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HOW TO PHOTOGRAPH THE NIGHT SKY

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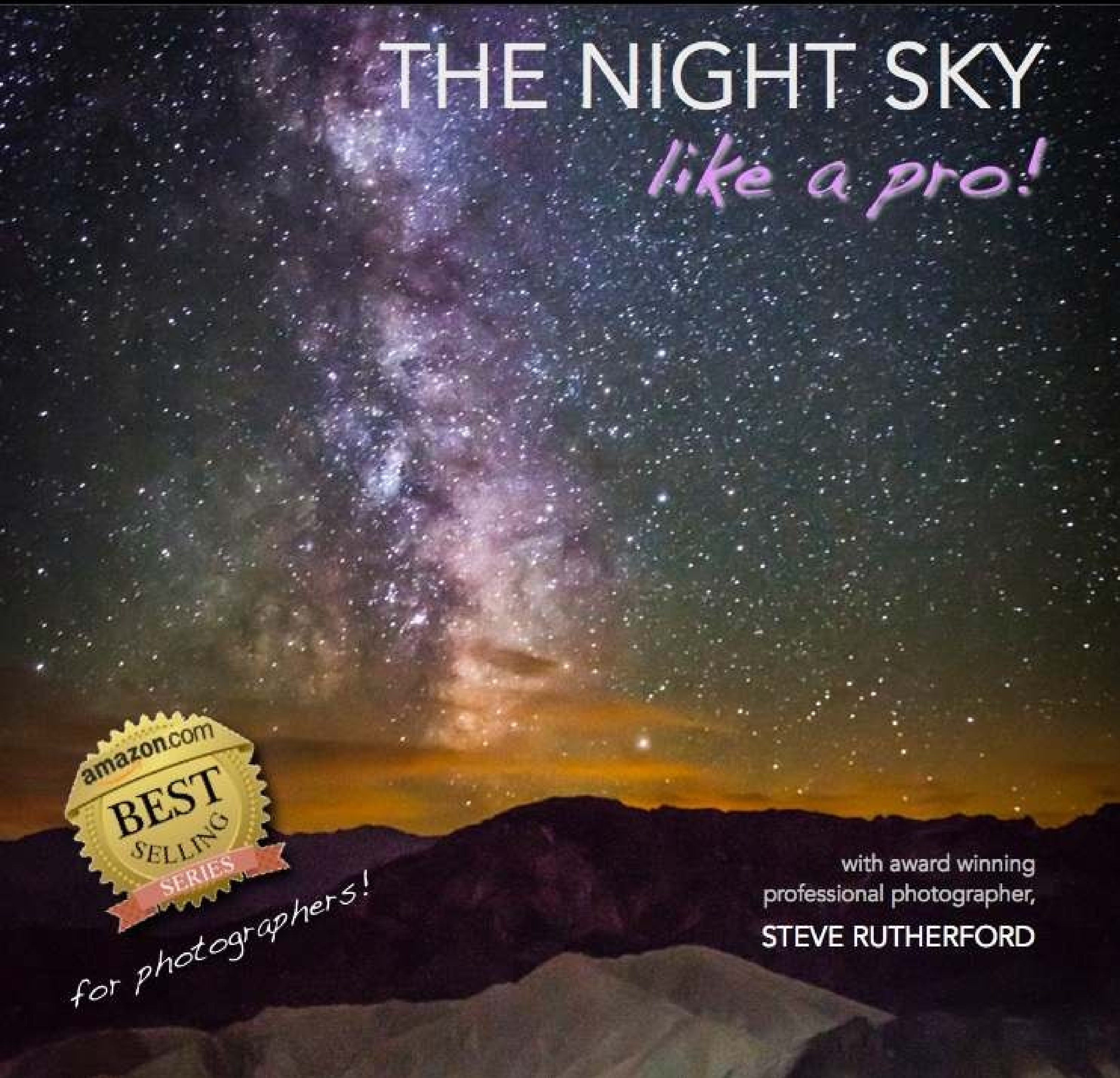

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with award winning
professional photographer,

STEVE RUTHERFORD

HOW TO
PHOTOGRAPH THE NIGHT SKY
LIKE A PRO

By Multi-Award Winning
Professional Photographer
and
Best Selling Author

STEVE RUTHERFORD

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RUTHERFORD
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WHAT OUR READERS AND STUDENTS ARE SAYING…

Praise from our readers and photography students taught by Internationally Awarded and Accredited Australian Pro Photographer Steve Rutherford who has been teaching photography for over a decade.

"As a photographer, in particular for landscape photography, it is a delight that a talented photographer like the author shares his knowledge and experience. Great hints, direction and tips."

Adrianus Hendriks, "How to Photograph Landscapes like a Pro – Best Seller" Amazon review

"A great read with all the information to get you started in taking great shots without the "filling" or confusing information that some other books have. Great reference material."

Paul B. "How to Photograph Landscapes like a Pro – Best Seller" Amazon review

"WOW, great training, so much content, wish I had done this earlier, thanks for your local advice too, Steve"

Heather Francini, Auckland NZ

"If you want to take your photography to the next level you have to discover photography with Steve Rutherford"

Dave Phillips, Mackay, Australia (davephillips.com.au)

"Hi Steve, Brilliant content….what a way to learn, now I know spending the $$ on my camera was worth it…thanks so much."

Tracey Woolstock, Darwin, NT, Australia

"Hey Steve, Thanks a million for your help I have over 400 images from my holiday to work on, I'm on it, Cheers"

Sandra Marks, Brisbane, QLD, Australia

"I haven't come across a better way to learn how to capture images in any situation, than this training"

Michael Pollock, Atherton, QLD, Australia

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Steve Rutherford
Author "How to Photograph Anything" Book Series

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ACKNOWLEDGEMENTS

Ah… books. What a wonderful resource at the end of our fingertips. Often it takes many people to bring a single book together, and often a seriously large team to bring a series of books together. A wise man once said, *"the heights of success are not climbed by oneself, but rather with others holding the ladder with you"*, implying a team of mentors and helpers is what drives you towards success, not the efforts of the "lone ranger". There are a few people that have helped bring this set of books in the "How to Photograph Anything Like a Pro" Series together, and they are to be acknowledged for their support, ideas, tenacious critique and selfless assistance and love.

Firstly, to my wife and intimate personal mentor, Tanya, thank you for your fervor and persistence, in pushing to have this project completed. You are my personal mentor in every day life and I love you very dearly. I'd also like to thank my friend and best selling author and entrepreneur, Andrew Griffiths. You have well and truly aided me in many areas of business, marketing and the importance of personal relationships. I can't thank you enough for your friendship. To the contributors and editors, who assisted in the compilation, checking and re-checking of content in this series of books, thank you also.

Finally I am deeply thankful to the multitudes of attendees at my photography training seminars, in Australia, and those readers of our magazine, Photographic Fanatic Magazine, for your continued support. Without each of you there would be no point in teaching people the passion of photography.

ABOUT THE AUTHOR

Award winning Australian Photographer, Best Selling Author and Editor of Photographic Fanatic Magazine, Steve Rutherford is regarded as a reputable name in the international photographic world. With a multitude of International awards, high demand for his creative vision in advertising and fine art, and hundreds seeking his training courses and seminars, he is clearly a photographer on the move.

Previously a high level manager within the Australian Federal Police and a Prison Officer with the notorious Long Bay Prison's Riot and Emergency Response Squad in Sydney, Australia, Steve Rutherford's background has been as diverse as the images he captures. There is no doubt that any person with this past has seen both the best and the worst that humanity can be. Steve uses this experience when adding his own unique perspective to the world. Such a perspective can expose the story of a single floating leaf on a tropical island paradise, or the grandeur of midnight in New York.

Steve Rutherford is accredited and registered as an award winning professional photographer by the AIPP (Australian Institute of Professional Photography), and the PPA (Professional Photographers of America) having accumulated over 50 International and National awards in a short span of years. Steve is also qualified as an Associate of Photography with the AIPP and a Master of Photography with the NZIPP (New Zealand Institute of Professional Photography), and was past President of the N. QLD Chapter of the AIPP.

Steve Rutherford travels extensively, both for commercial clients and to collect images for his own fine art and stock library. He has photographed extensively around Australia, NZ, Vanuatu, New Caledonia, Indonesia, Hawaii, mainland USA, Alaska and Canada. He is also represented by In Transit Images in Montreal, Canada. Visit – www.steverutherford.com

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CONTENTS

INTRODUCTION TO THIS BOOK

This book, “How to Photograph the Night Sky like a Pro” will take you on a journey of discovery of the many secrets that professional photographers, use to capture stunning award winning shots at night. Exploring the stars and the Milky Way galaxy, among moonlight and streetlight requires a different way of thinking and a different way of shooting.

This book assumes that the reader has limited knowledge in practical photography and the use of their own camera equipment. The information provided in this book is a compilation based on the experiences, trials and tests undertaken by Steve Rutherford, along with other photographic industry professionals, agencies and organizations. “Live website links” (blue underlined text) have been written into the text. Books in the “How to Photograph Anything like a Pro” series use the following visual cues and icons -

The lens icons indicate a technical area that you should take note of for future reference.

HOT PRO TIP

The “flaming book and green tick” icons indicate **“Hot PRO Tips”** that should be noted and used to get the best from your photography, during passages of text in the book.

The “eyeball” icons indicate “visual examples” that should be used as a guide or example that goes with the text in the section you are reading.

F4 - F8 The “red settings boxes” indicate “ideal or specific settings” to use for the scenario being explained.

This book may also refer to “film”. Although the advent of digital has well and truly taken over film for the most part, the applications still apply in the same way, whether digital or film, when considering the basics of photography. Photography is meant to be fun, so try to enjoy the process of creating photos, it doesn’t matter whether they are wrong, right or anywhere in between. Please enjoy this book, and remember only your imagination limits your photography.

Regards, **Steve Rutherford**

http://www.steverutherfordtraining.com.au

SHOOT FOR THE STARS

SHOOT FOR THE STARS – AN OVERVIEW OF NIGHT PHOTOGRAPHY

How often have you looked above your head on a clear night and thought, how do I capture an image of the universe, without being in space? I asked myself that question for years, just because I was intrigued about what exactly was out there, aside from what we know. Once I started to explore the world of photography (many, many years ago now), I quickly turned my attention to trying to capture the Milky Way. Now this was before digital cameras existed, at least in their current consumer form, so the immediate playback convenience was a week long wait for the return of your film (transparency slide film) to be looked at through a loupe over a light table. Thank god for the advent of digital, although I still love my old film cameras and use them regularly.

Newer digital cameras are increasingly better, and now come with the ability to quickly and easily capture images that include low light scenes and the night sky. This has caused night photography to become highly popular in the last couple of years. Not as many people take photos at night, so you will have the opportunity to capture some unique, eye-catching photos that will wow your friends after reading this night photography book.

Taking photographs at night does require more knowledge about camera functions than typical daylight pictures, and depending on the camera's settings you use, the results can be spectacular, and well worth the wait in the cold night air.

NOTE This book assumes you have a grip of the fundamentals of your camera and photography.**

If you don't quite have the knowledge yet, or feel you could improve before embarking on a complex shoot of the night sky, maybe start with our main guide book in the series – How to Photograph Anything Like a Pro. This will give you all the necessary fundamentals to build you skills to a level where you will feel confident in taking complex pictures.

A star trail captured over a long time, with the added use of a flash to freeze the girl standing on the rock. This is a complex form of shooting, but contrary to what you're probably thinking, doesn't require the subject to stand still for a hour non stop.

Now, lets take a look at some of the techniques, the equipment and the fundamentals needed to capture a striking photo of the night sky.

What Gear Will Get Me Started?

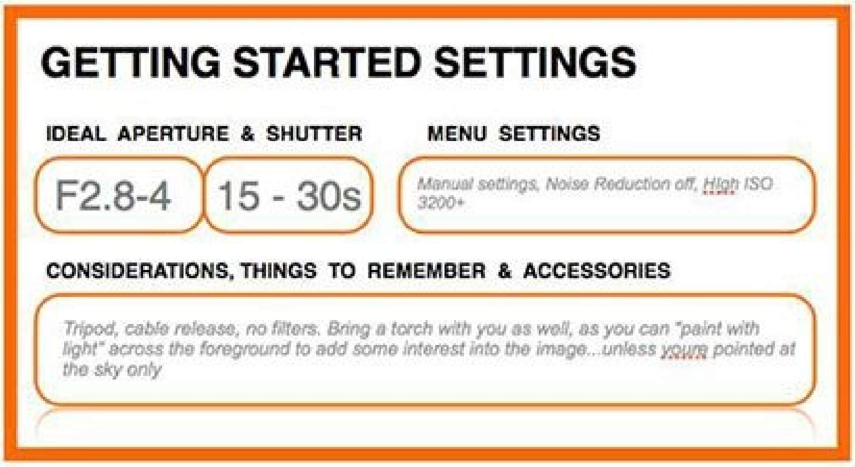
As an absolute minimum you need a digital single lens reflex (SLR) camera, a telephoto lens or telescope and an equatorial mount.

You could also use a CCD, that is, an astronomical “charge coupled device” (CCD) camera with regulated cooling, which reduces the noise caused by long exposures and filters that shut out all but a very narrow band of visible light. This all help to tackle light pollution greatly. Hydrogen alpha (H-alpha) filters transmit only the glow of distant HII nebula, while images captured through ionized sulphur (SII), ionized oxygen (OIII) and H-alpha filters can be combined to create color views of some incredible celestial objects.

Where do I Need to Go?

Assuming you cannot get to the top of an extinct volcano surrounded by ocean, head for high ground as far as possible from major light sources and polluted air. The Moon can cause more light pollution problems than nearby cities, making the time around the new moon ideal for deep space observing and imaging.

Practicing for the Very First Shot



Get use to manually setting your focus. Most modern DSLR cameras have a Live View function where you can see what your shooting o the LCD screen. You can then use the zoom buttons on your cameras rear panel to zoom in. Select a moderately bright star within your image frame, adjust your focus and choose the shortest exposure which will show the star without blowing in out into a highlight. Then zoom back out using your Live View function. Take some test shots for 15-30s @ F4, with an ISO of 3200 or above, tweaking your focus by very small amounts while watching the image’s histogram. You will be close to focus when the pixel value is at its highest. Don’t be afraid to experiment with various exposures.

Use an online exposure calculator to help, such as those provided by Starizona or

CCDWare to identify the optimal minimum exposure time where the sky background overwhelms the inherent noise. This will ensure you have the best possible noise reduction options when you process the images later. If, like the Orion nebula, your subject ranges widely from very dim to very bright, take optimal exposures for the dim areas and shorter exposures for the brighter sections. If you're already saying….what the?…..don't worry, we'll go into this in more detail throughout the book.

WHAT EQUIPMENT DO I NEED?

How to Pick a Camera

If you already have a digital camera, that’s the one you should get started with. Why? Why not?. Even if you don’t have any kind of telescope or other astronomical equipment, you can still take pictures of the Moon, constellations, star trails, and wide-angle scenic twilight shots in some way, even with a basic camera..

Before you buy anything, ask yourself these questions:

What kind of pictures do I want to take?

What is the best kind of camera to take them with?

How much do I want to spend?

How deep do I want to get into it?

Think seriously about these subjects before you decide which camera to buy. The best camera for you depends on the answers to these questions!

In any event, not rushing out and buying the first telescope or camera that you see at the nearest discount store will best serve you. Join an astronomy club, meet the members, and go to a star party and use their telescopes. See what kinds of cameras they are using and what kinds of results they are getting. Find out which kind of astronomical objects you are most interested in photographing, and then research which cameras and scopes are best at that specialty. If you don’t live near a club, then get on the internet and see what people are shooting. A good place to start looking is the Anacortes Telescope Photo Gallery Page. There you can see a wide variety of different astronomical subjects taken with all kinds of different cameras.

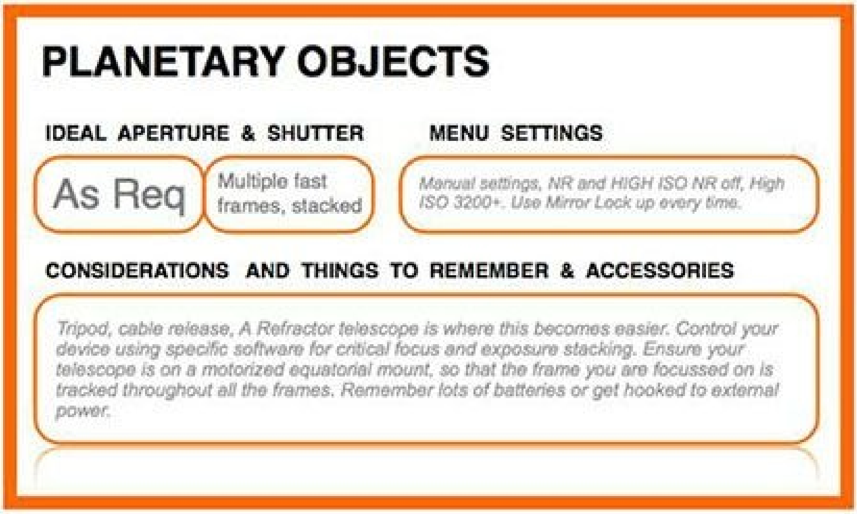
What Kind of Pictures Do You Want to Take?

There are different kinds of astrophotography and different cameras excel at different aspects of the hobby. It will take a while to get to know this equipment as many of the devices you can use, you may never have even heard of. That’s why Astrophotography intrigues me so much, as there are so many possibilities. My best advice would be to try each of the following types of Astrophotography styles at least 3 times each. Then you’ll appreciate the work involved and the incredible rewards you’ll see at the end

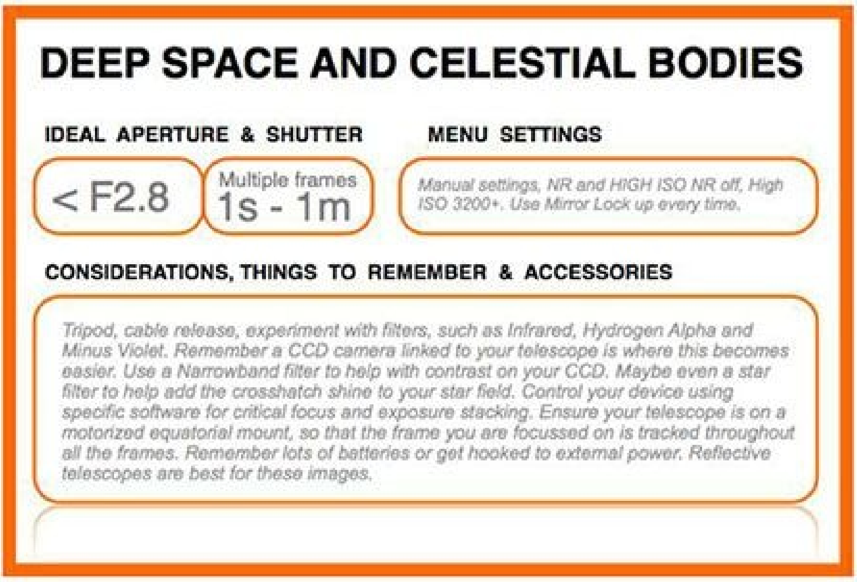
Scenic/Wide field/Star field – Scenic astrophotography would include wide-angle shots such as the crescent Moon setting in the twilight or the Milky Way. Photographs of atmospheric phenomenon, such as the aurora would also be included. This category doesn’t have strict definitions, but pretty much anything you can shoot on a fixed tripod with a relatively short exposure of about 15 seconds or less.

Planetary – Planetary photography encompasses the Sun, Moon, and planets of the solar system. Planetary photography requires high-resolution to pick out tiny details on planets such as Jupiter and Mars, as well as small craters on the Moon and details in sunspots. These objects are bright, so exposure is not the problem, but “seeing” or atmospheric steadiness is.

Saturn, Jupiter and two of its moons, Mars with its polar icecap, can all be captured using the right telescope, camera and processing software combination



Deep Space or Celestial – Deep-sky astrophotography includes the real jewels of the night sky - star clusters, nebulae and galaxies. These objects require long-exposures and low-noise cameras.



What's the Best Kind of Camera to Use?

Scenic - Scenic astrophotography can best be undertaken by a DSC - (Digital Still Camera or commonly known as a Compact Camera) or DSLR camera. DSC cameras cost a couple of hundred dollars. DSLR cameras cost from $500 to several thousand.

Planetary - The best solar system photography these days of the planets is being done by computer web cams which capture hundreds and thousands of frames at a time very quickly. Software then examines each frame and picks out the really sharp ones where the seeing was good and combines them to reduce the noise inherent in the imaging system. Some of the finest planetary photography ever done in the history of astronomy has been done with inexpensive web cams that cost less than $200.

If you already have a telescope and computer, you can do high-resolution planetary work for a couple of hundred dollars by buying a good webcam.

Deep Space - Deep-sky astrophotography requires a very different type of camera, one that can take long exposures of a couple to dozens of minutes with low noise. Dedicated astronomical CCD cameras reduce noise by cooling the camera many dozens of degrees below the ambient temperature. DSLR cameras can also be used for deep-sky imaging if they have low inherent noise and many short exposures are combined together to further reduce noise.

Inexpensive CCD cameras with extremely small chips can be purchased for $300. A good astronomical CCD camera with a decent sized chip can cost anywhere from $3,000 to $10,000. A good low-noise DSLR camera can cost from $750 to several thousand.

If you have been in the hobby of astronomy for some time, you may have an interest in one of these particular areas and want to specialize in it. If you do know, then get the kind of camera that is best for that particular type of astrophotography. If you don't know, or want to try them all out, then a DSLR camera would be a good choice.

No matter what kind of night photos you want to take, spend some time on the internet and with the popular astronomy magazines looking at the best astrophotography to see what kind of camera they were taken with. You will find that the same names keep coming up again and again, both in the photographers that excel in these realms, and also in the equipment that they use.

How Much Do You Need to Spend?

The categories below are a little arbitrary, but they will give you a general idea of where the price points are for various cameras and what you can do with them.

$300 and Less - If you already have a DSLR camera and telescope on an equatorial mount, you won't have to spend much at all to get started, just about $50 for a T-ring and 2-inch adapter to hook your camera up to your telescope.

- **DSC** - There are a lot of excellent inexpensive digital snapshot cameras on the market today that can be used for scenic twilight astrophotos and Afocal photography of the Moon and double stars.
- **Panasonic Lumix Cameras, Canon, Fuji, Olympus and Nikon** - $169

- **Webcam** - You can get a world class webcam for taking high-resolution planetary images of Mars, Saturn, Jupiter and the Moon for less than $200. Here are some good ones:

- **Phillips Toucam Pro II** - $159
- **Celestron NexImage Solar System Imager** - $99

- **DSLR** - You might be able to find an older model DSLR for sale used someplace like Astromart, but note that the older models like the Canon EOS D30 and D60 were relatively high noise.

- **CCD** - A low-end CCD camera can even be found at this price point, but the chips in them are going to be tiny.
- **Meade Deep-Sky Imager II**- $299, 48-bit, one-shot color, 510 x 492 pixel array, 9.6 micron pixels.

$300 - $750 - This is a kind of in-between price range. It's expensive for a DSC and Webcam, and not really enough to get a really good CCD camera, but at the top end of the range, just enough to get a really good DSLR.

- **DSC** - At this price there are many really good DSC cameras, but at this price, you can get a DSLR.

- **Webcam** - Most webcams are not this expensive.

- **DSLR** - Now you are in the price range to get a decent, late-model, low noise DSLR camera.
- **Nikon D3200** $520
- **Sony A58** $500
- **Canon EOS 550, 650, 700D Digital Rebel XT** - $550 - $750

- **CCD** - CCD cameras get a little better, but the chips are still small and you won't be able to make very large prints with them. Still, you can get into CCD imaging on a budget in this price range.
- **Atik Instruments ATK-1C CCD Camera** - $329, 24-bit, 1-shot color, 640x480 array and 5.6 micron pixel size.
- **Meade Deep-sky Imager III** - $399 - http://www.meade.com/dsi_3/

Here is a PDF Manual with instructions to set up and use Meade CCD imager with a telescope, to easily capture deep space nebulae, along with software – http://www.meade.com/manuals/TelescopeManuals/dsi/DSI_III_manual.pdf

$750 - $1,500 - In this range, forget about a DSC. If you are a high-end planetary imager, you can find some excellent, sophisticated, high-end "Webcams". The latest generations of low-noise DSLR cameras are found here, and we are just starting to get into the price range of some decent CCD cameras.

- **DSC** - Get a DSLR for this price.

- **Webcam** - Luminera LU075 $945

- **DSLR** –
- Canon EOS 20D $1,300
- Canon 350D Rebel XT Hutech Modified Type 1 - $1,350

- **CCD** -
- SBIG ST-402ME $1,300
- ATIK 16 CCD - $995

$1,500 - $10,000 - This is where we start to find top-of-the line modified DSLR cameras and CCD equipment.

- **DSC** - Get a DSLR or CCD.

- **Webcam** - You can find better for less.

- **DSLR** -
- **Canon 20D Hutech Modified Type 1** - $1,995
- **Canon EOS 20Da** - $2,200
- **Canon 5D Hutech Modified Type 1** - $3,795

- **CCD** -
- **Starlight Xpress - SXV-H9C** $2,895, 16-bit, one-shot color, 1392 x 1040 pixel array in 8.98mm x 6.7mm, 6.45 micron pixels
- **SBIG ST-2000XCM** $3,200, 16-bit, one-shot color, 1600 x 1200 pixel array in 11.8mm x 8.9mm, 7.4 micron pixels
- **SBIG Research Series STL-11000XMC** $8,995, 16-bit, one-shot color, 4008 x 2745 pixel array, 36mm x 24.7mm, 9 micron pixels

Decide what you want to shoot, and decide what your budget is, and stick to it. Critically evaluate your desires versus your budget. A burning desire to be the best deep-sky astrophotographer in the world must also be accompanied by the financial resources to put you in a position to acquire the equipment necessary to give you a chance to succeed. Even with an unlimited budget, it still requires time, dedication and expertise to excel. If you have grandiose dreams and limited resources, you are probably going to be disappointed, just like my dreams of playing professional basketball, which were crushed by my physical limitations of being slow, 5 foot 10, 250 pounds, and unable to jump. You have to have a realistic balance between expectations and resources.

Don’t forget to include money in your budget for things such as camera-to-telescope adapters, focusing accessories, remote release timers, software, and possibly a laptop computer for use in the field. You can get by on a reasonably frugal budget to get started, but this is not a hobby like chess where you have virtually no expenses for acquiring the equipment needed for it.

How CCDs Work

Most digital cameras work using a light sensor called a CCD - or “Charge couple device” - which contains a grid of millions of tiny devices called capacitors. When a picture is taken with a digital camera, the shutter opens and an image is projected onto the CCD. The light that hits each capacitor can bump electrons out of their atoms causing the capacitor to become charged. This is called the photoelectric effect. The more intense the light is at each site (or pixel) in the grid, the more charge will be held in that capacitor. You can think of the capacitors as buckets and the light as rain. After the shutter has been closed, the charge that has accumulated in each of the capacitors has to be measured in order to get the image data. First a circuit reads how much charge is in each of the capacitors in the bottom row. Then the charges in each row of capacitors are moved to the row below, the bottom row is read out again, and this process is repeated until all of the image data is read. This information tells us how bright the light is at each pixel but that would only give us a black and white image. To get a color image, some digital cameras use a device called a beam splitter, which splits up the light into red, blue, and green beams and sends each one to a different CCD. This kind of camera can generate very high quality pictures because it closely measures the color of the image at each pixel. But because they constain 3 CCD’s, these cameras are bulky and expensive. Most cheaper digital cameras use what’s called a Bayer mask to generate a color image using only one CCD. For each group of four pixels in a CCD with a Bayer mask, one is filtered to measure red light, one blue, and two green. After the data is read from the CCD, a computer chip finds the actual color and intensity of each pixel by averaging the amount of red, green, and blue in the nearby pixels. This process is called interpolation.

The number of “megapixels” a camera has refers to how many millions of capacitors there are in the CCD to measure the intensity of light. A 4 megapixel camera would have approximately 4 million capacitors on the CCD. A typical CCD in a digital camera is about 4 by 5 millimeters. That means that each capacitor on a 4 megapixel CCD is only about than 2/1000 of a millimeter or 2 microns long.

CCDs are also used by astronomers to carefully measure the intensity and frequency of light coming from objects in outer space. In fact, most of the images from the Hubble Space Telescope are taken with CCDs. Already we can see the importance of the digital data provided by a CCD in processing the data. It is possible to do similar processing with film (e.g. unsharp masking) but the precision of a computer allows the data to be processed such that the image is a true numerical representation of the light hitting the chip. This, together with careful imaging procedures, allows astronomers to make real measurements of object, providing accurate numerical data about an objects brightness and position.

Whats possible with a simple DSLR?

Image captured over Death Valley, USA at 11pm.

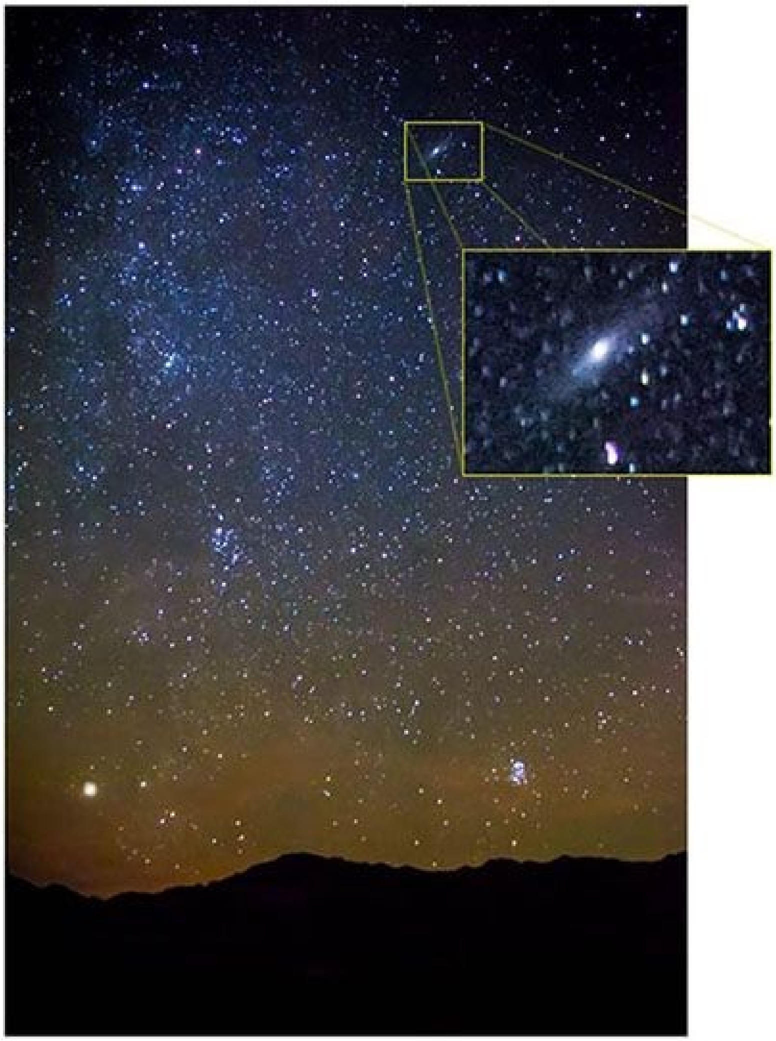
These three items in the sky of the original RAW image, interest me greatly. The bottom left is very possibly a planet. The bottom right is simply a star cluster but none the less exciting....but its the top element that got me jumping when I saw the images in Lightroom.

That my friends is a spiral galaxy!....caught on a DSLR at 28mm. NO telescope. Most likely the Andromeda Galaxy!

See the close up inset on the next page for more detail.

A processed version of the same image edited and enhanced in Lightroom. The light pollution is clearly visible, along with the stellar cloud in the top left quarter. With a DSLR this was challenging to capture, but with stacking on a CCD this would have been a piece of cake. To obtain a similar look, a lot of adjustments were made to develop the light in the image.

Our three main star-field elements above have also been enhanced.



Canon 5D Mk 2, 28mm Canon Lens. 30 seconds @ F3.5, ISO 6400. Noise reduction and enhancement in Adobe Lightroom.

ACCESSORIES AND ESSENTIALS

ACCESSORIES AND ESSENTIALS

The Telescope

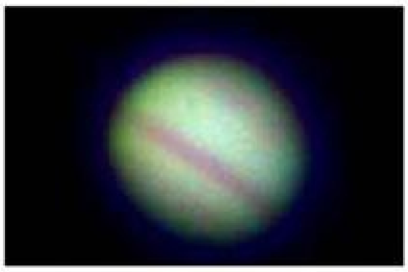
I guess this probably your most important accessory right? The telescope. Since this is about photography, I see the camera as our main tool and the telescope an accessory….some may not agree, but really the telescope gives you the view, the camera gives you the recorded result…So there, I win the argument (just jokes).

There are two ways that a telescope can be used. One way is to use the scope as a means of mounting the camera piggyback on the tube and using the scope as a tracking platform. The other is to transform the telescope into a long focal length camera lens.

Mounting the camera piggyback on a clock-driven telescope allows long exposure wide field photographs to be taken. Instead of using a telescope mounting for piggyback photography, you could construct a simple camera tracking platform, like the one described in Sky & Telescope magazine for February 1988. Essentially a hinged wooden platform, with a small motor that pulls the two hinged components away from each other at the rate which mimics the Earth's rotation. Constructing one of these is extremely simple, inexpensive and allows accurate tracking for periods as long as 20 minutes for lenses up to 210mm focal length.

Removing the telescope eyepiece and camera lens, and coupling the camera body to the telescope focusing unit allows close up views of the Moon and the brighter planets. Because of the large amount of light striking the film from these Solar System objects, use of fast films will allow short exposure photos which require no guiding and in some cases no tracking at all. Pictures such as this one can be taken easily, and with any telescope. And they yield results, which serve as encouragement to try more complicated photos next time.

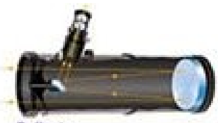
Here are the differences between three types of telescope. This is important. Refractors, Reflectors and Catadioptic (Compound).



6 inch Achromatic REFRACTOR

6 inch Newtonian REFLECTOR

Refractor

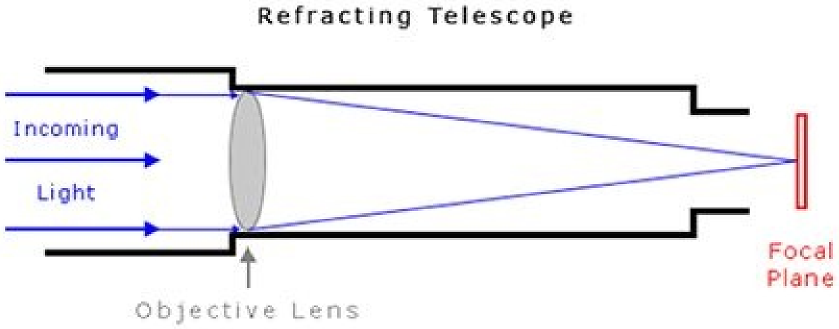


Reflector

Compound

REFRACTORS -

Refracting telescopes are the most common form of the telescope - a long, thin tube where light passes in a straight line from the front objective lens directly to the eyepiece at the opposite end of the tube.



Advantages

* Easy to use and consistent due to the simplicity of design.

* Good for distant terrestrial viewing

* Excellent for lunar, planetary and binary stargazing especially with larger apertures

* Sealed tube protects optics and reduces image degrading air currents

* Rugged, need little or no maintenance

Disadvantages

* Generally have small apertures, typically 3 to 5 inches

* Less suited for viewing small and faint deep sky objects such as distant galaxies and nebulae

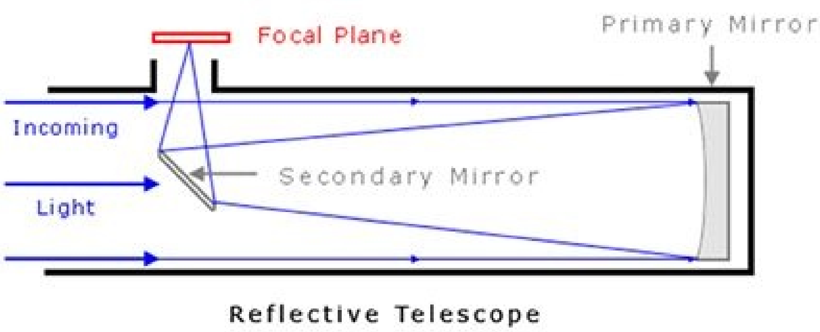
* Heavier and bulkier than equivalent aperture reflectors and catadioptrics (compund)

* Limited practical usefulness

* Good-quality refractors cost more per inch of aperture than any other kind of telescope.

REFLECTORS -

Reflecting telescopes use a huge concave parabolic mirror instead of a lens to gather and focus the light to a flat secondary mirror that in turn reflects the image out of an opening at the side of the main tube. You look through an eyepiece on the side of the tube up near the top.



Advantages

* Easy to use and even construct

* Excellent for faint deep sky objects such as remote galaxies, nebulae and star clusters because of their larger apertures for light gathering.

* Low in optical irregularities and deliver very bright images

* Reasonably compact and portable

* A reflector costs the least per inch of aperture compared to refractors and catadioptrics since mirrors can be produced at less cost than lenses

Disadvantages

* Generally, not suited for terrestrial applications

* Slight light loss due to secondary obstruction when compared with refractors

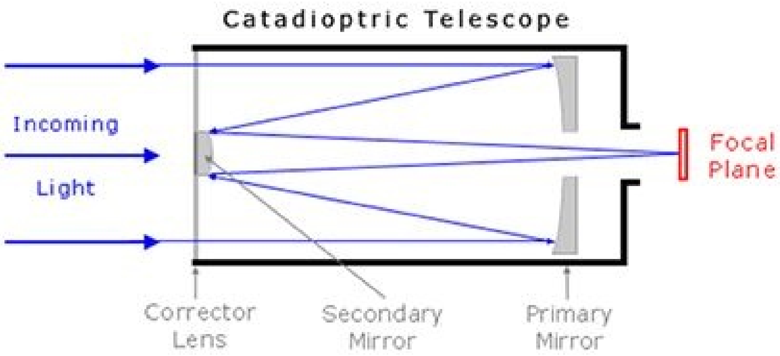
* The tube is open to the air, which means dust on the optics even if the tube is kept under wraps

* Reflectors may require a little more care and maintenance

CATADIOPTIC -

Catadioptric telescopes use a combination of mirrors and lenses to fold the optics and form an image. Catadioptrics are the most popular type of instrument, with the most modern design, marketed throughout the world in 3?” and larger apertures. There are two popular designs, the Schmidt-Cassegrain and the Maksutov-Cassegrain.

In the Schmidt-Cassegrain, light enters through a thin aspheric Schmidt correcting lens, then strikes the spherical primary mirror and is reflected back up the tube to be intercepted by a small secondary mirror. The mirror then reflects the light out an opening in the rear of the instrument where the image is formed at the eyepiece.



Advantages

* Most versatile type of telescope

* Best near focus capability of any type telescope

* First-rate for deep sky observing or astrophotography with fast films or CCD's

* Excellent for lunar, planetary and binary star observing plus terrestrial viewing and photography

* Closed tube design reduces image degrading air currents

* Compact and durable

Disadvantages

* More expensive than reflectors of equal aperture

* Its appearance may not be suited to everybody's taste

* Slight light loss due to secondary mirror obstruction compared to refractors

Telescope Attributes to be aware of -

Telescopes are designed to gather light and bring it to focus so that the image can be examined in detail with an eyepiece, or recorded on film or with a digital camera. Telescopes reveal fainter objects than can be seen with the eye because they gather more photons than the eye can gather. Smaller details can be seen because they also magnify objects.

The nomenclature used to describe telescopes and camera lenses can sometimes be confusing. Telescopes are usually talked about in terms of aperture, while camera lenses are usually talked about in terms of focal length. Most people will say they have an 8 inch telescope (meaning aperture), but they will also say them have a 300 millimeter camera lens (meaning 300mm of focal length). No wonder it's confusing! But we can easily sort this out.

Telescopes and camera lenses have three main numerical attributes that we are concerned with in describing them:

APERTURE - The aperture is the size of opening in the telescope through which the lens or mirror gathers light. It is the most important attribute of a telescope because light gathering is what telescopes are all about. In astrophotography, the larger the aperture, the more photons can be collected. Aperture, however, is not the only criteria for judging a telescope. Optical quality is just as important. You can have a gigantic aperture and if the optical quality of the telescope is not good, the light won't be very well focused, and the images produced won't be very good. Aperture is the main determinant in how faint of a star you can see with a telescope.

The down side to aperture is that as the size of the aperture goes up, so does the cost and complexity of making the optical system, as well as the weight and size. Bigger apertures also usually mean more focal length, and this makes mounting them, carrying them around and using them more difficult, especially for astrophotography. Aperture is measured in inches or millimeters (mm). There are 25.4 mm in an inch, so a 4-inch aperture telescope has an aperture of 101.6 mm.

FOCAL LENGTH - The focal length of a telescope is the distance from the objective lens or mirror at which the light comes to focus. The longer the focal length, the larger the image is that forms at the focal plane, and the higher the magnification of the telescope.

Increased magnification with longer focal lengths is a good thing for small objects like planets and double stars, but undesirable things also get magnified, like poor atmospheric seeing, and imperfections in the telescopes drive and wobble in the mounting.

Focal length is also measured in inches or millimeters. Camera lenses usually give the focal length in millimeters. A simple lens with a focal length of 300 mm will form the image 300 mm behind the lens. Some telescopes have a secondary mirror that bends the light path, sometimes even folding it back on itself, making the physical length of the instrument much shorter than the focal length would imply.

FOCAL RATIO - The focal ratio is the relationship between the aperture and focal length. The focal ratio is defined as the focal length divided by the aperture. For example, a refractor with a focal length of 800mm and an aperture of 100mm has a focal ratio of 800/100 = 8 or f/8.

The focal ration gives the relative "speed" of the optical system. This is important for recording extended objects such as nebulae and galaxies. A faster focal ratio will record an image faster (with a shorter exposure).

Focal ratio is also known as the f/ratio, and is described by the f/number.

For example, a 4 inch refractor has an aperture of about 100 millimeters. If the focal length of this scope is 500 millimeters, then we can determine the f/number by dividing the focal length by the aperture, which in this case is 500 / 100 = 5. So we say this scope has an f/ratio, or focal ratio, or f/number of f/5.

F/5 is a mid-range f/number. Mid-range f/ratios are usually about f/5 to f/8. "Fast" f/ratios are usually considered about f/4 or lower, such as f/2.8 or f/2. You won't usually find f/ratios this fast in a telescope, but you definitely will in camera lenses. Slow f/ratios are anything bigger than f/9 or so.

F/ratios are also known as f/stops in photography. Each f/stop is equal to a doubling or halving of the amount of light. For example, an f/ratio of f/4 lets in twice the amount of light as an f/ratio of f/5.6 and requires half the exposure.

The full f/stop series, in one stop increments is:

f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	f/64

These numbers continue on each end of the scale, but these are the practical working range of f/stops.

Each of these f/stops is equal to a one-stop difference in light getting through. So every time you change the f/stop by one full increment, you also have to change the shutter speed, or exposure time, by doubling or halving the exposure to compensate.

For example, at the same ISO (Film speed or digital camera sensitivity), a 1 second exposure at f/5.6 would equal a 2 second exposure at f/8, or a 1/2 second exposure at f/4. All would be equivalent.

Here is a list of equivalent exposures, all allowing the same amount of light to reach the sensor:

f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32	f/45	f/64
1/1024 sec	1/512 sec	1/256 sec	1/128 sec	1/64 sec	1/32 sec	1/16 sec	1/8 sec	1/4 sec	1/2 sec	1 sec	2 sec	4 sec

For simplicity in the short exposures, the higher shutter speeds are rounded off, such as 1/32nd sec is rounded to 1/30th sec, 1/64th to 1/60th, 1/128th to 1/125, 1/256th to 1/250th, 1/512th to 1/500th and 1/1024th to 1/1000th. The differences are so small as to be inconsequential.

If you take a camera lens with a fixed focal length, and stop down the lens, and look at the lens from the front, into the camera, you will see the size of the hole made by the diaphragm blades gets smaller as the f/number gets bigger. f/32 is a very small hole compared to f/2.8. f/32 is a “slow” aperture because the small hole does not let a lot of light get in over the same time exposure as a larger hole. It’s “slow” because it requires a longer exposure.

Long focal length instruments with slow focal ratios will work well for bright objects like the Sun, Moon and planets. You can get by with scopes with high f/numbers because the exposures will still be reasonably short. Long focal length instruments also have small fields of view.

Short focal length instruments have wider fields of view and usually have faster focal ratios and can record faint extended objects faster.

Tips on Buying a Telescope -

- Stay away from any telescope that brags about its power or magnification on the box.
- Stay away from any telescope that you can buy in a department store.
- Remember that you get what you pay for.
- The old cliche in astronomy is that there is no substitute for aperture, but this is not necessarily true for astrophotography. With good optical quality you can do a lot in astrophotography with a modest aperture.
- There is no substitute for optical quality. The optical quality of a telescope is one of

the most important attributes of a telescope. The biggest and fastest telescope won't work very well if its optical quality is not very good.

- The mount is as important as the scope.
- If you are just starting out in astrophotography, a small aperture refractor is the way to go.

Astrophotography can get to be as expensive a hobby as you want to make it. Some people spend, literally, hundreds of thousands of dollars on prime real estate in Arizona and New Mexico and build completely automated remote observatories and then stay in the comfort of their homes and download images over the internet. For those with the resources to do it, the sky is the limit on how much you can spend.

You don't have to spend a fortune however to have a million dollars worth of fun in the hobby of astrophotography. Modestly-priced equipment can take images that will give you immense satisfaction and provide years of fulfillment and enjoyment.

Buying Guides –

Here is a list of great telescopes and links to where you can get them for a decent price as well as some buying tips. All prices are approximate based on easy suppliers such as Amazon and B&H Photo-Video. Some items may have been discontinued, or updated.

Telescopes for Astrophotography **- 66mm to 85mm Aperture**

- Tele Vue TV-60is $1695 - 60mm aperture, 360mm focal length, f/6 doublet apochromatic refractor
- Astro-Tech AT65EDQ $549 - 65mm aperture, 420mm focal length, f/6.5 four-lens/two-group dual ED element refractor
- Stellarvue Raptor 70ED $449 - 70mm aperture, 420mm focal length, f/6 doublet achromatic refractor
- Astro-Tech AT72ED $379 - 72mm aperture, 430mm focal length, f/6 doublet apochromatic refractor
- Stellarvue SV80ED Raptor $599 - 80mm aperture, 560mm focal length, f/7 doublet apochromatic refractor
- Orion EON 80mm ED Apochromatic Refractor $599 - 80mm aperture, 500mm focal length, f/6.25 doublet ED apochromatic refractor
- Meade Series 5000 80mm ED $799 - 80mm aperture, 480mm focal length, f/6 triplet apochromatic refractor
- Explore Scientific 80mm f/6 Triplet ED Apochromatic Refractor $799 - 80mm aperture, 480mm focal length, f/6 air-spaced triplet ED apochromatic refractor
- Takahashi FSQ-85ED “Baby Q” $3095 - 85mm aperture, 450mm focal length, f/5.3 4-Element ED apochromatic refractor

Telescopes for Astrophotography **- 90mm to 110mm Aperture**

- Stellarvue SV90T 90mm Fluorite Triplet $1695 - 90mm aperture, 675mm focal length, f/7 fluorite apochromatic triplet refractor
- Stellarvue SV102ED Refractor $995 - 102mm aperture, 795mm focal length, f/6.95 doublet ED refractor
- Explore Scientific 102mm f/7 $1,499 - 102mm aperture, 714mm focal length, f/7 air-spaced triplet ED apochromatic refractor
- Takahashi TSA-102S $2,795 - 102mm aperture, 816mm focal length, f/8 triplet apochromatic refractor.
- Tele Vue 102iis APO $2,755 - 102mm aperture, 880mm focal length, f/8.6 doublet apochromatic refractor
- Takahashi FSQ-106ED $4,395 - 106mm aperture 530mm focal length, f/5 triplet apochromatic refractor

Telescopes for Astrophotography **- 125mm to 140mm Aperture**

- Explore Scientific 127 $1,999 - 127mm aperture, 952mm focal length, f/7.5 air-spaced triplet apochromatic refractor
- TMB 130mm f/7 Signature Series $3,790 - 130mm aperture, 910mm focal length, f/7 air-spaced triplet apochromatic refractor.
- Telescope Engineering Company TEC 140 APO Refractor $5,500 - 140mm aperture, 980mm focal length f/7 triplet apochromatic refractor
- Astro-Physics 130 EDFGT $5,975 - 130mm aperture, 780mm focal length f/6 triplet apochromatic refractor

In my short span of dabbling in astrophotography and the countless talks I have had with other astrophotographers and observatory staff, I can now admit to being prejudiced in favor of refractors. They are excellent for astrophotography. The lens is permanently mounted and usually does not require lining up. Refractors cool down quickly compared to Newtonians and other type designs. The tube is closed so that thermal currents are never a problem and dust is kept to a minimum in the optics and in the camera.

Most experienced astrophotographers find that a good 4 or 5 inch apochromatic refractor is an excellent choice for deep-sky astrophotography because of its versatility. Such a scope can keep you busy for a long time and last a lifetime.

For beginners, a small 66mm, 70mm or 80mm refractor is an excellent choice. A small telescope can more easily be mounted on a less expensive equatorial mount, and because it has less magnification, problems are not magnified as much either.

Astro-Physics makes the premier refractor telescopes on the planet, but they are difficult to obtain, with several years required on a waiting list to obtain one new from the manufacturer. Unlike most other scopes, they almost always appreciate in monetary value over time. They can sometimes be found used on Astro-Mart.

Thomas Back TMB Refractors are also excellent and much easier to obtain. Other excellent manufacturers of refractors for astrophotography are Borg, Takahashi, and Tele Vue.

Telescope Mounts

Now that you have learned about aperture, power and the different types of telescopes, let us discuss an often overlooked but very important aspect of using a telescope - the mountings. Remember that shaky view is all it takes to kill your enthusiasm! And a good mount can enhance your views. There are two basic telescope mountings:

* The equatorial and

* The altazimuth.

An Equatorial mount is designed so you can easily track the motion of the sky as the Earth turns and its motions indicate celestial north south and east west in the eyepiece. This is a great help when you’re trying to find your way among the stars with a map. If your equatorial mount is motorized it will auto track the sky and therefore your stars or celestial bodies in your frame will never move out of alignment, like a star trail.

The Altazimuth mounts are simpler and just swing up, down, left and right. You have to move the scope along every so often to follow the stars, moons and planets. An altazimuth mount is both cheaper and lighter for the same degree of stability, advantages that are offered by an equatorial mount design.

EQUATORIAL MOUNT ALTITUDE-AZIMUTH MOUNT

Tripods

A very sturdy camera tripod is needed to allow setup and pointing of the camera and also for proper sky orientation. Star and meteor trails can be obtained by simply pointing the camera and opening the shutter from 10 to 60 minutes (or longer if you wish), depending on the length of the star trail you want.

Technology has seen some amazing advances in recent years. With today’s fast lenses, you can take constellation pictures showing details down to about magnitude 9 in less than 20 seconds. Which means that no tracking of any sort is required. Just point the camera at your subject and shoot. If you're using a 50mm focal length lens, then the star trails will be small enough that they will not be seen. Using a 35mm focal length lens to capture an even wider area of the sky, increases the exposure time to approximately 25 seconds before star trails become a problem. Your tripod is going to become your trusty sidekick for every image. Get use to carrying it around.

Camera Adapters

You will need one of these to attach your DSLR camera to the telescope for prime focus astrophotography. This lets you use the scope in place of your camera lens.

A T-mount ring is a coupling that has the bayonet mount of your particular camera model on the back, and a standard T-thread on the front. An adapter threads into the T-ring, such as 1.25 inch and 2 inch tubes, that fit into standard telescope focusers. If your telescope has a 2 inch focuser, always get the 2 inch adapter. If you get the 1.25 inch adapter, it will almost certainly vignette the image.

Canon EOS T-Mount Ring $18 - You will need the specific adapter for your particular camera brand.

2-inch Adapter $20 - For 2 inch focusers.

CNC Parts Supply has combined the two parts into one piece with a wide opening. If you have a full-frame sensor camera, this is the adapter you want to prevent vignetting.

CNC Parts Supply "True-2" wide 2 inch Adapter $79 for Canon or for Nikon. This adapter is specifically made wider than a normal adapter so that it will not vignette.

Remote Release Switch (or cable release)

A remote switch is basically a button on a wire that plugs into the camera that allows you to open the shutter remotely, and keep it open as long as the button is pushed, or locked down. This allows the exposure to be started without touching the camera, to reduce vibration and possible movement when the shutter is opened or closed.

JCC Remote release timer for Canon consumer cameras.

DSLRbaby also makes models for most other DSLR cameras. ($30)

Canon TC-80N3 for the Canon 1D, 10D, 20D, etc. ($130)

Nikon MC-36 Remote Trigger with timer for F5, F100, N90S, D1, D2H, etc. ($140)

Adapter for TC-80N3 to use with the Canon 300D and 350D without changing the TC-80N3.

Stereo Plug adaptation in the cable of a TC-80N3 so the timer can be used with different cameras, or an extension cable used. ($28)

DSLRStar - DSLRStar is a special hardware/software device made by Cercis Astro for controlling long exposures on Canon DSLR cameras for astrophotography. It can work as a stand-alone device for control of the camera in the field without a computer, or it can interface between a computer and the DSLR camera body. DSLRStar will automate exposure sequences including type, duration, delay between exposures and mirror lockup use. DSLRStar also stores information about the exposure, such as type, duration, time, date and temperature in its non-volatile memory. This information can be synchronized later with the exposures. With a built-in temperature sensor it can automate the capture of dark frames, taking darks within a specified temperature range. ($150)

Canon TC80-N3 Remote Release Timer

Remote Timer Release (different to a cable release)

Not to be confused with a remote release switch, a remote timer release is basically a timer on a wire that plugs into the camera. Sophisticated timers like the Canon TC-80N3 and Nikon MC-36 allow the exposure length, number of exposures, time between exposures and a self-timer setting to be programmed. An entire exposure session can be programmed in, for example, 16 exposures of 5 minutes each with a pause of 10 seconds between each frame, allowing the photographer to take a nap while the camera merrily shoots away the night.

DSLR Camera Batteries / External Power

Shooting long-exposure astrophotographs uses up a lot of power, especially in cold weather. Shooting continuously with no display on the LCD, the in-camera Canon BP-511A lithium ion battery for the Canon 20Da will last about 3 hours at 50 degrees F. It will last a lot less time in cold weather.

If you are planning on shooting all night, especially in cold weather, you will need extra batteries, or alternative power supplies. I use a 40 watt Digital Camera Battery to power my DSLR camera, and it will last about 6 hours at 32F with the camera running continuously. If the LCD screen is used frequently, batteries will not last as long, and the camera will heat up more, so it's probably a good idea to use it as little as possible. If the in-camera battery dies in the middle of writing a file you may lose images and it may corrupt the images already stored on the card. Keep an eye on your battery level.

Telescope Power Supply

If you are shooting from your backyard, you can probably just run an extension cord and plug into your 110/220 volt household electricity. If you are shooting from a remote location without electricity, you will need an auxiliary power supply such as a 12 volt gel cell or deep-cycle marine battery.

You may think you can run your setup off the car's 12 volt battery, but this is definitely not recommended or you run the risk of getting stuck in the middle of the woods with a dead car battery in the morning. Car batteries were made to deliver a lot of power all at once to start an engine, and then to be charged continuously by the car's alternator after the engine starts. Car batteries were not made to deliver a continuous voltage over a long period of time.

Deep-cycle batteries are made to deliver a continuous voltage over long periods of time. Get a high capacity deep-cycle marine battery to run your astrophotography equipment for about $75 to $100.

Cold weather can also lower the capacity of a battery if you plan to use it in an all-night astrophotography session. By the time you supply power to the mounts drive, an equatorial auto guider, anti-dewers, camera, and computer, you may be using a lot more power than you think.

Computer Power Supply

For using a computer in the field at a remote location without AC power, consider purchasing an additional deep-cycle battery to power your computer separately from your telescope and mounting. There have been many reports of auto guiders not playing well with computers when everything is run from the same power supply. Also, electrical interference may show up in your digital images if everything (Scope motors, drive corrector, anti-dewers, camera, and computer) is powered from a single DC battery. You may be able to get away with it and not have any problems, but unless you have a battery with a huge capacity, you probably will not be able to make it through a long winter night on a single battery anyway.

Extra Memory cards

It is good to have several large capacity memory cards for your DSLR camera, unless you download the images directly to a laptop. If you shoot raw format for your light frames, and also shoot all of the support frames required for advanced calibration (darks, flats, bias, flat darks, and flat bias), you can easily fill up a 1 gigabyte card on only one object.

I don't recommend getting a single, gigantic-capacity memory card, such as a 16 gigabyte card and storing all of your images on that one card from an all-night astrophotography session. If something goes wrong with it, or it gets corrupted, you will lose a lot of hard work. Instead, get several smaller capacity cards and spread the night's images over them as the night goes on.

You will also need a compact flash or SD card reader for your computer. It will download images from your memory card much faster and more reliably than hooking up your camera to your computer. It will also save wear and tear on your camera.

Focusing Aids

Trust me, you will need something to help you focus, either hardware or software. The best and easiest solution is Live View focusing with one of the newer DSLR cameras. With Live View you can magnify the image of a moderately bright star 5x or 10x and focus very easily. You can also output the analog video signal out of the camera to a separate monitor or computer if the LCD on the back of the camera is at an awkward angle.

If you have an older DSLR camera, the easiest solution is probably to use a Bahtinov mask. You can easily make this mask yourself out of black poster board from instructions you can find here at the Astrojargon Bahtinov Mask Generator. You can also purchase a high-quality Bahtinov mask at Spike-A.

There are several ways to use the mask: looking through the viewfinder of the camera and focusing visually, examining the image after it is shot on the LCD on the back of the camera, or viewing the image with Live View in real time as you focus.

If you decide you want to try to focus visually through the viewfinder of the camera, and use a scope where the back of the camera is pointing down towards the ground when the scope is pointing overhead, you will find it very uncomfortable to try to look through the camera to focus. In this case you might want to consider a right angle finder. If you have a Newtonian telescope, you probably won't need one. If you plan on using a computer with your camera and software to focus, you probably won't need one. If you plan on using a camera with live-view focusing, you probably won't need one.

Other Hardware Focusing Aids

Another focusing solution is to use a knife edge or ronchi screen that has a matching lens mount for your camera, and that replaces the camera on the scope to focus, such as the Stellar International Stiletto. The knife edge or ronchi screen must be parfocal with the camera's sensor. After focusing with this hardware device, the camera is replaced and the image taken. These can work well because they do not require any computer equipment in the field, but they do not help with finding and framing dim deep-sky objects, and they do not work with extended objects such as the Moon.

Stellar-International also offers the CVF focuser. It also replaces your camera for focusing. It works by projecting the scope or lens' image onto a groundglass which is examined under magnification. The CVF focuser is parfocal with your particular camera model, and will work for daytime subjects as well as stars and extended objects.

Stiletto ronchi screen focuser $219

CVF focuser $169

Mitsubishi Canon EOS 202 knife-edge focuser $275

Live-View Focusing

The Canon 20Da was the first astronomical DSLR camera to offer live-view focusing. The latest generation of DSLR cameras, such as the Canon 5D Mark II, 50D, 40D, 450D, 500D, 550D 1000D, 1D Mark III, 1D Mark IV , and Nikon D3, D3S, D3X, D300S, D300, D5000, D700 and D90 also now offer this capability.

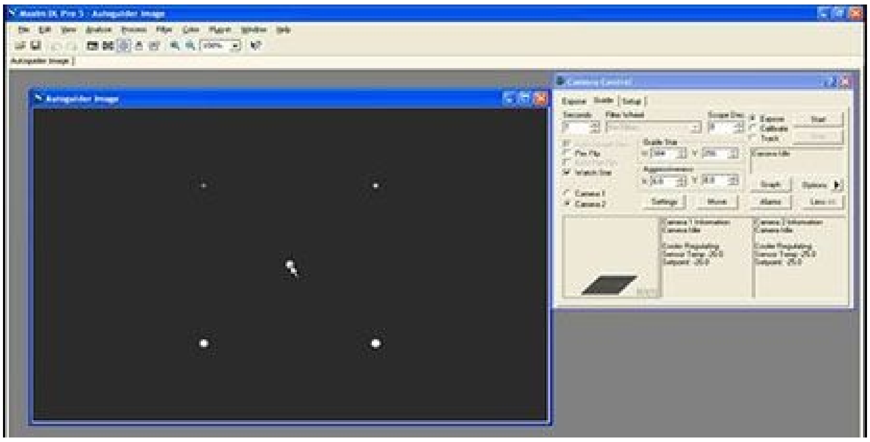
During live-view, the mirror is flipped up out of the way of the light path and the shutter is opened. The live image is then sent to the LCD screen on the back of the camera in real time or "Live-View". The image can also be enlarged and magnified electronically. This live-view can also be fed to an auxiliary monitor or computer for easier viewing.

The live-view video feed can be used directly to focus a star in real time. The location of the LCD screen on the back of the camera however can be at an awkward position such as when a refractor or SCT is pointed overhead. It can be much more convenient to use a separate external monitor in these cases.

With these new cameras, the Live-View video can be sent through a single USB 2 cable to special software running on a computer for viewing, camera control, and long-exposure shutter release. With previous camera models, two cables were necessary for computer control: one USB cable to control camera functions and one serial cable to control the long-exposure bulb remote release. For the Canon 20Da, a third cable was necessary for the live-view video out.

Computer Software Assisted Focusing

Any DSLR camera can be used with certain software programs like Images Plus, and Maxim DL and Nebulosity that can take over control of the camera and shoot a test exposure. The image is then downloaded to the computer and opened up and examined by the software. The software then calculates the size of the star and begin a series of test exposures where you changed the focus slightly and examined the numbers for the size or brightness of the star. Through a process of trial and error you could achieve a very accurate focus. This process can be time consuming, especially when the atmospheric seeing was not that good which would naturally cause star sizes to vary, but with patience, it yields very accurate focus.



For older camera models, such as the Canon 20D, 30D, 40D, 350D and 400D and the Nikon D70, D80, D50 and D40 that did not offer live-view focus, this type of computer software assisted focusing was probably the best way to focus because it uses an actual image off the sensor.

The drawback to computer software assisted focusing is that you must have a computer in the field with you, along with the extra complexity and logistics of powering it, and protecting it from cold and dew.

Canon’s computer-control software for the EOS 5D Mark II/III, 50D, 40D, 450D, 500D, 550D, 600D, 650D, 700D, 1000D, 7D, 70D, 1D Mark III, and 1D Mark IV allows total control of all camera functions via a single USB2 cable, including programing time exposures, display of the live-view video and even autofocus.

Nikon’s software offers much the same functionality for the D3, D3X, D3S, D300, D300S, D700, D5000 and D90, but the software costs extra and a second cable is required for bulb exposures longer than 30 seconds.

Computer Equipment

Depending on how you focus, you may not need a computer for work in the field. You could use the Canon or Nikon Remote timer release TC-80N3 or MC-36 to automate all of your exposures, or you could use a laptop computer in the field to run the camera and download images. You will need the computer if you decide to use a software assisted form of focusing. If you do use a computer, you won't need the TC-80N3 or MC-36.

- Laptop Computer for field work $450 and up. I use a MacBookPro.
- Ideal Astronomy SightSaver Red plexiglass for nighttime viewing on laptop computer $24.
- Red Rubylith for dimming the laptop display for use at night $14.
- Hoodman Light / Dew shield for laptop screen $35.
- Portable field power supply - 12 volt Marine deep-cycle battery and charger.
- Inverter to power laptop from 12 volt battery.

Hardware Cables for Long Exposures -

Almost every DSLR camera made offers the ability to take exposures longer than 30 seconds, but a special "Bulb" setting must be used. The shutter can be opened for as long as you like, but the shutter button must be held down the entire time, or a special long-exposure remote release cable used (see the section on remote release switches at the top of this page).

Newer cameras in the Canon line can access the bulb setting through software computer control through the USB2 cable, but Nikon cameras need a second cable and special program to run long time exposures through a computer.

Older DSLR cameras, such as Nikon's D40, D50, D70, and D80 and Canon's 20D, 30D, 350D and 400D, also offer the capability for longer exposures via a "bulb" setting, but it can not be accessed with the normal USB camera control cable. To use the bulb setting with a computer, you have to access it through the camera's remote release plug. In this case, both Canon and Nikon use a proprietary plug on their high-end DSLR cameras. The less expensive Canon Digital Rebels use a mini photo plug that is easily obtained. Nikon D70, D60, D50, D40, and D40X users can only remotely access the bulb setting remotely with an Infrared remote. In these cases, you will also need either a serial or parallel cable out of the computer to interface with the camera bulb plug, or IR remote.

Some new laptops do not offer either parallel or serial plugs, and only have USB ports. In this case, a USB to Serial adapter is needed.

Hap Griffin offers cables for controlling the DSLR from a computer via a serial or parallel port. Shoestring Astronomy also offers shutter control interface products.

For older Canon cameras, and all Nikon cameras, you need two cables to control and automate a long-exposure session from a computer:

USB cable to control the camera settings

Serial or Parallel cable to the camera bulb plug (or IR remote for Nikon) for long exposures

For the latest generation of Canon cameras you only need one USB2 cable to control and automate all camera functions from a computer.

Guiding

Even with excellent polar alignment and tracking, for the highest quality work, astrophotos need to be guided during long exposures. Guiding means keeping a star perfectly centered to account for variations in the telescope's drive and atmospheric effects. Guiding is usually accomplished with either an off-axis guider or separate guide scope.

Any type of telescope with a mirror, and especially Schmidt-Cassegrains, needs to be guided with an off-axis guider. This is because the primary mirror in the imaging scope can move while the guidestar in the guiding scope does not. An off-axis guider solves this problem by using the imaging scope to guide with. Many beginners try to re-invent the wheel and guide an SCT or Newtonian scope with a separate guide scope, but after they tire of hitting their head on the wall and get some experience with the frustrations of the inconsistency of this method, they realize that to produce excellent images, an off-axis guider is necessary. Off-axis guiders are more difficult to use, but guide star acquisition can be planned beforehand with star charts.

For refractors, the best separate guidescope is usually a well made, small refractor in the 50-80 millimeter aperture range. Mirror and compound telescopes do not work well as separate guidescopes because their mirrors can move separately from the imaging scope. If a separate guidescope is used, it must be rigidly mounted to prevent flexure between the guidescope and imaging scope. A piggyback arrangement with the guidescope on top of the main imaging scope usually works best. Very small scopes can be shot side-by-side on a tandem bar, but these setups are very prone to flexure with larger scopes.

Lumicon Newtonian Off-axis guider (OAG), Lumicon 2" Cassegrain Easy Guider - Because compound telescope designs can suffer from mirror movement and flexure during a long exposure, you will need to use an off-axis guider for guiding these types of scopes.

Guidescope - Auxiliary guide scopes (a small 50-80mm doublet refractor) can be used for long telephotos mounted directly on the tracking mount, or with refractors used as the primary photographic instrument. An auxiliary guidescope is easier to use than an off-axis guider in terms of convenience and setup, but should not be used with a Newtonian or SCT because the mirror can move in the primary scope and not be seen in the guidescope. Expect to pay between $120 for a small refractor, to $380 for a complete guidescope package including the scope, rings, autoguider, and dovetail bar.

Guidescope Rings ($110) - You will also need mounting rings for the guidescope.

Autoguider- An autoguider is basically a CCD camera and computer that monitors a guidestar's position and makes corrections to keep the guidestar exactly centered.

The guidestar is monitored either in a separate guidescope or through the main telescope with an off-axis guider. The computer then automatically controls the right ascension and declination motors of the mount through the drive corrector system of the telescope to correct for drift during an exposure caused by factors such as periodic error and atmospheric refraction.

There are basically three kinds of autoguiding setups:

Stand-Alone autoguiders have the computer built into the autoguider so a separate computer is not necessary.

SBIG's SG-4 is a new stand-alone autoguider that will be available in the spring of 2009. It will cost $995. All of the electronics are contained in the head unit with the sensor, and all that is required to use it is a power supply and interface cord for the autoguider port on the mount.

SBIG's SG-4 Autoguider

LVI in Italy, also offers a stand-alone autoguider, the LVI Smartguider, costs about 432 Euros. It is available from Orion Cameras in the United States and branded as the Orion Starshoot Solitaire autoguider. It costs $499.

Lacerta, a Hungarian company, makes the Lacerta MGEN, an interesting standalone autoguider that costs about 480 Euros. It will also control a Canon DSLR camera as an interval timer, and dither. Dithering means to move the pointing of the scope very slightly between exposures to reduce noise when the images are stacked.

Lacerta MGEN Autoguider

The SBIG ST-4 (approximately $500 or less used) is the classic stand-alone autoguiding solution. The SBIG ST-V ($1,000 used) was another stand-alone autoguider offered by SBIG. It uses a much more sensitive chip that can guide with only a small finder scope, but is more expensive because it is also offered as an imaging solution. Neither are currently manufactured, but they can be found used on Astromart.

SBIG now has a new stand-alone autoguider, the SG-4. It costs $995.

CCD cameras can also be used as autoguiders with the proper software, but require a separate computer, such as a laptop, that uses software to analyze the position of the guidestar and issue corrections to the telescope drive.

Orion StarShoot Autoguider $250

Fishcamp Engineering Starfish $995

SBIG ST-402 $1,495

Inexpensive CCD cameras such as the Celestron Neximage ($99) and Meade DSI can also be used as autoguiders.

These also require a separate computer to work.

Programs that control the telescope with an autoguider, such as GuideDog $Free, Guidemaster $Free, and PHD Guiding $Free should work with any mount that uses ASCOM protocols for telescope mount control.

You may also need some type of autoguider port interface. Orion offers a nice little package for autoguiding that includes a very short focal length refractor, mounting rings, dovetail plate, and the Orion Starshoot autoguider for $379. It requires a computer to run the autoguider.

KW Telescope in Canada also offers a similar KWIQ autoguiding package, but with the autoguider permanently focused at infinity in the guidescope, which is very convenient because you don’t have to focus the autoguider each time you go out. It costs $349 US, and also requires a computer to run the autoguider.

Unguided Astrophotography

With the widespread use of DSLR cameras for long-exposure deep-sky astrophotography, a school of philosophy has developed that says you might be able to get by without guiding at all. This can be very attractive because guiding adds additional expense and complexity to an astrophotography outing. If you can do this successfully, you can save the expense of either an off-axis guider, or separate guidescope, rings, diagonal, guiding eyepiece, autoguider and computer.

Basically, you just shoot a bunch of exposures, and then throw out the ones with poor tracking.

Dew caps, Anti-Dewers

Unless you live in the desert, you will probably encounter problems with dew, especially with SCTs. The first line of defense is a dew cap, but auxiliary heaters are also usually required. “Dew Removal” is a mis-misnomer. If correctly used, these systems will prevent dew from ever forming, which is really what you want.

Dew-Not anti-dewers

Kendrick’s Dew Removal system

Thousand Oaks digital dew heaters

Sky and Telescope article on how to make your own Anti-Dewers

Crayford Focusser

If properly constructed and manufactured, a Crayford focuser, by design, is excellent for both visual and astrophotographic work. It features two sets of bearings against which a focusing tube is help in place by the shaft for the focusing knobs. This gives three planes of contact that prevents wobble, backlash and radial play.

A good focuser is a critical component in obtaining excellent astrophotos. If there is slop in the focuser or it is not well constructed, the image will shift positions as the direction is changed making focusing a challenge. The focuser should also have a solid lock down so once focus is obtained it will not move or shift during long exposures. A 2 inch focuser is a requirement for almost all types of astrophotography.

Starlight Instruments Feathertouch

Motorized Focuser

Like a computerized Go To mount, a motorized focuser is not a requirement for astrophotography, but it can make life easier. Some designs have a position indicator that can be used to repeat a position accurately for use in trial and error software assisted focusing. In this procedure, a star is selected in the frame, and then a numerical readout is given of the star’s size or brightness. The focus is then moved a small amount and the numbers are recorded. This process is repeated until the position of best focus is obtained, and the focuser is moved back to that position based on the readout of the focuser position indicator.

Starlight Instruments Feathertouch motorized focuser

Starlight Instruments Digital Focusing System

JMI Motofocus

JMI Digital Focus Counter

[OPTEC Temperature Compensating Focuser]

Polar Alignment Scope

Some mounts come with a polar alignment scope as standard equipment. Some mounts don’t have a hollow polar axis to accommodate one. Some mounts can accept one, but must be obtained as an additional purchase. A good polar alignment scope can get you close enough so that you can shoot long exposures with camera lenses and not do any drift alignment. For long exposures at long focal lengths, a polar alignment scope can save quite a bit of time in the drift alignment process. Each mount that takes a polar alignment scope will require the specific one that it is compatible with, so no recommendations are made here, it just depends on which mount you have.

[Check out this PolarAlign App for the iPhone]

Astro-Physics PolarAlignAP 1.0, an App developed for use on iPhone and iPad

Filters

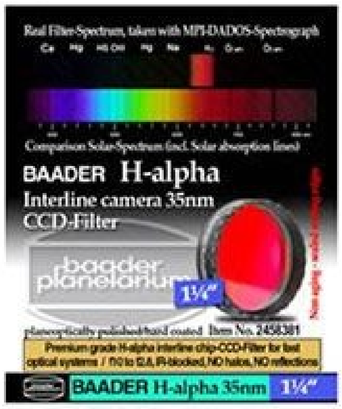
Different types of filters can be used for various purposes both for astrophotography and for visual observing.

[Hydrogen-Alpha Filter] - This is the wavelength that makes red emission nebulae glow. There are basically two types of hydrogen-alpha filter for deep-sky work. A cutoff filter blocks all of the light below the hydrogen-alpha wavelength. This greatly increases the contrast between the hydrogen-alpha emission nebula and the sky background but requires longer exposures. They are recommended for use with CCD cameras.

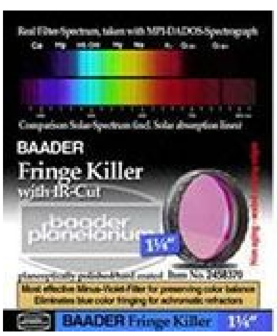
WARNING - THESE FILTERS ARE NOT TO BE USED FOR VISUAL OBSERVING OF THE SUN!

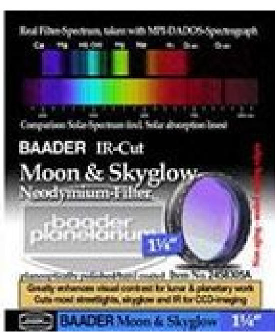
There are also extremely narrow band hydrogen-alpha filters with bandpasses under 1 nanometer that are used for visual solar work. These filters are used with an energy rejection pre-filter that goes in front of the objective of the scope while the hydrogen-alpha filter goes in the light path between the objective and eyepiece or camera. These filters typically range from 0.2 to 0.6 nanometers.

Warning! Never look at the sun without a proper safe solar filter.

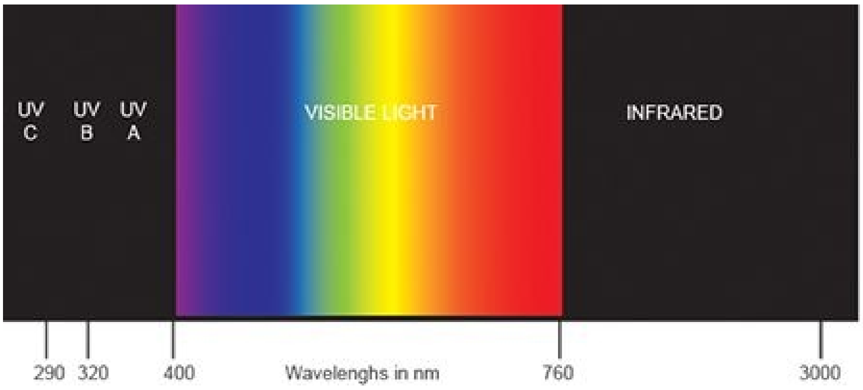


[Minus Violet]() - These filter out excessive blue wavelengths for refractors and camera lenses that are not apochromatic. Because these non-apo lenses do not focus the blue light at the same focus as the rest of the spectrum, they appear as out-of-focus blue halos around stars. The minus violet filter can remove most of this blue fringing and yield smaller stars.





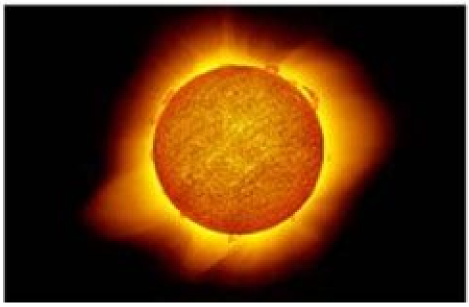
[Ultra Violet / Infrared (UV/IR)]() - Ultra violet wavelengths are those wavelengths shorter than the violet-blue end of the visible spectrum. Infrared wavelengths are those longer than red on the other end of the visible spectrum. These filters are primarily designed for use with optical systems that use lenses to correct for these wavelengths not coming to the same focus as the visual wavelengths.



Light Pollution - Filters such as the IDAS LPS1 and Astronomik CLS selectively filter out portions of the spectrum that are most adversely affected by man-made light pollution, but let wavelengths important to astronomical objects pass through. A typical exposure that would be limited to one minute because of sky-background light pollution can be increased to 3 to 5 minutes with a light-pollution filter. This will greatly improve the signal-to-noise ratio in the image.

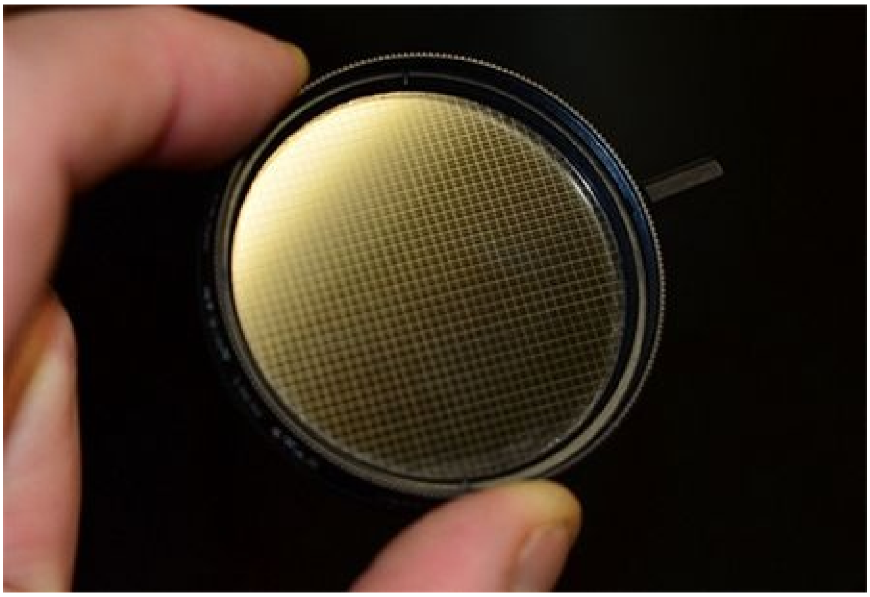
The Astronomik CLS filter “clips-in” to the inside of the camera body in front of the mirror. This allows you to buy just one filter and use it with any size scope or camera lens. The only drawback is that you can not use Canon EF-S lenses because they protrude too far into the camera body.

Solar Filters - These filters properly filter out the overwhelming energy of the Sun and allow safe visual and photographic observation in white light. Baader in Germany makes the best one. It can also be purchased from Amazon here.

[Narrowband Filters]() - These filters pass the wavelengths in a narrow band, typically 3-5 nanometers, around the wavelengths such as oxygen III, hydrogen-beta, or sulphur II. These filters increase the contrast between the wavelength of interest and the sky background. They are recommended for use with CCD cameras.

[Artistic Effects]() - Fog filters and “star” filters are used for artistic effects. A fog filter is a diffuser that is used in front of the lens that puts a halo or glow around bright stars. A star effect filter simulates diffraction spikes around stars that are typical in a newtonian reflector.



EXPOSURE

EXPOSURE

Using Available Light

This is where it gets interesting, because available light can come with light pollution, and that can both ruin and enhance your image depending on how you let the light pollution interact in your composition.

For wide star field images, start with some pretty standard settings, say F4, 30 seconds, ISO 3200, with focus set just a hair shy of the infinity mark. That will serve you in any setting to see just how much light pollution is sitting in your image. If the night sky has anything other than a dark, dark blue/black hue, then you have some level of light pollution. It could be a simple street lamp across the road or on an adjacent hill. Yes, your camera will pick up on that tiny amount of light.

If you have the ability to get any from the city, do it, trust me your images will be so much more improved, even if you start with the settings I mentioned above.

Low Light Rewards

Obtaining images at night or in very low light conditions can be surprising and rewarding. The camera reveals things that the unaided human eye cannot see. Our eyes only discern shades of gray in low light, but the camera sees color. Turning out the light does not make a thing go away. The chair still remains in the dark room as is painfully clear when “discovered” by means of the shin. Although our eyes can not see color in the dark or collect photons (light) over long periods of time the camera can. The amazing photographs from the Hubble Space Telescope are sometimes created by exposing the sensor for minutes – or hours – at a time. Because there is so little light it takes a long time to collect enough photons to reveal what is there. The camera can also “see” wavelengths (colors) that the human eye cannot – for example, infra-red and ultraviolet.

Metering at Night

The built-in light meter in your camera is completely unreliable when shooting at night. If I were giving odds, I’d say your chances of taking a photograph with correct exposure using a through-the-lens (TTL) meter—which is the most sophisticated type of in-camera meter available today—would be one in ten. There are two reasons for this: First, night compositions consist mostly of very dark or black shadows. In an attempt to interpret this as middle gray (which is the exposure value a camera is always trying to get to), the picture becomes lighter and is therefore overexposed. Since the ideal scenario is to have total control over your exposures, that isn’t acceptable. If the night sky is included in the shot, such as a starfield array, that makes it even more difficult for an in-camera meter to read the scene accurately.

Second, if there are brilliant highlights in the shot, like the moon, the meter will err in the other direction. In trying to make the highlights middle toned, it makes the picture too dark. An underexposed image may render highlights with some detail, but the rest of the picture will be hopelessly underexposed with a loss of detail in most or all of the shadows.

You may think that the dark shadows and the bright highlights will balance each other and the exposure will end up being perfect. This doesn't happen. There would have to be equal amounts of shadow and highlight for this to work, and in the real world, that's unlikely. The truth is that any combination of extremely bright highlights juxtaposed with dark shadows is a mystery to an in-camera meter. It tries to make sense of it to give you a correct exposure, but in most situations it fails because it only understands subjects that are middle toned.

Can you see how difficult a job the camera has at night?

Well, this is where our skills must enter and we have to negotiate with the camera a refined setting as close to what can possibly be achieved. Several settings in your camera and a hand held light meter allow this.

A handheld light meter gives you the option of reading a very small portion of a scene or subject. The spot metering function on Sekonic meters, for example, reads a narrow 1 degree. This is a precise way of determining exposure and it removes all the guesswork. You don't ever have to be insecure about exposure again when shooting at night.

Now I hear you ask….but all I see in the viewfinder is black and a few white dots being the stars…..how could I possibly use a light meter to measure that light. The answer is to use the "spot meter function" and pinpoint the brightest star in your frame. If you have the clouds of the Milky Way in your frame, measure parts of those as well. Your hand held light meter will give you a reading on what the different exposure values are for each part of the Milky Way. Surprisingly there isn't a great deal of difference between the highlights and shadows, as an overexposed star can be accepted a lot more than an overexposed street lamp.

The 500 rule

Due to the rotation of the earth it appears as though the stars are moving through the sky in long exposures. Star trails can be a desired effect when done for much longer exposures like this image Starry Night which was a 90 minute exposure. But in this case we want points of light to represent how we see the stars with our eyes. To achieve points of light you can use a simple rule, it's often called the '500 rule'.

The 500 Rule: is simply 500 divided by the focal length of your lens = the longest exposure before stars start to trail or blur (in seconds) For example; let's say your taking a shot with a 20mm lens on a full frame camera. 500 / 24 = 25 seconds. A 50mm lens would mean 500/50 = 10 seconds.

Others may talk of the 600 rule as well, but really, I believe the 500 rule is more accurate and is the best approach as you risk having a small amount of trail using 600. If you never intend to print your images very large then you can use this number to capture a bit more light and nobody will know any better. Smaller prints or web sizes will not show this small trail, but large prints will. This is your choice, but you don’t know what the future holds so you should consider starting with 500.

Use this handy chart to time your starfield shots BEFORE the trail begins.

Focal length (in mm)		Full frame 35mm	Crop Factor 1.5 (Nikon)	Crop Factor 1.6 (Canon)
10	→	40 seconds	33 seconds	31 seconds
20	→	25 seconds	17 seconds	16 seconds
28	→	18 seconds	12 seconds	11 seconds
35	→	14 seconds	10 seconds	9 seconds
50	→	10 seconds	7 seconds	6 seconds
70	→	7 seconds	5 seconds	4 seconds

Note the numbers above are not rounded. You do not have to use the exact number, and I would round down, for example for 18 seconds would round to 15 rather than 20. It is possible to use the exact number if you have an intervalometer; simply set your shutter to BULB and set your intervalometer with these settings: Delay-0, Long-18”, Intvl-1”, N-1. This will take 1 shot that is 18 seconds long.

Follow this simple formula and you will be well on your way to creating images of stars that will wow your viewers.

Stacking Exposures

Serious deep-sky astrophotography requires shooting many short exposures. This can be done manually, but it is very tedious. For example, faint deep-sky objects may require several hours worth of 5 minute exposures that are later stacked or combined in subsequent image processing.

Software such as Images Plus or MaxDSLR can automate this process. You simply specify in the software that you want the camera to shoot, say, 25 exposures of 5 minutes each at ISO 1600 with a pause of 10 seconds between frames (to give the system time to download each image).

Simply put, “stacking” means combining many individual short exposures into a master image by using mathematical processes such as averaging, or addition. The term originates in the days of film astrophotography where images were literally stacked on top of one another to improve contrast and color.

There are several different kinds of stacking, but what this treatise addresses is brightness compositing (called lighten mode in Photoshop). In brightness mode, the brightest pixel at each position from all of the images in the input appears in the resulting output image.

Now you cant just stack images, they will also need to be aligned so that the stars in them line up perfectly.

Whatever software you use for image calibration will almost certainly also do aligning and image stacking. It is possible to align and stack images in Photoshop, but for more than a couple of frames, the process is extremely tedious and not as accurate as with a dedicated astronomical image processing program.

To calibrate your original raw astronomical images, you will require some type of special astronomical image processing software, such as Images Plus, MaxDSLR, AIP (Astronomical Image Processing), AstroArt, IRIS, Deepsky Stacker or Regim.

Both Canon and Nikon usually include image processing software with their cameras, but this software is for processing normal daytime images. You can not use it for image calibration, aligning, or stacking at all.

When taking a star trail there are three options: one long exposure (often not practical due to battery, sky glow or camera noise limitations), several intermediate length exposures (e.g. one to ten minutes each) or a hundred or more short exposures (20 to 30 seconds each). If a programmable timer is not available then many short exposures may be the only viable option.

Use the table below to identify the best stacking method for your desired image.

EXPOSURE LENGTH (TIME)	ADVANTAGES	DISADVANTAGES
Less than 30 seconds	If an object (plane, car, cat, flashlight) marks up one image the image can be dropped from the stack or edited using a simple black out technique. May be the only practical solution if there is a lot of sky glow (which forces shorter exposures). Can be done by taping down the shutter button if the camera has a "continuous shutter" mode. Can create animation from the images. More images means averaging can reduce the overall noise.	Lots of images may use up card memory. May have to use lower quality images (smaller size). Must stack images (post processing). Cameras have an operational life span that is shortened by every "shutter operation" so more images means shorter camera life. Camera imposed delays between exposures may cause "dotted" star trail images.
More than 30 sec, but less than 10 minutes	Fewer images means more space available for highest quality images (preferably RAW). Every exposure has a segment of a trail. If the battery runs out only the last image is lost. Camera-delay imposed gaps between trails are less intrusive.	One blown exposure leaves a hole in the result. Requires a locking cable release and preferably an intervalometer (programmable timer). Must get the timer set properly to avoid gaps (e.g. must allow one to three seconds between the end of one exposure and the start of the next.
10 minutes or longer	Everything is in one exposure so there is less (or no) post processing. When using a locking release cable the exposure can be set and left alone for a long time without oversight or intervention. No intervalometer is needed. The "long exposure noise reduction" feature can be used to improve the image. No gaps in the trail.	It is an all or nothing proposition – your exposure completes properly or the battery runs out. Good star trails, IMHO require HOURS of exposure, not minutes. There may be unacceptable and uncorrectable noise. Some loss of contrast is likely. Foreign elements – head lights, flashlights, airplanes, etc. – may spoil the whole exposure. For film shooters, expect reciprocity failure and color shift. Long exposures with noise reduction turned on double the length of the exposure. Very long exposures are only possible in very dark skies.

CONSIDERATIONS

CONSIDERATIONS

Preparing the Photographer for the Night

This one is pretty simple. Bring layers of clothes and dress more warmly than expected. A thermos of hot beverage, snacks and perhaps a blanket or sleeping bag and a comfortable chair are all useful. While it is very tempting to use a flashlight or a headlight to see in the night and it is wise to bring one of each better overall night vision is achieved by turning off ALL light and allowing the eyes at least 15 minutes to dark adapt. Turning off all lights should include turning off the camera's various displays, or at least turning them to the lowest brightness level possible.

Preparing the Camera for the Night

When photographing with a digital single lens reflex (DSLR) camera each of the following guidelines should be heeded (in fact, we have a checklist with even more detail):

- Use the fastest, widest lens for capturing the sky such as f/2 or f/2.8 at 17mm (or wider) if possible. f/4 or f/4.5 will work, too.
- Keep extra batteries accessible.
- Know the camera controls and where the buttons are without resorting to flashlights or artificial light.
- Use a sturdy tripod, well supported and weighted down. Insure that you can change the memory card or the battery without moving or removing the camera on the tripod.
- Turn off all the accessories that drain battery life – e.g. turn off the "image preview" feature and the on-screen display of shooting data.
- If using a timer with an initial delay, the camera may auto-power off before the first image is taken. This means the camera must be able to return to the settings needed, not back to different power on settings. For many Canon DSLR models, it may be necessary to use the C1, C2 or C3 (customer user settings) function.
- Pre-focus on infinity and remember to TURN OFF AUTOFOCUS! The moon or a bright light in the distance are great tools for focusing the camera in the dark if the daytime focusing is forgotten or has been changed accidentally. On some camera models if Auto Focus (AF) is not turned off, the camera may refuse to take a picture since it can not focus in the dark.
- Set the camera to manual mode. Normally "BULB" mode is used. Bulb mode keeps the shutter open as long as the shutter button is pressed.

- Attach a programmable release cable (preferred) or locking remote release cable (second best), or be ready to have your finger, or a jury-rigged apparatus for holding your shutter button down (e.g. pebble and tape or rubber band).
- Set white balance to daylight.
- Turn OFF long exposure noise reduction.**
- Turn OFF high ISO noise reduction.

**Q: Why turn off long exposure noise reduction?

A: Long exposure noise reduction will introduce gaps in time between exposures. When taking a SINGLE shot "long exposure noise reduction" can be left on. But remember that when left on the exposure will take up to twice as long to complete. High ISO noise reduction may not be as effective in-camera as out of camera. Try it both ways.

Q: How long do I have to expose to get a trail?

A: As discussed earlier, the length of the trail depends on the field of view of your lens. The field of view can be calculated from the focal length and the crop-factor (also called focal length multiplier). Stars at the celestial equator travel 15 degrees each hour. If the field of view is 15 degrees – as it would be at 100 mm – one hour of exposure produces edge-to-edge star trails. A wider angle lens such as 17mm requires 4.5 hours to get edge-to-edge trails! Stars near the north celestial pole (i.e. near the North Star, Polaris) move as well, but the trails will be much shorter and more curved in the same period of time.

Please note that a pleasing star trail requires as many as 3 hours of exposure (longer if possible), so be prepared with a spare battery… or use an excessively massive battery rig.

Sky considerations

This one is pretty simple. Seek the darkest skies possible. Dark skies are found far away from city glow and when there is no moon in the sky. But don't despair if you live near heavily light polluted cities or only have a chance to shoot in strong moonlight. The sky is darkest when the all the following are true:

- There is no visible glow in the direction of the photographs from any man-made sources. Sometimes such glow is noticed only in long exposures!
- The sun has set for at least 90 minutes or it is at least 90 minutes before sunrise.
- The moon has set for at least 60 minutes or it is more than 60 minutes before it rises.

NOTE: The moon is a very useful tool to get some light on your foreground objects – particularly when the foreground is large and distant from the camera. The best star trail shots usually either start as the moon is setting or end when the moon is rising. If there is no moon, shooting can start or end at twilight.

- If the Milky Way is visible from horizon to horizon the environment is definitely dark enough and star trails are possible. Even when only a few stars are discernible in the sky, and even when the moon is full or nearly so star trails are usually possible – they just need more planning – usually shorter exposures.

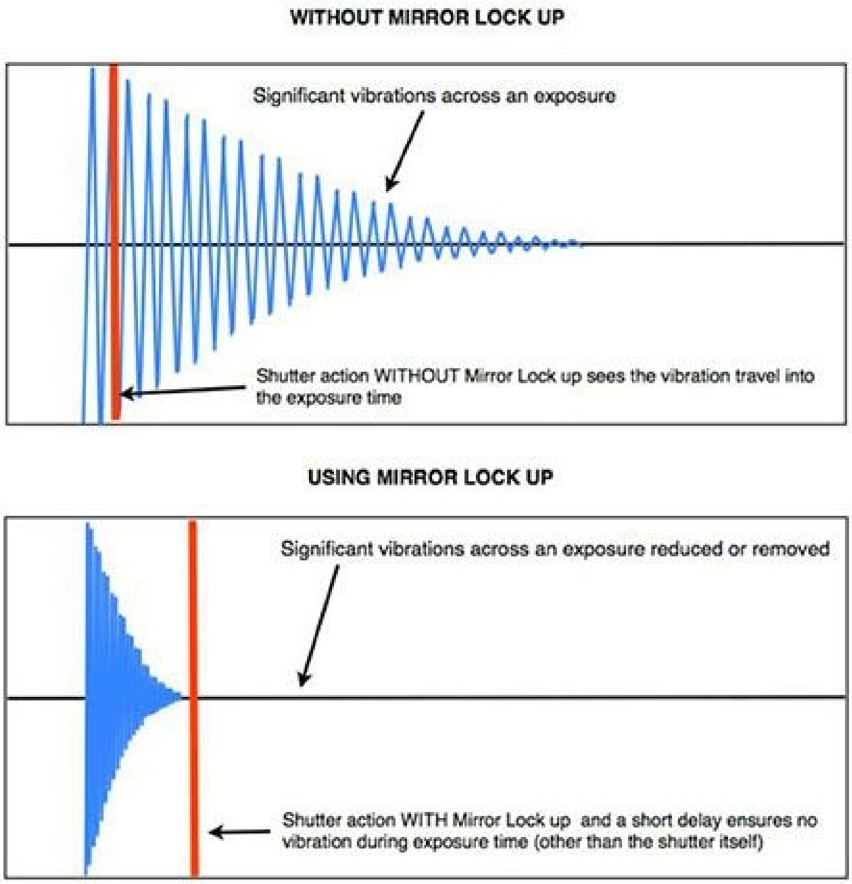
- Clouds – especially high, thin clouds can add some dramatic “milkiness” to the image – as can the Milky Way itself.

ADDITIONAL TIPS

ADDITIONAL TIPS

Mirror Lock up

The first press of the shutter button moves the mirror out of the way, the second press starts the exposure. When the exposure completes, the mirror moves back down. On my Canon cameras, putting the camera in mirror lock-up mode just does not work work as you would like. In lock-up mode the requirement of two presses of the shutter to take an image makes this mode worthless for star trails because an intervalometer can not be configured to generate two presses. Why use mirror lock-up at all? The theory around mirror lock-up is that certain exposures in the 1/20 to 2 second range are affected by the mechanical vibration that come from the mirror movement. This is especially true for telephoto arrangements and when the camera is not well secured. For 20 second or longer exposures mirror slap will make little or no difference. One way to minimize mirror slap is to use Live View mode – but that eats more batteries.



Focal Lengths

The one element of the focal length that matters is that the shorter focal lengths give smaller width trails. Theoretically stars are points of light, but as you can see from pretty much any astronomy or star trail photo there is some bending of the atmosphere that moves around the point light source and widens the image.

Another element of the focal length is that the shorter the focal length, the longer you have to expose to fill the frame with a star trail (as was briefly described under “What Kind of Image”). Shorter focal length lenses have a wider angle (field of view), and that affects how long an exposure is needed to get a noticeable trail.

If you use a telephoto lens you can fill the field of view with a star trail in less time than if you use a wide-angle lens. For example: 488 mm focal length can be achieved on a 1.6 crop factor camera (Canon 50D) using a 1.4 Tele-extender and a 200 mm lens. The field of view of this lens is 4.5 degrees by 3 degrees. It takes a star at the celestial equator 12 minutes to move 3 degrees so you can have an edge to edge star trail in about 18 minutes using the telephoto lens. With a 30 mm lens the field of view is 40.5 degrees in one direction and 27.6 in the other. Since 27.6 is more than nine times bigger then 3, you have to expose nine times longer 108 minutes (one hour, 48 minutes) to allow that same star to sweep across the entire (narrow) field in the frame. Finally, from a compositional standpoint, a wider angle lens allows you to include more terrestrial or celestial real-estate in the image. There is one additional advantage, too. Wide angle lenses have closer hyperfocal distances. The hyperfocal distance is the distance from the camera at which everything from that point to infinity is in focus. In a nutshell this means you can include a nearby tree, building, cactus or other interesting foreground object and both it and the stars will be in focus.

6 STANDOUT TIPS TO MASTER THE TECHNIQUE

Combine elements to create artistic interpretation

Grant rarely photographs just the night sky alone – he almost always seeks out unique elements in the landscape to combine with his night shots. The result is images that are based on reality, but contain his artistic interpretation of a scene. “I prefer to shoot in places that have both dark skies and interesting things in the landscape to combine with stars and other extraterrestrial objects,” explains Grant.

The elements that Grant chooses to include in his composition come in all shapes and sizes. It’s often the rugged or funky-looking trees native to the American Southwestern deserts, or a group of jagged rocks alongside a placid lake. The elements don’t take away from the starry skies, but actually add a focal point that draws the viewer into the entire image.

Gain a solid understanding of lunar and planetary motions

We can’t harp on this one enough – good, let alone great night photographers have a solid understanding of what the moon and stars are up to at any given time during the year. “Thorough knowledge of moon phase and rise/set times prior to going out shooting is crucial to achieving whatever kind of night shot you want to create,” Grant advises.

“Some images require a rising or setting moon, some a new moon, and some a full moon,” says Grant. “For example, shooting the bright center of our Milky Way galaxy requires dark skies and little-to-no moonlight to really bring out the colors in the ‘dust lanes’ of the galactic center. What’s more, there are only certain times of the year that the middle of the galaxy presents itself high enough above the horizon to shoot it in the dark part of the night.”

To get those stellar star trail shots, night photographers know that it’s all about the rotation of the earth. “A camera fixed on a tripod is actually moving along with everything else on the planet,” explains Grant. “So, if you start a long bulb exposure at night in the northern hemisphere facing in a northerly direction, the stars in the sky will appear as trails in concentric rings around the north star as result of the earth rotating on its north-south axis.”

Because stars appear the brightest when there is a new moon or the moon has yet to rise, photographers must make a tradeoff: no moonlight might mean better star trails, but you won’t get much illumination on the landscape. Grant suggests photographers pre-visualize how they want the image to come out, and marry that with their understanding of the lunar and planetary motions.

Grant says you have to ask yourself, “Are you shooting stars, or a moonlit landscape? Do you want star points, or trails? Is the moon up? If so what phase is it, and when does it rise and set? How much light pollution is around in the direction you are facing? Each one of those things requires a different strategy.” Proper planning means a better chance of getting the image that you want.

Invest in gear with strong low light capabilities

Photographers frequently ask Grant if they need to spend boatloads of money on gear to produce images like his. “The answer is mostly no,” says Grant. “All you really need to take photographs at night is a camera with manual mode, film or a memory card, and a tripod.”

Personally, Grant is a Canon shooter and currently uses his trusty 5D Mark II, though he recently purchased a Mark III and has been “blown away by the low-light capability.”

“In the last five years, shooting at night with digital cameras has improved one thousand-fold if not more,” says Grant. “Full-frame, low-noise sensors in cameras with fast RAW processing hardware and speedy storage cards have brought us into a new era of night photography.”

In addition to the Mark II/III, Grant also suggests the Nikon D3s and D800. When it comes to lenses, his go-to is the Canon 16-35mm f/2.8 lens. This gives him the possibility to shoot quality images in low light.

“The use of a wider-aperture prime lens will allow you to let in more light and bring down noise levels,” says Grant. “The Canon 24mm f/1.4 is excellent, but if this is out of your price range, consider getting the ‘nifty 50’ Canon 50mm f/1.8 for around $100. You’ll be shocked at what a difference there is in your night photography between f/2.8 and f/1.8.”

Beyond the body and lens, there are several pieces of equipment that Grant says can help improve the quality of the images you create:

- Cable release
- Intervalometer for creating time-lapse
- Motion control system (for adding an element of foreground motion to time-lapses)
- Sturdy tripod for wind resistance
- Headlamp with a red LED
- Flashlight for light painting
- Photoshop or Lightroom for noise removal, frame stacking, dodging and burning, etc.

While the above gear isn’t technically necessary, serious professionals should look into investing in a few of these to further improve their night photography.

Fall in love with low ISO

“There really is no catch-all recipe for camera settings and night photography,” admits Grant. “You really have to go back to pre-visualizing what kind of image you want to create, based on what landscape and astronomical features you hope to bring together.”

Still, the general rule for night photography is to use the lowest ISO possible and the widest aperture available. “Digital SLR sensors will start to suffer from high noise at higher ISO values,” says Grant, “and also when performing long exposure at lower values.”

“To throw any potential night shooters a bone… for the most part, you will be shooting at or above ISO 800, below f/6.7, and exposing for at least 10 seconds. Start there, make a guess, check your histogram and LCD screen (don’t bother with the light meter), and give it a try!”

Since star trail images are made with either long exposures or stacking multiple short exposures, noise can be a big issue. And that’s where your post-production skills come in.

Find the infinity point

Focusing and composing – they’re some of the most basic photographic techniques; but things get tricky when there’s no light to guide you. So instead, night photographers must find the “infinity point” on their lenses.

“I typically start out by temporarily setting my camera to the highest ISO it is capable of,” says Grant. “I then switch the camera into Bulb mode, adjust the focus to approximately where I think the infinity point is, and hold down the shutter with my finger for 2-6 seconds. The resulting image isn’t useable due to extremely high levels of ugly pattern noise, but it will tell you what is in your composition, and whether or not your focus is at the right point by whether the stars are crisp dots or fuzzy.”

From there, you can make small adjustments to your focus until you get it right, and then switch back to usable ISOs. It’s a departure from the “normal” routine, but then again, so is much of night photography.

Master your post-production

The truth is that no matter how high the ISO or how wide your fancy lens can go, it’s pretty difficult to get a totally clean night shot. So Grant suggests creating a “dark frame” and subtracting the noise from your photo.

“Let’s say you want to shoot a long, 15 minute exposure to make a star trails image, and there is a half moon,” says Grant. “You might be at f/2.8, ISO 400. After you make your 15-minute exposure, put the lens cap on, cover your viewfinder with your hat, and then make another 15-minute exposure, or ‘dark frame.’ Then take this image into Photoshop or Lightroom as a layer above your star trails image and change the blending mode of the dark frame to ‘difference.’” This post-production technique removes the noise and gives a cleaner final image.

Another method is to stack multiple images shot with as short of an interval that you camera/card combo can handle. “One second is ideal,” says Grant, “and then you can fire off a sequence of a few hundred shots. Others may want to do less post-processing, and they should shoot 3-5 minute exposures with a very short 1-5 second interval between frames, and then stack these.”

COMMON OBSTACLES IN NIGHT PHOTOGRAPHY

COMMON
OBSTACLES

Trade Offs

Fortunately, times have changed since the early days of night photography. Modern digital cameras are no longer limited by reciprocity failure and provide instant feedback — greatly increasing the enjoyment and lowering the risk of investing the time to take photographs at odd hours.

Even with all these advances, digital night photography is still not without its technical limitations. Photos are unavoidably limited by the trade-off between depth of field, exposure time and image noise.

Each scenario often has a technique which can minimize the trade-off; these include image averaging, stacking and multiple focal planes (to be added). Also note how even the minimum possible exposure time above is one second — making a sturdy camera tripod essential for any photos at night.

Fixed pattern noise is the only disadvantage to progressively longer exposures in digital photography (other than also possibly being impractical), much like the trade-off of reciprocity failure in film. Furthermore, moon movement and star trails can both limit the maximum exposure time.

Light Pollution

Astronomers world-wide are concerned with the disappearing stars in the night sky due to increasing skyglow from uncontrolled urban uplight.

Light pollution is stray light emitted from poorly designed and aimed lighting installations for advertising, business, security and street lighting. While some light is unavoidably reflected upward from illuminated surfaces, much of it spills outside the area that it is meant to illuminate creating glare, light-trespass and skyglow.

This stray light and the energy generated to produce it is wasted. It unnecessarily contributes to greenhouse emissions, and wastes money. Also, this wasted light does not necessarily contribute to safety nor enhance amenity. Very often it creates a nuisance. We do need outdoor lighting at night but there are better alternatives that save energy and improve the quality of nighttime lighting that also help to reduce skyglow and preserve the night sky. Light pollution is much easier and cheaper to remedy than most other kinds of pollution!

The Importance of Moonlight

Just as how daylight photographers pay attention to the position and angle of the sun, night photographers should also pay careful attention to the moon. A low-laying moon can create long shadows on cross-lit objects, whereas an overhead moon creates harsher, downward shadows.

An additional variable is that the moon can have varying degrees of intensity, depending where it is during its 29.5 day cycle of waxing and waning. A full moon can be a savior for reducing the required exposure time and allowing for extended depth of field, while a moonless night greatly increases star visibility. Furthermore, the intensity of the moon can be chosen at a time which provides the ideal balance between artificial light (streetlamps) and moonlight.

Gauging exposure times during a full moon can be tricky; use f/2.0 and 30 seconds at ISO100 as a starting point (if subject is diffuse and directly lit), then adjust towards scenarios 1-4 accordingly.

Another factor rarely noticed during daylight is movement of the light source (sun or moon). The long exposure time required for moonlight photography often means that the moon may have moved significantly over the course of the exposure. Moon movement softens harsh shadows, however too much movement can create seemingly flat light.

Shots which include the moon in the frame are also susceptible to moon movement. A rule of thumb is that **the moon appears to move its own diameter roughly every 2 minutes**. As a result, it can quickly appear elongated if this exposure time is approached.

Viewfinder Brightness

Properly composing your photograph in the viewfinder can be problematic when there is little available light. Even if you intend to expose using a small aperture, a lens with a large maximum aperture can greatly increase viewfinder brightness during composure. To see the effect of different apertures, manually choose an aperture by pressing the “depth of field preview” button (usually located on camera at base of lens).

The way a SLR camera redirects light from the lens to your eye can also affect brightness. Cameras with a pentaprism (as opposed to pentamirror) ensure that little light is lost before it hits your eye, however these often increase the cost of the camera significantly.

Larger format sensors also produce a brighter viewfinder image (such as full frame 35 mm, compared to 1.5-1.6X or smaller crop factors) . Finally, ensure that you give ample time for your eyes to fully adjust to the decrease in light — especially after standing in stronger light or using a flashlight.

EXAMPLE SUBJECTS AND IMAGES

EXAMPLE SUBJECTS AND IMAGES

The Stars and the Milky Way – A step by step guide

1. **Find a dark sky** - Just waiting until nighttime won't do. A dark sky free of light pollution is the first and most important requirement to even seeing the Milky Way, let alone photographing it.

2. **Know when and where to look** - The part of the Milky Way that is most easily visible to the naked eye isn't visible all year round, especially for those in the Northern Hemisphere where February through September are the optimal times. You will find your celestial subject in the southern half of the sky, rising from the west. Residents in the Southern Hemisphere may have a slight advantage in this regard, as the central parts of the Milky Way can be seen overhead.

3. **Use a digital camera with good high ISO capabilities.** You'll be shooting at night with very little available light; you want your cameras sensor to be able to handle the shooting conditions without introducing an excessive amount of noise. A full-frame camera is preferable but certainly not a necessity.

4. **Use a fast wide angle lens.** You should work with a lens with a maximum aperture of at least f/2.8; the faster the better. It's not that you're totally out of luck if your fastest lens is f/3.5 or so, but you'll have more of a challenge on your hands since the

lens won’t be able to gather as much light. The same principle applies to focal length; go as wide as you can. You may be seeing only a fraction of the Milky Way, but it’s still monstrous in size. The wider your lens, the more of it you can capture.

5. **Use a tripod**. This really isn’t optional. Bells and whistles are nice, but sturdiness is your number one concern.

6. **Use live view.** To avoid the headache of trying to focus in the dark, use your cameras live view feature to manually focus on a bright star. Alternatively, you could use the distance markings on your lens (if it has them) to set hyperfocal distance.

7. **Start with ISO 3200.** Referring back to the first point, a high ISO is essential to collecting enough light to render a bright image of the Milky Way. Under typical conditions, ISO 3200 is a good starting place. Based on how well this plays with other camera settings, you can go higher or lower from there.

8. **Set a long shutter speed.** This is how you will capture more light and create a sufficiently bright exposure. There just one problem, though. The planet doesn’t care if you’re new at astrophotography; it’s going to keep on rotating, which means if you leave the shutter open for too long, you’ll end up with star trails. There’s nothing wrong with star trails when that’s what you’re aiming for, but they aren’t really desirable for photographing the Milky Way. To get pinpoint stars, use the â€œ500 rule, which calls for you to divide 500 by the focal length of the lens you’re using. So, if you have a 24mm lens on a full-frame camera, you will set your shutter speed to 20 sec. (500/24 = 20.83). If you’re working with a crop sensor camera be sure to account for the crop factor (typically 1.5 for Nikon and Sony, 1.6 for Canon). As an example, using the same 24mm lens on a Nikon crop, you’d end up with an effective focal length of 36mm (24×1.5 = 36). Applying the 500 rule will yield a shutter speed of 13 sec. (500/36 = 13.89). There are those who debate about whether to use the 500 rule or the similar 600 rule; without delving further into the mathematics of it all, it really is more a matter of visual perception. In short, stick with the 500 rule, especially if you intend to make poster size prints. If, after you’ve gotten more comfortable and done some experimenting, you find the â€œ600 rule works better for you (should be find for web images) then definitely go with that.

9. **Set a wide open aperture.** Remember, it’s all about collecting as much light as possible; depth of field isn’t the primary concern here. In case of any significant softness you’ll want to stop your lens down. This is why it’s so important to use a fast lens in the first place; if you know your lens is unacceptably soft at f/1.4, stopping down to f/2 will sharpen things up without having a severe impact on the lens light gathering ability.

10. **Compose your shot.** There’s no right way or wrong way to compose your shot, but you can create a sense of depth by framing this as a standard landscape shot with the Milky Way serving as the background. Just because it’s dark out doesn’t mean you should forget about the foreground, though; you can add interest to your scene by including hills or mountains, trees, rock formations, or even a person. Experiment all you want.

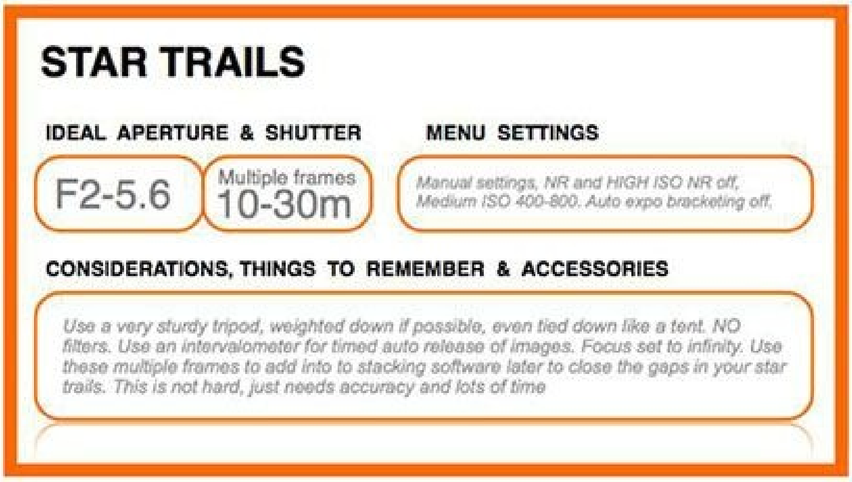
11. **Get a satisfactory exposure.** It’s very likely that your first shot won’t be an exposure you’re satisfied with (if you’re not happy with the focus or composition, adjust those things before moving on to worrying about exposure). If the exposure isn’t right you’ll have to identify the problem and work from there. If there’s too much noise, simply decrease the ISO. If the shot is overexposed, check your surroundings for light pollution; decrease shutter speed; stop down the lens; or decrease ISO. If it’s underexposed, make sure you’re using the widest aperture on your lens; increase shutter speed (but beware of star trails forming); increase ISO.

12. **Process it.** There will be a lot of variation at this final stage and, again, there is no one right way to handle the post processing of your shots. The two most important things you can do to make post processing a little easier is to shoot raw and get the best exposure you can in-camera. You may need to apply some sharpness and noise reduction. According to some sources, the color temperature of the Milky Way is around 4840Â°K; if you find it too much on the yellow/orange side, adjust white balance until you have a neutral scene. You will definitely need to increase contrast; it’s okay to be a bit heavy handed here, so long as you’re not losing shadow detail. If the photo editing software you are using allows curves adjustments, make use of it, as you can be more precise with your work. Assuming you got a good in-camera exposure you shouldn’t have to play with the exposure slider too much.

Star Trails

As described in the preceding paragraphs there are many considerations for planning a great star trail. Finding an interesting foreground, determining when the atmospheric and celestial conditions will best suit that location, scouting to find the best spots to photograph the image and so on. Here are some of the tools and tips that apply:

1. If shooting an object to the West a half-full moon (or less) rising in the East can provide light on the foreground.
2. If the object of interest is to the East, a setting sun or setting 1/2 full moon can be a good foreground illuminator.



Star Trails – step by step –

1. Pick your spot. Weigh down a sturdy tripod and make sure everything is solid. Wind and walking nearby should not rock the rig. If you are set up on a beach, make sure you are far enough from the surf that water will not wash near or under your tripod.
2. TIP: Be mindful of how you mount your camera on the tripod! You should be able to change both your battery and your memory card without having to unmount, move or dislodge the camera. If you have a shoulder strap on the camera, you may want to remove it to prevent the wind from wobbling the camera.
3. Frame your shot. Do a high ISO test exposure to confirm focus and operation. You

can also make a guesstimate at what length exposure is needed to properly expose the foreground. I have found that a well shot high – ISO exposure can be combined with the later shots to get a strong feeling for the sky.

4. Set the camera back to the target ISO, put on the lens cap, format your memory card and take an exposure equal to the majority of your images with Long Exposure noise reduction OFF. This will be one of your dark frames.
5. Start the automatic exposure sequence being sure to look at your first shot and allow enough time to be sure your second shot also starts immediately after the first one ends (three seconds is suggested).
6. If the first shot is OK, delete it and the one you interrupted.
7. Install a freshly charged battery and start the automated sequence over again. You may wish to first delete your prior shots so you do not later wonder why you have gaps in your star trail.
8. Take a nap, walk away, get some exercise… Come back in an hour or so to confirm everything is still working. Check the battery condition and check the lens for dew – still OK? Let the shooting continue.
9. As the current automated exposure completes, quickly reconfigure your camera to turn ON long exposure noise reduction and setup to take a LONG exposure – your goal in this shot is to get the foreground exposed pretty well and still have a long single star trail shot that is not washed out. Alternatively, you can make your exposures coincide with twilight at sunset or sunrise and use one or more shots from that (see Figure 12).
10. When your foreground exposure completes (after noise reduction), put the lens cap back on, reset to your automated exposure settings and take two more dark frames (again for noise reduction). Make sure to keep the camera in the same climate so the dark frames are taken at the same temperature as the prior frames.
11. Now you should check your last long exposure – the one exposed for the foreground. If it's not right, you may need to increase the ISO and expose again. You may also need to swap batteries. Note that any shot you take now will have an unusable star trail due to the large gap in time between this step and the end of step 7. Therefore this extra fix up is ONLY for getting a foreground. You may need to resort to light painting of various forms. Heck, it's worth a try even if your previous foreground exposure was great.
12. Only now can you pack up your camera.

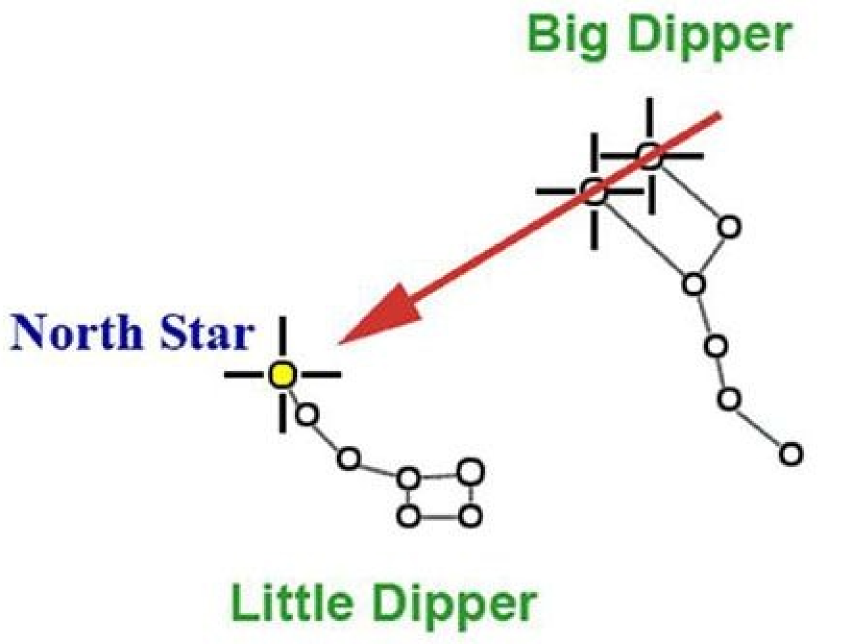
If the shot will run unattended, it is a good idea to double and triple check all of the following:

- The ISO is set correctly (e.g. 200 to 400).

- The f/stop is correct (2.8 to 5.6 recommended)
- The camera is set to “bulb” exposure mode.
- Auto exposure bracketing is OFF.
- Exposure mode is set to single exposure (not high speed or continuous)
- Your camera will return to the above settings if it enters auto-power down mode.
- The intervalometer and the camera have sufficient battery.
- The delay on the interval timer is set appropriately. It is best to start your first exposure near nautical twilight.
- The exposure length is set correctly (e.g. 3 minutes, 57 seconds)
- The delay between exposures is 3 seconds for older cameras but no less than one second for all cameras.
- The number of exposures is correct (e.g. for 4 hours of exposures at 4 minutes each you will need 60 exposures or more)
- The timer has been started!
- The timer, camera and batteries are secure.

Finding Polaris in the North

To locate Polaris, the North Star, just draw a line between the two outer stars in the bowl of the Big Dipper. Find the Little Dipper from the Big Dipper when you learn how the stars connect in a straight line. Polaris can be located by finding the two stars in the edge of the cup in the Big Dipper and following an imaginary line outwards, away from the cup.



Polaris, the North Star, is somewhat easier to find, using the "Little Dipper" in the northern sky. The "Big Dipper" actually points towards it.

Finding the Celestial Pole in the South

What to do to find true South and the South Celestial Pole (SCP):

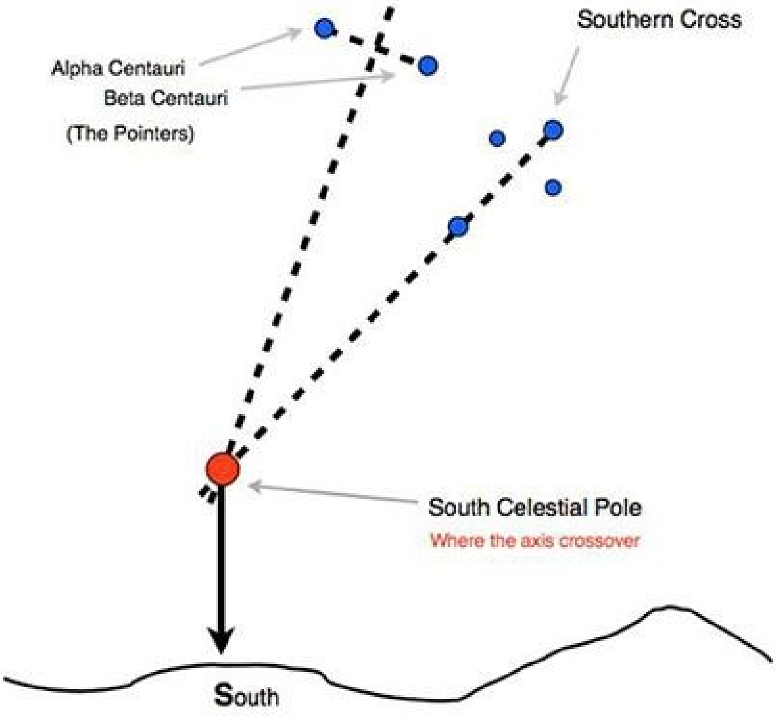
1 - Find the Southern Cross.

2 - Draw an imaginary line through the long axis of the Southern Cross beginning with the star that marks the top of the cross (note: during summer the Southern Cross is low in the sky and therefore upside-down).

3 – Use the two pointer stars (always to the left of the Southern Cross.) and replicate the cross shape of the Southern Cross.

4 – Extend a line down the middle of your second cross until the two lines intersect, which is usually about the height of a “fist held at arms length” from the horizon.

5 - From this point, drop a line vertically down to the horizon. This gives you true South on the ground. (Compasses find magnetic north/south, not True North/South, so a compass will measure magnetic south to be 11 degrees west of True South.)



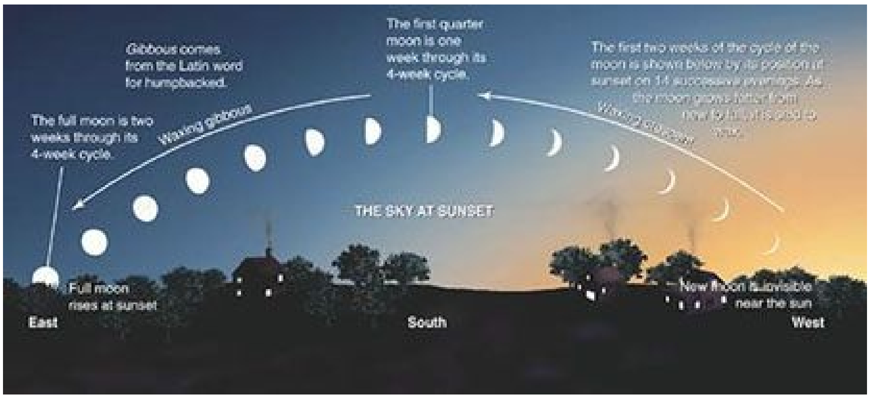
Shooting the Moon

There are a few things to be mindful of when shooting the moon. Lighting comes into play more than you think. Many people think the moon is a dark abject in a dark sky, so a long shutter is needed. Not true, in fact exactly the opposite is needed, if you wish to see the surface of the moon. Refracted light from the sun bouncing of a lunar surface will provide for a very bright light source, as seen by the camera. Therefore a fast shutter speed will be required to darken the image sufficiently to render the lunar surface visible. I have at times, shot the moon at up to 1/4000th of a second. The surrounding sky is rendered completely black but I do have a complete image of the moon that I can etch and drop into another scene if I want to.

Two moons, two shutters. LEFT : 1/100th sec @ F8, RIGHT : 1/2500th sec @ F8
The moon is visible only because it reflects light from the sun. Capturing it is no different that trying to photograph the sun or some other extremely bright object.

Another consideration is “Astronomical seeing” which refers to the blurring and twinkling of astronomical objects such as stars caused by turbulent mixing in the Earth’s atmosphere varying the optical refractive index. In other words, vibrations. When you look at the moon through a telescope, it can often seem like it’s vibrating…what your seeing is the

Earths atmosphere. The astronomical seeing conditions on a given night at a given location describe how much the Earth's atmosphere perturbs the images of stars as seen through a telescope. Here's a great video of the atmospheric turbulence impeding your ability to capture a pin sharp image of the moon.

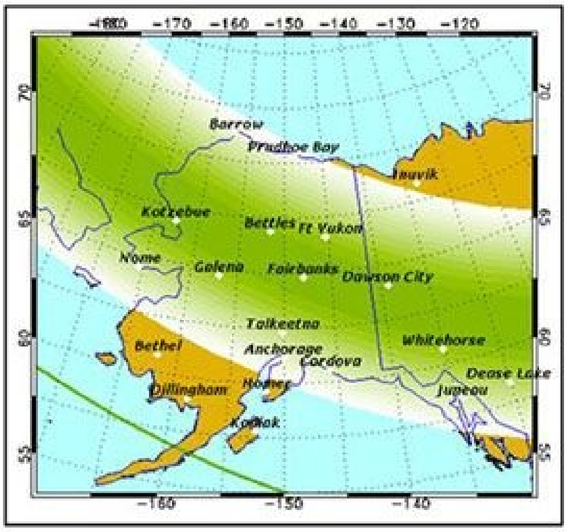


Polar Cap Auroras

Photographic Auroras is a magical experience, but does require experience. The Northern Lights (and Southern Aurora, over Antarctica) are caused by charged particles thrown off by the sun during periods of intense solar activity. As these particles, e.g., the "solar wind," enter the Earth's atmosphere, they excite the gas molecules in our upper atmosphere, primarily oxygen and nitrogen, causing them to emit light. The more powerful the solar activity, the brighter and more lively are the resulting auroras here on Planet Earth. Although auroras can appear to dance just overhead, they actually happen very high above the Earth, from 50 to 200 miles up. Most are lime green in color, but also can turn intense shades of purple and red. Keep in mind, though, that not all of the aurora color is visible to the human eye. Some of the intense reds you see in pictures are much less vivid in person, but are intensified with camera time exposures.

Where To Go

The best aurora viewing is within a donut-shaped band, the Auroral Oval, that circles both ends of the globe (the Southern Hemisphere has its own show called the Southern Lights, or Aurora Australis). The Oval passes directly over places like Fairbanks, Alaska, Yellowknife, Canada, and Reykjavik, Iceland, making all three excellent choices for auroras. During periods of intense auroras, the Oval expands, allowing the lights to be seen over a wider area. It takes a truly massive display, which may happen no more than once or twice a year, for the aurora to be visible in the Lower 48.



The Alaskan Geophysical Institute forecast Aurora activity, measuring solar wind activity.

Active: 0 1 2 3 **4** 5 6 7 8 9

Forecast: Auroral activity will be active. Weather permitting, active auroral displays will be visible overhead from Barrow to Anchorage and Juneau, and visible low on the horizon from King Salmon and Prince Rupert.

Visit the Geophysical Institute here - http://www.gi.alaska.edu/AuroraForecast

When To Go

The aurora can occur any time of year, but in the Land of the Midnight Sun, you're not going to see much between May and September. Just why this should be the case isn't entirely clear, but whatever the reason, these seasons also have the benefit of longer days and milder weather, and offer more things to do when not gazing skyward.

The greatest challenge for sky-watchers is the weather, of course. You can easily spend a week staring up at the bottom of a solid bank of clouds, tortured by the certainty that there's a dazzler going on somewhere up there, but you can't see it. When picking a location, check weather data to see what months tend to have more cloudless nights and then keep your fingers crossed.

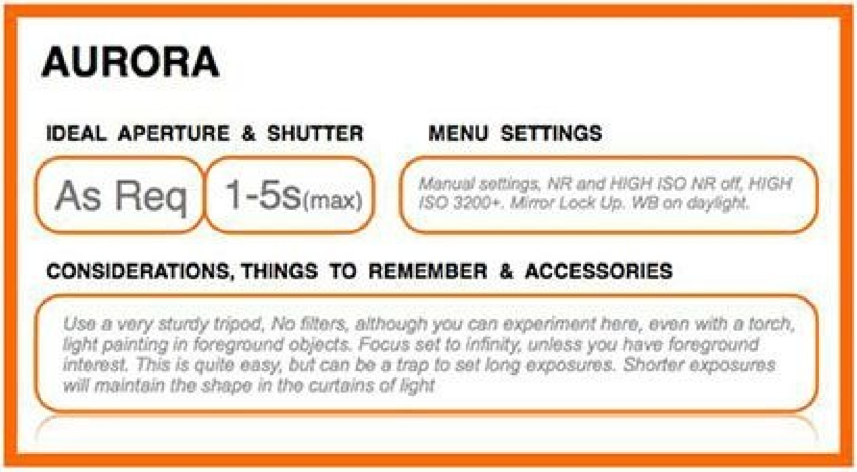
Some people prefer to avoid the full moon, whose brightness can diminish the intensity of aurora displays, but moonlight can add a wonderful luminosity to a snowy landscape.

One of the best resources for determining your travel to the Arctic Circle for Aurora viewing is the Geophysical Institute in Alaska.

Shooting the Aurora

If all goes well—the skies are clear and the aurora forecasts are looking good—it's shoot time. It may seem obvious, but you're going to get cold doing aurora photography—really cold. Winter temperatures in aurora country regularly drop far below freezing, and you'll need to be properly suited up to work outside. It can often get cold enough to freeze and crack your cable release.

Winterize everything, thats you and your camera. Lithium batteries are the best choice for cold weather, holding up much better than alkalines, which can lose their charge in less than an hour at subzero temperatures. If you must use alkalines, carry a spare set in your pocket and be prepared to switch them out to keep your camera running. Also consider bringing along some chemical heat packs, for both you and your camera.



There really isn't an ideal lens for shooting Auroras, although a wide-angle does capture displays that can often fill the sky. If you can, go for an ƒ/2.8 opening—ƒ/2 or less is even better. This will be fast enough to give you the shortest possible exposure times. Remember, the difference between an ƒ/1.4 lens and an ƒ/5.6 lens is three full stops—in other words, between a 10-second exposure and minute and a half exposure. The key is to remember that you're not just shooting the sky—you're creating a landscape composition in which the aurora is just a part.

HOT PRO TIP

Before your first night outside, get your lenses ready by turning off your autofocus—AF doesn't work well in the dark—and tape your lens at infinity to make sure you don't accidentally knock the lens off focus. Make sure you've taped the lens at actual infinity, not just at the symbol on your lens—each lens reaches infinity in a slightly different position. I recommend prefocusing before it gets dark at any distant object more than 100 feet away with whatever lens you plan to use and tape it there.

As a rule of thumb, shorter exposures produce the best results. If you can keep your exposures to 15 seconds or less, you have a much better chance of stopping the motion of the lights, giving them definition. Longer exposures make for fuzzy, shapeless auroras and longer star streaks.

Here's 5 x tips to keep you headed in the right direction toward a stunning Aurora shot –

1. **ISO.** Ideally, you'll want to choose the highest ISO that your camera can handle without excess noise. For some cameras, that's 400; for others, it may be as high as 2400. Good exposures are your best defense against noise, as well as the long-exposure noise reduction in your camera.

2. **Tripods.** These should be steady in the wind, of course, but also tall enough for you to shoot straight up without having to get down on your knees! Metal legs should be covered with tape or foam, which makes life easier for your hands.

3. **Filters.** Remove all lens filters when shooting the aurora—they can cause unwanted

image patterning with these specific wavelengths of light.

4. **Shutter Release.** You'll need either an electronic or cable release to reduce shake on long exposures.

5. **Condensation.** Be careful if you're going in and out of a warm car or lodge with your camera. The change in temperature can cause condensation to form on your lens, which can freeze into ice when you step outside again. One idea is to leave the camera outside and simply carry the battery inside with you.

Comets

Amongst all the wonders of the universe, comets arouse more than their fair share of interest. Is it because they are ephemeral beasts, here today and gone tomorrow, perhaps forever, or is it that they are everchanging on a daily or weekly time scale? Whatever the reason, they capture the interest of the general public and the dedicated amateur and professional astronomer alike. So the question that frequently arises is "How do I photograph a comet?"

There are several considerations to be mindful of here –

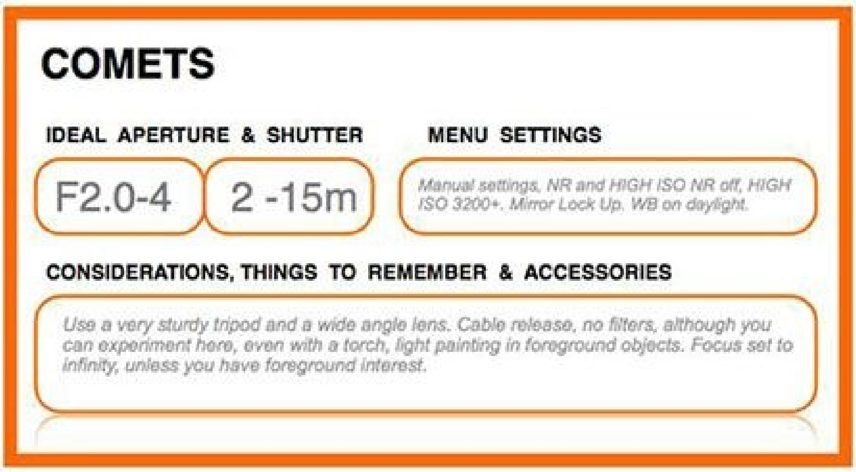
The Camera

An SLR camera (either manual or a digital SLR). Exposures to capture a comet will range from a few minutes to perhaps 15 minutes, so a cable release which will allow the shutter to be locked open for this period (the “B” setting on the shutter speed dial) is also necessary, as of course is a firm tripod on which to mount the camera.

What lens to use? Comets with their tails cover a surprising distance across the sky, frequently 10-15 degrees (a hand span at arms length) so a moderate wide-angle lens (i.e. 18-35mm focal length) is ideal, but a normal 50mm lens is still OK. Set the lens to its largest aperture (i.e. f =2.0) as the distant end of the comet’s tail is very faint. For more detail of the comet head use a 135-200mm telephoto lens, but don’t expect to capture fine detail of the comet head itself, it is after all, buried in a shroud of dust. Finally, check the lens focus and set to infinity.

ISO/Sensitivity

Comets move in case you hadn’t you noticed, so unless you want a somewhat blurred photograph, a fast setting (ISO 400 to 1600) is necessary. With these speeds, an exposure of 5 minutes will show the comet head and the brightest part of its tail, for capturing the full extent of the tail, go for 15 minutes. Again, these times could vary, so experiment. Don’t be afraid to take several photos of increasing time but check the position of the comet in the camera viewfinder before each photo.



Where To Photograph Comets

The limiting factor for all astrophotographs is the night sky fog limit. This is the time it takes for the background lighting to overwhelm the object being photographed. If you live in a city, this may be as short as a couple of minutes especially if bright flood lights or street lights are nearby. It really is best to get out of town. This is especially so when the comet (or any other object for that matter) is very low in the sky, as Comet Hale-Bopp was for us southern hemisphere observers. Finally, go where you won’t be troubled by car headlights, they really are annoying and will ruin any long exposure photograph.

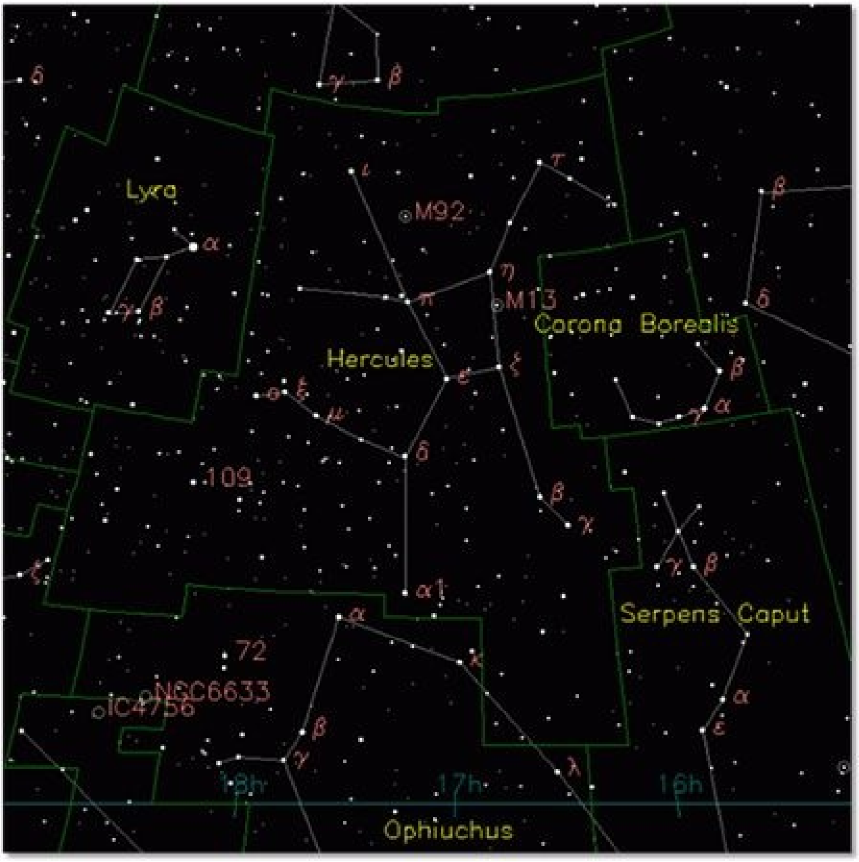
The top 5 Celestial bodies and where to find them, with just a basic camera or telescope.

You may be surprised to know there a number of celestial bodies that can be seen with the use of a very small basic telescope and or a camera with a decent zoom.

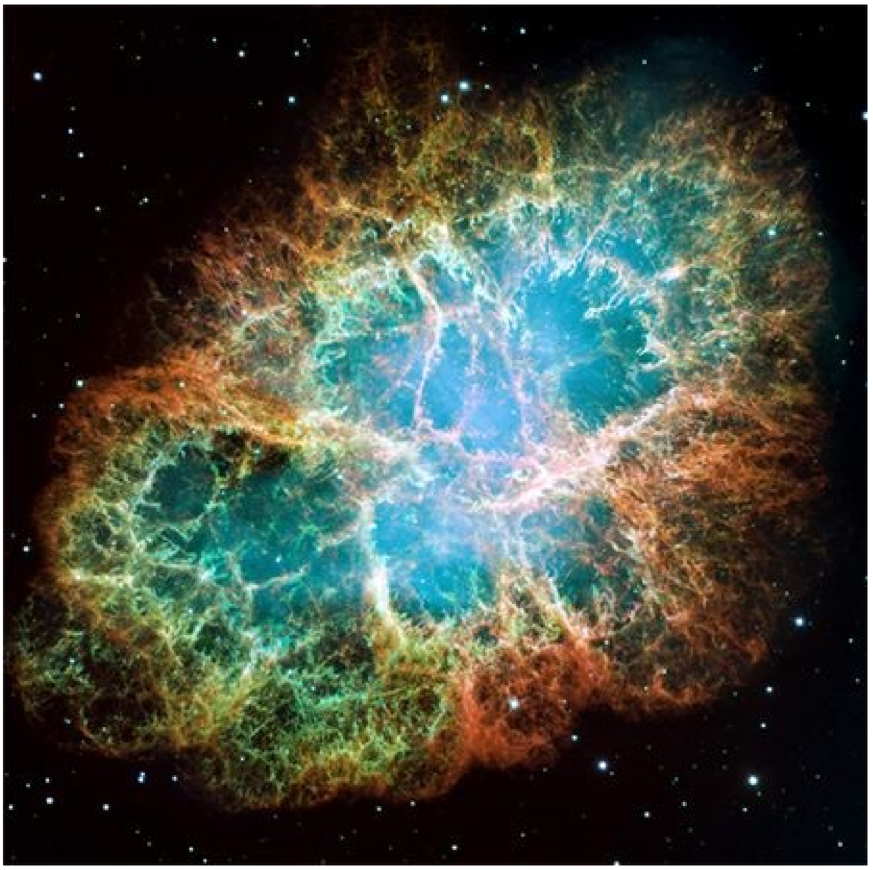
This new image of the Orion Nebula was captured using the Wide Field Imager camera on the MPG/ESO 2.2-meter telescope at the La Silla Observatory, Chile. This image is a composite of several exposures taken through a total of five different filters.

1. **Orion Nebula.** Granted, with small telescopes, it won't look like this Hubble Space Telescope image, but The Great Nebula is even visible with the naked eye in the northern hemisphere, and looks pretty impressive in small telescope, too. To find it, those in the northern hemisphere will have to wait until cooler weather approaches. But look for Orion's belt, three bright stars in a row. Hanging south from the belt is Orion's sword, composed of three bright dots; the center dot is the great nebula.

2. **Andromeda Galaxy.** A.K.A M31, this beautiful galaxy is another naked eye object that shows up well in small telescopes. To find it, locate the North Star, then the constellation Cassiopeia, which looks like a giant "W" and is directly across the Big Dipper, with the North Star in between the two. Look at the right "V" shape within the larger "W" of Cassiopeia; 15 degrees down from the tip of the 'V' is M31. Popular Mechanics recommends using the lowest power on the telescope to get as much as the galaxy into the field of view as possible.



3. **Hercules Globular Cluster.** It is relatively close, only about 25,000 light-years away and it pretty big –about 150 light-years wide, making it an easy target. Hercules is best viewed from the northern hemisphere in the summer months during a new moon. Locate Hercules by looking for the trademark trapezoidal keystone within the constellation. M13 is the brightest spot on the western side of the shape, about 20 degrees due west of the constellation Lyra.



4. **Crab Nebula**. This is the left-overs from a supernova that occurred in the year 1054. Back then it was bright enough to see in the daytime, and now it makes for a great sight at night, but a telescope is required. M1 is located on the southern horn of Taurus, the bull shaped constellation southeast of Orion. The object is best seen using a 200x zoom from the northern hemisphere around midnight.

5. **Whirlpool Galaxy**. A.K.A. M51, this is one of the largest galaxies visible without using professional telescope. Millions of years ago two galaxies collided to create this colorful and dramatic object. To find it, look about 3.5 degrees southeast of the last star in the Big Dipper's handle.

This new image of the Orion Nebula was captured using the Wide Field Imager camera on the MPG/ESO 2.2-meter telescope at the La Silla Observatory, Chile. This image is a composite of several exposures taken through a total of five different filters.

DIGITAL POST PRODUCTION AND SOFTWARE OPTIONS

DIGITAL POST PRODUCTION AND SOFTWARE OPTIONS

Processing

Aside from probably now having a whole drive full of images that may appear to be mostly black, you'll be surprised at what lies within. Use CCDStack software to process your calibration shots and create master frames with which to remove equipment irregularities and noise from your raw images. Align the calibrated images within CCDStack or PixInsight and use normalization to equalize the range of brightness levels across all the shots. Then apply min/max clip or sigma rejection to get rid of any unwanted data. When combining these stacked frames to create master images I usually create three combinations, using the sum, average and median tools. The sum version generally gives the greatest pixel values, providing the best canvas for applying sharpening algorithms; if you have not used a good noise rejection method, the average version is more appropriate.

If you have masters of filtered images, you can combine them into a colour image using your image-processing software's color combination procedure. Then use the deconvolution function and wavelet processing to sharpen the image and reduce noise, before experimenting with the curves and levels functions to brighten the image. Be careful not to go too far: keep a watchful eye on the image and its histogram, and undo any process that decreases resolution, clips the data or increases noise.

Experiment, that's the key….but do it carefully.

Free software for stacking star trails without the gaps

In order to help facilitate making gapless star trail photographs as composites from consecutive frames, as discussed in this free tutorial, I came across this simple Photoshop script that can be downloaded from this website:
http://www.artinnaturephotography.com/page/startrailstacker/

Click this link to download star trail stacking script (FREE!)

It's a ZIP file, so unpack it.

Version 0.21 - updated 3/29/2012 - see below for details

Instructions for use:

1. Unzip the file, it contains a photoshop script (star_trail_stacker_by_floris_v0.X.jsx),

instructions, and license – NOTE. There are two versions of the script, one preserves the layers, the other outputs a flattened image.

2. Make a directory containing TIF, TIFF, JPG, or JPEG files of all the frames you wish to merge
3. They must be named in consecutive order.
4. For preparing images follow the instructions in my tutorial for best results, repeated in brief below:
   a. Do a linear conversion of all your raw files: set all of the following values to zero in your raw converter, IE: recovery, fill light, blacks, brightness, contrast, clarity, and set the tone curve to "linear"
   b. Save all your raw files as TIF's in a new directory
5. Run script star_trail_stacker_by_floris.jsx on your directory using one of these methods:
   a. Double click the file star_trail_stacker_by_floris.jsx (say YES to the dialogue box that opens)
   — OR —
   From Photoshop, click File > Scripts > Browse… and navigate to the file star_trail_stacker_by_floris.jsx
   — OR —
   c. Copy the directory 'Star_Trail_Stacker_by_Floris' to the Presets/Scripts directory for Photoshop, restart Photoshop, and you can run the script from the File menu > Scripts.
6. Select your directory of TIF files in the dialogue that pops up
7. Save your merged file!

Astronomical Software For the PC

• DSLR Camera Control

- IRIS $Free - DSLR control, image acquisition automation
- PalmDSLR $Free - DSLR control with a Palm computer
- APT (Astro Photography Tool) - 12.70 Euros - Camera control, focus, image acquisition automation
- BackyardEOS $24 - Camera control, focus, image acquisition automation, drift alignment assist
- Nebulosity $60 - Camera control, focus, image acquisition automation, image calibration, image processing
- Images Plus Camera Control $70 - DSLR control, focusing, image acquisition automation

- AstroArt $185 - DSLR and CCD control and image processing.
- Maxim DL $399 - DSLR control and image processing.

- **Software-Assisted Focusing**

  - Focus Max $Free - Focusing software that automates focusing if you have a motorized focuser that works with Maxim DL or CCD Soft.
  - APT (Astro Photography Tool) - 12.70 Euros - Camera control, focus, image acquisition automation
  - BackyardEOS $24 - Camera control, focus, image acquisition automation, drift alignment assist
  - Nebulosity $60 - Camera control, focus, image acquisition automation, image calibration, image processing
  - Images Plus Camera Control $60 - DSLR control, focusing, image acquisition automation
  - AstroArt $185 - DSLR and CCD control and image processing.
  - Maxim DSLR $399 - DSLR control and image processing.

- **Image Acquisition Automation**

  - DSLR Shutter $Free - image acquisition automation
  - APT (Astro Photography Tool) - 12.70 Euros - Camera control, focus, image acquisition automation
  - BackyardEOS $24 - Camera control, focus, image acquisition automation, drift alignment assist
  - Nebulosity $60 - Camera control, focus, image acquisition automation, image calibration, image processing
  - Images Plus Camera Control $50 - DSLR control, focusing, image acquisition automation
  - AstroArt $179 - DSLR and CCD control and image processing.
  - Maxim DSLR $399 - DSLR control and image processing.

- **Image Calibration, Aligning and Stacking**

  - Deepsky Stacker $Free - Image calibration, alignment, stacking
  - Regim $Free - Image calibration, alignment, stacking
  - IRIS $Free - DSLR control, image acquisition automation
  - RegiStax $Free - for stacking planetary images shot with webcams
  - Nebulosity $60 - Camera control, focus, image acquisition automation, image

calibration, image processing

- AIP (Astronomical Image Processing) $99 Image calibration, correction, enhancement
- Images Plus $180 - Image calibration, correction, enhancement
- AstroArt $185 - DSLR and CCD control and image processing.
- PixInsight 171 Euros - Image calibration, correction, enhancement
- Maxim DSLR $399 - DSLR control and image processing.

• **Image Correction and Enhancement**

- IRIS $Free
- GIMPshop $Free
- Nebulosity $60
- Paint Shop Pro $80
- Picture Window Pro $90
- Photoshop Elements $98
- AIP (Astronomical Image Processing) $100
- Images Plus $180
- AstroArt $185
- PixInsight 171 Euros
- Maxim DSLR $399
- Photoshop Upgrade $189
- Photoshop Retail $660

• **Autoguiding Software**

- GuideDog $Free
- PHD (Push Here Dummy) $Free
- Metaguide $Free
- Guidemaster $Free
- AstroArt $179
- Maxim DSLR $399

• **Photo Utilities**

- Dark Library$Free - Sort Dark frames by EXIF temperature data
- EXIF Reader $Free - Reads EXIF data, such as shutter speed, ISO, aperture, date and

time of photo that is stored in the image file. Also a thumbnail and image viewer.

- FITS Liberator $Free - FITS file format image handling software.
- Noiseware Community Edition $Free - Noise Reduction software
- Background Subtraction Toolkit $Free - Remove gradients and vignetting
- IrfanView $Free - Image viewer.
- Picassa $Free - Thumbnail and Image Viewer and database
- ThumbsPlus $90 - Thumbnail viewer and database.
- StarTrails - $Free - Stack individual frames into a single star trail image, or movie.

- **Photoshop Filters and Actions**

  - Astronomy Tools $20 - Noel Carboni's Photoshop actions for various astrophoto techniques.
  - Annie's Astro Actions $10 - Astrophotography specific Photoshop actions.
  - Noise Ninja $35 - $80 - Noise Reduction filter.
  - GradientXTerminator $50 - Removes vignetting and gradients.

- **Tutorials on Image Processing of Astrophotos**

  - PixInsight Tutorials $Free
  - Photoshop for Astrophotographers $25 (Download version)
  - A Guide to Astrophotography with Digital SLR Cameras $40 (Book on CD-ROM)
  - Astronomical Image Processing $100
  - IP4AP $80 Warren Keller
  - EZ-CCD-DVD $95 - Tony Hallas Video Tutorials on DVD
  - Adam Block Video Tutorials on DVD $155
  - Images Plus Online and Video Tutorials $180

- **Planetarium Programs and Atlases**

  - Stellarium $Free
  - Cartes du Ciel $Free
  - Virtual Moon Atlas $Free
  - MegaStar $130
  - SkyMap Pro $110
  - The SkyX $79 - $349
  - Starry Night Pro 6 $102

Astronomical Software For the Mac

• DSLR Camera Control and Focusing

- DSLR Shutter $Free - image acquisition automation
- Nebulosity $60 - Camera control, focus, image acquisition automation, image calibration, image processing
- iAstrophoto $Free - Digital camera focus and control software for Canon astrophotography using Macintosh OS X
- Astro IIDC $110 - primarily for planetary imaging

• Astronomical Image Processing Programs

- Keith’s Image Stacker $15 - For stacking planetary images.
- Lykenos $Free - Planetary image stacking and processing.
- Astrostack $39 - Image stacking and processing.
- Nebulosity $60 - Camera control, focus, image acquisition automation, image calibration, image processing
- PixInsight 171 Euros

• General Image Processing Programs

- Photoshop Elements $90
- Photoshop CS5 upgrade $195
- Photoshop CS5 retail $649
- GIMPshop $Free

• Photo Utilities

- FITS Liberator $Free - FITS file format image handling software.
- iPhoto Bundled with New Macs, or available as part of iLife ($80) - image viewer, database, and image editing.
- StarStax $Free - Stack individual frames for a star trail image

• Photoshop Filters and Actions

- Astronomy Tools $20 - Noel Carboni’s Photoshop actions for various astrophoto techniques.
- Annie’s Astro Actions $10 - Astrophotography specific Photoshop actions.
- Noise Ninja $80 Noise Reduction filter.

• **Tutorials on Image Processing of Astrophotos**

- Photoshop for Astrophotographers $25 (download)
- A Guide to Astrophotography with Digital SLR Cameras $40 (Book on CD-ROM)
- Adam Block's Video Tutorials on DVD $155

• **Planetarium Programs, Atlases, Etc.**

- Stellarium $Free - Desktop planetarium and space simulation
- Celestia $Free - Desktop planetarium and space simulation
- AstroPlanner $45 - Planning, logging, telescope control
- Equinox6 $60 - Desktop planetarium, telescope, webcam and focuser control
- AstroImage Browser $15 - Digitized Sky Survey (DSS) front end, astrophotography planning, and ability to overlay your own images on DSS images for comparison
- The SkyX $79 - $349 - Desktop Planetarium
- Starry Night $249 - Desktop planetarium

Prices on all commercial software are subject to change without notice.

Note that you should be able to run any of the Windows programs listed above on your Mac with OS-X and software like Parallels or VMware Fusion.

Midnightkite also has a nice collection of links to lots of other astronomical related software for a variety of operating systems.

THANK YOU

Just a quick note to say ***thank you*** for buying this book. I truly hope you have enjoyed the journey of discovering all the aspects of photography in this book. It has taken a lot of my brain cells to pour out on the pages my many years of experience, as well as my successes and all of my errors.

I remember the very first 3 or 4 rolls of film I bought and how excited I was to head down to my local little beach at a place called South Cronulla in Sydney, Australia. I loaded the roll of Kodak 400 ISO speed negative film, into my little Pentax MZ-50 35mm SLR and set up my plastic legged tripod in the sand. It was a great feeling knowing I was about to create something…from nothing! I spent the next two hours photographing all the people, surfers, girls in bikinis and the rolling waves along the beach in the early morning sunlight. What an accomplishment!. I just created a roll of pictures that ***no one*** else has. I couldn't wait to see what the film looked like.

I waited an excruciatingly painful two days for my film to be developed and the pictures to be ready. I almost ran into the camera developers and asked for my pictures. The first snigger from the developer was odd, but after the second, I figured something was up. Low and behold every image was black, completely black. It was then very obvious that I needed help with my photography, as clearly I didn't have a clue! There began a very, very, long journey to learn the ins and outs of photography.

If you are beginning a journey in photography or simply looking to improve on what you already know, then remember, practice, practice, practice, and when you're not quite sure, practice some more. This is the only way you are guaranteed to stay on top of your craft, your passion, and therefore continue to enjoy what you do, taking photographs!

If you want further photography tuition in a certain topic please browse the other books in the "How to Photograph Anything like a Pro" book series. Or consider a photography class, tour, training course or workshop with me –www.steverutherfordtraining.com.au

Quote -

You don't stop shooting, because you get old….You get old, because you stop shooting!

Anon

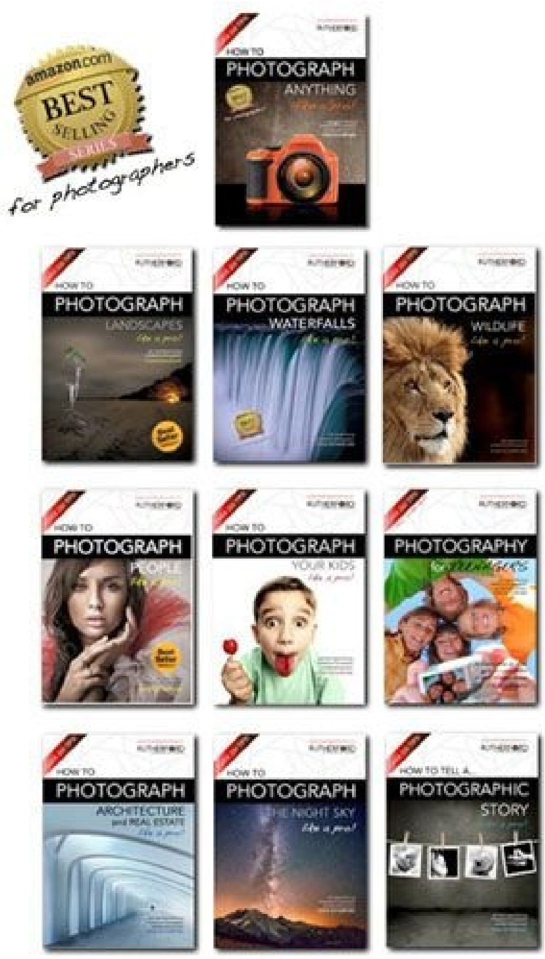
Regards,

Steve Rutherford

Best Selling Author "How to Photograph Anything like a Pro" Book Series

HOW TO PHOTOGRAPH ANYTHING LIKE A PRO BOOK SERIES

http://www.howtophotographanything.com



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Steve Rutherford
Author "How to Photograph Anything" Book Series

GLOSSARY

A

Additive Color - A method of creating color by combining red, green and blue lights. White is created by adding by adding all of these colors, each at maximum intensity. Black is created by a total absence of these colors.

A/D Converter - Analog to Digital Converter. The CCD or CMOS sensor in the camera outputs an analog voltage after detecting photons. The A/D converter turns **this** continuous voltage information into discrete steps of digital data.

ADU - Analog to Digital **unit.** A number that represents the CCD or CMOS sensor's digital output. The number of electrons in each ADU is determined by the system gain.

Aesthetic - Relating to artistic, non-tangible, qualitative, non-quantitative, aspects of a thing or concept that evoke a pleasant appreciation or perception of beauty by the viewer without regard to monetary value or utility.

A-focal - using a camera with its lens attached to take a picture through a telescope's eyepiece.

Airy Disk - The Airy Disk is a disk of light from **a** star that forms at the focal plane of an optical system instead of a point. The stars we **see** in the night sky are so far away that they are essentially point sources. But the image that forms at the focal plane is not a point, because the light that passes through the circular aperture opening of the telescope suffers from the effects of diffraction. Diffraction occurs because of the wave nature of light. It is **called** the Airy disk, after British Astronomer Royal Sir George Airy. It is also called the diffraction or spurious disk.

Algorithm - An algorithm is a series of mathematical instructions to solve a problem or produce a result in a step-by-step procedure.

Aliasing - Diagonal lines that appear stair-stepped or jagged.

Alt-azimuth - Altitude-Azimuth. A telescope that moves in two axes, one left-to-right around a turntable base, and one up and down. Any part of the sky can be located with movement in these two axes.

Amp Glow - A red glow in the corners and edges of a long exposure image caused by electrons in the metal-oxide semiconductor field-effect transistors (MQSFET) that are in the readout amplifier of the camera's sensor, Amp glow is not caused by heat, it is caused by electroluminescence. If not too severe, it can be removed by subtraction of a dark frame.

Analog - Continuously varying information that represents an infinite number of values, Analog data is usually sampled in a discrete, finite number of steps before it is turned into digital data.

Angstrom - A measure of distance, usually used to measure wavelengths of light. An angstrom is equal to 10^{-10} of **a** meter (0.0000000001 meter). The angstrom is named in honor of Swedish physicist Anders J. Angstrom.

Aperture - The size of the opening that lets light into a camera lens, which can usually be adjusted and changed, in a telescope, the aperture is usually fixed, and is defined by the size of the primary mirror or objective lens.

Array - A grid or rectangular arrangement of elements. In a digital camera it refers to arrangement of individual pixels in a sensor. The array size is specified by the number of pixels in the x and y dimensions of the chip, for example, the Canon 20Da has an array size of 3504 x 2336 Pixels, or 8,185,34 total pixels,

Artifacts - Artificial, spurious defects in an image that were not part of the original image or data.

Autoguider - A separate CCD or Webcam that is used to send corrections to the telescope's mounting to guide or follow the stars with high accuracy to compensate for inaccuracies in the mount's tracking.

Averaging - adding together a number of frames and dividing by the total. Averaging many frames together increases the signal-to-noise ratio in an image by the square root of the total number of images used. It works because the signal, which is constant, is reinforced, while the noise, **which** is random, is averaged out.

B

Banding (Posterization) - Visible steps in an area that is supposed to be even-toned or smoothly varying, such as a gradient of brightness in a blank sky that fades from light to dark. Banding is usually caused by an insufficient number of digital steps of tone.

Bayer Array - A CCD or CMOS sensor that has an individual red, green or blue filter over each pixel to synthesize color information from a grayscale sensor, The "Bayer" pattern is also called a Color Filter Array (CFA). It is named after Bryce **E.** Bayer, the Kodak engineer who invented it. The colored filters are arranged so that out of each four-pixel group, two will be green, one red, and one blue. Bayer found that because human perception was more sensitive to luminance (brightness) information in the green portion of the spectrum, increasing luminance resolution by using more green pixels meant more perceived sharpness in the final image. Color for each individual pixel is created by examining the color of the pixels around it and then processing this information through a sophisticates mathematical algorithm.

Bias - A low-level charge that **is** applied to a CCD or CMOS sensor in the form of a fixed offset voltage value.

Bias Frame - A zero second exposu**re** that records the bias signal present in every frame. **Used** in advanced calibration.

Binary -1.) Made of two components. ***2.)*** Using binary numbers in the base 2 number system. All computers are binary because the transistors of which they are made have only two states, on and off, which represent the numbers 0 and 1, the two numbers in the base ***2*** number system. 3.)Two stars that are gravitationally bound together and orbit around a common center of mass.

Bit - A contraction of “binary digit”, representing the number 1 or 0 in the base ***2*** number system that computers work with.

Bit Depth - Describes the number of steps of tonal resolution, or brightness levels, that the dynamic range is divided into when it is quantized by the Analog to Digital converter. Bit depth is specified in base ***2*** notation. Eight bits is 2^8 or 2 raised to the 8th power. Eight bits equals 256 steps or levels of information. Twelve bits is 2^{12} and equals 4096 levels. Sixteen bits is is 2^{16} and equals 65,536 levels.

Bitmap - A bitmap is an image that is made of a grid of pixels. Each pixel’s brightness and color information is described in terms of ***bits,*** and this information is ***map***ped to a specific location.

Black Point - The darkest area of an image that is mapped to level 0 (completely black) when setting the dynamic range during a levels adjustment in image processing.

Blooming –Electrons that spill over into adjacent wells when a potential well is full cause blooming, which appears as vertical spikes from bright stars that are overexposed.

Brightness Value (Gray Level, Gray Value, Pixel Value, Digital number) - The brightness of a pixel described as a number. Brightness levels range from 0 for black to 255 for white in an 8-bit image. They can range from 0 to 4095 for a 12-bit image, and 0 to 65,535 for a 16-bit image.

Bulb - The name given to the exposure setting where the shutter stays open for a long time exposure until it is closed by the photographer. Derives from the ancient days of film photography when an air bulb was used to pneumatically open a leaf shutter in a camera lens.

Byte - A basic computer unit of data made up of ***8*** bits.

C

Calibrate - l.) To remove unwanted fixed signals (such as thermal current and bias), and to correct signal modifications (such as vignetting) so that the raw image accurately represents the intensity of light incident on the sensor during the exposure. ***2.)*** To adjust a computer monitor into compliance with a pre-defined standard.

CCD - Charged Coupled Device. A light-sensitive solid-state silicon sensor used in digital cameras to record light intensities.

Celestial Equator - The Earth’s equator projected onto the celestial sphere.

Celestial Poles - The Earth’s axis of rotation projected onto the celestial sphere. The celestial poles on the celestial sphere correspond to the North and South rotational poles on the Earth.

Celestial sphere - The three-dimensional sky seemingly projected onto the inside two-dimensional surface of an imaginary, infinite sphere surrounding the Earth. The Sun, Moon, Planets and stars appear to be located on this celestial sphere. A celestial coordinate system of right ascension (similar to longitude) and declination (similar to latitude) allows location of objects in the sky.

CFA (Color Filter Array) - A CFA image is a monochrome (black and white and grayscale) image containing data from the Bayer array in the CCD or CMOS sensor in the DSLR camera that has not yet been interpolated into color. It presents the data from each individual filter, which has a red, green or blue color filter over it, as a grayscale tone with a brightness value.

Charge - The amount of electrical energy measured by the quantity of electrons stored. In digital imaging, the charge created by electrons generated by photons by the photoelectric effect that are stored in a pixel's potential well.

Clip, Clipping - To lose, cut off, or saturate data at either end, black or white, of the dynamic range by overexposure or incorrect manipulation of data.

Color Filter Array (CFA) - An arrangement of individual color filters over individual pixels in a CCD or CMOS detector designed to synthesize color from a grayscale sensor. A Bayer array using red, green and blue pixels is the most common type of CFA.

Color Depth - The number of steps or levels of tone that each primary color of the total dynamic range is divided into. In 24-bit color, 8 bits of color depth are assigned to each color channel of red, green and blue is represented by 256 steps. This yields more than 16 million total colors (256 * 256 * 256 = 16,777,216).

Color Gamut - A unique range of colors that a device can capture or represent.

Color Management System (CMS) - Color management is a way of trying to keep colors consistent across a range of input, display and output devices by the use of software.

Color Space - A color space is a three-dimensional model for mathematically representing colors with numbers in a coordinate system. A color space is defined by a set of three primaries and a white point. In a given color model, we can have various different color spaces. For instance, in the RGB color model, we can have these color spaces (among many others):

- Adobe RGB (1998)
- sRGB
- Apple RGB
- ColorMatch RGB

Combine - To merge individual images into a "master" image by adding, averaging or other mathematical operations, or to join individual frames into a single picture that is a larger mosaic.

Composite - In digital photography, to l.) combine different individual images sub frames of the same exposure into a single master image. 2.) to create an image with an extended dynamic range by combining exposures of different lengths through the use of masks, or functions such as Photoshop CS2's High Dynamic Range (HDR) command.

Compression - Compacting digital data so that it takes up less space. There are two kinds of compression: lossy and lossless. Lossy compression throws away original data. JPEG is an example of Lossy compression. Lossless compression does not throw away any of the original data. LZW is an example of Lossless compression.

Continuous-Tone - A smooth transition from one tone to another without any visible steps or banding. Continuous-tone usually refers to analog representations which have an infinite series of tones.

Convolution - Convolution is when one function modifies another, such as blurring from poor seeing modifying the point spread function of a star.

CMOS - Complimentary Metal Oxide Semiconductor. A solid-state electronic chip in a camera that can act as a sensor to detect photons, convert them into electrons and then a voltage that can be measured and digitized.

CMYK - A subtractive color printing system where the primary colors are comprised of Cyan, Magenta, Yellow and Black components. The pigments in inks of these colors subtract from white light. All of these primary colors mixed together equally in maximum intensity result in black.

CRW - Canon Raw file format. A proprietary file format with the, CRW file extension for storing the original data from a Canon digital camera.

CR2 - The second generation of Canon's Raw File Format with a, CR2 file extension.

D

Dark (Thermal) Current - Signal that is generated by electrons created in the silicon substrate of a CCD or CMOS sensor by heat. Dark current increases as temperature goes up. This happens even when the sensor is not exposed to light, hence the name "dark current". This signal is more properly called thermal current signal because it is present in all frames, light and dark. Thermal current signal can be removed by the proper subtraction of a dark frame.

Dark (Thermal) current Noise - Noise that is generated because of statistical variations in thermal (dark) current, equal to the square root of the thermal current. Because it is random, it cannot be removed from an image.

Dark Frame - A dark frame is a photo taken at the same exposure, ISO and temperature as a light frame, but with no light reaching the sensor. It is a picture of the camera's thermal current and bias current. Dark frames are used in calibration of digital image data in light frames. By subtracting a dark frame from a light frame, thermal current signal and bias signal are removed.

Dark Frame Subtraction - Removing thermal current signal by subtracting a dark frame. This can be done automatically as a custom function in some DSLR cameras, or manually in later processing.

DDP - Digital Development Processing is image processing that takes linear data and modifies it by gamma stretching and unsharp masking so that the shadow and highlight areas simulate traditional photographic images, which are non-linear.

Dead Pixel - An individual pixel in a sensor that does not respond to light and appears as black in an image.

Deconvolution - Deconvolution is a process that attempts to remove the effects of convolution. For example, deconvolution was used to attempt to restore the aberrated images in the Hubble Space Telescope that were caused by spherical aberration.

Diffraction - The bending of light waves as they pass through an aperture or go around an obstruction. Diffraction causes stars to appear as disks at the focal plane instead of points.

Digital - Represented by numbers.

Digitize - To convert continuous analog data or image to digital data.

DNG - Adobe's Digital Negative raw format. Adobe's attempt to create a non-proprietary, cross-platform, cross-manufacturer raw negative file format that any software can open.

DPI - Dots Per Inch. A measure of resolution that refers to the number of dots a printer can print in an inch of output. Higher resolution means more dots per inch. Often mistakenly used for PPI, or pixels per inch. It more correctly applies to output devices that print with dots, such as inkjet printers.

DSLR - Digital Single Lens Reflex. A camera that uses a mirror to intercept the light from the camera's lens and send it to a focusing screen for inspection by the photographer's eye. The reflex mirror swings up and out of the way when the picture is taken, allowing the light to reach the digital sensor.

Dust Donuts - Out of focus shadows that look like donuts that are caused pieces of dust on the sensor or cover glass in front of the sensor.

Dynamic Range - The range of brightness from light to dark in which detail can be recorded.

E

EOS, - Electro-Optical System. Canon's system where instructions for focus and aperture are sent to the control motors in the lens from the camera body by electrical signals instead of the traditional mechanical methods such as levers.

Equatorial Mount - A telescope mount designed with two axes, one of which (the Polar axis) is made parallel to the Earth's axis of rotation. Movement in this single axis allows celestial objects to be followed to compensate for the Earth's rotation. Any object in the sky can be found by a combination of movements in the two axes. The polar axis corresponds to right ascension, and the other axis to declination.

EXIF - Exchangeable Image File. A storage format that allows technical and other information about the camera, exposure, ISO, lens focal length, and many other settings to be stored along with the actual image data in a file. Other caption information can also be stored in the file. It is essentially a file "wrapper" around a JPEG or TIFF file.

Expose - To make an exposure, or to open the shutter to take a photograph.

Exposure - The length of time that the shutter is open and light is hitting the sensor in the camera.

Eyepiece Projection - A method of photography where the image is formed at the focal plane of the camera by projection by the eyepiece in a telescope. No camera lens is used on the camera, only the telescope's eyepiece is used in the scope.

F

Field of view (FOV) - The amount of a scene that is captured by a given focal-length lens. Wide-angle, short-focal length lenses capture a wide field of view. Telephoto lenses and telescopes capture a very narrow field of view. The field of view is usually specified as an angle that depends on the size of the sensor. For example, a lens or telescope of 500mm focal length will cover a field of view of 4 degrees, 17 arc minutes, 43 arc seconds by 2 degrees 51 arc minutes, 51 arc seconds with a Canon 20Da DSLR camera sensor that is 22.5 x 15mm.

File Format - The structure of a specific type of computer file. Different file formats are associated with different file types and programs. For example, JPEG and TIFF file formats are associated with image files. Their codes are JPG and TIF respectively. Files of a particular format are given a specific file extension in the form of a three letter code. The name of the file is separated from the file format code by a period, such as ORION.JPG, where ORION is the name of the file followed by a period and the extension code for the JPEG file format.

Fill Factor - The percentage of a photosite (pixel) that is actually sensitive to light. For example a CMOS sensor may only have a fill factor of 40 percent, so 60 percent of an individual photosite cannot collect photons. Designers sometimes use a microlens to collect photons over a wider area to increase the fill factor by sending the photons to the light sensitive portion of the photosite.

Filter -1.) A piece of glass or gelatin placed in the optical path that modifies the wavelength or light that ultimately reaches the sensor. An example would be a hydrogen-alpha filter that only allows the light of the hydrogen-alpha wavelength to pass. 2.) A piece of software that performs particular algorithms on digital data. An example would be a Gaussian blur filter in Photoshop that blurs an image.

Firmware - Instructions and software stored permanently in read-only memory, usually for control of a specific device such as a digital camera or CD-R drive. The firmware for most digital cameras can be updated to correct a problem when a manufacturer finds a bug in the way the camera operates.

FITS - Flexible Image Transport System. A file format specifically developed for scientific Images that are designated by the, FIT file extension. Non-image data can also be stored in a FITS file.

Fixed-Pattern Noise: Fixed-pattern noise is pattern that repeats in the same location in an image from frame to frame. It can be removed with proper calibration procedures. Technically it should be called fixed-pattern signal since noise is random and does not repeat.

Flatten - A term used In Photoshop that means to merge separate layers of corrections or masked data information in an image.

Flat-Field Frame - A calibration frame taken of an evenly illuminated subject used to correct for vignetting, uneven illumination, dust on the sensor’s cover glass, and uneven pixel response.

Frame - l.) Used as a noun, a frame is an image or an exposure. Derived from the days of film where images were taken on a roll of film and each individual image was called a frame. In digital astrophotograhy, you can have light frames, dark frames, bias frames and flat-field frames. 2.) Used as a verb, to frame means to compose the subject inside of the viewfinder. For example, you want to "frame" the Orion Nebula so that none of the faint outer nebulosity gets cut off.

F/Stop - The designation marker on a lens that indicates the focal ratio that is being created by stopping down the aperture of the lens with an internal diaphragm Inside of the lens. The F/stop is same thing as the focal ratio or F/ratio. It is defined as the ratio between the aperture and focal length of an optical system. For example, a 5 inch aperture telescope with a focal length of 40 inches has a focal ratio of 40/5 or f/8.

Focal Length - The distance from the lens or mirror in an optical system and the focal plane where the light is focused.

Focal Ratio (F/ratio) - the ratio between the aperture and focal length of a lens or telescope P-or example, a 127 mm aperture telescope with a focal length of 10l6 mm has a focal ratio of 1016/127 or f/8.

Focal Reducer (Telecompressor) - An optical component mace of a lens or class elements that decrease the focal length (and focal ratio) of a telescope.

Focus - Hocus is when the focal plane of an optical system is coincident with the focal plane of an eyepiece or digital camera. An optical system can be considered focused when the maximum amount of light from a star is concentrated into the smallest possible area at the photodetector sensor surface, yielding the smallest possible star size.

Full well capacity - I he number of electrons that can be stored in a potential well in a photosite (pixel) In a CCD or CMOS sensor. Full well capacity goes down as the ***ISO*** goes up In a digital camera.

Full Width Half Maximum (FWHM) - A measurement of the diameter of a star where the intensity is 50 percent of the star's maximum brightness value.

G

Gain - Gain defines how many electrons are represented by each Analog to Digital unit (ADU). A gain of 4 means that the A/D converter has digitized the signal so that each ADU corresponds to 4 electrons. DSLR cameras can change ISO by changing the gain.

Gamma - In photography, gamma refers to the midtone contrast of an image, "Technically, gamma refers to the relationship between input voltage and output Intensity, where gamma is the exponent in a power-law relationship between input values and output displayed brightness, such as in a computer monitor.

Gamut. - The -range of colors that can be detected, recorded or displayed by an imaging device. Each device has a unique gamut.

Gaussian Blur - A mathematical function that is applied to an image to blur it based on a bell-shaped curve or Gaussian distribution, named after the famous German mathematician Karl Friedrich Gauss.

GIF - Graphic Interchange Format, an image file format with a .GIF file extension that supports only 256 colors that Is useful for non-pictorial images, such as line drawings and diagrams.

Grayscale - Containing no color, only various shades of gray in a black and white image.

Gray Level (Gray Value, Brightness Value) - The brightness level of a monochrome (not color) pixel indicated by a number. Gray levels run from 0 to 253 for an 8-bit image.

Guiding - Manually or automatically following a star by making corrections in right ascension and declination to produce higher tracking accuracy.

H

High Dynamic Range (HOR) - 1.) An image with a larger dynamic range than usual. 2.) A method of combining different exposures to extend the dynamic range recorded in an image, such as Photoshop CS2's HDR function.

Highlight - The brightest areas of an image that contain detail.

Histogram - An image histogram is simply a bar graph that shows the number of pixels at each brightness level in an image. A histogram runs from pure black with a brightness value of 0 on the left to pure white with a brightness value of 255 on the right hand side of the graph,

Hot Pixel - A pixel that registers a brightness value much higher than it should based on the incident light that hit it.

Hydrogen Alpha - A specific emission line of ionized hydrogen at 656.3 nanometers, Hydrogen-alpha emissions are responsible for the red color in emission nebulae.

I

Image - 1.) used as a noun, an image is simply a picture. For example, "That is a very nice image of the Orion Nebula." 2.) used as a verb, to image is to take a picture. For example, "Tonight I am going to image the veil Nebula."

Image scale - The size on an image formed by a lens or telescope based on the magnification of the optical system, image scale is usually measured in a digital camera as arc seconds per micron, or arc seconds per pixel.

Infrared (IR) - Long wavelengths of light beyond the visible portion of the spectrum, typically between 770 nanometers and 1 millimeter,

Integration - Collecting photons for a given exposure time to accumulate a charge or signal in a digital sensor. Integration time is essentially equivalent to exposure time.

Interpolation - A mathematical procedure for increasing resolution by up-sampling, or decreasing resolution by down-sampling. up-sampling creates new data from existing data and increases file sizes. It is not real data though, It is the algorithm's best guess at what the real data would have been if It had actually existed, Down-sampling lowers resolution and decreases file size by throwing away real data In existing pixels and creating new pixels.

ISO - An international standard published by the international Organization for Standardization. In the field of photography, the term ISO is used as a shorthand name for the standard defined by the specification for determining the sensitivity to light of film or a digital camera sensor. In film, a higher ISO number means the film is more sensitive to light. Digital camera sensors really only have one sensitivity to light though. Changing the ISO on a digital camera changes the gain in the camera, seemingly changing the sensitivity,

J

JPEG - A file format with a .JPG extension that compresses image image data according to a standard algorithm as defined by the Joint Photographic Experts Group (JPEG). JPEG compression is lossy, It throws image data away, but in a method that reduces the visual impact at reasonable compression ratios.

K

Kilobyte – 1024 bytes.

L

Lab Color - Technically called L*a*b* color, Lap Color is a color model that encompasses all of the colors that the human eye can see, defined mathematically in a device-independent method that is perceptually uniform, The L* channel contains the luminance Information, Two other channels are the chromatic channels that contain the color information. The a* channel contains the red-green color axis and the b* channel contains the blue-yellow axis.

Layers - A separate channel from the color channels used to store information in a photo-editing program, such as Photoshop. Layers can be used for color and tonal adjustments without altering the original data in the file until the layer is merged or "flattened" with the other channels. Layers also allow the creation of masks for use in an Image.

Levels - Individual steps of brightness in an image. The Levels command in Photoshop allows adjustment of an images black and white points and mid-tone gamma in each individual color channel.

Light - Light is a form of radiant energy that we can see with our eyes, and record with film and CCD cameras, Visible light (400 nm to 770 nm) is the portion of the electromagnetic spectrum of energy that can be detected by the rods and cones in the retina of our eyes and that causes the sensation of vision in our mind. The nature of light is not completely understood. It is a complicated subject because it involves two of the deepest mysteries of which we are now aware - human consciousness and quantum mechanics.

Light Box Flat - A flat-field frame created with a light box with an artificial light source.

Light Frame - An exposure to the light from the subject through a lens or telescope.

Light Year - A measure of the distance (not time!) that light travels in vacuum in one year of Earth time, equal to 9.46 trillion kilometers or 5.88 trillion miles.

Linear Response - A response in a digital sensor where the output directly corresponds to the input signal. Most CCD and CMOS sensors have a linear response to light, that means that a doubling of exposure time results in a doubling of brightness in the recorded image.

Lossless Compression - A compression method, such as LZW, where the original data is completely preserved and no information is thrown away. Lossless, compression usually only results in a modest saving in file size for images.

Lossy Compression - A compression method, such as JPEG, where data is thrown away to gain increased compression ratios and smaller file sizes.

LRGB - A method of creating an image where high-resolution black and white Luminance data is combined with lower-resolution RGB color data to decrease total exposure time. The L in LRGB stands for Luminance.

M

Magnitude - A scale for measuring the brightness of a celestial object. Each magnitude varies by a factor of 2.5l2. The brightest star in the sky is Sirius at magnitude -1.4. The *apparent magnitude* of an abject Is how bright the object seems from the Earth. With two objects of the same intrinsic luminosity *or absolute magnitude* will appear with different apparent magnitudes if they are located at different distances from the Earth with the nearer one appearing brighter. On the magnitude scale, the lower the number the brighter the object. Diffuse objects are measured in magnitudes per square are second, as if starlight from a point source was spread out over an area of one square are second.

Mask - An overlay that blocks certain portions of an Image so that other portions can be selectively manipulated.

Master - In Photoshop and other image processing programs, a mask is used to block out certain areas of an image so that corrections and filters can be selectively applied. Masks range from black, where no effect is applied, to white where 100 percent of the effect is applied. Shades of gray in a Task allow varying percentages of the effect to get through in proportion to the brightness of the mask.

Median combine - A method of combining images mathematically where the middle value is used out of a distribution of different values, above and below which he an equal number of values. A median combine is useful for combining a group of images to remove renegade pixels that might result from cosmic ray strikes in different locations in each image.

Megapixel - A CCD or CMOS sensor that has one million pixels. A 5 megapixel camera has 5 million pixels.

Meter - A standard unit of length which defines the metric system and is equal to the distance traveled by light in a vacuum in 1/299,792,458 of a second. Approximately 39.37 inches. The speed of light, not coincidentally, is 299,792,458 meters per second in a vacuum.

Micron (Micrometer) - One millionth of a meter. Also equal to one thousandth of a millimeter. Abbreviated µm.

Microlens - An extremely small lens that goes over a photosite (pixel) to direct photons to the light sensitive photodiode that comprises only a part of the total area of the entire photosite. This increases the sensitivity of the detector and improves the fill factor.

Millimeter - One thousandth of a meter. Abbreviated mm. There are 25.4 millimeters in one inch.

Mosaic – 1.) In digital sensors, an arrangement of non-overlapping tiles or pixels that constitute the sensor array, such as a Bayer pattern in a DSLR CCD or CMOS sensor. 2.) In an astrophotographic image, a mosaic is a wider-angle picture made up of a series of narrower-angle pictures. Each Individual tile in the larger picture is shot so that there is some overlap with the tile next to it so that individual images can be correctly aligned. When the individual images are put together like a puzzle to form the larger image, the edges of the tiles that overlap are blended together seamlessly so that the edges are invisible. This creates a higher-resolution images with wider fields of view than would normally be possible.

N

Nanometer - A measure of distance usually used to measure wavelengths of light. A nanometer is equal to one billionth (10-9) of a meter.

Narrowband Imaging - The use of narrowband filters, which pass only selective wavelengths of light, to take an astrophotograph. For example, a narrowband Hydrogen-Alpha filter passes only a narrow window of wavelengths centered around 656.3 nm, the Hydrogen-Alpha wavelength of red emission nebula. By filtering out the rest of the spectrum, much more contrast is gained in the wavelength of interest, at the cost of increase exposure time. Some typical filters for narrowband imaging are Hydrogen-Alpha, Oxygen-III, and Sulfur-II.

NEF - Nikon Electronic Format. A proprietary raw file format with an NEF extension for Nikon Digital cameras.

Noise - Technically, random and non-repeatable signal in an image, in common use in digital photography, any unwanted or undesirable signal that does not convey useful information. For example, a dark frame is composed of thermal current signal, thermal signal noise (and bias). Thermal and bias signals are technically not noise because they are consistently repeatable, and this is how we are able to remove them by subtraction with a calibration frame, Thermal signal noise is random and cannot be removed. However many people refer to thermal current as “noise”.

Non-Linear Stretch - In image processing where the range of tones in an image are adjusted so that the contrast of a portion (usually the shadows) is increased while another (usually the highlights) is decreased. The mapping between brightness values in a scene and tones out of a raw file in a digital camera is linear. Human vision however, is not linear. A correct non-linear stretch must be applies to raw linear data out of a digital camera to present the tones in an image in the way that is expected by human perception.

Normalization - Applying a mathematical function like multiplication to data from one image to make it match another, For example, multiplying each pixel's brightness value by 2x in a 30 second exposure to make it match the pixel values in a 1 minute exposure.

Nyquist sampling Theorem - A theorem in communications theory, formulated by Harry Nyqulst in 1928, that says when converting an analog wave form to digital data, the sampling must be at two times the highest frequency of the original to preserve all of the information in the original. The theorem can also be applied to spatial information such as high-resolution detail in an image that is sampled by the pixels in a digital sensor.

O

Offset (Bias) - A low-level charge that is applied to a CCD or CMOS sensor in the form of a fixed offset voltage value.

Offset (Bias) Frame - A zero second exposure that records the offset signal present in every frame, used in advanced image calibration.

One-Shot Color - Color that is created in one exposure, such as with a Bayer array on a CCD or CMOS camera. Since these sensors are really monochrome grayscale devices, creating color with individual filters would usually require three separate exposures, one for each of the red, green and blue filters. A Bayer array places a pattern of red, green and blue filters over the pixels in a sensor and through interpolation creates color for each pixel location in a single exposure.

P

Periodic Error - An error in tracking that repeats with a regular period in an equatorial mount, usually the period of revolution of the worm gear. It is caused by imperfections in the gears which are used to move the telescope at the same rate that the Earth rotates.

Photon - A quantum of electromagnetic energy usually associated with light. Photons appear to be both waves and particles simultaneously.

Photodiode - An photodetector that converts light (photons) into an electric charge (electrons) through the photoelectric effect. The photodiode is the heart of the sensor in a digital camera.

Photoelectric Effect - The ejection of electrons from the surface of a substrate such as silicon caused by the energy contained in photons, such as in a photodiode in a CCD or CMOS sensor. The Photoelectric effect was explained by Einstein in 1905, for which he won a Nobel prize for Physics in 1921. It is the fundamental reason that silicon sensors can be used for digital photography. The energy of the photons that hit a photodiode release electrons that are stored in a potential well. These electrons form an electric current that is measured as a voltage. This analog voltage is amplified and then turned into a digital value (simply a number) by the Analog to Digital converter. The amount of current is proportional to the number of photons that hit the detector.

Photoelectron - An electron that is released through the photoelectric effect when a photon is absorbed in the silicon substrate of a photodetector in a digital camera.

Photon (Shot) Noise - Noise that is created because of the statistical variation of photon emission by a light source over time.

Photon Noise Limited - An image is photon-noise limited when the exposure is of sufficient length so that photon noise is the major source of noise in the image instead of read-out noise. Short exposures do not record many photons and therefore do not have much photon noise. The noise in short exposures is predominantly read-out noise and these short exposures are called read-out noise limited.

Photosite - An individual square in a sensor array that contains a photodiode and storage area for electrons. Also frequently called a pixel. In a CMOS chip a photosite may also contain additional electronics such as an amplifier, noise reduction circuitry and an analog to digital converter.

Piggyback - Mounting a camera and lens on top of a telescope on a mounting. Piggyback photography is usually used for long-exposure wide-angle astrophotography where the camera and lens take the picture while riding on top of a telescope on an equatorial mount that is polar aligned and tracking the stars to compensate for the Earth's rotation.

Pixel - A "Picture Element". In a digital camera, it refers to an individual photosite on the CCD or CMOS sensor. In the image it refers to the smallest building block out of which the image is made of. A pixel on the sensor corresponds one to one with a pixel in the final image.

Pixel Array - A grid or rectangular arrangement of pixels in the CCD or CMOS sensor in a digital camera.

Pixel Size - The physical size of the pixel in the pixel array in the sensor. Usually measured in microns. For example, the size of each individual pixel in the Canon 20Da camera is 6.4 microns.

Pixel well - An area in a photosite where electrons are stored that are released from the silicon surface by the energy of impacting photons through the photoelectric effect. Also called a potential well.

Pixelization - Pixelization occurs when an image is enlarged so much that Individual pixels become visible.

Point Spread Function (PSF) - A mathematical description of how the light from a theoretical point source like a star is spread out by seeing, diffraction, optical quality, tracking accuracy, and the resolution of the sensor.

Poisson distribution - A mathematical probability function that describes the distribution of a randomly occuring event over a specific time interval. For example, photons emitted by a source of constant Intensity are not output at a perfectly constant rate over time. In one minute, 100 photons may be counted. In the next minute, 110 photons may be counted. The minute after that, only 90 photons may be counted. The actual intensity of the source can be known only to the square root of the total number of photons that are measured. The result, over time, is a Poisson distribution which looks like a bell-shaped curve. A Poisson distribution is named after French mathematician Simeon-Denis Poisson, who developed the math.

Polar Alignment - Making the polar axis of an equatorial mount parallel to the Earth's axis of rotation by pointing It accurately at the North Celestial Pole in the Northern Hemisphere, or the South Celestial Pole in the Southern Hemisphere.

Posterizatlon (Banding) - Visible steps in an area that is supposed to be even-toned or smoothly varying, such as a gradient of brightness in a blank sky that fades from light to dark. Banding is usually caused by an insufficient number of digital steps of tone.

Potential Well - An area in a photosite where electrons are stored that are released from the silicon surface by the energy of impacting photons through the photoelectric effect. Also called a pixel well.

PPI - Pixels Per Inch. A basic measurement of resolution. More pixels per Inch yield higher resolution images.

Prime Focus - Prime focus describes a camera attached to a telescope without any other eyepieces or camera lenses in the optical path. The telescope then acts as the camera lens.

Q

Qualitative Analysis - Evaluation based on subjective judgement.

Quantitative Analysis - Evaluation based on objective, measurable quantities.

Quantum Efficiency - The percentage of photons that hit a CCD or CMOS sensor that are detected and turned into photoelectrons. Quantum efficiency varies by the wavelength of light. It can also vary by the color of the filter over an Individual pixel in a Bayer array.

R

Raster Data - In digital photography, data that is represented by a grid of pixels that make up an image, usually used for normal pictorial images. Vector Data is a mathematical description of the data that allows unlimited scaling of the image, usually used for typefaces and graphic line images and Illustrations.

Raw - Unprocessed data directly from the sensor.

Readout Amplifier - An electronic circuit that amplifies the signal after the charge in a digital sensor has been converted to a voltage and before it is sent to the analog to digital converter. The readout amplifier is the main source of readout noise in an image.

Read Noise (Read-Out Noise) - Electronic noise that is generated by the readout amplifier as the signal is read out, amplified, aid sent to the analog to digital converter.

Read-Noise Limited - The majority of noise in a digital image comes from photon noise, dark current noise and read noise. Dark current noise and read noise dominate when the total number of photons being gathered is small. Photon noise dominates when a large number of photons are gathered in long exposures. Short exposures are usually called "read-noise" limited because tine read-noise dominates.

Resampling - Resizing an image by mathematical algorithms that examine neighbouring existing pixels and create new ones based on this analysis.

Resolution - Spatial Resolution is the number of pixels that we have in an image, and the size of the space that these pixels are contained in. Two parameters are necessary to specify resolution: the number of pixels per inch or centimeter and the total number of inches or centimeters. More pixels in a given space mean higher resolution. Tonal resolution specifies the number of steps of tone that the dynamic range is divided into.

RGB – Red, Green and Blue. These are the three primary colors, out of which all other colors can be created, in the additive color model.

S

Sampling - Measurement in discrete, regular intervals. Spatial sampling in a digital camera is done by the number of pixels in a given sized area sensor. Tonal sampling is determined by the bit-depth of the analog to digital converter. Correct spatial sampling in high-resolution astrophotography matches the sample size (pixel size) to the size of the Airy disk and seeing, based on the Nyquist sampling theorem.

Saturation - 1.) Tonal or pixel values on the bright end of the dynamic range that are maxed out and contain no detail, ***2.)*** The purity or vividness of a color.

Scaling - 1.) Changing the black or white endpoints in image histogram to modify the data so that it changes its distribution in the dynamic range. 2.) Enlarging or reducing the size of an image.

Seeing - The steadiness of the atmosphere that allows fine details to be seen in celestial objects. If the seeing is good, detail is not blurred as much by atmospheric scintillation. Scintillation is what causes the stars to twinkle, which may be appreciated poetically, but usually means the seeing is not that good. Thermal gradients at different elevations in the atmosphere are usually responsible for the quality of the seeing. Seeing also usually deteriorates for objects closer to the horizon because the light has to pass through a greater air mass.

Sensor - Usually refers to the CCD or CMOS chip in the camera that senses photons of light and turns them into electrons which ultimately end up as digitized numbers that represent the light that hit the sensor,

Shadow Area - Dark areas in an image that contain detail.

Shoot - To take a picture.

Signal - In a digital camera, signal is an electric current or voltage, whose variations represent information. For example, the number of electrons released through the photoelectric effect from photons from a star forms a current that represents the brightness of the star. Signals can be Interesting, such as those from astronomical objects, or not interesting, such as that from thermal current.

Signal-to-noise ratio - A measure of the quality of a signal, expressed as the ratio of the signal to the noise present.

Sky Flat – A flat-field frame that uses the clear sky as a light source.

Stack - A generic term that means to combine images by any of several mathematical processes such as averaging, or addition. The term originates in the days of film astrophotography where images were literally stacked on top of one another to improve contrast and color.

Stretching - Redefining the black or white points in an image to increase the contrast.

Spatial Resolution - The amount of detail contained in a given space. In digital imaging, spatial resolution is defined by the number of pixels per unit area.

Spectral Sensitivity - The wavelengths of light to which the CCD or CMOS chip is sensitive.

Sub Exposure - A sub exposure is one of many shorter exposures that are made and then added or averaged together to equal a single longer exposure.

Subtractive Color – A color model where color is created by absorption of light by ink or pigments, for example, CMYK color printing.

Summing - Mathematically adding together individual shorter-exposure images to create the equivalent of a longer-exposure image.

Support Frames - Frames that are used to calibrate a light frame image, such as darks, flat-fields, and bias frames.

System Gain - The total gain in a system that defines how many electrons are represented by each Analog to Digital unit (ADU). A gain of 4 means that the A/D converter has digitized the signal so that each ADU corresponds to 4 electrons. DSLR cameras can change ISO by changing the gain.

System Noise - The total noise generated in the camera by various different sources such as interference, dark noise, photon noise and read noise.

T

Target - The astronomical object of interest.

Telecompressor (Focal Reducer) - An optical component made of a lens or glass elements that decrease the focal length (and focal ratio) of a telescope. For example, a 0.75x telecompressor will make a l,000mm focal length f/8 optical system into a 750mm f/6 optical system.

Tele-extender - An optical component made of a lens or glass elements that increases the focal length (and focal ratio) of a telescope, for example, a 2x tele-extender will turn a 1,000mm focal length f/8 optical system into a 2,000mm f/16 optical system.

Thermal Current - Signal that is created from electrons released by the thermal energy in the sensor substrate, even when it is not exposed to light.

Thermal Frame - A calibration frame that is comprised of the thermal current present in a sensor at a given exposure, ISO and temperature. A thermal frame is created by subtracting a bias frame from a dark frame.

Thermal Noise - Noise that is generates because of statistical variations in thermal (dark) current, equal to the square root of the thermal current. Because it is random, it cannot be removed from an image.

TIFF - Tagged Image file Format. An image file format with the, TIF file extension. The

TIFF file format has become a standard for storing uncompressed images.

Tonal Range - The range of tones present in an image from black to white. Also known as the dynamic range.

Tonal Resolution - The number of steps that the dynamic range is divided into as specified by the bit-depth of the analog to digital converter.

Tracking - Following a star with a telescope to compensate for the Earth's rotation.

Transparency - The clarity of the atmosphere.

Twilight Flat - A flat-field frame that uses the clear twilight sky as a light source,

U

Ultraviolet [UV] - The short wavelength region of the spectrum below blue and violet from about 10 nanometers to 380 nanometers.

Unsharp Mask - An image processing technique used to sharpen detail. The term derives from the graphic arts industry where a blurred positive copy of a negative image was registered with it and then contact printed, masking low-frequency information, allowing the contrast of the remaining high-frequency information to be increased, resulting in more apparent sharpness, The same effect is now accomplished in software in a somewhat analogous process.

USB - Universal Serial Bus. A protocol and hardware system for transferring data from peripherals to a computer over cables.

V

Vignetting - Light falloff in the corners of an image due to optical, geometrical or mechanical reasons.

W

Well Depth - How many electrons can be accumulated in an individual charge well in a photosite in a CCD or CMOS sensor. Well depth determines the available dynamic range once noise is factored in.

White Balance - Adjusting the color in an image to compensate for the color temperature of the illumination source.

White Point - The brightest area of an image that is mapped to the highest level available (pure white) based on the bit-depth of the image (Level 255 for an 8-bit image) when setting the dynamic range during a levels adjustment in image processing.

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