh with the telescope's drive gears are properly aligned. Also, be careful that the HC's declination cable goes to the declination motor and the RA cable goes to the RA motor.

The next action for the non-go-to owner is to ensure the mount moves smoothly on both axes. Before beginning, balance the tube in RA and declination following the instructions in the manual and in the go-to GEM checkout section of this chapter. After the scope is balanced, unlock the RA and declination locks and move the telescope on both axes. Movement should be smooth, without any binding.

Most non-go-to motorized GEMs are equipped with slow-motion controls. Before these can be used, a pair of clutches must be disengaged, usually by loosening knobs mounted on the same shafts as the RA and declination slow-motion knobs. Refer to the manual for instructions. When this is sorted out, exercise the declination and RA slow-motion controls. Movement should be smooth and fine. If the scope does not move when a slow-motion control is turned, check to make sure that the RA and declination locks are locked. Next, turn on the power switch on the HC.

Non-go-to GEMs typically feature sidereal speed tracking and one or two higher slewing speeds. When the power is turned on, the mount will be tracking, but it will be moving very slowly (RA drives are often called "clock drives" since their gears turn one revolution every 23 hours 56 minutes and 4 seconds), and the only indication the motor is running will be a faint noise (maybe) and a power-on light. Note that the declination motor will not turn unless the north or south button on the hand control is pressed. GEM tracking only requires the operation of the RA motor.

To check the drive's slewing, make sure that the RA and declination locks are locked, set the HC to the highest slewing speed, and press a direction button. Check all directions—north, south, east, and west (which may or may not be labeled as such on the HC). Motion should be even, and the scope should stop as soon as a direction button is released. Most small-to-medium-size GEMs do display some backlash. When reversing directions using the HC, the scope may pause. Although backlash is not exactly desirable, some is normal in most low- to medium-priced German mounts (and forks). For one additional check, most GEMs are designed for use in either the Northern or Southern Hemisphere, and there is usually a switch on the HC to set the proper direction for RA motor rotation. Make sure this is set to N or S, as appropriate.

Telescope Disassembly

That is all there is to indoor checkout. You will be hauling your beautiful new CAT out under the stars for first light as soon as night comes—if the "new scope curse" does not intervene, that is. Amateur astronomers have long observed that receiving a new telescope seems to cause clouds to instantly cover the sky. Sounds like superstition, but that is usually what happens.

Unless the CAT in question is a small one, disassemble it so it can be safely and easily moved into the backyard. Begin by shutting off the power. Disconnect the power cord from the battery or wall socket and then from the telescope. Unplug the HC and put it in a safe place. Remove the eyepiece, star diagonal, and visual back; cap the rear port and stow the ocular and diagonal with the HC (the eyepiece and star diagonal *could* be left in place, but it is all too easy to bang them into something on the way outside). Protect the corrector plate by replacing its cover if that is still off. Fork-mount telescopes should be positioned so the tube is pointing at the base for transport. When the tube is situated appropriately, undo the bolts on a Celestron and the spreader knob and threaded rod on a Meade (holding onto the scope with one hand if possible) and gently lift the OTA and fork off the tripod. Set the scope on its base somewhere where it will not be knocked over or return it to its case or shipping box. Leave the tripod assembled but loosen the spreader enough so the legs can be collapsed to get it through doors easily.

Let us digress for a moment and talk about the vital accessories CAT users need. You didn't think your astromnomy buying was over with just the purchase of a telescope, did you? It is not, not hardly. There is quite a bit more astrostuff that will need to be acquired before a novice astronomer can do productive observing—or, indeed, much observing at all.

CHAPTER SIX

Accessorizing a CAT

Before much real "work" can be done with a new Schmidt Cassegrain telescope, more accessories will be needed than just the paltry few that came in the box with the telescope. This has become especially true over the last decade. The world's two SCT makers, Meade and Celestron, locked in a perpetual battle for the same few customers, have had to cut fat to keep telescope prices low and competitive as production costs have risen. They have done that by eliminating accessories much beyond a finder, a star diagonal, and a single eyepiece of sometimes indifferent quality. At a minimum, a new catadioptric telescope (CAT) owner is going to require at least a couple of good eyepieces, a dew shield, and a case in which to store and transport the telescope.

Must-Have Accessories

Cases

The good old days of amateur astronomy weren't always so good. They *were* good for SCT buyers in one way, however. Both Meade and Celestron shipped new telescopes with sturdy cases. These cases might be simple wooden footlockers or they might be custom-made plastic cases with die-cut foam, but there was something to keep the CAT organized and safe. By the mid-1990s, the dollar had shrunk so much that the companies began to discontinue cases for all but their most expensive models, and soon those were gone as well.

Why are cases a big deal? Not having a case for an SCT compromises its portability, which is one of the reasons for buying a CAT in the first place. You have a beautiful new scope. Do you really want it rattling around in the back of a pickup

R. Mollise, *Choosing and Using a New CAT*,
DOI: 10.1007/978-0-387-09772-5_6,

truck wrapped in a bedspread or even bouncing around on the back seat of a Lexus? It is possible to make do with the telescope's cardboard shipping container for a while, but that will eventually disintegrate. What is needed is a permanent solution, both for transporting the telescope and for storing it. A case does more than make a scope easy to haul around; an SCT that is kept in a case will be much less prone to dust intrusion in its optical tube assembly (OTA).

There are several ways to solve the case dilemma: buy, adapt, or make. Buying is the easiest and often most practical solution. In the United States, long-time astronomy accessories dealer Jim's Mobile Industries (JMI) offers heavy-duty cases that will fit any current and many older Schmidt Cassegrains. These cases are not cheap—one for a basic fork-mount C8 costs a little over $300—but they are worth their asking prices. They are made from heavy-duty plastic, are filled with die-cut foam designed for each particular scope model, and often do not just make transporting a telescope easier, they make it *possible*. I own a JMI NexStar 11 case, which, like many of the company's cases for larger-aperture telescopes, is equipped with a set of wheels. I can guarantee that without my wheeled JMI I would use my NS11 a lot less. The combination of sturdy case and wheels makes it no more difficult to transport this "big" CAT than it is to haul around my C8.

Are JMI's cases too pricey? Soft Cordura fabric cases designed to fit around the foam a telescope was shipped in are available from Meade for some of their models (although they seem to be phasing them out). The price is about $160 for an 8- or 10-inch model. Similar soft cases are being sold by several other manufacturers for both Meade and Celestron fork-mount models. Some folks turn up their noses at soft cases, thinking they do not provide enough protection. However, when it comes to scope protection, it is what is *inside* that counts; the foam the telescope rests in and soft-side cases do protect the CAT as well as hard cases. Soft cases are also considerably lighter.

If spending $160 or more for a case right after plunking down a couple of grand for a telescope does not seem palatable, get on down to Walmart (or another discount store). It is especially easy to buy a "telescope case" there for a German equatorial mount (GEM), one that costs just a few dollars. A large Rubbermaid container that is large enough to hold both the OTA and the GEM head costs less than $10. Buy a few pieces of foam in a craft store, place one on the bottom of the Rubbermaid box, put the OTA on that, put the other piece of foam on top of the OTA, and lay a CG5 GEM head on that. The resulting case is not attractive or professional looking, but it is simple, cheap, and effective and can keep your scope and mount safe at home and on countless road trips for years.

Admittedly, it is not quite so easy to find a make-do case for a fork-mount CAT, particularly a larger-aperture one. It is possible, though. A good choice for an 8-inch, even in this day, is still the humble footlocker. Meade and Celestron did not make their footlocker-style SCT cases back in the day—they bought them and modified them—and so can you. At back-to-college time, it is even possible to find footlockers with nice shiny finishes in colors that approximate Celestron orange and Meade blue.

If the fork-mount CAT is much larger than a Celestron NexStar SE, though, a footlocker probably will not be big enough. Another item that has been used for fork-mount scope cases is large plastic toolboxes. Stanley's Job Box series models have wheels and handles and seem as if they were designed to be CAT cases. Even large ice chests (coolers) can be pressed into service as SCT containers.

One thing these solutions have in common is that they work best if it is possible to adapt the original scope packing foam to them, perhaps padding any voids with cheap foam. Dense foam for a heavy fork-mount scope is not easy to come by or cut. In the past, amateurs have tried soaking foam with water, freezing it, and then cutting with a sharp knife. Most often the end result was just a mass of soggy foam rubber.

Another option is building your own case. A skilled woodworker can probably cobble together a CAT case in an afternoon. In some ways, that is an easier solution than trying to adapt toolboxes and ice chests since the case can be built in the exact dimensions needed to hold the packing foam snugly. Other than the need for skill to do a nice job, there is only one drawback to going this route: weight. Homemade plywood scope cases often turn out to be so heavy that they do not get used much, even if they are equipped with wheels.

Eyepieces

Want to get an earful? Ask any practicing amateur astronomer his or her opinion about eyepieces (oculars). If there is one thing that provides a topic for endless discussion and even argument in the amateur ranks, it is oculars. There is a wealth of information about eyepieces available online and in books—almost too much. Endless reviews and comparisons (“shootouts”) are available on telescope review sites such as Astromart.com and Cloudynights.com. Unfortunately, these reams of data tend to confuse the situation more than clarify it for the novice. Fortunately, just as with SCTs, oculars sort themselves into several groups, which makes it easier to pick eyepieces to fit a particular budget and observe style without getting too deep into esoteric performance specs.

Choosing an eyepiece wisely has more to do with what will be done with it than how much it costs. For that reason, this roundup of oculars is divided into categories based on an optical characteristic, the eyepieces’ apparent fields of view (AFOVs), rather than price: *narrow field*, *medium-wide field*, and *ultrawide field*. Before doing any serious eyepiece shopping, though, it is mandatory to learn a little eyepiece language. Knowledge of the specifications and terminology used in the ads and by fellow amateurs makes picking oculars simpler.

Eyepiece Terminology and Technology

The most basic commercial eyepieces available today consist of two lens elements. No matter how many lenses make up an ocular, the one looked into is the *eye lens*, and the one at the other end of the eyepiece barrel, the telescope end, is the *field lens*. Eyepieces are produced in several barrel sizes. The 0.965-inch models are referred to as *Japanese standard* format. They are not often seen today, although some top Japanese scope makers such as Takahashi still make 0.965s. Much more common are the 1.25-inch diameter *American standard* eyepieces. No matter where a scope is made, its focuser will usually be able to accept 1.25-inch eyepieces. The 2-inch diameter eyepieces used to be rare and only used by “advanced” amateurs. Today, they are more common, and even some discount store scopes have focusers that will accept 2-inch oculars.

A feature of almost all eyepieces is an *eyecup*, a rubber shield around the eye lens that prevents stray light from striking it and helps with eye placement. Another common feature is filter threads on the field lens end of the barrel (28.4-mm diameter, 0.6-mm tpi [threads per inch] thread pitch on 1.25-inch eyepieces). To suppress undesirable reflections from stray light entering the telescope end of the barrel, the inside surface there is usually painted a flat black. The lenses of eyepieces are coated to reduce reflections and increase light transmission. Coatings can be as simple as a single layer of magnesium fluoride or as complex as multiple coatings of rare-earth elements. Modern eyepieces can be either multicoated (both air-glass surfaces are coated) or fully multicoated (all lens element surfaces are coated).

Focal Length An eyepiece’s *focal length* is the distance from the eye lens to the point where the rays of light converge on the focal plane of the scope. Eyepiece focal length is usually expressed in millimeters these days, and oculars are commonly found in focal lengths from about 4 to 40-mm. What is most important about eyepiece focal length for you is to be aware that it determines the magnification of an eyepiece.

Magnification Every beginner knows about magnification; it is a telescope’s *power* and determines how big the Moon, a planet, or other object will look. Magnifications below 50× (usually pronounced “50 power”) are considered low magnifications. Powers between 50× and about 150× are thought of as medium magnification. Above ×150 is the realm of high power.

How is a telescope’s magnification changed? This is done by swapping out eyepieces. A long focal length eyepiece like a 40 mm produces low magnification. A short focal length eyepiece like a 4 mm produces high magnification. A simple but vital telescope magnification formula was given in Chapter 2, but it is so important for astronomers, it is repeated here:

$$(\mathrm{Power})^{\mathrm{Magnification}} = \frac{(\mathrm{mm})^{\mathrm{Telescopefocallength}}}{(\mathrm{mm})^{\mathrm{Eyepiecefocallength}}}$$

A 12-mm focal length eyepiece in an 8-inch SCT—which usually has a focal length of about 2,000 mm—gives a magnification of 167× (2,000/12).

Eye Relief Eye relief, another important eyepiece specification, especially for those who wear glasses, is the distance the observer’s eye can be from the ocular’s eye lens while observing. Normally, the eye is not jammed up against the eye lens of an ocular; it is held a comfortable distance away, just far enough so that the whole eyepiece field can still be seen. The distance the eye can be from the lens and still take in the full field is the eyepiece’s *eye relief*. The amount of eye relief available in an ocular depends on its design, and it is sometimes the case that expensive eyepieces have less eye relief than cheaper ones. Generally, the shorter an eyepiece’s focal length, the smaller its eye relief.

How much eye relief is good? For an eyeglass wearer, anything less than 15-mm means not being able to see the whole field. Because of the presence of glasses, the eye will be positioned beyond the eye relief "limit," and the full field will not be visible; only the central area will be seen. The need for at least 15-mm of eye relief unfortunately eliminates many wonderful eyepieces from these folks' consideration. Luckily, many eyeglass wearers can observe without their glasses. Only in cases of severe astigmatism is glasses wearing mandatory for astronomers.

If there is such a thing as too little eye relief, can there also be too much? Yes, indeed, there can. Get much past 20-mm, and it becomes difficult to position the eye correctly for viewing. If the eye is not in the correct place, an eyepiece can suffer from *blackout*—portions of the field will suddenly go dark.

How is the eye relief distance of a particular eyepiece determined? To do this, either take the manufacturer's word for it—if it is listed in the eyepiece's specifications—or find out. Technically speaking, eye relief is the distance from the eye lens to the eyepiece's "exit pupil." To measure this distance, point the scope at a bright object (not the Sun)—maybe a bright terrestrial scene. Hold an index card or a piece of white paper behind the eyepiece so that an illuminated circle is visible on the card. Move the card toward the eyepiece or away from it until this bright circle of light is as sharply focused as possible. The point where it is sharpest is the exit pupil, and the distance from card to the eye lens represents the eyepiece's eye relief. Measure this distance with a ruler's millimeter scale (do not touch the lens with the end of the ruler; hold it beside the eyepiece).

Apparent Field of View

Apparent field is something amateurs go on and on about when they talk eyepieces. AFOV is a simple concept, but beginners often find it a difficult one to grasp. *Apparent field* is the diameter of the circular field of an eyepiece expressed in degrees. An eyepiece that has an AFOV of 50° will *not* show a swath of sky 50° across. A 50° 25-mm eyepiece shows something less than 1° of sky. Is this clear as mud? The situation with apparent field is analogous to the size of a television screen. Comparing an eyepiece with a small AFOV and one with a large AFOV is like comparing a 12-inch screen portable television set showing an image of the Grand Canyon to a 70-inch flat-screen monster showing the same scene. The big TV displays a much more expansive version of the same stretch of landscape. Using a large AFOV eyepiece is like viewing the universe through a spaceship porthole rather than a little peephole. Modern eyepieces usually have AFOVs from around 50° (Plössls) to 80° (ultrawide-field eyepieces). Apparent field also determines the *true* field shown by the ocular.

True Field of View

True field is easy to understand. It *is* the expanse of sky visible through an eyepiece, expressed in angular degrees. If, for example, an eyepiece just fits the entire disk of the Moon into its field of view, it has a true field of 0.5° or 30 minutes of arc. Why? Because the Moon itself is half a degree, 30 arc minutes, across in the sky. If only half the Moon fits into the eyepiece, then its true field is 0.25°, or 15 minutes of arc. The true field of an ocular will vary, depending on the focal length of the telescope in which it is used. Long focal length telescopes produce higher powers and smaller true fields with a given eyepiece than short focal length telescopes.

There are several ways to calculate an eyepiece's true field of view. The easiest method uses the AFOV figure from the eyepiece manufacturer's specifications:

$$\text{TFOV (degrees)} = \frac{\text{Apparent field (degrees)}}{\text{Magnification}}$$

A 35-mm eyepiece with a 68° apparent field in an 8-inch f/10 SCT yields a true field of 1.19°, over two full Moons wide: 68(AFOV)/57 (magnification).

Eyepiece Aberrations When amateur astronomers sit down to talk eyepieces, there is also a lot said about optical aberrations—optical problems. All eyepieces suffer from one or more optical defects. There are no perfect telescopes, and there also are no perfect eyepieces. Some common aberrations are discussed next.

Astigmatism Just as an observer's eyes can be astigmatic, so can eyepieces. Severe astigmatism manifests as oddly shaped stars. Rather than small points of light, they appear as ovals, crosses, or "seagulls." There is one sure way to diagnose astigmatism: observe a slightly defocused medium-bright star. If its diffraction rings are not round but elongated on one side of focus and the direction of this elongation changes 90° on the other side of focus, there is astigmatism somewhere—in the eyepiece, the telescope, or the astronomer's eyes. See Chapter 7 for some pointers on diagnosing the source of astigmatism. Don't worry too much if it seems an ocular is astigmatic. Many, if not most, eyepieces suffer from some astigmatism, and it will not do much more than make stars at the edge of the field look a little less pretty than they would otherwise.

Blackout and Kidney Beaning Blackout, already mentioned, is another common eyepiece problem. It usually happens with long eye relief eyepieces when the observer's eye is not in the proper position for viewing. Get too close or move the eye too far off axis, and the field will go dark. Sometimes, only *part* of the field will black out in small bean-shaped areas. The cause of this *kidney beaning* is usually the same as that of blackout: improper eye placement. It can also be a symptom of spherical aberration in the eyepiece. Both of these problems become more pronounced when the eye's pupil is small, as when viewing bright terrestrial scenes.

Field Curvature When stars at the center of an eyepiece's field are in focus and stars at the edge are out of focus and vice-versa, an eyepiece is showing field curvature. This is a familiar effect for the SCT owner because the focal plane of a Schmidt Cassegrain, its "field," is not flat but strongly curved. This defect may not be entirely the telescope's fault. Many eyepieces at least contribute to field curvature. More expensive and complex oculars such as the Naglers and Panoptics tend to be better corrected for this aberration than cheap, simple ones.

Lateral Color Have you ever observed a bright planet like Jupiter and noticed one of its limbs (disk edges) was blue and the other red? That is lateral color. Do not be too quick to accuse the eyepiece of this sin, however. Lateral color can also be caused by observing a planet that is too low in the sky. Wait until Jupiter is at least 30° to 40° above the horizon before laying blame for lateral color.

Pincushion and Barrel Distortion Pincushion and barrel distortion are two different but similar aberrations. They are easiest to see in terrestrial objects that include "lines," such as a rooftop's shingles or, even better, a fence's boards. If the lines of the boards appear curved rather than straight, diverging at the center and converging at top and bottom, that is *pincushion distortion*. If they do the opposite, come together at the center of the field and curve apart at top and bottom, the problem is *barrel distortion*. These aberrations are common in wide-field eyepieces and are usually not very obvious unless the scope is panned across a rich star field.

Eyepiece Image Orientation A telescope orients its images differently in the eyepiece, depending on its particular configuration of lenses and mirrors. One scope may place north at the top of the field and east on the right. Another may put south at the top and east at the left. It is sometimes important to know which direction is which in the eyepiece when searching for objects. The SCT, when used with a star diagonal, presents an image oriented just like a terrestrial map. North is up, and east is on the right, 90° from north. If this seems hard to remember, just keep in mind something my students have christened "Rod's rule": A telescope with an *even* number of mirrors or no mirrors (a Newtonian reflector or a refractor) yields an image that is *inverted* (upside down) but mirror correct. A telescope with an *odd* number of mirrors (an SCT or Maksutov Cassegrain telescope [MCT] or refractor with a star diagonal) gives an image that is right-side up, but *reversed* right to left.

Eyepiece Buyer's Guide Enough of the dad-gummed technical mumbo-jumbo. How many and what kind of eyepieces does an SCT owner need? A set of three is a good number to begin: a low-power eyepiece for big objects, maybe a 32 mm (62× in an 8-inch SCT); a medium-power ocular, like the 25 mm that probably came with the scope (80×), for most observing tasks; and a high-power 10 mm (200×) for small deep sky objects and for the Moon and planets. It might be nice to supplement this basic set with a really high-power ocular in the 6-mm (333×) range for use on the planets on nights of good seeing.

What about eyepiece design? And, how much are these things going to cost? Fortunately, we are living in a time when cheap, good eyepieces are the rule, mostly thanks to Chinese imports. Stop and think before filling an eyepiece case with cheap oculars. It is impossible to go wrong by buying good eyepieces. As has often been said, an eyepiece makes up half the scope's optical system. You agonized over choosing a good CAT, so why limit its performance with less-than-excellent eyepieces? If buying top-quality eyepieces means getting along with two instead of three oculars for a while, that is still the way to go. Without further ado, let us choose a few nice eyepieces.

Narrow AFOV Oculars: Plössls and Orthoscopics "Narrow" AFOV eyepieces are those with apparent fields of 50° or smaller. This group, over the years, has had quite a few members: Kellners, Erfles, Orthoscopics, and Plössls. Thanks to the wide availability of Chinese eyepieces and the decision by most of their makers to concentrate on the Plössl design, however, the Kellner and the Erfle have all but disappeared. The Orthoscopic has not been embraced by the Far Eastern optical manufacturers, but it is still widely available—if not in the huge numbers of the Plössl—due to its enduring popularity with amateurs.

Who forms the audience for this class of eyepieces? Folks who do not care about large AFOVs. An amateur who mainly looks at the planets, for example, does not need the "spacewalk" field offered by ultrawide AFOV oculars. Simpler eyepieces can also often produce brighter, sharper planetary images than can complicated wide-field designs. Price used to be an attraction of the narrow apparent field eyepieces, but that is less true now. Medium AFOV and even ultrawide eyepieces are now available for not much more money than the narrow types.

Plössls There is no doubt that the Plössl (Plate 36) is the "standard" amateur eyepiece of today because of the way it has been aggressively marketed. Is it the *best* eyepiece? Probably not because its design is far from perfect. Its strengths are its low price and its "reasonable" performance characteristics. The Plössl, which is sometimes referred to as the symmetrical, is a classic eyepiece design that dates to the nineteenth century; it was invented by an Austrian optician, G. S. Plössl, in 1860. Its optical design, seen in Figure 2, incorporates four convex lens elements placed back to back in two groups. Designers have played around with the Plössl formula a

Plate 36. (Narrow/Medium Field Eyepieces) A collection of narrow to medium field eyepieces, (l- r) Pro-optic 40mm Plössl, Orion Expanse 20mm, Orion Expanse 9mm, Celestron 9mm Orthoscopic. Credit: Author.

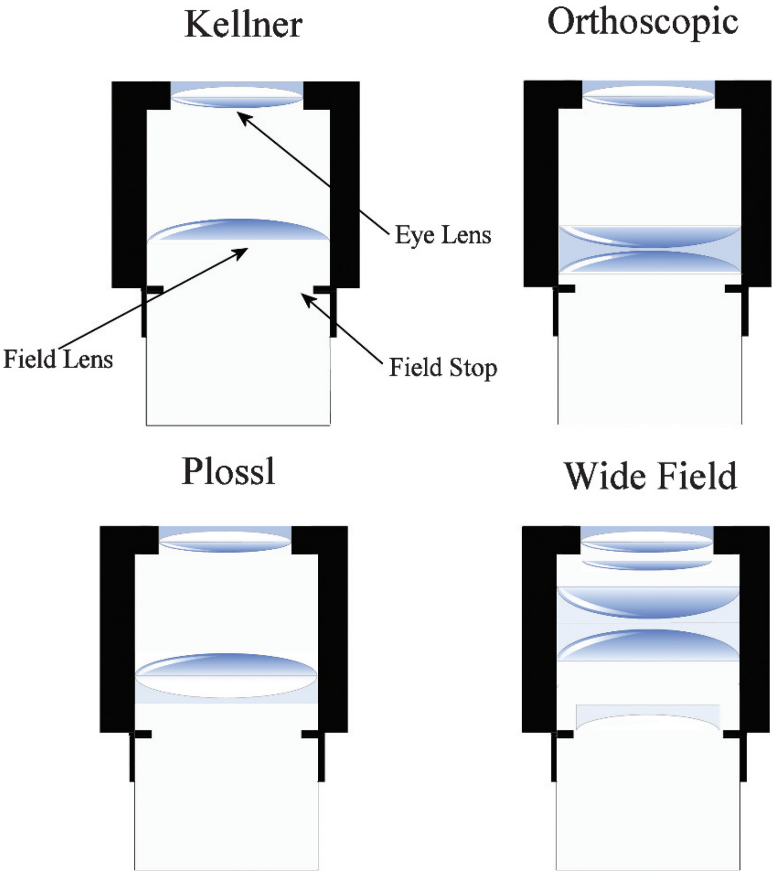

Figure 2. (Eyepiece Designs) Amateur astronomy's most popular eyepiece designs. Credit: Author.

lot over the last decade or two, and it is not uncommon to see Plössls with different numbers and types of lens elements being advertised as "modified Plössls."

What is the Plössl like in a telescope? It is made in a wide range of focal lengths and is a genuinely good performer in most of these focal lengths. Plössls are commonly available from 55 mm down to at least 6 mm. If properly manufactured, this eyepiece's color correction is good, as is its edge-of-field performance across the entire range of focal lengths (at least in SCTs, whose high focal ratios help eyepieces perform better). How about AFOV? Coming from someone who was raised on the 30° apparent field Ramsden eyepieces of the 1960s (do not ask), it almost seems a sin to call Plössls narrow-field eyepieces. The main drawback to Plössls is that in shorter focal lengths eye relief tends to be small. A 12 mm will likely have about 10 mm. As for a 6 mm, do not expect more than 3 to 4 mm of eye relief.

Then, there is the question of which Plössl to choose. If you are on a budget, go for the low-price leader. You will not be disappointed. Even $30 imported Plössls do a respectable job in SCTs. If possible, however, spend just a little more. Eyepiece industry leader TeleVue's Plössls, for example, are noticeably sharper than the cheapos. They are also much better built mechanically, incorporating good eyecups and rubber barrel grip rings. Despite these pluses, the TeleVues are only about $50 more than the lowest-priced imported eyepieces.

Orthoscopics Back in the 1960s when Uncle Rod was a young'un, the *ne plus ultra* of eyepieces was the Orthoscopic, sometimes referred to as Abbe Orthoscopic in honor of its designer, optical guru Ernst Abbé. These were the top-dog oculars we all wanted but could not afford. How things have changed. Although the Ortho is still a good performer, it is hardly considered tops these days—but it is no longer exorbitantly priced, either. The Orthoscopic (Plate 36) is, like the Plössl, a four-element design. Also like the Plössl, it was developed in the nineteenth century. The design of the Orthoscopic, *unlike* that of the Plössl, is pretty standard and consists of a single-element eye lens, a convex lens with the flat side facing out. At the other end of the barrel is a three-element field lens consisting of two convex lenses with their curved sides facing each other and separated by a double-concave negative element (Figure 2).

Orthoscopic apparent fields are nothing to write home about, usually being in the 40° to 45° range, but this weakness is easily offset by the design's strengths. The Orthoscopic is *sharp* all across its field and especially at the field edge, where many less-expensive oculars have trouble. Plössl edge sharpness is good, but Orthos are better, especially at shorter focal lengths. Orthoscopic color correction is excellent, and eye relief is fair—sometimes a little better than that of Plössls of the same focal length. When it comes to focal length choices, Orthos do not cover the whole range, like Plössls do, instead tending to concentrate on the shorter end. Usually, "long" for an Orthoscopic eyepiece is 25-mm. On the other hand, Orthos can be had in very short focal lengths: 4-, 3-, and even 2-mm.

Which *specific* Orthoscopic should you choose? You will not have to fight the allure of cheap imported Orthoscopics as there really are not any. On the other end of the price range, premium manufacturers such as Zeiss offer or have offered Orthoscopics that are crazy expensive and highly sought after by discriminating planetary observers. When talking "Orthoscopic," though, one maker's name gets mentioned more than any other, University Optics (Appendix 1). This U.S. firm's Abbé Orthoscopics are of outstanding optical quality and are very reasonably priced at $59.95 for all focal lengths from 25- to 4-mm.

Medium AFOV Designs *Medium* AFOV eyepieces are those oculars that provide apparent fields of about 65° to 70°. Although this is considerably smaller than the spaceship porthole fields of the ultrawides, it is still a big increase over Plössls. For amateurs on a budget, medium AFOVs are more optically forgiving than inexpensive 80° or higher ultrawides. It is pretty easy for a bargain 68° AFOV eyepiece to present good-looking stars at the edge of the field; it is much more difficult for a cheap 82° eyepiece to do the same thing.

Despite their considerably more expansive fields, these eyepieces are not always better than the narrow AFOV eyepieces. Most medium-wide designs use from 6 to 8 lens elements (Figure 2). Despite modern lens coatings, their images are usually slightly dimmer than those of narrow AFOV eyepieces. Most medium users think this sacrifice is acceptable to gain that extra apparent field, however.

Who likes the mediums? Many SCT owners do. Since our telescopes are driven, the big apparent fields of the ultrawide eyepieces are not as necessary for us as they are for Dobsonian owners, who must nudge their scopes along. Eyeglass owners may prefer the medium oculars as well since many offer excellent eye relief, better than what is usually found in the ultrawides. All observers may prefer the medium AFOV experience because it is easier to take in the whole field without moving the eye around than it is with the huge fields of the ultras.

It has only been in the last 5 years that 65° to 70° eyepieces have become available at popular prices. As with other bargain equipment on the amateur scene, the source of these eyepieces is Taiwan or mainland China, and the factories there are now turning out container ships full of 65° to 70° oculars, most of which are good performers.

Synta Ultrawides One of the first series of reasonably priced medium AFOVs to hit the United States was the Synta Ultrawides from Taiwan (Plate 36). These are all 1.25-inch barrel format eyepieces, and despite the name, all yield 66° apparent fields. These fields are satisfyingly sharp out to at least 90% of this field in f/10 SCTs. The prices of these eyepieces are very attractive, that is for sure, with all focal lengths available for about $50 apiece, depending on the seller. Like most Synta products, they are never sold as "Synta" but as various house brands, such as Skywatcher, Orion (as the Expanse series), or Pro Optic.

As nice as the Syntas are, they are not fault free. The shorter focal lengths are prone to light scatter and internal reflections—although this will not be much of a problem when observing the deep sky. Another annoyance is that the focal length range available is limited to four choices: 20-, 15-, 9-, and 6-mm. Don't try the longer focal length pair in fast scopes; edge-of-field stars fall apart badly in the 20-mm especially. One thing these eyepieces do have going for them is decent eye relief: 17-mm for the longer focal lengths and 13-mm for the shorter ones.

Vixen Lanthanum Superwides A step up from the Synta eyepieces is the Vixen Lanthanum Superwide series. The eyepieces in this group have been on the U.S. market for over a decade and, at a price of about $200 each, have been attractive to amateurs looking to save money over more expensive brands such as TeleVue. These are good eyepieces, although they lack the "snap," the excellent contrast, of more costly mediums such as the TeleVue Panoptics. One of the hallmarks of the Lanthanums (which refers to the rare-earth element used in their coatings) has always been good eye relief—20 mm across the board for the whole series, from 3.4 to 42 mm. Depending on focal length, the AFOVs of these eyepieces range from 65° to 72°. All feature good mechanical build quality.

Orion Stratuses With the budget medium-field eyepiece explosion, the Vixens have lost some ground in the astronomy marketplace. They do seem to be making a comeback of sorts lately—in a way. Orion has begun selling a line of eyepieces called the Stratus Wide Fields. The barrels of these eyepieces look very much like those of the Lanthanums, they offer similar eye relief, and their AFOVs are about the same. One thing the Stratus series lacks compared to the Lanthanums is longer focal lengths, with the longest Stratus a 24-mm. Are these eyepieces produced under license from Vixen, or are they "clones"? We do not know, but they *are* good values at $130 each.

TeleVue Panoptics Do you want the best medium-AFOV eyepieces money can buy? Try the TeleVue Panoptic series. These oculars (Plate 37) are available in a wide range of focal lengths, including 19-, 22-, 27-, 35-, and 41-mm. Eye relief ranges from 13 to 19 mm across the series, except for the big 41, which has a whopping 27-mm. All the "Pans" feature the same 68° AFOV. The 19-mm model has a 1.25-inch barrel, the 22-mm has a hybrid 1.25-inch/2-inch barrel (for use in either size focuser), and the 27, 35, and 41 are 2-inch format only eyepieces.

One other characteristic of the Panoptics is optical excellence. In f/10 SCTs, these things are *dead* sharp from field edge to field edge, and they perform nearly as well in faster telescopes. They are also extremely comfortable to use, lacking much of the blackout and field distortion found in less-expensive mediums. The only problem with the Pans may be their prices, which begin at about $200 for the shorter focal lengths, climb to $300 for the medium focal lengths, and top out at over $500 for the 41-mm.

Plate 37. (Medium/Wide Field Eyepieces) The upper crust of the eyepiece world, medium and ultra-wide premium oculars, (l – r) William Optics 28mm Uwan, William Optics 7mm Uwan, TeleVue 22mm Panoptic, TeleVue 12mm Nagler Type II. Credit: Author.

Pentax SMC XWs Pentax is a name that is been familiar to photographers for decades, usually as a manufacturer of high-quality 35-mm single-lens reflex cameras. This Japanese company also produces a few astronomy products, including its highly regarded medium-AFOV oculars, the Pentax SMC XWs. These eyepieces, which come in focal lengths from 3.5- to 40-mm, are of *incredibly* good quality both optically and mechanically. Are they as good as the Panoptics? Their fans will tell you they are better. The optics mounted in Pentax's heavy-duty weatherproof barrels provide generous 70° apparent fields slightly larger than the Pans, and do it without sacrificing eye relief. All focal lengths provide 20-mm. Except for the 30- and 40-mm models, all the XWs are 1.25-inch eyepieces.

There are two caveats concerning the Pentax oculars: Some amateurs have sometimes found it difficult to get needed service from Pentax, and these eyepieces are expensive. In that area, they definitely outdo TeleVue. The 19-mm Panoptic, for example, is $250. The comparable XW, the 20-mm, is $300.

Meade Super Wide Angles Are the Panoptics and Pentaxes, as good as they are, budget busters? If so, consider the Meade alternative. Meade's Series 5000 Super Wide Angles are a couple of cuts above the bargain-bin Syntas and Orions at prices a bit lower than those of the Panoptics. The Meades, available in the somewhat eccentric focal lengths of 13.8-, 18-, 24.8-, 32-, and 40-mm, have good eye relief that ranges from 12-mm on the short end to 31 mm on the long end. They are also sturdily constructed and attractively packaged. Optically, they perform quite similarly to the Panoptics in SCTs. They do give ground to the more expensive medium-AFOV oculars in faster scopes, where their field-edge sharpness deteriorates somewhat. Prices for the Super Wides begin at $180 for the short focal lengths and increase to $400 for the 40 mm.

Burgess Paragons Is the cost still too much? A relatively new medium-AFOV ocular that is garnering rave reviews is the Burgess Optical Paragon. Although this eyepiece is currently only available in focal lengths of 40- and 30-mm, the company apparently will soon be expanding the line to other focal lengths. The Paragon, designed by late apochromatic refractor guru Tom Back, performs as well as much more expensive oculars for a modest price ($250). The Paragon uses six lens elements in four groups in a 2-inch barrel to produce a 69° apparent field and images that, while not *quite* as sharp to the field edge as a Panoptic's or a Pentax's, are nevertheless satisfyingly good.

Ultrawides A first look through an ultrawide AFOV (Plate 37) eyepiece will be surprising, maybe shocking. It may even border on a religious experience. The huge field will not just look "good"; it will be overpoweringly immersive. You will feel as if you are falling into that distant star cluster. Even at higher powers, the 82° (usually) apparent fields of these eyepieces ensure that an observer never feels constricted. That comes at some cost, of course. The TeleVue Naglers, the premiere ultrawides since the first one was introduced in 1980, are pricey. Also, whether the eyepiece is a Nagler or one of the lower-priced alternatives now available, there is a cost in light. Like the medium-AFOV eyepieces, the ultrawide designs incorporate many elements—as many as seven separate lenses—that tend to dim images a bit. Another cost is eye relief. Eyeglass-wearing observers are in for more frustration than amazement with the ultras.

TeleVue Naglers The TeleVue Naglers are the eyepieces that started the spaceship porthole viewing craze, and Al Nagler's revolutionary oculars are still going strong 30 years later. Currently available in focal lengths from 31-mm all the way down to 2.5-mm, all Naglers feature AFOVs of 82°. Eye reliefs vary from 12- to 19-mm. Eye relief also varies according to the "design" type of the Nagler in question. Currently, TeleVue's Naglers are offered in three slightly different designs, types 4, 5, and 6. These design differences are a result of TeleVue's continual and laudable efforts to update and improve their eyepieces.

Innovation costs money, of course, and that means a selling price for these oculars that is a barrier for some amateurs. The least-expensive (shorter focal length) models retail for about $300 in the United States. The most expensive Nagler, the "holy hand grenade," the huge 31 mm, is a daunting $640. Another strike against them is weight. A 12-mm Nagler comes in at about a pound, and the 31 is over *2* pounds. That much weight on the rear cell can make it difficult to balance some scopes.

Amateur astronomers often complain about the cost of Naglers, but they rarely complain about these oculars' optical or mechanical quality. Optically, they are amazing in CATs, offering pinpoint stars all across their huge fields. Aberrations such as pincushion distortion or astigmatism are minor or nonexistent. In fact, objects may often look sharper in the Naglers than they do in narrow-field eyepieces. Yes, targets may be slightly dimmer in the "Nags" due to all that glass, but because of the superb lens coatings TeleVue uses, even that is held to a minimum. Mechanically, the Naglers are also top-notch. Dropping my beautiful 12-mm onto a concrete observing floor resulted in no shattering of glass and only in one tiny mark on the barrel. Replacing the eyepiece in the focuser, it was obvious that nothing was out of alignment; images were as good as ever.

Meade Ultra Wides Meade has been competing with TeleVue in the ultrawide market for many years, and the Meade 82° field oculars have always been acknowledged as good eyepieces—maybe not *quite* as good optically or mechanically as the Naglers, but good. Certainly, they have always been good values as their prices have consistently undercut those of the TeleVues. The major complaint about Meade's Ultras has been that, unlike Al Nagler, Meade did not continue to update their designs. Then, a few years ago, the company introduced the Series 5000 Ultra Wides that at least looked very different from the old ultras.

The most striking thing about the new Meades is their barrel design (see Plate 38), which is certainly futuristic looking. The eyecup at the end of the barrel is built into the eyepiece and can be extended or retracted to adjust its height as desired. Unfortunately, Meade uses a lot of grease on the eyecup's mechanism, and it tends to migrate onto a user's hands and telescope (the Super Wides use the same scheme and the same grease).

Plate 38. (Meade Ultrawides) Meade's modernistic Ultrawide Series 5000 collection. Credit: Image courtesy of Meade Instruments Corporation.

Optically, the Ultra Wides, which are available in focal lengths from 4.7- to 30-mm, appear to have been at least incrementally upgraded and are quite competitive with Naglers when it comes to raw sharpness and lack of distortion. Where they fall behind a bit is in the areas of baffling and coating. Focal length for focal length, there are more internal reflections with the Ultra Wides than with the Naglers. All eyepieces are subject to some stray reflections, but the problem seems a little worse in the Meades. Coatings on the ultrawides appear to be as good as those on the TeleVues but less carefully applied, with small flaws sometimes apparent.

One area in which the Meades are slightly better than the TeleVues is eye relief. Some Naglers have as little as 12-mm, but the Meade with the least eye relief is the 4.7-mm with 13-mm. Most of the ultrawides have 15 mm or more. The big draw here, of course, is price. The Series 5000 eyepieces are cheaper, with the "king," the 30 mm, selling for $450. Regarding the verdict on the Meade Ultra Wide Angles, they are cheaper and almost—but not quite—as good as Naglers.

William Optics Uwans The Meade Ultra Wides seemed to be about as good as it got in the 82° arena when it came to a balance between price and quality. Then came the William Optics Uwans. Although these eyepieces are made in Taiwan, Uwan is not a city in China. It is an acronym for ultrawide angle. The four eyepieces that have appeared in this series thus far—28-, 16-, 7-, and 4-mm—have turned out to be remarkable oculars, seeming to equal the TeleVue Naglers in most ways while undercutting even Meade's prices.

How good *are* the Uwans? I did not rely on their views in the optically forgiving SCTs to find out. I arranged a "shootout" between the 28-mm Uwan and the comparable 26-mm Nagler under the dark skies of Florida's Chiefland Star Party. The eyepieces were tested in big Dobsonians with focal ratios down to and including an eyepiece-punishing f/3.26. In the opinions of the experienced observers who participated in this comparison, the Uwan was "as good or a little *better*" than the 26-mm Nagler in the areas of sharpness and field-edge quality. This was on a variety of objects, including the monstrous globular star cluster Omega Centauri, with its countless tiny stars. In fact, the only time the informal panel of testers felt the Nagler pulled ahead was in the f/3.26 scope, and everybody agreed its advantage, even there, was relatively slight. The only area where the Uwans do seem to lag behind the Naglers is in viewing comfort. Eye placement is slightly more critical with the Uwans, with these eyepieces displaying more "blackout" than the Nags.

Mechanically, the Uwans are perhaps slightly better in some ways than the TeleVues and ultrawides. Their barrels are striking modern designs (see Plate 37), all black and high-tech looking. Unlike the TeleVues, most of which rely on plain old rubber eyecups, the Uwans integrate a hard mechanical eye cup, which is rotated to extend or collapse. This design, unlike that of the Meade Series 5000s, does not leave astronomers with greasy hands.

Pricewise, the Uwans beat everything in their class. The 30-mm goes for $398, the 16-mm is $238, and the 7- and 4-mm are $198 each. So, what is not to like? The main thing is the limited range of focal lengths. There are currently seven Meade Ultra Wides. The TeleVue Nagler lineup consists of an amazing 14 eyepieces. Despite this paucity of focal lengths, all things considered, the Uwans deserve "best buy" status.

Spaceship Picture Window: The TeleVue Ethos Recently, TeleVue has introduced a remarkable pair of eyepieces, the 13-mm and 7-mm Ethos oculars. Both have apparent fields of 100 degrees. That's right, 100 degrees. In addition to this huge AFOV, the Ethos eyepieces feature 15-mm of eye relief and display the best sharpness and contrast I have ever seen in ultra wide field eyepieces. By the time this book is published, TeleVue will have added two more oculars to the Ethos stable: A 6-mm and a 17-mm. The only bad thing about any of them? Their prices, which range from just under $600 to over $700.

Cheaper than Cheap? With Chinese medium-AFOV class oculars now common, you would think there would also be some imported ultrawides for less than the $100 prices. There are. Unfortunately, although the Chinese medium-wide AFOV eyepieces perform respectably, their ultra analogs are not *quite* there yet. A few, like the "Bird's-eye" oculars (11-, 15-, 16-, 30-mm), imported by U.S. astronomy retailer Anacortes Telescope and Wild Bird (Appendix 1), do an acceptable job in slow focal ratio CATs but are in no way comparable to Naglers or Uwans. They can at least give the new or cash-strapped astronomer a taste of eyepiece spacewalking at prices less than $100.

Hope for Ultrawide-Loving Eyeglass Wearers TeleVue has been well aware of the problem for eyeglass wearers posed by the Naglers' relatively short eye reliefs, which make it impossible for astigmatism sufferers to see the oculars' entire gigantic field. The solution TeleVue has come up with is an attachment that allows astigmatics to leave their glasses off. The Dioptrx can be attached to TeleVue eyepieces longer than 12-mm, including the Naglers and the new Ethos. This corrective lens element is available in different values to match glasses' prescriptions for astigmatism.

The Dioptrx must screw onto the eye lens end of an eyepiece, which is the reason it is only available for and usable on TeleVue oculars with larger eye lenses.

Eyepiece Cases

Where do you put eyepieces? Surely, you do not want your expensive glass rattling around on the floorboard of a pickup truck. Some kind of box or case to keep oculars safe from bumps, dust, and dew is essential. A number of astrovendors, such as Orion in the United States, sell cases made for this purpose, but actually any type of container filled with protective foam padding will do. Particularly good are some of the hard cases sold in camera stores for photographic equipment. These briefcase-size containers are usually furnished with "cubed" foam padding that can be customized to hold eyepieces perfectly.

Other Optical Accessories

Barlow Lenses No matter how many eyepieces a CAT user accumulates, a Barlow lens will increase the number. What is a Barlow? In its simplest form, it is a single-element negative lens mounted at one end of a barrel. An eyepiece is inserted into the other end, and the whole thing is placed in the CAT's star diagonal. What good is that? When an eyepiece is combined with the Barlow's negative lens, its magnification is doubled (usually). A Barlow is an *eyepiece multiplier*. For example, adding a Barlow to an eyepiece collection that consists of 15-, 10-, and 6-mm oculars adds "virtual" 12.5-, 5-, and 3-mm eyepieces. How? The Barlow lens makes the light cone coming from the telescope's optical system longer and skinnier. This "stretching" has the practical effect of making the telescope's focal length longer, and longer focal length telescopes produce higher magnifications than shorter focal length ones with any eyepiece.

Some new amateurs are skeptical about Barlows. Getting additional eyepieces just by adding a relatively inexpensive item to the accessory collection seems like a violation of the time-honored "there ain't no such thing as a free lunch" rule. For once, there is no catch. If well made, a Barlow not only can add focal lengths to an eyepiece collection, it can actually *improve* the images in these eyepieces. Most oculars perform better at longer telescope focal lengths, and a Barlow increases a telescope's focal length. Barlows can also increase viewing comfort. A 12-mm eyepiece, for example, is usually more comfortable to use than a 6-mm. It will likely have more eye relief and a larger eye lens. A Barlow will make this comfortable 12-mm eyepiece into a comfortable 6-mm eyepiece.

What should a buyer look for in a Barlow? Single-lens-element models may work okay, but it is best to choose a multielement achromatic or apochromatic Barlow to keep from adding spurious color to the eyepiece. The Barlow should be well built with a well-blackened barrel interior to prevent stray reflections. One that holds eyepieces in place by means of a compression ring instead of a setscrew is also desirable since a compression ring will hold heavy eyepieces more securely and will not mar their barrels like a tightly cranked-down setscrew. Finally, choose a Barlow in an appropriate "power." The 2× Barlows, which double an eyepiece's magnification, are most common, but 1.8× and 3× ones are also commonly available. An SCT owner should probably stick with the lower-power models since a 3x will not be very usable with most eyepieces except on nights of the best atmospheric seeing.

As for which *specific* Barlow, this is a golden age for this device, and all the models tested recently, even very inexpensive imported models such as Orion's $40 Shorty Barlow, performed well optically. The main difference between cheap and expensive Barlows is in their mechanics—things like barrel baffling, setscrews, and compression rings. Do you want the best? TeleVue makes Barlow lenses in both 1.25- and 2-inch models that are as renowned as their eyepieces. The 2-inch Big Barlow is not cheap at just over $200, but it is about as good as a conventional Barlow gets. The company also makes a superpremium model, the TeleVue Powermate. It is a top-of-the-line two-element model that also features a two-element corrector lens assembly for a total of four lens elements. It is even more expensive than the Big Barlow, at about $300 for the ×2 2-inch version (1.25-inch versions with powers up to ×5 are also sold), but it is famous for excellent images, especially in high-power planetary imaging.

Focal Reducers and Reducer/Correctors If only there were such a thing as a *reverse* Barlow. For years SCT users, who sometimes felt saddled by the CAT's long focal length, dreamed of a magic lens that would decrease a scope's effective focal length instead of increasing it. It is easy enough to get high power out of an SCT by adding short focal length oculars and high-power Barlows. It is harder to get low-power and wide-angle views from f/10 telescopes. Low-power eyepieces are expensive when they are really good, and these long focal length oculars can be uncomfortable to use because of their long eye relief. Simple lenses called *focal reducers* have been around years and do decrease the SCT's focal length. Unfortunately, these lenses do not work very well. What good is increasing the field of view if the stars at the edge of that field look like comets, even in expensive eyepieces?

Nothing much changed until the late 1980s when Celestron enlisted the efforts of master telescope and optics maker Jim Riffle to design a reducer that would not just be a reducer; it would be a reducer/*corrector* (r/c). The Celestron r/c (Plate 39) (Meade also sells one) is a two-element lens in a special housing that screws directly

Plate 39. (Assorted Accessories) A few of the accessories amateurs find themselves constantly buying, (l – r) Lumicon UHC LPR filter, Celestron f/6.3 reducer/corrector, Thousand Oaks OIII LPR filter, Meade 12mm illuminated reticle eyepiece, Lenspen, Celestron LED astronomer's flashlight. Credit: Author.

onto the rear port of an SCT. The threads on the other end of the r/c duplicate the SCT's rear-port threads, so anything that can be attached to a normal SCT port can be screwed onto the r/c. What is the magic of the r/c? It takes an f/10 SCT and turns it into an f/6.3 scope. With the r/c in place, a 25-mm eyepiece yields 50× (rather than 80× as it would at f/10) and delivers a concomitantly wider field. That is not all. The r/c also flattens the SCT's naturally curved field. Amazingly, stars at the edge of the field look better with an r/c in place than without it—in any eyepiece.

The r/c is a remarkable device, but it does have a few minor drawbacks. First, while the Celestron and Meade r/cs will work in any SCT, they seem to work best in 8-inchers. Field-edge correction in the larger telescopes does not seem quite as good. Also, r/cs, while usable for imaging, can cause vignetting with larger CCD (charge-coupled device) chips (those that approach 35-mm film frame size, like the sensors of digital single-lens reflex cameras). A photo taken with a large-chip camera through an r/c may be slightly darker at the edges and corners than it should be. Visually, an eyepiece with a longer focal length than about 32-mm may also show this vignetting. Despite its few faults, the r/c is a remarkable and remarkably useful accessory, especially given its reasonable price, about $130 for either the Celestron or the (apparently identical) Meade version.

Dew Shields Lucky astronomers do not just live where the sky is dark; they live where the atmosphere is dry. For CAT owners who observe where humidity is high and the dew point is low, dew is a huge roadblock on the path to productive observing. What happens to that big glass lens on the end of the scope when it cools below the dew point? It fogs up. Soon thereafter, it will be dripping wet, and the observing run will be over. In some parts of the world, like the southeastern United States, an SCT that is unprotected from dew will become useless in little more than an hour on many nights. How do southerners—or anybody else—keep dew from "falling" on their CATs? A simple dew shield is the first line of defense.

"Simple" is right. A dew shield is nothing more than a plastic or metal extension to the telescope tube that fits over the corrector end and shields the big lens from some of the heat-sucking sky. The less of the sky the corrector can "see," the longer before it dews up. A dew shield also has the added benefit of protecting the optical system from stray light (just like a lens shield on a 35-mm camera). A dew shield is a common item and is probably the first accessory most CAT users should buy. Meade and Celestron have sold them in the past, but today most U.S. amateurs are buying the nicely crafted Astrozap dewshields (Appendix 1), which are available either in metal painted to match the telescope's tube or as "flexible shields," flat plastic sheets that can be formed into a tube, fastened in place with Velcro, and slipped over the corrector end of the tube. In the United States, Orion also sells flexible dew shields, and a Google search will turn up a host of other makers of these simple accessories.

Dew Zapper Guns Outside the lowest-humidity areas, a dew shield alone will not be enough to allow all-night observing runs. The second line of defense is the dew "zapper" ( ). What is a zapper? That depends on where it is bought. At an astronomy store, it will be sold as a "dew removal gun." Anywhere else, it will be known as an automobile window defogger or 12-volt hair dryer. And that is actually the best description: a little 12-volt hair dryer. These devices put out amazingly little heat, but that is perfect for our purposes. High heat is not needed and can cause a corrector to deform slightly and produce poor images until it cools again. When dew begins to creep onto the corrector (halos will begin to appear around bright stars), fire up the zapper. Just a minute or two of use is enough to dry the corrector unless things have gone too far.

What if you cannot find a zapper for sale from an astronomy dealer or do not want to pay what one costs at the scope store? Check boating and outdoors suppliers where, as mentioned, these devices are sold as window defrosters and hair dryers. What if you cannot locate one there either? In a pinch, a plain old hair dryer can work if there is a source of 117-volt AC available. Just do not set the blow dryer to "high" and pump 2,000 watts onto the corrector. Using the lowest setting, hold the dryer a couple of feet from the corrector plate and keep moving it continuously. That will get the job done without ruining "local seeing."

Dew Heaters In the most humid areas, it may be necessary to go to the third line of defense in the war against soggy corrector plates: dew heaters. A dew zapper will work at the worst locales, but most observers soon tire of zapping the corrector every 10 minutes or so when dew is heavy. Dew heaters are the ultimate fix (Plate 40). They are narrow cloth bands that can be wrapped around the corrector end of the tube and fastened in place with Velcro (Velcro really is the astronomer's best friend). Heating elements made from resistors or resistive "heat rope" are sewn into these bands. Each heater strip has a cable that connects to a control box, usually via a phono-style (RCA) plug. In the past, some dew heaters were powered with AC current, but these were unreliable and even dangerous. All dew heaters sold today are DC powered.

For years, the answer to, "Where do you get a dew heater system?" was, "From Jim Kendrick." Kendrick, a Canadian amateur, did not invent dew heaters, but he was the first to integrate them with a control box that allowed users to adjust the heat applied to the corrector. His Kendrick System (Appendix 1) is still popular with

Plate 40. (Dew Fighting Tools) Dew fighting tools. Left to right: Dew-Buster heater controller, Kendrick 8-inch heater strip, 12 volt dew zapper gun." Credit: Author.

amateurs, and in addition to his original controller, he now offers a digital model that senses ambient temperature and applies just the right amount of heat to the lens, saving battery power and preventing seeing effects.

Actually, Kendrick was not there first with a temperature-regulated dew controller. A creative amateur, Ron Keating in Louisiana, did that with his DewBuster. The DewBuster uses a probe to provide temperature feedback to the control box. The user sets the system to a desired temperature above ambient, and dew is a thing of the past. The top-of-the-line Kendrick temperature-regulated Premier controller costs $350, while the DewBuster is $160. It should be noted, however, that the Kendrick can be interfaced to a computer; the DewBuster cannot. The Premier also features a much more sophisticated control panel and display—if that is important to you. A basic non-temperature-controlled Kendrick can still be had for less than $100.

The heater strips themselves can be purchased from Kendrick, with an 8-inch corrector heater costing about $65. DewBuster does not make heaters at this time, but Kendrick heaters work fine with it. Also available are the cheaper but still effective 8-inch heater strips sold by Dew-not for about $40. Both Kendrick and Dew-not sell heaters in sizes for any aperture CAT. Eyepieces, finders, and other accessories can also dew up, and both companies also make heater strips for these devices. Kendrick's and DewBuster's controllers have multiple outlets that allow the box to run multiple heater strips.

Flashlights

Another mandatory item for the CAT user is an astronomer's flashlight. Just any flashlight will not do for reading charts, operating the telescope, assembling/disassembling the CAT before and after the "run," and performing the other tasks that must be done on dark fields. The perfect astrotorch puts out a pure red beam that is dim enough not to harm dark adaptation. A too-bright red light can be nearly as harmful to night vision as a white light.

What to do? Some novices try covering the lens of a standard flashlight with layers of red cellophane or transparency film. That works but is not an optimum solution. Usually, the light is either too bright or too dim, and it is rarely very red. The best choice is a red light-emitting diode (LED) light sold specifically for use in astronomy (Plate 40). These flashlights give off a very pure light, are usually equipped with a dimmer control that will allow them to be adjusted for optimum illumination level and include features of vital interest to observers—such as neck straps—that are not common in "normal" flashlights.

Any astronomy seller will have scads of red lights for sale. Anacortes Telescope and Wild Bird, for example, lists 15 different astronomy lights on their Web sites. Which one is best? A good flashlight has both red and blue (or white) LEDs. With a flip of a switch, these can be changed from red to blue/white, helping you walk back to a cabin, tent, or car safely when you are done on the observing field. A current favorite is the Rigel Systems Skylite ($31). It has all the features you would want, four LEDs (two red, two blue-white), a strap, a dimmer control, and a sturdy housing.

It gives off a great deal of light when it is needed, but since it uses LEDs, it is very miserly in its consumption of batteries. There are plenty of cheap imported clones of the Skylight, but the genuine Rigel is by far the best.

Star Charts and Atlases

Who is still interested in paper star charts in this day of computerized planetarium/mapping programs? The traditional nonvirtual star atlas is dead as a doornail, right? Hardly! There are actually more print star atlases available now than there ever have been. Some amateurs do not own laptop computers, and not everybody who does wants to haul one out to a damp observing field. Sure, it is possible to print maps on a printer and take the hard copy onto the field, but many observers still like the convenience of a book of charts that covers the entire sky.

What is desirable in a set of star charts? Let us mention what *not* to get first. Avoid "mag 6" atlases. These charts only show stars as dim as magnitude 6 (lower magnitude numbers are brighter), which is the limit of naked-eye visibility. Forty years ago, books like the magnitude 6 *Norton's Star Atlas* were the principal tools of amateur astronomers, which is probably why we did not see many deep sky objects back then. The problem with them is not only that they do not show many of the thousands of deep sky objects visible in an 8-inch CAT, but they also do not show enough stars for star hopping to objects if a go-to scope is not being used (or if a go-to computer is acting cantankerous). There are plenty of good magnitude 8 atlases out there, and that is what is recommended both for go-to and non-go-to scope owners.

There are three books of charts—star atlases—in wide use by amateur astronomers today: *Sky Atlas 2000* (Wil Tirion), *Uranometria 2000* (Wil Tirion, Barry Rappaport, and Will Remaklus), and *The Millennium Star Atlas* (Roger W. Sinnott and Michael Perryman). *Sky Atlas 2000* is the baseline. It offers 81,312 stars and 2,000 deep sky objects. The 2,000 may not seem like many objects compared to the 100,000 or more contained in the average computer atlas, but it is guaranteed that it will take a long time to work through those 2,000 with a C8. *Sky Atlas 2000* is available in several editions, but perhaps the best is the deluxe, which is comprised of twenty-six 21 × 16-inch, spiral-bound, white-sky charts printed in color. *Sky Atlas 2000* is also available in a field edition, with white stars on a black sky, but this is much harder to decipher under a dim red light than dark stars on a white sky.

For years, *Sky Atlas 2000* was the deepest of the deep. But then came the two-volume *Uranometria 2000* to kick things up a notch. *Uranometria* includes an amazing 332,000 stars brighter than magnitude 9.5 and over 10,000 deep sky objects. To go this deep, *Uranometria* is composed of 259 charts that are 9 × 12-inches. Although this atlas is ideal for star hoppers, the small scale of these charts, 1.4° per inch, means a lot of page flipping is required to find objects of interest. Many *Uranometria* users keep a copy of *Sky Atlas 2000* at hand to help them "navigate."

Do you want deeper still? *The Millennium Star Atlas* goes down to magnitude 11 (1 million stars) and contains 10,000 deep sky objects. This atlas is even fatter than *Uranometria*, with three volumes packed with 1,548 charts that are 9 × 13-inches. However, at this level, computer star atlases become more practical. A few clicks will center you on an object that would have taken a half hour of squinting and page flipping in *Millennium*.

Batteries

Unless all observing will be done from home, batteries will be needed to power a current-hungry go-to scope. Even if all viewing is from the backyard, it may still be more convenient to power the CAT with a 12-volt DC source than to worry about extension cords and AC outlets. What is needed in a scope battery is *current capacity*. Batteries are rated for their capacity in "amp hours." If, for example, a manufacturer says a battery has a capacity of 12 amp hours, it will potentially deliver 1 amp of current for 12 hours. It could deliver less current—say 500 milliamps—for a longer time. The recommended lowest current capacity for the average go-to telescope is 17 amp hours. Not only are modern telescopes power hungry when slewing at high speed—often drawing more than 1 amp—the amp hour rating of a battery is only a ballpark estimate. If there is a frequent 1-amp current draw, a battery will likely lose current well before 17 hours elapse. And, 17 amp hours is a very commonly available capacity for batteries.

What is the best type of scope battery? A jump starter is—portable sealed lead-acid batteries are designed for jump starting cars with dead batteries. One feature common to all these units is 12-volt DC cigarette lighter receptacles, which makes them perfect for use at the scope since most scope DC power cords have cigarette lighter-style plugs. Jump starters often have other frills: built-in chargers, built-in lights, sometimes even built-in radios. Jump starter-style battery packs are available from scope retailers, but the best bet is an automotive discounter.

If you are like your old Uncle Rod, though, you are powering more than just a scope. There is the dew heating system and the laptop. Don't forget the CCD camera and the DVD recorder. For high-current situations, forget jump start packs and go with what we down here call a "trolling motor battery" (deep-cycle marine battery). Deep-cycle marine batteries with current capacities in the 75-amp hour range cost about what a 17-amp hour jump starter does. *Deep cycle* means that the battery can be completely discharged without harm, something that may come in handy for the CAT user on an observing field far from AC outlets for charging. As always, there are a few penalties for more-better-gooder. Marine batteries are heavy, and a good charger will also have to be purchased to go along with one. If "plenty of power" is the requirement, though, they cannot be beat. For more information on battery buying and care, see the CAT hacking chapter, Chapter 12.

Nice-to-Have Accessories

2-Inch Star Diagonals

It was mentioned that 2-inch barrel-format eyepieces will, naturally, require a 2-inch star diagonal in the telescopes. There are numerous 2-inch diagonals on sale from numerous companies, but before deciding on which brand to buy, a prospective user of 2-inchers must also decide which *style* diagonal to purchase; 2-inchers come in two distinct flavors: SCT and refractor.

SCT diagonals are made expressly for our CATs, and as shown in Plate 41, incorporate an integral threaded ring that allows them to screw directly onto the scope's rear port (or a reducer/corrector). The other type, the refractor style, looks just like an oversize 1.25-inch diagonal. It has a plain barrel that is designed to be inserted into a refractor's focuser. Since there is no threaded ring and a 2-inch barrel will not fit into a standard visual back, another item is needed before a refractor diagonal can be used with most SCTs (Meade Microfocuser-equipped SCTs accept 2-inch refractor diagonals directly), an inexpensive accessory called a 2-inch adapter or, interchangeably, a 2-inch visual back. Whatever it is called, this item is nothing more than a threaded tube that can be screwed onto the rear port and into which 2-inch devices can be inserted. One also features a setscrew or compression ring to hold the diagonal or other item in place. If possible, choose a model with a compression ring to best hold the 2-inch diagonal and eyepiece combination securely.

Which style diagonal is best? Both work fine. In the past, users were often advised to choose refractor diagonals since until recently there was a larger selection of quality models available in that style. Today, very high-quality SCT 2-inch diagonals have become available from companies like William Optics and TeleVue, and an SCT-style diagonal is often more convenient since there is no 2-inch visual back to install and keep up with.

In addition to choosing the style of diagonal, you must decide on the coating type. A standard aluminized diagonal's mirror will reflect about 88% of the light that strikes it. Premium dielectric-coated diagonals like William Optics Dielectric Carbon Fiber diagonal ($168) can reflect as much as 99% of incoming light. Dielectric coatings achieve this high reflectivity thanks to their multiple layers of different and sometimes-exotic materials. The choice of material for these layers allows manufacturers to tune diagonal mirrors for maximum reflectivity in visible light. Is a dielectric diagonal worth the extra money (about $100 more than standard aluminum)? That depends. There is not *much* difference visually between an 88% diagonal and a 99% diagonal, but there is some.

Is a 2-inch diagonal something a new SCT user needs? Only if 2-inch eyepieces will be used. A 2-inch diagonal will offer no improvement over a 1.25-inch model of similar optical quality. Think long and hard before buying a 2-incher if only

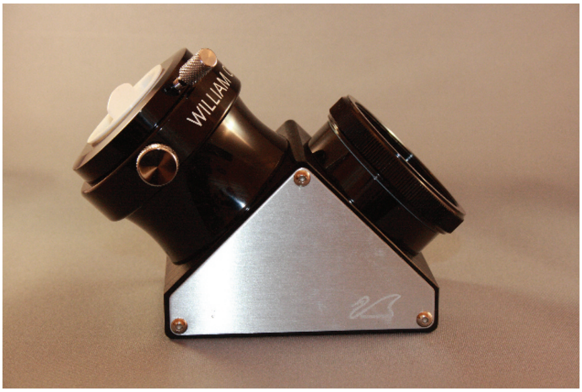

Plate 41. (2-inch Star Diagonal) William Optics 2-inch SCT-style dielectric star diagonal. Credit: Author.

1.25-inch eyepieces will be used. Sure, 2-inch diagonals come with 1.25-inch eyepiece adapters, but 1.25-inch eyepieces do not always work well in 2-inch diagonals. These adapters may place some 1.25-inch oculars far enough back that they will not reach focus. This problem is exacerbated with a reducer/corrector in place.

Forgoing a 2-inch star diagonal does not mean sticking with the cheap diagonal that came with the scope. The 1.25-inch models are every bit as good as the top 2-inchers that are available from William Optics, TeleVue, Astro-Physics, and other manufacturers. Dielectric 1.25-inch diagonals are also relatively inexpensive, costing as little as $80. Which is best, a prism or mirror diagonal?. Although 2-inch diagonals almost always use mirrors, 1.25-inchers sometimes use prisms to divert the incoming light 90°. Mirror diagonals are easier to make well than prism diagonals and are usually better optically for that reason.

The Denkmeier Power x Switch Diagonal

What is the *ultimate* star diagonal? It is not one of the fancy dielectrics from William Optics or TeleVue; it is the Denkmeier SCT Power x Switch. Denkmeier, a small U.S. company, established itself with amateurs with its high-quality yet reasonably priced binoviewers. It has now expanded its line of accessories with several interesting products, the most remarkable of which is the Power x Switch.

The Power x Switch 2-inch diagonal in Plate 42 includes a high quality dielectric diagonal, but that is just for starters. It also provides two “power switches” (slides, actually), seen on either side of the diagonal housing. Pushing the switch on the left introduces a high-quality Barlow into the light path and increases the current eyepiece’s magnification by ×2. Pull the switch out and slide the right switch into place, and a ×0.5 reducer moves into the light path, halving an eyepiece’s magnification. Images in this reducer seem nearly as good as those produced by the Meade and Celestron reducer/correctors. What is the true beauty of the Power x Switch? You can sit and observe, changing magnifications without having to change eyepieces or insert

Plate 42. (Denkmeier Powerswitch) The ultimate star diagonal? Denkmeier SCT Power-switch diagonal. Credit: Author.

Barlows. This will encourage you to try a wide variety of magnifications on difficult deep sky objects, often with startlingly good results. In the past, removing an eyepiece or fumbling with a Barlow meant you might wind up losing a difficult object.

No, the Power x Switch is not cheap. The SCT model goes for nearly $400. That is a lot, true, but it may enable many CAT users to forego buying yet another Nagler or Uwan. The easy-to-use reducer and Barlow of the Power x Switch effectively triple an eyepiece collection. You can go an entire week at a star party and use only two eyepieces in the Power x Switch. Besides, it is just so *cool*. Sitting there at the observing position of your Powerswitch-equipped go-to SCT, you will feel like Kirk on the bridge of the *Enterprise*: "More power, Scotty!"

Observing Chairs

It has been mentioned several times how nice it is to be able to sit and observe, which is one of the things that makes a CAT a great choice for an amateur astronomer. Okay, what are you going to sit *on*? The prime requirement for an observing "stool" is that it be light and adjustable. The eyepiece height of a CAT does not change much as the scope moves across the sky, but it does change. The time-honored solution has been a drummer's "throne," one of the adjustable stools used by musicians. These are almost perfect for astronomers, but not quite. Although they are adjustable, the range of adjustment is usually small, and changing height usually means fussing with bolts and nuts in the dark. Astronomy dealers sell drummer's throne observing chairs for around $50. They can also be bought in music stores, of course, but surprisingly, they tend to be more expensive there than in astronomy stores.

If a drummer's throne does not make a perfect observer's chair, what does? Look for something similar to the one in Plate 43, the Astro Chair from Buyastrostuff.com. This odd-looking little stool is light and easily adjustable. To change the height on this one and similar types of chairs, just tilt the seat up and slide it up or down in the "rails." Observing seats like this are sold by several astronomy manufacturers, and almost identical ones can be found in industrial supply houses, where they are sold as "utility chairs." However, the Buyastrostuff model offers the best price/performance ratio. Their version weighs a mere 10 pounds, is very sturdy, is adjustable in height from 18 to 32-inches, and costs a reasonable $105.

Observing Tables

You can use the Buyastrostuff chair as a place for yourself, but what about a place for your astrostuff? You could use a compact but capacious observing table. One choice is a folding-leg card table. These are easy to transport with the legs folded up and provide adequate space. Several astronomy dealers, including Orion, sell similar small tables with work surfaces that roll up into amazingly small packages. To do that, their surfaces are made of slats, however, which are not overly sturdy. The standard card table is sturdier, even if it takes up a little more room. Maybe even better are folding camp tables found in outdoor stores. The tops of these tables unfold in the middle and give twice as much space as a card table.

Plate 43. (Observing Chair) Buyastrostuff.com's inexpensive but effective observing chair. Credit: Author.

Supplementary Finders

Why worry about a finder scope? Most scopes sold today are go-to jobs. Beyond sighting alignment stars, a good finder *can* come in handy for go-to users on those not-unheard-of occasions when the scope computer misses a target. They can also be useful for finding objects the old-fashioned way—by star hopping, perhaps to objects not in the hand control's database. Although all go-to telescopes come with finders of some sort, these may not be adequate for much beyond sighting alignment stars. When it comes to a better finder for a scope, there are essentially two choices: zero power and optical.

Many lower-priced go-to telescopes come equipped with zero-power finders, most often of the red-dot variety. This type finder works okay, but it can be difficult to accurately place a small dot in just the correct position among the stars. A better zero-power unit is the Telrad ($40). The late American amateur astronomer

Steve Kufeld came up with what was the first commercially marketed zero-power finder, the Telescope Reticle Aiming Device—Telrad. Through clever use of a red LED-illuminated reticle and a beam-splitter window, the Telrad seems to project a bull's-eye onto the night sky. The three concentric circles that form this bull's-eye represent angular distances in the sky of 4°, 2°, and 0.5°. These circles, seeming to float among the stars, make aiming a telescope simple and intuitive. There are no upside-down images to figure out as in a finder scope. The reticle circles make it easy to position the telescope accurately when searching for dim deep sky objects. The Telrad mounts on a rectangular plastic base that is affixed to a telescope's tube by included double-sided tape.

The Telrad is not the perfect solution for star hopping, however. It does not collect more light than the unaided human eye and thus will not show stars dimmer than those that can be seen with the naked eye. That may make it difficult to find objects in star-poor areas. A good-size optical finder, one with an aperture of at least 50 mm, is a nice addition to a telescope equipped with a zero-power finder or replacement for one of the too small 30-mm finder scopes that come with less-expensive telescopes. A 50-mm will show stars down to at least magnitude 8, which includes every star plotted on *Sky Atlas 2000*. Good finders are not expensive, either, with decent Chinese-built models going for $75 or less.

Optical finder scopes are fine, but many amateurs do not like the way a normal finder telescope inverts its image or the way optical finders make a person contort his or her body to look through them when the scope is pointed near the zenith. Orion U.S. has a solution. Its 9 × 50 mm RACI (right angle correct image) finder yields an upright image of the sky with a comfortable built-in star diagonal that delivers images correct right to left so what is visible in its eyepiece exactly matches what is on charts. This is accomplished by an "Amici"-style prism contained in the finder's built-in star diagonal. The RACI works well, and at $80, it is not much more expensive than a normal "straight-through" finder scope.

Vibration Suppression Pads

A shaky scope is not much of a scope. What is the cure? A new mount might fix things, but that means spending more money. Some people do not like the idea of removing the tube from an otherwise-nice fork mount to place it on a GEM just to cure the shakes. Do not worry; Celestron, Meade, and Orion will sell the shaky-scope owner an accessory to cure the problem (it is a shame they cannot just upsize their tripods a wee bit): little pads that can be placed under the tips of tripod legs to reduce vibration. These vibration suppression pads feature a metal cup isolated from the rest of the pad by vibration-absorbing Sorbothane material. When tripod leg tips are placed in these cups, vibrations are greatly reduced. This is a simple but effective idea and can reduce a telescope's "settling time" from a bad 10 seconds to a good 2 seconds, which may be just as much of an improvement as would be gained by placing the OTA on a fairly hefty GEM. One thing is sure: These pads cost a lot less than a new mount. Expect to pay about $50 for a set of three.

Frills

Filters

Light pollution reduction (LPR) filters can be described as "frills" for observers blessed with dark skies, but for those of us living in urban and suburban areas, they are almost as important as eyepieces—for viewing some objects, anyway. What is the story on LPR filters (Plate 39)? It is important to know what they *will not* do first. The beginner, seeing advertisements in the astronomy magazines for LPR or "deep sky" filters, naturally thinks his or her problems with bright skies are over. Screw one of these things onto an eyepiece, and all those wonderful galaxies, nebulas, and star clusters will pop right out. Would that were so. LPR filters can help, but only with some types of objects and only to an extent.

Understanding the capabilities and limitations of LPR filters requires an understanding of how they work. To the eye, one appears to be nothing more than a darkly tinted red or blue piece of glass, no different from any other filter used in astronomy or photography. In reality, LPR filters are made by a considerably different process. They consist of an optically flat piece of glass that has had multiple layers of reflective material deposited on one surface in a vacuum chamber. Each layer reflects a different set of wavelengths of light. Light enters the filter from the telescope's optical system (filters are normally screwed onto the field lens end of the eyepiece) and hits the filter. The "good" wavelengths pass right through and into the eyepiece. The "bad" wavelengths—especially those from mercury vapor and sodium streetlights—are reflected away. Manufacturers choose filter coatings based on the wavelengths they wish to admit and exclude. This should make it obvious that LPR filters don't make objects brighter. They improve contrast between deep sky objects and the background sky by suppressing the light pollution wavelengths that make the sky bright.

That all sounds good, and LPR filters *do* work, but they have some severe limitations, the most serious being that they do not work on *all* objects. Unfortunately, light emitted by stars falls into the same range of wavelengths as that from earthly light sources. This means LPR filters are nearly useless on star clusters. The light from the stars making up these objects is rejected along with earthly light pollution. Galaxies are also made of stars, so LPR filters do not help them, either. One manufacturer is now offering a supposed "galaxy filter," but nevertheless LPR filters are *only* effective on planetary and diffuse nebulas. Period.

Do you still want an LPR filter? Prepare to be confused by the large number of different types and brands available. A little study of the magazine ads, however, reveals that they come in three "flavors" that represent their passbands. *Passband* is a forbidding-sounding word, but the concept is simple. A light pollution filter's passband refers to the range of frequencies of light allowed to pass through it. Filters are available with wide (broadband), normal (medium), and narrow (line-filter) passbands. Each type is different and is suited to a different application. Most types of LPR filter are available in either 1.25- or 2-inch formats and are marketed by a number of companies in the United States and Europe, with Lumicon, TeleVue, Orion, Thousand Oaks, and Baader Planetarium leaders in the field.

Broadband Filters

Mild broadband filters allow the widest range of wavelengths to pass through them. Compare one of these to other types of deep sky filters by holding it up to a lamp; you will see that it looks "light" in comparison. These LPRs are referred to as *mild filters* because they have the least effect on deep sky objects. There *is* a contrast boost; some light pollution *is* being stopped, but the increase is less than in other LPR types. Lumicon's Deep Sky filter is a mild filter, as is Orion's Skyglow model.

Why would anybody want to buy the least-effective type of LPR filter? One reason is that broadband filters can be used in picture taking. Although the narrower filters are sometimes used in deep sky photography, they are so dense that they require long exposures even on bright objects. Another reason to choose a wideband filter is because, in the opinion of some observers, they can improve views of galaxies and star clusters. It is said that these filters darken the sky background just enough to make galaxies look better without dimming their stars too much. Personally, I have never seen much—if any—improvement in galaxies or star clusters with one of these filters.

Medium Filters

Medium filters, represented by Lumicon's UHC and Orion's Ultrablock, are the bread and butter of deep sky observers. They are characterized by narrower passbands than the mild filters. More bad light is blocked, and they have a more noticeable effect on contrast. The improvement they bring to nebulas is truly dramatic. They also tend to work well on a wide variety of objects, from diffuse nebulas to planetary nebulas to supernova remnants. What are the trade-offs? The stars are dimmer in these filters than they are in the broadbands, making some fields a little less attractive than they would otherwise be. M42's nebulosity, for example, stands out beautifully, but the wondrous bright stars embedded within it are dimmed. A UHC, Ultrablock, or equivalent is the best filter for most objects and is probably the one to get first.

Line Filters

The passbands of line filters are narrower still. The best known of this class is the OIII ("oh three"), which is a very-high-contrast filter. By the judicious application of many reflective layers, the manufacturers produce a narrow (10-nanometer) passband centered on two Oxygen III nebula emission lines at 496 and 501 nm. What is this Oxygen III? Why is it desirable? *Oxygen III* is the light of doubly ionized oxygen. It is often referred to in astronomy texts as the "forbidden lines." What is important for the SCT user to know is that this wavelength of light predominates in many nebulae, especially planetary nebulae.

The OIII filter is truly amazing. My Lumicon OIII, when used with my 8-inch SCT, for example, has been able to turn the dim Owl Nebula (M97) from an almost invisible smudge to an easily observed showpiece object *in the city.* It can improve the appearance of almost any nebula, and not only from bright suburban skies but also from the darkest of dark sites. One of my fondest observing memories is of the Bridal Veil Nebula in Cygnus (NGC 6960) as seen in an OIII filter from dark skies. The filter made this already interesting object into a thing of unending wonder. I spent at least an hour panning my CAT up and down the Veil's wispy tendrils!

But there is always that piper to be paid. The OIII is not a filter for everyone. The OIII actually extinguishes dimmer field stars. There is no doubt that this makes many fields unattractive. Another disappointment with this filter is that it does not "work" on every nebula. Most nebulas, diffuse and planetary, do enjoy a boost from an OIII, but those that lack substantial OIII emission are not helped very much—if at all. Sadly, the greatest nebula in the northern skies, M42, is one of these. It always looks poorer with an OIII than without. Also, some observers think the OIII imparts too much contrast to objects, that nebulas tend to look "cartoonish" and "not real" in the OIII. Finally, because of its density, the OIII works best with telescopes of 8-inches aperture and up.

The OIII is not the only line filter out there. Another is the hbeta, the "Horsehead filter." This one has its passband centered on the red light of hydrogen. This emission predominates in the very dimmest of dim nebulas, such as the faint, legendary clouds like the Horsehead Nebula in Orion (B33/IC 434) and the California Nebula in Perseus (IC 1499). Although the hbeta filter can do a surprising job on these nebulas and a few others like them, it does not work on much else. An hbeta is not a filter to use every night. The Horse will not be visible from a light-polluted backyard with a C8 hbeta or no hbeta. The Celestial Nag did show with this filter and a C11, but only with extreme difficulty and only from the superbly dark skies of the Chiefland star party.

Should novices consider a line filter? A beginner should probably acquire an OIII as a second filter, after a medium-strength filter such as the UHC, and an hbeta as a "third-if-ever" buy.

How much do these things cost, anyway? This depends on the brand and type but expect to pay about $75 to $100 for a 1.25-inch and $150 for a 2-inch. As is the case with all other astrogear, Chinese imports are beginning to drive LPR prices down.

Color Filters

Color filters similar to those used by terrestrial photographers are available for visual use in astronomy. They will not do anything to help with the deep sky, but they can be a useful tool for solar system observers. An 80A (blue) filter, for example, can help bring out Jupiter's cloud bands. A red (25) filter can reveal surface detail on Mars. What do numbers like "80A" mean? They are *Wratten numbers* that specify color and density. One great thing about color filters is that they are cheaper to make and sell for less money than LPR filters. For example, a set of six is available from Orion for $125, less than the cost of one LPR filter. Do colored filters help you see more? Probably not, although some planetary observers swear by them. As they say on the Internet, "YMMV" (your mileage may vary).

Solar Filters

If done safely, solar observing can be a joy. Old Sol, especially at the height of the 11-year sunspot cycle, is endlessly fascinating. How does the CAT owner observe the Sun safely, so that neither eye nor telescope is harmed? This is possible using a full-aperture solar filter from a reputable manufacturer. A full-aperture filter fits securely over the corrector assembly and reduces the intensity of the Sun to a level that is safe for visual observing. The finder scope on the CAT should be left capped or removed so no one is tempted to use it. Find Sol by observing the shadow of the scope. When it is smallest, the Sun should be in the field.

Safety of the telescope also needs to be considered. Keep the CAT safe by ignoring the advice found in older astronomy books. They usually suggest "projection" is the safest way of observing the Sun. Projection is easy: place an eyepiece in the telescope, hold a white card a suitable distance behind it, point the scope at the Sun, and view the projected image of Sol. The problem is that a closed-tube SCT or MCT heats up very quickly, when the unfiltered Sun is allowed into the OTA. In almost no time, temperatures can climb high enough to cause severe damage. The secondary mirror holder can warp or melt, the baffle tube can be burned and distorted, and lubricants can vaporize and condense on the mirror and corrector. *So do not use a CAT for solar projection.*

What is visible with a safe solar filter? One thing that will *not* be seen is a solar prominence. The great fountains of fire spewing out from the solar limb require a very expensive hydrogen alpha filter for viewing. What a normal white light filter will mostly show are sunspots and the granulated "faculae" that form the Sun's photosphere. Truly, this is enough. Sunspots can be amazing, forming huge complexes that slowly move across the Sun's disk as it rotates. When things are hopping on the Sun, different, often bizarre-looking sunspot groups are on display almost every day. Occasionally, a solar flare may be intense enough to be visible in white light, but that is a fairly rare occurrence.

The first question a prospective solar filter buyers usually asks is, "Mylar or glass?" A solar filter's substrate can be either optical glass or thin sheets of Mylar plastic. It seems natural to expect glass filters to be better optically, but surprisingly, that is not the case. Mylar filters are capable of producing sharper images than glass ones. Mylar solar filters are made of (usually) two sheets of the plastic material stretched loosely across a filter cell that is fitted over the telescope's corrector assembly. Despite their wrinkled appearance (tightly stretching the Mylar in its holder to eliminate wrinkles actually harms filter performance), they deliver fine images.

The major problem with Mylar filters is that they do not produce a realistically colored image of the Sun. Glass filters often deliver a yellow or orange Sol, but most Mylar filters deliver a bluish or greenish image. In practice, that is not really a problem. As long as appropriate detail can be seen, who cares if the Sun is blue? If that is annoying, though, an appropriately colored eyepiece filter (used *in conjunction* with the solar filter, naturally) can give the Sun a more normal hue. Since they are made of thin plastic film, Mylar filters tend to be less durable than glass ones, but with reasonable care one filter should last for years.

Which filter, specifically, is best? If Mylar is the choice, one filter (or material) stands out: Baader Planetarium's AstroSolar film. It is available from various dealers mounted in filter cells for various aperture telescopes, but it is also commonly sold as unmounted film with instructions for building a simple cell that will fit snugly and safely over the corrector. The views of the Sun produced by AstroSolar film are probably superior to that of the best and most expensive glass filters. The color produced by AstroSolar is not natural, but it is not a disturbing blue or green, either, being a faintly bluish gray. Baader AstroSolar film in a commercially made cell for a C8 will cost about $100. Kendrick Astro Instruments sells AstroSolar filters in a huge variety of sizes to fit almost any aperture and type of scope. Prices vary depending on aperture.

Glass filters are still my choice, though, mainly because of their durability, and there are excellent ones from Orion, Thousand Oaks, and other manufacturers. The glass solar filter at the top of the list for quality, however, is the J. M. B. Identiview ($147 for the C8 model). This filter (Plate 44) seems almost as good optically as the AstroSolar film and presents a pleasing orange-colored Sun.

Plate 44. (Solar Filter) J. M. B. Identiview solar filter ready for some fun with old Sol. Credit: Author

For the CAT Owner Who Has Everything

Motorized Focusers and Rear-Cell Crayfords

Do you want to be able to focus an SCT without touching the knob and introducing shakes? The SCT accessory makers know you do and have been making "motofocus" units for years. JMI (Appendix 1) has been especially noted for its quality motorized focusers for SCTs. These battery-powered motors slip over the focus knob (sometimes, the stock focus knob is removed and replaced with one included with the motofocus) and provide remote focusing via a small hand control, or, increasingly, with a laptop computer. Does the average CAT owner *need* one of these $150 gadgets? The answer is probably not. They *can* be indispensable for imagers who just love the fine no-shake focus action and remote capability they provide.

One thing a standard motofocus unit will *not* do, to the surprise of some novices, is eliminate focus shift. There is no improvement at all. The image still moves in the field as focus is changed. One add-on focuser can help, the Crayford. This roller bearing focuser, originally developed for Newtonians, is now available for SCTs. It is threaded onto a scope's rear port, and an eyepiece, diagonal, or camera is inserted into it rather than into a visual back or other adapter. Since it does not provide the focus range of the SCT's normal moving-mirror system, the regular focus control has to be used initially to get in the Crayford's "range." Once that is done, the Crayford provides absolutely shift-free focus. Rear-cell Crayfords are available in both motorized and nonmotorized versions, with JMI offering a motorized model for about $450—somewhat pricey, but worth every penny for the planetary picture taker struggling with focus shift at high power.

Binoviewers

One of the most wonderful experiences in amateur astronomy does not involve a telescope: scanning dark skies with a pair of binoculars. Cruising along the Milky Way with a pair of 7 × 50s or 10 × 50s, going from glittering star cluster to wispy nebula, it is hard not to think this is the way deep sky observing was meant to be.

What makes binocular observing so pleasurable? One thing is a binocular's wide fields, but there is more to it than that. The main reason binocular observing is so much fun? You are relaxed and using both eyes as nature intended, instead of squinting through one eye. As has been said many times, the more relaxed you are, the more you will see. If only it were possible to look through a CAT with two eyes.

Well, it is, with the aid of a device called a *binoviewer* (Plate 45). A binoviewer is similar to the binocular heads used on some microscopes. Light that enters the unit from the telescope is split into two paths by prisms and is sent to each of two eyepieces. Observers who have not used a binoviewer sometimes question whether this is a practical arrangement. Does not running the light through prisms and

Plate 45. (Binoviewer) Denkmeier's binoviewer allows observers to use both eyes while viewing, just as nature intended. Credit: Author.

splitting it into two dim images mean that little can be seen at the eyepiece? Images *are* dimmer in binoviewers than in a single-eyepiece setup, but in the best models the loss is small. This light reduction does not do any harm in viewing the solar system, and its effect on deep sky objects is surprisingly small in good binoviewers.

The ground truth is that you can see more detail more easily in any object using a binoviewer than you can with a single eyepiece. The object may be dimmer, but you still get a better view of it. A good example is the faint nebula just north of M42 in Orion, the Running Man, NGC 1973. I had wanted a good look at this combination of reflection nebula and dark nebula for a long time but never could get one, not even in fairly large Dobsonians. One night under a dark Chiefland Astronomy Village sky, just after receiving my first binoviewer, I gave NGC 1973 another try. I sent my go-to Nexstar 11 to its location, focused up, and there it was. It was not even a difficult observation. I removed the binoviewer to be sure it, and not exceptional skies, was what was making the difference. Sure enough, when I viewed with a single eyepiece—"Cyclops style" as the binoviewer fans call it—the Running Man disappeared.

All this does not mean that a binoviewer is necessarily for everybody. One stumbling block for many people is the fact that two "copies" of every eyepiece are needed for the binoviewer. For best results, these must not only be the same focal length, brand, and design, but also they should have been manufactured at close to the same time. Eyepiece makers incorporate small changes in eyepieces from time to time, which can cause problems for binoviewers. What kind of problems? These mainly involve merging images.

If there is something wrong with a binoviewer, the eyepieces, or the observer's eyes, it may be impossible to successfully merge two images into one. Instead of seeing one Jupiter, there will be two. That is not only unattractive, it often leads to a serious headache. Even with identical eyepieces and a binoviewer that is in perfect optical alignment, some observers have considerable difficulty with merging. Try to use a binoviewer at a star party before investing a lot of money in one.

How much will a binoviewer cost? Like everything else in astronomy, they have gotten cheaper recently due to those ubiquitous Chinese optical factories. Orion, for example, sells one for $170. These bargain units may not be a good investment, however. Binoviewers are not something to skimp on. Beyond the question of mechanical quality—a binoviewer must have its optics perfectly aligned, and these optics must stay perfectly aligned—there is the question of clear aperture. The small prisms in inexpensive units mean longer focal length eyepieces will vignette; their fields will be cut off. That reduces these binoviewers' usefulness for observing wide, deep sky vistas. That said, for the money, the Orion and similar units do a good job.

Be prepared to invest enough money for a setup that will allow the full binoviewing experience: merged, bright images of solar system *and* deep sky objects. Two high-quality units are the TeleVue BinoVue ($840) and a personal favorite, the Denkmeier Optical Denk II ($900). Denkmeier also makes a basic binoviewer, the Standard, that performs almost as well as the Denk II at the more manageable price of $350. The TeleVue and the Denkmeier are of excellent mechanical quality and use top-quality optics with coatings that maximize light throughput.

At this point, you are loaded down with accessories, but now comes the payoff: Get out under the stars and start *using* that beautiful new CAT and all that cool astrostuff.

CHAPTER SEVEN

First Light With a CAT

Initial Field Setup, Alignment, Checkout, and Troubleshooting

Now is the time to stop being a CAT chooser and become a CAT user. Before beginning, please skim that darned telescope manual one last time and review the section in Chapter 5 concerning indoor ("fake") alignment.

Outdoor Setup, Alignment, and Checkout

The first priority on this first evening with the new telescope is finding a place to set it up, and the good old backyard is a natural. No, the skies probably are not dark, but this first time it is probably best to stick close to home, even if the sky is badly light polluted. You are going to spend as much time squinting at the instruction manual as squinting through the eyepiece, and it will be nice to be able to turn on a white light without incurring the wrath of fellow observers when there are problems—which there probably will be on this first run.

Where exactly should the scope be set up? That is easy. Take it to an open space with as clear a view of the sky as possible that is also as shielded as possible from ambient light sources. If the CAT is equipped with a German equatorial mount (GEM), try to find a location where Polaris is visible. As for ambient light, just do the best you can; the average suburban or urban backyard is illuminated by dozens of streetlights and porch lights. That is really not a problem this first evening, anyway. The goal the first time out is to make sure the scope is okay, not hunting dim deep sky objects.

R. Mollise, *Choosing and Using a New CAT*,
DOI: 10.1007/978-0-387-09772-5_7,

When should the Schmidt Cassegrain telescope (SCT) go outside? Get it out into the yard at least half an hour before dark to allow the optics to acclimate to outdoor temperatures. Normally, unless high-power views of the Moon and planets are on the evening's observing menu, cooldown is not a big deal. Deep sky objects look pretty good even in a nonacclimatized scope. One of tonight's tasks, however, will be to check the telescope's optical quality, and that does require it to be thoroughly "equilibrated" to outdoor conditions.

Maksutov Cassegrains tend to take longer than SCTs to cool off, especially in apertures larger than 6-inches, so "an hour or two"—or more—may be required for them to equilibrate. The reason for this difference is controversial, with some optical gurus asserting the thicker Mak corrector does not help speed along the cooldown time. The fact is that these telescopes *do* take longer to adjust, whether that is due to their "salad bowl" correctors or just because their longer focal length/higher magnification nature exaggerates the optical problems of a nonacclimatized scope. Longer cooldown times may also be required for SCTs larger than 8-inches or if the temperature differential is large between outdoors and indoors.

After a good spot has been found for the CAT, the next thing to do is assemble and level the tripod. There is no need to be obsessive. Getting the tripod precisely level will not, contrary to what some go-to users think, improve object-finding accuracy. Ensuring the scope is level *is* a help during alignment since the closer an alt-azimuth-mode scope is to level, the closer it will come to initial alignment stars. Celestron scopes are a little picky about tripod leveling when the SkyAlign procedure is used, but there is still no need to obsess. Get the thing reasonably level with a bubble level and move on.

When it is time to place CAT and mount on the tripod, follow the same procedure as when assembling it for the fake alignment, referencing the manual and the instructions in Chapter 5. As with the fake alignment, even if a fork-mount scope is to be used in equatorial mode on a wedge later, set it up in alt-azimuth mode tonight to simplify outdoor setup the first time. If the CAT's optical tube assembly is mounted on a GEM, point the right ascension axis of the mount north, using a compass if necessary (if Polaris is not visible), place the scope on the mount, and secure it according to the manual's instructions. In the Southern Hemisphere, a compass will be a necessity since the southern Pole Star is a dim magnitude 5.5. At this time, GEM users should skip ahead to the polar alignment section that comes just after the Tips for Happy Go-toing. When the mount is polar aligned, return to this section.

While waiting for the telescope to cool and darkness to arrive, install the accessories. If the finder was removed for storage, reattach it to the OTA. Remove the rear port's cap and thread on the visual back. Install the star diagonal and insert a low-power ocular into it. Some amateurs like to wait until darkness comes to screw on the visual back, diagonal, and eyepiece, leaving the rear cell uncapped until then to speed cooldown. But, you might want to wait a little longer for cooldown than try to figure out how to remove a mosquito from the OTA interior—something that has happened to amateur astronomers a time or two. Either attach the diagonal and eyepiece or leave the rear port capped to keep dust and critters out.

Connect the CAT's hand control and battery. Plug the HC into the proper port (be sure) and, after checking that the power switch is in the off position, connect the direct current (DC) power cable to scope and battery. If an AC adapter will be used to power the CAT, get set up with extension cords and power strips as needed. Do not use an

Plate 46. (Heater) Correctly positioning a dew heater strip behind the corrector assembly is important for good performance. Credit: Author.

extension cord any longer than absolutely necessary. The voltage drop incurred by a long cord run can make some computerized telescopes act "squirrelly."

With darkness falling, it is time to prepare the scope's dew-fighting tools. If the only antidew provision is a dew shield, set it aside until it is time to start observing. There is no point in exposing the corrector to dust and the depredations of birds until it is time to begin. Unless the backyard is large and open, the dew shield is probably all that will be needed to keep the corrector dry. Trees and houses ringing the scope tend to act as a natural dew shield, blocking portions of heat-sucking sky from the scope's view. If another dew-busting apparatus will be needed, go ahead and drag it out. Connect a dew zapper gun to its battery and place it somewhere where it will be handy. If a corrector plate heater system has been purchased, install it. Some SCT users wrap the heater strip over the corrector assembly at the end of the tube, but some of the best results come by wrapping it around the tube itself, just behind the corrector assembly (Plate 46). Where does the dew heater control box go? You can attach it to a tripod leg with Velcro.

Finder Alignment

A go-to scope will have to be pointed at alignment stars before it will find anything. To do that, the telescope's finder will have to be properly aligned. If the scope is a non-go-to model, accurate finder alignment is even more vital since the finder will be used to locate all objects for viewing. In an aligned finder, what is in the crosshairs of an optical finder or under the red dot of a zero-power sight is also in the center of the main telescope's field.

There are two ways to adjust a finder's alignment: by using a distant terrestrial object or by using Polaris or another bright star. A star is generally best since a terrestrial target must be far enough away that it will come to focus in the main scope and also far enough away that parallax is not a problem. If an object is too close, the physical separation between the main scope and the finder will cause targets centered in the finder to be "off" in the main scope, no matter how carefully the finder was aligned. A Polaris alignment will probably be required for a red-dot sight since the dot will likely not be visible in daylight. Why Polaris? For all intents and purposes, it does not move, which makes it a great alignment "tool."

To align the finder, insert the lowest-power eyepiece available in the main scope and remove the dust cap from the corrector. Uncap the finder objective and eyepiece or switch on a red-dot model. Unless the scope is one of the few that cannot be moved except with the hand control, it does not have to be powered up for finder alignment; just unlock the mount's locks and slowly move in the direction of Polaris. As the star is approached, look through the finder and continue to move the OTA until the star is in the crosshairs or under the red dot. When it is centered in the finder, lock both telescope axes.

Take a look through the main telescope. If all that is visible is something that looks like a donut, a round blob with a dark center (the shadow of the telescope's secondary mirror), turn the CAT's focus control until the star (that is what the donut is) becomes as small and sharp as possible. If it gets bigger, turn the control in the opposite direction. What if nothing at all is visible? It may be that focus is so far off that the star is a huge, invisible blur. Turn the knob a few turns in either direction experimentally and see if anything appears. Still nothing? It is likely the finder is so badly misaligned that Polaris is outside the field of even the lowest-power eyepiece. Move the scope slowly in all directions using the mount's slow-motion controls if it has them (and assuming it is okay to use them with the power off—check the manual) and sighting along the side of the tube if necessary until Polaris is in the eyepiece's field. If that does not help, move the scope to the Moon if it is in the sky or a streetlight. Neither of these is an ideal finder alignment target, but they can be used to get the finder "in the neighborhood."

When the star or other object is in the field of the main scope, tighten the mount's locks and look through the finder again to see if Polaris is still centered. It probably is not. Adjust the finder's aim until Polaris is back in the crosshairs by means of the adjustment screws in its ring mounts or, for a zero-power finder, by tweaking two little knobs or screws, one for left/right and one for up/down. When it is centered, look through the main scope again. Is it still in the middle? If not, adjust the mount until it is and go back to the finder and readjust that. Keep going, maybe changing to at least a medium-power eyepiece in the main scope, until whatever is put in the finder crosshairs or under a red dot is reliably centered in the main scope's eyepiece.

What now? Take another look at lovely yellow Polaris in the main scope. Can you see the tiny spark that is this double star's "little" companion? Whether you can or not, just enjoy the sight of the new CAT's first star for a moment. Savor the wonderful feeling that comes with taking first light with a new telescope and do not feel embarrassed if you find yourself yelling for your family to, "Come look at the beautiful star!"

Go-to Alignment

The specs of today's go-to scopes are impressive. The HC "library" contains tens of thousands of distant deep space objects, it knows the details of all of them, and it knows where each is located in the sky. That's pretty smart, huh? Nope. Computerized scopes are actually very dumb. They do not know a thing about the sky until you tell them. You tell them by entering time, date, location, and position information and by pointing them at two or three bright "alignment stars." These stars allow the telescope computer to develop a "model" of the sky in its pea brain (Figure 3). Once that is done, the CAT will impress, reliably pointing at those thousands of objects. Remember, though, that it can only do that accurately if it has been given accurate working information. For good go-to results, be scrupulous about entering data correctly and, even more important, doing a good job of centering alignment stars.

To get started, flip the telescope's on-off switch to on and follow the instructions in the manual and on the HC just as during the fake alignment. As before, the step is often to place the telescope in home position (some Celestron scopes skip this step). During the fake alignment, a compass was used to point the telescope north if pointing north was part of the "homing" process. This time, Polaris is the north reference. A compass would work, but that is usually not a very accurate way to point to *true*

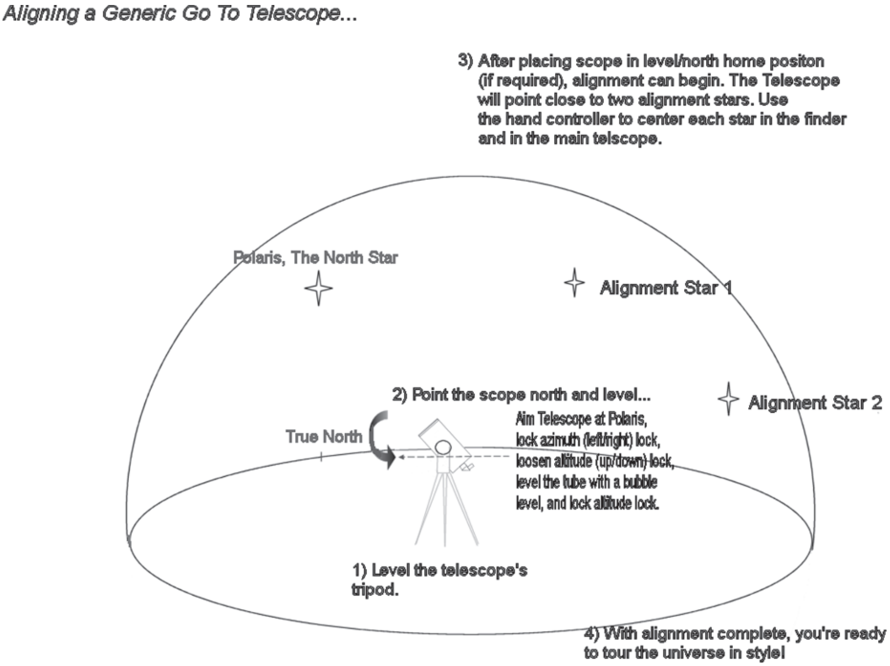

Figure 3. (Go-to Alignment) The go-to alignment process, which allows the telescope computer to develop a 'model' of the sky. Credit: Author.

north. In many areas, true north, what the scope wants, and "magnetic north," what a compass shows, differ. If Polaris can be seen, aiming north is easy. Undo the locks on the mount and point the scope at Polaris, centering it in the finder. Then, lock the RA/azimuth lock, level the tube using a bubble level if leveling is required, and lock the declination/altitude lock. Double-check that both locks are firmly in place before proceeding. Remember, the telescope cannot move under computer control unless both locks are firm.

Enter time, date, latitude, longitude, and any other required data as instructed by the HC and the telescope manual. If the telescope is equipped with a global positioning system (GPS), it will enter most of the data itself. The telescope should be able to determine time, date, and geographic position from GPS satellites if it can get a "fix." Most GPS scopes will not set the time zone or daylight savings time status, so double-check these entries. Some non-GPS Meade scopes, the LNT models, retain and update date and time from session to session and will not require these data to be entered every time the scope is used unless it has been moved to a new time zone or a geographic location greater than about 60 miles from the previous one.

It is time for the telescope to point at its go-to alignment stars. Select the alignment mode that allows the scope to choose its own stars ("Easy," "Auto," etc.) and push the "go" button—"Enter" or "Align," depending on the scope model—to begin. If you want to try SkyAlign, that is fine. Just be sure to follow the manual's "rules" for star/object selection carefully. The Celestron scopes' two-star mode seems to be a little quicker the first time out. The motors will hum (or grind), and the tube will slew to the place where it thinks the first alignment star ought to be. This is when novices often freak out. Usually, the telescope will stop at a spot considerably distant from the specified star. Even with the tripod precisely leveled, the scope accurately placed in home position, and all data entered correctly, it is almost certain that the chosen star will not be visible in the telescope's eyepiece. It may not even be in the finder scope. What happens now? Is it time to give up and start over? Is it time to call the dealer?

If the telescope stops half a sky away from the correct star or does something wacky like pointing at the ground, something *is* obviously wrong. Check the setup procedure in the manual and the troubleshooting tips in this chapter. If, however, the scope stops only a relatively short distance from the first alignment star—say, one or two fists' widths when a fist is held at arm's length (10 to 20 degrees)—the telescope is probably okay. Just move the star into the center of the finder's field using the direction buttons on the HC and center it in the main eyepiece. If the HC moves the scope too quickly or too slowly, adjust slewing speed by following the instructions in the manual.

If you are a new astronomer and not overly familiar with the sky, there may be one other big monkey wrench thrown into the go-to alignment business: How do you know whether you are centering the correct star? When the telescope stops moving, there will probably be quite a few stars visible in the finder. Some astronomy old-timers will suggest you stop, get a chart, and begin to learn the bright stars. That is not a bad idea since knowing which star is which is handy knowledge to have. You do not have to sit down and learn all those stars right now, though. Here is a trick: Alignment stars are *always* bright. Use the brightest one closest to the place where the scope stopped.

Center the first star as precisely as possible. You probably should use a medium-power crosshair reticle eyepiece (available from most scope dealers). When the first alignment star is dead center in the ocular, move on to the second one by pressing Align or Enter as required. Center star number two and press the button that accepts it. If everything has gone well, the HC will think for a while (sometimes for minute or more) and display "Alignment Successful" (unless it is a GEM, in which case it may need several more alignment stars first). What if it says "Alignment Failed"? Most of the time, it is not the scope, it is the operator; usually, needed data have been entered incorrectly. Power the scope off and start all over again. If it turns out it was "pilot error" and not the fault of the scope, do not beat yourself up. If you still do not get that "successful" message, proceed to the troubleshooting section. Otherwise, try a go-to or two.

Go-toing the First Go-to

Assuming the go-to alignment was completed successfully, it is time to let it rip: Send the telescope to its first object. Which object? That is for you to decide. Pick something exciting that is also easy to identify. Jupiter, Saturn, M42 (winter), M13 (summer), or some other bright and spectacular object is perfect both to verify that the scope is working properly and to give you a treat for all the work you have done. How exactly do you go-to an object? That depends on the scope. Reference the manual for instructions. As mentioned in Chapter 5, objects are available from dedicated NexStar buttons (the Autostar II also has this feature) and are accessed from nested menus on the Autostar. However it is done, send the CAT to something nice and spend a while enjoying the view and showing it off to family and friends.

Go-to Troubleshooting

If the go-to alignment has been done and redone carefully, but the scope *still* will not find objects, the following discussion, the manual, and the Quick CAT Troubleshooting Guide provided with this chapter should help.

Alignment Problems

An "Alignment Failed" message is almost always the result of user error, specifically misidentification of alignment stars. As noted, alignment stars are always bright, but there are areas in the sky where there are plenty of bright stars. If the CAT's slew stops at a point where it is midway between bright stars, it is quite possible for novices to pick the wrong one. Heck, it is easy for an experienced observer to make a wrong choice, especially when most telescope HCs identify stars by their proper names instead of Greek (Bayer) letters or Arabic (Flamsteed) numbers. Sure, you know where Arcturus is, but where the heck is "Rasalhague"?

What is the solution? Keep a star chart on the observing table during alignment. What if you still cannot figure out which star the telescope wants? Have the telescope select a different star. Even in "auto-alignment" modes, go-to scopes will allow the user to choose alternate stars (when operating in the backyard, it is likely some first choices will probably be blocked by houses and trees anyway). Use the "Undo" button on a NexStar or the up/down keys on an Autostar to scroll through alignment star choices. Usually, the first star the scope picks will give the best alignment "solution," but even if go-to accuracy suffers a little from using alternate stars, at least it will be working.

SkyAlign users do not have to be able to identify alignment stars, but they are required to choose good ones. What is good? First, choose three bright objects. Even more important, the second of these three objects should be as far as possible from the first one—at least 90° away. The third choice should not be on a line connecting the first two. Although it is possible to use the Moon as an alignment object, don't do that unless there is no choice due to obstructions. Planets can also be used, but generally bright stars yield better SkyAlign alignments.

Another common cause of alignment problems is failure to place the scope in home position or failure to position it in home position accurately. Telescopes that require homing do so for one reason: They need to know their exact starting position before heading for alignment stars; if they do not know where to start, they will never be able to "hit" alignment stars. Understand how to home the telescope, and do so accurately.

Poor Go-to Accuracy

The "Alignment Successful" message appeared on the HC, and the scope slews to where it thinks the object of choice *should* be. But, there is nothing in the eyepiece. The root of this problem is usually insufficient care taken in alignment star centering. Center the stars in the main scope's eyepiece as accurately as possible, preferably using a medium-power crosshair reticle eyepiece.

Another potential cause of poor go-to is backlash. The gears on most telescopes have some slack in them. That can be a problem for go-to accuracy if the scope does not know about it during alignment. Meade telescopes inform the computer about backlash via a procedure called *drive training*, which is found in the Autostar utility menu. This procedure has the user point the scope at a distant terrestrial object (Polaris works even better). The CAT then slews away from the target and has the operator recenter it with the HC direction buttons, enabling the computer to determine the exact amount of backlash present. Be sure to do both azimuth *and* altitude training; they are separate procedures in the hand control. Celestron scopes use a simpler method to take into account backlash effects during alignment. When centering alignment stars with the NexStar controller, *only* use the up and right keys (down and left on some models; see the manual) for final centering. Down and left can be used to position the star in the eyepiece field initially.

There is one other major reason nothing is in the CAT's eyepiece after the slew stops: The object selected is too dim for the scope or conditions. Just because the Autostar's object library includes M74 that does not mean that terrifyingly dim face-on Messier galaxy will be visible from a bright backyard with an ETX90.

Finally, Meade and Celestron go-to CATs work well, but they are not dead-on accurate all the time across the entire sky. Objects in the east, for example, may be near the center of the eyepiece field, while those in the west are not visible at all. One way to fix that is to "sync" the scope on a bright star in the area of interest. Go to a prominent star in the "off" area, center it in the scope, and, following HC/manual instructions, sync it. That alters the scope's model of the sky and ensures objects in the area of the sync star wind up in the eyepiece. The only problem with syncing is that when the scope is moved very far from the sync star, go-to accuracy will degrade rapidly. Celestron scopes include an "unsync" feature that returns the sky model to its original condition.

As a final suggestion, If you are having go-to problems in a particular part of the sky, just switch to your lowest-power, widest-field eyepiece to give the scope the best chance of landing on its targets; most of the time that works fine. Some scopes feature a "Precise Go-to" mode that also works well. When Precise Go-to is turned on, the scope will stop at a bright star in the area of the target object. The observer centers this star, pushes a button, and the telescope continues on to the requested object, which will usually wind up in the field thanks to the "auxiliary centering" of the bright star.

Lost Alignments

Sometimes, it would be nice to be able to loosen a go-to telescope's locks and move it by hand. It is a lot quicker to move a scope from one side of the sky to the other by hand than with the scope's motors. Unfortunately, all currently made go-to CATs lose alignment when they are moved by hand (the optical encoders that determine the telescope's position are part of the motor assemblies). If a motor is not turning, the computer does not know the telescope is moving. The only way to move a go-to scope "manually" without losing alignment is to use the directional buttons on the HC. That is no faster than a go-to but will allow finding objects the old-fashioned way, by star hopping.

Poor Lunar and Planetary Accuracy

It is not unheard of for a go-to telescope to place deep sky objects and stars dead center in the eyepiece field of view but "miss" the Moon and planets. Most computerized telescopes have trouble locating the Moon due to the complicated calculations involved in figuring out Luna's rather eccentric path across the stars. Planets also move across the starry firmament, but their paths are slower and more regular. If the telescope has a hard time with planets, the reason is usually poor time/date/location data. Neither time or latitude and longitude entries have to be exact to the second or even minute, but if these things are off by hours or degrees, the planets and Moon may be missed. The CAT has to know when and where to land on a planet, especially the relatively rapidly moving inner planets. If the Moon or a planet is *always* off 15°, check daylight savings time on/off status. Stars and planets move across the sky at the sidereal rate of 15° per hour (the Moon's speed is only a little different). If a planet is off 15°, th'at usually means time is off by 1 hour, either because of wrong daylight savings time status or a wrong time zone entry.

Tips for Happy Go-toing

- What is the number one cause of poor go-to scope performance? *Poor power*. As has mentioned throughout this book, if the telescope does not receive adequate, “clean” electricity, expect it to act weird. This is especially common when using a small AC adapter as a power source. Once, when using one of these “wall-wart” supplies with a NexStar 11 (one supplied by Celestron, incidentally), my scope’s computer decided Alpha Centauri would be a good alignment star for me at my latitude of 31° north. Run the telescope off a strong battery such as a (fully charged) jump start power pack for best results.
- Tired of the nagging “do not look at the Sun” warning Meade Autostar HC shows at startup? It can be turned off by going to “Display Options” in the Autostar’s (or Autostar II’s) utility menu.
- Do the messages on the Autostar’s display scroll by so fast they are difficult to read? Slow them down (or speed them up) with the up/down (not direction) keys.
- Does it look like the scope is going to crash into a tripod leg during a go-to? Most often, the scope knows exactly what it is doing and that will not happen, but if a go-to needs to be stopped for any reason, remember to press one of the direction keys to stop a Celestron or any key *except* a direction key or the go-to button on a Meade.
- Would you maybe like a little information about an object before wasting time going to something that is dim or unimpressive? Both the Autostar and NexStar controllers can give an object’s vital statistics, including magnitude (brightness). With the object ID displayed on the HC, press “Info” on the NexStar controller or the down key on the Autostar.
- Do a go-to scope’s motors sound like weasels with tuberculosis? *Loud* weasels with tuberculosis? Afraid the scope will actually wake the neighbors? Meade allows the user to select a “quiet mode” on the Autostar. Doing so slows the scope’s max slew speed, but will keep the neighbors in their beds.
- Controlling a go-to scope with a laptop computer can be fun and useful, but wait until you are comfortable with basic scope operation before adding *another* computer to the mix (see Chapter 10 for more on personal computers [PCs] and telescopes).
- Are go-tos good but not great despite careful alignments? Accuracy problems can be caused by poor scope balance. Undo the telescope’s locks and see if the tube has a tendency to move by itself. If so, adding small counterweights (available from most telescope dealers) to the tube and fork may improve accuracy. GEM scopes can be balanced without extra weights by following the procedures in Chapter 5. Usually, GEM go-to accuracy will be best if the scope is not actually precisely balanced but is just slightly east heavy in RA.
- If the scope is acting funky and nothing seems to help, a computer reset may fix it. Doing so will return the HC to factory defaults, so remember to reenter time zone and other site-specific data. Reset (called “Factory Settings” on the Celestron NexStar) is an option in the utility menus of both Meade and Celestron HC.

- Resist the urge to tinker with the CAT's innards. If it is working okay, leave it alone. If it is not, consult the manufacturer. Here is Uncle Rod's number one go-to scope rule: The only enemy of good enough is more better. If it is doing what it is supposed to do, relax and enjoy despite contrary advice found on Internet sites and groups.
- Do keep an eye on the Internet for scope software updates. Most go-to scope manufacturers add features and exterminate bugs regularly, and if the HC is "user updatable," a few minutes downloading and installing new software may make a CAT act like a whole new—and better—scope.

POLAR ALIGNMENT OF GEMs AND EQUATORIAL-MODE FORKS

GEM Alignment

GEMs must be at least casually polar aligned if they are to track the stars and (maybe) go-to accurately. The closer the mount's RA axis points to the true pole, the more precise its tracking (but not necessarily go-to) will be. The major symptom of poor polar alignment is constant object drift in declination (north/south) in the eyepiece. There are three basic methods of polar alignment: boresight, borescope, and software assisted.

The first step for polar alignment for Northern Hemisphere observers is always locating Polaris as it provides a prominent signpost to the true North Celestial Pole. Since Polaris is the end star in the Little Dipper's handle, that constellation can be used to find it if light pollution has not made dim Ursa Minor totally invisible. Another way to locate Polaris is by its altitude and azimuth. Using a compass, look north. Polaris will be in that direction and at an altitude equal to the site's latitude. If the latitude is 40° , Polaris will be 40° above the horizon. It will be eminently noticeable, since second-magnitude yellowish Polaris is the only bright star in the area.

Some GEM mounts, like those sold by Celestron, do not need overly precise polar alignment to yield good go-to performance. Just sighting Polaris through the hollow bore of the RA axis (with no polar scope installed) is good enough to ensure excellent go-to accuracy, and more precise polar alignment will not improve go-tos. Tracking will not be as good as it would be with a more precise polar alignment, but that is not usually a problem for visual observing.

To perform a boresight alignment, set the telescope up with the RA axis pointed north and elevated to an angle that matches the site's latitude. Altitude is adjusted on most GEMs with the aid of a latitude scale on the side of the mount and a simple bolt arrangement: Tighten a bolt on the "south" side of the mount and loosen one on the "north" side to raise the RA axis; do the reverse to lower it. Before beginning, remove any caps blocking the polar bore (usually one on each end). It is almost always also necessary to move the mount in declination until the telescope tube is perpendicular to the polar axis to open a hole in the intruding declination shaft. Sight through the south end of the bore and adjust altitude (with the two bolts) and azimuth (usually via a pair of knobs) until Polaris is centered. If the mount is way off in azimuth, it may be necessary to lift it and the tripod bodily and turn it until Polaris is visible in the bore before doing finer adjustments with the azimuth adjustment knobs.

A few German mounts, including Celestron's CGEs, do not have hollow polar bores. What do you do then? Sighting along the polar axis or centering Polaris in the main scope's finder with it set to a declination of 90° and the counterweights "down" is "good enough."

Not all GEMs deliver good go-to accuracy without a more accurate alignment than that provided by the boresight method. One way to get better accuracy is with a polar alignment borescope (Plate 47). This small refractor fits into the hollow bore of the RA axis (or is mounted beside it). The borescope will have a reticle similar to that in Plate 48. Move the mount in altitude and azimuth until Polaris is in the little circle provided for it on the reticle and the mount is polar aligned, just like magic—simple.

Unfortunately, it is not quite that simple. Polaris circles the actual North Celestial Pole once every 23 hours 56 minutes and 4 seconds at a distance of about two-thirds of a degree. For that reason, the polar scope must be rotated (usually by moving the mount in right ascension) until the Polaris marker is in the proper position for the date and time of day when the alignment is performed. That is done by rotating the mount in RA until the proper day and time line up on a pair of graduated scales. Before setting date and time, these dials must be calibrated for the user's longitude; see the mount's instruction manual for details. Some polar scopes use a simpler if somewhat less-accurate method of calibration: The reticle will show the positions of several constellations near the pole. Turn the scope in RA until the constellations are in roughly the correct positions, and the polar scope will be ready for use.

If these instructions sound way too complicated, there is a trick you can use that eliminates the need to calibrate the polar scope. Using this method, the date/time

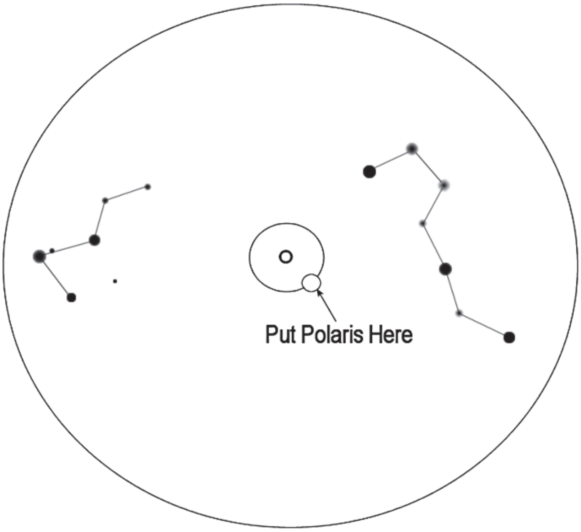

Plate 47. (Polar Reticle) Placing Polaris in the proper spot on the polar alignment scope's reticle yields an alignment good enough for most purposes. Credit: Author.

Plate 48. (Polar Scope) The eyepiece end of a German equatorial mount's polar alignment borescope. Credit: Author.

scales are not needed. The key is a small PC (Windows) program, PolarFinder. Given location (longitude) and time, it will display a graphic that shows where Polaris should be placed. See Appendix 2 for further information.

How does alignment accuracy compare to that done by calibrating the polar scope for time and date? There does not seem to be any noticeable difference, and actually this method is more accurate than the line-up-the-constellation-figures routine.

A go-to scope has a computer. Can't that help in polar alignment? Indeed, it can be. Some GEMs, most notably Celestron's CG5 and CGE mounts, include a built-in polar alignment software routine. Select this from the HC utility menu following a successful go-to alignment, and the mount will slew to the place it thinks Polaris would be if the mount were precisely polar aligned. The user is then instructed to adjust the mount's altitude and azimuth (*not* RA and declination) until Polaris is centered in the crosshairs of the finder and in the main scope's eyepiece. When that is done, the mount is polar aligned. This method yields an alignment that is at least as good as a borescope alignment and maybe a bit better. This routine should be more than adequate for guided charge coupled device (CCD) imaging at short focal lengths. The only catch is that since the mount head has been moved, the go-to alignment must be redone following the polar alignment.

The preceding polar alignment methods ensure accurate go-to performance and will deliver tracking good enough for all visual use. If serious imaging is the goal, however, most amateurs use a much more accurate method of alignment called *declination drift*. Drift alignment takes a minimum of a half hour to perform and is only needed for imaging. See Chapter 11 for instructions.

Wedge Alignment

A CAT setup on a wedge needs to be polar aligned, just like a GEM. Some fork-mount CAT OTAs have finders with polar alignment reticles that can provide a semiaccurate alignment, but most wedge users just do a drift alignment as described in Chapter 11. The only reason to put a fork on a wedge is for imaging, and a drift alignment is almost always required for imaging quality tracking, whether a finder of this type is available or not. A "polar finder" can shorten drift time, however.

Southern Hemisphere Polar Alignment

Southern Hemisphere observers cannot polar align on Polaris—it is invisible. Polar alignment south of the equator is a little more difficult than it is in the north because there is no bright star to mark the location of the South Celestial Pole (SCP). The SCP lurks among the dim stars of the far southern constellation, Octans, the Octant. The southern pole star, the star currently closest to the SCP, is Sigma Octanis, which is pretty dim at magnitude 5.5. It is almost as well placed as Polaris, however, being approximately 1 degree from the SCP at this time.

Sigma Octanis should be visible through a polar borescope, and the process for aligning on it is identical to that for Northern Hemisphere alignment. There should be a circle on the borescope reticle for Sigma or other stars in the area. Place the stars in their spots (assuming the borescope is properly calibrated), and the mount is aligned.

What about a simple sight-through-the-bore alignment? If the skies are dark and Sigma is high enough in the sky, that is possible. Frankly, any scope for which a boresight alignment is good enough, like the Celestrons, is probably forgiving enough to provide good go-tos if the RA axis has been pointed south with the aid of a compass and elevated to an angle equal to the site's latitude. Do not forget to flip the "N/S" switch on the mount to "S" or select "Southern Hemisphere" in the HC to set mount rotation for Southern Hemisphere operation before beginning a go-to alignment.

Many beginners worry needlessly about polar alignment. The foregoing "easy" methods are, again, all that is required for visual observing. The occasional declination adjustments required to keep a target object centered will not get in the way of productive observing.

How Good Is the New Scope?

If the telescope mount is hitting go-to targets, seems to track well, and is not overly shaky, the mount is in good shape mechanically, electrically, and electronically. Often, getting a mount that works reliably is the biggest hurdle when buying a new mass-produced scope. Go-tos and mount steadiness are not the only things to worry about, however. Before giving the new CAT a clean bill of health, pay some attention to the OTA's mechanical and optical integrity.

Focus Shift

As mentioned several times, most catadioptric scopes focus by moving the primary mirror forward and back. That works well, but, especially in scopes larger than 6-inches, there is always some play between the primary and the baffle tube it slides on; this causes the mirror to tilt slightly and images to move across the field. If the movement is small, not much more than the width of Jupiter, 45 arc seconds, focus shift is a minor annoyance and nothing more. If focus shift is enough to move an object off the chip of a CCD camera or out of the field of view of an eyepiece, however, it is a problem, and the scope's manufacturer or the dealer should be consulted.

Image Clarity

Do images in the new scope seem a little less sharp than expected? That usually does not mean the CAT has bad optics. SCT optics especially are pretty consistently good these days whether they come from Meade or Celestron. The problem is most often collimation, the alignment of the secondary and primary mirrors. See Chapter 9 for collimation instructions. Do not feel bad if the new scope arrives out of collimation. Given the bumps a scope must take on its way from the factory or dealer, it is amazing when one arrives *in* collimation. What does miscollimation look like? Stars, even those near the center of the field, tend to look more like little comets than points.

A close runner-up to collimation is cooldown. If the scope has not been allowed to acclimate to outdoor temperatures, to equilibrate, there is no way it will deliver good images. On some evenings, a half hour or even 2 or 3 hours is not enough time for a complete cooldown. When the temperature is falling steadily, a larger-aperture CAT, especially an MCT, may *never* cool off. "Shimmering," or moving images, are the hallmark of incomplete cooldown. The Moon or a planet will tend to waver in a large-aperture SCT and bounce around in the field of a small-aperture one. The star test (discussed in the next section) can reveal cooldown problems.

Closely related to cooldown is *seeing*. A scope can be perfectly equilibrated but still deliver poor images if the atmosphere above the observing site is disturbed. Poor seeing is typical for many locations in the wintertime, when the jet stream is roaring overhead. How do you tell if the seeing is bad? Take a look at the sky. Are the stars twinkling madly? If so, do not expect good seeing. For a more scientific forecast of seeing conditions for a particular location, try the Clear Sky Clock at http://www.cleardarksky.com/csk/. This weather tool for amateur astronomers gives seeing predictions in addition to transparency and cloud cover forecasts for specific locations.

If seeing is poor, forget doing high-magnification planetary observing, but it may still be possible to have some fun by sticking to low powers and the deep sky. Higher magnifications exacerbate problems with seeing and cooldown. Star clusters, nebulas, and galaxies are also degraded by poor seeing, but far less so than planets. Generally, smaller-aperture telescopes are less affected by seeing than larger-aperture ones. A 5-inch SCT, after all, is looking up through a smaller diameter column of disturbed air than a 10-inch.

The Star Test

Assuming everything else—collimation, cooldown, and seeing—checks out, but images remain poor, it might be wise to test the CAT's optical quality. That is relatively simple to do via the star test, in theory at least. In theory, the star test is easy to perform and very informative. On a night of good seeing—this is very important—point a telescope at a medium-bright star such as Polaris. Use an eyepiece that gives a magnification of about 150x and rack the star out of focus slightly until four or more diffraction rings are visible; the star should now look like a little bull's-eye, as seen in Figure 4a.

Compare the way the diffraction rings of a slightly out-of-focus star look on each "side" of focus, intrafocal (inside focus), and extrafocal (outside focus). In an SCT or other moving mirror-focusing scope, intrafocal images come when the focus knob is turned counterclockwise through sharp focus and beyond; extrafocal images happen when focus is passed by turning the knob clockwise. If the patterns are identical on each side, then the scope's optics are perfect. Slight differences indicate optical problems. Figure 4a shows how a perfect telescope's intrafocal and extrafocal star diffraction patterns should look.

Star test tolerances are stated in terms of wavelengths of light, and a good optical system will have errors in its figure no larger than a quarter of a wavelength of light. The fact that the star test can easily detect such tiny irregularities gives an idea of how sensitive it is. Fortunately, star testing a new scope's optical quality does not require quantifying exact mirror figure deviations. The basic job is merely to examine the appearance of a star's diffraction rings; how they look will tell what is wrong—or right—with a new scope's optics. Note that a telescope can suffer from more than one problem, and that a real-life star test may show diffraction patterns that are the combinations of several different aberrations.

Spherical Aberration

If a CAT's corrector plate is not doing its job, not completely eliminating the primary mirror's spherical aberration, the system is said to be *undercorrected*. The effect of this aberration is to make the diffraction pattern look brighter on one side of focus than the other. More light is being thrown into the rings on one side of focus. The centers of the bull's-eyes on either side of focus are different, with the intrafocal image showing a little disk or fuzz ball in its middle. The extrafocal image shows a darker spot dead center. What is the effect of spherical aberration on in-focus images? Looking at the image of the star in Figure 4b, it does not seem too bad. The diffraction ring around the star is a bit brighter, but that appears to be all. The Jupiter image in Figure 4c tells the tale. At one-third wave of spherical aberration, much detail has been lost.

Telescope optics can also be overcorrected, and that is just as bad as undercorrection. Figure 4a shows that going from under- to overcorrection swaps the way the intra- and extrafocal images look. Otherwise, the bull's-eyes are identical in appearance to the undercorrected patterns. The result of overcorrection in focus is still as much a disaster as undercorrection.

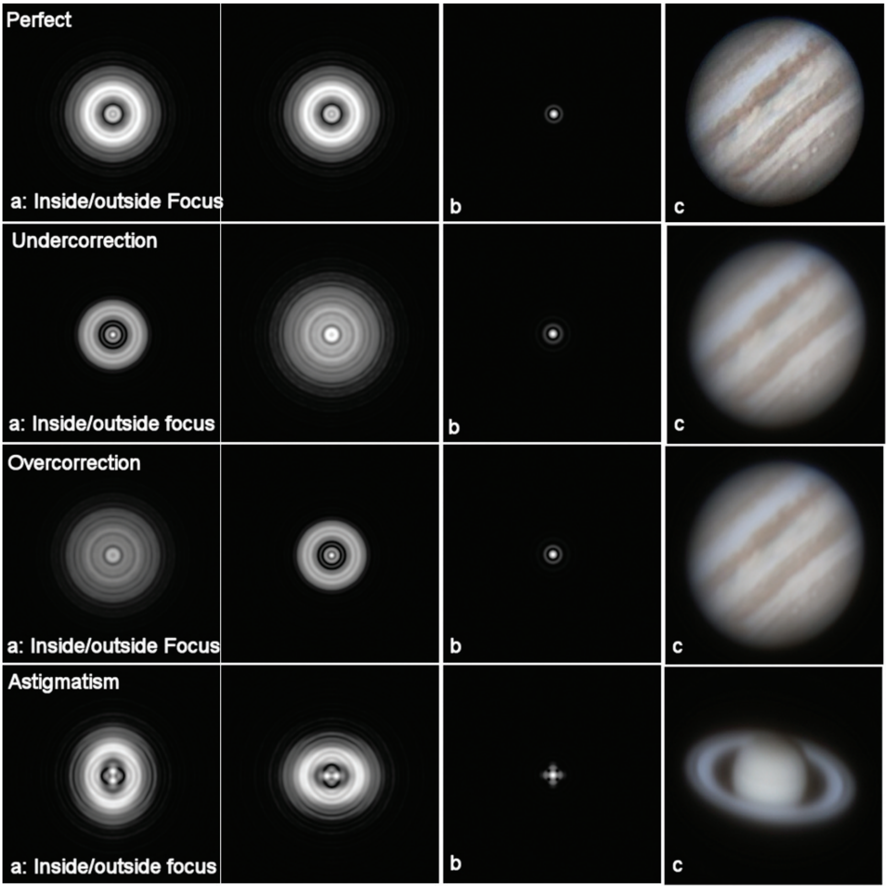

Figure 4. (Star Test 1) Star test diffraction patterns page one. Credit: Author.

Astigmatism

When a telescope mirror is ground asymmetrically—so one axis has a shorter focal length than the other—it suffers from astigmatism. This aberration is less common in machine-made CAT mirrors than it is in home-built Newtonian primaries, but it can still happen. Severe astigmatism, seen in Figure 4a through 4c, makes in-focus stars, especially at the edge of the field, look more like crosses than points. If the aberration is less severe, these stars may merely look slightly elongated or enlarged (unlike stars in a miscollimated scope, they will look worse at the field edge than at the center). Stars at the field edge of a "good" scope will also look enlarged or elongated due to the SCT's naturally curved field, but real astigmatism is very obvious in the star test. The intrafocal and extrafocal diffraction patterns are elongated, with the elongations at an angle of 90° to each other. This elongation is the classic symptom of astigmatism. If astigmatism is suspected, the first thing to do is swap eyepieces. If there are still obvious defects in the stars, rotate your head. If the defects—elongation, "spikes," and the like—seem to track head movement, the problem is your eyes, not your scope or eyepiece.

Turned-Down Edge

Turned-down edge (TDE), shown at the top of Figure 5, is, like astigmatism, less common in commercially made SCTs than in homemade Newtonians. It is still possible, however. The signature of this defect is that diffraction rings on one side of focus are more sharply defined than they are on the other side. TDE happens when the edge of the primary mirror is flat rather than gently sloping to the center, as it should be. During grinding and polishing, the edge has literally been "turned down." Its effect on images can be as bad as that of the other aberrations.

Cooldown

Want to know if the telescope is properly equilibrated to outdoor temperatures? Use the star test. An uncooled scope will have "currents" of hot air coursing through the tube. These often show up as "plumes," one of which is visible in the intra- and extrafocal images in Figure 5a to 5c. Not sure if the plume is due to improper cooldown or some weird optical aberration? Move the scope so the tube's rotation changes (this is easy with an equatorially mounted scope). The plume should not move.

Miscollimation

A telescope whose mirror alignment is less than perfect will show in-focus star images like those in the miscollimation example in 5b. The star looks lopsided, almost like a little comet. The inside and outside focus diffraction patterns of a miscollimated scope have rings that are visibly compressed on one side.

Poor Seeing

Figure 5a shows why good seeing is necessary before attempting the star test. If the air is not still, the in-focus star image will be smeared out, and intra- and extrafocal diffraction patterns will be an absolute mess. Looking at those two images, could you tell whether the scope's diffraction patterns are the same on both sides of focus? Probably not. Trying to star test under conditions of atmospheric turbulence is a complete waste of time.

Star Test Caveats

Sitting in a comfortable den reading about it, the star test seems to be simplicity itself. Aim the scope at a star, defocus, and the exact optical condition of a CAT is

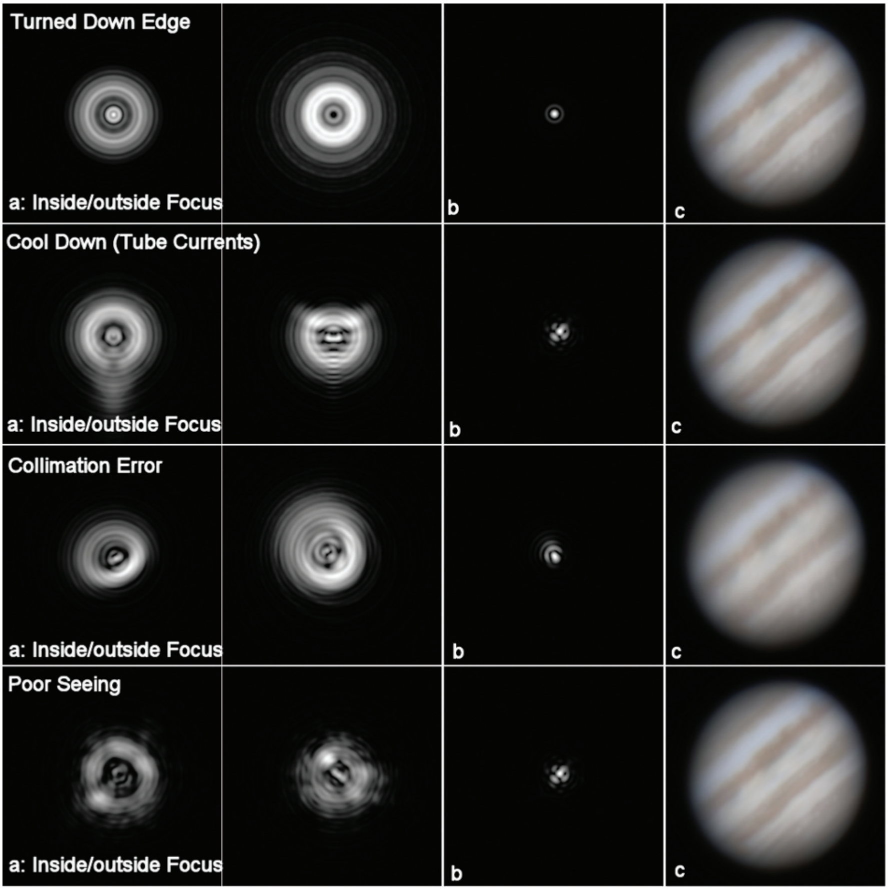

Figure 5. (Star Test 2) Star test diffraction patterns page two. Credit: Author.

revealed. Move outside into the real world, and it becomes more difficult. If the air is not steady—and it is not perfectly steady on most nights—diffraction patterns will be dancing around. They might just as easily indicate "terrible" as "perfect." Even on nights of good seeing, it is never as easy to tell what is going on as it is in the nice, clear, computer-generated diffraction patterns in Figure 4a. The software that produced these pictures, Cor Berrevoets' freeware program Aberrator, is a fantastic tool for star testers, but it cannot duplicate exactly what you will see with *your* scope and *your* eyepieces under *your* sky.

There is also the question of the basic validity of the star test for CAT owners. As has been noted by many CAT fanciers (and telescope makers, including Astro-Physics' Roland Christen), unlike a Newtonian or a simple achromatic refractor, a CAT's intrafocal and extrafocal images are rarely identical, even when the optics are perfectly made. The complex arrangement of lenses and mirrors in these scopes means the in-focus images' "wavefront" can be great, while slightly out-of-focus images are strongly degraded. That does not hurt the scope a bit in normal use, but it is a killer for the star test.

If the star test is not always a good way to test a CAT's optical quality, what is? Go back to planetary images. As is shown in Figures 4 and 5, introducing optical aberrations has a severe effect on the planets. The effect in the real world is just as striking. A look at Jupiter and Saturn at medium to high magnification easily reveals a scope's optical quality. Does Jupiter display plenty of cloud bands and, on good nights, detail within these cloud bands? Does it show subtle extensions and rifts? Does Saturn show off the Cassini division? How about brightness and color variations across the rings? Even more difficult, are a fair amount of Saturn's subtle atmospheric features visible on the disk? If these things are visible in a cooled and collimated CAT, rest assured that the telescope is up to snuff.

Quick CAT Troubleshooting Guide

The Quick CAT Troubleshooting Guide is based on military technical manual troubleshooting guides and lists some common CAT and mount failures and problems, their causes, and possible corrective action. When problems are suspected, naturally the first place to look for solutions is in the telescope's instruction manual. The items listed in the corrective action column are arranged in order of their likelihood of effecting a fix. The final option is always to contact the manufacturer, but for new, out-of-the-box scopes with problems, that should be interpreted to read "call dealer first."

What to Do If Everything Is Not the Way it Ought To Be

If a star test or planetary image seems to reveal subpar optics, what should you do? If you are a beginner, get a second opinion from an experienced SCT-using a fellow amateur from the astronomy club or an Internet group. Couple factors such as collimation, cooldown, and seeing with the anxious feelings that come when testing a new and expensive telescope, and it is all too likely you will condemn an excellent SCT. As a novice, you really do not have a good idea what star test or planetary images *should* look like under a given set of conditions. Get help.

If all the checking and consulting in the world still shows the optics to be punk, get on the telephone. If the CAT is new, call the dealer; if you have had it for a while, call the manufacturer. When you speak to either, describe exactly what you have seen. The good thing is that both Meade and Celestron have excellent records of correcting optical problems. Just be sure you know what you are talking about.

Chapter 8 is the "why you came here in the first place" one: a tour of the night sky's wonders with your CAT.

Quick CAT Troubleshooting Guide

Symptom	Probable Cause	Corrective Action
Computer/Go-to/Electrical Problems		
Telescope is dead. Hand control display is blank, and power-on light is not illuminated.	No power to system. Batteries low or dead, no AC power to AC adapter, faulty AC adapter, cords or connections faulty, fuse(s) blown.	Double-check that telescope/mount power switch is on. Test batteries under load using battery tester (not just a multimeter). If the scope is normally powered by batteries, if possible, switch to AC power. If an AC power source is not available, try a different DC source (12-volt DC battery or internal cells). If the scope is normally run on AC, switch to a DC power source. Check power cords for continuity. Ensure all connections are secure (at both telescope and battery/AC adapter ends). Replace batteries and repair/replace cords as necessary. Check status of fuses inside telescope drive base if present (refer to manual for location/presence) or in the DC line cord (typically, there is a small fuse in the tip of DC "cigarette lighter adapters" that is revealed by unscrewing the tip). If the scope fails to power up after these checks, **CONTACT MANUFACTURER**.
Abnormal electronic indications at power up, especially garbled hand control display or unresponsive hand control.	Connectors or cables faulty, low power, poor power quality. Computer/firmware problems.	Check battery and battery cable. If the battery is low, recharge. If on AC power, switch to DC. Small AC power supplies produce poorly filtered DC that can cause computer problems. Check/clean hand control RJ style ("telephone") connectors. During cold weather (below freezing, especially), battery performance will decrease. Keep the battery warm, at least prior to beginning observing, or operate from an AC power supply. Check/replace hand control connecting cable. Perform a "reset" ("factory defaults" for Celestron NexStar telescopes) of the hand controller to resolve program/firmware problems. If no improvement is noted, try reloading hand control firmware. If the telescope is a Celestron NexStar, try reloading motor control firmware as well. If problems persist, **CONTACT MANUFACTURER**.
Hand controller stops responding to all commands. Display is frozen.	Program problem. Cable problem. Defective hand controller.	Power scope off, wait 90 seconds, and power scope back on. If problem clears initially but returns, check HC cable. Try a hand controller software reload. If the hand controller is still frozen after power up, it may still be possible to reload Meade Autostar firmware via their "safe load" procedure (see manual). If power cycling, a software reload, or a cable check fail, **CONTACT MANUFACTURER**.

Quick CAT Troubleshooting Guide (continued)

Symptom	Probable Cause	Corrective Action
Go-to alignment failure.	Wrong go-to alignment stars were centered. Poor SkyAlign alignment objects chosen. Telescope was not placed in home position properly. Incorrect setup information entered in hand control. Electronic compass or level sensor failure. Circuit board failure. Motor failure or problems.	Use a star chart or planisphere to help ensure correct alignment stars were centered. If stars selected by the telescope were unfamiliar, try alignment again, selecting known stars as alternatives (correct stars will always be the brightest stars in the area where the scope stops). Follow manufacturer guidelines for choosing alignment stars carefully if the telescope does not normally pick them ("Celestron" SkyAlign procedure). Try an alternate alignment method: for instance, Two Star instead of "SkyAlign". If the telescope does not center alignment stars in the eyepiece or finder, do not stop or accept them; center them using the hand control direction buttons. Check manual and online sources for home position setting information. If home position requires pointing scope north and level, use Polaris rather than a compass as a north reference. Level the telescope using a carpenter's bubble level. Check settings in hand control and especially proper "scope type/model" entry. If alignment continues to fail, **CONTACT MANUFACTURER**.
During alignment, the telescope always stops its alignment slew a great distance (more than 10) from target stars.	Incorrectly set time, time zone, date, latitude, or longitude. Poorly leveled alt-azimuth mode telescope. Poorly polar aligned equatorial mode telescope. If the telescope points north during alignment or is pointed north to place it in Home Position, magnetic variation or improper setting of Home Position.	Review hand control entries for correct time, time zone, date, and position entry. The user is required to set time zone and Daylight Savings Time (DST) status (on/off), even with GPS telescopes. Double-check for correct DST state. If the telescope uses an electronic compass for north-pointing, check the manual for a compass calibration (sometimes referred to as "calibrate sensors") routine to correct for magnetic variation. Use Polaris as a north reference when setting Home Position. Use a polar borescope or other aid for polar alignment of an equatorial mode telescope.
Telescope misses go-to targets despite successful alignment.	Poor centering of alignment stars, backlash, normal accuracy variations due to telescope mechanical characteristics. Poor polar alignment with some equatorial mode telescopes.	Use a medium-power (100–150x) crosshair reticle eyepiece for centering go-to alignment stars. Center alignment stars using only up/right or down/left keys as instructed (Celestron). Perform Calibrate Motors and Train Drives routines as outlined in manual (Meade). If objects are accurately placed on one side of the sky and are off on another, switch to a lower-power eyepiece for object finding or use "sync" or "precise go-to" as appropriate. Some GEM and equatorial mode fork-mount telescopes require good polar alignment for best go-to performance. Use a polar alignment aid such as a polar borescope or polar alignment reticle on a finder or a drift alignment (see the astro-imaging chapter) to improve polar alignment accuracy.

Telescope begins slewing uncontrollably during observing.	Low battery, poor-quality AC power, cable problems. Circuit board failure.	Switch to a DC power source if on AC; use an alternate DC source or switch to AC if on battery. Check power cable and connections. Check declination cable if the mount has one. Cycle power to scope (turn scope off and back on), leaving power off for at least 90 seconds. Reset hand control. **CONTACT MANUFACTURER.**
Telescope motors stall.	Unbalanced load. Low battery power due to cold weather. Circuit board problems.	Ensure the telescope is balanced in RA/declination and altitude/azimuth, adding balance weights to fork-mount telescopes as required. Meade scopes may need to have the "calibrate motors" procedure performed per the manual, especially if the power source has been changed (including the installation of new internal batteries). When temperatures are below freezing, battery power output drops, sometimes enough to cause erratic telescope operation and motor stalling. Use AC power or keep battery warm prior to beginning an observing run. **CONTACT MANUFACTURER**.
Motors do not move telescope tube when hand control buttons are pressed. Telescope appears to have powered up normally.	Slewing (moving) speed too slow. Altitude-azimuth/RA declination locks not firmly engaged. Slew limit "filters" in the hand control that prevent the telescope from moving below the horizon or bumping into a tripod leg during slews are incorrectly set. Circuit board problems. If only one axis is affected, defective motor or declination cable.	Follow the instructions in telescope instruction manual to see how to increase slewing speed with hand control. Lock locks on both axes securely. Check "slew limit" settings in the hand control for proper settings. Check declination cable if present. **CONTACT MANUFACTURER**.
Hand control display dims and becomes difficult to read, or displayed messages scroll too slowly	Cold weather dims and slows LCD displays.	Keep hand control by keeping it in a pocket or attaching a small heat source.
Telescope GPS receiver never gets a position fix (finds site latitude and longitude) or takes a long time (more than 30 minutes) to pick up satellites.	Obstructed view of GPS satellites. Failure of receiver to retain almanac data. Faulty GPS receiver.	If the telescope/mount *never* gets a fix, check for a clear view of the sky; especially the celestial equator and southern horizon. If the GPS receiver is an optional add-on module, ensure GPS is turned "on" in the hand control. For a telescope that consistently takes longer than 30 minutes to get a fix, check GPS receiver for the presence of a battery. Some Celestron SCTs use a small rechargeable battery to hold almanac data in memory (see http://www.nexstarsite.com). In some cases this battery can become discharged if the telescope has not been used in a considerable length of time, but can be recharged by leaving telescope plugged in and powered on for 48 hours. If GPS remains problematical, **CONTACT MANUFACTURER**.

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Quick CAT Troubleshooting Guide (continued)

Symptom	Probable Cause	Corrective Action
Objects are difficult to center in the eyepiece using hand control direction buttons.	Slewing speed set too high. Backlash (telescope does not begin moving immediately when a button is pressed).	Follow instructions in the manual to reduce slewing speed of hand controller. Also check the instructions for procedures for reducing backlash.
Fuses in the telescope drive base or DC line cord blow repeatedly.	Mechanical problems causing motor stalling. Electronics failure. Short in power cord/connector.	Test for possible mechanical binding of the mount by unlocking its locks and moving the telescope by hand in altitude/azimuth or Right ascension /declination. Check for damaged power cords and connectors. Verify that replaced fuses are seated securely in their holders. **CONTACT MANUFACTURER**.
Telescope does not communicate with an external laptop computer connected to its serial port. Or communications are intermittent. Or telescope demonstrates erratic behavior (uncontrolled or improper slewing) when connected to a laptop or other PC.	Faulty serial cable or connectors. Improper communications setup. Computer serial port problem. Electronics problem.	Ensure proper style of serial cable is in use (i.e., Celestron for Celestron telescopes, Meade for Meade telescopes). Check serial cable with a multimeter. Inspect serial receptacle (usually on the hand controller). Be sure proper serial (com) port is identified in the program on the PC used to control the telescope. If the computer is using a USB–serial adapter cable, try a different brand of USB–serial adapter or a PCMCIA serial card. Double-check all settings in the PC software (including communications parameters, telescope type, and site latitude and longitude) and in the ASCOM utility if the program uses that to communicate with the telescope.
Telescope is very loud during high-speed slewing.	Most go-to telescope motors are noisy when slewing at maximum speed. Motor gear problems.	High-noise levels are normal for many telescopes/mounts during go-to slews. If the sound threatens to wake the neighbors, speed during go-tos can be reduced for some telescopes, resulting in less noise. See the instruction manual. If motor noise has increased markedly recently, **CONTACT MANUFACTURER**.
Optical Problems		
Images of stars, planets, and other objects are not sharp and clear. Images cannot be properly focused. Planetary detail is lacking.	Poor seeing conditions indicated by an image that "boils," wavers, or moves around in the field of view, especially at high magnifications. The object being observed is too close to the horizon. Poor seeing caused by local terrain.	Wait until seeing conditions improve. Conduct critical observing only when target objects are at least 30 degrees above the horizon. Avoid observing objects "over" heat-radiating roofs, paved parking lots, etc.

Images are poor early in the evening, but improve as the night wears on.	Tube currents and mirror figure problems caused by a telescope that has not been allowed to adjust, or "equilibrate," to outdoor temperatures.	Allow the telescope to cool sufficiently. If the temperature differential between inside and outside is small, 30 minutes is adequate cool-down time. If, however, the temperature difference is large or critical or high-resolution observing or imaging is to be attempted, at least 2 hours should be allowed. A rear port cooling fan, either home built or purchased (**Appendix 1**) can speed cooldown.
Objects are blurry and indistinct. Stars resemble donuts with dark centers.	Telescope not focused.	Adjust the focus until the image is sharp. Turn the control in the direction that makes stars and planets "smaller" or increases the sharpness and contrast of lunar details. Continue turning through best focus until the image begins to defocus again, and then turn in the opposite direction to bring the image back to maximum clarity. If the telescope is initially *greatly* out of focus, all but the brightest objects may be invisible. In that case, point the telescope at a bright star, planet, or a distant terrestrial object such as a streetlight, and turn the CAT's focus knob until the target begins to get smaller/brighter. If no improvement or the image gets worse, turn the control in the opposite direction.
Planets lack detail and stars, even those near the center of the field, are oblong, resembling comets rather than symmetrical points.	The telescope is out of collimation.	Perform rough and fine collimation using the procedures outlined in **Chapter 9**.
Objects are blurred, surrounded by haloes, and dimmer than normal.	Telescope optics *extremely* dirty.	Follow the optical cleaning instructions in Chapter 9. Optics dirty enough to cause performance degradation will be immediately obvious.
Stars at the edge of field are out of focus. When they are focused sharply, stars in the center are out of focus.	Curved SCT field of view or poor-quality eyepiece.	The SCT's curved focal plane will distort stars at the edge of the field. An f/6.3 reducer corrector or a higher quality eyepiece will improve their appearance.
Stars toward eyepiece field edge are badly misshapen and look more like seagulls or footballs than stars. "Footballs" change orientation on either side of focus (astigmatism).	Eyepieces are of poor quality and exhibit astigmatism or other optical aberrations. Astigmatism in user eyes cause Astigmatism in telescope.	Use higher-quality oculars if the edge-of-field appearance is important. If astigmatism appears to be the problem (see the star test section in this chapter), ensure it is not in the observer's eyes. If astigmatism elongation "tracks" as the observer's head is rotated about the eyepiece, the problem is in the eye. If the astigmatism moves as the eyepiece is rotated in the diagonal, the problem is in the eyepiece. If neither, the astigmatism is in the telescope itself. **CONTACT MANUFACTURER**.

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Quick CAT Troubleshooting Guide (continued)

Symptom	Probable Cause	Corrective Action
Few details visible on the Moon and planets at higher powers (150x and above).	Magnification is too high for telescope aperture or current seeing conditions.	Reduce magnification. "Maximum" usable magnification for a given telescope is about 60x per inch of aperture (480x for an 8-inch telescope). Poor seeing conditions, not enough telescope cooldown time, or an inexperienced observer, will limit maximum usable magnification to much less.
Stars and planets were initially clear and sharp, but begin to display halos later in the evening.	Optical elements (corrector plate or eyepiece) have become covered with dew.	Use dew removal/prevention tools including a dew shield, dew zapper gun, and dew heater strips. Early dew buildup will be subtle. The first indication is that bright objects will develop halos of scattered light. As more dew collects on the corrector, detail will be lost.
Objects lack clarity when observed from indoors through a window.	Aberrations introduced by observing through window glass. Seeing problems caused by an open window.	Modern plate glass is surprisingly flat, but some aberrations will be introduced. Opening a window causes air from inside the house to flow out, creating turbulence and ruining seeing. Under normal circumstances, do not attempt to observe through an open *or* a shut window.
Planetary or deep sky images are sharp until a filter is placed on the eyepiece.	Defective or poorly made eyepiece filter. Failure to refocus following attachment of filter.	Replace the filter with a better-made one. Most filters will require refocusing of the telescope after they are added to an eyepiece.
Telescope was precisely collimated in straight-through fashion (eyepiece inserted directly in visual back), but collimation appears off when a star diagonal is used.	Defective star diagonal. A poorly constructed or defective star diagonal can affect telescope alignment.	Either replace the star diagonal with a better-quality unit or collimate with the diagonal in place. If the diagonal is very poor, collimation will only be good for the rotational position the diagonal was in when the telescope was collimated.
Optics are free of dew and dirt, but bright stars display halos.	Tree limbs or other obstructions are blocking the telescope's view of an object. This will appear at first as a halo, a diffuse ring of light around the object, and will cause a loss of detail. Defocusing the image by a large amount will reveal obstructing objects by their outlines against a defocused bright star or planet.	Move the telescope or change its aim until its view is clear of obstructions.

Moon or planet limbs (edges) are rimmed with red and blue light.	Differential refraction. Eyepiece aberration.	Differential refraction caused by thick air near the horizon will give one limb of a planet or the Moon a red-colored border and the opposite limb a blue border. This is *NOT* caused by chromatic aberration in eyepieces or the main optics. This effect can also be caused by tube currents in an uncooled telescope. Do not attempt to observe when the Moon or a planet is less than 30 degrees above the horizon. Allow telescope sufficient cooldown time. If the effect continues, replace eyepiece with a higher quality model.
Focus control action is stiff or rough.	Focus control alignment or bearing problems.	Try moving focus to both ends of travel (do not force anything; if knob does not turn easily, stop). If action does not improve, **CONTACT MANUFACTURER**.
Images move across the eyepiece field of view when the focus control is turned.	Focus shift caused by the moving-mirror-focusing system of SCTs.	About 30 to 45 arc seconds of focus shift are normal in mass-produced SCTs. If the shift is excessive, try moving the mirror to both ends of its travel using the focus control. That will help redistribute grease on the baffle tube. If focus shift is still "excessive", **CONTACT MANUFACTURER**.
Images of all objects poor despite good collimation, adequate cooldown, clear and transparent skies, and stable atmospheric or local seeing.	Telescope optics defective.	If defective optics are suspected, perform the star test. If possible, get a "second opinion" from an experienced SCT user. If results indicate faulty optics, **CONTACT MANUFACTURER**.
Mount/Mechanical Problems		
Tracking is poor. Objects drift out of eyepiece field in only a few minutes.	Poor polar alignment for GEM or wedge-mounted fork telescopes. Poor go-to alignment for alt-azimuth mode fork-mounted scopes.	Improve polar alignment accuracy by using polar alignment aids such as polar alignment borescopes (GEM mounts) and finders with polar alignment reticles (forks). Perform a drift alignment (see astro-imaging chapter). Improve on go-to alignment by precise star centering using a reticle eyepiece.
Images "shake" and vibrate when the telescope or focus control is touched, even at low–medium magnifications.	Too light or improperly assembled telescope mounting. High magnification. Windy conditions. Unbalanced OTA.	Ensure all tripod (and wedge if one is in use) hardware—bolts, nuts, etc.—is sufficiently tight. Tripod spreader should be firm against tripod legs but not so tight it will cause damage. Learn to exercise a "light touch" when focusing or purchase a remote-control electric focus motor. If telescope tripod legs are equipped with both rubber "crutch tips" and spikes, remove the rubber tips to reveal the spikes. Purchase shock isolation "vibration suppression" pads (sold by Celestron, Meade, and Orion) for use under telescope leg tips. An unbalanced condition of the

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Quick CAT Troubleshooting Guide (continued)

Symptom	Probable Cause	Corrective Action
		CAT's OTA (tube) will add to vibration problems. Balance the telescope using optional balance weight systems if necessary. GEMs can be adequately balanced by moving the counterweight along its shaft (an additional counterweight may have to be purchased in some cases) or the telescope along its mounting rail.
A fork-mount telescope is overly prone to vibration (vibrates for more than 5 seconds) when the telescope is set up on a wedge for equatorial mode tracking.	Wedge too light for telescope. Wedge hardware is loose.	Wedge may need to be replaced with a heavier duty model. Check that all bolts; especially those loosened to adjust wedge in altitude, are tight.
High-power images vibrate continuously even when telescope is not being touched.	A stepper motor drive is causing vibration as it moves in discrete "steps" as the telescope tracks.	This usually is due to maladjustment or misalignment of gears and or RA drive motor **CONTACT MANUFACTURER.**
During long-exposure astrophotography, star images trail; they are lines or ovals rather than points.	Poor polar alignment. Periodic error causes star trailing when not "guided out."	See instructions in the imaging chapter for performing an accurate drift polar alignment. Guide out errors either manually with a crosshair eyepiece and a guide scope or automatically using a guide camera. If the telescope mount features periodic error correction (PEC), make a "PEC" recording to reduce periodic error.
Telescope mount movement is very stiff in cold weather.	Grease used to lubricate the mount is overly viscous at low temperature.	**CONTACT MANUFACTURER.**
The telescope can be moved a small amount in RA/declination or altitude/azimuth when mount locks are engaged.	Improper gear mesh.	A small amount (¼-inch or less) of "play" is normal. If the gears are tightly meshed enough to eliminate all slop, they will usually bind and stall the mount motors at some point in their rotation. If play is excessive, **CONTACT MANUFACTURER**.
Tripod leg extensions slip.	Weak or damaged leg extension locks.	Do not over-tighten leg locks, which will cause damage and prevent them from being adequately secured. Never extend tripod legs if they cannot be locked firmly. **CONTACT MANUFACTURER.**

Bolts, nuts, and other hardware on mount and OTA begin to rust.	Low-grade stainless steel hardware was used on mount and OTA.	Some bolts, nuts, and fasteners can easily be replaced with higher-grade stainless steel hardware. Be cautious about removing and replacing hardware on OTA. If in doubt, **CONTACT MANUFACTURER**.

AC alternating current, *CAT* catadioptric telescope, *DC* direct current, *GEM* German equatorial mount, *GPS* global positioning system, *LCD* liquid crystal digital, *OTA* optical tube assembly, *PC* personal computer, *PCMCIA* Personal Computer Memory Card International Association, RA right ascension, *SCT* Schmidt Cassegrain telescope, *USB* universal serial bus

CHAPTER EIGHT

Enjoying a CAT

Beginning Observing

Choosing an SCT or other CAT turned out to be a lot of work, but it's worth it for the reward that's coming. It's time to forget about star tests and go-to alignment procedures and just let the telescope do its thing on the sky. Not that all the work is *quite* over yet. Getting maximum enjoyment from the observing experience means learning how to observe and what to observe.

Preparing Yourself

Observers need to be prepared to face nighttime observing conditions, even if those conditions are merely those of the friendly backyard. This preparation mostly consists of staying warm and keeping insects at bay. A CAT user who is freezing cold or being bitten by skeeters will forget plans for an all-night Messier marathon in a hurry and soon be back inside watching TV.

Even in the summer, keeping warm is a necessity. It's sometimes difficult to believe a person could get uncomfortably cold on an August night in the deep South. But no matter where the observing site is located, cold is always a factor. Observing means being out under the open sky and standing nearly stock-still for hours on end. Always dress more warmly than seems necessary. When observing from home it's possible to run inside occasionally and warm-up, but that gets old in a hurry. Not only does carefully planned observing come to a screeching halt just when the sky's getting good, dark adaptation is wrecked.

How do astronomers stay warm? Climate will dictate exactly how to dress, but always dress in layers. Layers of clothing rather than one heavy coat or sweater help the body retain heat. Much of the body's heat loss is through the feet, so take special

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care to insulate them. On a mild evening, that may be as simple as putting on a pair of wool socks to help isolate the feet from the cold, cold ground. On bitter nights, boots designed for harsh conditions may be required. Even more heat is lost is from the head, so keep it protected with a hat—a fuzzy cap or a "watch cap" is better than a baseball cap, but anything helps.

Keep the body's insides warm on bitter nights, too. On cold evenings a thermos of hot liquid will be most welcome in the wee hours. According to the experts, the best beverages are caffeine-free, like hot cider. For some people, caffeine can adversely affect the body's ability to retain heat. Don't drink alcoholic beverages. They dilate blood vessels in the skin, causing the body to lose heat more quickly than normal—even though you think you feel warmer for a little while after a shot of whiskey. Alcohol also seems to have a bad effect on dark adaptation. Save the Rebel Yell Bourbon for after the observing run.

Bugs? Depending on the climate, mosquitoes can be a serious problem. In subtropical or tropical areas they can easily halt an observing run. There's no shortage of advice from astronomy club buddies on how to keep the skeeters at bay, and store shelves are crowded with preparations guaranteed to keep the little suckers from biting. There are no magical remedies; only one thing makes a difference: DEET. "DEET" is the abbreviation for a chemical called "n-diethyl-m-toluamide," and a repellent that doesn't contain it will not work. Be careful with DEET-based repellants, though; they act as solvents and can ruin plastic, paint, and maybe even optical coatings. When it's time to spray on the stuff, move downwind of the scope. Also, wipe repellent off fingers before touching the telescope or eyepieces. (In most cases, it's not necessary to bathe in repellent; a light spraying will do.).

Preparing the CAT If you've read through the earlier chapters, you already know the basics: allow the scope to acclimatize to outdoor temperatures, set up in an area protected from ambient light, and be prepared to deal with dew. One last thing: make sure everything that will be needed during the evening's observing is close at hand. Eyepieces, charts, and other items should be positioned on a table so you don't have to get up from the observing chair to get at them. If accessories are not easily available, they won't get used, and the considerable sums spent during accessory buying madness will have been wasted.

Beginning to Observe: The Solar System

The Solar System, including the good old Moon, has its charms. On any evening a bright planet over the horizon is impossible not to send the scope to. Even if Solar System work isn't to be a mainstay of the hobby, it's still fun and can let a new telescope prove its mettle. A look at the Moon and planets with the new SCT will also prove once and for all that the "experts" down at the club and on the Internet who say SCTs are "no good" for planets are wrong. Yes, the SCT has a large central obstruction. No, that doesn't stop it from doing a terrific job on the Solar System.

The Moon What better first light subject for a CAT is there than Earth's faithful companion, Luna? Deep sky fans may disagree, but lucky is the amateur who's fortunate enough to find a nice crescent or gibbous Moonhanging in the sky on a first light evening (a full Moon doesn't reveal many details due to the high Sun angle).

Ready to begin a voyage of discovery? Point the CAT at the wonderful Moon. Once the go-to scope stops go-toing or a manual telescope's finder is centered on Earth's satellite, put an eye to the eyepiece. You'll probably be half-blinded at first. The Moon is bright in an 8-inch or larger scope at low power. Some beginners are struck by how bright Luna is through the telescope and wonder if this intense light might be harmful. Don't be concerned. At a magnitude of –12.7, the Moon is roughly 400,000 times dimmer than the magnitude -26.7 Sun. Luna's silvery light is not anywhere near intense enough to damage eyesight. Actually, the Moon's surface, despite what poets say, is not "silver"; it is a color similar to fresh asphalt; it looks bright at low power but really isn't.

Once they are over the shock of the Moon's brightness, most new astronomers are overwhelmed at the incredible wealth of detail a telescope is capable of revealing on this ancient relic of a world. Your telescope should reveal a wealth of details. If the image of the Moon in the CAT doesn't appear crystal clear, adjust the focus control until it is as sharp as possible. Focus by observing the craters and mountains that stand out in stark relief along the Moon's day/night terminator line. And then just look for a while. Use the hand controller to keep the Moon centered if necessary (with good telescope alignments adjustments should only be needed occasionally) and to scan up and down the terminator line.

When Luna has been examined at low power, switch to a shorter focal length eyepiece. Higher magnification makes the image dimmer, but many more fine details are revealed, especially on the day-night line. Not only are there craters, there are craters within craters. Seeing the smallest details available to even a small scope requires plenty of power. How much power? Continue to increase magnification until you can't see any additional detail. At some point more power won't show anything more. The image will get fuzzier as well as bigger because of unsteadiness in Earth's atmosphere, too little telescope aperture, not enough optical quality, or poor collimation of the telescope's optical system. Magnification that doesn't produce more detail is referred to as "empty magnification." It's not at all unusual, however, to have to use powers of 300x and more on the Moon with an 8-inch. Despite what those strait-laced "experts" at the club may have said about high power, high magnification does have its place; especially in lunar and planetary observing.

Lunar Features

Craters

A casual glance at the Moon reveals that her landscape can be divided into two general types of terrain, "highlands" covered with the ring-shaped formations called "craters" and relatively smooth areas, the "mare," the lunar "seas." The highland area, particularly the Moon's southwest quadrant, is a paradise for a Moon lover, as it is composed of unending numbers of shoulder-to-shoulder craters of all types, sizes, and shapes.

These seemingly innumerable craters are the product of eons of bombardment of the airless Moon by debris left over after the formation of the Solar System. Lunar craters range in size from tiny, less than an inch across, to great dishes hundreds of miles in diameter. One of the first things a beginning observer wants to know is, "What's the smallest crater I can see?" A well-collimated 8-inch SCT (or other CAT) under excellent atmospheric seeing can reveal craters 1/2 mile across, which is smaller than what should be theoretically possible for an 8-inch scope. Contrast is the reason; shadows created by crater walls at lunar sunset and sunrise help the SCT resolve detail that would normally be too small for it to make out. A 12-inch CAT might be able to distinguish craters *somewhat* smaller than 1/2 mile in diameter, but bigger telescopes usually won't do too much better than an 8-inch because atmospheric seeing limits their better resolving power.

Some craters that deserve the novice's attention are Tycho, Copernicus, and Plato. Tycho, 85 km across, is prominent because it's young, "only" about 108 million years old. For that reason it's sharply defined, standing out well in its crowded area. What makes it truly wonderful, however, is its huge system of "rays." Tycho's rays are the ejecta thrown from the crater during the impact of the body that formed it. This debris is lighter than the landscape it's deposited on and stands out starkly as bright radial streaks emanating from the parent crater. Tycho's rays, which are especially brilliant at full Moon time, stretch nearly 1,500 km across the surface. Copernicus (Plate 49), 93 km in size, has a prominent ray system, too, if not as an extensive a one as Tycho. What's special about Copernicus is the crater itself. It features a "terraced" inner wall and an intricate system of central peaks. Plato is strikingly different from the other two. It's located away from the highlands in the northwestern quadrant and doesn't have a ray system. If it ever did have rays, they were extinguished long ago by the lava floods that formed nearby Mare Imbrium. Under good conditions (good seeing and low Sun angle), a C8 will reveal that Plato's floor is littered with numerous small craterlets.

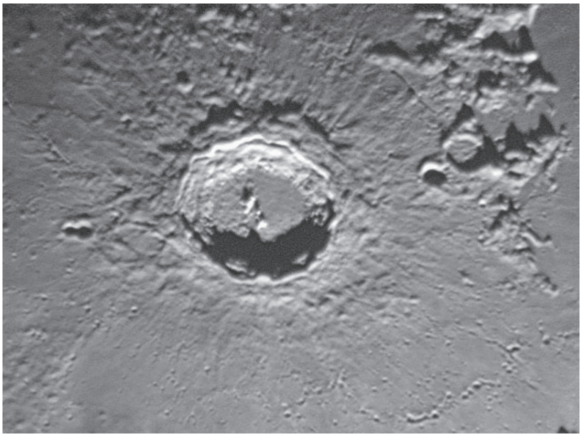

Plate 49. (Copernicus) The great crater Copernicus as seen by an 8-inch SCT. Credit: Author.

Maria

After craters, the most noticeable lunar features in a telescope are the maria, the lunar seas. It's long been obvious the dark areas on the Moon's visible face aren't really seas, though they do look a little like that to the naked eye. Even a tiny telescope or a pair of binoculars reveals these them for what they are: huge plains surfaced in a dark material. A 5-inch SCT or a 90mm MCT easily shows that the maria are peppered with craters, crater ejecta, and other solid features.

At first, the Moon's plains may seem less interesting than the highlands, but these areas have their own attractions. One thing that will be noticed immediately is that the dark, dried lava material that covers these areas is not of a uniform color, but can vary over a fairly wide range from sea to sea and even across the larger maria. In some areas it's a bland gray. In others it's reddish-brown or bluish-green. Like the highlands, these areas are also home to craters, just in less profusion. Some of the most magnificent craters, such as Copernicus and Kepler, are visible in the midst of the maria. In some places, especially near the "shores," lava piled up in frozen waves, creating wrinkles in the ridges that look a little like frozen ripples on a pond.

Are there any mare that deserve special attention? They all have interesting features. One favorite is the huge, "isolated" Mare Crisium, but the most interesting one for new observers is probably Mare Tranquilitatus, because it was the spot where the *Apollo 11* lunar module touched down. It's fun to try to pin down the exact landing spot using a CAT. Most lunar atlases show the spot where Armstrong and Aldrin set *Eagle* down.

Other Features

Even a 90mm ETX will show that craters and maria aren't all there is to see on the Moon. Systems of rilles, cracks in the lunar surface, are visible in many locations, sometimes stretching for hundreds of miles and forming intricate networks. There are also valleys, like the magnificent and imposing Alpine Valley near Plato, and scarps, places where the lunar surface has been elevated in linear fashion, forming great cliffs. The Straight Wall scarp, visible in an ETX or C5 with ease as a razor-thin black line, is one of the first lunar attractions the new CAT owner should visit. Less obvious are lunar *domes*, gentle swellings of the surface. These strange features may have been created by volcanic activity and are almost impossible to detect except under the lowest Sun angles.

There's a spot on the Moon where many of these interesting sights are all jumbled together: Aristarchus. This 40-km-diameter crater is strangely bright against the darker surface around it and is abutted by a long, sinuous rille and numerous domes that can be seen when the Sun is rising or setting (Plate 50).

Accessories for Lunar Observers

There are a few items that can make lunar exploring more productive. The most important is a map of the Moon or a lunar atlas. Luna's face is a maze of confusing details, and a map is mandatory for making sense of the landscape. At first, a simple

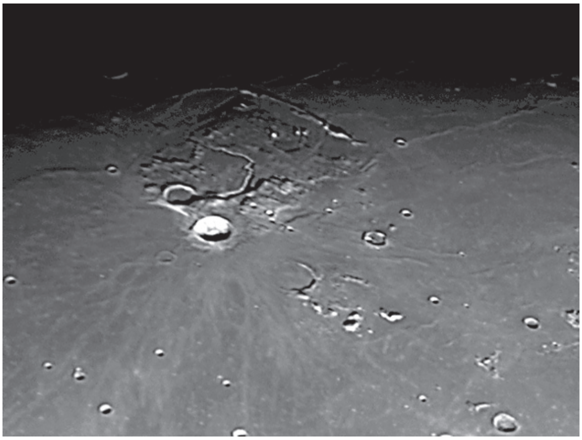

Plate 50. (Aristarchus) Bright Aristarchus lies in the midst of one of the Moon's most interesting and mysterious areas. Credit: Author.

large-scale map such as one found in many general observing guides will suffice. If the Moon becomes a real interest, though, something more detailed is called for. Antonin Rukl's *Atlas of the Moon* is the standard reference for amateur "lunatics." This is a true atlas, with the Moon's entire visible disk portrayed in considerable detail in large and beautiful airbrushed maps. Unfortunately for CAT owners who use star diagonals, the view in an SCT is mirror reversed and will never match the Rukl charts. That can be dealt with by copying charts onto transparency film with a Xerox machine and flipping them over for a correct view.

Or take the easy way out and use a computerized lunar atlas. Just as computer programs dominate in the star atlas business, computerized Moon maps are now making their presence felt. See Chapter 10 for details on specific programs. In addition to showing detail far smaller than that in Rukl or other books, computer atlases have one huge strength: their views can be flipped or rotated to exactly match the orientation seen in the telescope.

The Moon is not dangerously bright, but it is bright enough to make it sometimes difficult to see small details because of the glare. Some observers turn to Moon filters to dim Luna down a bit. These are usually neutral density filters and are not colored but only serve to reduce the intensity of the light. Like most other astronomical filters they screw onto the field lens end of an eyepiece. Moon filtersare not highly recommended for lunar observing. They reduce light too much for many telescopes, even when used at low power. They also don't do anything to enhance the appearance of the Moon's features. All they do is attenuate light. A slightly better choice for someone who wants to reduce Luna's silv'ry light is color eyepiece filters. These can work as well as a Moon filter to minimize the glare, and some colors have the added benefit of enhancing surface detail. An 80A blue filter, for example, increases the contrast of small details. A #15 yellow makes crater ray systems and rilles pop out of the landscape.

Does the CAT's drive need to be adjusted when observing the Moon? Most go-to SCTs have a Lunar Drive Rate selection in the hand controller menus. Since the Moon moves at a speed slightly faster than sidereal rate, switching over to the

"Lunar" position allows the telescope to track the Moon with more precision. Some computerized telescopes even switch to Lunar tracking speed automatically when the Moon is selected as a go-to target. In practice, the difference between sidereal and lunar rates is small enough so that you needn't bother changing the drive speed.

A Tour of the Rest of the Solar System

The Sun It's true the hazards of Sun observing have probably been overstressed in amateur literature, needlessly scaring people out of viewing the Sun, but the danger is real. A moment's carelessness can result in a lifetime of damaged eyesight. If the Sun is treated with respect, though, it can be a rewarding subject for observation and study.

What's visible on the Sun? As mentioned in the solar filter discussion, an inexpensive white-light filter will mostly show sunspots and the granular structure of the Sun's surface, the "faculae." These things can be endlessly fascinating, but most Sun-worshiping amateurs wind up wanting more. A hydrogen alpha filter is an expensive buy for most amateurs, but the dim red light of hydrogen that passes through it can reveal the Sun's more dramatic secrets, including prominences, the glorious fountains of fire that ring the Sun's disk. Hydrogen alpha filters are complex and hard to make and will probably never be truly inexpensive, but Lumicon's Solar Prominence filter system is at least palatable, with the 8-inch SCT model going for $780.

The biggest problem for the prospective solar observer? Seeing. Whether trying to view or image the Sun, daytime atmospheric turbulence is always a problem. Not only is the daytime atmosphere usually in turmoil, the scope is "shooting" over Sun-warmed ground, and its tube is sitting in the full Sun and filled with currents of hot air. The most effective way to deal with solar seeing is to observe in the early morning, just as the Sun attains 30 degrees of altitude over the horizon. At that time the atmosphere will be at its steadiest, Earth will not yet be overly warmed, and the rays hitting the telescope OTA will be relatively gentle.

Mercury Mercury, named after the fleet-footed messenger of the gods, is the first stone from the Sun, orbiting at a distance of about 58,000,000 km, making it swiftest member of Sun's family. With a diameter of less than 5,000 km it is also the smallest major planet. Being close to the Sun, Mercury is never far from its master in the sky. As it swings around in orbit, it appears as a "morning star" before dawn on one side of its orbit and as an "evening star" after sunset on the other side. At its greatest "elongation," its greatest distance from Sol, Mercury is no more than about 30 degrees from our blinding star. Given its small size and considerable distance from us, Mercury is understandably small in telescopes, no more than 5 to 7 seconds of arc in diameter.

What can an SCT owner see of Mercury? Before seeing anything, Mercury will have to be found. That's not usually a problem, even without go-to. Despite a reputation for being elusive, Mercury stands out like a sore thumb at observing sites with uncluttered horizons. People who've never seen the planet are often amazed at how prominent the little guy is. Mercury can get as luminous as magnitude –1.9 and appears as an unmistakable yellowish "star" lurking near the horizon. Locating Mercury is one thing; seeing much of this distant, rocky world in a telescope is another.

How much Mercurian detail is visible in an 8-inch or larger SCT? Little or none. Being so close to the Sun, it can only be viewed down in the thick, dirty, turbulent air near the horizon. An "inferior" planet (closer to the Sun than Earth), Mercury goes through phases, just like the Moon, growing from a slim crescent to almost full (the Sun always hides a "full Mercury"). That's about all most amateurs will ever see of this planet: a tiny Moon-like thing that moves swiftly into and out of the solar glare. Can anything help with Mercury? Mainly, just observing the planet when it's as high in the sky as possible. That means catching it just after sunset in the evening and just before sunrise in the morning. At those times the background sky is admittedly bright, but eyepiece filters can help with that. Red and orange are particularly good for darkening the sky and increasing contrast between Mercury and the background. Some observers have had good results by observing Mercurywhen the Sun is *over* the horizon. It's easy enough to view the planet in the daylight by continuing to watch it as the Sun rises, or, if it's in its evening star role, by enlisting the aid of a go-to system to locate it. The important thing? *Extreme* care must be taken not to get the Sun in the field by accident!

Images delivered by the *Pioneer 10* spacecraft revealed Mercury's surface as a crater covered landscape similar to the Moon. Can hints, at least, of these craters be seen from Earth? It does not appear so—not visually, anyway. Over the years, visual observers with a variety of telescope types have recorded dusky markings on the planet, but these do not seem to correspond to real features in spacecraft images. Recently, however, amateurs using webcams (Chapter 11) have produced pictures of the planet with features that seem to tally with *Pioneer* images and those returned by the recent (2008) Messenger spacecraft.

Venus The next planet out from the Sun is Venus. Aphrodite's beautiful appearance in morning and evening skies, where she outshines everything except the Moon and Sun, leads novices to expect great things from her. I remember how excited I was to get my first look at the planet through a telescope. What wonders would be on display? Venus had, up until the end of the 1960s, almost as romantic a reputation as Mars, being imagined as a watery ocean-covered world or a steamy swamp-dominated planet, perhaps inhabited by dinosaurs. What would I see in my 3-inch telescope?

Not much. Through a small instrument, and indeed through *any* telescope, Venus turns out to be another disappointment. It is really just a larger and brighter version of Mercury, a featureless disk that, due to its status as an inferior planet, shows phases like the Moon. The bland nature of Venus despite its close proximity to Earth is due to a deep blanket of clouds. The spacecraft that began visiting the planet in the 1960s found Venus suffers from a terminal case of runaway greenhouse effect. The carbon dioxide-laden atmosphere traps heat, resulting in a surface temperature of about 900 degrees Fahrenheit. Goodbye Venusian dinosaurs and mermaids.

Is Venus a complete waste of time for an SCT user? Not necessarily. It *is* much less interesting than Jupiter, Saturn, or Mars, but there are things to see. It's fun to watch Venus's phases and see it grow from a small gibbous disk to a large, thin crescent and vice-versa. There's also the *ashen light*. If you've ever admired a lovely crescent Moon, you've no doubt noticed you can see not only the Sun-illuminated portion but also the night side glowing feebly. The reason the dark part of the Moon's disk is visible is simple: a bright Earth is in the lunar night skies illuminating the landscape with reflected sunlight, just as a full Moon lights-up the landscape of our own world. Over the years, quite a few Venus observers, including your author, have noted a similar effect on that planet. In addition to the illuminated part of the disk, the dark portion of Venus can sometimes also be seen faintly. But how is that possible? Venus has no Moon to light its evenings!

Nevertheless, the ashen light must be real. I myself saw it convincingly for the first time in 1999 with an 8-inch Schmidt Cassegrain. I'd imagined I'd seen the effect occasionally a time or two before that, but was never was completely sure. On this particular night there was no doubt. The night side of the half-illuminated planet was remarkably visible. The faint yet obvious glow remained visible even when an 80A blue filter was added to the eyepiece.

What is the ashen light? It is a real effect, but it may not necessarily be a real phenomenon of the planet. The human eye/mind is a wondrous combination, but is all too prone to showing us what we expect to see. Venus looks like a little Moon, so the brain delivers a little Moon image, complete with Earthshine. Combine this "fill in the blanks" characteristic of the eye/brain with effects caused by the high contrast between the brilliantly illuminated planet (as bright as magnitude –4.6) and the sky, and we don't have to look to Venusian aurorae for the cause of the ashen light. The ashen light "case" is far from closed, however.

An even higher challenge for the visual observer is Venus's markings. By markings, we mean shadings in the planet's impenetrable atmosphere caused by clouds, not anything on the surface. Don't imagine these atmospheric features will stand out like the cloud bands of Jupiter. They are incredibly faint and subtle. Occasionally faint patches can be noticed along the terminator, but these can usually be ascribed to contrast effects. A #47 violet eyepiece filtercan help some, but seeing the Venusian clouds is still close to hopeless. It *is* possible to record details in the atmosphere of the planet easily enough. A webcam, especially one equipped with a filter that passes UV and blocks most other wavelengths, will definitely show shadings in Venus's steaming atmosphere.

How often should you observe the lovely lady? Maybe a few times per Venus apparition. For most SCT users, Venus is a featureless blank of a world, an object of occasional interest rather than a lifelong obsession, like the "big three," Mars, Jupiter, and Saturn. This is not to say Venus does not have her fans. The amateur organization for planetary observers, ALPO, the Association of Lunar and Planetary Observers, has an active Venus section.

Mars Mars has fascinated astronomers for centuries. After Jupiter, it is probably the most interesting planet for SCT owners. Unlike Venus, Mars offers detail aplenty: subtle but easily visible surface markings that sometimes change, polar ice caps that grow and shrink with the planet's seasons, atmospheric clouds that come and go, planet-girdling dust storms, and more. Plus, there's the simple fascination of Mars as a place that keeps us coming back. Though we now know Mars is not the "abode of life" that wealthy American amateur astronomer Percival Lowell imagined, it's possible life (most likely microbial life) existed there in the distant past. It's even conceivable there's still some primitive life lurking on this small (6,800-km) world. There is little doubt Mars was once much warmer and much wetter.

Because of these things, it's no surprise Mars is one of the first targets to attract the attention of a new CAT owner. Unfortunately, the novice often feels short-changed. Mars can be fascinating for the visual observer equipped with a small telescope, but it is usually just plain difficult. Why? Because it is small and far away. Mars, barely more than half the size of Earth, orbits the Sun at a distance of about 225 million kilometers. In some parts of its orbit it can be almost 400 million kilometers away from Earth. At that distance it's so tiny in the telescope it's barely worth a glance. Even large instruments show little or nothing of its surface features. If that were all there were to the Mars story, it would probably elicit less interest from amateur astronomers than even bland Venus. But that's *not* the whole story. Every two years, there's a magical Mars Time.

Every other year Mars comes to "opposition," the point in its orbit when Earth is directly between it and the Sun. At that time it is closest to Earth and directly opposite the Sun in our sky, making it well placed for telescopic observation all night long. The distances of Mars' closest approaches depend on exactly where it is in its fairly eccentric elliptical orbit at opposition time. Every 15 to 17 years, though, it comes really close. The 2003's Mars opposition, when the planet was a "mere" 55,768,000 kilometers from Earth, was the closest in 60,000 years. At that opposition Mars was over 25 arc seconds in diameter and shone at a magnitude of –2.7. That is remarkably big and bright for this planet, and, as might be expected, the amateur images and visual observations done at the time revealed amazing detail (Plate 51). Sorry if you missed it, since it won't be that good again until 2287, but even a not-so-close opposition (in 2010 Mars will be 99,000,000 km away) is a fine time to be a Mars watcher equipped with an 8-inch or larger CAT.

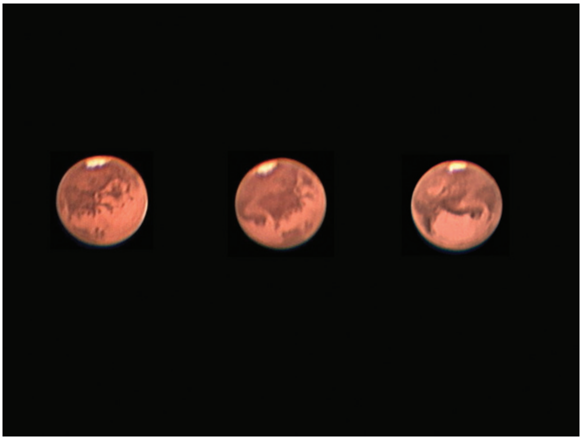

Plate 51. (Mars) Mars by a C8 and a webcam during the amazingly close 2003 opposition. Credit: Author.

As an opposition approaches, the tiny red speck of a planet grows and grows, and the normally featureless disk begins showing more and more detail, the legendary dark patches and ice caps popping into view. At opposition the magnitude of Mars also increases, making the normally sedate planet positively glaring. During these times it seems as if every telescope on Earth is staring at the Red Planet.

The Martian polar ice caps and dark ("albedo") features are easy even in a 4- or 5-inch CAT when the planet is at opposition. Depending upon where the planet is in its orbit, either the north polar ice cap or the southern one may be pointed in our direction, and will be easy to make out as an intensely bright white spot. As the seasons change, the visible polar cap grows and disappears. Larger CATs may show that the cap changes shape as it grows and shrinks, and may even reveal a dark "melt" line adjacent to it as summer comes in. The dark surface features of the planet are what really draw observers, though. There are no canals, but their lack is more than made up for by the maria of Mars. These subtle dark patches were once thought to represent vegetation but are now known to be nothing more than areas of the planet that have been scoured clean of dust by Martian winds. The dark areas bear watching by amateurs because they can change subtly, and this is of interest to planetary scientists. The easiest of these dark features to identify, a true Martian landmark, is the "Indian Subcontinent of Mars," Syrtis Major, the large, dark area centered in the middle image of Plate 51.

Even at opposition time, there's no denying Mars is small (less than half the average size of Jupiter), and that picking out surface features can be tough. Don't be afraid to use high magnification. It's always easier to pick out details in a larger image than a smaller one, even if more magnification makes the planet less sharp. One other thing that will help is a filter. A red or orange filter (Wratten #21 orange or #25 red) works, but even more contrast can be achieved with the peach-colored "Mars filters" astro-vendors sell around opposition time. The biggest help, though? Experience. After a few weeks of observing the planet at high power, details that were initially hard to make out become easy.

Mars is a fairly dynamic world, and changes in its atmosphere happen on a regular basis. It's not unusual for its clouds and weather systems to be prominent enough to be seen in an 8-inch SCT. In addition to yellow clouds that represent dust storms, there are frequent blue clouds caused by planetary weather systems. A large dust storm can be obvious in a 90mm ETX, while the blue clouds of Martian cold fronts may need a big CAT and an experienced observer. As with the maria, filters can help with clouds. Try green or blue for fronts and hazes and yellow for dust-storm clouds.

How about Mars' two moons, Phobos(fear) and Deimos(panic)? These asteroid-sized chunks of rock require at least an 8-inch SCT. At opposition they are not that tough—or wouldn't be if it weren't for the overwhelming glare of the planet. The magnitudes of the pair are not overly dim; Phobos gets as bright as magnitude 12, while Deimos is about 13. Despite Phobos's relative brightness, it's the more difficult of the two, since it's closer to the planet. The trick to seeing these two worldlets is to either get Mars out of the field or arrange some kind of "occulting bar" in the eyepiece—maybe a strip of aluminum foil taped across the telescope end of the eyepiece. Hide Mars behind this bar, and one or both of the minute moons may pop into view. Before trying to observe the moons, find out when and where they will be at their greatest distances (elongations) from the planet, which is when they'll be easiest to find. Times/dates of Phobos' and Deimos' elongations can be found on the Internet or in the astronomy magazines.

Mars, riding high in the night sky at opposition, is a magnet for amateur astronomers. For those of us who dream of traveling there or even of colonizing this strange world, our little CATs provide us with a unique opportunity to visit this fabled and secretive world vicariously. Sadly, few, if any, people now living will have a chance to actually walk the sands of Mars; that appears to be an honor reserved for our grandchildren or great grandchildren. But our faithful CATs allow us to travel there in spirit and taste a few of the wonders of humankind's most likely second home.

Jupiter Jupiter (Plate **52**) is the king of the planets and not just because of his enormous girth—this monster of a world is 142,984 km in diameter. Jupiter is also king in the affections of amateur planetary observers. Why? Because this great ball of gas is just so consistently interesting. There's always something to see any time Jupiter is in the sky. Even a little MCT reveals multi-colored cloud bands. The Great Red Spot, the planet's enormous storm system, cruises sedately around the planet, drawing the eye of the telescopic observer. Accompanying the planet are the four huge "Galilean" moons discovered by Galileo on the night when he first turned his telescope to the sky. These satellites shuttle back and forth from evening to evening, crossing in front of Jupiter's disk (transits), casting dark, pinpoint shadows on the planet's cloud deck (shadow transits), and disappearing behind the globe (eclipses). And Jupiter is not just interesting because of the wealth of detail on its huge (45 arc second diameter) disk but because these details are always changing.

Mars is fascinating, sure, but fans of the Red One have to wait for every-other-year oppositions before being able to see much. In contrast, Jupiter, although more distant than Mars, orbiting 778,330,000km from the Sun, is so big that it is a worthy target for CATs anytime it is visible, which is for months at a time every single year. Jupiter does vary a bit in size, but never gets small, and details are always easy to discern even with small apertures and low magnifications. For example, although

Plate 52. (Jupiter) Jupiter presents a mass of detail both to the camera and to the naked eye." Credit: Author.

the Great Red Spot is currently (2008) a fairly pale pinkish-red, itvcan be seen with a 90mm inch ETX. Imagine the kind of detail visible in an 8- to 10- or 12-inch SCT. On a night of good atmospheric seeing, the features on Jupiter visible in an 8-inch CAT are almost mind-boggling. Not only are there four or five dark cloud belts but also a wealth of detail in these belts, ranging from ragged edges to streamers (festoons) impinging into the bright "zones" that separate the dark bands. When the Great Red Spot is undergoing one of its darker periods, you can detect not just its oval shape but tantalizing hints of detail within it.

The four Galilean moons, one of which is visible in Plate 53, also put on a wondrous display in a C8. When the atmosphere is at maximum steadiness, they are not just star-like points; they show tiny perfect disks at high magnification (the largest, Ganymede, at 5,262 km is planet-sized). It's easy to spot the hard little shadows these moons cast on Jupiter's cloudtops as they transit in front of the disk. Under stable seeing conditions it's even possible to track a satellite itself as it moves across the planet. The moon will appear as a tiny, bright disk set against the darker background of mighty Jove.

Some beginners wonder why their SCTs show only four moons despite the fact that Jupiter is known to have a huge retinue of at least 62 satellites. The reason is that the other moons are all tiny and dim. They are flying mountains rather than small worlds. The brightest of them, Amalthea, the last of Jupiter's companions to be discovered visually (1892), is a dim magnitude 14.1. When this is coupled with the moon's nearness to the bright disk of the planet, Amalthea becomes a terribly challenging object, even for the largest amateur SCTs. Think "Phobos and Deimos" but much worse.

Jupiter is immediately impressive to the new SCT owner, but beyond cloud bands and the moons, not much will be visible initially. Making out detail on Jupiter is easy compared to the difficulties the other planets present, but it still requires experience and knowing a few tricks of the trade. Foremost—as with all the planets—is the requirement for precise collimation of the telescope. That makes all the difference in the world with SCTs. Magnification? Jupiter, being larger, doesn't need as much as

Plate 53. (Jupiter and Satellite) Distant Jupiter's largest moons show their disks to webcam-equipped SCTs and in high power eyepieces on steady nights. Credit: Author.

Mars. The Great Red Spot and small atmospheric features such as spots and festoons are often detectable at powers of 100x by experienced observers, and 200x is often more than enough magnification to reveal smaller features. As always in the planetary game, however, don't be afraid to kick the power up a couple of notches.

Despite the planet's many wonders, new Jupiter observers are often let down by the subdued colors of the planet. It doesn't look a thing like the *Voyager* spacecraft pictures. It's all washed out. Where are the dark reds and bright blues and fluorescent yellows? The *Voyager* pictures, while amazing, are not a realistic representation of the planet's appearance. Contrast and color saturation in spacecraft images were boosted in order to make small details more visible. Jupiter, the real planet, seen live in the eyepiece, is not a riot of color; it's a pastel world. Colors are visible to the experienced observer, but they tend to be muted tans, creamy-yellows, and subtle blues, not strong primary colors.

Does Jupiter seem a bit *too* pastel to make it easy to see belts, spots, and festoons? There's a way to enhance the Jupiter experience: a Wratten #80A blue filter. This probably does more to enhance the planet than any other filter on any other planetary subject. An 80A sometimes makes the difference in seeing and not seeing barely visible belt features. As we said earlier, the 80A is indispensable for Jupiter watching. A few other filters can help a little, too. A yellow one (Wratten #12 or #15) will darken the festoons. A magenta filter (#30) can help with bright spots and ovals.

This author been observing Jupiter for over 40 years, and the planet never fails to amaze. Just when you think you've seen it all, something dramatic happens. The Great Red Spot fades, belts disappear and reappear, long-lived white spots bloom and cruise and collide and merge, or a comet slams into the planet with incredible violence. This enormous world, almost frightening in its majesty, reminds one that our Solar System is not a static thing but an entity that changes and lives. The truly wonderful thing is that even the tiniest CAT provides a ring-side seat for Jupiter's ever changing and never ending show.

Saturn Saturn, Lord of the Rings, is without doubt the most beautiful object in the heavens. A first glimpse of this almost artificial-looking world is unforgettable. It's just too perfect to be believed. Guests at public star parties peer down the corrector end of a scope after viewing Saturn, looking for the photo of the planet they're sure was pasted on the end of the telescope!"

Beyond the striking beauty of Saturn's golden-orbed, ringed visage, there's a fair, if not overwhelming, amount of detail for CAT owners. Examine the rings carefully, even with a 90mm ETX, and a thin black line dividing Saturn's "A" and "B" rings (the outer and inner rings, respectively) will be obvious. This is the Cassini division, named for the seventeenth-century astronomer who first noted this curious feature. It is caused by gravitational effects that sweep this area clean of ring particles. The rings, of course, are not solid but are composed of pebble- to mountain-sized chunks of ice. The *Voyager* spacecraft revealed numerous other gaps in the rings, all of them much narrower than Cassini's. The only one of these other ring divisions visible from Earth lies almost at the edge of the "A" ring and is called the "Encke" or "Keeler" gap.

Over the years, numerous amateur observers who reported a division in that spot at the edge of the rings were met with skepticism on the part of the pros. Finally, the *Voyagers* put the question to rest in 1980 and 1981, imaging the Encke Gap clearly. Occasionally one can catch a glimpse of it in an 8-inch SCT at obscenely high powers on the best nights, but what most small scope owners may actually be seeing is the Encke "Minima," a slight darkening of the A ring near its outer edge rather than the gap itself. Even this "Minima" not overly easy to see, even with a webcam. Plate 54 shows it but just barely.

Inward from the "B" ring is Saturn's final major ring, the "C," or Crepe, Ring. The Crepe is somewhat difficult to see in small telescopes. It is semi-transparent and appears as nothing more than a faint haze inside the "B" ring. Often the easiest way to detect this subtle band is to look for a darkening where the ring passes in front of the planet.

Like Jupiter, Saturn is a gas giant world, a great ball of (mainly) hydrogen with (perhaps) a small rocky core at its center. The appearance of its globe is very different from that of Jupiter, however. Jupiter is a pastel low-contrast world, but the cloud features on Saturn are even more understated. Because of what is apparently a hydrocarbon haze high in the atmosphere, Saturn's belts, spots, and zones are lower in contrast than those of Jupiter. Most obvious is a bright equatorial zone. This is flanked on either side by tan north and south equatorial belts that are fairly easy to detect against the burnished gold of Saturn's globe. Other belts can be seen higher in latitude in either hemisphere, but the narrow, subdued zones that separate them make it difficult to distinguish one from another. On particularly steady nights, 8-inch and larger CATs may be able to detect a faint darkening around the pole of the planet that is currently pointing towards Earth.

Not only is Saturn's atmosphere lower in contrast than Jupiter's, it's less active, probably because the planet, a whopping 1.35 billion kilometers from the Sun, is colder. Bright spots can occasionally be seen, but they are far more difficult to observe than comparable features on Jupiter. These spots seem to be associated with Saturn's closest approaches to the Sun (perihelion) during its 29-year orbit and are

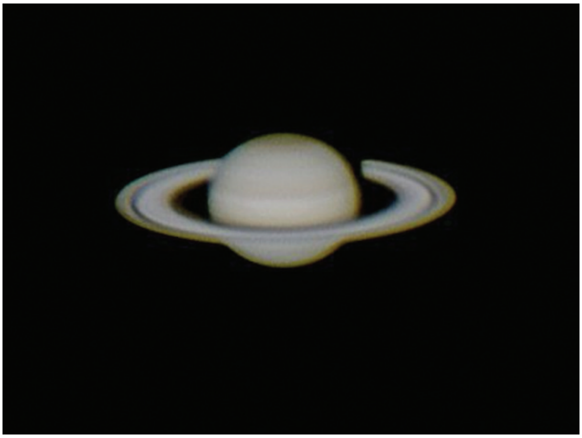

Plate 54. (Saturn) Saturn is beautiful but (almost) unchanging. Credit: Author.

usually found near the equatorial zone. Frankly, the best way to "see" Saturn's spots is with a webcam; even then they are not exactly prominent.

What special problems does Saturn present to the SCT owner? The main trouble with Saturn is its huge distance from the Sun. New observers, once they get over the initial impact of Saturn's beauty, are distressed by how tiny it is. At opposition, Saturn's disk is about half the size of Jupiter's, and to see many details in the rings or on the globe high power is required. The 200x is a good "Jupiter power," but this is merely the starting place for Saturn. Luckily, the planet seems to "take" magnification better than Jupe. You can use as much as 600x on Saturn with a C8. When the seeing is good, the planet doesn't break down easily; it keeps getting bigger and delivering more detail.

Like the disk, Saturn's rings are almost unchanging, "almost" because they do change their tilt. Saturn's inclination to the ecliptic (the plane of Earth's orbit) causes the aspect of the rings as seen from Earth to change as the planet moves along. Eventually, the rings appear edge on. Such a "ring plane crossing" last took place in 1995 and will happen again in 2009. At those times the rings, which are only about 100 meters thick, briefly disappear, which normally allows Earthly observers a good look at the disk and the planet's faint moons without the interfering glow of the ring system. Unfortunately, the precise moment of ring plane crossing won't be seen in 2009, since the planet will be in conjunction with the Sun at that time. The progression from open rings to closed rings to open again occurs in cycles of 13.7 and 15.2 years.

Moons? You want moons? Saturn's got 'em. An amazing retinue of 60 at last count. Most are small, but Saturn's largest satellite, Titan, at 5,150 km in diameter, is planet-sized. Titan, easily visible in a 90mm MCT, even has a thick atmosphere, which is dominated by nitrogen and traces of methane and other gases. The makeup of Titan's atmosphere gives the moon an orange color easily detectable in an 8-inch SCT. In addition to magnitude 8.4 Titan, four other Saturnian moons, Rhea (9.0), Tethys (10.3), Dione (10.4), and Enceladus (11.8), are easy to see in modest instruments. Rhea and Tethys definitely show in the ETX 90. The identities of the moons can be figured out with the aid of computer software or with the diagrams astronomy magazines print during Saturn's apparitions.

Saturn isn't as interesting a world for the CAT-equipped amateur as Jupiter, but it's beautiful. Its relative changelessness seems to fit the massive and brooding father of the gods. Even though you *probably* won't see anything new on this distant giant from night to night, you might not be able to stop yourself from turning your SCT to the ringed wonder any time it's over the horizon.

The Distant Giants For SCT-users, Uranus and Neptune, the Solar System's outer pair of planets, are the been there worlds, "been there" because there's not much to see. The only attraction for most amateurs is the simple satisfaction of having tracked down and viewed these objects in the telescope—you've been there.

Uranus Locating magnitude 5.8 Uranusisn't much of a problem for the CAT owner. The planet is even visible to the naked eye from somewhat dark sites and is obvious in a pair of binoculars, making it easy to find even with a non go-to CAT.

Though it's not a challenge to locate, Uranus can be a bit of a challenge to see. Its tiny disk, averaging 3.6 arc seconds across, makes it easy to mistake the planet for just another field star. Once the telescope is in the correct area, a fairly bright faintly greenish "star" should be obvious in the field. It won't show much indication of a disk at typical "finding powers" of 100x or below, but it will look distinctly non-stellar. Once the planet is centered, run the magnification up to at least 250x-300x to get as good a look as possible at this distant giant's minute globe.

Don't expect to see anything much, even at 500x. Uranus is a huge, slightly flattened gas giant 51,118 km in diameter at the equator, but it is very far away, in the vast outer reaches of the Solar System nearly 3 billion kilometers from the Sun. As at Saturn, there's a haze in the upper atmosphere that tends to mask atmospheric activity. What weather patterns there are are intrinsically faint. It's really cold out there, and there's very little energy to drive the planet's weather. Even *Voyager 2,* which flew by Uranus in 1986 at a distance of 81,500 km, didn't see much more than a featureless green globe.

Uranus is currently known to have 27 moons (named for Shakespearean characters). Out of these 27, only 4 can be glimpsed visually in amateur telescopes, and only 2, Oberon and Titania, are doable (though not easily doable) with an 8-inch. Oberon is close to magnitude 14, and Titania is only slightly brighter at 13.7. The way to conquer the pair is to use high magnification to suppress background sky glow in the field, get Uranus out of the field with an occulting bar, like one used to hunt Phobos and Deimos at Mars, and to know exactly where to look. *Sky & Telescope* magazine's website includes a nice java applet that shows the locations of Uranus's moons for any date and time. No luck? A CCDcamera or a long-exposure-modified webcam will make quick work of the planet's five brightest satellites, which range down to "only" 15th magnitude. Uranus possesses a set of rings, but they are made of dark material and are virtually invisible from Earth—in amateur scopes, anyway.

Neptune Neptune is a lot like Uranus for telescopic observers—only more so. The bluish-green sea god is only slightly smaller in diameter than brother Uranus, being an immense 49,532 km across, but is even more distant from Father Sun at 4.5 billion kilometers. So, Neptune is both smaller and dimmer than Uranus. Its magnitude is 7.9, so we've left the realm of naked-eye objects; a pair binoculars or a small telescope is required even to see this distant planet as a "star." Neptune makes Uranus look big in a telescope. Its disk is a miniscule 2.9 arc seconds across, and high power, 300x and above, is needed to resolve it as a disk. Like Uranus, it isn't terribly difficult to locate, even without go-to. Also like Uranus, the problem is knowing for sure it's in the field. It does look somewhat non-stellar at modest powers but is not nearly as noticeable as Uranus. Use as much magnification as the seeing will allow to ferret out the disk.

What's visible on the 8th planet? Neptune *does* have a more active atmosphere than Uranus, one probably driven by the heat generated in the planet's interior. Neptune has a much stronger internal heat source than Uranus—no one is quite sure why—and some visual observers and webcam imagers using large, long, focal length telescopes do occasionally seem to have seen some atmospheric detail—perhaps hints of the white clouds or the Great Dark Spot *Voyager 2* imaged in 1989.

Like the other gas giants, Neptune is accompanied by a large train of moons: 13 are now known. Only one of these, Triton, is visible in amateur scopes. Surprisingly, this large world (2,700 km in diameter) is easier to see than any of the Uranian moons. At magnitude 13 Triton is fairly easy to pick out, if it's position relative to the planet is known. Most planetarium software will plot the current position of Neptune's big moon and will also allow the planet to be oriented to match the view in a CAT (right side up and mirror reversed). As for the other Neptunian satellites, the next brightest is Nereid at magnitude of 19.2. For this, you'd need to break out the CCD camera.

Pluto It will be up to you to decide whether to agree or disagree with the International Astronomical Union's decision to strip poor little Plutoof major planet status. One thing is clear: Pluto is in a whole other class compared to the larger members of the Sun's family, both in makeup and difficulty for observers. Unlike the outer gas giants that share its distant neighborhood, Pluto is a tiny ball of rock and ice—with the emphasis probably on ice. Once thought to be larger than Mercury, Pluto has been downsized every time we've learned more about it. The current accepted diameter of this moon-like world is a mere 2,274km. It would be tempting to dismiss this speck of a world as an escaped satellite of one of the gas giants, but current theories do not support that. Though it may be moon-like in size and composition, Pluto is actually the owner of three moons of its own, Charon, which is just a little smaller than Pluto itself, and two asteroid-sized chunks of ice and/or rock. All these moons are invisible in amateur scopes.

Pluto is also incredibly distant. On average, it is 5 billion kilometers from the Sun and subtends a bare .1 arc second in Earthly telescopes. Pluto is simply not resolvable as a disk by amateur scopes (large professional telescopes equipped with adaptive optics do have a shot). This tiny world is also dim at an average magnitude close to 14.0. That probably puts it out of range of smaller than 8-inch CATs, and it is not easy even in an 8-inch. Experienced observers can find Pluto with a C8, but the task becomes easier in an 11- or 12-inch. As with Neptune, the problem in this age of go-to is not so much finding Pluto but knowing it's been found. Worse, unlike Neptune, Pluto won't show even a tiny disk no matter how much power is thrown at it. To be sure it's is in the bag, check the eyepiece field against a detailed chart showing stars down to magnitude 14 and dimmer. The astronomy magazines usually print Pluto finder charts once a year, but the best bet is a computer program that will tailor the view to a particular scope and eyepiece. Even a highly detailed chart may not make it *absolutely* certain Pluto has been glimpsed. The time-honored verification method is to draw a quick sketch or make a CCDexposure of the field. Come back the next evening and check to see if the Pluto "candidate" has moved with respect to field stars. If so, success!

Why devote so much time to tracking down visually uninteresting Pluto? There's a special thrill in tracking down a world that until recent times—until Clyde Tombaugh discovered it in the 1930s—was completely unknown. Finding Pluto is also a good test of both telescope and observing skills. Most of all, though, the pleasure comes from gazing upon a world that has been seen by few human eyes.

Comets and Asteroids

We don't usually think of Earth or Mars or the other worlds as "leftovers," but the Solar System has been pretty accurately described as "Jupiter plus debris." There is quite a lot of real junk left over from the formation of the Solar System floating around out there: comets and asteroids are a further area for the planetary enthusiast to explore.

Comets Every once in a while a spectacular comet visits the inner Solar System. After a comet drought that lasted over twenty years, we were treated to two "great" ones in the mid 1990s, Comet Hyakutake and Comet Hale Bopp. Another surprise came in 2007 when the normally sedate Comet Holmes (Plate 55) flared to brilliance and dominated northern hemisphere skies for weeks. The visit of a spectacular comet is a particularly exciting and busy time for both amateur and professional astronomers. We're in the spotlight, with the public looking to us for both views and information. Suddenly it seems as if everybody's interested in looking through the CAT. Even your formerly skeptical brother-in-law is no longer puzzled about why you spent all that money on a telescope.

Actually, an SCT is not required when a great comet is in full flower; a pair of binoculars or just a pair of eyes will do fine. An SCT *can* do a good job when the comet is dimmer, while approaching or moving away, and a telescope is required for the run-of-the mill comets that visit the inner Solar System every year. Most of these interlopers don't get much brighter than magnitude 8, and that makes them perfect candidates for viewing in an 8-inch or larger CAT. Some are fairly impressive, like the recent (2006) Comet Barnard, which showed a hint of a small tail as it drifted sedately through Hercules. Most comets are mere smudges, but all are interesting. Watch the astronomy magazines and the Internet for news of "good" comets. Spotting these little fellows can become a nice pastime.

Can anything help with dim comets? They are much like deep sky objects, and the tricks that work on the deep sky—averted vision, jiggling the telescope, etc.—

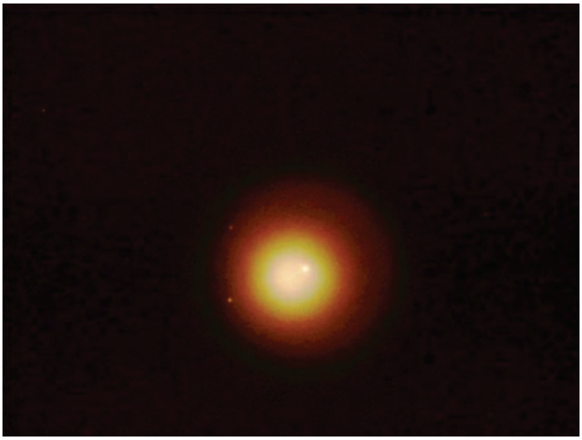

Plate 55. (Comet Holmes) The sky is full of surprises, like Comet Holmes, which went from invisible to astounding in late 2007. Credit: Author.

work on them, too. How about light pollution reduction filters? Lumicon sells a filter formerly called the "Swan Band Filter," and now just called the "Comet Filter," that passes OIII and cometary "C2" lines. Does it work? On comets that display C2 emission (from diatomic carbon), it works pretty well. Unfortunately not all comets show this emission.

Asteroids Think Pluto is boring? Then you probably won't like asteroids, either. As the name implies, they look just like stars ("asters") in the eyepiece. The only sure means of identifying them, like Pluto, is by checking to see if they move against the background stars. Asteroids are inherently interesting because of what they are rather than how they look. They are the leftover pieces of a planet that was prevented from forming by the gravitational influence of mighty Jupiter. The area between Jupiter and Mars is littered with these chunks, which range from a few hundred kilometers to a few meters in size. Most interesting for the SCT user is the handful of relatively large and bright minor planets, with Ceres and Vesta being the best of the bunch. The prime attraction other than the "been there" factor is watching their motion against the stars.

Deep Sky Observing

Planet watching is fun, but there is no denying the siren call of deep space. After looking at the Moon and a planet or two, most new CAT owners are eager to see all the stuff in the Great Out There: majestic spiral galaxies, great glowing nebulas, blazing globular clusters, and gas-clogged nests of newborn stars. An 8-inch SCT is capable of showing thousands of distant and lovely objects and showing considerable detail in the brighter ones.

Deep Sky Hints and Tips Beyond the obvious, "Get the CAT to the darkest site possible," what can the new observer do to maximize deep sky "returns"? We've already discussed light pollution reduction filters; they work, on nebulas anyway, and can make the difference between seeing and not seeing elusive objects. Shielding the observing position from ambient light is also very important. But is there anything else that can make dim objects easier to see? Yep, averted vision.

To use averted vision, look away from a deep sky object in the eyepiece rather than directly at it. That will bring the eye's dim light sensors into play, and objects at the edge of the visual field will become surprisingly brighter. There's another peculiarity of the human eye the deep sky observer can capitalize on: moving objects are easier to see than stationary ones (maybe an evolutionary adaptation that helped our ancestors detect stalking predators). Gently rap the tube of the scope so that it vibrates a little, and "not seen" objects may suddenly pop into view. Using these two techniques can make a so-so observing session better and can make a good site great. One thing's sure, as in planetary observing, experience helps more than anything else. The more you look, the more you'll see.

Deep Sky Object Brightness (Magnitude) This is probably a good time to talk about "magnitude," the system that describes the brightness of sky objects. We've thrown the term around a little previously, but it really becomes important when describing deep sky objects. How does it work? The human eye can see stars as dim as about magnitude 6 unaided, and each whole number magnitude jump makes an object 2.5 times dimmer (or brighter). A magnitude 7 star cluster is 2.5 times dimmer than a magnitude 6 one, and a magnitude 5 cluster is 2.5 times brighter than the magnitude 6 group. Brightness goes down as positive numbers become larger and goes up as they get smaller. Objects brighter than magnitude 0 are assigned negative magnitudes. A magnitude –1 object is 2.5 times brighter than a magnitude 0 one, which is 2.5 times brighter than magnitude 1.

The magnitude system works well for stars but can be deceptive with other deep sky objects. A galaxy may be said to have a magnitude of "3.5" but appear far, far dimmer than a magnitude 3.5 star. That's because the galaxy's given "visual" magnitude expresses what its brightness would be if it were squeezed down to the size of a star. Obviously, that makes a big galaxy like M31 very dim. Defocusing a magnitude 3.5 star until it is several degrees across would make it nearly invisible. For a better idea of a deep sky object's true brightness, some deep sky observers suggest using a magnitude system that reflects "surface brightness" not "visual magnitude." Many books and lists will give both types of magnitude. The values given in the section below are in visual magnitude, but with a bit of experience it's easy to get an idea how bright objects are from this figure and their given sizes. Surface brightness is better in some ways, but you might find it easier to remember how an object with a visual magnitude value of 3.5 will appear in your telescope than with a "mean surface brightness of 23.1 per square centimeter." Use whichever magnitude "system" you prefer.

Visiting the Deep Sky Menagerie

Today, object finding usually consists of nothing more than pushing a couple of buttons. But *what* is there to find? Which objects are worthy of attention? The sky is filled with beautiful deep sky wonders, but the Messier list is the time-honored place for deep sky explorers to start. These 110 objects, discovered by Charles Messier and others in the eighteenth century, are a sampling of the best and the brightest. Once the Messier list has been conquered, most observers move on to the 8,000 objects of the New General Catalog. The "NGC" list of objects, originally published by John Dreyer in 1888, was partly based on work done by renowned amateur astronomer Sir William Herschel. The DSOs in the NGC range from Messier class in brightness and detail to ones that are challenges for the largest CATs. What can be expected of the various species of deep sky objects in either catalog?

Galaxies Galaxies, massive island universes that are the sisters of our Milky Way, are the objects of many an amateur astronomer's desires. Beginners, particularly, long to see the beautiful pinwheel-like spiral arms some galaxies display. Alas, that's not easy: galaxies are far, far away; they are the most distant objects in the cosmic zoo. The nearest large galaxy, M31 in Andromeda, is a staggering 2.3 million light-years distant. Because of their huge distances galaxies are almost always small and dim. They are also badly affected by light pollution, and, again, they are not helped at all by LPR filters. Many galaxies are visible from compromised urban and suburban sites, but just as fuzzy smudges. To have a prayer of seeing spiral arms with an SCT, no matter what its aperture, a dark site is a must.

What are the most visually stunning galaxies? M51, the Whirlpool Galaxy (Plate **56**), is the place to go to see spiral arms visually. This is an interesting and fairly bright galaxy located near the Big Dipper asterism, within the borders of the small neighboring constellation Canes Venatici. Magnitude 8.0 M51 is prominent enough to be dramatically visible in 8-inch CATs, and its spiral structure is visible from less than perfect locations with a 5-inch telescope. Also interesting is the little irregular galaxy NGC 5195 just to the north of M51. A bridge of stars appears to connect the two galaxies and seems to be evidence of a recent interaction between the two ("recent" as in "millions of years ago"). This hazy pulled-off stream of stars is visible in 10- to 12-inch scopes from dark locations. From the typical suburban neighborhood? All that's seen of these two wonders is a pair of dim blobs, even in a C14.

M31is the most easily seen galaxy in the sky, visible to the naked eye among the stars of Andromeda even from urban observing sites. Beginners usually expect a lot from Andromeda, as M31 is usually known, since it is so bright (visual magnitude 3.5). They are also usually bitterly disappointed by this galaxy's appearance when they finally get a look at it. At first glance, M31 appears as nothing more than a bright, elongated blob.

Why? One reason is M31's sheer size. At 3 degrees across, it's impossible to fit this monster in one field of view even using long focal length eyepieces and an f/6.3 reducer/corrector. All that's in the field of even a low power eyepiece is the galaxy's round core. Another problem with Andromeda is its inclination. It is tilted only 6 degrees from our line of sight, so the arms aren't well seen even in CCD images. Nevertheless, M31 can be an amazing object for the experienced observer, showing off a couple of dark lanes; a giant cluster of stars; a pair of small satellite galaxies,

Plate 56. (M51) Traces of M51's delicate spiral arms are easily visible with an 8-inch SCT from dark sites. Credit: Author.

M32 and M110; and a huge retinue of globular clusters, the brightest of which are visible in an 8-inch SCT.

NGC 253, the Silver Dollar or Golden Galleon galaxy is, in some observers' opinion, one of the top two or three galaxies in the heavens for CAT users. It's bright (magnitude 7.1) even though it's an eyepiece-filling 25 arc minutes in size, and it displays a wealth of detail. Why doesn't it have a Messier number, then? Probably because its southerly declination of –25 degrees made it difficult for a mid-high northern hemisphere observer like Mssr. Messier.

M104, a magnitude 9.0 Virgo spiral is probably the best example in the sky of an edge-on oriented galaxy. Even 5-inch CATs reveal not only its thin sliver of a body but the huge central bulge that gives it its name, the Sombrero Galaxy. In addition to these features, an 8-inch SCT shows that M104 is bisected lengthwise by a dark lane of dust. In photographs and in really big CATs this lane has scalloped, irregular edges.

Nebulas Nebulas (nebulae) are the great clouds of dust and gas that lurk in interstellar space. Bright nebulas can be divided into four different and distinct types: emission nebulas, reflection nebulas, planetary nebulas, and supernova remnants.

Emission nebulas are great stretches of (mostly) hydrogen that pepper the Milky Way's spiral arms and which, when they contract due to gravitational effects and shockwaves from nearby supernovas, give birth to new generations of stars. Until stars are born, diffuse nebulas are dark objects—there's no light to "excite" them. When hot and massive young stars come to life in the midst of these clouds of gas and begin radiating torrents of ultraviolet light, nebulas begin to glow with the ruddy light of luminous hydrogen—think "neon tube." Diffuse nebulas are among the most beautiful objects in the heavens.

Reflection nebulas do not emit light on their own; they are composed mainly of dust rather than gas and "shine" by reflecting the light of nearby stars. For that reason they are blue instead of red. Some reflection nebulas contain enough excited hydrogen to show some red emission in images.

Planetary nebulas are entirely different from emission and reflection nebulas. Despite their name, they have nothing to do with planets, other than that most are round in shape. A planetary nebula is the corpse of a star. A star in the size range of our Sun does not explode violently as a supernova; instead it undergoes a lingering death, inflating to red giant size as it runs out of hydrogen fuel in its core. When fusion stops, what's left is the star's bare core, a "white dwarf" that forms the planetary nebula's central star. The nebula part of the planetary is composed of the outer layers of the star that were blown off during the red giant phase.

A supernova remnant is what's left over after the death of a large star, one that's exploded as a supernova. An expanding cloud of shockwave-disturbed gas with a tiny and dim neutron star or pulsar at its heart is all that remains of a once-glorious super-sun. Supernova remnants tend to be large and dim.

Diffuse nebulas and supernova remnants are as damaged by light pollution as galaxies. The largest ones, like the elusive California Nebula in Perseus, are actually harder to see from suburban and urban sites than the most challenging island universes. Fortunately, the suburban/urban amateur can always grab a light pollution reduction filter. A filter probably won't help much with the California or the Horsehead or the Cocoon or the Bubble or any of the really hard ones, but a UHC or OIII will increase the number of nebulas visible and the details in brighter ones. In the following paragraphs we will introduce some of the most interesting nebulas.

M42, the great glowing mass in Orion's sword (Plate 57) is the most wonderful nebula in the skies—for northern hemisphere CAT users, anyway. Some would say it's the most beautiful deep sky object of all. It's easily visible to the naked eye, and because of its "reasonable" size of 1 degree it's not too large to be appreciated in long focal length SCTs and MCTs. M42 is flanked by a small, detached, comma-shaped patch that has its own M number, M43. The Great Orion Nebula looks beautiful in *all* telescopes, from the largest to the smallest, and cuts through even heavy light pollution with aplomb. It's also home to some fascinating stars. Of particular note is the Trapezium, a small star cluster near M42's heart. A 90mm CATs shows a little square (trapezium) of four stars, and 6-inch and larger CATs regularly reveal two more members.

South-of-the-equator astronomers, in addition to getting a really good look at M42 (its southern declination places it high in the sky for some southern hemisphere observers), have another "great nebula" to marvel over, the Tarantula Nebula, NGC 2070, located in the far southern constellation of Dorado. This monstrous cloud stretches 40 arc minutes across the sky. It is not only larger than M42 in the telescope, it's larger in reality, but it's considerably farther away. If it were located at the same distance as the Orion Nebula, it would cover nearly 30 degrees—60 full Moons—of sky!

M78, surrounding a pair of dim stars not far from Orion's belt, is probably the best example of the reflection nebula species. It is fairly small at 8 arc minutes across, but that makes it show up easily despite a rather dim visual magnitude of 11.0. Don't expect to see the beautiful blue color visible in images, though. All the eye will make out is a dim gray smudge around two unimpressive stars.

Plate 57. (M42) The Great Orion Nebula, M42, the most wonderful DSO in the northern sky. One of the first DSLR images taken by the author, using a C8 and Canon 400D Digital Rebel. Credit: Author.

M57, the justly famous Ring Nebula, is but one fine example of the multitude of beautiful planetaries that litter the Milky Way. This dead star is located in the small but prominent constellation Lyra (home to the bright star Vega) and is bright and unmistakable at magnitude 8.7 and a size of a bit more than 1 minute of arc in diameter. A 90mm MCT will reveal M57 without effort as a tiny spot of light. High magnifications and good seeing conditions can show at least hints of the Ring's "donut hole" in an ETX or a Questar, but it generally takes a C5 to show the donut shape clearly. An 8-inch SCT will display the ring shape *very* plainly and will show it is not round but somewhat elongated. An 8-inch will also make clear that the middle of the ring is not dark but a gray color. SCTs in the 12-inch class may show the Ring's central star, a magnitude 15 white dwarf, but not easily; not only is the star dim, but it is possibly variable and is masked by the thin nebulosity in the Ring's central hole.

M1, the first object in Messier's catalog, is the best and brightest supernova remnant in the sky. That said, it's not very bright in amateur telescopes and may be hard to spot in surburbia with smaller than 5-inch CATs. This object, which appears as a 1.5 x 1 arc minute 9th magnitude glow, is found in the prominent zodiacal constellation Taurus. Large SCTs, especially those equipped with OIII filters, may show hints of the strange tendrils that give this nebula its name. This expanding cloud of gaseous debris is the result of a supernova that exploded in 1054.

Globular Clusters Globular star clusters are incredibly ancient balls of stars. They are thousands of light years across and contain from thousands to millions of aged suns. They orbit the nucleus of our galaxy and are so old they were possibly witness to the birth of the Milky Way galaxy itself. Globulars are one of the best reasons for buying a larger aperture CAT. Even the brightest "globs" are mostly composed of magnitude 13 and dimmer stars, so at least a 6-inch telescope is recommended to revolve many stars in the brightest clusters, and considerably larger

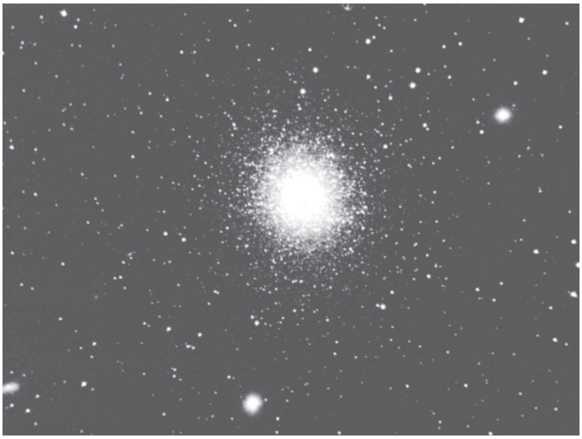

Plate 58. (M13) Awesome globular cluster M13 delivers scads of tiny stars to both visual observers and astrophotographers. C8 image with SBIG ST2000 camera. Credit: Author.

Plate 59. (Omega Centauri) This C8 astrophoto, done with 35mm film, only hints at the beauty of the sky's most incredible globular star cluster, Omega Centauri." Credit: Author.

apertures are needed to pick out the stars in dimmer globs. The old reliable 8-inch SCT is a decent globular hunter; under dark skies it provides good resolution on many clusters, showing stars in almost all the Messier globs.

M13(Plate 58) is the Great Cluster in Hercules. For northern hemisphere observers, this is it, the most beautiful globular of them all—that's what most amateurs say, anyway. At magnitude 5.8 and 20 arc minutes across, this object is undeniably prominent. However, although bright, it is not necessarily the easiest globular to resolve in small telescopes. Its stars are fairly tightly packed and can be difficult to separate in small telescopes.

M5, which lives not far from M13 in another "summer constellation," Serpens Caput is probably even better than M13. With a magnitude of 5.6, it's actually brighter than its more famous neighbor. Not only is it brighter, it's easier for small CATs to pick apart. It's larger, 23 arc minutes in size, and a little "looser" than M13, so a C5 will show many more stars more easily in this one than it will in Herc. You can usually pick out a few stars in M5 in an ETX on nights when M13 is nothing more than a featureless glow, even at high power. High power, by the way, is a good tool for the glob hunter. These objects take magnification well, and increasing the power almost always brings out more stars.

Omega Centauri, aka NGC 5139 (Plate 59), is *the* greatest glob. M13 pales beside it. Glowing at magnitude 3.9, it's visible from modestly dark sites as a "star." That's why it received the "Bayer Letter" Omega, an identifier usually reserved for stars. It is also huge, 53 arc minutes across, almost twice the size of the full Moon. This nearly indescribable beauty looks better in finder scopes than many globular clusters do in an SCT. Resolution? Resolving scads of tiny stars is a snap, even in the smallest CATs. The sad thing--for northern hemisphere observers—is that this is really a southern object. At –47 degrees south, it is invisible, or nearly so, from the more northerly parts of the United States and Europe.

M22 is a nice consolation prize for those denied the full beauty of Omega. It's still a southern object with a declination "address" of –23 degrees, but it's not insanely low for most northern hemisphere amateurs. This Sagittarius globular has a magnitude of 5.1 and a size of 23 arc minutes, so it looks good in any telescope. Own a 90mm ETX or Questar 3.5 and want to see globular cluster stars? This is the one.

Open ("Galactic") Clusters An open cluster is a nursery full of infant stars. Stars are born in clouds of gas, and when the gas dissipates, what is left behind is a close group of young sparklers. Their movements and gravity will eventually cause them to disperse, but for a time they present us with lovely groupings. Open clusters are as different from globular clusters as can be; they are composed of the very youngest stars, often suns no more than a few million years old. Globular stars count their ages in *billions* of years. Open clusters are essentially formless groupings, rather than well defined balls of stars like globs, but they make up for this shapelessness with luminosity. Galactic clusters are made incredibly lustrous by the presence of young, hot, massive blue and white stars, those of spectral types "O" and "B."

Most observers probably rate galactic clusters as the least interesting DSOs. In the eyepiece, it's often difficult to tell if what's visible is a true cluster or just a normal sprinkling of background stars. In the denser portions of the Milky Way, especially, it's hard to pick open clusters out from the general stellar background. Nevertheless, there are open clusters beautiful enough to impress the most die-hard glob fan. One advantage galactic clusters have over other deep sky objects is that many are bright enough to be relatively unaffected by light pollution.

For example, M37, located in the fall/winter constellation Auriga the Charioteer is a personal favorite. An integrated magnitude of 5.6 and a size of 21 arc minutes across mean it is bright and reasonably compact for a galactic. It is also insanely rich in stars. A telescope that can reach down to magnitude 12 (like a C5 or C6) will reveal at least 150 suns. This cluster is made even more beautiful by the presence of a lone reddish-orange star near its heart. Set off by the cluster's mostly blue and white stars, it provides a wonderful contrast that further enhances the great view this cluster provides.

M45, the Pleiades, are, like M31, hurt by size. This cluster is almost 2 degrees across, so a finder delivers a better view of it than an f/10 SCT. Nevertheless, it's still possible to get a nice view of the rich field of this naked eye group at CAT's lowest magnification. You can just barely squeeze all Seven Sisters into the field of your C8 by means of an f/6.3 reducer and a 35mm TeleVue Panoptic eyepiece. On a really good night, it's possible to (barely) glimpse the tenuous reflection nebula that surrounds Merope and several of the cluster's other stars. It used to be thought this was the gas left over from the cluster's formation, but it's now thought the Pleiades are just passing through a nebula-filled area.

M46, magnitude 6 and 27 arc minutes in size, is located in the southern constellation of Puppis. It is a nice, rich open cluster that's available to both northern and southern hemisphere observers, but what makes it a standout is the tiny planetary nebula NGC 2438 lurking among its stars. Just over 1 arc minute in diameter, the nebula needs high power to make it pop out from the cluster. An OIII can also help if the skies aren't what they oughta be. In the eyepieces of large scopes and in images NGC 2438 is revealed as a miniature Ring Nebula.

On crisp late fall nights don't forget to cruise over to M35 in Gemini. Like M46, it's impressive in itself. Its magnitude is 5.3, and its size is 28 arc minutes. Also like M46, it offers a bonus. In this case, the neighboring, much dimmer, and more distant galactic cluster, magnitude 8.6 NGC 2158. In the city it's hard to spot M35's little brother with anything smaller than a 12-inch, but under dark skies even a C5 will reveal a roundish glow, maybe sprinkled with a few stars at M35's side, 15 arc minutes to the southwest.

Keep the Starship Flying Right

At the end of this wonderful first light night, once you've had a surfeit of the sky's wonders, disassemble the CAT by reversing the scope set-up procedure. Start by powering down the telescope and detaching the power cable, hand controller, and any accessories that are normally removed for storage. Take a look at the corrector before putting the dust cover back on. If there's any evidence of dew, don't cover it or put the OTA in its case. Either dry the lens off with a dew zapper gun or allow it to dry naturally indoors uncovered. Once the scope is inside, don't just leave it all by its lonesome in a corner till the next observing run, either. Although today's SCTs and other CATs are remarkably trouble-free, they do require a little routine maintenance and TLC, which is the subject of the next chapter.

CHAPTER NINE

Care and Feeding of a CAT

Maintenance

You wouldn't expect a car to go tens of thousands of miles without a tune up, and you can't expect an SCT to put in night after night under the stars without some maintenance, either. The most frequent and important task for SCT users is collimation, the procedure for adjusting the alignment of the telescope's mirrors. Renowned *Sky & Telescope* columnist Scotty Houston once said, "Collimation is the number one killer of telescopes." If an SCT is to perform up to snuff, its mirrors must be precisely aligned. The 5x magnifying secondary mirror in these scopes means small errors are exaggerated. Even a slight misalignment of the secondary mirror will wreck images. Unfortunately, many SCT users are afraid to collimate their telescopes, don't collimate correctly, or don't collimate frequently. That's a shame, because collimation is a trivially simple operation to perform on SCTs. You just have to resolve to do it.

SCT Collimation

There's only one way to successfully collimate an SCT, and that involves looking at the diffraction rings of a star, just as is done in the star test. That's a good thing. Unlike the Newtonian owner, the SCT user doesn't need to buy collimation tools. All that's required is an eye, a medium-high powered eyepiece, and a bright star. Magnitude 2.0 Polaris is just about perfect, since it doesn't move much. What if Polaris isn't conveniently placed? Use another star of similar brightness. If a larger than 8-inch scope is to

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be collimated, a star dimmer than 2^{nd} magnitude may show its diffraction rings more clearly. Believe it or not, Polaris becomes too bright in a large aperture CAT.

Collimation can also be done in the daytime with an artificial star, if that's more convenient. The time honored way to "make" a star is to point the scope at the reflection of the Sun off a distant power pole insulator. That works fine, though daytime seeing effects may make it hard to see diffraction rings clearly. If there isn't a suitable power pole insulator in the vicinity, climb into the attic and retrieve a shiny round Christmas tree ornament. Place it in the Sun so it provides a good reflection. Be careful not to point the scope at the actual Sun, of course. See Chapter 12 for some further ideas for artificial stars.

SCT collimation is a three-step process. First is a rough collimation to get the secondary mirror "in the neighborhood." Next is fine tuning, where the secondary is tweaked while observing the star's diffraction pattern. If conditions permit, a final check and an even more precise adjustment can be made by observing an in-focus star's diffraction pattern. As mentioned earlier, the only collimation adjustment that can be made by SCT users is to the secondary mirror via three screws.

Rough Collimation

Set up the SCT as usual, insert an eyepiece that yields a magnification of 100 to 150x, and aim it at Polaris or an artificial star. When the star is in the center of the eyepiece field, defocus (either way) until it becomes a donut that covers about 1/4 to 1/2 of the field, and recenter if necessary. Is this donut's hole, the shadow of the secondary mirror , more or less centered? If so, move on to fine collimation. If not, secondary adjustment is required.

Older Celestrons have an orange plastic cover on the secondary mounting . It must be removed to expose the three adjustment screws. This cover is held in place by two plastic tabs inserted into the secondary assembly and is removed by snapping it off. If this cover has never been removed, it may be necessary to pry gently with a small screwdriver until it comes free. Just remember the cardinal rule of telescope maintenance: never force anything. A few newer Celestron models feature a rotating cover that must be turned to reveal the screws. If in doubt, check the manual. Meade secondary holders usually don't have covers, so the screws should be immediately visible. Meade currently uses Allen-head screws that require a small wrench for adjustment. A small Allen "key" may have been included with the telescope, but if not, these tools are very inexpensive and can be purchased at almost any hardware store. Later Celestron SCTs replace these Allen screws with standard Phillips ("cross-point") screws, which are turned with a screwdriver.

A few older telescopes, both Meade and Celestron, have a fourth screw in the center of the secondary mount. Don't touch it. In these CATs, the secondary mirror is attached to the mount via this central screw. Remove it, and the secondary drops onto the primary. Modern CATs use secondary backing plates with three threaded holes for the collimation screws and a central pivot or leaf spring the mirror rides on. The secondary will remain attached unless all three screws are removed. Actually, the Meade LX400 and some other recent Meade models use six screws rather than three or four. These are arranged in three pairs of outer and inner screws. The inner screws provide collimation adjustment; the outer ones hold the secondary assembly to a mounting assembly on the corrector. The advantage is that the secondary can be taken out without removing the corrector plate, a difficult operation on the LX400. Unlike the adjustments on other SCTs, the LX400 collimation screws (and those on a few other newer Meade models) are spring loaded, so there's no need to worry about leaving them too loose at the end of collimation; the spring applies even tension across the whole range of adjustment.

How does turning the collimation screws adjust the aim of the secondary mirror? Since the mirror rides on a central pivot, tightening or loosening the screws causes them to push or pull the secondary mirror backing plate and tilt it and the secondary in or out, causing collimation to change and the target star to move in the field of the eyepiece.

Now to the task at hand. Looking in the eyepiece, it should be fairly obvious which direction the donut hole needs to be "moved" in order to center things up. What may not be obvious is which screw needs to be turned to move the dark spot the correct way. Don't waste time trying to figure out which screw will move the spot which way. Instead, just pick a screw and tighten it a little. Wrong way? Try another screw. In the rough stage of collimation, turning a screw by small amounts won't have a dramatic effect on the donut hole. If the secondary shadow doesn't seem to move, turn the screw a little more, but resist the temptation to turn by large amounts. The secret to successful collimation, even in the rough stage, is working slowly and methodically.

When it's clear which screw (or combination of screws) needs to be tightened to center the secondary shadow, slowly turn that screw, stopping frequently to peep through the eyepiece and moving the scope to re-center the donut in the ocular (with the telescope's slow motion controls or hand control) after each adjustment until the secondary shadow is centered. Always adjust the secondary by tightening the screws. Only if a screw is snug—hand tight—and can't be turned easily should an "opposite" screw or screws be loosened to continue moving the dark spot in the proper direction by tightening the original screw some more.

Occasionally a telescope is so far out of collimation that it's difficult to get a clear image of the donut. That is usually the result of the owner having turned one or more adjustment screws by large amounts in the wrong direction. To get a scope like that back in the ballpark, stand about 6 feet from the corrector and look down the front of the tube. Do the mirrors' reflections look concentric? Or is the reflection of the secondary off to one side? If it is, adjust the collimation screws until it is roughly centered. That will get the secondary back to the point where a rough collimation can be performed.

Once the donut hole is centered, stop. Don't tighten any screws. Nothing needs to be locked down. As long as the rule "Never loosen a screw unless its opposite number can't be tightened easily" is followed, the secondary will be perfectly secure.

Fine Collimation

Rough collimation will improve a scope's performance somewhat, but not enough to support high power observing. Fine tuning is needed for that. To do a fine collimation, center Polaris and defocus just slightly until a series of diffraction rings

Figure 6. (Fine Collimation) If the 'bull's-eye' diffraction rings are not concentric, there's collimating to do!

similar to what's shown in Figure 6 appears. It doesn't matter which "side" of focus the telescope is on; if one side looks clearer than the other, use that. In order to make the rings large enough to show collimation errors clearly, pump up the power. Use a minimum of 250x for fine collimation. If Polaris can't be used for some reason, choose a similar star that's at least 30 degrees above the horizon. If diffraction rings are not obvious no matter how high the magnification, it's possible atmospheric seeing is too poor to allow fine collimation or that the scope is not yet adequately cooled.

Center the star as precisely as possible (a crosshair eyepiece may help), and when the SCT is properly defocused, examine the bulls-eye formed by the star's airy disk and diffraction rings carefully. Are the rings concentric or does the bull's-eye look squished on one side? If the rings are skewed, there's adjustin' to do.

To make adjustments, follow exactly the same procedure as during rough collimation: tighten screws by small amounts until the rings are perfectly concentric. If a screw is snug, loosen the opposite screw(s). One trick you can use is placing the squished side of the bull's-eye at the edge of the field. To collimate, then turn the screw or screws that move the bulls-eye to the center of the field. If the rings are still not perfect, move the bulls-eye back to the field edge and center it with the collimation screws again, repeating this procedure until the diffraction rings are as concentric as you can make them.

In-focus Collimation

Once fine tuning is complete an SCT is ready to take on most observing assignments, but there is a final step for observers engaged in demanding pursuits such as high-resolution planetary imaging. In-focus collimation is done by observing

Figure 7. (In-focus Collimation) If the seeing is good enough, an in-focus collimation can be performed to get the scope dialed-in precisely.

the precisely focused image of a star and its first diffraction ring. The requirements for performing in-focus collimation are high power (300 x and more) and steady seeing. The slightest turbulence will make a star's in-focus diffraction ring and Airy disk smear together into a blob.

If the seeing is right, center Polaris in the field and focus up at high power. A tiny disk, the Airy disk, surrounded by one bright and (maybe) one or more dim rings (Figure 7) should be visible. Take a close look at the first diffraction ring. Is it complete and unbroken? If not, adjust the collimation screws by small amounts until it is complete around the star as in Figure 7b. This is very critical work. You might sometimes find it necessary to wait for the heat waves left in front of the corrector by your hand after adjusting the secondary to dissipate before you can see the first diffraction ring clearly again!

Collimation Tips

Should you collimate an SCT with a star diagonal installed or in a "straight-through" configuration with an eyepiece inserted directly into the visual back? There is no doubt a diagonal can affect collimation if its mirror or prism is misaligned. If the diagonal is rotated to a viewing position different from the one it was in when collimation was done, any alignment error may make cause collimation to be "off" at the new position. Worse, if the diagonal is removed to take pictures through the telescope in straight through fashion, the SCT may then be way out of adjustment.

Collimate with a diagonal or not, then? First, determine whether the diagonal has problems. If its prism's or mirror's alignment is not right, the image of a star will move a considerable distance in the field of an eyepiece when the diagonal is rotated to new observing positions. One possible solution is to purchase a high-quality star diagonal. The stock units that come with new telescopes are often of low quality. Even high quality units will show some image movement, however, because of a particular telescope's particular mechanical alignment characteristics rather than problems with the diagonal. Luckily, most diagonal alignment problems are too small to have much effect on collimation. Thus, it's best to collimate with the diagonal if observing will be done with the diagonal. If the scope is mostly used for imaging in straight-through fashion, collimate that way.

Another frequent question novices ask is, "How often should I collimate?" The answer is, "As often as necessary." Check collimation on a regular basis. A quick glance at a slightly out of focus star will instantly show whether the CAT needs attention or not. An SCT that doesn't go on many road trips may go months or even years before anything more than minor touchups is needed. If collimation *is* needed before every observing run, something is wrong. Usually the secondary is loose because collimation screws were loosened to adjust collimation before their opposite numbers were snug. Will a brand-new SCT need adjustment? Probably. Even if it was precisely collimated at the factory, a long trip and rough handling likely ensures it needs adjustment.

MCT Collimation A Rumak -style Maksutov Cassegrain with a "separate" secondary mirror holder is collimated just like an SCT. Adjust the secondary mirror mount's three screws while observing the diffraction rings of a star. In a Gregory-style MCT , like a Meade ETX, the secondary is a silvered spot on the inside of the corrector plate, and there's no obvious way to adjust anything. Normally, collimation isn't required for these telescopes. A few Gregory Maks—including new and expensive ones—do develop collimation problems. In most cases, a new or old Gregory that's out of collimation should go back to the dealer. Although these scopes *can* be adjusted, they often have to be partially disassembled to do so. Properly collimating a Gregory MCT is not easy and frankly calls for an optical bench and plenty of know-how.

You probably shouldn't even dream of hacking into a Questar or other expensive MCT, but let's say you find a dirt-cheap ETX or Synta/Orion MCT on a swap table at a local star party. The price is right, but the collimation is off. You might consider a little tweaking in that case. The ETX, the Syntas, and other Gregorys are collimated by adjusting the primary mirror. The Syntas are comparatively easy to collimate, since their primary mirror adjustment screws (Allen screws) are exposed on the back of the rear cell. The secret to success is working very slowly and very carefully and being obsessive about re-entering the target star between tweaks.

The ETX and quite a few other Gregory MCTs have their mirror adjustment screws hidden under the rear cell cover and eyepiece holder and are much harder to work with. Removing the cover, which often requires removing focuser knobs and other hardware first, will expose three pairs of push-pull bolts on the primary mirror cell. One bolt of each pair is a locking screw and the other is the adjustment screw. A little careful experimentation may be required to decide which is which. When that is sorted out, loosen the three lock screws slightly and proceed to collimate the scope on a target star's donut and diffraction rings.

Unfortunately, that's easier said than done. The rear cell cover and eyepiece holder will have to be replaced after each collimation tweak so an ocular can be inserted to check the star. When the star is a perfect bulls-eye, the locking screws should be tightened down sequentially and evenly, and the scope given a final check on the star. Likely, locking down the mirror has thrown collimation slightly off, and the cover will have to be removed and the lock screw tensions fiddled with until collimation is "in" again Think long and hard before attempting to collimate any Gregory Maksutov. I can almost guarantee an unpleasant and unsuccessful experience. Even if it's "just" a 90mm ETX, send it back to the factory for collimation.

Schmidt Newtonian and Maksutov Newtonian Collimation

Amateur astronomers who have collimated a "straight" Newtonian already know now to collimate SNTs and MNTs. You haven't? Don't worry; it's harder than adjusting an SCT, but is easy enough to accomplish once the process is understood. A lot has been written about Newtonian collimation, but it's really a simple procedure that can be broken into three steps: center the reflection of the primary mirror in the secondary mirror, center the reflection of the secondary in the primary, and do final tweaking on the diffraction rings of a slightly out of focus star.

Step one, centering the primary in the secondary, is done by observing the reflection of the primary in the secondary mirror while looking into the focuser with no eyepiece installed. Take a look. The reflection should resemble what's seen in Figure 8. If the reflection of the primary mirror is *not* centered, adjust the secondary mirror via three or four screws on the exposed surface of the secondary holder. Collimate as with an SCT, tightening screws to move the reflection of the primary mirror until it's centered. Note that some MNTs and SNTs have small covers on their secondary holders that must be removed for access to the adjustment screws.

In rare cases it may be impossible to center the primary reflection in the secondary because the secondary and holder have rotated with respect to the focuser. It's easy to adjust the rotation of the secondary assembly in a standard Newtonian, but not so easy with an SNT—the corrector complicates matters. If the mirror only needs to be rotated a small amount, maybe 1/4-inch or so, it's permissible to loosen the

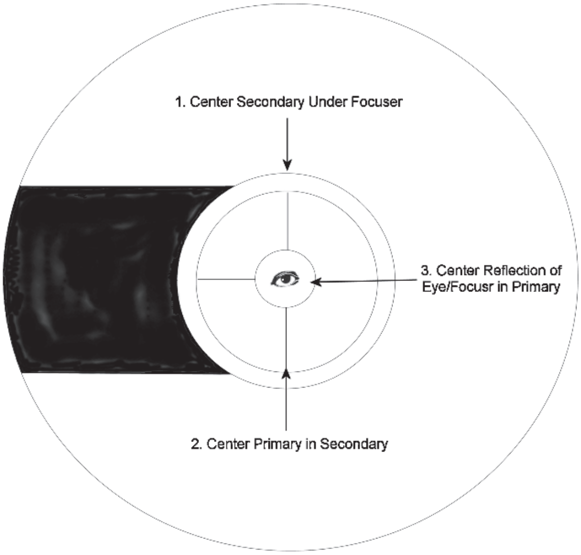


Figure 8. (SNT Collimation) Schmidt Newtonian collimation is harder than SCT collimation, but not much harder, and very necessary.

corrector retaining ring and turn the whole thing—corrector and secondary. If more rotation is required, forget that. Rotating the corrector may cause optical problems. The corrector will have to be removed for the secondary's rotation to be adjusted (usually via a central screw on the secondary holder). For many if not most SNT/MNT owners, that is a good time to call the scope maker.

In step two—still with no eyepiece in the focuser—check that the secondary reflection is centered in the primary. Center it by adjusting the scope's primary mirror collimation screws. On the Meade SNTs and many MNTs, there are six bolts on the main mirror cell. Three are locking bolts that must be loosened before adjustments can be made. Adjust the primary slowly and carefully, doing plenty of checking until the secondary reflection is centered. Once it is, lock the primary mirror by tightening the lock screws. Don't tighten each locking screw all the way at once. Instead, turn each screw small amounts until all three are tight, checking the secondary's reflection as you go. Tighten or loosen one or more lock screws slightly if collimation has been thrown off.

A Newtonian collimation tool, a "Cheshire" eyepiece , can help a lot when adjusting the primary mirrors of these scopes. It's essentially a peep sight that fits into the focuser in place of an eyepiece, and, if the center of the primary mirror is marked (as many are with a small sticker), the Cheshire will make primary adjustment very easy. Line up the sticker with the "dot" that is the reflection of the Cheshire's peephole, and mirror adjustment is done.

The final act in the Schmidt/Maksutov Newtonian collimation drama is a star check. If the diffraction ring bulls-eye is skewed, fix it as described in the SCT fine collimation section. The only difference is that the primary mirror on an SNT or MNT is adjusted at this stage rather than the secondary, as on an SCT.

Optical Cleaning SCT users get off easy when it comes to collimation. There's only one element, the secondary mirror. We (and other CAT owners) also luck out when it comes to optical cleaning . For most users only one surface ever needs attention: the exterior surface of the corrector plate. Cleaning correctors is pretty much a no-fault operation. A Newtonian user always runs the risk of scratching a primary or secondary mirror's delicate coating during cleaning. The SCT's corrector plate, in contrast, is like a camera lens; it's reasonably tough and will survive *some* wrong-headed cleaning.

Still, the last thing a CAT user should do is clean optics that don't need it. The usual advice to novices regarding cleaning is *don't!* Though correctors are tough compared to mirrors, there is still the chance of doing more harm than good. Don't set out to clean the corrector because of a speck of dust or two. There will always be a little dust on a telescope that's actually used, and a few dust motes on a corrector will not hurt a thing. A speck of dust will most assuredly do less harm than a big scratch left on the lens as a result of one cleaning too many. This really can't be overemphasized: *leave the corrector alone unless it's dirty.* It would do novices good to see how dirty the optics of professional telescopes are allowed to get before they are cleaned.

The time will come when an SCT or MCT will need a gentle corrector cleaning, of course. It may have accumulated a fingerprint or two at the last star party. In the spring many areas are plagued by airborne pollen that can potentially damage coatings and should be removed. It's not unheard of for birds to undertake "bombing missions" against CATs, too. What's the secret to safely cleaning the corrector plate? Treat it with respect like, a fine camera lens. It is a fine lens that is beautifully polished and multicoated for optimum performance.

Cleaning Procedure

Before breaking out the lens cleaner and tissues, let's review how to minimize the need for cleaning. Always keep the corrector cover in place when the scope is not being used. It's also a good idea to leave the cap on when the scope is outside cooling down prior to use. Storing the telescope in a case also tends to minimize contamination. Keep the rear port capped at all times. Dust, bugs, and other contaminants can enter the OTA via that route, and removing them is a huge hassle. A major source of corrector contamination is dew. Dust and pollen and other contaminants will tend to stick to a wet corrector. Dampness can also promote the growth of fungi that will literally eat the lens. Keeping dew from adding to cleanliness problems is easy to do with one of the corrector heaters described in Chapter 5.

So, how to do the cleaning? Deal with the easy stuff first, the loose accumulation of dust on the corrector's surface. The easiest way to get rid of dust particles is with "canned air," compressed air designed for cleaning optics and electronics. If possible, purchase a brand designed expressly for photo/optical use, since that is more likely to be free of contaminants than a brand designed for cleaning computers.

To dust the corrector, move the OTA until it's just above level and lock it. Remove the dust cover and, holding the canned air "gun" level to prevent liquid propellant from being sprayed onto the lens, give the corrector a few blasts to blow the loose dirt away. Don't hold the trigger down; instead, apply 2- to 4-second bursts and move the air stream around. For best results, blast the corrector at an angle from about a foot-and-a-half away. Continue until all the removable dust is gone. Some amateur astronomers fear canned air, having been told by those supposedly in the know to never use it around telescopes. Like many stories passed from amateur to amateur over the Internet, there is a grain of truth there. It is inadvisable to use canned air on a first surface mirror. Depositing liquid propellant on a mirror or blowing a particle of foreign matter onto it at high velocity can do damage. One of the major applications for canned air, however, is cleaning lenses, which is what the corrector plate is, and it works well and safely in that role if the above cautions are observed.

What if some stubborn dust remains after a canned air dusting? Or if, in addition to loose dust, the corrector has smudges and spots—"crud"—on its surface? Proceed to the next "level" of cleaning to remove small blemishes. What you should consider using for these small jobs is a remarkable device called the "Lenspen" (Plate 39) found in camera stores and at astro-dealers. There's a soft extendable brush on one end for dusting the area of interest. When that's done, the cap is removed from the other end of the Lenspen to expose a soft disk impregnated with non-liquid cleaner that is used to wipe away smudges and dirt with a gentle circular motion. Some CAT users wonder about using the Lenspen's tip over and over to clean; all I can say is that I have been using this handy device for years without a single problem. Lenspens are available with tip sizes that range from small, which is useful for cleaning short focal length eyepieces, to larger sizes appropriate for small areas on the corrector and other lenses.

Cleaning the whole corrector with a Lenspen would be a slow and tedious process. If there are large dirty areas, it's time to hit the lens cleaning fluid and lens tissues. *Never* use tissues designed for eyeglasses lenses. These are often impregnated with a silicone compound that will make a smudged mess of the corrector plate. Lens tissues designed for photographic use are available in camera stores. Don't use cleaning fluid designed for glasses, either. Who knows what's in it? It is as likely to make the lens worse as better. Camera equipment dealers sell cleaning fluid, but if that's not available the formula Meade publishes in its manuals works well: one part pure isopropyl alcohol, two parts distilled water, and one drop of biodegradable unscented liquid dishwashing soap (Ivory is good) to make a pint of solution.

Whatever kind of fluid is used, always apply it to the lens tissue and not to the surface of the corrector. It's easy to use too much cleaner, which can migrate into the interior of the OTA and leave stains or promote fungal growth as it slowly dries. To clean, dampen a tissue and wipe using gentle linear strokes and working from the secondary holder outward. Rotate the tissue after each stroke to expose its clean surface, and change tissues often. When the smudges and dirt are gone, set the cleaning fluid aside and gently dry the surface with clean tissues.

A less costly solution? Windex glass cleaner and Kleenex tissues. This combination has worked spectacularly well for this author for over thirty years, yielding squeaky clean correctors. There are a few caveats. First, use only the "original" blue Windex . Additives designed to make the stuff smell like a flower garden won't do anything good for a corrector. Be careful about the type of tissues, too. Buy only unscented, lotion-free white ones. The only problem with the Windex/Kleenex combo is that a small amount of lint can be left over after cleaning. That's easily gotten rid of with a Lenspen's brush or some canned air. You can also use Windex on both UHTC and XLT coated correctors as well as with Meade and Celestron coatings: it does not damage them and cleans better than anything else.

Now, let's consider how to clean the inside surface of the corrector. Normally, it should never require cleaning. An SCT that is kept in a case with the rear port capped will likely go many years—perhaps a lifetime—before "inside" problems develop. However, some older SCTs, especially those stored in hot attics and garages, develop a hazy film on the inside surface. This appears to be caused by outgassing from materials used in the OTA interior. Primary and secondary mirror s can also develop cleanliness problems. That is even more unlikely than problems with the corrector's inside surface, however. Stuff happens, though, and it is possible (though not recommended) to clean the primary and secondary yourself.

When a problem develops with an interior optical surface of a telescope, the best course of action is to ship the CAT back to the manufacturer for cleaning. Most often, interior cleanliness issues occur in older telescopes that are good candidates for a thorough factory cleaning of both optical and mechanical components and—importantly for older SCTs and moving mirror MCTs—a re-lube of the baffle tube. The problems are that you'll be without your beloved scope for a while, you'll have to trust it to the tender mercies of the UPS and FedEx folks, and the cost of cleaning and freight charges can be substantial.

If all the CAT needs is an inside surface corrector cleaning, the job is fairly easy and safe to perform and is a perfectly reasonable course of action for many amateurs. There are a few warnings that should be understood. Delving into the interior of the telescope's OTA may void its warranty, though it's unlikely the manufacturer will be able to tell the scope's been opened as long as it has been reassembled correctly. More seriously, any big mistake, ranging from accidental misalignment of optics to breaking the corrector plate, will probably cost more in repairs than a cleaning by the maker would have. If, and only if, you accept full responsibility for these possible outcomes, proceed to attempt a cleaning of a telescope's interior optical components as described in the following paragraphs.

After these dire warnings, the actual act of removing the corrector plate is anticlimactic. There are only a couple of precautions to observe. Most critical is returning the corrector to its factory rotational position when it's replaced. If the corrector is reinstalled in a different position, images will be degraded. Most Meade telescopes have marks on the corrector and the lip it rests on to indicate proper orientation. If there are no obvious marks, scribe both corrector and lip with a soft pencil or marker. Celestron corrector plates are usually not marked, but there will almost always be a small serial number engraved in the outer surface at the edge. The correct rotational position will be with the serial number at the 3:00 o'clock position.

All SCTs have small cork or paper shims along the edge of the corrector that keep it precisely centered (Plate 60c). Try not to disturb the shims, and mark their positions so they can be replaced during reassembly if they go flying when the corrector is removed. They are clearly visible when the retaining ring is removed and before the corrector is pulled out. It's not a bad idea to make notes on disassembly during the process as an aid in putting things back together.

Before pulling the corrector, place the SCT on a solid, clean surface, and prepare a place for the lens to go when it's out. You might lay it on a couple of soft bath towels. Tilt the OTA up at a 45 degree angle and lock it so the corrector won't fall out when the retaining ring is removed. Remove the screws (either Allen or Phillips head) that hold the plastic retaining ring in place (Plate 60a), set the ring aside in a safe place, and mark shim positions with a pencil. Lastly, remove the corrector plate itself by grasping the secondary mount and pulling gently but firmly (Plate 60d). Sometimes the corrector won't want to come out easily. Deal with a sticky one by gently prying along its edge—very gently—with a small flat-blade screwdriver or a wooden tool (manicure sticks work) while continuing to pull steadily on the secondary mount. Don't pull too hard, though, or the corrector could go flying across the room, leaving you standing there like a refugee from a Three Stooges film. When the lens comes free, set it on the towel with its inside surface up (to protect the secondary mirror). Handle the corrector only by its edges or by the secondary mounting.

Clean the corrector's inside surface using canned air, a Lenspen, or tissues and fluid as appropriate. *Be careful.* The corrector plate is almost window glass thin and fairly easy to break. Replacing it will cost substantially more than replacing a broken window, though! Be sure to keep fingers away from the exposed surface of the secondary mirror . Luckily it is partially protected by the short cone-shaped baffle that extends out from its mounting.

Plate 60. (Pulling a Corrector) Clockwise from upper left, (a) unscrew Allen head screws, (b) remove the retaining ring, (c) hold onto the secondary mount and pull the corrector out, (d) carefully note the positions of paper shims.

When the corrector's inside is satisfactorily clean, reinstall it. Before setting it into the OTA , replace any dislodged shims in their original positions. If they don't want to stay in place, moisten them with a little saliva. Tilt the corrector on edge on its towel, touching its edges and secondary baffle only, and, holding it in place with one hand, grasp the outer secondary mount firmly. For safety's sake, keep one hand on the corrector's lower edge and guide it into place, observing the proper rotational orientation (the marks on lip and corrector or the serial number). Double check that the corrector is properly positioned before replacing the retainer ring and installing its screws. Don't tighten these screws down too much—finger tight only. If there are now a few fingerprints on the outer surface of the corrector that were put there during the process of replacing it, clean them as before. Done!

Fixing a Loose Secondary Holder

Occasionally secondary holders will become loose and rotate freely. That's not good. Like the corrector, the secondary mirror needs to be in a particular rotational position for optical performance. It's easy to fix this problem with recent telescopes. The secondary mount is a two-piece assembly held in place by the conical baffle surrounding the secondary mirror on the inside surface. The baffle screws onto the secondary mount, sandwiching it to the corrector. Remove the corrector plate as above, and, grasping the outer surface of the secondary mirror, mount with one hand and tighten the baffle, making sure the secondary mount remains in the correct orientation. Unfortunately, some Celestron OTAs—mostly earlier ones—have secondary assemblies that are glued in addition to being screwed together. In these cases, it's probably best to consult the manufacturer.

What is the correct secondary holder orientation? On a Celestron fork mount scope, the word "Celestron" printed on the secondary holder should be right-side-up, with the tube level, and will line up with the serial number on the corrector. Some scopes may not have "Celestron" on the secondary, but there will almost always be a serial number. On a Celestron GEM OTA oriented so the focus control is level and on the right, "Celestron" will, again, be right-side-up. Meades usually do not have words or serial numbers on their secondary holders. Assuming the secondary mount hasn't rotated too far, orienting it so that the triangle formed by the three collimation screws has its apex pointing up will (usually) yield the correct orientation. If in doubt, you can mark the back of the secondary mirror 's backing plate. The mirror can be removed from the holder in order to examine it by unscrewing all three collimation screws, but most users stop there and just call Meade.

Mirror cleaning? It can be done in a pinch. The best tool is a soft brush. The brush on a Lenspen will work (don't use the cleaning tip). A clean camel's hair brush is even better. If more than dusting is required, use the Meade cleaning fluid recipe. Work the same way as when cleaning a corrector, but use USP cotton balls purchased at a pharmacy rather than lens tissues. Do not apply any pressure to the fluid-wet cotton; just drag it across the primary's surface, changing cotton balls frequently and dabbing the mirror dry with clean ones when done. It's best not to try to remove the primary for cleaning; work with it in place, taking care not to spill excess lens fluid into the rear cell assembly. Again, it's almost always best to leave both mirrors strictly alone and call Meade or Celestron.

Cleaning MCT, MNT, and SNT Correctors

Clean the exteriors of Mak and Schmidt Newtonians using the same method used for SCTs. Interior surfaces? SNTs are "done" the same way as SCTs when it comes to corrector cleaning. As for Maks, well, that depends. You should probably not attempt to pull the corrector of a big and fancy MCT or MNT without guidance from the manufacturer. On the other hand, the correctors of small MCTs screw on, and don't seem to be harmed in any way by being unscrewed and removed. You might even accidentally remove ETX correctors a time or two as you attempt to unthread their screwed-on corrector covers!

What now? The telescope is up and running, it's going to its go-tos, and it's perfectly collimated. What more could any CAT wielding astronomer want? Well, it's the computer age. The CAT *is* a computer if it's a go-to model, but hooking it to another computer, a PC or Mac laptop, can add even more functionality and fun.

CHAPTER TEN

Computerizing a CAT

What could possibly make it worthwhile to haul an expensive laptop computer onto a dark and damp observing field? At the most basic level, a PC (or Macintosh) can fill-in the details lacking in a telescope's hand controller. Sure, the HC contains the locations of tens of thousands of deep sky objects, but what are they and where are they, exactly? The hand controller will probably display some basic information about an object: that it's a galaxy in Pegasus, for example. It might even know that the faint fuzzy in question has a magnitude of 11 and is umpteen gazillion light-years distant from our comfortable rock. But that's not much to go on when trying to decide whether the object in question is a showpiece or a barely discernable lint ball. And what else of interest is close to this particular DSO? Where is it in relationship to other sky objects?

A laptop hooked to a go-to scope makes these "what and where" questions easy to answer. With a PC interfaced to the CAT there'll be a graphic representation of the night sky that shows exactly where the telescope is pointed and what's around it. Send the scope on a go-to slew, and an onscreen bulls-eye will move across the PC's star map as the telescope moves. Wondering about an object? Click on it and learn all about it. Even the simplest and cheapest planetarium programs provide far more extensive details about deep sky denizens than a telescope hand controller can, maybe even including excerpts from experienced amateurs' observing logs. Still not sure if NGC umptysquat is worth a look? Many programs can display actual photos of thousands of objects, sometimes superimposed on the PC's virtual sky.

What's the coolest thing about running a go-to scope with a laptop, though, especially for beginners? The click factor. In the beginning, nothing is more amazing than mouse-clicking on an object on the laptop screen and watching the telescope slew to that target. Even after using computers at the scope for years its still exciting. It's actually somewhat useful, too. If the computer is handling go-tos, the hand con-

R. Mollise, *Choosing and Using a New CAT*,
DOI: 10.1007/978-0-387-09772-5_10, © Springer Science + Business Media, LLC 2009

trol can stay Velcroed to the tripod. This is especially helpful if you are continually dropping and losing the HC all night long when issuing go-to commands by mashing its (too small) buttons.

Hardware Considerations

Even those novices who agree that running a go-to scope from a laptop sounds downright cool become a little skittish when it comes to hardware. Doesn't astronomy software require a powerful computer? What effect is dew going to have on an expensive laptop? Will low nighttime temperatures send a brand new Dell to hell Isn't that nice, bright LCD screen going to ruin the dark adaptation of everybody on the observing field? How complicated *is* interfacing a scope to a PC?

Truth is, almost all astronomy software is less demanding of computer resources than the PC games the kids (and maybe you) play. Even the most advanced astroware doesn't need much horsepower; it pales in comparison to something like *Doom*. There are laptops on the market today able to handle the most graphics intensive astro-ware selling for $400. If beautiful graphics aren't important, a five-year-old used computer will be more than adequate. Basic astronomy program functions such as drawing star maps, identifying objects, and sending the SCT on go-tos are far less demanding than building the 3-D world of *The Sims*. How about desktops? You should avoid using one of these at the scope for two reasons: safety and convenience. Since a desktop needs 110vac to operate and is designed for use indoors in a dry environment, exposing one to dew isn't smart or safe. Convenience? It's just too much of a pain to lug out monitor, keyboard, and system unit for each observing session.

Won't dew do-in a laptop? Don't worry too much about it. Most laptop computers generate enough internal heat to keep them dry under the dampest conditions. Or build a simple enclosure to protect the PC (Plate 61) using, perhaps, lightweight vinyl sign material. This is the stuff politicians use for those annoying yard signs at election time and is available in easily cut sheets online for modest prices. Fasten the sheets together with strips of self-adhesive Velcro so your laptop enclosure stores flat for easy transport. Even cheaper and locally available is foam-core board (sold in craft stores), which is composed of a thin sheet of Styrofoam-like plastic sandwiched between two sheets of poster paper. Seal the paper with a can of spray stuff from the same craft store, strengthen it along the edges with some half-round molding from a home improvement place, and put it together with—what else?—duct tape. You can also store in this enclosure eyepieces and other small items during an evening's observing run in order to keep them dew-free.

Low temperaturesare usually not any more of a problem than dew. Again, the computer generates enough heat internally to keep it happy. Under truly bitter conditions some laptop displays, especially those on older machines, may become slow and unresponsive, not unlike hand controller displays. Kendrick makes a dew heater for laptop screens for use with their heater controllers that should keep the PC usable under harsh conditions. Although this heating pad affair is surprisingly expensive, at $155, it may be a godsend for laptop users in the frozen north.

Plate 61. (Computer Enclosure) Corrugated plastic sign material is perfect for building a simple laptop enclosure. Credit: Author.

Most astronomy programs feature a night-vision mode that turns the Windows (or Mac) screen colors to shades of red and black. Invoke that, turn down the laptop's display brightness to a low setting, and the screen may be dim enough to preserve night vision—but probably not. Usually some element, often the taskbar in Windows, will be left white and will be too bright no matter how the display is adjusted. Most observers solve this problem by using a material called "Rubylith," which is a transparent red film used in the graphics/printing industry. It's commonly available at graphics/art suppliers but, increasingly, can be obtained from astronomy dealers due to the popularity of laptops for use at the scope. Cut a piece to fit the screen, either tape it down along the edges or just let static cling hold it in place, and the laptop's display will be more than red enough and dim enough.

The laptop is snug in its little enclosure and its screen is red and dim. All that remains is the physical act of hooking PC to go-to. Unless the telescope is a Meade RCX400, that means buying or making a serial cable in the proper format for the scope and plugging it into the laptop's and mount's serial ports. As mentioned previously, most modern laptops do not possess serial ports. The usual solution is a USB-serial adapter. Yes, I discourage the use of these little cables earlier, but most of the time they do work OK for simple tasks such as sending a scope on go-tos from the PC. It's also true that some USB serial cords work better with scopes than others. If trouble is encountered the easiest solution may be to buy an adapter from Meade or Celestron. Both companies sell them, and there should be no question that they will work with their scopes.

What kind of serial cable is needed to hook the laptop to the scope? Not the standard RS-232 serial cables; the right kind can be purchased from most telescope dealers. Can't spend for yet *another* CAT accessory? These cords are nothing fancy and aren't hard for experienced electronics tinkerers to make. For instructions on building Celestron cables see Michael Swanson's excellent "NexStar Resource Site." For Meades, have a look at Mike Weasner's famous "Mighty ETX Site" (Appendix 2). Serial cables are available in various lengths, but you should probably choose a good long one, at least 12 feet. There won't be any trouble with the serial data signal getting weak or corrupted with this relatively short run, and a 12-foot length will allow the laptop to be positioned a convenient distance from the scope.

What does the serial cable plug into on the scope end? Celestrons have a port labeled "PC," but, as discussed in the Buyer's Guide chapter, that's not where the laptop cable goes. It goes into a small RJ-style receptacle on the base of the hand controller. Same with some Meades; there's a plug called "Aux" on their mounts that sounds like it might accept computer input, but that is exactly where *not* to plug in the laptop. Instead, as with Celestron, the serial cable goes into an RJ receptacle on the Autostar hand controller. Some Meade scopes feature RS-232 connectors on their drive bases as well.

Astronomy software has come a long way over the last twenty years. The typical program now offers *millions* of stars, hundreds of thousands of deep sky objects, and (sometimes) a photo-realistic depiction of the sky. Astro-ware has also branched out into a couple of different "genres." You wouldn't use *Microsoft Excel* to write a letter (though you could), and you also wouldn't use a planetarium program to plan a night's observing (though you could). Astronomy software comes in two distinct flavors now, *planetariums* and *planners*.

Planetarium Software

This is what most amateur astronomers think of when they think about astro-ware. A planetarium program creates a graphic representation of the night sky on the computer's screen. This may be a simple depiction with dots and lines to represent stars and constellations and small symbols for deep sky objects, or it may be a near photographic—or photographic—representation of the sky with stars in their proper spectral colors and deep sky objects that are photographic images rather than symbols. Some of the more "prettified" programs even go so far as to allow users to superimpose digital pictures of a particular observing site's horizons onto the virtual sky's horizon.

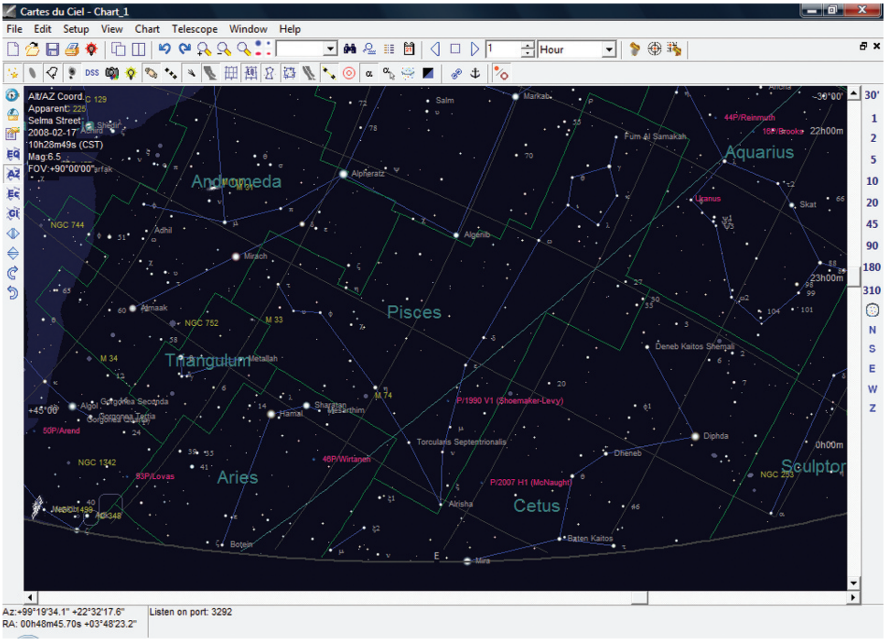
Almost all top-of-the-line planetarium programs seem to be going this route, competing to see who can produce the prettiest graphics. That's not a bad thing for educators and armchair astronomers. Projecting one of these programs' skies on a big screen with an LCD projector can provide a breathtaking experience for students. Unfortunately, what's amazing in the classroom can be annoying on a dark observing field at 3:00 a. m. For example, when the display is zoomed out enough to show a respectable portion of the sky, those beautiful DSO images become nearly invisible gray spots. Most pretty planetariums can be customized to improve their legibility in the field, but there's no denying that for the working observer simpler is sometimes better. Luckily, quite a few of the smaller players in the planetarium field have stuck to simple and legible.

Which particular planetarium program is best? That depends on you, your scope, your observing habits, and how much you want to spend, but the following programs have been tested extensively and have been judged suitable for most astronomy tasks.

Cartes du Ciel

For new astro-ware users, this is the place to start. Switzerland’s Patrick Chevalley has been working steadily for over a decade to improve and enhance his freeware program, *Cartes du Ciel*, “*CdC*,” (Plate 62). Today, there’s very little *CdC* can’t do and do well. Many of its users wonder why anyone would pay money for a planetarium program when they can download the Sky Charts section for free (Appendix 2).

What exactly can *CdC* do? All the things any good planetarium can: show the skies for any date, time, and location; control a go-to scope (with the aid of the ASCOM telescope interface program); print detailed charts; display hundreds of thousands of deep sky objects and millions of stars; and even show Earth satellites. Actually, *CdC* will do some things many other astronomy programs, even the more expensive



Alt/AZ Coord.
Apparent
Selma Street
2008-02-17
10h28m49s (CST)
Mag:6.5
FOV:+90°00'00"

Az:+99°19'34.1" +22°32'17.6"
RA: 00h48m45.70s +03°48'23.2"
Listen on port: 3292

Plate 62. (Cartes du Ciel) *Cartes du Ciel*, amateur astronomy’s number one freeware planetarium program can do anything commercial software can—and more. Credit: Author.

ones, can't. Most planetarium programs provide dimmer than magnitude12 stars by using the huge Hubble Guide Star catalog (GSC), which goes down to about magnitude 16 and fills up most of a CD ROM. Manipulating this massive catalog can be a problem for an older computer, which many amateurs use in their observatories. *CdC* can work around that by downloading fields full of GSC stars from the Internet as needed. It can also download pictures of deep sky objects from the Digitized Sky Survey or superimpose user-generated pictures on its charts.

As always, there ain't no such thing as a free lunch. Being a freeware offering, *Cartes du Ciel* is only available via Internet download. In order to get the entire program, including the Tycho 2 star catalog that takes the program's star display to magnitude 12, a prospective user will need to download nearly 50 megabytes of data, which will be a show-stopper for someone without a broadband Internet connection. An Internet connection will also be needed any time the Hubble GSC stars are accessed. The program *can* read GSC stars off a CD, but it's up to the user to locate a copy of the catalog in a compatible format. Finally, this program won't win any beauty contests. Oh, the display is attractive enough, but it is certainly not photorealistic. Despite these quibbles, this is a fine program and, again, is all many people ever need. It's so good, in fact, that it was used to generate the star charts used in my last book, *The Urban Astronomer's Guide*.

Cartes du Ciel's current release, version 2.76, is only available for Windows PCs. Chevalley is currently at work on a new version, however, *CdC 3.0,* which will be Linux compatible and therefore able to be easily ported to OSX (Macintosh) computers. It's in an advanced "beta" stage of development at the time of this writing and has already been compiled and run on Macs. Although *CdC* is not the fastest-executing planetarium program, it runs respectably well even on older PCs like the 566 MHz Celeron.

Hallo Northern Sky

Cartes du Ciel is a good thing, but it's not the only thing when it comes to no-cost planetarium programs, at least not for Windows PCs. A close runner-up in the freeware sweepstakes is Hans Kleijn's somewhat oddly named *Hallo Northern Sky.* Despite its name, "*HNS*" is more than capable of displaying the southern celestial hemisphere and doing it with aplomb. *HSN* can also control just about any telescope through the auspices of ASCOM, just like *Cartes.*

Indeed, in most ways *HNS* is very similar to *CdC,* if not quite as finished looking. Although *CdC's* display is not overly fancy, *HNS's* sky is downright plain. Not that that's necessarily a bad thing. At 2:00 o'clock in the a.m. on a cold and dark observing field, *HNS's* display is eminently readable. One other way in which *HNS* doesn't seem quite as finished as *CdC,* not to mention commercial programs, is in its lineup of deep sky catalogs. Although the objects included in the larger of two available download packages will last many observers a lifetime, there's not the wealth of specialized object lists there is available for *Cartes*. Finally, *Hallo Northern Sky* can download deep sky pictures but not GSC stars. It can access the Hubble catalog, but the user must locate and install a copy.

This is not meant to belittle the achievement *Hallo Northern Sky* represents; it didn't achieve the status it's attained in the amateur world by being a second-rate program. Actually, some of *HNS's* features are preferable to those in *CdC.* For example, retrieving detailed information on an object in *Cartes du Ciel* requires clicking to open a window, which gets in the way of the sky display. In contrast, clicking on a star, DSO, or planet in *HSN* brings up an unobtrusive description in the upper left area of the main screen. One other nice thing about *Hallo Northern Sky*? It is fast, blazingly fast, even on older PCs. It far outstrips *Cartes du Ciel* in that regard. The current version of *HNS* is Windows only, but it has reportedly been run under the Linux operating system via emulator software.

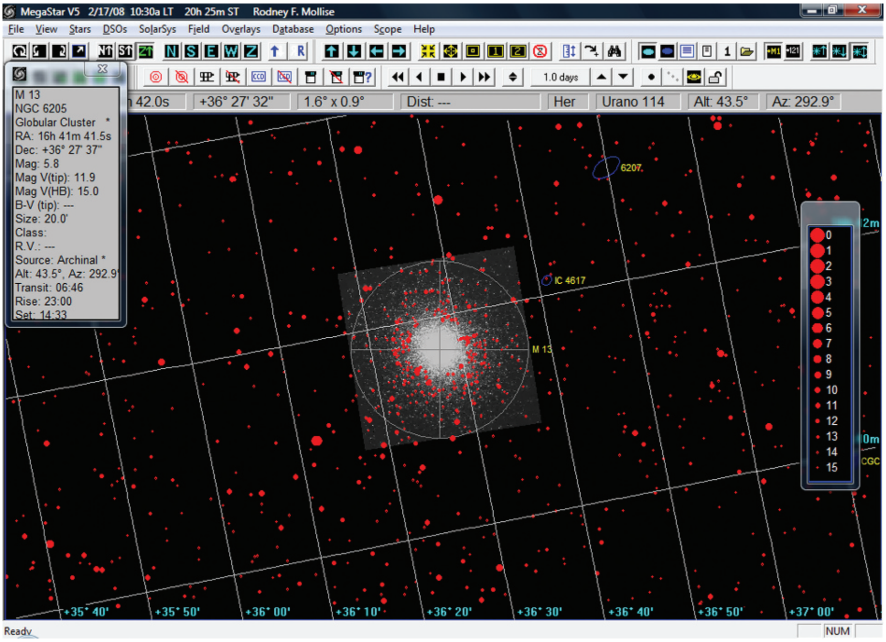
Megastar5

Megastar, which hit the astro-software market in the early 1990s, has the distinction of being the first really deep astronomy program and featured tens of thousands of deep sky objects and the Hubble GSC from the beginning. The original program, which appeared on CD-ROMs and included fifty 3.5-inch floppy disks, didn't seem too practical at first. But here was a program that could outdo the best print atlas available.

Megastar's author, Emil Bonano, has continued to improve his program as the years have rolled by—if only incrementally of late. One of the more important recent additions to *Megastar* has been an enhancement of its planetarium features. In the beginning it really was more a computerized star atlas than a planetarium and lacked many of the features planetarium users expect—sky animation and extensive Solar System functions, for example. Even today, *Megastar* retains its atlas heritage. The program can, for example, zoom in on planets, but don't expect to see planetary satellites or realistic surface details. Bonano has promised planetary moons will be included in a future release, but that promise was made several years ago.

Megastar is not the program to choose if you are mainly interested in Solar System observing or just want a quick look at the current configuration of the sky. Its appeal is to hard core deep sky observers. The base version of the current release, Version 5, includes an impressive 208,000 deep sky objects (mostly galaxies). It also provides "thumbnail" images of some 78,000 DSOs that can be superimposed on star charts (Plate 63). One thing *Megastar* has that no other program does is the Mitchell Anonymous Catalog. This is a list of 117,000 galaxies compiled by Texas amateur and deep sky observer extraordinaire, Larry Mitchell. Be aware, however, that the "MAC" galaxies are ferociously dim. How do you know if an object is dim or not? A mouse click will bring up adequate if not lavish details on each object. Add to these resources the ability to print typeset-quality charts and facilities for controlling *some* go-to scopes (via built-in drivers), and it's no wonder the program has been a perennial favorite of the deep sky gang. Stroll across the observing field of the Texas Star Party and you'll note that most of the serious observers are using computers running *Megastar*.

Megastar's sky is plain but legible, period. Might we expect this venerable program to add more "pretty" features in the future? Maybe, but probably not. Since the program moved from being marketed by the author to being sold by publisher Willman-Bell, continued development has been slow. You're spending the $130 this



MegaStar V5 2/17/08 10:30a LT 20h 25m ST Rodney F. Mollise

M 13
NGC 6205
Globular Cluster *
RA: 16h 41m 41.5s
Dec: +36° 27' 37"
Mag: 5.8
Mag V(tip): 11.9
Mag V(HB): 15.0
B-V (tip): ---
Size: 20.0'
Class:
R.V.: ---
Source: Archinal *
Alt: 43.5°, Az: 292.9
Transit: 06:46
Rise: 23:00
Set: 14:33

42.0s | +36° 27' 32" | 1.6° x 0.9° | Dist: --- | Her | Urano 114 | Alt: 43.5° | Az: 292.9°

Plate 63. (Megastar) *Megastar* is a computerized star atlas loaded with many more stars and deep space objects than any print atlas can boast of. Credit: Author.

program commands on a tool to help with observing, not something to wow the spouse and kids. Despite its tremendous level of detail, *Megastar* is, thankfully, easy to learn to operate despite the fact that this Windows-only program uses a non-standard user interface—probably a hold-over from its MS-DOS days. It's also very forgiving of older, slower computers.

The Earth Centered UniversePro

What program most resembles *Megastar* but refines the user interface and places a copious collection of deep sky objects in a more full-featured planetarium setting? That would be *Earth Centered Universe*. Not only does "*ECU*" carry on the deep sky atlas tradition established by *Megastar*, it actually outdoes that program for detail. In addition to the millions of stars of the GSC and Tycho star catalogs, *Earth Centered Universe* throws in over 1,000,000 deep sky objects. Don't get too excited, though: the majority of these objects are insanely dim galaxies from the *Principal Galaxy Catalog* (*PGC*) that won't even begin to be visible in anything but the largest SCTs (many can be "seen" with smaller scopes with the aid of a CCD camera).

Unlike *Megastar, ECU* utilizes ASCOM, which means it can interface with almost any brand of go-to scope, old or new. Clicking on objects on *ECU's* display opens an information window with sufficient details on each object. One nice idea (provided there's an Internet connection available) is that these abbreviated details can be supplemented by a web search from the info window with results returned in whichever browser is installed on the PC (*ECU* is only available for Windows). One of the best features of this program is its printed output, which is of astonishing quality. The hard-copy charts produced by this program don't just resemble the best typeset star maps; they actually look better than what's found in some print atlases.

Like *Megastar*, *ECU* wraps all this power up in a plain-looking virtual sky, functional but not exactly attractive. Zoom in on a planet and *ECU* displays a colored dot. The program does offer planetary satellites, however. Although *Earth Centered Universe*'s sky looks much like *Megastar*'s, the user interface used to control the program sticks more closely to the Windows standard and is therefore easier to learn.

Who's likely to be pleased with *ECU?* Deep sky oriented observers who want the power of *Megastar* but are more comfortable with the familiar desktop planetarium paradigm. Perhaps the most attractive thing about *ECU,* though, is its price; at $60 most people can afford to take a chance on this one. *ECU's* recent development history? There *is* none. Maybe somedy there will be a successor to the current Version 5.0, but expect the changes to be small. The author appears to have stopped working on this solid but simple and somewhat old-fashioned looking program.

TheSky 6Professional

When it comes to astronomy software, do you need it all? Or just want it all? If the answer to either question is "yes," Software Bisque's *TheSky 6 Professional* may be just the thing. In addition to the now-common Hubble GSC, *TheSky 6 Pro* comes with databases containing over 1,000,000 objects in dozens of catalogs as well as pictures to go with many of these objects. But that's just the beginning. Need to operate a remote observatory dome, or acquire images with a CCD camera, or operate Bisque's "robotic" Paramount ME GEM? *Pro* will do all these things, seamlessly integrating with the Software Bisque programs designed for these tasks. Despite the fact that *Pro* is being used for some very serious tasks, often in professional observatories, don't imagine that it looks stodgy. *TheSky's* display is one of the most attractive in the business, featuring a beautiful Milky Way, real-looking stars, and photographic horizons (Plate 64). *TheSky* also provides extensive scope control facilities, either through its built-in scope drivers or the ASCOM program.

Does this power and sophistication come at a price? Sure it does. One is the cost in dollars for this top-of-the heap astro-soft: $280, which gives some amateurs pause. There is another "cost" involved with *TheSky 6 Professional* in addition to the monetary one—a fairly demanding need for computer resources. The photorealistic skies and other features do tend to make some machines pant a little. There's a way around the slow-downs, though: the pretty stuff can be selectively turned off, giving the oldest computers a leg up. A final "cost" is the program's fairly steep learning curve. Due to the nature of the audience this software is aimed at—advanced amateurs and professionals—*TheSky6 Pro* is almost infinitely customizable. Everything can be changed, even the constellation stick figure lines. The first confrontation between a new user and the program's "display explorer," where many of these changes are made, can be a confusing and even scary one.

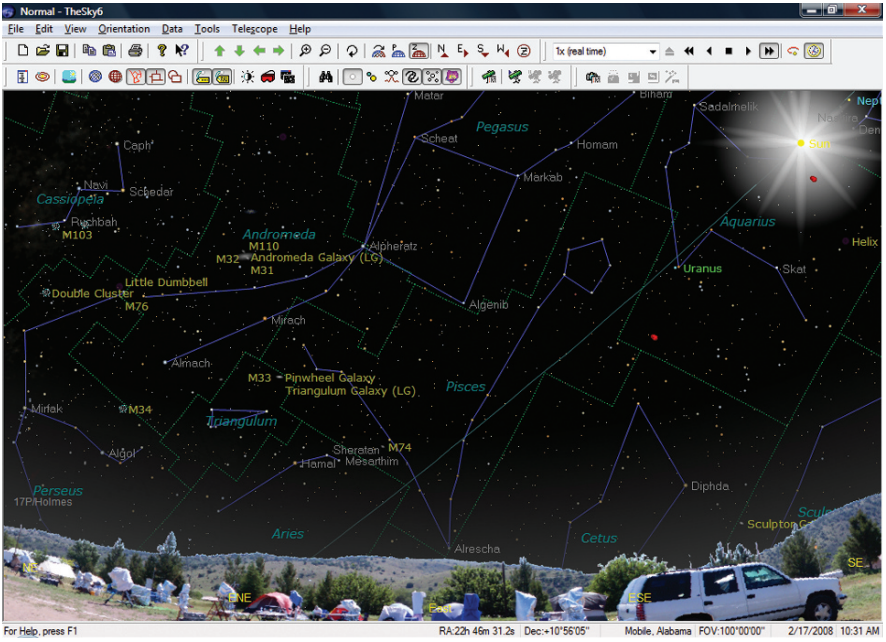


Plate 64. (TheSky 6) *TheSky 6 Professional* is a beautiful program, but it is the software's advanced capabilities that attract serious amateur astronomers. Credit: Author.

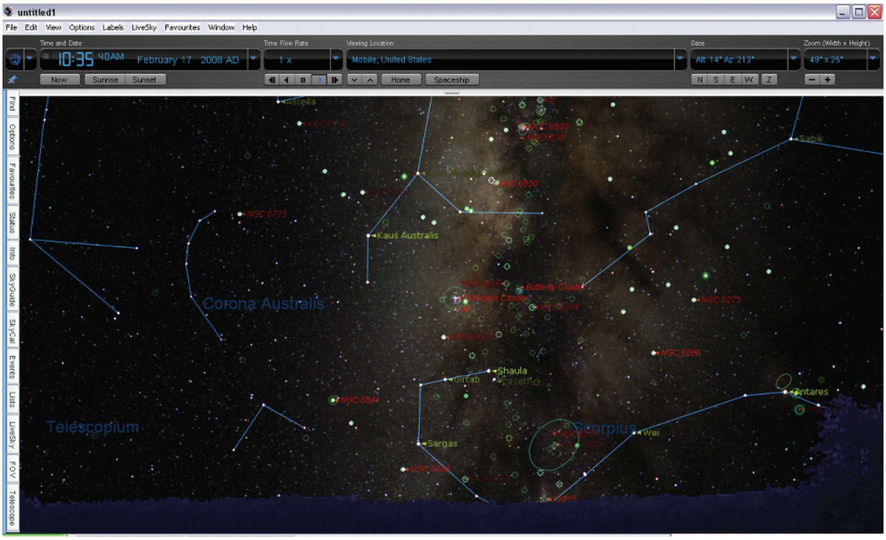
Yes, *The Sky* has a steep learning curve, but so does *Microsoft Excel*. Most computer users wouldn't expect to whip out multi-page workbooks on the first day with *Excel*, so why expect not to have to do some studying to learn an astronomy program as sophisticated and rich as *TheSky 6 Professional*?

Given the program's sophistication, it's a good thing it is thoroughly documented via a detailed manual and a fairly good help system. At this price level there probably should have been a printed manual, not just a pdf file, which is all that's included with *Professional,* though. To its credit, Software Bisque provides extensive support via both a Yahoo group and the company website.

Does *TheSky* sound interesting but the $280 kills it for you? The program comes in two "less advanced" versions that preserve much of what makes *TheSky Pro* great while dispensing with some of the more arcane features. *TheSky Serious Astronomer Edition* and *TheSky Student Edition* are beautiful and useful if not as awe-inspiring as *Professional*. *TheSky 6* was "Windows only," as this was written, but Bisque was working on a new version, *TheSky X*, which will be also be available for Macs.

Starry Night ProPlus

TheSky6 Professional's virtual sky looks realistic. *Starry Night Pro Plus*'s sky (Plate 65), on the other hand, *is* real. It's not a computer graphics representation of the heavens but an actual image of the entire night sky comprised of 20,000



untitled1

Time and Date: 10:35 40AM February 17 2008 AD

Time Flow Rate: 1 x

Viewing Location: Mobile, United States

Gaze: Alt: 14° Az: 212°

Zoom (Width x Height): 49° x 25°

Plate 65. (Starry Night) Unarguably the most beautiful of the 'pretty planetarium' genre of astronomy software, *Starry Night Pro Plus* doesn't skimp on useful features. Credit: Author.

separate CCD pictures. Whether zoomed out or zoomed in, *Starry Night's Pro Plus's* sky is a seamless mosaic composed of some 6 billion pixels. The beauty of *Starry Night's* display is undeniable; this is what many planetarium fans have wanted for years. It's actually useful; too, You can get a better sense of objects and their context with *Starry Night* than with other planetariums. If you're in doubt as to whether you're really interested in looking at a particular deep sky object, one glance at *Starry Night's* sky will often tell the tale.

This is not to say *Starry Night Pro Plus*' "AllSky" display is perfect. Really enjoying this feature requires considerable computing horsepower, including an Open GL video display adapter with plenty of memory. Despite that, AllSky works well enough with older top-of-the-line computers. Performance issues aside, the only criticism that can be leveled at it is that the resolution available from AllSky, 12 arc-seconds per pixel, is not sufficient for really tight zooms. Zoom in to a degree-sized field, and many deep sky objects become pixilated blobs. All is not lost, however, as *Starry Night* makes it easy to download deep sky images from the Internet (from the Digitized Sky Survey website). These pictures can be superimposed onto AllSky and automatically displayed during "tight" zooms.

If all there were to *Starry Night* were AllSky, it would not (along with *TheSky*) rule the roost when it comes to advanced astronomy software. At heart, it's a well thought out, feature-heavy, and competent planetarium. Beyond the "pretty," which includes startlingly realistic horizons, sunsets, and more (even audio of chirping of crickets) are the features that make any planetarium useful. In addition to millions of stars and the ability to download millions more online, and catalogs full of hundreds of thousands of deep sky objects, *SNPP* also includes a genuinely useful observation planning module, telescope control via ASCOM, and very cool Internet features (download satellite weather images for the current observing location).

How does *Starry Night Pro Plus* stack up against *TheSky 6 Professional*? There are a few things *TheSky* can do that *Starry Night* can't. Chief among those is interfacing with other Software Bisque programs such as *CCDsoft*. *Starry Night Pro Plus* can, however, work with that other popular CCD camera program, *Maxim DL*. *Starry Night* may not allow the user to change quite as many things as *TheSky*, but it's far easier for most users to make those changes with *Starry Night*'s more user-friendly interface. Like *TheSky*, *Starry Night* can interface to any scope imaginable via ASCOM. In fact, *Starry Night* tended to work more reliably with some ASCOM drivers than *TheSky* did. (*TheSky*'s "primary" interface is via its built in drivers, not ASCOM). Finally, *Starry Night* really won me over with its inclusion of an honest-to-god printed manual. It's all gravy, then? Not quite. In addition to the high level of computing power *Starry Night* requires for best performance, its piling on of feature after feature seems to make it more prone to bugs than *TheSky*. Most users won't be troubled by the program's (usually minor) *faux pas*, but they are there.

Like its chief competitor, this flagship program doesn't come cheap—it's $250. For serious amateurs that is not a huge impediment. Some hard-core imagers, for example, think nothing of paying more than $5,000 for a "mid-range" CCD camera, making the admission price for this excellent program seem quite reasonable. For less rabid astronomers, cheaper flavors of *Starry Night* are available, most notably, *Starry Night Pro* (no *Plus*). It doesn't have AllSky but is still very attractive, does include most of *Plus's* other features, and sells for $100 less. Macintosh fanciers will be happy to know that *Starry Night* continues to be available in Mac format and that it reputedly runs even better on Apples than it does on Windows PCs.

Voyager4

The Macintosh computer has gained many new converts recently, and that's finally beginning to be reflected in the astronomy software available for it, with quite a few programs being offered in Mac versions as well as the ubiquitous PC releases. One company stands out for its long-term commitment to the Macintosh astronomy community, however: Carina Software, with their *Voyager* planetarium, which is now in Version 4.

As would be expected for a Mac program, *Voyager* is a lovely thing. *Voyager* is more than just a pretty face, however; it offers features and capabilities fully competitive with the top Windows software, including millions of stars, millions of deep sky objects, and the ability to control go-to scopes. *Voyager*'s Solar System capabilities, in particular, have always been impressive, and the latest release carries on that tradition with the inclusion of a very high precision ephemeris that helps it determine positions of planets, moons, asteroids, and comets with amazing accuracy.

As is the case with any big-time planetarium software, power costs money. At $200, *Voyager* is at least a little less expensive than *TheSky 6 Professional* and *Starry Night Pro Plus*, and even if it doesn't sport all the features of those titans, it will more than satisfy almost any Apple-toting amateur. One small annoyance for those using older Macintosh operating systems is that *Voyager 4* is only for OSX. The company continues to offer the earlier release, *Voyager 3*, for OS9 users. Don't like Apples but like the look of *Voyager*? Carina also sells a Windows version of this fine astro-soft.

XEphem

Not every amateur uses—or wants to use—Windows or the Mac O/S. Many tech-savvy astronomers have turned to the "open source" operating system, Linux, for their computer needs, including the running of astronomy software. There are several planetarium packages available for this UNIX-like o/s, but the most fully realized is probably Elwood Downey's *XEphem*. Most open-source users are probably accustomed to software that's just a little different from what's offered to the Win-Mac masses, but even then this planetarium software (if it can be called that) may be something of a shock.

Executing *XEphem* does not bring up a computerized vista of the sky. Instead, the user is rewarded with a text-based main screen that displays current program status regarding time, location, and other settings, and which allows the user to change these settings, load catalog files, generate an ephemeris for various objects (that's where the "ephem" part of the program's name comes in), and access the program's graphical displays, the area of the program that is probably of the most interest to amateur astronomers.

Clicking "Skyview" under the main window's "View" menu brings up a very respectable graphical sky not unlike those provided by *Megastar* and *Earth Centered Universe*. This part of the program mostly works like what most of us are accustomed to, if with a few variations. For example, most planetariums handle zooms by having the user draw a box around the area of interest and click inside that box to execute the zoom. Not *XEphem*. A zoom is started by drawing a box, but it's finished by clicking a magnifying glass icon on the toolbar. That, like most of the program's other functions, worked well, but seems rather counterintuitive. *XEphem* can control go-to telescopes, but interfacing a scope is a decidedly more involved task than getting ASCOM talking. Since most Linux users are probably a lot more computer literate than average, that may not be a huge problem for them.

Why haven't we mentioned the program's object numbers? Because the installation package only includes relatively small "sample" catalogs; it's up to users to find and install catalogs that will bring the program up to the "millions of stars and hundreds of thousands of deep sky objects" of Windows and Macintosh programs, though it's fairly simple to do. Like many Linux offerings, *XEphem* sports a large and enthusiastic user community that can provide all the data files a deep sky happy CAT user could hope for.

Planners

Planning software, for want of a better name, is substantially different from the planetariums, where beautiful representations of the sky are an important measure of how good a program is. In the planners, the virtual sky takes a backseat to other functions. These programs are essentially giant databases—many boasting well over 1 million objects (not including stars) out of the box—and very robust search tools that allow users to select objects, build observing lists, and log observations. Charting is not the main course, but most planners can do sky maps of some kind, and some more than keep up with the planetariums.

Open a planner and what bursts onto the screen is not a pretty sky. Instead, it's a dry-as-dust list of objects that looks about as exciting as an *Excel* spreadsheet. Why would anyone want to give up *TheSky* or *Starry Night* for that? Because, for non-armchair astronomers, people who actually get out and observe objects, planners are usually more helpful than planetariums. Not only will a planner tell "what's up," it will show, at a glance, how bright an object is, when it's best viewed, and what its vital statistics are, all without having to click through layers of menus and windows.

Some planetariums—*Starry Night* most notably—can perform planning functions, but their planning features are usually rudimentary and sometimes awkward to use. Many of us who do use planners as our main observing tools, though, still supplement them with *TheSky* or S*tarry Night* or *Cartes du Ciel* due to the more advanced charting features of those programs.

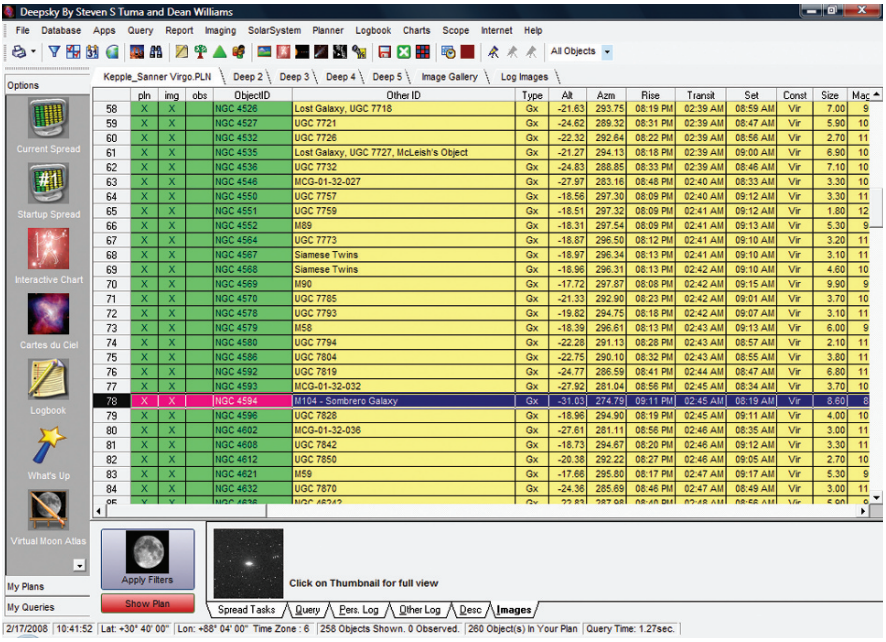
Deepsky

Deepsky is the granddaddy of the planning genre, having been on the scene for over a decade. "Planner" almost seems insufficient to describe this program, which is a sprawling observing *system* that integrates databases filled with 726,000 non-stellar objects, extensive planning and logging features, and an "interactive" charting system. In addition, *Deepsky* offers go-to control (via ASCOM), Internet links to things such as the Digitized Sky Survey and the NASA Extragalactic database, and libraries of deep sky object descriptions written by renowned observers such as Houston's Barbara Wilson. The Solar System isn't forgotten, either, with plenty of facilities for the comet/asteroid fan. The program has long included a simple lunar map, but it now also interfaces with Patrick Chevalley's *Virtual Moon Atlas*.

Like other programs in this category, most indoor time with *Deepsky* is spent planning: searching for objects in the program's databases, adding found objects to spreadsheets, and selecting objects from these spreadsheets to place in an evening's "plan" (observing list). A typical session starts with setting *Deepsky*'s search filters. You might, for example, ask it to retrieve every NGC object in Virgo. That results in a spreadsheet full of 832 DSOs—a bit much for a casual Saturday night run from the Mobile Astronomical Society dark site. To cull this list down, you scan through it, paying attention to object names, brightness, and extended details (retrieved by clicking on objects in the spreadsheet). When you happen on something that looks interesting or is on your lists of "wannasees," you click the "plan" column on the sheet. The object is then automatically added to your observing list. When you're done, you save the completed plan, and you're all set for a night of productive DSO-ing. In addition to its filters, the program provides a powerful and sophisticated search engine that's a big help in retrieving particular objects from the databases.

Out under the night sky with your plan onscreen and laptop connected to scope, you can cruise through your list, clicking one object after another to send the scope on its go-tos. If you want to take notes on a particular DSO, you click "logbook" on the program's side toolbar (Plate 66), and enter all the data you desire. What if you're not sure exactly what you're supposed to be looking at? *Deepsky* ships with a supplementary CD containing 10,000 images of DSOs for display in the program. Searching out dim little PGC galaxies with the aid of a CCD? The DVD version of *Deepsky* includes an amazing 410,000 images.

It is not an exaggeration to say you could give up your other astro-ware and do all your observing with the aid of *Deepsky* alone. That doesn't mean everything about the program is wonderful. Although the charts it plots are OK, they are beginning to show their age, looking more like what's found in *Megastar* than the state of the art represented by *Starry Night*. The author calls these charts "interactive," but they could be more so. For example, most planetarium programs allow users to navigate by clicking on the chart or dragging the sky; *DeepSky* moves are done via direction arrows or RA and declination sliders. Don't like the *Deepsky* charts? The program interfaces with *Cartes du Ciel* and will send plan objects to that program with a click of the mouse. One of the program's big draws is its computerized observation logging system; it is very good, even allowing images and drawings to be appended to log entries. The log entry screens could be simplified and streamlined a bit, though. In the middle of the night you want everything to be stupid-simple.



	pln	img	obs	ObjectID	Other ID	Type	Alt	Azm	Rise	Transit	Set	Const	Size	Mag
58	X	X		NGC 4526	Lost Galaxy, UGC 7718	Gx	-21.63	293.75	08:19 PM	02:39 AM	08:59 AM	Vir	7.00	9
59	X	X		NGC 4527	UGC 7721	Gx	-24.62	289.32	08:31 PM	02:39 AM	08:47 AM	Vir	5.90	10
60	X	X		NGC 4532	UGC 7726	Gx	-22.32	292.64	08:22 PM	02:39 AM	08:56 AM	Vir	2.70	11
61	X	X		NGC 4535	Lost Galaxy, UGC 7727, McLeish's Object	Gx	-21.27	294.13	08:18 PM	02:39 AM	09:00 AM	Vir	6.90	10
62	X	X		NGC 4536	UGC 7732	Gx	-24.83	288.85	08:33 PM	02:39 AM	08:46 AM	Vir	7.10	10
63	X	X		NGC 4546	MCG-01-32-027	Gx	-27.97	283.16	08:48 PM	02:40 AM	08:33 AM	Vir	3.30	10
64	X	X		NGC 4550	UGC 7757	Gx	-18.56	297.30	08:09 PM	02:40 AM	09:12 AM	Vir	3.30	11
65	X	X		NGC 4551	UGC 7759	Gx	-18.51	297.32	08:09 PM	02:41 AM	09:12 AM	Vir	1.80	12
66	X	X		NGC 4552	M89	Gx	-18.31	297.54	08:09 PM	02:41 AM	09:13 AM	Vir	5.30	9
67	X	X		NGC 4564	UGC 7773	Gx	-18.87	296.50	08:12 PM	02:41 AM	09:10 AM	Vir	3.20	11
68	X	X		NGC 4567	Siamese Twins	Gx	-18.97	296.34	08:13 PM	02:41 AM	09:10 AM	Vir	3.10	11
69	X	X		NGC 4568	Siamese Twins	Gx	-18.96	296.31	08:13 PM	02:42 AM	09:10 AM	Vir	4.60	10
70	X	X		NGC 4569	M90	Gx	-17.72	297.87	08:08 PM	02:42 AM	09:15 AM	Vir	9.90	9
71	X	X		NGC 4570	UGC 7785	Gx	-21.33	292.90	08:23 PM	02:42 AM	09:01 AM	Vir	3.70	10
72	X	X		NGC 4578	UGC 7793	Gx	-19.82	294.75	08:18 PM	02:42 AM	09:07 AM	Vir	3.10	11
73	X	X		NGC 4579	M58	Gx	-18.39	296.61	08:13 PM	02:43 AM	09:13 AM	Vir	6.00	9
74	X	X		NGC 4580	UGC 7794	Gx	-22.28	291.13	08:28 PM	02:43 AM	08:57 AM	Vir	2.10	11
75	X	X		NGC 4586	UGC 7804	Gx	-22.75	290.10	08:32 PM	02:43 AM	08:55 AM	Vir	3.80	11
76	X	X		NGC 4592	UGC 7819	Gx	-24.77	286.59	08:41 PM	02:44 AM	08:47 AM	Vir	6.80	11
77	X	X		NGC 4593	MCG-01-32-032	Gx	-27.92	281.04	08:56 PM	02:45 AM	08:34 AM	Vir	3.70	10
78	X	X		NGC 4594	M104 - Sombrero Galaxy	Gx	-31.03	274.79	09:11 PM	02:45 AM	08:19 AM	Vir	8.60	8
79	X	X		NGC 4596	UGC 7828	Gx	-18.96	294.90	08:19 PM	02:45 AM	09:11 AM	Vir	4.00	10
80	X	X		NGC 4602	MCG-01-32-036	Gx	-27.61	281.11	08:56 PM	02:46 AM	08:35 AM	Vir	3.00	11
81	X	X		NGC 4608	UGC 7842	Gx	-18.73	294.67	08:20 PM	02:46 AM	09:12 AM	Vir	3.30	11
82	X	X		NGC 4612	UGC 7850	Gx	-20.38	292.22	08:27 PM	02:46 AM	09:05 AM	Vir	2.70	10
83	X	X		NGC 4621	M59	Gx	-17.66	295.80	08:17 PM	02:47 AM	09:17 AM	Vir	5.30	9
84	X	X		NGC 4632	UGC 7870	Gx	-24.36	285.69	08:46 PM	02:47 AM	08:49 AM	Vir	3.00	11

2/17/2008 | 10:41:52 | Lat: +30° 40' 00" | Lon: +88° 04' 00" Time Zone : 6 | 258 Objects Shown. 0 Observed. | 260 Object(s) In Your Plan | Query Time: 1.27sec.

Plate 66. (Deepsky) One of the first 'planners' to be offered to amateur astronomers, *Deepsky* provides the tools that make productive observing possible. Credit: Author.

One great thing about *Deepsky* is that the author (who markets the program himself) has managed to keep the price down. The CD version of this Windows-only program is $53 and the DVD edition a mere $70. A downloadable version with a small library of DSO pictures can be had for an amazing $30.

AstroPlanner

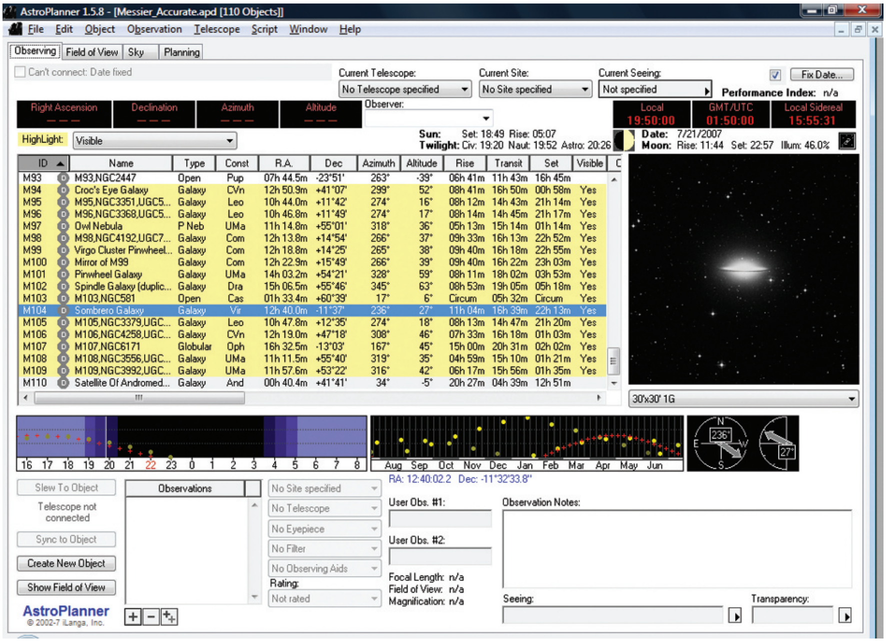
What about Macintosh owners who want a planning program? That segment of the astronomy software audience is being well served by *AstroPlanner*. Unlike some Mac astronomy programs, this isn't just a "port." It was originally written for the Macintosh and it shows. There is a Windows version, but, for once, that came second. One thing's sure: *AstroPlanner* doesn't give any ground to *Deepsky* or any other program, competing with other planners feature-for-feature and often exceeding them.

The software's data specs alone are enough to make obvious the fact that "*AP*" is one heavyweight program. Off the shelf, it comes with over 100 astronomical catalogs containing an astounding 1.3 million deep sky objects. Stars? In addition to the millions in the Hubble Guide Star Catalog, *AstroPlanner* can use the USNO star catalog containing data on over 500 million suns. Don't want to pay extra for a USNO DVD? *AP* can access the catalog online for free.

Data, tons of it, ain't worth a hoot if it's hard to access. *AstroPlanner* makes searching for dim and obscure objects easy with a powerful but simple search engine. Not only can you search for "NGC 2024," if you can't remember the darned NGC number you can just type in "Flame Nebula," and *AP* will still find the object pretty as you please. Like *Deepsky*, *AstroPlanner* is very image-centric and is capable of displaying photographs for any object in its library. Unlike *Deepsky*, it doesn't do that with a CD or DVD, but with an Internet connection, downloading pictures for observing lists in batches from the Digitized Sky Survey. What if there's no Internet access at the star party? Download the pictures before leaving home. Unless it's told not to, AP will "cache" downloaded photos so they are available from then on.

Even more impressive than the program's huge libraries and tons of features is the way *AstroPlanner's* creator, Paul Rodman, has laid it out. He is an expert programmer, and one focused on the user interface and the user. Rodman has made a huge effort to save us from navigating endless menus, which is a nice feature. Most similar software requires users to wade through numerous buttons and tabs just to fill in a log entry for an observed object. Not *AstroPlanner*. Its main screen (Plate 67) displays logbook entry fields at all times. Not just that, either. Without leaving the home screen and the night's object list, observers can see when the Sun will set, when objects of choice will rise, examine object images, send the telescope on go-tos, and more.

The "don't likes" with *AstroPlanner* are few. One is its facilities for telescope control. *AstroPlanner* uses built-in telescope drivers rather than ASCOM for telescope interfacing, so it's not able to support the huge number of scopes ASCOM-compliant programs can. That should have changed by the time you read this, however. *AstroPlanner* Version 2.0 will "do" ASCOM. One thing some new *AP* users are taken aback by is the program's lack of charting features. It has some; it will draw eyepiece-sized field charts with alacrity and can even do constellation-sized swathes of sky without much trouble. There's no denying, though, that its map-drawing is slow and



AstroPlanner 1.5.8 - [Messier_Accurate.apd [110 Objects]]

☐ Can't connect: Date fixed

Current Telescope: No Telescope specified

Current Site: No Site specified

Current Seeing: Not specified

☑ Fix Date...

Performance Index: n/a

Observer:

Local 19:50:00 GMT/UTC 01:50:00 Local Sidereal 15:55:31

HighLight: Visible

Sun: Set: 18:49 Rise: 05:07
Twilight: Civ: 19:20 Naut: 19:52 Astro: 20:26

Date: 7/21/2007
Moon: Rise: 11:44 Set: 22:57 Illum: 46.0%

ID	Name	Type	Const	R.A.	Dec	Azimuth	Altitude	Rise	Transit	Set	Visible
M93	M93,NGC2447	Open	Pup	07h 44.5m	-23°51'	263°	-39°	06h 41m	11h 43m	16h 45m	
M94	Croc's Eye Galaxy	Galaxy	CVn	12h 50.9m	+41°07'	299°	52°	08h 41m	16h 50m	00h 58m	Yes
M95	M95,NGC3351,UGC5...	Galaxy	Leo	10h 44.0m	+11°42'	274°	16°	08h 12m	14h 43m	21h 14m	Yes
M96	M96,NGC3368,UGC5...	Galaxy	Leo	10h 46.8m	+11°49'	274°	17°	08h 14m	14h 45m	21h 17m	Yes
M97	Owl Nebula	P Neb	UMa	11h 14.8m	+55°01'	318°	36°	05h 13m	15h 14m	01h 14m	Yes
M98	M98,NGC4192,UGC7...	Galaxy	Com	12h 13.8m	+14°54'	266°	37°	09h 33m	16h 13m	22h 52m	Yes
M99	Virgo Cluster Pinwheel...	Galaxy	Com	12h 18.8m	+14°25'	265°	38°	09h 40m	16h 18m	22h 55m	Yes
M100	Mirror of M99	Galaxy	Com	12h 22.9m	+15°49'	266°	39°	09h 40m	16h 22m	23h 03m	Yes
M101	Pinwheel Galaxy	Galaxy	UMa	14h 03.2m	+54°21'	328°	59°	08h 11m	18h 02m	03h 53m	Yes
M102	Spindle Galaxy (duplic...	Galaxy	Dra	15h 06.5m	+55°46'	345°	63°	08h 53m	19h 05m	05h 18m	Yes
M103	M103,NGC581	Open	Cas	01h 33.4m	+60°39'	17°	6°	Circum	05h 32m	Circum	Yes
M104	Sombrero Galaxy	Galaxy	Vir	12h 40.0m	-11°37'	236°	27°	11h 04m	16h 39m	22h 13m	Yes
M105	M105,NGC3379,UGC...	Galaxy	Leo	10h 47.8m	+12°35'	274°	18°	08h 13m	14h 47m	21h 20m	Yes
M106	M106,NGC4258,UGC...	Galaxy	CVn	12h 19.0m	+47°18'	308°	46°	07h 33m	16h 18m	01h 03m	Yes
M107	M107,NGC6171	Globular	Oph	16h 32.5m	-13°03'	167°	45°	15h 00m	20h 31m	02h 02m	Yes
M108	M108,NGC3556,UGC...	Galaxy	UMa	11h 11.5m	+55°40'	319°	35°	04h 59m	15h 10m	01h 21m	Yes
M109	M109,NGC3992,UGC...	Galaxy	UMa	11h 57.6m	+53°22'	316°	42°	06h 17m	15h 56m	01h 35m	Yes
M110	Satellite Of Andromed...	Galaxy	And	00h 40.4m	+41°41'	34°	-5°	20h 27m	04h 39m	12h 51m	

30'x30' 1G

RA: 12:40:02.2 Dec: -11°32'33.8"

Telescope not connected

No Site specified
No Telescope
No Eyepiece
No Filter
No Observing Aids
Rating: Not rated

User Obs. #1:
User Obs. #2:
Focal Length: n/a
Field of View: n/a
Magnification: n/a

Observation Notes:

Plate 67. (AstroPlanner) *AstroPlanner* is a world-class planning and logging program that's available for both Windows and Macintosh computers. Credit: Author.

somewhat primitive compared to something like *TheSky*—or even *Deepsky*. But this should not be a showstopper for the program. Most go-to scope users, if they are honest with themselves, don't really need or use extensive charting facilities. When a large chart is a must, *AstroPlanner*, like *Deepsky*, can interface with *Cartes du Ciel*, and *AP's* native sky map features will undoubtedly expand as time goes on.

One of the very best things about *AP* is that its author never seems to rest. He is continually adding new features, fixing problems, and taking suggestions from his large and enthusiastic user base. In addition to maintaining a Yahoo group for the program, there's a website where users can share observing lists they've created with the program. These lists can be automatically downloaded by *AstroPlanner* and are one of this astro-soft's real strengths. How much for this good stuff? *AstroPlanner* is insanely cheap. Currently, the cost is $40 for the program on CD, $25 for a download, and $30 for the add-on USNO DVD. Surely, you cannot beat that with a stick.

SkyTools

SkyTools, which should be in Version 3 by the time this book is published, was not the first planner, but it quickly became a favorite. In fact, it's one of the best astronomy programs of any kind. There's a good reason for that: its powerful capabilities.

SkyTools boasts millions of deep sky objects, millions of stars, and feature after feature ranging from telescope control to downloading stars from the USNO database to drawing charts that compete with or exceed anything found in print atlases.

Our favorites among this soft's many features? It's a tie. One thing great about *SkyTools* is its "Nightbar," which is a graphic representation of sky darkness and the altitude of a chosen object. Although other programs offer similar displays, none are as easy to decipher or as versatile as the Nightbar. Then there are the charts. Although not as "pretty" as those in *Starry Night Pro Plus*, perhaps, they are close in that department, and the program's printed output is far better. Truth is, there is not an astronomy program of any kind that prints better than *SkyTools*. What's the most outstanding thing about this planner? Its solidity. *SkyTools* is marketed directly by its author, Greg Crinklaw, but it does not have a "garage" feel to it. It doesn't crash or hang up. It operates smoothly and reliably and feels more like *Microsoft Access* than something your brother-in-law cobbled together on his bedroom PC.

Quibbles? Not many. First, if the standard Windows user interface is what you're after, forget it. Crinklaw has his own take on how a UI should be laid out, and that does not consist of the same old "File," "Edit," "Window," and "Help" menus. He goes his own way, so be prepared to do some book learning (via the program's "how do I" tool; there is no printed manual). After a while Crinklaw's way of doing things doesn't just seem OK; it seems better. Anything else? The program's charting facilities are good but a bit difficult to use. That's because everything can be changed and rearranged, something I find confusing, but which more computer literate astronomers will no doubt appreciate. Finally, although the program offers go-to scope control by means of internal drivers, users have to pay for that privilege. Go-to is in the form of an add-on extra-cost module, *SkyTools Real Time*, which is included with the program but which must be paid for before it can be "unlocked."

Ready to buy? *SkyTools*, which, like *Deepsky*, is currently Windows only, is somewhat more expensive than the other planners at $100. Most CAT users will definitely want to unlock *Real Time*, too, which adds another $40 to the price for a total of $140. Expensive, perhaps, but it is still cheaper than some big-name astronomy programs that do far less than *SkyTools*.

Other Astronomy Software

Ascom

When is an astronomy program not an astronomy program? When it's ASCOM. "ASCOM," an acronym for "Astronomy Common Object Model," is more a collection of drivers designed to allow "client programs" to interface with go-to telescopes and other equipment (observatory domes and motorized focusers, for example) than it is an astronomy program in its own right. The beauty of ASCOM is that it allows astro-ware to communicate with go-to scopes without their developers having to write drivers for each supported telescope. A planetarium or planner talks to ASCOM, and ASCOM talks to the telescope.

ASCOM is pretty sophisticated under the hood, but we users don't need to know anything about that. This "utility" (for want of a better classification) is simple to use. Download and install this freeware program from its website (Appendix 2), select "ASCOM" in a compatible astronomy application, fill in user-specific details about the scope in the windows that ASCOM throws up, and the work is done. Although ASCOM isn't much of a program when it comes to interacting with users on a visible level, it does offer a simple onscreen hand control and a few other features for supported scopes, if desired.

Some users find the idea of having to install a program to make another program talk to a telescope a little scary, but there's not much to go wrong. The only caveats with ASCOM are that some telescopes will require add-on drivers not included in the basic ASCOM package. These are easy to find on the website, however, and installation instructions are clear. A few programs—*Cartes du Ciel*, for example—will need to have an ASCOM plug-in downloaded and installed in addition to the main ASCOM program and drivers.

All in all, ASCOM has been a godsend for amateurs. Before its coming, there was no assurance a program would work with a specific telescope. Now, there's usually little doubt in that regard; when a new scope is released, it's not long at all before one of its computer-savvy users writes a driver for it, which is promptly posted on the ASCOM website for everybody to enjoy. Maybe one day soon all software authors will make life simple for everybody and just use ASCOM.

Virtual Moon Atlas

For years the "Lunatics" wondered, "When will somebody do a *TheSky* for lunar observers?" It took a while, but over the last five years several programs aimed at Moon watchers have appeared. The best of them is this freeware offering from the author of *Cartes du Ciel*, Patrick Chevalley, and lunar expert Christian Legrand.

What these two men have done is nothing short of amazing. They've developed an astro-soft that features an interactive Moon map with detail on a level comparable to hard-to-find resources such as the *Lunar Aeronautical Charts* and far beyond the print atlases most amateur lunar observers had been using. Being able to zoom in until a crater fills the display is not all "VMA" can do, either. It provides extensive labeling and information on features, allows users to display lunar images with the click of a mouse, and even lets Moon fans navigate a go-to scope around the lunar landscape. Best of all, like *Cartes*, VMA is free.

There are only a couple of not-so-hots with VMA. One is the size of the thing. The complete "professional" package with all picture libraries requires a download of 496 megabytes of data. In this day of broadband, that's not too bad, but it is a barrier for people who are still on dial-up. Because of the large size of this offering, Chevalley and Legrand are offering a CD version for 20 Euros. If that doesn't appeal, less graphics-laden but still useful versions are available. Another problem for some users will be the display adapter requirements of *Virtual Moon Atlas*. Although it will run on so-so video cards, the program really needs an Open GL graphics adapter to provide the clearest, most detailed views of Luna.

NexRemote

I've seen it all when it comes to astro-ware. That's what I *thought*, anyway, until the evening I was introduced to a program that changed my entire observing lifestyle. If you're a Celestron go-to user, *NexRemote* may do the same for you. One cloudy night a few years back I was browsing through my copious email. Buried among the Yahoo group traffic was a personal missive from one Ray St. Denis. Denis asked if I'd be interested in helping beta test a new software package for Celestron's NexStar scopes he and his buddy, Andre Paquette, were working on.

I was, I will admit, not overly excited about yet *another* planetarium program. Paquette responded by saying this was a very special and very different software. What this application, which he and Denis were calling *HCAnywhere*, did was duplicate the NexStar computer hand controller on a PC screen. But that was not the big news. After all, ASCOM can display a simple virtual HC. The big news was the fact that, as Denis explained, *HCAnywhere* replaced the hand controller. That is, it would allow users to leave their hand controllers at home!

A virtual hand controller was something go-to users had dreamed about for a long time. To sweeten the deal, Paquette said he'd send a "programming cable" along with the software so I wouldn't have to scrounge one up somewhere. Why a programming cable? *HCAnywhere*, he informed me, used the NexStar's "PC" port rather than the normal RS-232 socket in the base of the hand paddle to connect to the scope.

Once I got the package, I found that "just" duplicating the HC was only a small part of the story. Thanks to *HCAnywhere*, I now had something I'd wanted for a long time: wireless scope control. *HCAnywhere*, you see, was compatible with Logitech's wireless "Wingman" series of gamepads (PC joysticks). Not only could the gamepad be used to slew the scope, its many buttons had been assigned to perform various hand controller functions. It was possible to use the Wingman to access menus and perform alignments without touching the computer. This made *HCAnywhere* seem much more useful. Initially, I'd wondered about the practicality of aligning the scope with a PC. Unless the laptop were near the eyepiece, a star would have to be centered and then the observer would have to run over to the laptop and try to "accept" it as quickly as possible before it drifted away.

For such a complex piece of code, it all worked perfectly. No crashes, no errors. Plus, *HCAnywhere* had a "virtual (serial) port" that would allow other programs to share the PC port connection. Turn that virtual port option on, startup *Cartes du Ciel* (or any other astronomy program), with the virtual port number *HCAnywhere* assigned, and the planetarium software worked just like it always had. Click on a DSO, scope went there.

Only major annoyance? While the Wingman made it easy to do alignments, I still had to wander back to the PC and read the display to do some operations. When I mentioned this to the program's creators, they said, "Why don't you enable speech?" Turns out the speech-synthesis function was well documented in the program's help file and that *HCAnywhere* was able to use the Microsoft Mike/Mary speech synthesis utility. It was strangely appealing to hear the "scope" intone: "NexStar Ready!" or "Object Acquired!" in a female *U.S.S. Enterprise*-computer-like voice. And useful. With the volume at a reasonable level you can do many hand controller functions without returning to the laptop.

But why the past tense, and what's this *HCAnywhere* thing got to do with *NexRemote*? Celestron took immediate interest in the program and soon made a deal with the creators to bring *HCAnywhere* into the official Celestron corral under the name "*NexRemote.*" Why don't we see more Celestron NexStar users running *NexRemote* on star party fields? It's probably not because of the program's price. It can be found for less than $100 at many astronomy dealers. In fact, the program CD comes in the box with many new Celestron telescopes, so many folks won't pay a dime (other than for a programming cable). Why don't all Celestron owners use it, then? Maybe they just don't know what it is or at least don't know how *wonderful* it is. The only bad thing? *NexRemote* is only usable with Celestron telescopes (and Windows PCs). Users of the Synta EQ6/Atlas and HEQ5/Sirius mounts do have a similar application, *EQMOD,* available that offers much of the *NexRemote* functionality, including the use of a wireless "hand control" (gamepad). See Appendix 2 for more information about this excellent free program.

Astronomy Software Troubleshooting

There's plenty of advice available on the Internet when it comes to getting a balky PC or Mac program to run right. Most of the problems amateurs have with astroware, however, don't involve getting a program to run; they are about getting a program to talk to a telescope.

The first step in isolating scope communications problems, as when troubleshooting any go-to scope problem, is to check the cables. If the software replies with a "telescope not found" message when the telescope link button is clicked, drag out the multimeter (a great tool for the modern amateur) and check the serial cable for continuity. Also examine those dratted RJ connectors for cleanliness and condition and do the same for the port on the telescope.

The most frequent cause of difficulties with telescope coms after cable problems is configuration. If the PC's com (serial port) is "com 3," and "com 4" is entered in the program's (or ASCOM's) configuration screens, nothing good will happen. To determine the correct com port on a Windows computer, open Control Panel, select System, Hardware, and Device Manager; then click "Ports" in the tree that appears. The computer's com port number will be listed. If a USB serial converter cable is in use, don't assume com 4 will always be com 4. Plugging the cable into a different USB port than the last time may result in a new and different com port number being assigned.

What about the well-known astro-programs that weren't mentioned in this chapter? What about *CCDsoft*, *Maxim DL*, and *K3CCD Tools*? These and other imaging applications appear in the next chapter, which concerns what some amateurs consider the most difficult—and most rewarding—pursuit in CATworld: celestial picture taking.

CHAPTER ELEVEN

Taking Pictures with a CAT

Does a chapter on astrophotography, celestial picture taking, belong in a general interest/beginning book about SCTs? Yes, because it's impossible to talk about Schmidt Cassegrains without discussing imaging. These telescopes were designed with picture taking in mind, and astrophotography is often a goal of prospective CAT owners. Of course, a single chapter is not nearly enough space for an in-depth discussion of imaging methods. An entire book the length of this one is needed. What I can do here is give a general overview of the imaging game and steer new CAT users to the type of gear needed—and the challenges that will be faced.

Astrophotography is not one thing, but many things. Some amateurs spend their time capturing the Moon and planets, some focus on wide-field vistas, and others concentrate on detailed portraits of individual deep sky objects. Amateurs engaged in these different branches of astrophotography don't just shoot different objects; they typically use very different equipment. The choice of target will determine what kind of camera, software, and technique is needed: "the right tool for the job." For that reason, camera/software choices have been broken into "Lunar/Planetary" and "Deep Sky" categories. There is one basic need all astrophotographers have in common, however: a good, stable telescope mount.

Mounts

Accomplished imagers will say the CAT's mount is 90 percent of the reason for their success and that a prospective astrophotographer should plan to spend about 90 percent of an initial budget on the mount. That's true, all things being equal, but all things are *not* equal. If the goal is long exposure prime focus imaging, a heavy

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duty mount along the lines of (at least) a Losmandy Titan or an Astro-Physics 900 is very desirable. Unfortunately, these are in the $8,000 and up price range. They are also heavy as well as heavy duty. Don't imagine investing in a mount in this class or the next tier ($10,000 range), assures good results, either. Even with the best equipment, imaging is challenging, and the learning curve is steep. There is no doubt big German equatorial mounts make a new astrophotographer's teeth-cutting easier, though.

Are big-dog GEMs too rich for your blood? One secret of the deep sky imaging game is to make up for a less-than-heavy-duty mount by downsizing the telescope that will ride on it. Although a Losmandy G11 or Celestron CGE might not support a 14-inch SCT for hours-long exposures, they can do well with a 10- or 11-inch. If money is a real issue, even a humble CG5 can produce surprisingly good pictures with a 6- or 8-inch SCT.

How much telescope is too much telescope for a mount? The best guide is the manufacturer's stated payload capacity. These capacities are usually realistic for visual observers, but not for imagers. Expect to put about half as much weight on a mount as the maker recommends if picture taking is the agenda. For example, the CG5 is rated for 35 pounds. Halving that leaves a "practical" weight limit of 17 pounds. It's best to keep under even that, if possible. An 8-inch SCT at approximately 12 pounds is just right for a CG5. Also keep in mind that a CG5 or Meade's LXD75 might work well on a calm night but become useless for picture-taking in a light wind no matter how light its load. A good mount isn't just a requirement for long exposure deep sky picture taking, it's very desirable for Solar System imaging, too. Planetary photography requires high magnification to produce high-resolution images, and a steady mount is almost as important there as it is for two-hour deep sky exposures.

Is a German equatorial mount the only way to take pictures? What about the fork mount that came with the telescope? Imaging is generally considered easier with GEMs. They are easier to balance, less shaky pound for pound, and may track better than comparably priced forks. Not everybody shares this opinion, though; the fork has many fans among astrophotographers. There is no doubt a fork mount SCT can produce excellent deep sky images—hundreds of thousands have been done since the C8 debuted in 1970.

As mentioned several times previously, if a fork mount telescope is to be used for long exposure imaging, it must be set up in equatorial mode on a wedge. Not just any wedge will do for serious prime focus imaging. Those sold by Meade and Celestron are simply not sturdy enough for long exposures or easy enough to adjust to make precise polar alignment simple. Fortunately, third-party manufacturers such as Mitty Industries (Appendix 1) are producing after-market wedges that are more than up to the task of long exposure prime focus work. Probably one of the main reasons forks have gotten a bad rap for imaging is insufficient wedges. Even a C8 needs a sturdy platform.

One other weak link for both GEMs and forks is often the tripod. Both Meade and Celestron have improved their standard tripods over the years, but there's still room for considerable improvement. One thing some serious imagers do is adapt heavier tripods to their scopes. Meade's Giant Field Tripod, for example, designed for use with its 12-inch and larger scopes, can, sometimes with a bit of ingenuity, be used with Meade or Celestron 8-inchers and offers a great deal of improvement.

Film

Yeah, you know, the stuff that used to go in cameras. When preparing to write this book, some of my astrophotographer friends urged me to "keep film." I wanted to, but I just could not do it. I bow to no one in my love for the old way of astrophotography. Even after using CCDs/electronic cameras exclusively for nearly a decade, I still find myself missing the smell of darkroom chemicals. Unfortunately I decided film would go for a couple of reasons. Foremost is quality and ease of use. Today's big-chip CCD cameras can produce images of the night sky better than those the best film astrophotographers were turning out a decade ago. CCD cams are easier to use, too. Not only are exposures shorter, lessening problems with things like guiding, there's immediate feedback at the end of that exposure. Even without post-processing, it's usually clear if the shot is "in the can." With film it was necessary to wait until the roll was developed the next day. Finally and most fatally, the number of astrophotography suitable films (and all films) continues to shrink as the big names, Kodak and Fuji, abandon film for digital.

Not that there are not still things in film's favor. Very good used 35mm single lens reflex cameras that are perfect for deep sky imaging are dirt cheap now. Not sure if astro-imaging is for you? Spend a little on 35mm before spending a lot on CCD. Most of the techniques learned with film—focusing, guiding, etc.—are at least partially transferrable to the CCD world. One group i don't recommend film for? Solar System imagers. Unless the Moon and the Moon alone is the target, forget it. The best professional film images of the planets don't hold a candle to pictures produced with a webcam.

Point and Shoot Cameras

Plenty of experienced astrophotographers have gotten their start in imaging using the ubiquitous digital "point and shoot" camera (Plate 68). If one's available, give it a try at the telescope; the results may be surprisingly good. Plate 69, a recent partial lunar eclipse, was taken with a four-year-old Canon A70 3.2 megapixel camera. How does it attach to the telescope? It doesn't. All you need to do is hold the Canon up to the eyepiece of an ETX125 and focus the scope until the image on the camera's display is as sharp as you can get it. Not bad quality, and falling-off-a-log easy.

But point and shoot cameras are a little less than satisfactory for anything other than for casual experimentation. Their big failing is that their lenses cannot be removed, making it impossible to couple them to a scope using standard T adaptors. Creative vendors such as Baader Planetarium have devised brackets to hold these cameras in place over the eyepiece, and a rig like the one in Plate 68 can help, but that's still a compromise. Shooting in this fashion, through an eyepiece ("afocally"), it's impossible to achieve wide-field views suitable for most deep sky objects. Most point and shoots deliver fairly noisy images in exposures over 30 seconds as well.

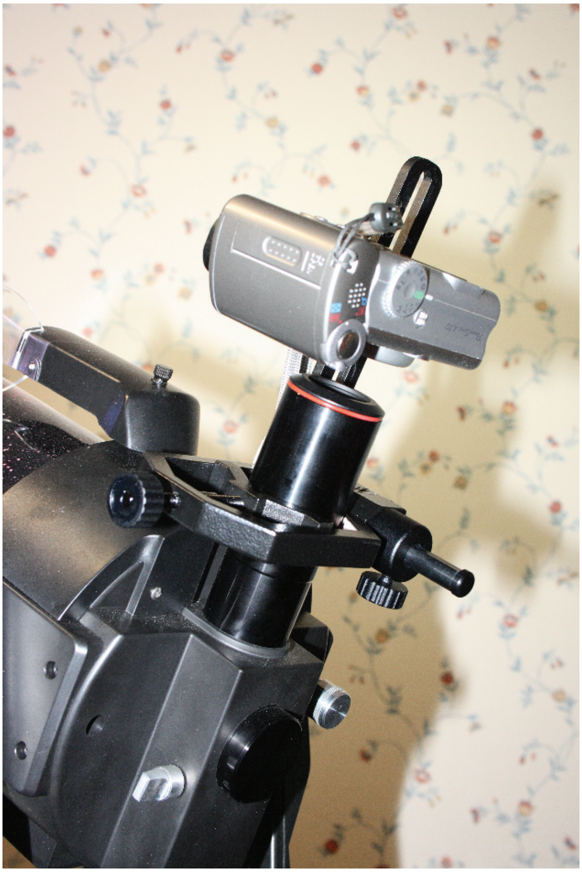

Plate 68. (Point 'n Shoot) Since the lenses of point 'n shoot digital cameras can't be removed, these cameras can't be directly connected to a telescope. Baader planetarium and other vendors offer clever brackets that allow the cameras to be used at the telescope in an afocal set up. Credit: Author.

Plate 69. (Eclipse) Digital point 'n shoot cameras are not recommended for deep space imaging, but they are capable of delivering high quality Solar System photos. Credit: Author.

Yeah, it's possible to get acceptable results on the Solar System, but a simple (and less expensive) webcam will blow the doors off any point 'n shoot.

Lunar and Planetary Imaging

Not only is Solar System imaging an absorbing field in its own right; it's a good way to get started in astrophotography. Not everything learned by taking pictures of the planets is applicable to the deep sky, but it will allow a new astrophotographer to get a feel for basic equipment set up and techniques. One nice thing about Solar System work is that there's no need for exacting polar alignment—or polar alignment at all. A Meade or Celestron fork mount in alt-azimuth mode will do fine. The best thing for beginners, though? Planetary cameras are cheap, and so is the software needed to run them.

Telescope Choices

Any CAT can be used for planetary imaging, but some CATs are more equal than others. The most critical requirement? Quality optics, but most CATs fulfill that these days. Almost as important is focal length. A detailed planetary image requires a lot. It's possible to extend the focal length of any telescope by the use of a Barlow lens, but it's usually best to start out with a "slow" scope to begin with. A telescope that brings a lot of millimeters to the table is the Maksutov Cassegrain, and it can blow other designs out of the water on the Solar System. Its only failing? Aperture. In the interest of sharp images, it's desirable to keep webcam frame exposures as short as possible. That's no problem for a 6-inch Maksutov on the Moon or Jupiter, but it can be a problem on Saturn, or when very large image scales on any planet are desired.

All in all, the good old SCT is, once again, the workhorse. Its images, although maybe not as sharp as those of other designs, are still very good, it offers plenty of focal length, plenty of aperture, and its moving mirror focusing means almost any camera can be brought to focus. The SCT's main problem for Solar System work is focus shift. At high power, focusing can drive the image of a planet right off a webcam chip. This problem can be cured by the simple addition of a rear cell Crayford focuser. Browse through the astronomy magazines and have a look at the high-resolution planetary images done by the expert imagers. What do they have in common besides their amazing detail and beauty? Most were shot with Schmidt Cassegrains.

Planetary Cameras

It's possible to use a cooled, integrating "deep sky" CCDcamera like an SBIG or a Starlight Xpress to image the planets. Some amateurs, like Houston's Ed Grafton, have produced impressive Solar System pictures that way, but, surprisingly, a $100 webcam will almost always best a $3,000 CCD camera on planetary subjects. What's needed for high resolution planetary pictures is not big CCD chips. Small chips with small pixels are just right. "Project" a large image onto a chip with small pixels, and extremely fine details can be registered. Long exposures are not needed, either. Usually 1/30-second is more than enough. Because exposures are this short, it's not necessary to cool the CCD chip to reduce noise. "One shot color" is nice too: all currently available webcams are color devices. Most astronomical CCD cameras require users to take and combine three filtered black-and-white shots to produce one color picture. By the time the last exposure is done, Jupiter's fast-rotating disk may have caused details to smear out in the final combined color image. "Small chips," "small pixels," "one-shot color." These add up to great planetary images.

You can spend a thousand dollars or more on a camera specifically designed for planetary imaging, like the Lumenera SkyNx, but that's not necessary in the beginning. Start with something cheap, learn the game with that, and then think about investing big bucks if planetary imaging becomes an enduring interest. The traditional place to start has been with an off-the-shelf webcam. One of these little devices, designed for video teleconferencing, connects to a PC via a USB port and sends its streams of digital video directly to the hard drive without need for tapes or DVDs.

Where to get a webcam? There are plenty on the shelves at Walmart, but the webcams there probably will not be optimum for astronomy. Most of them use CMOS rather than CCD chips as their imaging sensors, which makes them less sensitive to light. One of these CMOS cams can do a fine job on the Moon and is a way to get going at minimal cost, but there's a better solution, the Phillips Toucam. This tiny camera has been popular with amateurs for years and is still available as the Phillips SPC900NC. It features a 1/4-inch CCD chip with small (5.6 micron) pixels, is impressively sensitive, and delivers good color. These things, combined with a price of about $125, make it a natural for beginning imagers. Phillips cameras can be difficult to find at U.S. electronics discounters but are easily available from astronomy dealers, most notably Adirondack Video Astronomy.

What does it take to get an off-the-shelf webcamready for the telescope? First, some kind of an adapter is needed to allow it to be inserted into a 1.25-inch focuser or Barlow. A plastic 35mm film canister duct-taped onto the camera will work, but a more attractive and durable factory-made "nosepiece" is desirable. Adirondack sells these as does an Australian company, Mogg, which sells worldwide (Appendix 1). To use these adapters, the lens of the webcam is removed and the adapter screwed on in its place. Don't worry about having to remove the lens; it's useless for planetary imaging. "Barlow projection" (see below) is the path to high-resolution planetary images.

One other desirable accessory is an Infrared (IR) blocking filter.. Webcam chips are very sensitive to IR, and unless it's kept out the color balance of the camera will be badly skewed into the red. It's possible to fix the color of a strongly pink Jupiter or Saturn in post-processing, but even then color will usually be better in filtered shots than in unfiltered ones. An IR filter can improve sharpness in refractors (which may not be color corrected for IR), but CATs are not affected by this problem. Some webcams contain built-in IR filters, but an add-on like the Baader IR block filter (a 1.25-inch filter that screws onto the webcam adapter or Barlow) usually provides noticeably better results. If possible, a webcam's built-in IR filter—usually a tiny film chip—should be removed, since it will typically be of poor quality.

Choosing a planetary camera used to be easy: you bought a webcam and that was that. Today, there are more choices. Astronomy-ready webcam-like devices are available from both Meade and Celestron (Plate 70) and have the advantage of being ready-to-go out of the box. A 1.25-inch adapter is built in, the astronomy-oriented software needed to control the camera and process images is in the box, and there are instructions sufficient to help get a novice started in webcam astronomy.

Meade's entry, the LPI($100), is nicely priced and its 1/3-inch chip is substantially larger than the average 1/4-inch webcam sensor. That makes it possible to take in wider vistas of the Moon, focal length for focal length, and makes it easier to get a planet in the frame at high magnification. The camera ships with Meade's innovative *Envisage* software that can not only take images but can do a large part of image processing on the fly. Despite these good things, we don't recommend the LPI except for the Moon. Although the chip is larger than the average webcam CCD chip, it's a less sensitive CMOS device. Also, its relatively large (8 micron) pixels tend to blur detail. Do use an LPI on the Moon, however, where it does an admirable job.

The best inexpensive "astronomy webcam" is probably Celestron's NexImage ($100). The company isn't overly informative about the parentage of the camera, but it appears to be a repackaged Toucam or something similar. It definitely uses the same CCDchip as the Phillips camera and is capable of producing images identical to those from the Toucam. The NexImage package includes a 1.25-inch adapter and a CD containing image capture and processing software. Like the Toucam, the NexImage can benefit from an IR blocking filter (Celestron sells one for the camera).

Plate 70. (Webcams) Webcams and webcam like imagers can shoot everything from the Moon to the most distant galaxies. L – r: Celestron NexImage, Meade Deep Space Imager (DSI), Meade Lunar and Planetary Imager (LPI). Credit: Author.

Computer Hardware and Software for Planetary Imagers

Since a cheap webcam doesn't have a tape or disk recording system, a PC or Macintosh is required to save the data captured by the camera. The processing power of the computer is not overly important, as webcam image capture software is pretty simple and undemanding. What is needed is plenty of hard drive space. Webcams don't produce single frames; they produce streams of video, usually in .avi fomat. A 90-second image sequence will require around 100 to 200 megabytes of storage. Thankfully, hard drives are cheap these days. If it's not possible to fit an older computer with a new drive large enough to accommodate big .avi files, it is possible to buy inexpensive external drives that hook to the computer via a USB connection. Unlike normal webcams, the Meade LPI doesn't require tons of drive space. It can automatically combine hundreds of frames without saving them as a big .avi file first.

Non-astronomy webcams come with the programs and "drivers" needed to capture video sequences, and the included software could be used for planetary imaging, but it's not designed with astronomy in mind and lacks things like focus indicators that astro-imagers need. What's recommended for astro-webcammers is the program *K3CCD Tools* (Appendix 1). *K3CCD* is available in both freeware and inexpensive ($50) versions, and contains everything the planetary imager could want. *K3CCD*uses the drivers provided by the webcam manufacturer but replaces the application software that came with the webcam. If possible, just install the drivers and leave the webcam maker's application software off to save disk space.

Finished .avi sequences are just the start of the planetary imaging process, since the goal of most Solar System astrophotographers is high resolution "stills." To achieve that, thousands of video frames must be combined into a single picture, and that picture must be adjusted to bring out maximum detail. One program has revolutionized planetary imaging: *Registax*. This freeware application amazed both amateur and professional astronomers when it was first released in the 1990s. It did the seemingly impossible task of allowing a webcam and C8 to produce pictures that were considerably better than most planetary images produced by professional ground-based telescopes. *Registax*, now in Version 4, is still working wonders today, is still free, and is still indispensable for Solar System imagers. See Appendix 2 for information on downloading this revolutionary astro-soft.

Unfortunately for Macintosh users, *Registax* is Windows only. So is *K3CCD Tools*. Luckily there's a pair of very good alternatives. *Keith's Image Stacker* for OSX Macs is similar in capability to *Registax,* and Keith (Keith Wiley) has camera control and image acquisition covered as well with his excellent *Keith's Astroimager*, which is just as nice as *K3CCD Tools*. Both these Mac apps are freeware.

Despite the fact that *Registax* contains some impressive image processing tools, it's still good to have a dedicated photo-processing program on hand for final tweaks. The "king" of these programs is *Adobe Photoshop*, which can do anything imaginable to images, from sharpening them to blurring them. Its high price (over $700) and giant feature set are probably overkill for the average webcam imager, though. A good and relatively inexpensive alternative is Corel's *Paint Shop Pro* ($100). This time-tested program will do almost anything Photoshop will, and will sometimes do it more quickly and easily.

Basic Technique

With webcam and laptop ready to go, it's time to take the whole set up into the field. When imaging at home (there's no need to go to a dark site for planetary picture taking), use an extension cord from the house or a garden outlet to provide AC for the computer. Yes, laptops have built-in batteries, but most will poop out in an hour or less. Nothing is more annoying than having the computer battery die just as the good images are starting to roll in.

Power ready and scope aligned and tracking, it's time to hook camera to scope. How? For high resolution images, insert the camera's nosepiece into a Barlow lens and insert this Barlow/camera combo into the scope's visual back. Start with a 2x Barlow, and, once framing and focusing become easy (with practice), move up to a 3x for even higher resolution—assuming atmospheric seeing will allow that. The more magnification supplied by a Barlow, the more the image will fuzz-out under poor seeing.

The initial challenge for the novice webcam imager is twofold: framing and focusing. Even with an accurate go-to scope, it can be incredibly difficult to get Jupiter (or anything else other than the Moon) in the field of the camera. In the beginning, in fact, this will seem like an almost insurmountable difficulty. Webcam chips are small, and at a focal length of 4000mm (2x Barlow + 2000mm C8) even bright objects are hard to find. The fact that the planet will probably be way out of focus at first doesn't help, either. One trick that can be used to get a planet pinned down is to set the webcam control program for "autoexposure." The image will be very overexposed, but it will be easier to find if it's a big, bright blob.

The best way to find planets with a webcam? With a flip mirror. A flip mirror, like Meade's $150 model #644 seen in Plate 71, is a special sort of star diagonal. It threads onto the scope's rear port and normally sends light up a focus tube to an eyepiece, like any other diagonal. There's a knob, however, that allows the mirror to be flipped down, sending images straight out the back of the assembly to a Barlow lens and camera. Center Jupiter in the field of the eyepiece, flip the mirror down, and the planet should appear on the laptop display. Flip mirrors' eyepiece tubes can be adjusted via a helical focuser, so that what's in focus in the eyepiece is also in focus on the camera (some minor focus tweaking will probably still be required). The tilt of the flip mirror can be adjusted if necessary so whatever is centered in the eyepiece is precisely centered on the webcam chip. Flip mirrors make the difference between a hair-pulling experience and a pleasant one.

Focus is the other bugaboo for webcam imagers. Close is not good enough. At high magnifications precise focus makes the difference—more difference than anything else—between good images and poor ones. It's not unusual to spend a half hour focusing initially and to continue to tweak focus throughout an evening. What should good focus look like? The planet should be reasonably sharp edged (Jupiter's limb is never razor sharp), and some surface details should be discernable, if not nearly as detailed as they will be in a finished image. *K3CCD Tools* includes a focus indicator that displays changing numbers. The better the focus (brighter the image), the higher the numbers. Details invisible no matter how focus is adjusted? Probably seeing is not good enough for planetary imaging. Sometimes seeing improves as the night wears on, but it's usually best after sunset, and if it's poor then it's usually time to pack everything up and wait for a better night. Such is the nature of amateur astronomy.

Plate 71. (Meade 644 Flip Mirror) A flip mirror like Meade's model #644 makes it easy to center planets on tiny webcam chips. Credit: Author.

How about exposure? Webcams have several settings that will need adjustment. The first is *frame rate*, which can typically be set so the camera delivers images to the computer at 5, 10, 15, and more frames per second. This should normally be set to 5fps. Higher frame rates are achieved by compressing images before they are sent to the laptop—which doesn't do anything good for resolution.

Exposure time and brightness need to be set as well. The goal should be the shortest exposure possible; one in which the "live" on screen image looks a little dimmer than what would look good for a finished image. It's probably best to keep brightness no more than about ? of maximum. There are also controls for hue and saturation and gamma. Leave these at their halfway settings at first and play around with them later. The final control is sharpness. Leave this low, but not at zero. Too much sharpness will introduce noise, but too little will cause weird artifacts in finished images. Jupiter will take on an "onion skin" appearance around its limb. Leave sharpness at about 1/5 of its travel or a little less.

Once everything is set, start taking pictures. Try to obtain at least 10 to 15 "good" .avi sequences of 60 to 90 seconds. Next? The real work begins—image processing beginning with *Registax*. *Registax* takes an .avi video and stacks the hundreds or thousands of frames into a still image. Not only that, it will automatically throw out any frames that don't meet a baseline for quality that's established by the user picking a "best" frame before beginning the stacking process. Stacking many frames in this fashion results in a final picture that's much less noisy than any of the individual frames in the .avi video sequence.

Registax doesn't stop there, though. It's also got an array of image processing tools. Some of these are similar to what's found in Photoshop or similar programs, but one is unique, the "wavelet" filters. This consists of a set of sliders that adjust the sharpness of the image's various "layers." Each one of *Registax*'*s* multiple sliders works on a different size of detail. What the wavelets do is apply unsharp masking to the various detail sizes in the image. To truly understand the way this works would mean mastering some fancy math, but using the wavelets doesn't require that. Once stacking is finished, play around with the wavelet sliders to see what looks best. The results, even in the beginning, will be astounding.

What makes *Registax* able to produce images so much better than what was possible before? By using *Registax*, amateurs are, for all intents and purposes, equipping themselves with adaptive optics. Professional scopes use various complex and expensive systems to counteract seeing effects. The process often requires firing a laser beam into the sky to create an artificial star for use as a reference. Amateurs, however, are doing the same thing with our cheap webcams and laptops. By taking many, many frames and including only those taken during the best seeing in the final composite image we are accomplishing the same things the pros are doing with lasers and tilt mirrors.

Planetary Subjects

Webcam? Check. Image capture program? Check. Stacker? Check. What to take pictures of, though? What are good webcam subjects? The best target for beginners is, hands down, the Moon. She's easy to find and focus and offers tons of details. But the Moon is hardly the only destination for a webcam user. The whole Solar System lies open before you.

The Moon

The only "gotcha" when imaging the Moon is usually color correction. If at all possible, use an IR blocking filter on the webcam. Otherwise Luna will be strongly pink in webcam images. As mentioned earlier, this colr cast can be removed with an image processing program, but the Moon will be so darned pink that it will be hard to get it right. If no IR filter is available, and the color balance doesn't look right despite tweaking in *Paintshop Pro*, the picture can be converted to black and white in *Paintshop* and still look very good. The Moon does possess subtle colors a webcam can pick up, but, honestly, monochrome Moon pictures look better. One especially wonderful thing about the Moon is that she looks great anytime, no matter what her phase. Its astonishing the detail your camera can capture on a nearly full (Plate 72) or even completely full Moon. The large dynamic range of CCDimages (remember, a little

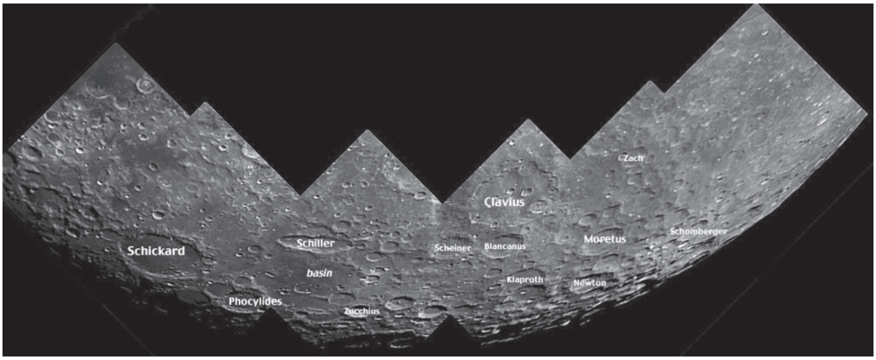

Plate 72. (Nearly Full Moon) Even a nearly full Moon offers up a wealth of detail to webcam-equipped CAT users. Credit: Author.

webcam is a CCD camera) allows any detail present in images to be considerably enhanced.

The Sun

The Sun has much of the same attraction for the webcam imager as the Moon: it's bright and easy to find and focus. Naturally, a filter will be required for imaging the Sun just as for visual observing, but, otherwise, the main problems for solar imagers are seeing and detail. With the Sun heating the scope and landscape and atmosphere, steady air can be a problem. Seeing always settles downs at least briefly, though, and capturing these brief instances of good seeing is what webcams excel at. Detail is the other problem. At the time of the writing of this book the Sun is quiescent, showing little more than a blank disk in white light. As the new solar cycle gets underway, that will change.

Mars

Mars used to be of interest to astrophotographers only when it was at opposition and closest to Earth. That was before the webcam revolution, however. Today, talented imagers using high focal ratios like f/30, f/40, and higher are bringing back details of the Red Planet almost any time it is visible in the sky. Still, there's no denying that for most of us it's easiest to capture fine detail at opposition time. During 2003 I was a webcam novice, but thanks to the extraordinarily favorable opposition that summer I was able to capture some amazing details (Plate 73). The southern polar ice cap was not just visible; it changed shape in the pictures as it melted. I wasn't just imaging the famous dark "maria" of Mars. I was seeing detail within those areas, including hints of a prominent crater in Syrtis Major. Mars' stupendous shield volcanoes were often easy.

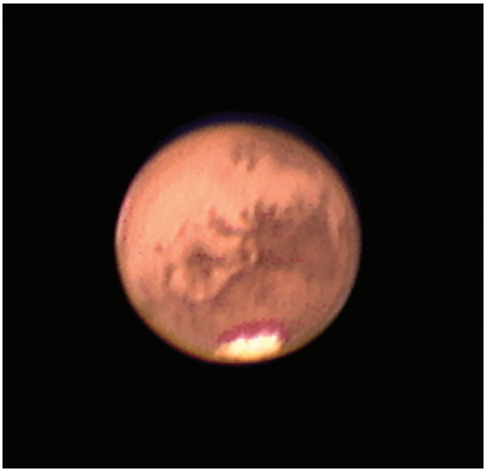

Plate 73. (Mars Polar Cap) When Mars is at opposition much detail is visible to the eye and the camera, including the shapes of the polar ice caps. Credit: Author.

Jupiter

Jupiter is probably the most consistently interesting planet for the Solar System imager. With the coming of the webcam, the planet went from being a distant and difficult subject where amateurs struggled to get convincing pictures of cloud bands and the Great Red Spot, to a world of riotous detail (Plate 53). Even amateurs not blessed with superb seeing can bring back good Jupiter images almost any time the planet is visible. What makes that possible is Jupiter's huge size. With an angular size of as much as 45 arc seconds, the planet is large enough to reveal considerable detail in webcam pictures taken through a C8 at the fairly low focal ratio of f/20 (with a 2x Barlow, that is). Being able to keep focal length/magnification low helps with seeing problems. The only particular problems Jupiter hold for the imager concern focusing and exposure. Jupiter, as mentioned earlier, presents a less hard-edged limb than the Moon or Mars, making it more difficult to focus. It never looks quite sharp. Solution? Spend plenty of time focusing. Pay attention to the clarity of detail on the disk and *K3CCD*'s exposure level "meter." How long an exposure? It's good to have plenty of frames, but Jupiter spins rapidly, rotating once on its axis in 9.8 hours. To avoid blurring, keep .avi length to 90 seconds or less.

Saturn

Many imagers start out strongly with Saturn, spending numerous hours with the planet in an attempt to capture subtle details such as the Encke Minima at the ring's outer edge or the disk's faint banding. Once a few processed images reveal these features, Saturn is forgotten. The rings as seen from Earth don't change much (other than their tilt), and the markings on the planet's face seem unchanging. But they're not. If you don't neglect Saturn, you might capture evidence of a massive storm on the disk. Consider imaging the ringed wonder any time it is in your skies.

Uranus and Neptune

The key to getting a good shot of Uranus? Get the focal ratio up. Uranus is relatively dim at magnitude 6.0 and small at 3.5 arc seconds, so a medium aperture SCT, an 11- or 12-inch, will need to be used at f/30 (via a 3x Barlow) at least if Uranus is to look like anything more than a dot. Unfortunately, at that magnification, the planet may be too dim to yield a good exposure in a standard webcam, even in a larger CAT. One solution is to use the Meade LPI, which is capable of exposing for the 2 to 3 seconds that may be needed. It's also possible to modify Phillips (and other) webcams for long exposure. A source of instructions, and also an excellent place to learn about webcam astro-imaging in general, is the Internet QCUIAG website (Quickcam and Unconventional Imaging Astronomy Group; see Appendix 2). No LPI available? Don't feel like taking a soldering iron to the interior of a webcam? Uranus has been imaged at high magnification with unmodified cameras by exposing and stacking many frames (10,000 or more).

Neptune is worse. It will cry out for a long exposure webcam. Like Uranus, though, it can be mastered by an unmodified camera by stacking long .avi sequences and processing carefully. Don't expect to come out with much more than a pale blue dot, however.

Pluto

At 13th magnitude Pluto needs a modified webcam, no ifs, ands, or buts. It might be captured with an LPI, but that camera's lower sensitivity is likely to cause problems. Imaging Pluto is not as hard as might be expected, however. Since it's only going to be visible as a dimensionless star in amateur scopes, no Barlow is needed to enhance details—there aren't any to enhance. At f/3.3 or f/6.3 a modified webcam can bring back the former 9th planet in a stack of 10-second to 30-second exposures. The only hard thing about imaging Pluto, in fact, is deciding which dim star is the little world.

Deep Sky Imaging

As wonderful and engaging as Solar System imaging is, there's no doubt that most CAT owners interested in astrophotography eventually turn to the deep sky. Sure, hundreds of beautiful deep sky images from the Hubble and other professional observatories can be viewed online, but that's just not the same as looking at pictures of galaxies, nebulas, and clusters you've taken yourself. Your pictures may not be of Hubble quality—or as good as what many of your fellow amateurs are doing—but they are yours.

Before charging into the Great Out There on a quest to capture its beauty and mystery, it's necessary to decide how to do that: which kind of camera to buy and use. There are several alternatives, and the particular style of camera used will determine imaging procedure to some extent.

Modified Webcams

As mentioned in the Solar System section, webcams can be electronically modified to take long exposures. It's way beyond the scope of this chapter to explain what needs to be done, but suffice to say the job is an exacting one, demanding good soldering skills and a good knowledge of electronics. In the past, several companies offered "professionally" modified webcams. Recently, though, with the introduction of inexpensive integrating CCDcameras, these outfits seem to have disappeared. The Meade LPI (Plate 70) is still available, but it's not a good choice for deep sky imaging. No matter how long the exposure or how many frames are stacked, its CMOS chip is not sensitive enough to record even bright deep sky objects in detail.

A modified webcam is a cost effective way of getting into the deep sky game. However, the small chips that make webcams great for planetary imaging are a drawback for the deep sky. In deep sky picture taking, what's usually wanted is a relatively wide field, low magnification views of the sky. Long exposure webcam images also tend to be noisy, making them hard to process without heroic efforts. There is one type of webcam-like imager that can ease entry into the deep sky arena, the Meade DSI (see the section on CCD cameras). It operates much like a webcam, but is much more sensitive.

DSLRs

The next step up from webcams are DSLRs, "digital single lens reflex" cameras. These cameras are much like their film-using ancestors in that they feature interchangeable lenses and through-the-lens viewing and composing. They are different in that they replace film with an electronic chip. When DSLRs first came out, amateurs were anxious to try them on the night sky. Being self-contained (no computer) and looking just like the 35mm SLRs of yore, they seemed a natural for astrophotography. Not only would there be the attraction of a sensitive CCD chip (actually, for most DSLRS, then and now, a CMOS chip), they could be used at the telescope in much the same way as a film SLR using many of the same accessories. Before long, cutting-edge amateurs were shooting the night sky with their DSLRs with varying results.

Early digital single lens reflexes turned out to be limited for astrophotography. The biggest problem was they couldn't expose for very long—30 seconds was usually the max—and the resulting images were quite noisy. Also, the chips in the initial cameras were fairly small and low-resolution affairs. Talented amateurs found workarounds such as stacking multiple images, but the biggest help was that DSLRs began evolving rapidly. Chips started getting bigger, and sensors as large as a 35mm frame were soon available for costs that were at least manageable by serious but not wealthy astrophotographers. Even better, camera makers began giving their DSLRs the capability of exposing for as long as desired via a "bulb" setting, like that on film SLRs. Canon and Nikon, especially, also worked to make long exposures less noisy. Canon actually acknowledged that its cameras were used for astrophotography and even released a model, the 20Da (no longer available) aimed at the astro market.

It wasn't all sweetness and light, though. Despite these advances, DSLRs are less sensitive than (monochrome) astronomical CCD cameras. Longer exposures are required, and guiding and mount sturdiness has become more critical. Also, our dreams of using DSLRs just like SLRs—no computer to lug into the field, just mount on scope and shoot—came to naught. Some astrophotographers *do* use DSLRs that way, but the best results are obtained by connecting the cameras to laptops. If nothing else, this makes focusing much easier. Squinting through the dim and small finders of these cameras or at the small “live” video displays a few DSLRs now feature, it’s hard to see anything, much less focus a star field sharply. The biggest drawback to the DSLR, however, is that camera manufacturers add a strong IR block filter to the cameras’ innards. This is done to make lifelike color easy to obtain in terrestrial images, but it harms DSLR sensitivity to dim red nebulas.

Despite these caveats and a few others, amateurs are doing remarkable work with these cameras, producing some incredibly beautiful color sky shots. Most of this has been a matter of adequate processing software; amateurs have helped here, designing hardware interfaces that make the cameras easy to control from PCs and writing the software needed to maximize the DSLR’s astronomical potential. Some astronomy entrepreneurs are even selling “modified” DSLRs that have had their IR block filters removed (as Canon did with its 20Da). One thing makes a DSLR a great choice for many folks: it can be used for general picture taking as well as astro-use, which makes the price a little easier for many families to bear. Let’s go so far as to say that for imagers who want large and easy color pictures, a DSLR, not an astro CCD cam, is the way to go. One thing is for sure: the color images you can get with one of these (Plate 57) is better than anything you could have gotten back in the “good old” film days.

What about specific DSLRs? Look through the photo magazines, and it appears not much has changed in SLR photography in the last thirty years. The top dogs are still Canon, Nikon, Pentax, and Olympus. When it comes to astrophotography, however, things have changed. Canon has surpassed Olympus, the former favorite of celestial imagers, and for good reason: the Canon DSLRs’ low noise characteristics. Which Canon? The Digital Rebel is probably the most popular DSLR for astro-imaging. This reasonably priced camera—about $750 with a lens—and now boasting a 12.2 megapixel sensor in its latest (XTsi/450D) version is the closest thing we’ve got to a digital OM1 (the film SLR so beloved of astrophotographers). This is not to suggest a Nikon, Pentax, or Olympus can’t take decent sky pictures—they can. But the astrophotos done by today’s Canons are better. Is there any reason to invest in a non-Canon DSLR? Perhaps, if you’ve got a large collection of Pentax, Nikon, or Olympus lenses left over from the film days.

CCD Cameras

Even webcams, some of them at least, use CCD chips, but “CCD” in amateur astronomy has come to refer to cooled long-exposure cameras designed specifically for astronomical use. CCD cameras are at the top of the heap when it comes to capability in astronomy picture taking, but may seem a little more complicated than the other choices—at first, anyway. DSLRs, at the most basic level, are used like film cameras: screw one onto the back of an SCT and snap away. CCD cameras require a computer to do anything at all and are more dependent on “calibration,” plus the use of "dark frames" and "flat-field frames" and other specialized processing techniques to perform at their best. There's no viewfinder or display screen, either. Targets are focused and finished images are displayed on the PC. When an integrating camera's exposure ends, it assembles the picture and sends it (usually via a USB connection) to the laptop for display and processing.

One other important difference between DSLRs and CCDs is cooling. Much of the noise seen in DSLR images is thermal noise. When light strikes a CCD or CMOS chip pixel, it liberates an electron that is "counted." The counting of electrons determines how bright or dim that pixel is in the final image. Unfortunately, heat (from camera electronics or the environment) can also free electrons. These "thermal electrons" get counted, too, and appear as white dots—"false stars"—in images. Some thermal noise can be dealt with by dark frames. Take an exposure with the dust cap on the scope's corrector, combine this "dark" with the image frame, and the computer can subtract out the thermal noise—most of it, anyway. Some doesn't go away, not in an uncooled camera such as a DSLR. CCD cameras are able to eliminate almost all the noise "specks" with a dark frame because they start out with less noise than an uncooled camera has. Chilling the CCDchip to at least below freezing (usually by a Peltier cooler, a solid state "heat pump") gets rid of enough of those dratted false stars to allow a dark frame to take care of the rest.

What about specific models? Unlike DSLRs, no single brand completely dominates the CCD arena. These cams are, instead, divided into three tiers, much like CATs: inexpensive, mainline, and top-of-the-line. As with telescopes, capabilities increase (bigger CCD chips) with price. Also like telescopes, though, a dedicated and talented user can make a less expensive camera perform like one costing much more.

Inexpensive Cameras

This used to be an oxymoron. There were no cheap CCD cameras unless you consider "$1,000" cheap. That changed a few years ago with Meade's release of the DSI, the "Deep Space Imager." This started out as a simple, uncooled device that seemed a lot like a webcam to most amateurs—until they used one. Not only did the original DSI, a one-shot color camera, sport a slightly larger chip (5.59mm x 4.68mm) than many webcams, its pictures were much less noisy than those of a modified webcam. This was accomplished by an innovative passive cooling system. There's no Peltier cooler; instead, heat is radiated away by cooling fins on the back of the camera and is kept low to begin with since the camera turns off as many of its heat-generating internal electronic circuits as possible during exposures. Although not nearly as noise free as a cooled camera, the original DSI was capable of producing very pleasing images, as seen in Plate 74, and did it for an unbelievable $300.

The DSI was a huge hit, and Meade continued to work on it, releasing a second camera, a more sensitive monochrome imager, the DSI Pro, and, then, a second generation camera, the DSI II, available both in one-shot color and monochrome ("Pro") formats that featured still larger chips (7.40mm x 5.95mm) and still lower noise. The DSI II goes for a reasonable $600 for either the color or black and white version. Meade's not through with the DSI yet. As this is being written, a DSI III has been announced, which will contain a 10.20mm x 8.20mm CCD chip.

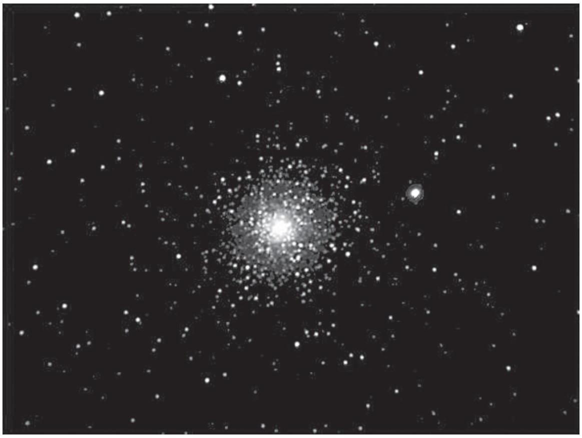

Plate 74. (DSI M15) Meade's DSI camera is inexpensive and easy to operate, but is still capable of delivering images of surprising quality. Credit: Author.

Meade's cameras made a big splash on the astrophotographyscene, but they are no longer the only game in town in the low-priced category. One very popular manufacturer is the Portuguese company Atik Instruments. Starting out as a webcam modifier, Atik has progressed to the point where they are offering some very sophisticated integrating cameras. They still keep a toe in the low end of the market, however, with their Atik 16IC color and monochrome cameras. At a current price of $645, these CCDs are remarkable values. In addition to a sensitive chip in the same size range as the DSI and II, there's a Peltier cooler and a hardware guider output that will allow the camera to be interfaced to a telescope and act as an autoguider instead of an imaging camera. Atik cameras are easily available in the United States from Adirondack Video Astronomy. Orion (also in the United States) offers a camera similar to the Atik, the Starshoot II. One interesting feature of the Starshoot is that its Peltier cooler is powered by two D-cell batteries. Heretofore, power-hungry Peltiers needed hefty 12vdc power supplies.

Mid-price Cameras

Many astro-imagers will say that this is where "real" CCDing begins, with Santa Barbara Instrument Group (SBIG) in the U. S. and Starlight Xpress in the U. K. Both companies produce a range of cameras from the relatively inexpensive to the near professional grade. They are probably most well-known for mid-priced "workhorse" CCDs ($3,000 to $6,000).

Many amateurs start out with an inexpensive SBIG camera and stay with this California company's products forever. There's good reasons for that: quality, value, and performance. SBIG offers one attractively priced entry-level cam that hovers just above the lower price region, the ST-402, a 4.6mm x 6.9mm 657 x 495 chip monochrome camera that goes for $1400. Like all SBIG's CCDs it features a Peltier cooler that is regulated. Many other CCDs, both low priced and more expensive, have coolers that cool continuously. Turn them on and they cool. Turn them off and they stop. The SBIG cameras allow the user to determine a "setpoint" temperature.

The camera software will keep the camera at that temperature, which results in much higher quality dark frames and, for that reason, less noisy final images. Like the ST402, most of SBIG's more expensive cameras use monochrome chips. Black and white chips are more sensitive than color chips but require three separate exposures through three filters (red, green, and blue) to produce color images.

In the opinion of some amateurs, the real meat of the SBIG line lies in its more advanced cameras. One favorite is the ST-2000 (Plate 75). The nicest things the 2000 brings to the table are a large 11.8mm x 8.9mm (1600x1200 pixels) CCD and, for the most expensive version, a separate guide chip. Telescopes must be guided—have their aim fine-tuned—during imaging if they are to produce round stars. The ST-2000 can be purchased with an additional, smaller CCD chip mounted alongside the imaging chip that allows the camera to guide and image at the same time (most cameras can do one or the other but not both). That makes it amazingly easy to get well-guided pictures with the ST-2000, even with less robust and less expensive mounts. For users wanting color pictures but not wanting to mess around with tricolor imaging, SBIG offers a one-shot color version of the ST-2000 that is gaining quite a few fans, including amateurs who previously disdained one-shot color.

The other long-time CCD player in the mid-range ranks is Starlight Xpress in the U.K. Although Starlight has never been as popular in the U.S. as SBIG (the situation is reversed in the U.K.), the company has plenty of fans on this side of the water, and, like SBIG, sells cameras all the way from the beginning to the near-professional level.

The junior member of the Starlight family, and the one that best carries on the tradition of the popular MX5 of yore is the SXVF-M7 ($1,600), with a monochrome 6.3mm x 4.76mm 752x580 chip. This camera features a regulated cooler, and, when this is coupled with its very low thermal noise characteristics, some users may be able to get by without taking a single dark frame. We described Starlight Xpress as being "innovative," and this little camera is one of the offerings that really shows that spirit of innovation, in this case with its "STAR 2000" interface.

The only CCD cameras on the market that feature separate guide chips are the SBIGs, since that's a proprietary and patented invention. In some ways, though,

Plate 75. (SBIG ST2000) SBIG's ST2000 CCD camera offers both a generous-size imaging chip and extreme sensitivity. Credit: Author.

Starlight's STAR 2000 system is even better; it allows guiding and imaging with the same chip at the same time. The optional STAR 2000 cable and interface box connect between the laptop and the mount's autoguide port and keep the scope positioned on the chosen guide star. How can it guide and image at the same time? The chip used in the M7 can alternate guide "fields" with imaging fields. Essentially, half a frame is imaging and half is guiding at any given time, with everything being reassembled by the computer when the exposure is over. The only drawback is that this unavoidably reduces the sensitivity of the chip, and the M7's chip is already less sensitive than that of the comparable SBIG ST-402.

Earlier it was said that Starlight cameras are not as popular as SBIG in the U.S. That's true, but Starlight's SXVF-H9 ($3,000) seems to be threatening to even the score. More and more of these are appearing at star parties, anyway. The H9 is a monochrome camera with a good-sized 9 x 6.7mm 1392x1040 pixel chip. Like the M7, it's got excellent noise characteristics, a regulated cooling system, and is capable of producing beautiful pictures. Since it is not compatible with the STAR 2000 system, Starlight offers a separate guide camera head for use with an off-axis guider or separate guide scope. Starlight Xpress has long been a leader in one-shot color cameras and makes color versions of the M7 and the H9, the M7C and H9C, respectively.

Deep Pockets Cameras

Are even SBIG's and Starlight's big chip cameras not big enough? Amateurs with money to spend and a desire for large chips can turn to several companies. Two of special note are Apogee and Fingerlake Instruments (FLI). These companies make professional grade cameras, but they also make less expensive ones, and they are used to dealing with amateur astronomers. On the lower end of its pro range, Apogee offers the U16M, which sports a 4096x4096 pixel 39mm x 39mm chip. It might be just the thing for the advanced imager dreaming of wide-field CCDshots who doesn't mind spending $10,000 for a camera. On the FLI side is the Proline 16000M, which features a 35mm format 4872 x 3248 CCD and many other advanced features and options—all for a mere $11,000. Yes, the prices are daunting, but some imagers find themselves working their way up the CCD ladder, buying and selling cameras, starting with a DSI, moving to an inexpensive SBIG or Starlight, and winding up in Apogee/FLI territory, which many astrophotographers will say is CCD heaven.

Computer Software/Hardware for DSLRs and CCDs

A DSLR imager can make do without a computer, relying on the camera's memory card for storage and the viewfinder for focusing. That's a way to get started, but it's not a recipe for getting the best out of a camera. A computer isn't just nice for modified webcams and CCD cameras, it's a necessity. What's required? A laptop is the best and safest choice. It need not be the latest laptop, however, since most imaging software, unlike some planetarium software, is not demanding of computer resources. What's most needed is, as for a webcam computer, plenty of storage space. Unless the camera in use has a very small chip, many megabytes of data will be accumulated from a single evening's observing run. A minimum hard drive size of about 80 GB is desirable.

Webcam Software

For deep sky imaging with a modified webcam, as for planetary imaging, one program stands out: *K3CCDTools* ($50). In addition to its ability to control most long-exposure modified webcams, it provides utilities that are very useful for deep sky workers, such as a polar alignment helper and a module that will display the periodic error of a telescope's drive.

DSLR Software

A current favorite in this category is an inexpensive but very capable program, *Nebulosity*($45). Not only does *Nebulosity* display the DSLR's images on the PC screen, making for easy focusing, it does many of the things any CCD software does: control camera settings, take single exposures or a series of exposures, take and subtract dark frames, and even do some fairly sophisticated image processing. *Nebulosity* doesn't stop with DSLRs, either. It can be used to operate the Meade DSI, the Starlight Xpress, the SBIG CCD cameras, and a growing array of other deep sky and planetary imagers.

Like other DSLR programs designed to allow the cameras to take long exposures, *Nebulosity* requires two connections from camera to PC. One cable delivers image data to the computer. The other connects to the camera's remote ("cable release") interface to allow for and control long exposures. These cables and interface boxes are inexpensive and are available from Shoestring Astronomy Products (Appendix 1).

ImagesPlus ($150) is one of the most popular camera control and imaging programs on the DSLR scene. In addition to operating Canon and Nikon cameras, *ImagesPlus*contains extensive image processing facilities. In fact, it is so capable in this area that the services of another image processing program such as *Adobe Photoshop* may not be required.

At the top of the heap, at least pricewise, is Cyanogen's *MaxDSLR*. ($300). In addition to all the camera control and image processing features of programs such as *Nebulosity* and *ImagesPlus* have, Maxim DSLR adds other desirable features, including the ability to operate a guide camera. *Max DSLR*, like *Nebulosity,* supports a number of non-DSLR cams, including the Meade DSI and LPI, webcams, and the Luminera "planetcams." *MaxDSLR* is considerably more expensive than the other programs, but keep in mind that it can be upgraded to *Maxim DL*, the company's legendary CCD imaging program for an additional $250.

CCD Software

CCD camera makers include a camera control program in the boxes with the cameras. These programs are sufficient for operating the camera on a basic level and doing minor image processing, but most CCDers soon want something that makes image acquisition quicker and easier and which includes a more full-featured suite of image processing tools.

Software Bisque's *CCDSoft* is probably the "step up" program used by more imagers than any other. There are a couple of reasons for that. First, it was designed for the SBIG cameras and is therefore the natural choice for their owners once they outgrow *CCDops* (SBIG's "included" program). *CCDSoft*'s strengths are a very clean, easy to learn interface and an ability to interface with other Bisque programs. For example, it's usually necessary to know the telescope's current declination when "calibrating" for autoguiding. If the user has Bisque's *TheSky* planetarium program connected to the telescope, that program can automatically pass the declination value to *CCDSoft*.

Is there anything not to like? At $350, the program isn't exactly cheap, but there's little that any imager will want to do that can't be done with *CCDSoft* somehow, even if it's not always easy to do. It's also true that the program has been locked in Version 5.0 for quite a while and is beginning to show its age as far as "look." However, the biggest strike against *CCDSoft* is that it is designed for SBIG users. If you want to use this program with non-SBIG imaging—or even guiding—cams, good luck. There are a few drivers for non SBIG cameras, but not many.

Astroart

Users of Starlight Xpress' CCD cams are not left out in the cold by *CCDSoft*'s lack of drivers for their cameras. There's no need to stick with the simple (and simplistic) software that ships with the Starlight cameras. *Astroart* is very reasonably priced ($185) and full-featured. Like *CCDSoft*, there's little the dedicated imager can't do with *Astroart*, from taking pretty pictures to conducting serious scientific pursuits such as astrometry and photometry. The biggest plus for this camera control and image processing program, however? It will work with just about any imaging/guiding camera, from humble Meade DSIs to ritzy FLI and Apogee big-chippers.

Potential *Astroart* problems and dislikes are few. This is a mature and stable program. The downsides? The somewhat cluttered user interface is not perfect, and it is easier to "relearn" *CCDSoft* than *Astroart* after weeks of cloudy skies. Plus, some users may not like the basic design thrust of the program. It's really more of an image processing application that can control cameras than a camera control program that can do processing. That is probably the inevitable result of one of the program's strengths, its "generic" nature. Finally, it supports a slew of different camera models via "plug-in" drivers, which makes *Astroart*'s camera control facilities feel a bit like an afterthought.

Maxim DL

Cyanogen calls their CCD program, *Maxim DL*, the "gold standard." It is certainly that when it comes to price, at least; it retails for $500 (for a "brick and mortar" version that comes with a manual; a download is less expensive). How does it stack up otherwise? This is an incredibly feature-laden application that can do everything you can ever imagine any CCDer wanting to do. Interfacing with planetarium programs such as *Starry Night Pro Plus* is just the beginning. Maxim can control camera filter wheels, motorized focusers, and, by connecting to other software, can even manage observatory domes and remote/Internet telescope connections. Compatibility? Cyanogen claims the program "supports more CCD cameras than any competing software." That's probably true. There are few cameras, cheap or expensive, old or new, that can't be run by this program. Naturally, it also includes a huge selection of image processing tools.

What didn't impress? This big, complex, and capable app is quite a bit for a new CCD imager to digest. That being the case, you might want to get friendly with a new camera using its included software before moving up to *Maxim DL*. Who absolutely won't like Maxim? Only those folks irrevocably wedded to the SBIG/Bisque way of doing things.

Basic Deep Sky Technique

Widefield (Piggyback) Deep sky Imaging

Is exactly what it sounds like: the camera rides "piggyback" on top of the telescope, making use of the scope drive to track the stars but shooting though its lens or small refractor instead of through the main telescope (Plate 76). Piggyback photography is often recommended for beginners since it eliminates—or at least reduces—the need for accurate guiding. Inaccurate polar alignment is also much less noticeable when doing piggyback photography.

The items needed to allow DSLR users to get started in piggyback photography are few. The main one is a bracketto enable the camera to be mounted on the scope. These are available from astronomy accessory dealers, are inexpensive in their most

Plate 76. (Piggyback) A piggyback mount and a ball-and-socket tripod head allow a beginning imager to take attractive wide-field shots easily. Credit: Author.

basic forms, and mount easily in the "accessory holes" on the rear cells of CATs. One additional item, a "ball type" camera tripod head like that seen in Plate 76, is also desirable. If the camera is mounted directly to the piggyback bracket, it will be limited in the directions it can be aimed independently of the main scope. Finally, DSLR users will need a remote release cable (or a connection to a computer running a program such as *Nebulosity*) that allows the camera to take long exposures.

CCD cameras can also be used for piggybacking. Almost all the CCDs produced lately either include an integral tripod mounting socket or can be equipped with one. Naturally, "real" CCD cameras will need some kind of adapter to allow camera lenses to be mounted to them for wide field work (a very effective combination). The good news is these "T-to-camera lens" spacer-adapters are common and inexpensive.

For initial piggyback experiments, begin with a "normal" lens on the camera, a lens with a focal length of around 18 to 50mm. This will not only give a wide field of view, it will completely eliminate the need to guide the scope if polar alignment is even fair. With the scope set up and tracking, mount the camera on the piggyback bracket/ball head and point it in the general direction of a photogenic part of the sky (the southern Milky Way is especially good). Focus the camera as accurately as possible using either its viewfinder or, better, the big-screen display of a laptop program (don't depend on the infinity mark on a lens), and open the shutter with the remote release or PC program. Most SLR lenses deliver maximum sharpness if they are closed down an f-stop or two, so it's wise to try a couple of stopped-down shots and compare the results with "wide open" frames. A normal lens often has a speed of f/2 or faster, so don't expose for too long. Sky fog will set in quickly unless the skies are dark. Two or three minutes is a good start. Don't stop with one image, either. Take multiple images, as "stacking" them with image processing software will keep noise down.

The biggest challenge, it will rapidly become apparent, is not exposing images, it's processing them. Be forewarned, the pictures that initially come out of the camera will look awful. One of the most amazing aspects of the electronic imaging game is what a few simple processing steps will do to turn frighteningly ugly piggyback shots into detailed and beautiful celestial images. Where can a new astrophotographer learn this art? The books listed in Appendix 1 take novices through the process of "developing" digital images in step-by-step fashion.

Advanced Piggybacking

The next step up from piggybacking is shooting through either a long focal length camera lens or a small refractor, something with a focal length in the range of 400 to 500mm, perhaps. This extra focal length will deliver finer details in larger deep sky objects and permit the capture of some medium-sized DSOs. Galaxies M81 and M82, for example, are minute smudges at 50mm, but begin to come alive with detail at 500mm.

Small refractors are attractive to piggybackers, since they are more versatile than long camera lenses. Also, a small refractor can be used for guiding and visual observing as well as imaging. A little achromat like Synta's much-loved Short Tube 80 may also be a hair better on sharpness than a DSLR "kit" zoom lens. Unfortunately, the refractor's stars will be bloated and will display plenty of chromatic aberration (false color) due to the simple achromatic objective. A nice alternative to an ST80 is one of the inexpensive "ED" apochromat refractors from China that are now available from outfits such as William Optics.

Although not as color free or sharp as top-of-the-line camera lenses or "true" APO refractors (with three-lenses element and/or a fluorite element), the EDs can do nearly as good a job, especially if equipped with one of the field flattener lenses available for many of them. A nice choice for the new astro-imager is one of the ubiquitous 66mm f/6 EDs that can often be bought for less than $400. The 66mm doesn't sound like much aperture, but it's utterly amazing what can be captured by one using a sensitive camera (Plate 77). At the longer focal lengths produced by even a 66mm ED scope, the imager's life does become more complicated; guiding the telescope, for example, becomes a necessity if perfect stars are desired. The upside is that guiding is still relatively non-critical at 300 to 600mm. See the Prime Focus discussion and the "Demon" section below for tips.

Prime Focus

This is the Holy Grail for most aspiring imagers: taking long exposure shots through the CAT, beautiful pictures like those produced by that icon of amateur astrophotographers, Jack Newton. We won't all be able to make sky pictures like Newton's; most of us don't have the equipment, the time, the talent, or the skies. It is relatively easy, however, for most of us to produce at least recognizable deep sky images these days. With sensitive CCD cameras, a 3- to 5-minute exposure through a C8 delivers a huge amount of detail, more than an hour of exposure did during the film days. Shorter exposure also means there is less time for things to go wrong.

What's needed in addition to a camera and a CAT for prime focus imaging? A very desirable accessory for most imagers is a focal reducer (see Chapter 6). A non-reduced f/10 C8 has a focal length of 2000mm, and it is insanely difficult for even experienced astrophotographers to get perfect results with a set up like that. All that

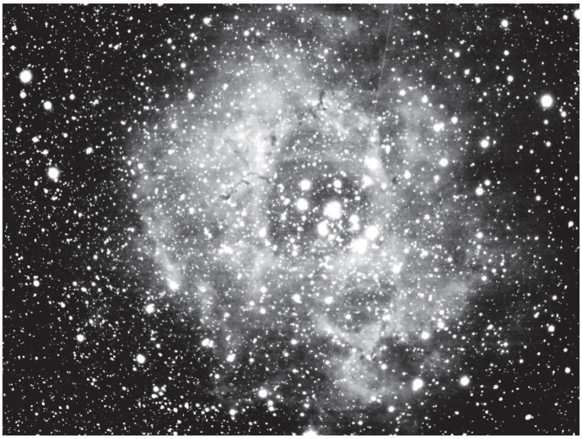

Plate 77. (Rosette Nebula) Today's sensitive CCD cameras make it possible for even a 66mm aperture telescope to bring home the faint wonders of deep space, such as the Rosette Nebula. Piggybacked William Optics 66SD refractor and SBIG ST2000 camera. Credit: Author.

focal length makes guiding hyper-critical. Any small errors in keeping the guide star centered will be very obvious in images. Exposures must be relatively long, too, even with sensitive CCD cameras. An f/10 system is, in photographer's parlance, "slow;" which means it takes a long time to build up a well-exposed image. Celestron sells an f/6.3 reducer/corrector and Meade sells both an f/6.3 reducer/corrector and an f/3.3 reducer. Large chip CCD cameras and DSLRs do best with the f/6.3, since stars at the edge of the field tend to be badly distorted in f/3.3 reducers. A camera with a smaller imaging chip, like the DSI, may do well with an f/3.3. If the chip is not large enough to register the ugly stars at the f/3.3's field edge, its wider field and faster optics are real advantages, especially for beginning astrophotographers. Other manufacturers produce both cheaper and more expensive reducers, but I have not seen one yet that's worlds better (or worse) than Meade's and Celestron's bread and butter reducers and reducer/correctors.

How is a camera attached to a CAT? A CCD is usually furnished with a 1.25- or 2-inch "nosepiece" that allows it to be inserted into a visual back of the telescope. A DSLR will need a T-adapter and a prime focus adapter. A T-adapter is a metal ring that takes the place of the camera's lens. One end features a mount appropriate for a particular camera model—Canon, Nikon, etc.—the other end is equipped with T (universal mount) threads, which can be screwed onto a prime focus adapter. The scope end of an SCT style prime focus adapter features a threaded ring that lets the whole shebang thread onto the rear port (or a focal reducer). Note that most integrating cameras' nosepieces can be unscrewed to reveal T threads that will allow the camera to be mounted on a prime focus adapter, which is usually a more secure arrangement than using the nosepiece and a visual back. Prime focus adapters are available from most astro-dealers.

If the intent is to take exposures longer than one minute, some kind of guiding system will be needed. In the past many astrophotographers used a device called an Off Axis Guider (OAG), which used a small prism to intercept a small amount of light before it reached the camera. This tiny prism was able to deliver star images from the edge of the telescope's field, allowing the scope to be guided during the exposure with the aid of a crosshair reticle eyepiece. Watch the star, and when it drifts off the crosshair, push a button on the hand control. Continue to watch and make corrections for the duration of the exposure. Today a few imagers still use OAGs (with guide cameras, usually, not "manually"), but most often with guide cameras (see the Guiding Demon section below) rather than with eyepieces.

Given the current unpopularity of OAGs, most CAT users guide with a small piggyback scope on the main tube. This does add the problem of flexure to the mix; if its mounting bracket is not stiff enough, the guide scope may move independently of the main scope as it changes position while tracking across the sky. Even a small bit of flexure will cause trailed stars in images. Thankfully, the short exposures required by CCD and DSLR cameras make this a minor problem for most imagers. The mount doesn't move far enough across the sky over the course of a 5- to 15-minute exposure to cause the guide scope to flex much. Guide scopes are certainly easier to use than OAGs, as they are not limited to the tiny selection of stars provided by the OAG's ridiculously tiny "pickoff" prism.

Many SBIG users have almost returned to the days of OAGs—in a sense. Some of the company's cameras, as mentioned earlier, are equipped with guide chips. Like the OAG, the guide chip is limited to stars at the periphery of the field. Due to the sensitivity of SBIG guide chips, however, you can almost always find a suitable star.

Fastar

Owners of some of Celestron's older SCTs, current C14s, and modified/custom-order Meade and Celestron OTAs have a special method of picture taking available beyond piggyback and prime focus—Fastar. In a Fastar set up, the SCT's secondary mirroris removed and replaced by a CCD camera, which takes advantage of the SCT's fast f/2 primary mirror for wide-field imaging with little or no guiding. How can the secondary mirror be removed? Fastar compatible telescopes feature a mirror holder that allows the secondary to be pulled out after unscrewing a threaded ring.

Why isn't every astro-imager using Fastar? One reason is that the camera can't just be mounted in place of the secondary mirror. The steeply curved spherical primary mirror would deliver images that would suffer from multiple sharpness problems such as aberrations. Fastar gets around that by having users install a corrective optics package ahead of the camera. Unfortunately, the prices of these corrective lenses, currently only available from the U. S. vendor Starizona, are relatively high. The company's "Hyperstar" lens for a C11 is nearly $700. Many imagers would rather invest that money in an ED refractor if wide-field imaging is a goal. Hanging a CCD camera off a thin corrector would also seem to invite disaster. One slip of the declination clutch and the camera will contact a fork mount scope's drive base; the probable result will be a broken corrector. This is a real concern and has happened to several astrophotographers at least. Despite these caveats, there is no doubt that Fastar is a path to relatively easy wide-field imaging; at f/2 tracking is forgiving and exposures are very short.

The Astrophotographer's Three Demons

Astrophotography just ain't easy. So many things can go wrong during an exposure. There are three areas that cause the most failures, though, and concentrating on exorcising these three "demons" maximizes the chances of coming home with at least a few good images. These three fearsome creatures are the Demon of Polar Alignment, the Demon of Focus, and the Demon of Guiding.

The Polar Alignment Demon

Why take pains to point the scope's RA axis precisely at the celestial pole? Poor polar alignment causes objects to drift in declination, resulting in trailed stars. The only cure for that is to improve polar alignment accuracy. Just aligning on Polaris isn't good enough. Even the fairly accurate alignment produced by polar finders is usually not precise enough for exposures more than a minute or two long. What may be needed is a drift alignment.

I used to recommend that astrophotographers always drift align their scopes. Today, that's probably less necessary. The combination autoguiding, short focal lengths, and short exposures make dead-on alignment less importantl. Something better than pointing the polar axis at Polaris is still required, but that "something" may be quickly and easily achieved with the polar alignment routines featured by some go-to scopes' hand controllers.

What is drift alignment? It is the process of accurately adjusting a telescope's mounting by watching the north/south and drift of selected stars. This procedure seems complicated at first but will soon become second nature. Begin a drift alignment by doing a good "normal" alignment. Point the RA axis at the pole as accurately as possible using a polar scope, the hand controller's polar align procedure, or any other means that's better than "point at Polaris." The closer the mount is to the pole initially, the quicker the drift alignment will be. Next, locate a star close to the Local Meridian (the imaginary line that runs through the north and south celestial poles and the zenith and nadir) and around approximately 15 to 20 degrees north of the celestial equator (i.e., at a declination of about +20). This is not hyper-critical. Just find a nice medium-bright star in the general area. When the star is in the crosshairs of an illuminated reticle eyepiece at 250x or higher (using a Barlow if necessary to achieve this magnification), rotate the eyepiece and diagonal until the crosshairs are aligned so up-down is declination. Ensure the star moves precisely along this vertical crosshair when the scope is moved in declination and along the horizontal one when it's moved in RA

Now, let's drift. Put the star in the center of the crosshairs using the hand paddle and watch for movement up or down—for drift along the N/S crosshair. Don't worry about E/W drift. It's OK to guide in RA with the hand controller to keep the star near the center of the crosshairs, but all we want to know at this time is whether the star is drifting up or down in the field. If the star drifts up in the field, adjust the azimuth (left-right) of the wedgeor a GEM's polar axis to make the star move right in the field (Figure 9). How much? About the same distance the star drifted. If the star drifts down, move the star left in the field. After these azimuth adjustments, use the hand controller to re-center the star in the crosshairs. Keep watching for up/down drift and moving the wedge or polar axis in azimuth until the star doesn't move up or down for at least five minutes.

An accurate drift alignment usually requires the mount also be adjusted in altitude. Locate another medium-bright star, this time right on the celestial equator and roughly 15 to 20 degrees above the eastern horizon. Set the eyepiece up as above (by rotating the diagonal in the visual back as required), with the up-down crosshair again defining declination movement and the left right crosshair defining RA. Center the chosen star in the crosshairs and watch for drift. We're still watching for up/down drift, but the wedge/polar axis adjustment differs. If the star drifts up, adjust elevation to move the star down in the field. If the star drifts down, move it up. Keep doing this (re-centering the star between adjustments) until there's no visible up/down drift for five minutes. With the "elevation" star steady, carefully tighten down the wedge's bolts to lock it in altitude and azimuth. A careful "five minute"

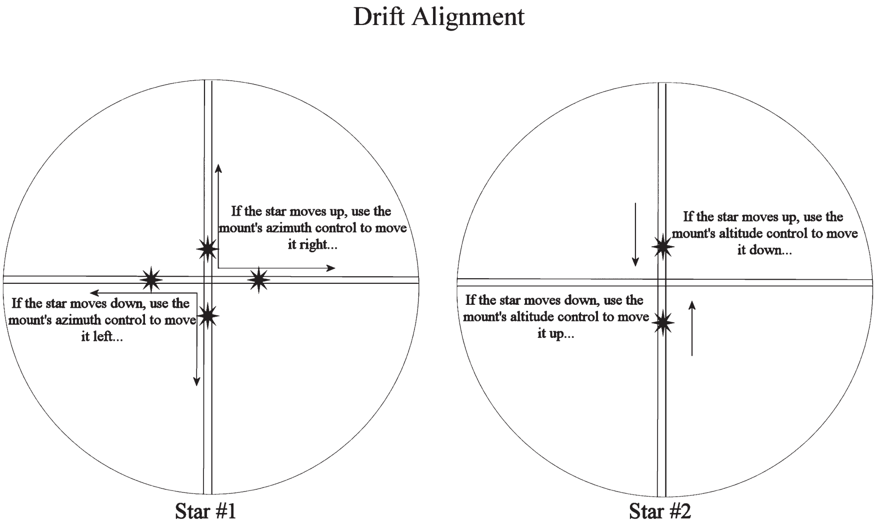

Figure 9. (Drift Alignment) A drift-type polar alignment is easy to do and offers the precision necessary for long exposure astro-imaging. Credit: Author.

drift alignment should allow exposures of at least an hour, with no trailing due to declination drift.

The Focus Demon

The only thing that makes an astrophoto look worse than trailed stars is bloated and out-of-focus stars. Getting good focus is important but not difficult. Make focusing easy, first of all, by not trying to focus using the dim viewfinder of a DSLR. If at all possible take a laptop into the field. It's hard to overstate how much easier it is to get good focus by looking at a PC display than squinting through a viewfinder. Many DSLR and CCD programs have additional focus aids, too, like a quickly updating focus mode, a zoomed-in magnified focus frame, and an "intensity" indicator—the higher the number, the better the focus.

What's a good way to focus? Start out with a bright star, usually your last alignment/sync star. Set the camera to expose for 1 second or less (so the star is not insanely overexposed), and adjust focus until the star is as "small" as possible. You can observe the changing numbers of your program's focus indicator, but mostly rely on the visual appearance of the star. When it's as good as you can get it, ramp up the exposure to two, three, or more seconds, until dim stars begin to appear in the frame. Continue to modify focus until these are hard little pinpoints. How long should you spend focusing? As long as it takes. Continue to check focus over the course of the evening and refocus when needed; aluminum scope tubes can and will expand and contract with temperature changes, altering focus. If you are having difficulties achieving focus on a particular object, try slewing to a Messier globular cluster, if one is available. As a friend of mine once said, "Globs are God's gift to astrophotographers." What that means is that bright globulars, with their scads of tiny stars, provide a perfect target for achieving exact focus.

The Guiding Demon

This used to be the number one killer of good astrophotos. Back in the bad ol' pre-CCD days it was really tiresome to keep a dim star exactly centered in the field of a crosshair eyepiece. You could sit out there in the cold for hours, doing one-hour exposures, pushing hand controller buttons whenever the guide star drifted, unable to get up and stretch your legs for fear of missing one of your drive's periodic error excursions. Today, most imagers use autoguide, either with built-in guide chips or separate guide cameras and guide scopes. Once an autoguidingsystem is working, it is just like heaven. Start the exposure, get up, wander around the field or backyard, go inside for a snack, maybe even take a short nap.

The problem for most new imagers, however, is getting the system going. Most autoguide programs have quite a few variables to set, things like "aggressiveness" and "track time." Read the guide program/camera's manual carefully and prepare to do a lot of experimenting. If you're a lazybones, however, you may want to try a freeware guiding program called *PHD Guiding*. "*PHD*" in this case does *not* mean "doctor of philosophy," but, instead, "push here dummy." *PHD* works with most CCD/guide cameras, and in most cases no fiddling with settings is required. Find a guide star, focus the guide scope, and push the "go" button.

What do astro-imagers use as guide cameras? With the right software, almost any electronic camera, even a video camera, can be pressed into service to watch a guide star and report its movements to the guide program. Imagers get good results with webcams and cheap "obsolete" CCD cameras. There's no need to run out and buy a camera specifically designed for this purpose (though several are available). The best choice for a guide camera is one with enough sensitivity to show plenty of guide stars in almost any field. A webcam probably won't be sensitive enough to do that, and neither will the Meade LPI. A modified webcam can. One of the best and most popular guide camera choices lately? The Meade DSI. The original is inexpensive, especially used, and is sensitive enough to offer plenty of guide star choices with 1- to 2-second exposures.

The guide camera must be connected to the mount so guiding commands can be sent to it to keep the star precisely centered. There are two ways of making this connection. If, like SBIG cameras, the guide camera has an "ST4" compatible output and the mount has an ST4 ("autoguide") input, the scope is interfaced directly to the camera. Shoestring Astronomy can provide an ST4 adapter for the computer to enable cameras without autoguide outputs to be used. If the mount doesn't have an autoguide port, guiding must be done via the computer's RS-232 output and the mount's serial input (usually on the hand controller). Which is better, ST4 or RS-232 guiding? Some folks swear "ST4" is better, since the mount is being guided by simple "switch closures" that don't involve software commands. But generally speaking, both methods work equally well.

The Deep Sky on TV

Want to go deep, *really* deep? But don't want to fool with guide scopes or hyper-expensive CCD cameras? What about video? Beginning about a decade ago, amateur astronomers gained the ability to capture the deep sky on video in near real time. This was made possible by the very sensitive astro-video cameras sold (in the United States) by Adirondack Video Astronomy ("Stellacam") and Jack's Astro Accessories LLC ("Mallincam"). These vidcams are not just very sensitive to light; they can expose for much longer than the 1/30-second of the family camcorder. The latest Stellacam, the III, for example, can "integrate" for as long as the user wishes. The Mallincam Hyper Plus is limited to about a minute, but that's *more* than enough for most users. More than one minute means the telescope will probably need to be guided, and freedom from guiding is one of the attractions of deep sky video. How deep can these cameras go? The Stellacam II (Plate 78), which is limited to 12-second exposures, has easily imaged small 18th magnitude Hickson galaxies!

The bottom line on astrovideo? These cameras act as 3x (roughly) aperture multipliers. There's no longer any need to suffer from big Dob aperture envy when a Stellacam or Mallincam can turn a C11 into the equivalent of a 33-inch telescope. Admittedly, looking at a video monitor doesn't have quite the charm of looking through an eyepiece, but the experiences are actually similar. Most objects on video look surprisingly like visual counterparts. Globular star clusters, for example, don't have the burned out cores seen in many CCD images. Another great thing about video? Sequences can be recorded to videotape or DVD for enjoyment on a big-screen TV the next morning!

Deep sky video cameras are an absolute bargain when compared to CCD cams. Top of the line Mallincams and Stellacams hover around the $1,000 price point, and that covers almost everything. No expensive laptop is required. Yes, some kind of video

Plate 78. (Stellacam II) The small but sensitive Stellacam II deep sky video camera is able to provide near real time images of deep space objects. Credit: Author.

monitor is required, but many of us make do with inexpensive portable DVD players. Most of these players can accept an external video input from a camera and can be powered by 12vdc. Even better, very usable ones can be bought for less than $150.

Deep Sky Targets

What's good to shoot? That's the easy part of the deep sky imaging business. The place to start—for northern hemisphere residents, anyway—is the Messier list. Most of these objects are bright, easy to find, and photogenic. The showpiece globulars, M13, M5, M22, M15, are particularly impressive and easy to capture targets for the novice DSLRer or CCDer.

Next up we hack a CAT. No, we won't be taking an axe to a pretty new telescope. "Hack" in the sense astronomy geeks use the word: to skillfully improve or modify a telescope. New amateurs tend to view the equipment side of SCT ownership as merely a process of buying accessories and telescope components from astronomy dealers. Some people do only that, but quite a few amateurs spend plenty of time dreaming up and making various "homebrew" items to improve their CATs. Amateur astronomers have always been known for their inventiveness, and this continues. In fact, most of the accessories—and telescopes—on the market today were originally whipped up by inventive amateur astronomers.

CHAPTER TWELVE

Hacking a CAT

Hints, Tips, and Projects

Some of the most useful "hacks" for CAT users—tips and projects that make good telescopes better—aren't found in manufacturers manuals. They are passed around at astronomy club meetings or, increasingly, on the Internet in spots where CAT fanciers gather. Following is a sample of CAT hacks, tips, and projects contributed by members of my Internet SCT User and Meade Uncensored groups. These folks, noted in the Acknowledgments at the beginning of this book, were kind enough to share their expert knowledge in the interest of making your SCT better, easier to operate, and more user friendly. Keep in mind that none of the hacks that follow are in the form of detailed step-by-step projects. They are little blurbs and bullets that are only detailed enough to get you going on your own variations—to get the amateur astronomy creative juices flowing.

Collimation

Pinhole Artificial Star It would be nice to be able to collimate during daylight hours indoors or at least in a sunny backyard. To do so, however, requires something to fill in for a star. The time honored method is observing the glint of the Sun off a distant power pole insulator. What if none is in view or the day is cloudy? Make a star. A simple artificial star can be made using aluminum foil and a high

R. Mollise, *Choosing and Using a New CAT*,
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intensity light source. The "star" is formed by making a very small hole in the foil, and that is the only marginally difficult part of artificial star construction.

To work effectively at reasonably close distances, the hole must be tiny. You can make one using a small sewing needle, but an even better-sized hole can be made with a .12mm acupuncture needle. Light source? Any bright light will do, and you can get good results with a PAR floodlight. Even better for the electronically inclined would be a high intensity ("super bright") LED. Don't have the soldering wherewithal to make an LED illuminator (most LEDs need to be connected in series with a resistor for use with batteries)? Bright LED flashlights are easy to come by at discount and sporting goods houses.

A very neat LED artificial star can be made from a rubber or plastic bolt/nut cover from the hardware store. Look for one that fits snugly over a the high intensity LED that's to be used as the light source, and make an appropriately small hole in it with a needle or a very small drill bit.

In a Pinch Artificial Star Need a simple artificial star right now? A miniature Christmas tree bulb will do yeoman's duty for collimation. The small bulbs found in almost all modern Christmas light strings and decorations produce a decent diffraction pattern without the need for a pinhole of any kind. Just focus the scope (or defocus, actually) on the brightly illuminated filament of a bulb. The diffraction pattern bull's-eye may not look quite as good as one produced by a fancier artificial star, but is definitely good enough to get CAT collimation "in the neighborhood."

Slide Projector Star One day while rummaging around in the garage for a light fixture of some kind to use with an artificial star, my eyes came to rest on an old 35mm slide (transparency) projector. "Hmm," thought I, "bright light source, AC powered, convenient on-off switch. I wonder if it will work?" Indeed it did. I figured the bright projection bulb would be good, but I was not sure about the lens: leave it on or remove it? In the end, I just mounted my pinhole-in-foil star on the end of the lens. To my surprise, the addition of the optics seemed to make the diffraction rings look a little better than I'd achieved by placing a bare light source behind the pinhole. Discarded but working slide projectors are plentiful at flea markets and yard sales in this day of digital photography.

Fiber Optics Star Want the ultimate artificial star? Some enterprising amateurs are experimenting with fiber optics. "Fiber optics," as you probably know, uses strands of glass fiber material to conduct laser light for communications and other purposes. Don't use a laser to collimate, of course. One is temptingly bright, but even a low power laser pointer carries the potential for eye damage. One's not needed anyhow. Fiber optics conductors also pass normal visible light—if not as efficiently. Attach a fiber strand to a light source; mount the other end so the tip is surrounded by a dark square of cardboard or other material, and the artificial star blues will be over. Nothing produces a smaller and sharper star than fiber optics.

What kind of fiber optics? There's multi-mode and single-mode optical fibers. Single mode fibers are smaller than multi-mode, but multi-mode is better at conducting white light. In reality, it probably doesn't make much difference. Where do you get the stuff? Surplus retailers and outfits like Edmund Scientifics have short lengths of fiber available for small prices—or be creative. Holiday decorations that use optical fibers are available at flea markets and similar venues. For optical fiber to be effective as an artificial star, a high intensity light source will be required. A high-intensity LED will do the trick.

Collimation Screw Handles

One of the hardest things about SCT collimationis the fact that, unless you have really long arms, you may not be able to turn the collimation screws on a larger than 5-inch CAT's secondary mirror mount without taking your eye away from the eyepiece. Adjustment is much easier if you're able to watch the image of a star while moving the screws. A clever solution for Meade and older Celestron telescopes is to make an extension handle for the Allen wrench used to turn the screws. A length of wooden dowel or a piece of coat hanger wire can be taped to a wrench and will allow collimation to be adjusted while watching the star image.

Some amateurs make collimation adjustments easier still by making three wrench/handle combinations, inserting one wrench in each collimation screw before beginning an adjustment session. If the Allen wrenches are the proper size for the telescope's screws, they should stay in place in the screw heads by themselves, even with the added weight of a handle. With a wrench in place in each screw, collimation goes quickly, as there's no need to remove a wrench from one screw and fumble it into another in the dark. Sadly, Celestron SCTs now use Phillips rather than Allen screws, which do not lend themselves to handles. Owners of Celestron telescopes are probably best off replacing the screws, with Bob's Knobs, knob-headed screws designed to ease collimation.

Video Collimation All is not lost for Celestron owners—or anyone who wants a super-precise easy-to-use collimation method. A small, sensitive video camera can be used in place of an eyepiece to display a star's diffraction rings on a monitor screen. Use a Barlow ahead of the camera, and a large diffraction pattern can be achieved. Place the monitor near the corrector end of the telescope and collimate with ease. Video cameras suitable for collimation use can be obtained from the security video dealer, Supercircuits (Appendix 1). Their PC33C camera, which costs $100, is great for collimating and also can deliver excellent (color) images of the Moon and planets.

A webcam is even better than a video camera for collimating. See the discussion on these devices in Chapter 11 for a rundown on choosing an astronomy-appropriate webcam. Why are webcams better? They are lightweight, feature small chips that provide high magnification "factors," and, most of all, they are digital devices that can be used with software. What makes the webcam a real winner for CAT collimation is a piece of freeware called *MetaGuide*. What *MetaGuide* does that is special is that it creates a very clear diffraction pattern from an incoming webcam video of the defocused star, and does that even when seeing is relatively poor. It also provides an on-screen indication of the screw or screws that should be turned to produce a perfect collimation bull's-eye. Finally, if *MetaGuide* is connected to a scope via an autoguide cable, it will re-center the star automatically, following collimation adjustments. See Appendix 2 for information on how to get this handy astro-soft.

Optical Tube Assembly (OTA)

Peanut Butter Jar Lid Focusers The problem with SCT focus controls is that they are too small in diameter. If they were larger they would deliver finer focusing, which would be handy during imaging or high power planetary observing. Fine focus controls like the Feathertouch focuser that replace the stock SCT knob are readily available and work great. Unfortunately, they cost close to $150. Is there a low-cost solution? Actually, the lids from many food jars are just the right size to "enlarge" the focus knob and make focus action noticeably better. The tops found on some popular brands of peanut butter are perfect; they are just the right size and even have textured ridges around their circumferences to make it easier to grip the lid—or focus a telescope. To make a peanut butter focuser, cut or punch a hole in the lid slightly larger in diameter than the focus control. Take care to center this hole as accurately as possible. Wrap a few layers of masking tape around the focuser if necessary to ensure a non-slip fit, slide lid over knob, and enjoy precision focusing for the cost of a jar of peanut butter (Plate 79).

Hartman Mask Does it seem overwhelmingly difficult to focus the CAT accurately enough for CCD or webcam imaging? The focus aids on CCD camera control programs help, but they are not perfect. On less than stable nights the numbers they display tend to jump around as the seeing changes. Isn't there some easy way of obtaining exact focus? You bet: a simple tool called a "Hartman focusing mask" (Plate 80), an aperture cover with two small holes cut in it.

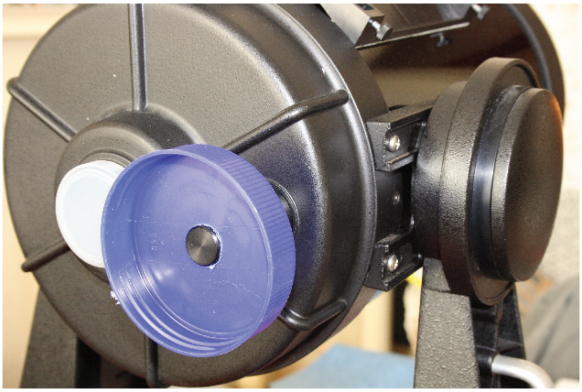
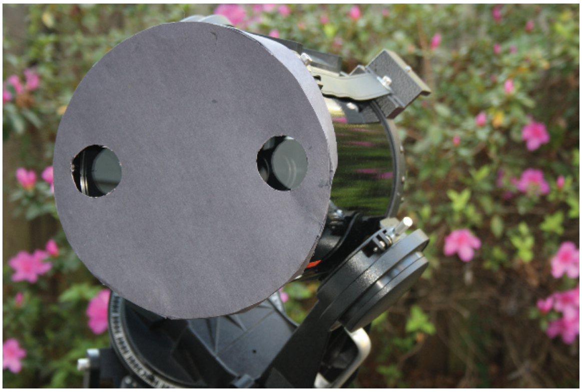


Plate 79. (Peanut Butter Focuser) A focus knob made from a peanut butter jar lid makes SCT focusing finer and easier. Credit: Author.

Plate 80. (Hartman Mask) The Hartman mask turns every star in the sky into a double star. Adjust the CAT's focus control until two star images merge, and the telescope is in perfect focus. Credit: Author.



What does a Hartman mask do? Point the scope at a single bright star with the mask in place and look thorough an eyepiece. Due to the twin apertures, two images of the same star will be visible in the eyepiece unless the scope is in perfect focus. They'll be separated by a small distance, and the star will look like a binary. Turn the focus control experimentally, and the star images will either move closer together or farther apart. If the stars move farther apart turn the control the other way. When the knob is turned in the proper direction, the two star images move closer and closer together and finally join. When the images are perfectly merged at high power, focus is close to perfect.

A Hartman mask is simplicity itself to make. Obtain a piece of heavy cardboard or poster paper (black is nice). Cut a circle just a little larger than the end diameter of the telescope's tube. Then, cut two small holes in this circle. Use a compass to draw the holes and cut them out with a sharp blade. An Exacto knife works perfectly. These holes should be directly opposite each other and should be positioned near the edge of the circle so they will be away from the secondary mount. The size of the holes is not critical, but about 1/5 the diameter of the primary mirror works well. That would make each hole 1.5-inches in diameter for an 8-inch telescope. To finish the mask, glue or tape a cardboard strip around the circumference to act as a "lip" to hold the mask in place at the end of the tube. If that seems like too much work, just tape the mask over the end of the scope (the Harman mask works best when it's mounted over the end of the tube, not the dew shield) with tape.

Diffraction Spike Focusing A Hartman mask sounds good, but making one sounds like too much trouble? There's an even simpler method for achieving exact focus. Tape two lengths of cord across the front of the dew shield in crosshair fashion. Think "Newtonian telescope secondary mirror support" (a "spider"). What this will do is to add a cross shaped diffraction pattern to bright stars as seen in a Newtonian reflector. The stars will show four "spikes." Focus until these diffraction spikes are sharpest and skinniest, and the scope will then be in good focus. This method of assisted focusing works especially well with CCDcameras. If lengths of cord don't seem fancy or neat enough, wide rubber bands or pieces of fabric work even better and can be secured to the dew shield with Velcro if desired.

Motorized Focusing on the Cheap "Motofocus" is super if you're an imager or a high power planetary observer. No need to touch the focus control and induce shakes while focusing. Unfortunately, motofocus units made for SCTs and other CATs are fairly expensive—usually about $150. There's an out: motors sold for the rack and pinion focusers of small refractors and Newtonians cost only a fraction of what CAT motor focusers go for. These devices, almost always with included push-button control boxes, can often be found on swap tables at star parties often for less than $10. Of course some cuttin', fittin', and cussin' will be required to adapt one to an SCT's focus knob. It's possible one of these motors can be fitted to the focus control with its supplied coupler and bracket in a set up similar to that of commercial SCT motofocus units. Unfortunately, that's unlikely to work without a lot of bracket and coupler modification and fabrication. Don't give up, though.

The most elegant and simplest solution might be a belt drive. Not only does a belt installation avoid coupling and bracket issues, it allows the focus control to be turned manually with ease when desired. The focus motor itself is mounted to the rear cell of the scope via the telescope's accessory mounting holes. It may be necessary to drill one hole in the focus motor's mounting bracket, but that will probably be it. The focus knob and motor are coupled together with a belt of the proper size. That's the only marginally difficult part of this project: finding a workable belt. Look around, especially at auto parts houses—an engine timing belt is a possibility—and something will turn up eventually.

Rear Cell Plug and Dehumidifier If the plastic cap that seals the telescope rear port opening goes missing, a plastic 35mm film canister inserted into a visual back makes a good substitute. Leave the cap on to prevent the canister from slipping into the OTA interior accidentally. Kick it up a notch and add functionality by turning the rear port seal into a humidity reducer. Drill a few holes in the canister bottom with a 1/6-inch drill, drop a few small packets of silica gel (often found packed with consumer electronics and available from a variety of sources) into the canister, and insert that into the visual back. Not only will dust be kept out, the tube interior will be kept dry.

Dew and Cool Down

Homemade Dew Shields The first line of defense against dew for SCT or MCT users is a dew shield. A metal or plastic extension for the end of the tube provides some protection for the dew-attracting corrector plate. The only problem with dew shields is their cost. A dew shield is such an easy thing to make, though, that there's really no excuse for buying one instead of rolling your own. The most convenient style of dew shield is of the flexible variety, a flat piece of heavy-duty plastic that is formed into a tube, fastened together in that shape, and slid over the end of the telescope. The hardest part of making one is finding a suitable sheet of plastic.

The perfect material is a brand of plastic sheeting called Kydex, which is used for wall covering and similar applications. This material can be obtained in a range of colors, with flat black being readily available—if any Kydex at all can be found, that is. The best bet is a local plastics distributor. No Kydex? A trip to the hardware or home improvement store will turn up a good alternative. Plastic sheeting designed to be used for bagging leaves is a common item in lawn and garden departments. This stuff is intended to keep a trash bag open and standing on its own when leaves are being dumped into it, is the right size to make a dew shield for a large CAT, and it's easy to cut down for use with smaller apertures. The leaf-bagger material has a natural spring-curl to it, but that doesn't hurt anything and may actually help when it is being secured to the end of the telescope tube.

Before purchasing a sheet of dew shield material of any kind, ascertain how big a piece will be required. It should be long enough to go around the circumference of the tube with 1 or 2-inches of overlap for fastening. The other dimension, the length of the finished dew shield, is determined by the size of the primary mirror. It should extend at least the width of the primary mirror in front of the corrector plate for adequate protection. Longer is even better. Velcro will be used to hold the sheet in the shape of a cylinder so that it can be slid over the end of the scope. Purchase strips of self-adhesive Velcro if possible, but small squares can be used if long strips can't be found. It's usually possible to purchase "industrial strength" strips, and these are preferable, since the adhesive on their backings seems stronger.

Carefully cut the sheet of Kydex or other material into dimensions appropriate for the telescope. It's a good idea to "measure twice and cut once," since screwing up and having to buy more plastic will eat some of the savings that are the reason for homebrewing a dew shield in the first place. Set up the SCT inside the house and remove its aperture cover. Wrap the material around the end of the tube experimentally to make sure it fits and fasten it in place with a few pieces of masking tape. The fit should be snug enough that the end of the shield does not droop. It's a good idea to make the sky end of the dew shield slightly smaller than the scope end for best performance. Don't make the sky end so small as to "stop down" the telescope's aperture, of course. Mark the overlap point with a soft pencil to provide a reference for positioning the Velcro strips.

Pull the dew shield off the scope, remove the masking tape that held it together, and apply two strips of Velcro (one "hooks," one "fuzz") so they join the shield together at the overlap point. One length will face up, mounting on the top of the edge that is overlapped, and one piece will face down, being applied on the underside of the edge that's "on top." Allow the adhesive to set for several hours before trying the new dew shield. The sticky glue used on self-adhering Velcro may not hold well unless it's allowed to "cure" for a little while. It is also a good idea to clean both surfaces with alcohol before applying the Velcro, to ensure a good bond. Once the strips are secure, wrap the dew shield around the end of the scope, fastening it into place with the Velcro. Looks great, works great!

There is another material that may work even better than plastic sheeting for dew protection. Being employed as an engineer at a shipyard as my day job, I try to keep my eyes open for telescope ideas as I walk around ships and materials warehouses. One day I was looking at some water chiller air conditioning equipment and noticed the black rubber-like foam used to insulate pipes. Observing buddy Pat Rochford and

I were soon hunting down this material at an air conditioning equipment supplier and making dew shields from it.

What is not good about this material? Special and somewhat vile-smelling glue is required to fasten this material together in the shape of a tube. The glue will be carried by any place that sells this insulating foam. Why not just use Velcro to hold it in a cylinder shape? The foam does not lend itself to being unfastened and stored flat, and it's easier just to glue it together. When shaped into a tube of a size appropriate for my C11, the foam tended to sag at the end. Solution? Pat cut a ring of plastic from some leaf-bagger sheeting and glued that onto the dew shield's end. With this necessary stiffening ring on the end of the dew shield, it couldn't be unfastened if Velcro were used. To install on the scope, the shield, which we made slightly smaller in diameter than the corrector assembly of the scope, is stretched slightly and pulled over the end.

If it proves difficult to find the above material, a good alternative is the thin rubber-like foam sold in sporting goods stores for use as a pad under sleeping bags. There's no need to stop with rubber foam, either. Use your imagination. Almost any insulating material that can be shaped into a light, durable tube will work very well as a dew shield. Much better, in fact, than the pretty but expensive metal dew shields sold by scope merchants.

Securing a Dew Shield Sometimes the Velcro that holds a flat, flexible dew shield in place around the corrector end of a CAT just doesn't cut the mustard. If that's the case, help out the Velcro by securing the shield to the corrector end of the scope with a clothes drier vent clamp. These hose clamp-like gadgets, designed to fasten an exhaust hose to a drier, work great for smaller CATs and can be linked together for use with larger aperture scopes.

Dew Protection for Red Dot Finders Everybody loves "bb gun finders." They present a non-magnified right-side-up image that makes a CAT easy to aim. They also collect dew and become useless in an hour or less in humid areas. To protect a red-dot sight (or Telrad) from dewing, cut down a worn-out sock until it fits snugly over the sight's glass window. Remove the sock only when it's time to use the finder and *voila!* Dew protection that doesn't cost money or use battery power.

Cool Down Even if you happen to live in the sunny southern United States where a winter's eve with a temperature below 32 degrees Fahrenheit is rare, you still have to allow some time for your CAT to adjust to outside temperature after being taken from the warm house. On weekends, that is not a problem, but this waiting period becomes a pain when you're intent on getting a spur of the moment weeknight observing run going. A possible "fix" would be to store the scope permanently in an unheated shed or garage. Alas, these locations are no good for many of us due to cleanliness and security concerns. There is a way to speed the cool-down process, nevertheless.

Owners of large Dobsonian telescopes have found small battery-operated fans located at the mirror end of the telescope greatly decrease the time it takes for a mirror to equilibrate, and CAT owners have realized they can do the same thing by arranging a fan to blow air into the scope's rear port. Devices to do this are available commercially, with the SCT Cooler from Lymax being a standout product. Not unexpectedly, they don't exactly give these things away. That's OK. Something similar is not difficult to make.

The most important item is a battery-operated fan that produces a good amount of air flow. One possibility is a muffin fan either purchased new or scrounged from somewhere (maybe from an old computer power supply). More elegant, if maybe not as effective, are little CPU fans. These 12 volt (usually) devices are designed to sit atop a computer's CPU and provide a cooling flow of air. CPU fans are available online and at most brick and mortar computer discount houses and "office" stores.

When a suitable fan has been located, procure a tube that will fit into the telescope's visual back. A piece of sink drain tube (PVC) works nicely, being the same diameter (1.25-inches) as an American standard eyepiece. The length of the tube is not critical. Next, affix the fan to the outside end of the tube, mounted so that air blows into the telescope. Some fans are reversible by reversing their power leads; others may have to be mounted facing in a particular direction. How exactly the fan is mounted to the tube will depend on its size and shape. It may be possible to glue it to PVC pipe with epoxy or Super Glue. In a pinch, duct tape works, even if it doesn't look very professional.

The fan will also need to be connected to a DC power source. If it is a 12-volt model, purchase a male cigarette lighter plug and cord and connect that to the leads coming off the fan. Solder these into place and wrap electrical tape around the connections. No switch is needed; just plug the fan in to turn it on. If a different DC voltage is required, dry cell batteries are the way to go. Obtain a battery case appropriate for the combination of batteries the fan needs, add a switch, and away ya go.

When it's done, slip the fan tube into the visual back, turn on the power, and let 'er rip. Ambient temperature air will be blown into the OTA, making cool down go quickly. There are enough gaps in the OTA—around the corrector end, for example—to allow sufficient air flow through the tube. Some folks worry about blowing dust into the tube, but this is not really a problem. If that is a concern, a small pad of filter material—perhaps from an air conditioning system filter—positioned over the fan's intake will keep dirt out of the OTA.

Tripods and Mounts

A Wedge and Pier of Wood The first obstacle facing a beginning astrophotographer equipped with a forkmount CAT is the need to buy "more stuff." In addition to cameras and computers and software, the tyro imager must also obtain a wedge in order to set the telescope up in equatorial mode for serious long-exposure photography. Even basic wedges sold by Meade and Celestron cost a pretty penny.

My friend Pat Rochford, was in this position some years ago as he embarked upon CCDing with his new 8-inch LX200. Like me, Pat is loath to buy anything when it can be made or modified. What he came up with was a wedge of (ply)wood. We originally looked on this concoction as a temporary fix, something to be used until a better one could be purchased. The wedge of wood worked so well, however, that Pat never had reason to buy another for his Meade SCT. Since the scope was to be placed in a permanent observatory, he also designed and constructed a wooden pier to go with the wedge.

The pier is made from 1/2-inch plywood (3/4-inch might be even better), with all pieces being glued and screwed together. Double-thicknesses of ?-inch were used in places where it was thought necessary: the base plate at the bottom of the pier and the upper plate on which the wedge rests. The dimensions for Pat's pier were 20-inches x 20-inches for the base, a height of 40-inches, and pier body 9-inches square, but these can be modified to fit the needs of a particular scope and observer. There is a 4 ?-inch square opening near the top of the pier to allow for tightening or loosening of the bolt that holds the wedge to the pier top. Gussets running from the base were used strengthen the pier, and the whole thing was varnished and sealed and bolted to a concrete footing in the ground beneath the observatory.

The wedge (Plate 81) was slightly more complicated to make than the pier, but not much. Since as much stiffness as possible is desirable in a wedge, Pat used 3/4-inch plywood throughout. The main hurdle for wedge builders is providing a means for fine altitude adjustment for polar alignment. This particular wedge would be used in a permanent observatory, so only a small amount of altitude adjustment was required, just a degree or two. If a portable wedge is needed, it wouldn't be hard to devise an altitude adjustment scheme that allows for greater range—maybe copied from the metal wedges Meade and Celestron sell.

The wood wedge's dimensions are 18-inches long x 8-inches wide and 12-inches high. This is for an 8-inch CAT; naturally, there will need to be considerable upsizing (and strengthening, perhaps) for larger telescopes. For Pat's "permanent" wedge, the side plates were cut at an angle equal to our latitude, 30 degrees. Adjustment up or down is accomplished by four 7/16-inch bolts inserted into T-nuts installed in the corners of the wedge base plate. These bolts turn through the T-nuts and push against the pier top plate to raise or lower either the north or south end of the wedge, as required. Wedge azimuth adjustment is even simpler. Leaving a little slack in the bolt that attaches the wedge to the pier top gives fine enough action when moving the wedge by hand to do a good drift polar alignment. When azimuth is perfect, the center bolt is tightened down carefully by reaching through the hole left in the side of the upper pier.

How well did the wedge and pier of wood work out? Over the months, there was no detectable change in scope alignment due to shrinkage or expansion of the wood—one of our big concerns. Stability? Outstanding. Pat was able to produce excellent unguided 1-minute CCD exposures with the LX200.

Astro-Imaging Weight The astrophotography gurus preach that a telescope needs to be kept "east heavy" for best tracking during picture taking. And that's true.

Plate 81. (Wooden Wedge/Pier) A wooden wedge and pier are easy to make, inexpensive, and amazingly effective. Credit: Author.

But how is that done with a fork mount? A GEM is easy to balance, but a fork, it appears, will need the addition of store-bought balance weights on the fork arm. Not so. Hang a small bucket or jug full of rocks, fishing weights, or water (if a jug is used) from the eastern arm by means of a bungee cord (one with a hook on either end) long enough to suspend the weight well away from the mount/telescope. This simple hack can dramatically reduce both backlash and tracking errors.

Milk Jug Weights A larger container filled with water can help reduce a tripod's annoying shakes. A 1-gallon milk jug filled with water (or the beverage of choice) is perfect for this purpose. Most milk jugs have integral handles molded into them that allow the jug to be easily suspended from the CAT's tripod. Use nylon line rather than a bungee cord for this weight, and tie one end securely around the top of the tripod so it extends down between the legs. Knot the free end to the handle of the water-filled jug so it is suspended a couple of inches from the ground. High power views will now be considerably steadier. This scheme also works well to help hold the scope still during focusing. Be careful not to bump the jug while viewing, though, as moving it will introduce swaying that will ruin the view and tend to make observers seasick!

Paint Can Lid Accessory Tray and Tripod Leg Spreader An accessory tray mounted on the telescope's tripod is a handy thing to have. It provides a convenient place to keep eyepieces and other small items handy for immediate use. Unfortunately, the tripods of most fork-mounted SCTs and other CATs do not feature these trays. Some GEM scopes do have accessory trays, but they are usually poorly designed and don't feature much space for astro-stuff. A nice tray that can be used with most fork and some German mount CATs can be made for just a dollar or two and takes less than five minutes to make.

The only material this project requires is the lid from a plastic 5 gallon paint bucket; empty ones are available from most home improvement stores. Discard the bucket or use it for another project (empty buckets are great for carrying small items to the observing site). Drill a hole in the center of the lid the same diameter as the threaded rod the tripod's leg spreader is attached to. Loosen the knob holding the spreader in place and remove it temporarily. Slide the paint lid onto the threaded rod, orienting it so that the lid's lip is facing up. That will keep eyepieces from sliding off. Replace the spreader on the rod and tighten it down. That's all there is to this simple, but remarkably useful, project (Plate 82).

Ersatz Shake Enders Celestron, Meade, and Orion sell an accessory called "Vibration Suppression Pads." These tripodfootpads are shock-absorbing disks that fit under each tripod leg tip to reduce vibration. They are a very desirable item and really do improve telescope steadiness. They are also relatively expensive. That seems

Plate 82. (Accessory Tray) Many SCT tripods lack handy accessory trays. This can be rectified at almost no cost with the lid of a 5-gallon paint bucket. Credit: Author.

surprising, but close examination reveals they are not as simple as they look. They appear similar to the pads that go under furniture legs to prevent scuffing but are actually cleverly made, consisting of an inner cup the tripod leg end tip rests in, which is isolated from the rest of the pad by a layer of "Sorbothane" rubber. Could the enterprising amateur make her or his own? Well certainly! Homemade shake-suppression pads may not be as effective as the real thing, but when combined with other vibration-reducing strategies, they can help.

The simplest homemade pads are nothing more than upside-down bathtub drain stoppers. The best stoppers to use for this purpose are those with an inner ring molded into their surface. This ring would normally face down and would be inserted into the tub drain, but we'll place the tripod leg tip into this depression. The opposite side of the stopper has a narrow raised portion for attachment of a metal ring and chain that may be trimmed off with a sharp hobby knife. If there's a wide raised area, just leave it in place, as it will add to the stopper's vibration-reducing characteristics. Remove the metal pull chain, if present. Placing three tub drain stoppers under the tripod legs might seem to be a slightly humorous and overly hopeful method of trying to stop a CAT's palsy, but users report that this really works. The person who suggested this trick experienced a reduction in "shake time" from 5 seconds to an excellent time of less than one second.

What else can be pressed into service as homemade shake-enders? Well, what looks like a Shake Ender? The aforementioned furniture carpet or scuff protectors for furniture. Sadly, these do little or nothing to reduce the shakes. But that can be fixed! Buy three carpet protectors—hard rubber ones are the best choice. On the way home stop off at the office or computer supply store and buy a couple of neoprene mouse pads. At home, take the three carpet protectors and the mouse pads and make little "sandwiches." Cut neoprene circles from the pads the same diameter as the carpet protectors. Place one circular cutout piece of mouse pad on the bottom of each protector and another piece on top, where the tripod tip will rest. The pieces of neoprene can be glued into place with contact cement or Super Glue. Place a completed "shake ender" under each tripod leg and enjoy.

Strengthen Tripod Legs with Sand If the telescope is still too shaky despite weights and homemade vibration suppression pads, the problem may be that the tripodis just too light. As a last resort, try a trick that many scope users, especially those saddled with the light extruded aluminum tripods, swear by: fill the legs of the tripod with sand. This can, in some instances, have a dramatic effect on scope steadiness. Use nice clean sand from the home improvement store (it will be in the same area as the concrete mixes). One bag should be more than enough. How the tripod is filled and sealed will depend on the particular model. Often, the easiest method will be to pour in sand from bottom of the legs after having removed their tips. Before doing that, remove mount head or wedge, of course. If the tripod is an extruded aluminum job (light square leg sections), it will probably be necessary to seal small gaps in the tripod to prevent sand from leaking out. Any type of silicone sealer (RTV) will work well. Make sure the sand can be removed if this trick doesn't work out—don't glue tip ends back on permanently.

“Permanent” Polar Alignment for portable CATs Polar alignment is a pain, but a necessary one for astrophotography and for accurate go-to with some GEM telescopes. Is there some way to avoid having to do a polar alignment every time the scope is used? If the CAT is used in the backyard or at a site owned by a club, it is possible to preserve a good alignment by marking the exact positions of the telescope’s tripod legs. If only middling accuracy is required, do this by placing some simple markers. These can be three stakes driven into the lawn next to each tripod leg tip after a good alignment. Just don’t forget and run the lawnmower over these stakes the next time the grass needs to be cut.

An even better solution involves three lengths of PVC pipe. Go to a plumbing supply store and purchase a length of 3- or 4-inch diameter PVC pipe a couple of feet long. Cut off three 6-inch-long sections and, using a hammer, drive them into the ground at previously determined and marked positions appropriate for the telescope’s tripod, leaving maybe a half-inch of each section above ground. Each leg tip of the tripod will be placed in the exact center of one of the protruding pipe ends. The pipe ends should not touch the tripod legs. That could cause vibration. Their only purpose is to act as position markers.

When the three pipes are in place and the tripod is properly positioned, do a good polar alignment. When the alignment is complete, make sure the wedgeor GEM altitude and azimuth adjusters are tightly secured. Observe as normal and return the scope to the house when the run is over. The fun part comes on the next evening. Instead of polar aligning, just set the scope up so the tips of the tripod are again positioned in the centers of the pipe ends. The scope’s polar alignment should still be very close. The most that will be needed will be a quick fine-tuning drift alignment if astrophotography is on the evening’s agenda. Likely that will not even be required. Naturally, if the altitude or azimuth of the wedge or GEM head is changed, either purposefully to observe from another site or accidentally, a new polar alignment will be required.

If driving PVC pipe sections into the ground is not possible at a particular observing site, there are other ways to “mark” polar alignment. If the telescope is set up on a concrete pad, a driveway, or a deck make small marks with paint or a permanent marker to indicate leg positions. A nice solution, and one that’s super-permanent, would be pouring three round concrete pads in the yard for the scope legs to rest on. That is not hard to do, since small, easy-to-use bags of concrete (“Sackcrete,” “Quickcrete”) are readily available at home improvement stores. If placing permanent concrete pads on the lawn isn’t practical, building supply houses sell concrete paving blocks or “stepping stones” that will work as scope leg pads. These can be found in sizes as small as 6-inches x 6-inches and in various pastel colors.

A Permanent Telescope Without an Observatory Thanks to superb and inexpensive pre-fab observatory domes like the Skyshed Pod, more amateurs than ever can realize the dream of a permanent backyard scope installation. Some can’t, however. Some neighborhood ordinances restrict the use of even “temporary” buildings. If a permanent observatory isn’t possible, how about a permanent pier? A sturdy and weatherproof pier, either homemade or store bought, can provide at least some of the benefits of an observatory. If used with a fork mount scope in equatorial mode, the wedge can be left in place, and the CAT will not need much—if any—polar alignment before an observing run. Some amateurs take this a step further and leave scope and mount out in the yard on a pier all the time. Before contemplating that, be sure that bugs, the elements, or theft won't be problems. A good weatherproof cover is a must.

Shortening Tripod Legs Some CAT tripods are too tall. Even when fully collapsed, they are difficult to use seated, especially if the telescope is placed on a wedge. Some tripods can be improved by removing the legs and cutting off 4 or 5-inches from top or bottom. This will not be easy for all tripods, but if it's possible to do so, cutting down a tripod a bit may have a benefit in addition to more comfortable observing. A shorter tripod may be considerably more stable when fully collapsed.

Field Issues and Accessories

Telescope Warning Lights It's amazing how dark it can get on a Moonless night away from city lights. It'll get so pitch-black that scopes on the observing field will be nothing but vague shapes in the darkness. A modern SCT with its dark blue or gray tube becomes as invisible as a Cheshire CAT. Most of the time that is not a problem. Amateur astronomers encountered at club or larger star parties are careful as they walk across the field and carry red lights for navigation. At a public outreach evening it might be a different story. Visitors or novices without scopes of their own tend to wander from telescope to telescope in the dark and don't carry flashlights: "Hi! Mind if I look through—OOPS!—sorry, was that your telescope?"

The solution is three small red LED lights strategically positioned on the telescope tripod. These can be purchased from astronomy equipment suppliers, but there is no reason to do that. They are easy to make, and putting together telescope warning beacons makes a nice cloudy night project. An electronics supplier like Radio Shack can furnish three red LEDs, three AA battery cases, three switches, and the three resistors needed to drop battery voltage enough to prevent the LEDs from "frying." The package the LEDs come in will usually contain instructions that show how to wire up the LED and which value of resistor to use. Choose standard brightness LEDs rather than high intensity models to protect everybody's night vision.

Wire the three resistors and LEDs and switches in series to the proper terminals of each battery case, tape leads and LEDs to the sides of the cases, stick a piece of Velcro to each tripod leg at a suitable height off the ground, apply pieces of the "opposite" type of Velcro to each battery case, and insert batteries. Stick lights to tripod legs using the Velcro and that's it—fire 'em up, and the CAT will be noticed by even the most starry-eyed novice. An even more effective warning system—or at least one that looks cool—can be made by using blinking LEDs (actually small assemblies) instead of regulars. These are nearly as easy to find at a local electronics store as standard LEDs

Telescope Equipment Transporter Most CAT-wielding amateurs soon accumulate tons of gear: in addition to scope and tripod, there's the observing table, observing chair, accessory case, dew shield, batteries, laptop computer, and who knows what else. When observing from home, it's a positive pain to carry all the astro-stuff to the far side of the yard. To alleviate this pain, create a telescope equipment transporter (TET) by customizing a high-sided garden cart. Actually, the only customization required is the addition of a piece of fiberboard or plywood large enough to cover the cart top. Place all the astrostuff in the TET, wheel it out to the observing location, remove the stuff, and cover the TET top with the fiberboard so it becomes a movable observing table. For even more convenience, leave the batteries used to power the scope, computer, and dew heater system in the cart and run cables from the TET to the CAT. Using a TET can make a high-capacity (and heavy) deep-cycle marine battery practical for use with the scope.

Eyepiece Cases Aluminum cases filled with cubed foam are the ultimate accessory case. They are sturdy and can be customized to hold everything from large 2-inch eyepieces to big Barlows to reducer/correctors. Formerly, these cases were expensive items; usually they were sold for carrying pro-level photographic equipment. But then a wonderful thing happened. The same style aluminum attaché cases began to be produced in China. Shortly thereafter, various astronomy vendors began selling these reinforced boxes expressly for use as eyepiece cases. And they sold them for a fraction of the cost of similar photo cases. It's true these Chinese-made wonders are not as strongly built as a "real" camera gear case, but they are more than adequate for most amateur astronomy applications. Look in the tool/hardware section rather than the photo department, as they are usually advertised as toolboxes or "tool attachés" and sell for less than $20 apiece!

The tool attachés are a great boon, but there are plenty of other boxes that can be adapted to that purpose. Particularly nice are large plastic toolboxes. Larger ones can even be found with wheels and handles so that they can be wheeled out to the observing position, sparing a tired astronomer's back the strain of lifting a bunch of Naglers. Plastic pistol cases also work well. Most are inexpensive, lightweight, waterproof, and include cubed foam.

Dryboxes Where do all the countless little widgets astronomers buy in addition to eyepieces—cords, computer accessories, scope tools, filters, spare batteries, etc.—go? The local sporting goods seller has the perfect astrostuff carrier in the form of a "drybox." A drybox is a plastic box, usually in the 12x10x10-inch size range, used by hunters for carrying ammunition and other things that need to be kept dry and organized. The dryboxes sold today resemble (and are probably based on the design of) the .50 caliber ammunition boxes used by the military. Hunters and astronomers have in common the need to carry small, fussy, moisture-hating things into the field, so these boxes work perfectly for either pursuit. In addition to providing dry storage, they include trays featuring small compartments that are a natural for small astro-items. Hunting not popular in your area? If fishing is a common pastime, a tacklebox can serve just as well as a drybox.

Electronics, Power, and Cables

Autostar Patches Meade is very conscientious about releasing software updates for the Autostar II and Autostar 497 hand controllers. Most of the new software releases, however, are minor updates designed to extinguish bugs, not add new features. Meade isn't the only game in town for Autostar users, however; ETX guru Dick Seymour regularly releases "patches" for the Autostar that add new capabilities and go beyond Meade in squashing minor bugs. Dick's patch "kits" are easy to install and modify the current Autostar software ("patch it"). The Autostar patches, including those for non-ETX telescopes, are available free for download at Weasner's Mighty ETX site (Appendix 2).

Telescope Connector Protectors Meade and Celestron scope bases and control panels are festooned with RJ-type connectors. Some of these, such as the Aux Port on Meades and the PC port on Celestrons, are not used frequently, and when it comes time to use them, sometimes they don't work or work intermittently. That's because these female RJ connectors have gone years being exposed to the oxidizing air and collecting dirt. A simple preventive measure is to plug male RJ plugs (without cables) into them and remove them only when it's time to use the ports. If it's difficult to unplug these RJs, make handles for them. Small thumbscrews or knobs can be glued to the connectors and will make them easier to unplug.

Battery Box A 12-volt garden tractor or motorcycle battery can provide all the power a go-to telescope needs. However, using a bare battery may not be the best idea. A battery sitting under the tripod and connected to the scope and accessories via a pair of alligator clips is just asking to be knocked over in the dark, possibly shorting out the telescope and causing damage. If the battery is a non-sealed type (not recommended), battery acid may spill everywhere. The same may happen when it's being transported in the trunk of the car. The solution is simple. The local auto parts or marine store sells plastic battery boxes (Plate 83). These cost only a few dol-

Plate 83. (Battery Box) A plastic battery box from an automotive discounter provides a secure home for a 12-volt lawn tractor battery used to power a go-to telescope. Credit: Author.

lars and are big enough to accommodate large deep-cycle marine cells. This large size can also work very well for the amateur using a smaller motorcycle battery, as it allows enough room for some wiring if desired.

While at the auto parts house also purchase a female cigarette-style receptacle, one that attaches to a battery via two large alligator clips. Place the battery in the box—there'll sometimes be a strap or bracket to hold it firmly in place. Then just attach the cables to the battery with the alligator clips, hang the cigarette lighter receptacle outside the box, put the box lid on (don't fasten it down tightly enough to pinch the cigarette lighter cable), and the project is done.

This box is a considerable improvement over a bare battery, but it would be nice to eliminate the alligator clips. To make a neater and more permanent battery box, while at the auto parts store pick up two battery cables with terminal connectors appropriate for the battery that is to be used. Get the shortest ones available without regard to whether they are black or red. The ends not connected to the battery will be fastened to a small terminal strip. This terminal is just a small piece of wood. Drill holes in the wood large enough for two ? inch bolts. Insert these bolts through the connectors on the free ends of the battery cables and through the wood, securing them with nuts and washers on the other side of the terminal board. Mark each terminal in some way as + or –. Cut the alligator clips from the ends of the wire going to the cigarette lighter receptacle and strip the insulation off about 1-inch of the ends. Attach the bare wires to the bolts on the terminal strip (observing correct polarity) by wrapping the wires around the nut end of the bolts between nut and washer and tighten the nuts down. Route the cigarette lighter cable out of the box through a small hole or mount the female plug receptacle in a hole drilled in the side of the battery box.

Scope Batteries on the Cheap One big facet of the modern CAT experience is the need for plenty of power to run scopes and computers. The astronomy merchants offer batteries, but as mentioned elsewhere in this book, they are not any better (and are sometimes worse) than what can be found at the local Costco, Walmart, or Asda. Keep a weather eye out for specials on jump start battery packs in these stores. Often battery packs with 25 to 50 percent more power than those sold by scope companies can be found for considerably less money than those with a "Celestron" or "Orion" sticker on them. I'm constantly amazed at how much "astronomy gear" its possible to acquire by watching the ads of discount department and sporting goods stores. Everything from dew heaters (hand warmer packs) to eyepiece cases (pistol cases) can be got there on the cheap.

Maintaining a Scope Battery Inexpensive 12-volt lead acid batteries used in lawn tractors and snowmobiles can work well as telescope and dew heater power sources. So do automotive jumpstartbattery packs, which usually also contain (sealed) lead-acid batteries. Neither battery type will work well for long, however, without occasional TLC. Want to destroy a lead acid battery? Discharge it completely a few times. Or let it sit around for months unused. Or partially discharge it and let it sit. It's easy to keep the battery healthy by avoiding these things and following the instructions below.

After each use, place the battery on charge for 12 hours. If it has not been used over the course of a month, charge it anyway. Just as it's inadvisable to discharge a battery all the way, it's also a bad thing to overcharge one. However, 12 hours on a trickle charger or a computer controlled charger won't hurt it. How do you tell when a battery is sufficiently charged? Modern, inexpensive battery chargers include charge indictors—lights or meters—to tell the tale. These indicators are usually built into jumpstart packs. Unless a battery is very low, a voltmeter across the battery terminals will not give a reliable indication. If the charger doesn't have an indicator, an inexpensive 12-volt battery tester can be bought at an automotive discounter.

Dressing Cables The average go-to scope sports enough cords to make it look like a demented octopus. There are dew heater cords, power cords, hand controller cords, camera cords, computer cords, and more. To impose some order and provide strain relief, visit the local hardware store and look for bundles of Velcro ties. Sold in packages of a dozen, these can help reduce cord tangle, and prevent that bane of go-to fanatics—a suddenly unplugged power cable. Another way to keep telescope cables neat is a thing called a "wire loom." These hollow flexible tubes can be found at home entertainment and electronics discount stores. Run all the cables through one of these tubes and cable mess is a thing of the past.

Snugger Power Cables for NexStars Celestron's NexStar go-to telescopes are reliable and easy to operate. Unfortunately, almost all of them suffer from a minor but aggravating problem: the scope end of the power cord does not plug in firmly and is prone to being accidentally disconnected during observing or becoming so loose that it does not provide sufficient power to run the scope. The Velcro ties in the hack above can help by providing strain relief (Velcro the cable to the tripod at a point near the tripod head), but the ultimate solution is to fix the scope side connector's center pin. This pin is composed of two halves that can be spread apart to provide a better connection. Spread these halves a little bit using a jeweler's screwdriver, and power cord problems will be permanently banished.

Computer Program "Upgrade" of an Older Go-to Scope Some users of older computer telescopes, like the LX200 Classic, constantly dream of upgrading to the latest go-to marvels, moving up to the hundreds of thousands of objects and countless features that the new scopes possess. If the old CAT is functioning properly, however, there's no need for that. The simple addition of a laptop computer will "upgrade" older scopes to match or exceed the latest one.

Controlling a CAT with the freeware program *Cartes du Ciel*, for example, brings the number of objects available to the telescope into the hundreds of thousands. Most programs also add features older telescope may be missing, such as sync. Some software will even allow GPS to be used with a non-GPS telescope if a handheld GPS receiver is available—all this for just the cost of a cable (assuming a laptop is available). Don't want to tote a laptop PC or Macintosh into the field? Many of the same benefits can be achieved by operating the scope with handheld computers alike the Pocket PC and Palm. A surprising amount of full-featured astronomy software is available for these PDAs.

Powering a Computer in the Field Some laptops are more power-hungry than others, but all need a reliable external power source. In most cases, a computer's built-in battery won't have the oomph to power the computer for more than a few hours—especially if power-sucking USB devices such as CCD cameras are connected to the laptop. There are two ways to supply external power to a computer: with an inverter or with a DC converter. Inverters, which are sold by automotive and garden supply stores, take 12 volts DC and convert it to AC. Hook the inverter to a battery and plug the laptop's AC power cord into the inverter. The power produced by modern inverters is of good quality and is more than sufficient to run computers reliably. The only problem is they are not very efficient. The process of changing DC to AC eats up a lot of energy, and a hefty battery may be required to run inverter and laptop all night long.

A better choice is a DC converter. This is a power supply that takes 12 volts DC and changes it to a DC voltage the computer can use. Converters are usually equipped with cigarette lighter connectors and can be plugged directly into a jumpstart battery pack, which makes for a neat portable set up. Since laptops use various voltages and various size connectors, DC converters are designed for use with specific makes and models of laptop. They are easily available for most brands and cost about $50.

Observing

Dark Hood The difficulty in seeing deep sky objects from urban and suburban sites does not come only from the general brightness of the sky but also from nearby lights that prevent the eyes from becoming even partially dark adapted. It's easy enough to rig up a series of light shields to protect the telescope from the glare of a neighbor's security light, but that is impractical—or at least annoying—if the telescope has to be moved around the yard to avoid trees and other obstructions. A good solution is a dark hood. This is a piece of black cloth large enough to go over the head and eyepiece and block stray ambient light. Picture the dark cloths old-fashioned photographers used on the backs of their "view" cameras to shield their focusing screens from daylight. Just trot down to the local fabric store and pick a piece of appropriate material. Nylon, for example, is nice and light and muslin "breathes" in hot weather. Cut to size and enjoy.

Binoculars No matter how good a go-to telescope's accuracy, binoculars come in handy. Scanning an area of interest with binoculars can give a good idea of the lay of the land before beginning serious observing. If the scope misses an occasional target, binoculars can help fine-tune its aim, especially if the onboard finder is a red dot unit that doesn't reveal dim objects. It's surprising, in fact, what binoculars can reveal. It's not that difficult, for example, to detect the dim galaxies M74 and M101 with 10x50 binoculars from dark sites. Binoculars can also be fun to use for real observing. At times, the comfortable wide-field view and informality they offer are a welcome break from several hours of hard core observing through a big, long, focal length CAT.

Warm Feet Most observers know they have to keep their heads warm in cold weather via a good hat or hood. The head is a prime avenue for the loss of body heat, and once the cold begins to seep in it will become impossible to concentrate on the dim deep sky objects the scope is delivering. Fewer observers, especially those from southern climes, know it is just as vital to keep the feet warm. One way to do that is by purchasing an expensive pair of ski boots or other insulated footwear, but unless the observing site is really and regularly cold, that is probably overkill. A piece of carpet to stand on or rest the feet on while seated can be almost as effective as expensive boots. An integral part of many an observing kit is a thick bathmat. The rubber covered bottom side of this mat keeps out moisture and helps insulate the observer from the ground. Couple this with the deep pile on the other side, designed to absorb bathroom moisture, and my feet rarely become cold. When it's bitterly cold, more active measures may be required in the form of electrically (battery) heated socks or the chemical warmers described below.

Warm Hands Hands are a problem for the astronomer. They get cold, but covering them with warm gloves makes it hard or impossible to delicately adjust focus or push a small drive corrector button. Removing gloves temporarily to manipulate the scope is not a solution; it becomes an extreme nuisance in a hurry. What's needed are the right gloves. Soft and supple gloves made from deerskin can keep the hands nice and warm but preserve manipulative ability. Even more desirable are gloves or mittens that open up to expose the hands without removing the glove and quickly and easily buttoned up against the cold again.

Also recommended are clever hand warming devices that can help as much or more than good gloves. Some of these are in the form of small, sealed packets that contain chemicals that, when mixed, generate heat. Remove the hand warmer from its plastic pack, shake to mix the chemicals, and it will begin generating a surprising amount of warmth. Most warmers will continue to generate heat for several hours. At the end of their life, the little (inexpensive) packets are discarded. Chemical warmers are available in a variety of sizes suitable for use as body warmers and foot warmers as well as hand warmers. Another alternative is warmers that don't generate their own heat. They are first heated in the microwave and emit this stored heat over several hours. Like the chemical warmers, they are made in a variety of shapes and sizes and are often sold for use by spectators at wintertime sporting events, so check sporting goods as well as outdoor equipment vendors for both types.

Warming a Hand Controller As temperatures approach freezing, the displays of telescope hand controllers become more and more cantankerous. Text becomes dim and scrolling messages slow to a crawl. One solution is to keep the HC in a pocket. That works but tethers the observer to the telescope. How to keep the HC warm? Kendrick sells an HC heater, but that costs money. An old sock costs nothing. Often that's enough to keep the controller warm enough for normal operation, since even modern and efficient electronics generate a little internal heat. In really cold climates, more will be required. The cheapest and simplest fix is the chemical hand warmers described above. Rubber-band one to the HC and away you go. In very severe conditions the combination of hand warmer and sock may be required to keep the HC happy. The only caveat is that these hand warmer packs have a finite lifetime. One that's been in the accessory box for a year will not generate much heat, even though it's been stored in its original package. Some people wonder whether these hand warmers get too warm and might damage an HC. Unlikely. Anything an observer's hands can stand, the hand controller can stand.

It's been a long road, but if you've stayed with us you are now prepared to enjoy the myriad wonders of the universe that your beloved CAT can show. You are skilled in the set up and operation of an SCT or other CAT. You know how to polar align and have at least an idea of what's required to take images with the telescope. You can even connect your CAT to a computer, moving the number of objects available to your eye and camera from the thousands to the hundreds of thousands or millions. But how do you keep your love for the night sky alive and fresh season after season and year after year?

CHAPTER THIRTEEN

Keeping the Passion Alive

I've been observing for close to forty-five years now, thirty-five of those with an SCT (Plate 84). A lot has changed over those decades. Actually, a lot has changed over the nine years since I wrote my original CAT book, *Choosing and Using a Schmidt Cassegrain Telescope*. One thing that hasn't changed, unfortunately, is the CAT in the Closet Syndrome. Some people get all enthusiastic about astronomy, rush out, and buy a big, fancy SCT, use it a few times, and deposit it in a closet, where it remains until it's eventually sold. Other new amateurs get a hold of a scope, aim at the star,s and keep going year after year. How does one remain interested observing season after observing season?

One way is to never look on amateur astronomy as a mere hobby. To me it's always been much more than that; I've always approached it as my "real" vocation. I am employed in astronomy, writing and teaching, but I don't take this wonderful science any more for granted now than I did when I was "just" an 11- year-old amateur with a cheap 3-inch scope. Even then astronomy felt like a way of life rather than a pastime. Other than making the practice of astronomy an important priority, though, what else will keep the initial enthusiasm alive and refreshed over the coming decades?

Set Goals

The surest way to keep things interesting is to set and work at goals. The major reason CATs hit the closet is that the owners have decided that they've seen everything there is to see. Questioning these individuals will reveal they've actually hardly seen anything. Most have barely scratched the surface of the thousands of objects available to an 8-inch Schmidt Cassegrain. "Everything" turns out to be the Moon, Jupiter, Saturn, Mars, and a few of the brightest Messier objects.

R. Mollise, *Choosing and Using a New CAT*,
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Plate 84. (Uncle Rod) "Thirty-five years down the SCT road, I'm still in love with CATs." Credit: Quote and image courtesy of Dorothy C. Mollise.

Why would a person think he or she has seen everything when very little has been observed? Usually because there is no plan. These amateurs drag the scope into the backyard, look at any bright planets that happen to be visible, point at a Messier object or two—M42, M13, and similar showpieces—stand around for a few minutes staring blankly at the sky, and pack it in. As mentioned earlier, having a well-planned observing list is very important. Without at least a semi-detailed list of what is to be observed, nothing much will be observed.

Some amateurs need a little more motivation to keep pushing back the deep space frontiers than a mere self-made observing list, and some of these folks find that motivation in the awarding of honors by observing clubs sponsored by the Astronomical League(Appendix 2), which is the national amateur astronomy organization in the United States. The league has a variety of clubs, but the one to start with is the Messier Club. Two classes of their much-coveted award are offered, "Standard" and "Honorary." The standard certificate is given to any amateur who successfully logs observations of seventy of the objects in Charles Messier's list. The Honorary award is reserved for those observers who manage to find all 110 objects and consists of a handsome pin as well as a certificate. With the Messier conquered, it's time to proceed to the slightly fearsome "Herschel 400," a club that requires the observation of some truly challenging objects; something that will consume many a happy night of deep sky hunting.

Join a Club

One of the surest and most pleasant ways to continue enjoying amateur astronomy is to join an active astronomy club. There is joy in being alone under the stars with a telescope, but observing with groups of like-minded people can be a welcome relief from the Lone Astronomer act after a while. Not just that; the enthusiasm of fellow club members acts as a reinforcement, as does the constant sharing of knowledge. There's also a social aspect many of us find engaging—group trips to observing sites, holiday dinners, late-night bull sessions, and more.

Don't have a local club or don't have the spare time to participate in one? There's a virtual astronomy club meeting going on day and night on the Internet. Places like the astronomy-oriented Yahoo groups and Astromart's and Cloudynights' forums can be almost as much fun as a non-virtual astronomical society. There isn't the group observing and socializing of a "real" club, but otherwise the experience is much the same and just as rewarding.

Contribute to Science

As mentioned in the first chapter of this book, for many amateurs the sense that they are actually doing something beyond looking at pretty things or taking pretty pictures is the impetus to keep pushing on night after night. Given the incredible and powerful scopes, computers, and CCD cameras we have at our disposal today, scientific contribution is an area that's understandably beginning to experience growth. Where in astronomy can amateurs find the opportunity to do science?

Traditionally, the amateur "beats" have been comet-searching, variable star observing, double star measurement, and planet monitoring. Although sophisticated and automated professional surveys have reduced the amateur comet "take," dedicated hunters like David Levy are still beating the pros to the punch occasionally. Variable star observing and binary star measurement were two pursuits that seemed to be dying out among amateurs, but the coming of computers and CCDs has made both activities easier and more fun, and both of these traditional amateur pursuits are surging back. Planet monitoring has not only made a big comeback, amateurs are contributing more than ever. A C14 can deliver details on Jupiter rivaling Hubble, and can do it every single night Jupiter is in the sky. Given the high quality of current amateur gear, it's not surprising that some amateurs are engaged in far more sophisticated scientific programs than even these traditional ones. Some, for example, are on the forefront of science assisting the pros in identifying gamma ray bursters and searching for extrasolar planets.

Buy a New Telescope

There is no doubt that for a person in the observing doldrums a new SCT can help make observing fun again. The thrill of a new scope can be experienced both by going up and down in aperture. Naturally, a larger scope will open up considerably more deep sky real estate. A smaller scope, something like a C5 or an ETX 90, can also be a joy, since one is so easy to transport and set up. An "iffy" sky may no longer mean canceling a trip to a dark site, and every family vacation may be an occasion for bringing the telescope along and doing a little casual observing.

Buy Better Eyepieces

Sometimes a new telescope isn't needed to refresh the astronomical soul. A new eyepiece may be all it takes. Ultrawide oculars can make an old warhorse orange-tube C8 into a brand-new deep space machine if it's been struggling along with "soda straw field" eyepieces such as Plössls and Orthoscopics. Going from an apparent field of 40 to 50 degrees to 65 to 85 degrees is like turning on the lights in a dark room.

Pursue a Different Hobby

No, not stamp collecting. Take up a different astronomy hobby. Amateur astronomy is not really one thing; it's many different things. Just about anything can get boring after a while. If you're a dyed in the wool visual worker, think about trying the difficult but rewarding art of CCD imaging. Planetary fanatic? Consider becoming a deep sky observer. Hunting for and observing faint fuzzies may provide a ticket out of dullsville.

Attend a Star Party

Joining a local astronomy club and observing at their dark site is a good way to "keep going," but the local scene is not all there is. Throughout the United States and Europe, star partiesare incredibly popular. A "star party" happens when amateurs from a region, a country, or the entire world assemble at a remote and dark location for a few days to a couple of weeks, to do observing and share the fun. These events owe much of their popularity to the growth of light pollution. Beginning in the 1970s, the average amateur found it more and more necessary to travel to dark locations to do "real" deep sky observing. Those areas blessed with really dark sites began to attract amateurs from far afield. What began as semi-informal gatherings became more organized, offering convention-type activities as well as observing.

Keep Your Balance

Astronomy is the Queen of the Sciences. What she offers is both aesthetic and intellectual beauty. Unfortunately for many amateurs this giver of beauty is a source of friction with family members, especially non-astronomer spouses. What do you do if a husband or wife simply can't understand why you want to spend "all that money" on telescopes and accessories only to stand out in the middle of the dark yard alone all night? The advice usually given to people in these circumstances is to keep things balanced. Don't neglect your family to pursue your observing program. That is good advice.

What do you do about a husband or wife who becomes upset even though you don't neglect your family? When all you want to do is observe for a few hours once every week or two? Make it clear that astronomy is what you do and who you are, and that it is very important to you. Sometimes showing is better than telling, though. Involve your significant other. Instead of packing up the scope, jumping in the car, and leaving husband or wife in the dust, why not invite him or her along once in a while? Pack a couple of lawn chairs. Maybe even a bottle of wine. Set up the scope as normal, but also spend some time with your companion looking at the constellations and telling their stories. Put some particularly attractive and interesting objects in the field of the CAT. As dawn breaks, open the wine and toast the stars and your love. In this way, the telescope may become the spouse's friend instead of a rival.

Keep the Stars in Your Eyes

There is one final bit of advice that should really see you through over the long run: keep the stars in your eyes. Try to remember why you came here. The reason most of us entered astronomy and started lusting after Schmidt Cassegrains was because our sense of wonder had been stimulated, because every time we looked up at the night sky, we were filled with an almost mystical curiosity about the Great Out There. If you feel burned out, recall those feelings of awe. Remember the first time you looked at a globular cluster and wondered if anybody were looking back? That is the only secret to becoming an astronomy old-timer. Forget the minutiae of eyepiece designs, PEC recordings, and CCD chip sizes once in a while and just wonder again. If you can do that, your journey of discovery with your beloved CAT will be a long and fruitful one.

Nine years ago, in my last CAT book, I wished this for you, and I offer you the same wish again: "May the stars light the end of your road."

APPENDIX ONE

Telescope and Accessory Dealers and Manufacturers

There are many excellent makers and sellers of astrogear, but here are some of the most outstanding dealers and manufacturers.

Adirondack Video Astronomy
http://astrovid.com
Cameras and imaging accessories; manufacturer/dealer of the Stellacam deep sky video cameras

Anacortes Telescope and Wild Bird
http://buytelescopes.com
Full-line dealer of telescopes and amateur astronomy products and accessories of all kinds

Apogee Instruments Incorporated
http://www.ccd.com
Advanced CCD cameras

APT Astro
http://www.aptastro.com/products/wedge.php
Heavy-duty equatorial wedges for fork-mount Meade and Celestron telescopes

Astronomical League
http://www.astroleague.org/
The U.S. national organization for amateur astronomers; famous for their “observing clubs”

Astronomics
http://www.astronomics.com
Full-line dealer of telescopes and accessories

Astro-Physics Incorporated
http://www.astroleague.org/
Manufacturer and direct seller of apochromatic refracting telescopes, German equatorial mounts, and accessories for these products

Astrozap
http://www.astrozap.com/
Dew shields to fit almost any telescope

Atik
http://www.atik-instruments.com/
Beginning, intermediate, advanced CCD cameras

Baader
http://www.baader-planetarium.com/
Wide range of accessories, especially filters; Baader (Germany) products are available from many U.S. astronomy dealers

Bob’s Knobs
http://bobsknobs.com/
The “knobs” replace SCT and MCT collimation screws and make optical alignment easier

Buyastrostuff.com
http://www.buyastrostuff.com/
High-quality but inexpensive accessories, including observing chairs

Celestron
http://www.celestron.com
World-famous maker of Schmidt Cassegrain telescopes

Denkmeier Optical
http://www.deepskybinoviewer.com/
Binoviewers and diagonals

Dewbuster
http://dewbuster.com/
Innovative temperature-regulated dew removal heaters

Dew-Not
http://www.dew-not.com/
Inexpensive but good-quality dew heater strips, controllers, and related items

Feathertouch Focusers (Starlight Instruments)
http://www.starlightinstruments.com/
Crayford focusers and replacement (two-speed) SCT focuser knobs

FLI (Finger Lakes Instrumentation)
http://www.flicamera.com/
Advanced CCD cameras (available through dealers)

Hands On Optics
http://handsonoptics.com/
Telescopes and accessories—many exclusive items

Internet Telescope Exchange (ITE)
http://www.iteastronomy.com/
Dealer for Russia's Intes Micro telescopes

J.M.B. Incorporated
http://identi-view.com/Welcome.htm
Identiview solar filters (available through dealers)

JMI (Jim's Mobile Incorporated)
http://www.jimsmobile.com/
Cases and many other accessories

Kendrick Astro Instruments
http://www.kendrickastro.com/astro/index.html
Dew heater strips, heater controllers, and other items

Lenspen
http://www.lenspen.com/
Lenspen cleaning system (available through dealers http://www.lenspen.com)

Losmandy
http://losmandy.com/
German equatorial mounts and accessories

Lumicon
http://lumicon.com/
Light pollution reduction filters and other astroaccessories

Luminera
http://www.lumenera.com/
Planetary imaging cameras (available through dealers)

Lymax
http://www.lymax.com/
SCT coolers and other accessories

Meade
http://www.meade.com
One of the two largest SCT makers and the largest telescope manufacturer in the world

Mitty
http://www.mittyindustries.com/
Heavy-duty wedges for Meade and Celestron fork-mount telescopes

Mogg
http://webcaddy.com.au/astro/adapter.htm
Webcam adapters and accessories; based in Australia but ships worldwide

OPT (Oceanside Photo and Telescope)
http://www.optcorp.com/
Full-line telescope and accessory dealer

Orion (Telescope and Binocular Center)
http://telescope.com
Synta-made telescopes and accessories (including Celestron products); also a dealer for TeleVue, Intes Micro, and several other manufacturers

Orion Optics UK
http://www.orionoptics.co.uk/
Maksutov Cassegrains, Newtonians, and Vixen mounts

Scopestuff
http://scopestuff.com/
Large selection of inexpensive and hard-to-find accessories

Shoestring Astronomy
http://www.shoestringastronomy.com/
Electronic accessories for imagers (including DSLR interface cables and guide-port interfaces)

Skies Unlimited
http://www.skiesunlimited.net/
Full-line dealer of telescopes and accessories

Starizona
http://starizona.com/acb/
Telescopes and accessories including the Hyperstar/Fastar imaging system

TeleVue Optics Incorporated
http://televue.com/
Eyepieces (Nagler, Panoptics, Ethos, Radian) and apochromatic refracting telescopes

Teton Telescope
http://www.tetontelescope.com
U.S. dealer for Intes Micro and other imported Maksutovs

Thousand Oaks
http://www.thousandoaksoptical.com/
Solar and light pollution reduction filters

University Optics
http://www.universityoptics.com/
Eyepieces (especially Orthoscopics) and accessories

Vixen
http://www.vixenoptics.com/tele.htm
Telescopes and accessories from Japan; available worldwide through dealers

William Optics
http://www.williamoptics.com/
Refracting telescopes, eyepieces, and accessories; available through dealers

APPENDIX TWO

Internet Resources, Software, and Books for CAT Users

This is but the merest sampling of the Internet and print resources available to CAT owners.

Software

Aberrator
http://aberrator.astronomy.net/
Freeware star test “simulator”

ASCOM
http://ascom-standards.org/
The free telescope driver system

AstroPlanner
http://www.ilangainc.com/astroplanner/
Observing planning and logging for both Apple and Windows users

Cartes du Ciel
http://www.stargazing.net/astropc/
Sky Charts, amateur astronomy’s favorite freeware planetarium software

Deepsky
http://www.deepsky2000.com/
Observing planning and logging; also includes extensive charting and image-processing features

Earth Centered Universe
http://www.nova-astro.com/
Inexpensive planetarium/atlas software

EQMOD
http://eq-mod.sourceforge.net/testimages/
Freeware telescope control program/driver for Synta GEM mounts

K3CCD
http://www.pk3.org/Astro/
Webcam control and image processing

Keith's Astroimager and Keith's Image Stacker
http://www.cs.unm.edu/~kwiley/software.html
Free webcam control and image stacking software for Macintosh users

Megastar
http://www.willbell.com/software/megastar/index.htm
The computer star atlas

Metaguide
http://astrogeeks.com/Bliss/MetaGuide/index.html
Webcam-based autoguiding and automated collimation

NexRemote
http://www.celestron.com/c2/technology_view.php?TechnologyID=3
Virtual hand control for Celestron NexStar telescopes

PolarFinder
http://arnholm.org/astro/polar_alignment/index.html
A simple but clever program that makes polar alignment with a borescope easy

Registax
http://www.astronomie.be/registax/
The premier image stacking program for Windows users

SkyTools
http://www.skyhound.com/cs.html
Innovative observing, planning, and logging program with many charting features

Starry Night
http://www.starrynightstore.com/stniso.html
The prettiest of the "pretty planetariums" software programs

TheSky
http://www.bisque.com/Products/TheSky6/
Advanced planetarium program/telescope control system; currently in Version 6 but soon appearing in a new version

Virtual Moon Atlas
http://www.astrosurf.com/avl/UK_index.html
Detailed lunar mapping program with many utilities for Moon observers; freeware

Voyager
http://www.carinasoft.com/
Full-featured planetarium software for Apple and Windows users

Internet Resources

Arkansas Sky Observatory
http://www.arksky.org/
SCT expert “Doc” Clay Sherrod’s extensive Web site

Astromart
http://www.astromart.com
The most popular astronomy classified ads Web site; also features many reviews of scopes and equipment and dozens of discussion groups

CGE Telescopes Uncensored
http://groups.yahoo.com/group/CGE-TelescopesUNCENSORED/
Devoted to Celestron’s CGE series of German mount SCTs; Moderated by the author

Cloudy Nights
http://www.cloudynights.com
Similar to Astromart but with an emphasis on reviews and discussion groups rather than on classified ads

LX200GPS
http://tech.groups.yahoo.com/group/lx200gps/
The most popular group for the discussion of Meade’s LX200GPS and follow-on telescopes

Meade Uncensored
http://tech.groups.yahoo.com/group/meade-uncensored/
Rod Mollise’s Yahoo group for general Meade discussions

QCUIAG
http://tech.groups.yahoo.com/group/QCUIAG/
Webcam imaging headquarters

SCT User
http://tech.groups.yahoo.com/group/sct-user/
Rod Mollise’s general interest Yahoo group for CAT users; over 4,000 subscribers/users

Uncle Rod’s Astroland
http://skywatch.brainiac.com/astroland
Rod Mollise’s home page

Weasner’s Mighty ETX Site
http://www.weasner.com/etx/menu.html
The place to go for all things ETX

Magazines

Amateur Astronomy Magazine
http://www.amateurastronomy.com/
Articles by and for amateur astronomers; subscription only

Astronomy
http://www.astronomy.com/asy/default.aspx
Available on newsstands

Sky & Telescope
http://www.skyandtelescope.com/
U.S. amateur astronomy's oldest (and most respected) magazine; available on newsstands

Astronomy Technology Today
http://www.astronomytechnologytoday.com/
A new subscription-only periodical focused on telescopes and accessories; of much interest to CAT mavens

The Sky at Night
http://www.skyatnightmagazine.com/Default.asp?bhcp=1
From the BBC and Sir Patrick Moore

Books

Covington, Micahel. *Astrophotography for the Amateur*. Cambridge: Cambridge University Press, 1999

The time-honored reference on amateur astrophotography newly updated with information on digital imaging

Lodriguss, Jerry. *A Guide to Astrophotography with Digital SLR Cameras*. Somerdale, NJ: Astropix LLC, 2006

The hows and whys of DSLR imaging; CD-ROM e-book available from Amazon.com and other sources

Mollise, Rod. *Choosing and Using a Schmidt Cassegrain Telescope*. London: Springer Verlag, 2000

Uncle Rod's original SCT book; still of interest for its extensive information on pre-go-to SCTs

Mollise, Rod. *Uncle Rod's Used CAT Buyer's Guide*. Mobile, AL: Possum Swamp Productions, 2007

http://skywatch.brainiac.com/used/index.htm

Rod's free e-book guide to evaluating and buying used CATs

Piekiel, Robert. *Celestron: The Early Years*. Marcellus, NY: Robert Piekiel, 2004

CD-ROM e-book available exclusively from the author through Astromart.com

Wodaski, Ron. *The New CCD Astronomy*. Duvall, WA: Multimedia Madness Inc., 2002

For beginning/intermediate astrophotographers using astronomical CCD cameras

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