

PLATE IX.



METEORIC DISPLAY OF FEBRUARY 9, 1913

(From a drawing by Gustave Hahn, Toronto).

The above represents a portion of the display as observed by Mr. and Mrs. Hahn, in the vicinity of High Park, Toronto.
The spaces between succeeding clusters were actually somewhat greater than shown here.

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AN EXTRAORDINARY METEORIC DISPLAY

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ON the evening of Sunday, February 9, 1913, the inhabitants of an extended portion of the United States and Canada witnessed a meteoric display which, as far as I can learn, is quite without a parallel. It was not my good fortune to be an eye-witness of the phenomenon, but when, a few minutes after it had passed, telephone messages were received describing it, I realised that there had been a very exceptional occurrence. Yet it was only on the following day, after interviewing various observers and reading the reports in the newspapers, that the truly extraordinary nature of the display was recognised.

I then decided to investigate the matter. In response to a request for reports of observations, courteously published in the daily newspapers of Toronto and repeated in some of the papers in others places, many letters and verbal communications were received. By reading the vivid descriptions and examining the illustrative sketches supplied by my correspondents, I have been enabled, in imagination, to view the wonderful spectacle again and again. The information supplied has also permitted me to

trace the path of the meteors with considerable accuracy and to determine various other facts connected with their flight.

My inquiries also revealed the fact that during a few hours before and after the great display several other striking meteors were observed, though I have not a complete enough record of the fireballs to enable me to compute their paths.

I propose to give, first, a brief general account of the display and then a statement of the conclusions I have reached regarding the path of the meteors, their height above the earth, their speed, the sounds heard, the duration of the display and the size of the bodies. After this I shall refer to other meteors seen within a few hours of the main display, and at the end I shall add extended extracts from many communications sent in. The reports regarding the great display, which extended from Saskatchewan to Bermuda, are printed first, the places from which they were received being arranged in alphabetical order; those referring to the other meteors appear together at the end. Along with the reports are reproductions of sketches sent with the letters. These were for the most part hastily drawn by people who have no particular talent for drawing, but they well illustrate what the text describes and are printed without any attempt to turn them into works of art.

The reader will be interested in examining these extracts from the letters. He will also see that intelligent people can differ widely in describing a phenomenon, and will be able to appreciate the difficulty I have had in discriminating between very discordant observations.

The numerous communications which I have received regarding this peculiar natural phenomenon have afforded me much pleasure, especially those sent by the boys and girls; and the readiness to respond to my requests for further information has been very gratifying.

GENERAL DESCRIPTION

[AS SEEN IN WESTERN ONTARIO]

At about 9.05 on the evening in question there suddenly appeared in the northwestern sky a fiery red body which quickly

grew larger as it came nearer, and which was then seen to be followed by a long tail. Some observers state that the body was single, some that it was composed of two distinct parts and others that there were three parts, all travelling together and each followed by a long tail.

The front portion of the body appears to have been somewhat brighter than the rest, but the general color was a fiery red or golden yellow. To some the tail seemed like the glare from the open door of a furnace in which is a fierce fire; to others, it was like the illumination from a search light; to others, like the stream of sparks blown away from a burning chimney by strong wind.

The first suggestion which occurred to many who saw the body was that someone had set off a great sky-rocket. In the streaming of the tail behind, as well as in the color, both of the head and the tail, it resembled a rocket; but, unlike the rocket, the body showed no indication of dropping to the earth. On the contrary it moved forward on a perfectly horizontal path with peculiar, majestic, dignified deliberation; and continuing in its course, without the least apparent sinking towards the earth, it moved on to the south-west where it simply disappeared in the distance.

As we all know, most shooting stars are visible for but a very short time, and the brilliant ones very generally descend rapidly towards the earth, seemingly (as one of my correspondents remarked) "in a mighty hurry to reach their destination"; but here were bodies moving leisurely along, giving ample time for the fortunate observer to make *several* wishes if he were so inclined. Some report that just before disappearing this body burst, leaving behind it a trail of stars.

Before the astonishment aroused by this first meteor had subsided, other bodies were seen coming from the north-west, emerging from precisely the same place as the first one. Onward they moved, at the same deliberate pace, in twos or threes or fours, with tails streaming behind, though not so long nor so bright as in the first case. They all traversed the

same path and were headed for the same point in the south-eastern sky.

Gradually the bodies became smaller, until the last ones were but red sparks, some of which were snuffed out before they reached their destination. Several report that near the middle of the great procession was a fine large star without a tail, and that a similar body brought up the rear.

To most observers the outstanding feature of the phenomenon was the slow, majestic motion of the bodies; and almost equally remarkable was the perfect formation which they retained. Many compared them to a fleet of airships, with lights on either side and forward and aft; but airmen will have to practice many years before they will be able to preserve such perfect order. Others, again, likened them to great battleships, attended by cruisers and destroyers. Should these bodies strike the earth they might prove destroyers indeed! Still others thought they resembled a brilliantly lighted passenger train, travelling in sections and seen from a distance of several miles. The flight of the meteors has also been compared to that of a flock of wild geese; to a number of men or horses in a race, and to a school of fish, startled and darting off in a single direction. These and many others interesting details will be found in the reports of observations printed below.

Just as the bodies were vanishing, or shortly afterwards, there was heard in many places a distinct rumbling sound, like distant thunder or like a carriage passing over rough roads or over a bridge. In some cases three such sounds, following at short intervals, were heard; while a number of people felt a shaking of the earth or of the house.

As to the number of bodies there is great diversity of statement. The usual estimate is from 15 to 20 but some say 60 or 100, while some say there were thousands. Various reasons can be assigned for the discrepancy between these numbers. Those giving the small numbers probably refer only to the chief bodies, and as some people have better eyesight than others, where one would see a single body others would see its

different parts. Those who report the large numbers undoubtedly included fragments of the larger bodies and also the many red stars bringing up the rear. The only person that I have heard of who viewed the meteors with any instrumental assistance was Master Cecil Carley, a pupil of the Trenton High School, who used an opera glass. He says: "There were about ten groups in all and each group, as seen through the opera glass, consisted of from twenty to forty meteors."

The entire time occupied by the display cannot be determined accurately, but is given below as perhaps 3.3 minutes. This is an extraordinarily long time for such a phenomenon, but there is good evidence that it is not an exaggeration.

The stretch of country over which the display was seen is also unprecedented. In September, 1868, a fire-ball was traced from over the Black Sea to France, about 1500 miles; and on December 21, 1876, such a body first became visible in Kansas and disappeared near Niagara Falls, thus covering a distance of over 1000 miles; but in the present case persons living 2500 miles (one-tenth of the earth's circumference) apart saw the same bodies. Moreover the description furnished by observers in Bermuda, in Ontario and in Saskatchewan do not materially differ.

In all ages comets and meteors have excited popular interest and in some cases alarm. Their appearance, entirely unannounced, their varied and extraordinary forms, as well as their almost inexplicable motions are well qualified to inspire terror to those unlearned in scientific matters. We are therefore not surprised to learn that some who saw this weird and unwonted spectacle were deeply impressed. One of my Toronto correspondents wrote: "It was a most beautiful sight. There were a number of us on the street watching them in the sky, and a remark from one of the ladies standing near me and who appeared to be in great distress, was that some dire calamity was coming to the earth. Another remark was, that they must be souls going to heaven, and so on, and a more or less serious impression was for the time being upon us all." Dr. Robert

Moore, of Fort Frances, who visited some Indian patients soon after the display states that an Indian remarked; "I am sure you will hear something. It must be the end of the world!"

THE PATH OF THE METEORS

As the meteors were observed at places a very great distance apart the *direction* of their path can be determined with considerable accuracy, though its exact location may be slightly in doubt. The place farthest west from which a report has been received was Mortlach, which is about 65 miles west of Regina, in Saskatchewan. Here they were described as travelling from west to east. At Pense, about 48 miles to the east, they were described as moving "in the sky directly overhead, in a direction from west to east."

When seen in Ontario the meteors were described as travelling generally from north-west to south-east, and sufficient observations were reported to enable one to determine with some definiteness a point which was directly below the path in the sky. From Campbellville the report states: "They passed *directly* overhead, travelling from north-west to south-east." At Hespeler, they "seemed to go right over our heads, or a little to the north." At Elora they appeared as "rising straight overhead." At Guelph, on plotting the path on a plan of the city streets, they seemed to have passed slightly to the south-west of the zenith. At Waterloo the course of the first was described as "almost directly overhead, but a little to the east." As to the rest, the majority were "a little to the east of us, with a few directly overhead, none to the west." At Berlin the course was judged to be 15° to the north-east of the zenith; at Georgetown, about 30° from the zenith; and at Sheridan, about 15° to the west of the zenith. Reference to the map (Fig. 1) shows that there is considerable discrepancy between these observations. Indeed, observers at points still farther away reported the bodies as having passed overhead.

However, we should not be much surprised at this. Unless a person has some definite objects to guide him it is very

difficult to judge angular distances correctly. To view a body directly overhead is extremely uncomfortable, and by most people a body is thought to be overhead when it is at a considerable distance from the zenith. Similarly, angular elevation of a body above the horizon is almost always adjudged too great. This question will be referred to again when discussing the height of the bodies above the earth.

In view of these conflicting reports it was necessary to arrive at some compromise, and the most probable path seemed to me to be a line passing almost over the city of Guelph, but a little to the south-west. The error in the location of this line may amount to three or four miles; and indeed it is well to remember that the meteoric bodies themselves were scattered over a path of perhaps this width.

The line on the earth's surface directly beneath the path of the meteors in the air, I shall call the *trace* of the meteors. This line cuts the 80th meridian in north latitude $43^\circ 24'$.

Now the observations show that the meteors were travelling practically parallel to the surface of the earth. It is true that some observers thought they detected a slightly downward tendency, but when seen a thousand miles farther on they were apparently as high, if not higher, in the air. The downward tendency, if it existed, was very slight.

It would seem that the bodies had been travelling through space, probably in an orbit about the sun, and that on coming near the earth they were promptly captured by it and caused to move about it as a satellite. It seemed reasonable, then, to consider the plane of the path as passing through the centre of the earth and hence cutting its surface in a great circle.

By means of the formulas of spherical trigonometry I determined the location on the surface of the earth of a great circle passing through Pense, W. Long. $104^\circ 59'$, N. Lat. $50^\circ 25'$, and the point in Ontario, W. Long. 80° , N. Lat. $43^\circ 24'$. In the accompanying table are given points on this circle ranging over two-thirds of the circumference of the earth.

TABLE I.

TRACE ON THE EARTH OF THE PATH OF THE METEORS

Longitude	Latitude	Longitude	Latitude
104° 59' W.	50° 25' N.	50° 00' W.	21° 53' N.
100 00	49 34	35 00	4 29 N.
95 00	48 28	20 00 W.	14 2 S.
90 00	47 06	0 00	33 20
85 00	45 25	20 00 E.	44 36
82 00	44 15	40 00	50 5
81 00	43 50	60 00	51 34
80 00	43 24	80 00	49 34
79 00	42 57	100 00	43 24
75 00	41 00	120 00	31 5
65 00	34 53	140 00 E.	10 38 S.

The first entry in the table is Pense, and the seventh is the determined point in Ontario; the succeeding points are on this line extended.

At Watchung, N. J., 22 miles west of New York City, an observer reported that the meteors appeared to be overhead. The line drawn as described passes a little to the south of this place. The meteors were also seen by observers in the Bermuda Islands (W. Long. 64° 50', N. Lat. 32° 15') and the calculated line runs 131 miles to the north-east. The display was seen at North Bay, Ont., 186 miles, and at Winchester, Ont., 221 miles, from its trace on the earth. It must be remembered, however, that Pense and the Ontario point, which we took to fix our line, may be a few miles north or south of the true path, and so the true trace might come somewhat (perhaps 10 miles) nearer to or farther from Bermuda.

The angles made with the east-and-west line by this line are:— at Pense, 12° 49'; at the determined Ontario point, 31° 14'; and when passing the Bermudas, 40° 46'.

From Mortlach, Sask., to Bermuda, the extreme points at which the bodies were seen, the distance is 2437 miles; from the determined Ontario point to Bermuda is 1184 miles. In figure 2 is shown the path from Mortlach to Bermuda.

As the observed path of the meteors was so extraordinarily long I thought it interesting to examine the position beyond Bermuda of the great circle over which they were believed to have passed. I found that it went over the South Atlantic Ocean, around the Cape of Good Hope at a distance of about 600 miles from it, through the Indian Ocean, and that the first land to be reached was Western Anstralia. Of course one cannot say that the bodies ever arrived there, though I would not be surprised to learn that they did. No reports of observations of the phenomenon by mariners have come to my notice.

THE HEIGHT OF THE BODIES ABOVE THE EARTH

Having determined the trace on the earth's surface of the path of the meteors, their height can be easily deduced if their angle of elevation at any place is known. Many estimates of this angle were communicated to me, but as a large portion of them were made without reference to any object whose elevation could be measured, these have not been of great assistance in fixing the height. A few, however, allow the deduction of definite results and, as we shall see, many of the others when interpreted properly corroborate these results.

In Toronto Mr. Gustave Hahn, to whom I am indebted for the sketch from which Plate IX. has been made, observed the bodies to pass about midway between Rigel and the Belt of Orion; and Rev. F. Herman, of Caledon East, in his report sketched the Belt and the sword and stated: "The meteors went over, or nearly over, the face of this group." Now a line joining Toronto and Caledon East, (see Fig. 1) is almost parallel to the path of the meteors and these places are only about 27½ miles apart. Hence at the two places the bodies would appear to take very nearly the same course in the sky.

Now at 9.05 p.m. E.S.T., February 9, in Toronto a point midway between Rigel and the Belt had an elevation of about 40° and azimuth 16° west of south. Taking the path of the bodies to make an angle of 31° with the east-and-west line we

find that if θ is the elevation of the bodies when nearest to us, that is as seen in a direction at right angles to their path,

$$\begin{aligned}\tan \theta &= \tan 40^\circ / \cos 15^\circ, \\ &= \tan 41^\circ.\end{aligned}$$

That is, the elevation was 41° .

Then, measuring on the map* (see Fig 1) the distance of Toronto from the trace of the meteors, we find it to be 30 miles; and if h is the height of the meteors, we have,

$$\begin{aligned}h &= 30 \tan 41^\circ, \\ &= 26.1 \text{ miles.}\end{aligned}$$

As I have already remarked, the distance to the trace of the meteors may be in error 3 or 4 miles, and so the height is also doubtful almost to this amount.

The elevation from Mr. Herman's observations is about 43° , and his distance from the trace is $28\frac{1}{2}$ miles; from which the height comes out to be 26.5 miles.

Rev. Dr. Marsh, at Springville, observed the meteors to pass mainly behind the top of a telephone pole, though he states that some were slightly above, some slightly below. Afterwards he found the top of the pole to have an elevation of $14^\circ 58'$ above the eye, and the line joining the observer to the pole made an angle of 49° with the north-and-south line.

$$\begin{aligned}\text{Hence } \tan \theta &= \tan 14^\circ 58' / \cos 17^\circ 46', \\ &= \tan 15^\circ 41'.\end{aligned}$$

That is, the elevation of the meteors at the highest part of their path was $15^\circ 41'$. The distance of Springville from their trace on the earth is 91 miles, from which we have

$$\begin{aligned}\text{Height} &= 91 \times \tan 15^\circ 41', \\ &= 25.5 \text{ miles.}\end{aligned}$$

This agrees very well with the results just obtained.

The writer was much interested in the observations made by Mr. E. A. Norman, of Mill Bridge, (Hastings County).

* Measurements were made on a map of Ontario on a scale of 30 miles to the inch, not on the map from which this cut was obtained.

Mr. Norman was standing at the south-east corner of his barn when the meteors appeared at the south-west corner, seemingly just below the eave. A simple measurement of the height of the eave above the eye and the length of the barn gave the elevation of the meteors as 22° , as seen in the west. This leads to a height of 106 miles, an impossible result. At the writer's request Mr. Norman verified his measurements, and the only conclusion is that he was mistaken in thinking them up to the eave, although his statement that the first thought which came to him was that his barn was on fire at the eave is evidence to the contrary.

Mr. James G. MacMillan, B.A.Sc., of Toronto, estimated the elevation to be 30° , and afterwards verified it with a clinometer. This leads to a height of 17.4 miles, a result evidently too small. Mr. MacMillan explains, however, that he could not recover the precise position in which he stood when viewing the display, that he may have been 30 or 40 feet from it, which would explain the lowness of the result.

Mr. H. G. Murray, a student in mathematics at the University, when reporting to the writer first gave the elevation as 55° , but on a closer examination shortly after, he stated that he was confident it was not over 45° . This gives a height of 30 miles.

Again, when Mr. John Clark, of Moore Park, Toronto, was recounting to the writer all the circumstances of the display, he indicated the elevation above the south-west horizon, which was about 40° . This gives a height of 25.2 miles.

In Table II. are given the values of the height which I have deduced. The first three are the best determinations, and the average of these is 26.0 miles. In the last four cases the elevation appears to have been estimated with care, and the heights deduced are not greatly above the accepted value of 26 miles.

TABLE II.
HEIGHT OF THE METEORS

Place	Observer	Elevation	Distance to Trace	Height
Best Determinations				
Toronto	Hahn	41°	30 mi.	26.1 mi.
Caledon East	Herman	43	28½ "	26.5 "
Springville	Marsh	15° 41'	91 "	25.5 "
			Average	26.0 mi.
Other Determinations				
Toronto	Murray	45°	30 mi.	30.0 mi.
Toronto	Clark	40	30 "	25.2 "
Georgetown	McKay	60	17 "	29.4 "
Edgar	Jamieson	22½	72 "	29.8 "

As already remarked, the elevation above the horizon is almost invariably estimated too high. Robert Smith, in his "Compleat Optics," published in 1738, explains why this is so. To ordinary observation the sky does not appear to be a complete hemisphere but only a portion of one, the part overhead seeming to be nearer than that at the horizon. From experiment Smith showed that the arc of the sky appears to be shaped as in Figure 3, in which OZ the vertical height of the zenith is $\frac{3}{10}$ of OB the

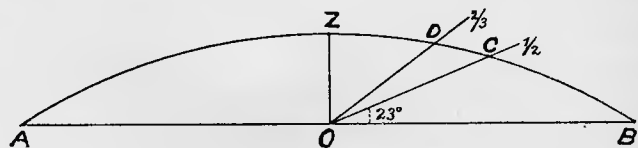


FIG. 3.—The curve AZB represents approximately the apparent shape of the sky. $\frac{3}{10}$ The distance from O the observer to Z the zenith is $\frac{3}{10}$ of the distance from O to the horizon B .

distance of the horizon. Further he states, "By the eye we estimate the distance between any two objects in the heavens by the quantity of sky which appears to lie between them; as upon earth we estimate it by the quantity of ground which lies between them." Hence any point C will appear half-way between horizon and zenith when the arcs BC , CZ are equal; but by

actual measurement the angle BOC is found to be only 23° . When the arc BD is $\frac{2}{3}$ of BZ the angle BOD is but 37° . That is, when an observer estimates the elevation of a heavenly body to be 45° , it is probably about 23° ; if the estimate is 60° , the true value is about 37° .

Interpreting in this way some of the estimates sent to me I obtained the accompanying table, though the results given in it must not be considered of very high scientific value.

TABLE III.

OTHER DEDUCED HEIGHTS OF THE METEORS

Station	Estimated Elevation	Corrected Elevation	Distance per Trace	Deduced Height
Dutton	45°	23°	78 mi.	32 mi.
Dresden	45	23	102 "	42 "
Rodney	45	23	93 "	38 "
Barrie (1)	50	25	66 "	31 "
Barrie (2)	45	23	66 "	27 "
Coldwater	45	23	86 "	35 "
Fenelon Falls	<45	20	102 "	37 "
Elmvale	45	23	72 "	30 "
Parry Sound	37	17	115 "	32 "

In almost every case the height is too great but the results as a whole indicate the correctness of the explanation offered.

It would be very interesting to determine the heights of the meteors at the beginning and the end, as well as at the middle, of the observed flight; but the data at hand are insufficient. In Saskatchewan no observations whatever are available for the purpose. Col. W. R. Winter, from his location almost in the centre of the Bermuda Islands, estimated the elevation at 35° . If they were 131 miles away, this would give a height of 92 miles. Colonel Winter estimated the angle by the branch of a tree on the road in front of him. This height is pretty certainly too high. Even supposing the value of the angle to be corrected in the manner explained above, it would be 17° , which would give a height of 40 miles. The indications are that the bodies rose

after leaving Ontario rather than that they fell, but evidence is not sufficient to finally determine the question.

THE SPEED OF THE METEORS

As the meteors were seen at places nearly 2500 miles apart it might be supposed that by obtaining the times when they were seen at the two extremes of this distance we could easily deduce the speed. But the entire time consumed in travelling this distance was very short, perhaps 4 or 5 minutes, and the times observed are not accurate enough to be used for this purpose. The time at which the phenomenon was seen is given as the same all along the line — 7 o'clock (M.T.) in Saskatchewan, 9 o'clock (E.S.T.) in Ontario, and 10 o'clock (Atl. T.) in Bermuda.

In my request for information I asked for estimates of the time during which a single body was visible. These varied all the way from 6 to nearly 60 seconds, but the ordinary values are from 20 to 30 seconds. From several persons in Toronto who observed the phenomenon I obtained estimates of the angle traversed during this time, varying from 120° to 135° .

Now at Toronto an angle of 120° would be subtended by 160 miles, and an angle of 135° by 192 miles of actual path. If traversed in 30 seconds this would give speeds of $5\frac{1}{3}$ and $6\frac{2}{5}$ miles per second, respectively. If the time taken was 20 seconds, the speeds would be 8 and $9\frac{1}{2}$ miles per second, respectively.

The first value, $5\frac{1}{3}$ miles per second, is probably too low. A body travelling close to the earth's surface as a satellite would perform a revolution in 84 minutes, or at the rate of 5.0 miles per second. This result is obtained on the assumption that the body is travelling in a vacuum. The bodies under consideration, though moving comparatively slowly, as their reddish color attested, were travelling in the atmosphere, and would surely have been brought to earth during their observed course if their speed had been so near that of a satellite in a vacuum. But, as we have seen, all observers agree in saying that the path was practically parallel to the earth's surface. I am inclined to

believe that the speed with respect to the earth's surface was greater than 5 and less than 10 miles per second.

Of course the velocity in space was greater. When seen the bodies were travelling largely in the direction of the earth's orbital motion, and also with the rotational motion of the earth.

THE SOUNDS HEARD AND THE DURATION OF THE DISPLAY

On the map (Figure 1) I have indicated those places at which sounds were heard, and it will be seen that they extend to a considerable distance from the path of the meteors. Those farthest away are Edgar,* 78 miles from the actual path in one direction and Cayuga, 33 miles in the other.

In some localities a shaking of the earth or of the buildings was detected. In the neighborhood of Shelburne this was especially noticeable. At Keldon Mr. Wm. Anderson "felt a slight tremor in the floor," and on going outside heard a rumbling noise, reminding him of a slight earthquake. A man living three miles farther west was in bed at the time and was awakened by the sound, and fearing that his horses were wrecking the stable got up to investigate, — only to find them perfectly quiet. I have learned of several in Toronto who detected the quivering of the house and remarked it at the time, among them being Mrs. and Miss Davis, of Poplar Plains Road. Many others heard the sounds.

In the Niagara peninsula these effects were very pronounced. At Niagara-on-the-Lake the windows rattled, and at St. Davids Rev. G. Munro heard the sound and looked in vain up in the sky to see the cause of it.

The sound has been compared to low distant thunder, to a wagon passing over hard rough roads or over a bridge, to the report of small arms in a sham battle at a distance; and a lady at Canfield likened it to the crashing together of two railway

*Dr. Jamieson, who reported from Edgar, did not hear the sounds himself but stated that others had. Several observers in Barrie did not hear the sounds. The places next farthest from the meteors where sounds were heard are, Unionville, 51 miles, and Jackson, 49 miles.

trains at a distance. In some places three distinct rumblings were heard, separated by intervals of a few seconds, while at others only one or two were detected.

In this connection it may be interesting to state that Mr. W. F. Denning, of Bristol, England, our leading authority on meteors, has recently expressed the opinion that many of the window-shakings usually attributed to earthquake shocks are really due to the explosions of meteoric bodies high in the air. He has investigated a number of instances of this sort and has very strong evidence in favor of his view.

Knowing that sound travels at the rate of about 12 miles per minute, I have endeavored to compute the distance of the bodies by considering the interval between their passing and the hearing of the sound; the results are not very satisfactory.

It is pretty well agreed that the first bodies were the largest and most active of all. Some observers state that they burst into several pieces, and that they were continually giving off sparks which went to form their tails. It would naturally be expected that the interval between the passing of these bodies and the arrival of the first sound would be the time taken by sound to travel from its path to us.

Unfortunately the times are not accurately determined. The first bodies appear to have come well into view at about 9.05 (E.S.T.). Dr. Marsh, at Springville, gives it as 9.04½. Several in Toronto who consulted their watches give 9.05. An observer at Brampton gives 9.06 and one at Jarvis gives 9.08, as noted on a watch which may have been 50 seconds fast. Again, Mr. John Butterfield, of Toronto, states that on hearing the sound he immediately looked at his watch and the time was 9.12, which, he assures me, was closely accurate. From 9.05 to 9.12 is an interval of 7 minutes during which time sound would travel 84 miles, while the bodies passed within about 40 miles. Perhaps the sound heard was not produced by the first bodies.

Observers were also asked to state when the sound was heard; and some say just as the last bodies were disappearing,

while others say 1 minute, 2 minutes or 3 minutes after they had gone.

The estimates of the duration of the entire display also vary between wide limits. As has been stated, the beginning was in the neighborhood of 9.05, and Mr. Walter L. Haight, of Parry Sound, states that at the end of the flight he took out his watch and the time was 9.10. I have taken the average of 89 estimates, which run from 1 minute to 7 minutes, and find it to be 3.3 minutes. The bodies, when nearest to Toronto, were about 40 miles away, and sound would travel this distance in about 3.3 minutes. Hence, if the first noise heard was that produced by the first bodies it should have been heard just at the close of the display.

THE SIZE OF THE BODIES

It is interesting to consider the size of the bodies; but the observations again are very discordant and an accurate estimate is out of the question. However there is sufficient evidence to show that they were of considerable size.

Mr. Hewitson, of Jackson, states that the head of the first body was larger than the full moon, which is about 30' in diameter. Mr. Norman, at Mill Bridge, estimates the leader to have been half the diameter of the moon, while Mr. White, of Coboconk, places the size as three-quarters of that diameter. Colonel Winter, in Bermuda, states that the apparent diameter of the leading bodies was equal to that of the moon. Jackson was about 50 miles while the other places were all more than 100 miles away. On the other hand Mr. Barber, a University student, states that he did not think the diameter to have been more than $\frac{1}{15}$ of the moon's diameter.

Referring to this matter, Young (*General Astronomy*, Art. 762) says:

"As seen from a distance of many miles, the meteoric fire-ball sometimes appears to have a diameter as large as the moon, which would indicate a real diameter of several hundred feet. The great apparent size, however, is an illusion, partly due to irradiation, and partly, undoubtedly, to the fact that the meteor itself

is surrounded by an extensive envelope of heated air and smoke which becomes luminous throughout. Probably no single meteor ever yet investigated was a solid mass as large as ten feet in diameter."

It may be pointed out, however, that these meteors were not intensely white as most fire-balls are, and so the effect of irradiation would not be so pronounced. Taking the diameter, as seen from Toronto, to have been $\frac{1}{15}$ of the moon's diameter, or 2' of arc, this would give a diameter of 123 feet; while half the diameter of the moon as seen at Mill Bridge would correspond to a diameter of over 3000 feet. This latter value is probably a decided over-estimate, but I am inclined to think the largest bodies to have been at least 100 feet in diameter.

A rough approximation can also be made of the length of the tail of the largest meteor. At Centreton (see Figure 6) it appeared to be about 23° long, which would correspond to an actual length of 39 miles. Other estimates lead to an estimate of about this order, but all these values are liable to considerable error.

OTHER METEORS SEEN WITHIN A FEW HOURS OF THE GREAT DISPLAY

During the course of the present investigation the writer was greatly surprised and interested to learn that several other bright meteors were seen within a few hours of the great display. Extracts from letters received regarding these are given at the end of this account.

Mr. F. W. O. Werry, B.A., of Saranac Lake, N.Y., (W. Long. $74^\circ 10'$, N. Lat. $44^\circ 20'$) states that between 7.30 and 7.45, p.m. (February 9) he saw a shooting star begin about 10° higher up than Venus and move rapidly along a horizontal line (or nearly so) for about 30° towards the north. In a few minutes another meteor, starting in the same region, shot across the same part of the heavens, but its path was only about half as long,

Mr. J. G. Beatty, a student in Mathematics in the University of Toronto, living at Brampton, reports that at about 8.20 p.m., while watching Venus in the west, he saw a bright meteor



move quite slowly from north-west to south-east, apparently in about the same path as that taken by the great display 45 minutes later.

Mr. George H. Brooks, a teacher, of Roblin, Ont., states that at 9.30 he saw a meteor in the west which seemed to travel south or south-west, and which was visible for fully half-a-minute. It left a long trail behind.

Upon receiving Mr. Brooks's letter I first thought it referred to the great display, the time being in error by 25 minutes. But a communication from Mr. Walter Peters, the meteorological observer at Peterborough, led me to think otherwise. Mr. Peters stated that a reliable person at Peterborough had reported to him that he had observed between 9 and 10 o'clock a very bright meteor moving directly overhead from east to west. On intimating that I thought this was an isolated meteor, Mr. Peters consulted his informant, who was confident that he had seen the great display. I can hardly think so. Roblin is about 70 miles almost east of Peterborough, and I suspect that these two observations refer to the same object.

In *Popular Astronomy* for March, Mr. Lewis L. Mellor, of the Detroit Observatory, Ann Arbor, describes a very bright meteor which he observed at 10.15 p.m. (C.S.T.) (*i.e.* 11.15 E.S.T.) and which travelled towards the south-west. The object was brighter than Venus and its flight occupied 5 or 6 seconds. The body exploded violently, and the resulting flash of intense blue light illuminated the city for a fraction of a second. (For full details see below).

Another bright meteor was seen early Monday morning, and it is remarkable that it was reported by four observers from points many miles apart. Dr. J. J. Morrow, of Arthur (Wellington Co.), when returning from a sick call, was surprised to see the heavens light up for some seconds. The time he gives is about 1.15; and the light appeared to flash out of the northern sky. Mr. T. H. Banks, of Perm, (about 38 miles north-east of Arthur), saw the same meteor, the time given being 1.27 a.m. At Vitoria, (Norfolk Co., about 73 miles almost south of Arthur),

this meteor was seen by Mr. Joseph A. Montrose. The time given is 1.30 a.m. But the fullest account of it is by Mr. Geo. A. Deane, of the Circulation Department of *The Record*, Windsor, (161 miles south-west of Arthur). He had an excellent view of it and states that it was a remarkable phenomenon. The time was noted to be 1.23 a.m. Fuller details are given in Mr. Deane's letter, printed below.

For the report of Mr. Deane I have to thank Mr. F. P. Gavin, B.A., Principal of the Collegiate Institute, Windsor. He also furnished some observations by Mr. A. W. Brown, of Windsor, who was left as watchman at a train wreck on the C.P.R. near Bothwell. At about 9 p.m. Mr. Brown saw a bright meteor travelling from north-east to south-west. It was bright enough to attract the attention of one not watching for any such phenomenon. Again, at about 2.20 a.m. (Monday) he saw a series of less brilliant ones, though they were visible for a longer time. These appeared brightest about 70° or 80° above the horizon and seemed to travel right down to the earth.

In *Nature* for April 10 a correspondent living in the southern part of Patagonia (about 70° W. Long., 52° S. Lat.) who describes a fire-ball which visited that part of the world at about 6 a.m., Monday, February 10. As it was broad daylight it was seen only by a few, but violent sounds and vigorous shaking of windows were observed over a wide area. The direction of motion was east to west, which would correspond approximately to the direction in space taken by the great display of the evening before.

From England also comes a report of meteors about this time. In a letter to the writer, Mr. W. F. Denning states that very bright meteors were seen there on February 8, 9 and 10. He remarks that the date about February 10 is remarkable for meteoric fireballs, which sometimes have their radiant near Capella. Those seen by Mr. Brown may have been from this radiant.

In conclusion I shall refer to a curious observation reported in *The Toronto Daily Star* for Monday, February 10. At about

2 p.m. on that date some of the occupants of a tall building near the lake front saw some strange objects moving out over the lake and passing to the east. They were not seen clearly enough to determine their nature, but they did not seem to be clouds, or birds, or smoke, and it was suggested at the time that, perhaps, they were airships cruising over the city. Afterwards it was surmised that they may have been of the nature of meteors moving in much the same path as those seen the night before.

REPORTS OF OBSERVATIONS

PART I.

THE GREAT DISPLAY

In the following pages are given extracts from letters received from observers, the places from which they come being arranged in alphabetical order. In the brackets after the name of the place are given the distance in miles and the direction from Toronto, the direction being always referred to the nearest cardinal point of the compass.

Thus "Brampton, (16 miles, W. 8° N.)," means that this place is 16 miles distant and 8° north of west from Toronto.

Agincourt, 2 miles N. E. of (12 miles, N. 27° E.).

JAMES STONEHOUSE.

About 10 or 15 with tails seemed to be longer than the rest. At certain distances they seemed to be more clustered, the intervening spaces being filled with smaller ones, like stars, reminding one of the Milky Way, only so much brighter. There were thousands of them. Reports were heard, reminding one of a sham battle with small arms a long way off, but no explosions. They appeared first in the northwestern sky, about midway between the zenith and the horizon, and they disappeared in the same manner in the southeastern sky. They did not appear to drop towards the horizon, from which I would conclude they were very high. Duration, 3 or 4 minutes.

Appin (128 miles, W. 26° S.).

A correspondent reports the following statement as made to him:

A huge meteor appeared travelling from northwest by west to south-

cast, which, as it approached, was seen to be in two parts and looked like two bars of flaming material, one following the other. They were throwing out a constant stream of sparks and after they had passed they shot out balls of fire straight ahead that travelled more rapidly than the main bodies. They seemed to pass over slowly and were in sight about five minutes. Immediately after their disappearance in the southeast a ball of clear fire, that looked like a big star, passed across the sky in their wake. This ball did not have a tail or show sparks of any kind. Instead of being yellow like the meteors, it was clear like a star. No sound was heard. Others reported seeing a shower of meteors, but they were not seen by the one who gives the above account.

Appleby (23 miles, W. 37° S.).

MISS FLOY PREST.

About 9 o'clock or a little after as I was on my way home from church I saw a large meteor fall to the earth, leaving a tail of fire as long as Halley's Comet behind it. Then, turning towards the north, I saw a large black cloud, out of which shooting stars were coming, as it seemed, about 50, each having a line of fire in its path, and disappearing in a large black cloud in the south. After this there began a low rumbling sound like thunder.

Aurora (24 miles, N. 5° W.).

G. A. THOMAS.

They passed almost overhead, from northwest to southeast. The first group (about 15 or 20) resembled a shower from a rocket, only they moved in a straight line. It was followed by a smaller cluster, then two or three at a time; the whole lasting about one minute. They did not lower as meteors usually do, but appeared and disappeared as if obstructed by a cloud. Did not hear any sound or see any tails.

Aylmer (100 miles, W. 36° S.).

W. E. STEWART.

The display appeared to occupy a space in the sky about 10° wide, running almost from west to east, a little to the south. The upper edge appeared to have an elevation of about 70°. The meteors seemed to move at a uniform rate. First would be a cluster containing 25 or 30; then a few straggling ones; then another cluster. The larger ones, with the exception of a few extra bright ones, had the brightness of stars of the

second magnitude. A great many of these were in pairs, a short distance apart. These were again surrounded by very small meteors, some trailing out behind.

I did not hear any sound, and I would think the display lasted about two minutes. There were about 200 of the larger meteors in all, and the time for one meteor to traverse the course would be between 10 and 15 seconds.

The display appeared to come out from the west and move out of sight in the east, just as a railway train would.

Ayr (60 miles, W. 23° S.).

MRS. A. E. SARGEANT.

There were four distinct lots. As one died out another appeared in close succession. They looked like a mass of golden sparks, tapering off to a point. I stood at the northeast corner of the house, and the meteors started almost directly overhead and travelled at an angle from the corner of the house of nearly 45°. As they disappeared there was a distinct report, just like thunder.

Barrie (52 miles, N. 14° W.).

N. B. JOHNSTON.

I was walking westward when a large meteor appeared about midway between horizon and zenith, travelling about south-southeast, and going very slowly, that is, for a meteor. It was of a reddish color and had a long tail. When it had passed a distance south the tail broke into four pieces, and each part appeared to take on a head and continue in the same course until they disappeared—though not suddenly, as many meteors appear to do.

This one was followed by seven others, all of the same appearance and following each other in the same direction and apparently on the same line. The seventh and eighth were a pair, travelling parallel to each other. The first one was the only one that broke up. No noise was heard; each one was in sight 6 or 8 seconds.

JUSTINE J. MCBRIDE.

The path was about 50° above the horizon. Duration, about two minutes. No sound heard. The bodies were broken up and had tails. I think there were about 15 clusters.

C. A. SHEPARD.

Duration, 3 to 5 minutes. First was a group of 6 or 7 bodies. After that they came in singles and doubles. In one instance a fracture took place, forming a couple more bright spots. They travelled in parallel lines, apparently floating like gas balls, not appearing any lower at last than when first seen. Color, dull reddish yellow, like a burning coal. Total number, 15 or 20. No sound heard.

MRS. THOS. SIBBALD AND MISS GLADYS FIRMAN.

The course was not directly overhead, but somewhat towards the south.

There appeared to be four groups. In the first were six stars with long streamers or tails; in the second, four stars with streamers or tails not so long or bright as in first group; in the third, two or three stars, with tails not so bright or long as in either of former groups; the fourth was merely like a large star or ball of fire, and it disappeared very quickly.

Duration, 3 to 5 minutes; no sound heard.

Berlin (58 miles, W. 15° S.).

A. W. BANFIELD (a missionary from W. Africa).

The meteors travelled parallel with the earth, and disappeared before they showed any signs of falling. I should say there were 20 to 25. From where I was standing, in the open, they were all visible at one time; all I had to do was to look in the direction from which they were coming and I could see them coming in groups—of four or five at a time.

The whole phenomenon lasted about two minutes, and as I stood waiting to see if any more would follow I heard a roar of thunder. I heard the thunder about one minute after the last meteor had passed. The bodies remained intact, but as they passed off the scene they seemed either to burn out or disappear in space. To me they seemed to have tails, and the proportionate length I will give in a small sketch (Fig. 4).

I was facing the east and the meteors were in front of me at about the angle shown. (About 15° from the zenith.—C. A. C.) It may be of interest to you to know that my wife was walking west on Galley Avenue (Toronto) on that Sunday night and she saw the meteors passing in front of her, i.e., to the west of her, at about the same angle that I saw them east of me. According to that they must have passed directly overhead somewhere between Toronto and Berlin.

Birdsall (74 miles, E. 33° N.).

M. M. BIRDSALL.

I should say there were more than a dozen. Three together particularly drew my attention. They travelled slowly and never lost their position relative to one another. The bodies I saw remained intact and had no tails.

Bolton (23 miles, W. 42° N.).

JAMES H. BOLTON.

When I saw the first meteor at 9.05 it was a little west of north-west from here and travelling nearly toward me. I took it for an aeroplane with both headlights lit, and as it came nearer the sparks falling behind it made it appear still more like one. However, after a minute or a minute and a half I could see it was a meteor, and the tail seemed to cover about half the sky distance when it was passing. It was very low, apparently just above the hills, and by this time I noticed about 12 or 15 more following it. Would guess that it was about 3 minutes from the time I saw the first and largest one until it got out of sight.

The smaller ones were going a little more slowly, and some of them died out just as they passed over, though they were not directly over me, but a little to the southwest. Would think it about 5 minutes from the time of first notice until they were all gone.

About 2 minutes after they disappeared there was a heavy noise like a clap of thunder at a distance. Half a dozen of us were together and all noticed it distinctly; in fact it was too heavy to go unnoticed.

There would be 12 or 15 passing at one time, so would think there were about 30 in the whole procession.

I have been fortunate enough to see nearly every big meteoric display for the past 50 years, but never saw anything as fine as this.

R. E. CALDWELL.

They appeared in the western sky, about four-fifths of the way up from the horizon. As nearly as I can judge they lasted about one or two minutes.

There were about 40 or 50 in all. The first one was the largest, the next four smaller than the first but about equal to each other; the rest kept getting smaller until the last were mere red sparks. The largest ones had long tails of sparks, while the smaller ones had not.

The sound that was produced was a low rumble which at first made me think it was a buggy going along the road from church.

Bracebridge (95 miles, N. 4° E.).

E. J. KIRK.

The first meteor seemed to be a cluster of stars looking like a ball of fire. It came into view in the southwest, travelled close to the horizon towards the east.

A short distance behind the first cluster followed a small bunch of slightly bursting stars, which seemed to form the end of the tail or arrow; all the intermediate part appeared to be a streak of fire which partly hid from view the stars which had fallen into line and were keeping up the procession.

The first portion of the flight seemed to last nearly a minute, and this was followed by four or five similar processions of stars at intervals of a few seconds, but the succeeding ones were less brilliant.

Duration, about 2½ minutes; no sound was heard.

Bermuda (Waterville, Paget East).

COL. W. R. WINTER.

Time: 10 p.m. Position: east of my position. Altitude, roughly 35° when opposite my point of observation. (Later.—I estimated the angle by the branch of a tree on the road in front of me, and got my angle from the spot next day. I may have been out a bit.)

Direction of motion: about northwest to south-southeast.

I saw two leading bodies like large arc lights in appearance, slightly violet in color; diameter, as far as the brilliance would permit of judgment, equal to that of the moon; one lower than the other and a little in advance of it. Both were coruscating or breaking into small pieces. As these pieces separated from the parent bodies they developed trails of sparks and gas. There were about 100 of these followers. Each had a nucleus, and perceptibly dwindled away in length as they got behind, from a length of about 13° near the head of the procession to small spots resembling pieces of wind-driven burning brown paper at the end. The longer ones were slightly scimitar-shaped and of a yellowish-red appearance, the nucleus being very bright. As they shortened up the color became more red, until at the last they were quite red, with a bluish flame above—exactly as if they were burning. These latter appeared to drift with the wind. The short ones preceding these were apparently egg-shaped. They were travelling horizontally, with a slight downward tendency as a whole.

I was unable to see the sky in the direction of Ursa Major, owing

to trees. I am informed that they appeared to come out of that constellation to people eastward of me.

I estimated that the display took 2 minutes to pass a given spot. It appeared to be travelling very slowly.

I enclose a rough sketch (Fig. 5) from a pencil sketch made at the time; this represents about three-fifths of the length, as I started on too large a scale. One-fifth more requires to be inserted at each arrow mark.

The trailers followed in groups divided by gaps, containing two only, and sometimes one. I counted 80 before getting mixed up.

It is impossible to sketch or describe the uncanny appearance of the display.

Mr. R. Ingham, who was four miles to the westward of my position (which was in Paget, due south of Hamilton, practically in the centre of the islands) reports that he observed them from a hill in Warwick, near the lighthouse. He mentions two leaders only, and states that one burst all to pieces when well away from the land.

From the east end of the island they appeared well to the eastward, and three leaders, well in advance of the two seen by me are reported by one man. No one else saw these as far as I can ascertain.

G. A. OUTERBRIDGE.

In a letter in "The Royal Gazette" of February 27, Mr. Outerbridge states that he saw three exceptionally large bodies throwing out a stream of sparks. "Then came two, not so bright, also emitting sparks; then a cluster of five, and then it seemed as if all the stars had made up their minds to move southerly. No sparks were thrown out by any but the first five."

Mr. Outerbridge counted upwards of 80 bodies, but another correspondent informs the present writer that some of his friends did not think there were as many.

Brampton (16 miles, W. 8° N.).

J. G. BEATTY (University Student in Mathematics).

Did not see the meteors, being in the house, but heard the noise, like thunder, loud at first and rumbling every 2 or 3 seconds. Lasted about 2 minutes.

A. G. BERRY.

Position in sky: a little west of the point overhead. Number: 15 in all, one at a time, but they followed each other quickly. Duration: 3

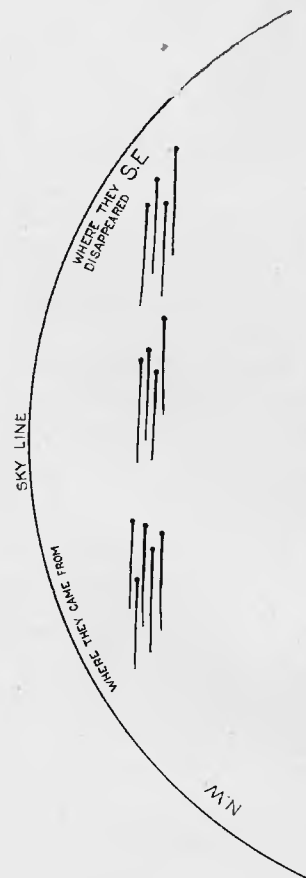


FIG. 4.—The flight of the Meteors, as sketched by Mr. A. W. Banfield at Berlin. The observer was at X and faced north-east. The place where the sounds appeared to come from is indicated in the left foreground.



X, MY POSITION



FIG. 5.—From a rough sketch of the Meteoric Display made by Col. W. R. Winter, Bermuda. Apparent course N.W. to S.S.E. Wind, N.W. about 20 miles. This represents about 3/5 of the entire display, 1/5 more requires to be inserted at each arrow. (The curvature of the tails must have been apparent, not real.—C. A. C.)

An Extraordinary Meteoric Display

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to 4 minutes. Sounds: the first was the loudest, like a horse and rig going over a bridge; the other was not so loud, and both sounds were short. They occurred last of all. The bodies were intact, and each had a tail. Each was in sight, I should think, about 15 seconds.

E. P. COISH.

Saw the phenomenon and heard a sound like a wagon passing over a rough road.

Brighton (87 miles, E. 18° N.).

J. H. MORROW.

The first was brighter than Venus, and took perhaps a minute to travel its course. It had a trail behind it about 10° long. The second and third were not so bright, but moved similarly. Think there were over a dozen bodies. The course seemed to be about 30° above the horizon, and the entire duration was from 1½ to 2 minutes.

Buttonville (14 miles, N. 8° E.).

MRS. R. B. ELLIOTT.

A few seconds after seeing the first body, the second appeared. It shot a stream of brilliant stars, which formed a long tail. This body was the largest of all. I counted 19 bodies. Two went out before reaching the place where the others disappeared, and the other 17 were in sight at one time. No sound was heard.

Caledon East (29 miles, W. 29° N.).

REV. F. HERMAN.

Saw two main displays. The first I mistook for a sky-rocket, which, after going some distance, appeared to open towards me. Before it had disappeared the other was well in sight, seeming to have about the same formation, following the same course with the same speed.

The centre meteors seemed to have no tails, being about the size of large stars, and having nearly their brilliancy. There may have been a dozen or so within the "tail" of the first.

Between the two displays, and after the last one, hundreds of dull-red sparks followed, giving the stars the appearance of being all in rapid motion.

A noise like a distant roll of thunder, probably lasting 4 seconds, was heard at least 4 minutes after the first display. From the first appearance to the last of the sparks, probably 4 minutes. Each display

took nearly 45 seconds to complete its course. The middle of the course, which was to the southeast, was about 40° from the zenith. The meteors went over, or nearly over, the Belt of Orion.

W. S. JONES.

Time, 9.07 or 9.08. The whole lasted about 2 minutes, and the next minute there was a noise like a short crash of thunder, and I imagined that the ground shook under me. About three-quarters to the end there was a big star with no tail, alone, with a few following.

Campbellford (91 miles, E. 30° N.).

MRS. WM. HUMBLE.

The meteors were low down in the sky, travelling towards the east I think I saw at one time about 20. There were three very distinct ones, near together, but yet clearly separate. Others followed, and some disappeared before the three distinct ones I speak of. Think the display lasted 2 minutes. No sound. There were tails to each one, just narrow ones.

J. T. VOSPER.

Gives information communicated to him by eye-witnesses. The first meteor was of a bright white color, with a long and distinct tail resembling a comet. It was attended, or surrounded, by a number of smaller meteors of a bright red color. Following this came a group of red meteors, but unlike the first from the fact that there was no "ball" of light or comet-tail—simply a group moving in the same direction. Then came another group, resembling the second, all quite brilliant and distinct. A fourth group followed, but it was composed of three meteors; and a fifth group, of only two, yet a bright red. The groups remained about the same distance apart from first to last. Duration, about 3 minutes.

A second person says he saw one meteor disappear as if it had exploded.

Campbellville (30 miles, W. 20° S.)

REV. WILLIAM BURT.

They passed *directly* overhead, travelling northwest to southeast. I did not count them, but should say there were 50 or 60. Duration, probably 3 minutes. The only sound I heard was a faint whistling like that of bullets whilst they passed overhead. The bodies remained intact until they reached half-way to the horizon, when they simply disappeared.

The first appearance was that of a large body, very bright, having a long fiery tail—very much like a comet.

Canfield (50 miles, S. 22° W.).

A woman living near Canfield heard a noise which she compared to the crashing together of two trains, or some terrific explosion in the direction of Hamilton.

Cayuga (52 miles, S. 27° W.).

T. J. CRAVEN.

There were not only a dozen or fifteen meteors, large and small, but I don't think I am exaggerating when I say there were hundreds. The duration was from 2 to 4 minutes, and in color they were reddish, not like ordinary stars. Some of the large ones had long tails. After the meteors had all disappeared we heard a noise like thunder, apparently north of us.

Centreton (74 miles, E. 23° N.).

JOHN T. ORMISTON.

We went to the south end of the house to get a better view, and as far in that direction as we could see there were meteors. There were seven or eight ahead of the larger one shown in sketch (Fig. 6), so we had missed seeing the first. About seven passed after the large one, and we are sure we saw twelve. They were all in view at once and for the space of 2 minutes. When all had passed we looked at the clock and it said 9.15.

Coboconk (76 miles, N. 24° E.).

J. B. WHITE.

I think they were in view $1\frac{1}{2}$ or 2 minutes, and I counted 13 in sight at one time. I think there were 20 in all. They travelled on an exact level with the ground.

The tail kept the one size throughout its length, as if drawn through a tube. I believe when the large one was opposite me the tail was one-quarter the length of its flight; or perhaps 50 times its own length, supposing it to be a round body. The body looked about three-quarters the size of the full moon.

The course of the meteors was about 20° above the horizon. They were very low, compared with anything I ever saw before.

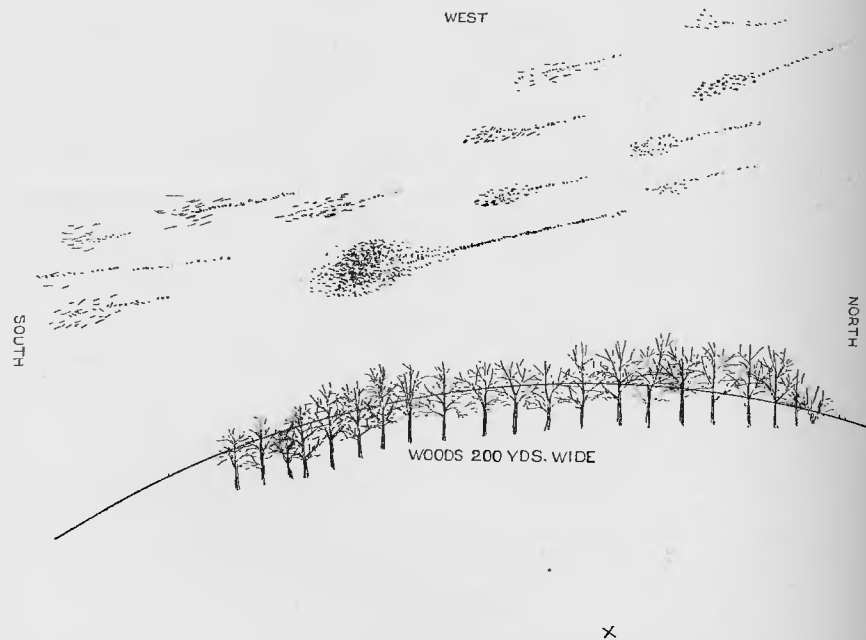


FIG. 6.—From a sketch made by Mr. J. T. Ormiston, Centreton. The woods in the foreground are about 200 yards wide and the meteors were observed from a point X, about 200 yards in front. The woods, therefore, subtended an angle of about 55° and the tail of the longest meteor shown was from 21 to 26° long.

Cobourg (64 miles, E. 19° N.).

J. E. SKIDMORE.

They glided along so leisurely and did not seem to be falling as meteors usually do, but kept a straight course about 45° , or a little more, above the horizon. Our first impression was that a fleet of illuminated air-ships of monstrous size were passing. The incandescent fragments themselves formed what to us looked like the illuminations, while the tails seemed to make the frame of the machine.

Sometimes there would be just a single collection, forming a single ship; then in a half-minute several collections would pass, looking like ships travelling in company. It took fully 3 minutes to pass. There was no noise; only beauty, beauty!

Coldwater (71 miles, N. 7° W.).

J. L. SHIELDS.

Time, about 9.08. Bodies came out of northwest and disappeared in southeast without any perceptible fall. Position in sky, about 45° above horizon. About 20 seen in all, 8 or 10 being visible at one time. Duration of display, about 2 minutes. Brightest meteor was in sight about 45 seconds. No sound.

The largest meteor, which came first, proved to be two or three abreast, the sparks from them intermingling and forming one long tail, the whole apparently merging into one body again as it passed farther away. The first was followed by many more, going at the same speed and the same direction, but not all in the same path, some being above the line of flight of the first one while others were below.

Consecon (98 miles, E. 15° N.).

CECIL CARLEY (a student of Trenton High School).

There were about ten groups in all, and each group, as seen through the opera glass, consisted of from twenty to forty smaller meteors. The leader of the group was generally the largest, the smaller ones following closely behind.

The first group had the largest number and was led by a large body which was brighter and larger than all the rest. Each separate body had a tail which was from five to fifteen times as long as the main part, which seemed to diminish and go into the tail. Some seemed to break up into smaller bodies.

About three or four groups were seen at a time, the three appearing to the northwest, while the fourth was passing in the middle of its course. Each group was in sight from 15 to 25 seconds, and the duration of the whole phenomenon was about 5 minutes. No sound was heard.

Corinth (92 miles, W. 37° S.).

WILL BEATTIE.

Time: shortly after 9 p.m. Direction: from the north-west to the south-east, and slightly downward. Number: would judge 15 or more, and some may have passed before I saw them. Size: The first ones were larger and brighter than the brightest stars and had tails which looked as long as the distance between the "Pointers" of the "Dipper." The last ones were like very faint stars.

I believe some of them were visible for as long as 10 seconds, and

the whole thing lasted between 2 and 3 minutes. I did not hear any noise, but was riding in a buggy over frozen roads.

Deseronto (120 miles, E. 18° N.).

MISS LENA J. WARREN.

The first meteor looked like a fiery streak or bar when it came out of the north-west. When it had traversed about a quarter way across the sky it broke into four fiery red stars with long fiery tails, which fell into the position shown.

After this group had gone some distance there came behind it a collection of similar stars, some with long tails, some with short tails. They moved in regular form straight across the sky, and disappeared in the south.

Dresden (159 Miles, W. 27° S.).

JNO. A. McVEAN.

The course was about midway between the horizon and the sky in the north towards the south-east.

When I first turned to look there was one that broke into four pieces, each piece having a separate tail. The color was that of fire. This one seemed to be visible for nearly a minute. The four pieces seemed to keep together. There were two others that had tails similar to these, but they remained intact throughout their course. Then seven or eight more followed, having no tails at all, and of a different color, more that of stars—a blue white.

The first four were just passing from sight when the second one (with a tail) was about midway in the sky, and the other with a tail followed at about the same distance, and then the ones without tails came very close to one another, about three times as close as the other. There were three or four of the latter in sight at one time.

Duration, about 5 or 6 minutes. No sounds heard.

Dunnville (53 miles, S. 13° W.).

WM. H. SHARP, B.A., reports that a gentleman gave him the following particulars: The meteors passed directly overhead, were travelling due east-south-east, were about 100 in number. The display lasted about three minutes, and the sound was heard just after they had disappeared.

WM. WINGFIELD.

Estimated that the meteors passed about 10° south-west of the zenith.

Dutton (127 miles, W. 32° S.).

MISS ISOBEL O. HALLY, B.A., reports that before being called to see the meteors the large first body had evidently passed. She saw a sequence of small, short, meteor-like appearances, moving in the same direction as the larger body—from north to south, perhaps slightly towards south-east. When facing slightly north of east the bodies in the middle part of their course appeared to be 45° above the horizon. They moved very slowly, several being visible at a time; then there was an interval of perhaps less than a second, and about half-a-dozen more appeared. These were short-tailed like the others, but whereas the others had appeared more in a body—two sometimes being parallel—these trailed one behind the other (two or three being visible at once) so slowly that each was easily visible several seconds. No sound was heard. All that was seen passed in about a minute.

Edgar (57 miles, N. 8° W.).

GEORGE B. JAMIESON, M.D.

The meteors seemed to come from a point west of northwest and they disappeared nearly at the south point. They travelled in horizontal lines, and all had the same leisurely rate of motion. Their course was about 22½° or 30° above the horizon. They travelled either singly or in pairs, and when in pairs one was above the other. I think I saw only two with tails, and these two were travelling in a pair. The tails were composed of other distinct meteors, gradually diminishing in size and trailing off as a flare of light at the end.

Duration of display, probably not more than 1½ minutes, each meteor being visible 3 to 7 seconds.

I heard no noise, but a neighbor saw the display, and he says he heard a sound like thunder, and counted 14 bodies.

Elmvale (65 miles, N. 19° W.).

JOSEPH DRYSDALE.

The display lasted four or five minutes. The meteors seemed to go in groups of threes, with tails behind them. They seemed to be midway between the earth and the sky. [Elevation 45°.] No noise was heard.

Elora (52 miles, W. 3° N.).

WM. FAIRWEATHER.

From eyewitnesses the course seemed to be right overhead. There were hundreds of them, throwing off sparks, and several exploding with a loud noise. Many persons heard the noise and thought it thundered.

Falkenburg (Muskoka, 98 miles, N. 4° E.).

G. S. YEARSLEY.

The first meteor came out of the northwest, about as bright as the evening star. It had a tail, and after travelling across the sky, disappeared in the south-southeast. It was visible 2½ or 3 minutes. It was followed in about 1 minute by two more, not quite so large, and travelling faster. After them came about 20 bodies like stars, some of which disappeared before reaching the horizon. I heard no noise. Night clear; temperature -14° F.

Fenelon Falls, 1 mile E. of (68 miles, N. 30° E.).

WALTER H. STEVENSON.

I counted seven bright stars surrounded by light. The cluster occupied a space about the size of the sun. A reflection followed, which was about the length of the tail of Urse Major [say 18°]. About the distance between the Pointers [say 6°] behind this appeared a bright white star, as clear, but a little smaller than Venus is now [mag. -4]; then a few clusters reddish like the first, but not so bright, say five or six clusters. Spread out on a wider track, there might have been eight or nine clusters, but I suddenly found that the whole heavens, from the zenith to the horizon, was full of meteors. They may have extended to the east, but there was such a wonderful display in front of me I never thought of turning. (See Fig. 7.)

The advance meteors, the brightest, passed slightly nearer the horizon than the zenith [say, elevation 40°]. The duration, probably three minutes, more or less. They travelled no faster than a crow flies. There was absolute silence. The whole was wonderful, but the most wonderful was the lone star following the first cluster.

Half an hour previously (about 8.30, I had been waiting outside with my rig, and when the others came out, I remarked to them that there seemed to be meteors "in the air," as I had noticed flashes or point-like sparks at intervals, as from an emery-wheel, single sparks overhead, where Auriga and Perseus must have been at that time, but I don't think the display which followed had anything to do with them.

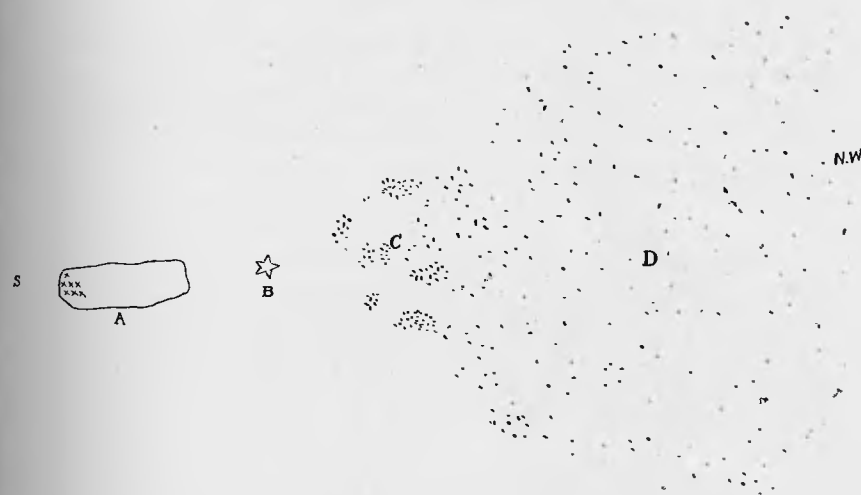


FIG. 7.—From a sketch made by Mr. W. H. Stevenson, Fenelon Falls. In the fore-part of *A* was a cluster of bright white stars; the rear was a reddish reflection, like glare from fire. *B*, a bright white star, of the size of Venus. *C*, reddish clusters. *D*, a shower of red meteors.

Fonthill (Welland Co., 46 miles, S. 10° E.).

ARTHUR GILBEY.

I saw several flashes reflected from the snow and seeming to come from the north. The sky being clouded in that direction, I could not see distinctly, but a few moments afterward I heard a rumbling, short and heavy, which I could not account for. I took no notice of it until a few seconds later I heard it again, and then for a third time. This was about 9.10 p.m. The rumbling was very plain.

Fort Frances (on Rainy Lake, midway between Ft. William and Winnipeg).

ROBERT MOORE, M.D.

Dr. Moore did not see the display, but on making his rounds in the Indian village near Fort Frances he obtained the following story from an Indian within 30 minutes after the phenomenon: "I saw them come slowly from the northwest; first, a string like candles, about forty of them; then, after 5 minutes, another string in the same line and about eight in number. They made the snow red quite a while after they had disappeared in the east. There was no sound, and they were lower than

the stars. They went slow. A big one led the first string. I am sure you will hear something. It must be the end of the world. It was about 9 p.m. They did not pass overhead, but north of us." (I think the time should be 8 p.m., C.S.T., and the Indian must have confused his directions. The course must have been south of the zenith—C.A.C.).

Fort William (W. end of Lake Superior).

JAS. A. UNDERHILL.

From observations made by Mr. Williamson, Gen. Sec. of the Y.M.C.A., and a young man who, with a party of snowshoers, was out in the open, the following information was obtained. Duration: quite a few minutes, 5 or 6, until it stopped. Direction: from N.W. by W. to S.E. by E. Middle of path about 30° S.W. of zenith. No sound heard. Number: perhaps 50, and many of them in sight at once. "A very amazing appearance."

Fox Point (Muskoka, 117 miles, N. 6° E.).

EDWARD A. BOOTHBY.

The meteors seemed to travel about 5° east of southeast, and the path appeared to be about 40° from the zenith.

Fullarton (91 miles, W. 8° S.).

FRED M. HAYNES.

The sky was somewhat clouded, but I saw the display coming from the north-west, but it disappeared under a cloud before half-way to the horizon. Probably the number would be from twelve to twenty, quite close together, without tails at all. Lasted not more than two or three minutes. Owing to small clouds in the sky, bodies were visible only when out from them. No noise whatever; bodies did not break up.

Georgetown (27 miles, W. 1° N.).

W. N. MCKAY.

The meteors travelled a little to the west of overhead, perhaps 60° from the horizon. They seemed to rise a little to the north of north-west. The first or leading meteor broke into pieces much like a Roman candle; of the others, some went right across the sky, and some disappeared while in flight.

Mr. McKay sent a clipping from the *Acton Free Press*, which, he thinks, describes very well their appearance. It says: "The phenomenon

witnessed was an irregular procession of luminous meteors as they traversed the sky from northwest to southeast. There were perhaps 15 or 20 meteors visible here. They were brilliant, fiery, luminous bodies, each bearing a tail after it, which disappeared in scintillations. A few seconds after the passing of the last meteor a series of explosions were distinctly heard, resembling peals of thunder."

Guelph (45 miles, W. 10° S.).

H. WESTOBY.

Though not fortunate enough to see the display himself, friends reported it to him at once. One gives the following: "About 20 or 30 lights appeared coming from the northwest by west, and shot across the sky, disappearing in the southeast. After the first lot had gone, some smaller ones appeared, following in apparently the same path and also disappearing in the southeast."

From a sketch which he was able to make, the path of the meteors appears to have been in the direction N. 57° W., and to have passed slightly to the northeast of the zenith.

Hepworth (109 miles, W. 38° N.).

EDITOR O. M. SEIM, "Hepworth Progress."

A cluster of brilliant meteors, somewhat resembling the fireworks of the Toronto Exhibition, passed through the sky from northwest to southeast, going at perhaps half the speed at which single meteors usually travel. This bunch of meteors was followed by innumerable stars, going in the same direction. This kept up for nearly five minutes. We would judge about 100 stars went through the air in that short time.

Hespeler (50 miles, W. 18° S.).

WILLIAM FOSTER.

The meteor started in the northwest, and when first noticed looked like a very high sky-rocket which was still going up. It travelled very fast towards us, and seemed to go right over our heads, or a little to the north.

In the display were many stars which seemed to start off with a jerk, and left a trail of light behind them. All travelled in the same direction, but some did not follow all the way. We noticed about two dozen or more.

A noise like a low rumble of thunder was heard after the display.

The following times were made out by going over the ground again, watch in hand. Time meteor was in view, 85 seconds; time stars were seen moving, 135 seconds; or total duration, 3 minutes 40 seconds. Time after end of display to noise of thunder, 50 seconds.

Hydro Glen (Muskoka, 85 miles, N. 2° W.)

NEAL McLEAN.

A large meteor appeared in the northwest, at an elevation of about 30°, with a long tail. When it was due south a second one appeared, not quite as large, and a trifle lower. They did not appear to come any nearer the earth, and the fragments thrown off seemed to continue after the main body.

There was no sound, and the display lasted about 3 minutes.

Islington (11 miles, W. 15° S.).

MRS. D. D. FRANKS.

In the northwest I noticed a luminous streak of light, much like the flame of a common oil lamp, interspersed with what appeared to be many stars. Its length seemed about twenty times its width. It moved compactly and comparatively slowly across the sky. A few seconds later another meteor came into view, similar to the first, but shorter. Then a third appeared, still shorter, but just as bright and beautiful as the first, and followed in the path of the others. Smaller ones appeared; these shot up the sky for a short distance and disappeared. They were paler and more rapid in motion than the larger ones.

The display lasted perhaps 3 minutes. I did not hear any report. The large meteors were the most magnificent sight I have ever seen.

Jarvis (65 miles, S. 36° W.)

THOS. J. HICKS, B.A.

Beginning of display, 9.08 p.m. (watch usually accurate, but may have been 50 seconds fast). The bodies followed in such rapid succession that one could not count them. They followed one another in fives; then a pause, and five more shot across the sky. I counted some 40 in a space of perhaps 24 seconds. They continued passing for about 2 minutes. No noise. Tails not noticeable, and bodies seemed to remain whole.

Jackson (103 miles, W. 38° N.).

JOHN HEWITSON.

It was a cold, calm, starlit night. Suddenly, from the northwestern sky there appeared what looked like an immense ball of red fire coming towards us at a tremendous rate, with a long tail streaming behind it at what seemed not a very great height from the earth, in comparison to the height of the stars. The head seemed much larger than the full moon, very red, and the tails extended a considerable distance behind, with pieces of the tails dropping off from the head every little while, but following on behind in the mad race.

It passed nearly over our heads, but a little to the southeast, and finally, instead of dipping below the horizon, it kept on its course in the sky towards the southeast at what seemed the same height from the earth, until it was lost in the distance.

We gazed after it for some time, fairly spellbound, even after it was lost to view, and in a minute or two we saw some smaller ones coming from the same direction, one by one rushing after the big one in the same track, as if a mighty current were drawing them along. These last did not seem to have any tails.

We waited around a few minutes, but saw no more, but what seemed like heavy rolls of distant thunder sounded. We heard no noise until after the meteors had disappeared.

Keldon (54 miles, W. 35° N.).

WM. ANDERSON.

I felt a slight tremor in the floor, and shortly afterwards went outside, and after shutting the door, which faces north, I heard a rumbling noise, which reminded me of a slight earthquake shock that I once felt in Scotland. If the building had not intervened I should probably have seen the meteors passing southward.

I find that residents here heard three distinct reports at different times.

Kinmount (83 miles, N. 26° E.).

JAMES LYLE.

At times there were only 2 or 3 in sight; then there were 8 or 10; and at one time as many as 12. Duration, 5 minutes. Some two or three had tails, and others sparkled.

London (105 miles, W. 25° S.).

F. C. W. BALL and F. E. WEIR (students in Engineering, University of Toronto).

The meteors appeared at intervals of 15 to 20 seconds. Color, reddish yellow. Their path passed about 15° east of the zenith. The first bodies were single, but the last four appeared in pairs, of which the last pair were fainter than the others. No noise was heard, either during or after the display.

REV. R. J. BOWEN.

Observed the meteors from a point four miles east of London. At 9.12 p.m. I noticed a glare of light in the sky, moving slowly in a southeasterly direction. It then exploded like a sky-rocket and broke into about thirty or more meteors, each having a tail one-third to one-thirtieth as long as the tail of the original body. I heard no noise whatever, and this large display was visible to me for two or three minutes. It moved very slowly, and was well overhead. Had to put down the top of the buggy to get a better view.

While this large group of meteors were in view, the phenomenon developed and assumed great dimensions, for dozens of meteors came into vision. They were quite plain, but not nearly so brilliant, and had tails which seemed to be drawn after them and in the same direction as the large bunch of meteors seen first. By this time we had turned the horse and we were scanning the heavens to the northward, and suddenly a movement commenced, and I am not exaggerating when I say hundreds of tailless meteors moved slowly across the sky. These were not nearly so bright as the former ones mentioned. The impression it left upon me was the instability of the whole.

I have seen meteoric displays and phenomena in the Arctic regions and all over Western Canada, but never have I been so privileged to see so many heavenly bodies moving at one time, or any moving so slowly or in so low an altitude.

Mr. Bowen states further that his watch is usually pretty accurate and is never allowed to get more than two or three minutes fast.

Magnetawan (Parry Sound, 139 miles, N. 4° W.).

DONALD ROSS.

The meteors travelled from northwest in a direction south by east, and about 20° above the horizon. I saw about 20. Their motion

was not like that of shooting stars; much slower, four or five being seen at a time, and each being in sight about 30 seconds. The duration of the entire phenomenon would be close to 3 minutes.

They were round, with a tail to each, a fraction of a degree long; and appeared to emit sparks from each side as they sped along. About 30 seconds after the smaller ones (which were all of a size) had passed, a much larger ball of light appeared, white like the others, and with the same and in the same direction, but without any tail. When about midway horizon to horizon it burst and sent forth a shower of sparks, much like a rocket, and for a second it brightened the sky. I did not hear any sound.

Marshall, Mich. (100 miles W. of Detroit).

FRED. CAVANAGH, of Oakville, sent a clipping from the *Marshall Chronicle* of February 10, 1913, containing the following: "Miss Vera Murray and Carl Schnaitman spent Sunday at Warren Clark's, in Fredonia, and when returning to the city last evening they saw two enormous meteors, with tails many miles in length. This happened shortly after 8.00 o'clock, and when Miss Murray and Mr. Schnaitman reached the city they reported that they had seen an airship going east. The heavens were brilliantly illuminated, and with the passage of the meteors a shower of stones was seen to fall. The display lasted for many minutes."

Melrose (Hastings Co., 113 miles, E. 20° N.).

H. O. LAUFEAR.

The meteors seemed to come from a point almost due west, or slightly north of west, and not far above the horizon. The first one had a short tail, which looked dull to me, and it was quickly followed by 8 or 10 others, most of which had no tails at all. Duration, probably not more than 15 to 30 seconds; all in sight at one time. The middle one apparently burst into a number of pieces, but I heard no sound.

Midland (77 miles, N. 16° W.).

REV. J. J. ELLIOTT, B.A.

Did not see the display himself, but from eyewitnesses he learns the following: The brightest part of the spectacle was the leading group of four or five, travelling close together, and each leaving a trail of light of considerable length. About a minute afterwards there was another

and then others, until about fifteen in all were seen. No sound was heard. The direction was from northwest to southeast. The altitude was not high, and the meteors moved at a comparatively low speed.

Midhurst (58 miles, N. 13° W.).

R. D. COURTS.

So far as I remember, a large meteor was in the lead, although I think the largest of all led a group some distance behind the first. Both those and a few others had tails, although the most of them had not. Those were followed by still others, growing fewer and dimmer, the last I saw being scarcely visible.

They appeared to be going at the same speed, the paths being nearly level, as if unaffected by gravity, and they were travelling south by east.

Duration, about 5 minutes. Number of bodies, possibly 15 or 20 large ones, and quite as many or more small ones.

Mill Bridge (Hastings Co., 115 miles, E. 37° N.).

E. A. NORMAN.

I had just gone to feed my horse for the night, and as I opened a stable door at the southeast corner of the barn the first meteor flashed past the eave of the roof at the far end, or southwest corner of the barn. I went over this evening and took measurements. The barn is 50 feet long, and from my head to the eave of the roof is 20 feet; therefore the first meteor would be on an incline of 20 feet in 50, or 22° above the horizon.

Some of the meteors were higher and some lower. Two in particular, which travelled together, were one about three times the diameter of the moon above the other. I think there were about 12 or 14 in all. I think the leader was the largest, and was about half the diameter of the moon. They appeared to move quite slowly. They were about west when I first saw them, and about south when they got out of my range of vision. The new moon had set, and the large evening star was within 15 minutes of setting.

I heard no noises whatever. Sparks seemed to fly out from them, especially the leader, and smaller things like ordinary stars seemed to be darting about in their train. The leader was like a red ball of fire seen through a mist.

Milliken (12 miles, N. 17° E.).

ALEX. MACKLIN.

I had just gone out to view the heavens, as I often do on a clear night, when my eye was attracted by a gleam of light, followed by a group of about 7 of the fire-balls. They went from north-northwest to south-southeast, and the elevation was about 50°. These were quickly followed by several very bright ones, and numerous small ones, all following in the same plane. I should judge 15 or 20 in all, and not appearing to move swiftly as meteors generally do.

The largest of the fire-balls appeared almost white on the front, and seemed to be giving off sparks which quickly faded out, but a luminous tail was left to trace their path. They all had long, tapering tails.

Duration, probably 3 or 4 minutes. Two or 3 minutes after a rumbling noise like distant thunder was heard, repeated three or four times.

What struck me most was their comparative closeness, and when the sound was heard I could not but associate it with the display. All was over by 9.12, noted on an accurate clock.

Mortlach, Sask. (65 miles W. of Regina).

JNO. R. SMITH.

The time was somewhere between 7.06 and 7.15 p.m. (Mountain Time). I did not attempt to count them, but I imagine there must have been hundreds of them. They did not appear to me to be on a downward course, but on more of a straight line from west to east. I could not say how long they were visible, as I probably did not see the first of them. What impressed me more than anything else was that very few resembled shooting stars, only some of them having the tail or streamer behind them.

Mt. Charles (13 miles, W. 12° N.).

MRS. T. AIRKINS.

Meteors passed directly overhead. The heads were large and luminous, tinged with red and supplied with tails which seemed to have from four to seven glittering particles behind them, a short distance apart. The space between was bright and white-looking. They came into sight and went out of sight like a flock of birds. They lasted for 5 minutes or more, and were followed by a rumbling noise like an explosion; and a second or two later was another not quite so loud.

Mount Forest (69 miles, W. 18° N.).

The Mount Forest *Confederate* says: A loud noise like that of thunder was heard here on Sunday evening, shortly after 9.00 o'clock. Some who were out walking at the time thought it was thunder; others thought it was ice cracking in the river; still others, that horses were kicking in a stable.

Muncey (116 miles, W. 28° S.).

JOHN STEWART.

The writer had a splendid view of the display. Position in sky, about 30° from point overhead. They were going about directly east and did not appear to be getting any nearer the earth. There were probably about 18 or 20 in all, about 6 or 7 being visible at once. Lasted about 2 minutes altogether. Heard no sound of any kind. Two had tails. About one-half remained intact; the others broke up—some more, some less. Each body remained in sight perhaps 30 or 40 seconds.

New York City.

MRS. MARGARET GRIFFITHS, of Watchung, N.J., 22 miles West of New York City.

I was returning from church with a party of friends, and was walking northwards; and the meteors passed directly over my head. We all had to hold our heads away back to see them. There were seven distinct meteors, or balls of fire, as they appeared to us, and two of them burst just as a sky-rocket does.

Niagara-on-the-Lake (31 miles, S. 30° E.).

A correspondent writes: "As we saw nothing of the display, I can only tell you of the sound, which was similar to the starting of a heavy wagon, and gradually dying away. There was also a slight vibration, which made the windows rattle. It lasted 2 or 3 seconds.

Oakville, 7 miles N. of (17 miles, W. 26° S.).

FRED CAVANAGH.

I distinctly heard the noise, like the rumble of thunder, coming from the north, and in a few seconds another less distinct.

Orangeville (40 miles, W. 29° N.).

MR. ALEX. STEELE, B.A., Principal of the High School, at the writer's request, made inquiries in Orangeville, and found two who saw

the meteors, but several who heard sounds which were pretty evidently produced by the meteors. These were compared to the rumbling caused on taking a carriage out of a stable.

Orillia (64 miles, N. 3° E.).

MISS ADELAIDE KING.

First seen in northwest about half-way between horizon and zenith. There were about 30 stars in all, divided into four groups. In the first group were about a dozen very large, bright stars, with a long tail resembling a large sky-rocket. Following this were three smaller groups (three stars in each) less bright, with no tails; and ending up were a few single stars.

Duration, about 5 minutes; largest body seen for 2 or 3 minutes. No sound.

MRS. C. E. GRANT.

I noticed a bright object suddenly appear in the western sky. It seemed at first like a shooting star, but instead of descending, or growing fainter, it appeared to move towards me and grow brighter, until it seemed to be quite close and not very high. It resembled a very large sky-rocket in brilliancy, shape and length, but instead of the bright balls at the head scattering and disappearing, the whole body retained the same form as it moved along in a stately way, going in a southeasterly direction and becoming less bright. But before this one was out of sight another one appeared from the same direction, quite as brilliant and as large as the first one, but the bright balls at the head seemed larger and not so numerous. It followed in the same direction, but had only passed when a group of three appeared, one above the other, not nearly as large or bright, with the tails rather separated. Then followed quickly another group of three, and immediately after two, then two more, then one, becoming less brilliant, much smaller and more detached, more like single bright stars, moving in the same direction, keeping the same position and form until lost in the distance.

No sound was heard. Duration less than five minutes.

Painswick (48 miles, N. 15° W.).

S. BLACKMORE.

There were about 12 meteors, and I watched them about five minutes. The first five or six were quite close together, the rest follow-

ing like a flock of wild geese and with about the same speed. Some left tails almost like a sky-rocket, others were like moving stars. The course seemed to be about 30° above the horizon.

Parry Sound (120 miles, N. 12° W.).

WALTER L. HAIGHT.

On the evening in question I happened to be returning from a snowshoe tramp, and was in the act of tightening up the straps on my foot when my companion called out: "Look! Look!" and I immediately threw my head up and caught sight of the large meteor, which appeared to be travelling very slowly—so slowly that the stateliness of its motion excited my liveliest surprise and wonderment. I have seen many meteors while out boating and walking at night, and many larger and more brilliant than the one in question; but this was markedly different from the rest in two main features, viz., that it was not so luminous, being of a distinctly reddish color, and that it moved with unprecedented slowness on a level plane.

As will be seen and noted on the rough sketch (Fig. 8), it moved at an elevation of from 35° to 38° , fixed by my companion and myself after going back and determining its position from our point of view.

The meteor was in two distinct portions, the head being round,

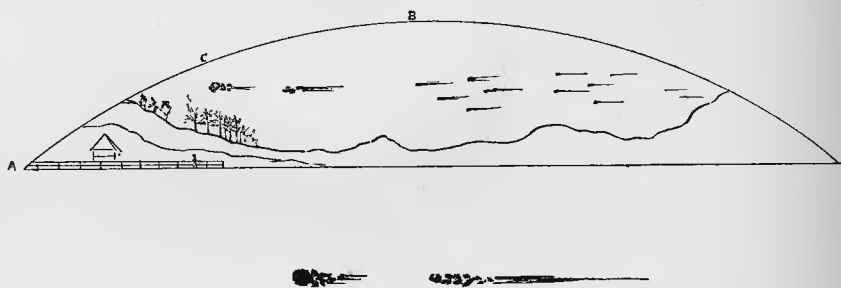


FIG. 8.—From a sketch by Mr. Walter L. Haight, Parry Sound. The observer is seen in the left fore-ground and the hill is shown behind which the large meteor disappeared. In the rear are shown meteors,—a group of four or possibly five; and, separated by a larger interval, another group of four or five; followed by a few scattered ones, bringing the number up to perhaps 14. *A* is the horizon, *B* the zenith and *C* is midway between *A* and *B*. The separate drawing below roughly shows the appearance of the large meteor. It is given mainly to illustrate the split between the head and the tail.

with fragments grouped about it and separated from the other portion by a short distance, and my somewhat dimmer recollection is that the rear portion was composed of globular masses, smaller and fainter than the head, and fading into a streak of dull reddish fire.

While my gaze was riveted on the large body, and just when it was about passing out of sight, my companion again called out, "Look! There and there!" and I looked up and saw the first group of following meteoric bodies, some five in number, I believe, looking like spent rocket-sticks when they first begin to move downwards—like them in the dull red of their glow and the slowness of their motion. They all appeared to be moving on a level plane and grouped approximately as in sketch.

Before I could recover from my astonishment, a new group of smaller ones, computed at four or five, came sailing along, followed by others more widely separated, and making a total of from ten to fourteen.

Possibly the flight occupied one and a half to two minutes. They moved from about west by north to east by south. I took out my watch when the flight passed, and it was 9.10.

I likened them at the time, and the resemblance seems yet apt and appropriate, to a large battleship moving ahead with attendant squadrons of torpedo-destroyers and torpedo boats. Never have I seen bodies in the heavens move at such a slow, stately and measured pace. That remains the most outstanding and remarkable feature of a most entrancing spectacle.

'Pon my word, I don't think I would have been more surprised had they swung about and sailed back into the west from which they sprung.

ASAHEL WRIGHT.

The series of lights travelled in unison and so horizontal that I could think only of a gigantic flying machine. The lights were at different points, one in front, one farther back, and a rear light, then a succession of small lights in the tail.

Pefferlaw (47 miles, N. 10° E.).

W. J. BOYNTON, M.D.

First, was a cluster of bodies moving rapidly to the southeast. These soon disappeared, but others followed in quick succession. They all came into sight from the northwest at about 45° from the horizon and disappeared about the same elevation in the southeast. Each body

took about 20 seconds to travel this distance, that is, half-way across the sky.

Probably 20 were visible at one time at the beginning. They were more numerous then, and became fewer at last until the last one was a considerable distance behind.

The display as a whole might be compared to an arrow, one bar ahead and many others following, and extending a considerable distance out at each side. I should judge there were between 50 and 100 bodies in all. The time of the display was close to $2\frac{1}{2}$ minutes, estimated from the distance travelled, and my rate, which I know pretty well.

The bodies themselves were like red-hot missiles or shafts flying through the air. There was no luminous stream or tail like the tail of a comet, but they were both surrounded and followed by myriads of sparks resembling the fixed stars. These extended out a considerable distance from the sides, completely filled up the spaces between the different shafts, and followed the last one for some distance.

There was no sound. The bodies passed nearly overhead— 10° or 15° to the west of the zenith.

Pense, Sask. (17 miles W. of Regina).

MESSRS. G. and B. SPRING RICE, when sending a report to the Agent of the Meteorological Service at Moose Jaw, make reference to the meteors, as follows:

I would call your attention to a curious phenomenon observed on the night of February 9th (Sunday). It was observed at about 7 o'clock (Mountain Time) in the evening, and I have called it a procession of stars. The first two stars were followed by a long tail, much like a falling star, but moved comparatively slowly in the sky, directly overhead, in a direction from west to east. These were followed by a number of other stars, sometimes singly and sometimes in groups, all of which moved across the sky at the same deliberate pace and in the same course. The procession must have lasted about two minutes. . . . I have never seen anything like it before.

Peterborough (69 miles, E. 41° N.).

REV. W. E. HASSARD, B.A., B.D.

The appearance was like that of an express train lighted up at night. The elevation was about 25° . Movement was slow and the duration about 3 minutes. In the first section there seemed to be from six to nine lights, with slightly spreading ends. Then, in succession, some

three or four, not so brilliant sections passed. The most striking feature to me was the regular movement in an even plane. There appeared to be no curve whatever. No noise was heard. It was the grandest display I have ever seen.

Picton (114 miles, E. 12° N.).

E. M. BIGG, M.A.

A pupil of the Picton High School states that he saw the meteors nearly due west. About 20 in number and about 25° above the horizon

Port Hope (57 miles, E. 20° N.).

MRS. MARGARET KETCHUM.

We stood under a west verandah and the procession of fire-colored globular stars seemed to come from the north-northwest, sailing over to south-southeast. The elevation was about 40° . We thought there were at least 25 stars. All had tails of the color of fire, a dull red.

Port Sydney (Muskoka, 105 miles, N. 2° W.).

A correspondent writes:

The first meteor resembled a kite with a remarkably long tail. They were decidedly low down and rather to the west. At least 10 or 12 bodies were seen, each one following close to the tail of the one before. Duration, not more than 3 minutes; no sound heard.

Richard's Landing (St. Joseph's I, Algoma, 287 miles, W. 40° N.).

J. H. ALLAN.

The meteors travelled from a little north of west, ending up a little south of east. When first seen their elevation was about 45° , and they did not appear to pass directly overhead, but about $22\frac{1}{2}^\circ$ to the south of the zenith. In all, there must have been between 50 and 60, as many as 10 or 12 being seen at once.

Duration of display, about 2 minutes. No sound was heard. The bodies remained intact. One was considerably larger than the rest. Two or three had tails. Several remained in sight from 6 to 8 seconds. The color was that of a bright fire, not the clear white color of the average meteor.

Ridgeway (55 miles, S. 17° E.).

REV. S. A. LAIDMAN, M.A., Ph.D.

Three members of a troop of "Scouts" reported having seen the meteors. One large ball was seen first, about the size of the full moon,

and it was followed by about one hundred of the size of the brightest stars. These last all appeared at about the same time, and were not widely scattered. No tails noticed, but larger one was elongated.

There was a noise like rumbling thunder, which gradually increased in volume, then decreased again.

Rodney (139 miles, W. 32° S.).

JOHN A. CUNNINGHAM.

The meteors appeared in the northeastern part of the sky, half-way between the horizon and the point directly overhead. They travelled slowly from northwest to southeast. There were about thirty in all, and the largest number I saw at one time was five.

The bodies remained intact and the majority of them had tails more or less brilliant. One meteor at the close of the display was very bright and had a long tail. The phenomenon lasted three or four minutes, and the longest one body was in sight would be about ten seconds.

I did not hear any sound; if there was any I think I would have heard it, for I was in the country, where all was quiet.

Rothsay (65 miles, W. 9° N.).

The correspondent from Rothsay to the *Drayton Advocate*:

We did not witness the meteors last Sunday night, but we heard a noise like thunder, and felt a distinct shock as if an earthquake had taken place.

Rydal Bank (Algoma, 292 miles, W. 44° N.).

JOS. E. ASAM.

The first meteor at first appeared to be of the size and color of a large star, growing as it advanced. There was a tail of a red, shadowy appearance, which also grew in size and deepened in color. A little further on to the east it seemed to explode, much like a sky-rocket, throwing out a dozen or more balls.

This was followed by a second meteor somewhat smaller, travelling slightly higher. Then came a group of 15 to 20 travelling together and rather higher than the two preceding. Then followed a group, still higher, but travelling in the same course, and after this followed a group in the same course, only still higher.

In all, I would say there were about 40. They looked to pass about

one mile south and at an elevation of about 300 feet. (That would be 3° 16' above the horizon.—C. A. C.)

The bodies appeared to travel almost east, with a downward tendency. The first was in sight about 1½ minutes, and I think it had disappeared when the last group came in sight.

St. Davids (36 miles, S. 20° E.).

RIV. G. MUNRO.

I saw no display. . . I was somewhat startled by a thunder-like sound. It seemed to come from almost directly overhead, or a little to the west. The sound was of the deep tone of distant thunder, but explosive rather than rolling. There was a rapid succession of distinctly explosive sounds, such as one hears in a quarry sometimes when a whole series of deep charges are exploded.

I gazed intently into the heavens all the while, but saw nothing. The time was approximately 9.15, and the duration of the sound perhaps somewhat more than half a minute. Others in the neighborhood heard the sound, but none saw the display. Some of them estimate the duration of the sound as much as 2 minutes.

St. Thomas (109 miles, W. 32° S.).

HARRY WILKINSON (age 12 years).

I saw about fifty meteors. At first there came about three, then about seven, and then they kept on coming in large clusers till they all passed. Some had sparks shooting from them, and some had tails more like comets. They were travelling from northwest to southeast. They looked like sky-rockets, only they did not fall.

Sand Hill (26 miles, W. 33° N.).

MRS. D. TIGHE.

Some had tails and some seemed to shoot a red vapor which threw a beautiful red glow. They came in bunches or groups. I counted ten in one group and I think there were 20 groups. As they disappeared in the east there was a loud report like rolling thunder, and then another sound like thunder, and a tremor of the earth.

Shelburne (49 miles, W. 37° N.).

R. A. RIXY states that a man who lives four miles east of Shelburne reported to him on Monday morning that there must have been

an earthquake the night before, that the vibration was quite perceptible, and the noise was like a series of blasts going off.

In the Shelburne *Economist* it is stated that a man living 12 miles west of the town was awakened from sleep and thought that his horses were wrecking the stable. On investigating, however, he found the horses perfectly quiet.

Eheridan (17 miles, W. 36° S.).

H. A. LEAMON.

The path of the meteors passed about 15° southwest of the zenith.

As the first meteor got higher in the sky and nearer me, I saw it had an immense tail which seemed to have very bright little sparks in it from one end to the other. Those at the head were larger than the others, but not a bit brighter. As it got nearer the ball of fire seemed to break up, and as nearly as I could count there were 17 more with little tails. Then again, somewhere between 50 and 100 individual sparks appeared, as if they shot off the main body when it broke, or seemed to break.

Long after the main body had passed and was fast disappearing in the southeast, I saw tiny sparks just whizz by, seemingly endeavoring to catch up with the big fellow which had left them behind.

The whole display must have lasted 4 minutes, and just after the first disappeared in the southeast I heard a rumbling. The main body must have been in sight 2 to 2½ minutes.

Springbrooke, 3 miles west of Brampton (19 miles, W. 7° N.).

J. P. HENSHAW.

Commencement of display, 9.05, taken on a watch correct to a few seconds. The bodies had tails. The first was the biggest, and it looked as if the others all came from it and naturally had shorter tails. There must have been at least 60 bodies. Sound was heard in the midst of the occurrence, like a rig going over a bridge.

Springville (65 miles, E. 42° N.).

REV. D. B. MARSH, F.R.A.S.

As the congregation was leaving the church after the Young People's meeting, Mr. F. E. Wilson called me to the door, which faces west. I immediately saw a large red meteor, followed by others, coming from the northwest. I looked at my watch; the time was 9.04½. The forward meteor was very large and very red, with the tail several de-

grees in length. Those following were irregular in size, some in pairs and others following lazily along the sky. The head of the large meteor was eclipsed for a moment by the top of a telephone pole, so placed that the line adjoining it to the observer made an angle of 49° with the meridian. Afterwards I set up a transit instrument to represent my position, and sighted the top of the telephone pole, which gave me an elevation of 14° 58' above the horizon.

After looking upon the grand spectacle for (say) 2 minutes, I counted 10 meteors in all. (Some of the people say they counted more.) I then ran into my house adjoining the church and got out a 3-inch telescope, but the last body had vanished. Some of these meteors passed on to the southeastward out of view, while some burned out and vanished before our vision. I believe there was no noise heard by anyone. Their duration was about 3½ to 4 minutes.

Stouffville (23 miles, N. 16° E.).

MISS GERTRUDE KENDRICK.

The first meteor was funnel-shaped; it was small at first, but grew larger as it passed from about half-way up from the horizon in the northwest to about half-way down to the horizon in the southeast. I saw about 8 meteors, the first being the largest, and the ones following being each a little smaller than its predecessor. The bodies did not break up, and each had a tail. Duration, about 2 minutes; and the first one was in sight almost the entire time. It had just nicely disappeared before the last one came to view.

Sturgeon Falls (186 miles, N. 6° W.).

The North Bay *Times* states that there was a mysterious visitor to Sturgeon Falls on Sunday night, when several citizens were surprised to see a slow-moving object in the air a short distance from the earth. The meteor resembled a large aeroplane or dirigible, with two tiers of lights strung along the sides, and moved slowly toward Lake Nipissing.

Sudbury (Nipissing, 214 miles, N. 9° W.).

W. J. BELL.

The meteors were seen close to the southern horizon, and the duration was about 30 seconds. The number of meteors counted in the first place was 5, all of which exploded into parts of two to six each, and all had tails. These were observed from the street, and the view to the south was somewhat obstructed by a hill, which may possibly have hidden some of the meteors.

Sunderland (45 miles, N. 23° E.).

JOSEPH PURVIS.

In the first lot there were about ten, and two of them, which were quite close together, were much larger than the rest. The whole cluster was as wide as the distance between the points of the moon on Sunday night. There was a bright red light all around them, with a more distinct light behind as they travelled along.

There were four distinct clusters. The first, of about ten; the second, of about three; the next, two; the fourth, one—this one having the size of a bright star. All visible at one time. First cluster visible to me about 1½ to 2 minutes; it disappeared behind a building. No sound heard.

Thamesville (151 miles, W. 29° S.).

MISS CATHARINE MACVICAR DUNCAN.

The sky was not so bright as on the evening before; large areas of the sky were in misty darkness. Suddenly, right under Cassiopeia, travelling from northwest to southeast in a horizontal plane and *very* slowly, almost as if it were stopping or just going to dissolve in air (*not* drop), appeared the Head Light. It glowed now brighter, now duller, and it looked like a parallel trail of dozens or perhaps hundreds of distinct stars or sparks, that either went out or fell behind (*not* down). My brother shouted to me, "An air-ship!" And I said, "Mrs. M—'s chimney is on fire." It looked that near. (This house was about 70 feet away, and obscured behind spruce trees.) The big leader seemed to curve a little to the south, but those that almost immediately appeared, one at a time, seemed to follow exactly in his path. It was a slow procession, not more than three or four being seen at one time. It reminded me of a dozen fish swimming at intervals, and one after the other.

To the eye they were little above the housetops. There might have

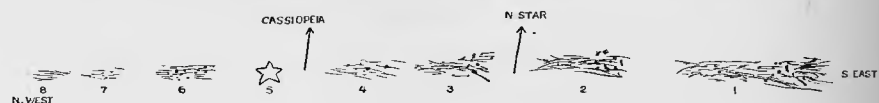


FIG. 9.—From a sketch by Miss Catharine MacVicar Duncan, Thamesville. There were hundreds of sparks in group No. 1, dozens in No. 2, fewer in the followers. No. 5 was a big one floating along by himself. Each group was distinct and separated from the others. There might have been 12 of them, but no more. The last ones were very dim, like luminous gas.

been 12 groups of bodies, but no more. I am sure of 8. In the first there were hundreds of following sparks; dozens in the second; fewer in the rest. One big body floated along by himself after about the fourth group. Each group was distinct and separated from the others. The last ones were very dim, like luminous gas, fluttering now brighter, now dimmer. (Fig. 9.)

The phenomenon lasted three or four minutes, perhaps longer. We had to get to the south side of the street the better to see them. No sounds were heard. The big leader was in sight longest, over a minute, I should say.

TORONTO

Sydenham and Parliament Sts.

H. D. ASHLEY, of the Toronto Police Force.

The meteors were observed in company with Sergt. Lydiatt. The first meteor was by far the most brilliant of all, had the general appearance of a chain of fire-balls decreasing in size and followed by a pale beam of light not unlike that of a large searchlight.

It was followed by five others, not nearly so luminous. I counted 16 in all, the last 4 being extremely dim. Indeed two of these were seen to rise in the northwest, but became entirely invisible before passing over. Duration of entire display, 340 seconds.

Cecil and Bathurst Sts.

W. A. BARBER (University Student in Mathematics.)

There were 17 or 18 meteors, and the color was reddish. The course was about 60° above the horizon. All had long tails, perhaps 30° long. The head of the meteors seemed to break up. Diameter not greater than 2'. Heard sound like thunder about 1 minute after last had gone.

St. Clair Ave., near Oakwood School.

W. BETTS.

There were about as many as shown in the diagram (Fig. 10), and the display lasted from 5 to 8 minutes. The bodies remained as shown in the diagram. Any one body was in sight about 30 seconds.



FIG. 10.—From a sketch by Mr. W. Betts, Toronto. The front meteors were very brilliant and appeared to be like fireworks on the point of exploding, the heads appearing like golden balls. Those next following were less brilliant although very bright. They gradually diminished but looked like remnants of fireworks or like stars flying through space—all at the same speed. The meteors appeared far more scattered than represented above. (See note to Fig. 5).

Parkdale.

JOHN BUTTERFIELD.

We heard a heavy rumbling noise, but the sky was clear. There was a short interval of silence, and then a rumbling and a noise like thunder. The time was observed on a watch afterwards tested and found to be correct, and was 9.12. It reminded me of an earthquake I heard in September, 1910, near Cobalt, Ont.

Bedford Rd., near Lowther Ave.

MISS BOYD.

The bodies went in regular procession, travelling quite slowly. After all the rest had gone a single one appeared. Sounds like cannon were heard as the lights disappeared, four or five rumbling sounds, very distinct, but not continuous. They were heard by Mrs. Boyd in the house.

Roxborough St., near Yonge St.

HERBERT E. BROWN.

One meteor appeared first, then another of about the same size (the first leading by a short distance), then closely following the second were six somewhat smaller ones, travelling two-by-two, and the rest came close behind these in irregular order, about fifteen in all. I tried to count them, but owing to questions from my companions and the awful majesty of it all, I lost the count. The first two broke into many pieces and left a trail of fire in their wake. Duration of display, about

3 minutes. From the time the first one struck the atmosphere until it passed out it was about a half-minute. A noise like distant thunder was heard.

Kenilworth Cres.

E. CHEETHAM.

There were 21 meteors. The first was a very large one; then came three more, nearly as large and very bright. Then came two more, but smaller; then four and three and two, until they got like sparks in the sky. After the last meteor had passed there was a rumble like thunder, which I spoke of at the time, as the night was very cold.

Moore Park.

JOHN CLARK.

In the first group were three bodies, two abreast and the third below the others. Each of these three had a long tail. Then came a pair, and then other bodies not so bright and without tails. One of these in particular was very noticeable, having a kind of quivering motion. After this were two more bright ones, like the first pair of bright ones, and then after this a shower of sparks was seen in the northwest where the meteors had come from. These were much like sparks blown from a chimney. They did not pass over like the meteors, or if they did come they were not visible to us.

The whole lasted about 4 minutes, and the path was about 40° above the horizon. Heard no sound.

Robert St., near Russell St.

WM. R. EVANS.

In the first lot there were two, side by side: Then four or five followed singly, and then two came close together. The rest followed singly. The time between successive ones varied from 10 to 20 seconds, or not more than 3 minutes in all.

Delaware Ave., near Bloor St.

FRED M. FISHER.

The total number I counted was 22, and the entire flight, I judge, occupied about 1½ minutes. At one time possibly 10 were in view. The course passed about 30° southwest of the zenith.

Broadview Ave., near Bain Ave.

CHARLES FULLER.

The meteors came into sight right over the Swiss Cottage. (As seen from the corner of Broadview and Bain Avenues, this building is 27° N. of W.—C. A. C.)

I did not count them, but thought there were about 20, appearing like this:—

1—3—2—6—4—2—1—1.

The six in the middle formed a grand group, and they all kept regular formation all the time.

No noise was heard, and the duration of the entire display was about 4 minutes.

Gerrard St., near General Hospital.

W. H. GREGORY (University Student).

The shower, which consisted of some 18 meteors, seemed to appear in the north, a little to the west, and travelled across the sky to the south-east. They seemed to pass nearly overhead, about 5° from the zenith. Most of the meteors had streaming tails, and the first one broke up. The bodies travelled in groups of three, and the first were considerably brighter than the later ones.

Earlscourt, N. W. of the City.

EDWARD GURNEY.

The meteors came from a point about 5° west of Cassiopeia, and appeared to be about 45° above the western horizon.

Windermere Ave., Swansea.

MISS IDA HOWARD.

The path was about 60° above the horizon. The first group consisted of one large one leading two abreast. These were of about the same size and had tails, which appeared to be parts of the main body, breaking off like a rocket.

These were followed by about ten others, not quite so large and with smaller tails. Then after a few seconds there appeared a great number of small bodies following in the same direction as the first. They were all of a bright red color.

Duration, from 3 to 5 minutes. After the display had passed my two companions and I all heard a sound like two rolls of thunder.

Hepbourne St. and Dovercourt Rd.

E. C. HUNT.

The first meteor was the most brilliant of all; it was like a ball of fire, with a long tail. During its flight other bodies left it and followed in its tail. Then two more followed, but not quite so brilliant; these travelled abreast. Three others followed, just behind each other, two of which had tails breaking up in the flight, the third remaining intact. These were followed by a cluster of eight, not nearly so brilliant, only one having a tail. Nine more followed, remaining intact and being very dull. Altogether I counted 6 with tails and 17 without, 23 in all. They all passed in 4 minutes; no sound was heard.

Yonge St., near St. Michael's Cemetery.

E. KIRBY.

There were from 12 to 15 bodies, and they appeared to be travelling from west towards the east. They had the appearance of rockets, on account of the fiery tail. Duration, 2 or 3 minutes; after which there seemed to be two peals of thunder.

Balmoral Ave., near Avenue Rd.

A. T. LAING, B.A.Sc.

The bodies had streamers behind them which looked like ribbons of light, and they moved slowly and uniformly, as if all were drawn along by a cord. The course was horizontal, with no apparent downward tendency.

The width of their path was about 4° or 5° and they passed about 20° southwest of the zenith. The path, from the point where they were

FIG. 11.—From a sketch by Mr. A. T. Laing, B.A.Sc., Toronto. This represents about 90° of the flight.

first seen to that where they disappeared, subtended an angle to the eye of about 120°. The brightest bodies were visible about 30 seconds.

On the following Saturday, with the assistance of Prof. L. B. Stewart and a prismatic compass, an attempt was made to determine the direction of the course. By sighting on the beginning and the ending of the path it was found to be from about 26° north of west to the same distance south of east.

Don Valley, ¼ Mile N. of Bloor St.

J. G. MACARTHUR.

There were probably 30 or 32 bodies, and the peculiar thing about them was their moving in fours, threes and twos, abreast of one another, and so perfect was the lining up you would have thought it was an aerial fleet manoeuvring after rigid drilling.

About half of them had passed when an unusually large one hove in sight, fully ten times as large as the others.

Five or six would appear in two detachments, probably 5 seconds apart; then another wait of 5 or 10 seconds and another detachment would come into view. We could see each detachment for probably 20 or 25 seconds. The display lasted about 3 minutes.

As the last detachment vanished the booming as of thunder was heard—about 5 or 6 very pronounced reports. It sounded in the valley as if some of the balls of fire had dashed into Humber Bay. The bodies vanished in the southeast, but the booming appeared to come from the west or northwest, and the time it was heard was close to 9.12 p.m.

Pape Avenue.

E. MCGILL.

There would be a number of the bodies in a line with a light streak between them; and the last was one large ball by itself. The display lasted fully 3 minutes. While we were gazing with awe on the brilliant display far above us in the clear sky a voice from a group of men was heard to say: "Oh, boys, I'll tell you what it is—an aeroplane race."

It was 9.10 by my watch. About 3 minutes later we heard three reports like thunder, which seemed to come from the west.

Indian Rd. and Geoffrey St.

JAMES G. McMILLAN, B.A.Sc.

The path of the meteors when passing appeared to have an elevation of about 30° above the horizon.

The tail of the first and those of some of the following ones extended to a considerable length, and looked not unlike the sheaf effect produced by certain rockets, except for the differences of direction. They would subtend an angle of perhaps 5°. At the end of the display several luminous balls appeared, travelling with a somewhat wavy motion and not in so direct a line as the larger meteors. I followed one of these, and

think I counted three others, which, except for their motion, were not readily distinguished from stars of a red color.

A sound was heard by some of our party after I had left them, which must have been about 1½ minutes after the last bodies had passed and nearly 4 minutes after the appearance of the first ones.

Bathurst and Dupont Sts.

CYRIL A. MOSS.

There were about 15 meteors, and all had long tails except the last, which was just like a star and came some time after the others. The first meteor broke into three parts, which all travelled together. Then there were two pairs and the rest were single ones.

Two sounds were heard, not just like thunder, but like immense upheavals in the earth some miles away. The first was louder than the second, and in the interval between I had walked two (short) blocks.

Brunswick and College Sts.

H. G. MURRAY (University Student in Mathematics).

Course from N. W. by N. (34° W. of N.), but could not see the beginning for houses; centre of path, about 45° above western horizon; width of stream, about 3°; color, golden yellow, like a sky-rocket but not so bright; a single body visible about 30 seconds. All had tails, which seemed to be lost as the bodies moved away, due to foreshortening. Duration, not greater than 5 minutes; no sound heard.

Queen's Park.

JOHN H. PARKER.

The first group seemed to number five. Then followed a group of three and after that four or five single ones. Heard a sound like distant thunder. The path seemed to be about 20° from the zenith.

Bloor St., near McMaster University.

N. S. ROBERTSON (University Student in Mathematics).

Beginning of display, 9.05 by watch. Duration, 1 minute or more. Saw small ones break off from larger ones. There were about 17 or 18 of them, 3 or 4 being seen at one time. There was usually a large mass followed by smaller ones. The path in the sky subtended about 1½ right angles. The elevation of the course of the meteors was about 55° above the southwest horizon, and on tracing the course on a city map it appeared to be from a point about 47° west of north.

Walter St. and Kingston Rd.

KENNETH SNYDER (age 12 years).

The meteors appeared to be a little west of overhead, travelling from northwest to southeast. I did not count them, but I judge there were twenty or more. They usually went in pairs, each pair being quite a distance behind the one next ahead of it. The whole phenomenon lasted about 3 minutes, each body being visible from 15 to 25 seconds. After the last ones had gone a dull sound like distant thunder was heard.

Near King and Jarvis Sts.

H. A. VAN WINCKEL.

The position in the sky of the first one seemed very low, so low that at first I thought it was a rocket. The succeeding ones seemed much higher. I should judge there were 15 bodies, or a few more. Some were single and some went in twos and threes. The first appeared to be the largest and most brilliant of all; and the phenomenon lasted, I would say, between 3 and 5 minutes.

The bodies broke up without exception and left a tail behind as they went through the sky. I would not consider that any of them were visible for more than 30 seconds, with a possible exception of the first, which seemed larger and brighter than the others.

Queen's Park.

DR. W. M. WUNDER.

There were about 25 bodies in all, and the centre of the path was about 25° southwest from the zenith.

Bloor St., near Robert St.

A CORRESPONDENT.

The meteors were fairly high up in the sky, but at no time overhead. About 15 or 20 bodies seen; duration, 3 or 4 minutes. About 3 minutes after the display was over a noise like thunder was heard—very loud, but decidedly like thunder. The bodies remained intact. They had long tails and moved quite slowly. Some would be seen coming in the distance while others were disappearing. When all were gone two large stars with tails remained.

Poplar Plains Rd.

Mrs. Davis and Miss Florence Davis clearly observed the trembling

of the house and heard the noise, being especially impressed by the trembling.

Mr. J. C. Dempster (University student) and Rev. Professor Bowles of Victoria College also heard the sound and remarked it at the time.

Trenton (94 miles, E. 18° N.).

J. T. MAY.

We caught sight of a brilliant body in the western sky. At first glance I thought it a comet, of large proportions but of reddish color. We followed it, as it moved quickly in a southerly or south-southeasterly direction, for perhaps 1½ minutes, as it was growing fainter in the southeastern sky. Meantime others of smaller size came into view—five or six, followed closely by others, not in a string, but in about the same order as horses or men in a race, to the number of about twenty, over the same course. Altitude, about 25°. Time of visibility of the meteors, about 4 to 6 minutes.

Trout Creek (Parry Sound, 158 miles, N. 2° E.).

REV. T. A. McCOMB.

I saw a cluster of brilliant stars, apparently 12 or 15, but no doubt there were more than that, sailing along in the sky, going almost south, probably a little southeast, followed by a train of light. Soon appeared a smaller cluster, not so brilliant, with a train of light; then another and another, each smaller and less brilliant; but all appeared to follow in the same course. They were on the western side of the town, low down towards the horizon.

In all there must have been 15 clusters, though the last ones appeared only as one star. The whole phenomenon lasted probably 3 or 4 minutes. No sound was heard.

The bodies remained intact and did not appear to move with great rapidity, but with steady horizontal motion. They reminded one of the motion of a railway train at night seen at a distance of 5 or 6 miles.

Udora (42 miles, N. 10° E.).

MRS. NORMAN HARVEY.

The meteors were seen in the west, about half-way to the zenith. They seemed to be going slowly from northwest to a little east of south. The first set was the brightest; it seemed very low down, as if it might

drop at any time, and there were dozens in it, some large and some small. There was one very large one, and the others were of various sizes. After that they came in great number, following after the first, for about five minutes. No noise was heard.

Unionville (15 miles, N. 16° E.).

ARTHUR E. STIVER.

First there were 5 large ones, then 2 small ones, then 1 with a tail on it, then 7 more. A sound like thunder was heard.
Walsh (80 miles, S. 40° W.).

GRANT BINGLEMAN.

Time, about 9.10 p.m. They came from the northwest and went southeast. The first was a large meteor, which went apparently quite fast. When nearing the southeast it burst, leaving many small meteors in the sky. Then followed small meteors, about twelve in number; these had but short tails.

The display lasted about two minutes in all. The first large meteor burst shortly before it vanished; the others remained intact. I heard no noise. Each meteor remained in view only a few seconds.

Warsaw (84 miles, E. 40° N.).

MRS. DAVID MILLER.

The meteors were in a belt about 10° or less in width, and the highest ones were about 35° or a little less above the horizon. About 20

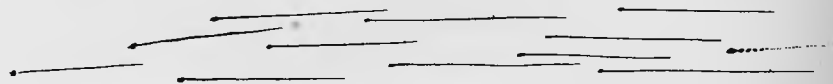


FIG. 12.—From a sketch by Mrs. David Miller, Warsaw. This does not represent the number but it shows the style of the bodies and their motion. They had long, narrow, straight tails; one leader; one at last. The leader and a few others had disappeared before the last came in sight. They seemed to travel in a prescribed belt.

bodies; no sound heard. One seemed to me to stay in sight nearly two minutes, but this is uncertain.

They came along like a lot of fish distributed in a pond, straight and parallel. None had very big heads, and all had perfectly straight tails.

The first ones were quite white, the last ones very red. The last one seemed to be different; the head was a little larger and the tail seemed like a string of stars (Fig. 12).

Waterloo (58 miles, W. 11° S.).

E. D. CUNNINGHAM.

The first meteor seen was the largest. Its course was almost directly overhead, but a little to the east. It passed slowly across the heavens, disappearing in the southeast, taking fully 10 seconds to cross. It had a tail probably 10° in length. The course seemed to be from 30° west of north to 30° east of south.

The first one was followed by at least thirty others, the majority being a little to the east of us, with a few directly overhead, none to the west. Very few of these had any sign of a tail, the majority being simply bright bodies. Many did not cross the heavens, but disappeared when overhead.

The display lasted for about 2 minutes, from 1 to 5 meteors being constantly in view. After the meteors had disappeared fully 2 minutes elapsed before any unusual sound was heard, and then we distinctly heard, at intervals, a succession of explosions which could not be better described than by comparing them to the report of heavy guns heard from a distance.

Wexford (10 miles, E. 41° N.).

HUGH DOHERTY.

I looked southwest, and it was just one long stream coming from a northwest direction. I noticed the stars shining through the long line of fire which was moving along. We all heard the thunder; it fairly made the house shake, and we said there was another earthquake in Toronto.

Whitby (27 miles, E. 32° N.).

ALMOND RICHARDSON.

The first meteor was much the largest and possessed a much longer tail than the others. The rest of the collection were spread out on either side and behind the first, but all were going in the same direction and at the same speed. They gradually got smaller towards the last, but all had tails, the first ones being about four times as long as the last. About 30 bodies in all and about one-third of them in view at one time. Duration, about 2 minutes; no sound heard.

Winchester (222 miles, E. 27° N.).

REV. R. H. ARCHER.

I saw two meteors at 9.10 p.m., approximately. They looked to be about $\frac{1}{4}$ mile in front of me, travelling in a southeast direction. The first I saw for about 15 seconds; the second, coming immediately after it, I saw for about half a minute. In that time it seemed to go about 150 yards. (This corresponds to an angular path of about 20°.) Estimated elevation about 15°.

PART II.

OTHER BRIGHT METEORS SEEN WITHIN A FEW HOURS OF THE GREAT DISPLAY

Brampton.

MR. J. G. BEATTY, a University student, reported that at about 8.20 p.m. (Sunday), while watching the bright planet Venus, he saw a bright meteor moving quite slowly, approximately from northwest to southeast

Saranac Lake, N.Y.

F. W. O. WERRY, B.A.

Venus and the moon were low down in the west. Between 7.30 and 7.45 I was facing the west by north. I saw a shooting star start about 10° higher up than Venus and move rapidly along a horizontal line (or nearly so) for about 30° and towards the north. In a few minutes another meteor started in the same region and shot across the same part of the heavens, though not reaching more than half its length.

Peterborough.

WALTER PETERS (Meteorological observer) did not see the display, but a reliable man reported to him as follows: "I was out Sunday evening between 9 and 10. Suddenly I noticed the snow illuminated brightly. My first thought was that someone's chimney was on fire. On looking up I saw a large ball of fire moving westerly. At this time it was distinctly overhead. It had begun some distance east of the zenith, for some time elapsed before I looked upward. It proceeded directly westward. It had the appearance of a large rocket. The "head" was of considerable size. Behind it there were perhaps a dozen smaller balls of fire. The spectacle was splendid. The ball did not go below the horizon. There was no explosion and no noise. It died out naturally."

Roblin (Lennox and Addington Co.).

GEO. H. BROOKS.

I had the good luck to observe the meteor. It was at 9.30 p.m., and appeared in the western sky, seeming to travel south or southwest and about 20° above the horizon as nearly as I could judge. There appeared to be an extra large ball ahead, then a dark space, followed by a long tail. The meteor did not appear very distinct to me, and for a short time disappeared. It was visible for fully half a minute.

Ann Arbor.

LEWIS L. MELLOR, of the Detroit Observatory, in *Popular Astronomy* for March:

On February 9, 1913, an exceedingly bright meteor was observed here at 10.15 p.m. C.S.T. It first appeared as a bright star in the neighborhood of β Cassiopeia; its position was approximately, $\alpha = 0h$, $\delta = + 58^\circ$. It travelled in a path which if continued would have joined Saturn and β Cassiopeia, and a seemingly violent explosion occurred just before the Pleiades were reached. Simultaneously with the explosion came a flash of intense blue light, which was bright enough to illuminate the entire city of Ann Arbor for a fraction of a second. The disintegrated mass spread out into several hundred visible fragments, a few of which disappeared below the horizon before being completely consumed. At the time of the meteor's disruption its co-ordinates were approximately, $\alpha = 3h 30m$, $\delta = + 17^\circ$. The minimum intensity greatly exceeded that of Venus, which is so conspicuous during the early evening; at the maximum the apparent size of the disc of the meteor appeared to be about one-fourth that of the moon, but its surface brightness greatly exceeded that of our satellite, for it emitted an intense white light resembling the magnesium flash.

The flight of the meteor occupied 5 or 6 seconds. Its continuous trail remained visible for the same length of time. As the meteor increased in apparent speed its path became irregular, following a zig-zag curve, and accompanying showers of sparks seem to indicate that it was revolving very rapidly on its axis. The features were so distinct that I estimated its distance to be about 75 miles west of Ann Arbor, although I did not hear the report of the explosion; in all probability this may be due to the fact that the wind was blowing from the southeast at the rate of 12 miles an hour.

Arthur (Wellington Co.).

J. J. MORROW, M.D.

When returning from a sick call, about 1.15 a.m., Monday (Feb. 10), I was surprised to notice the whole heavens light up. The condition lasted for 3 or 4 seconds. I was driving in a westerly direction and the light appeared to flash out of the northern heavens. I did not see any meteors or hear any sound.

Perm (Dufferin Co.).

T. H. BANKS.

Time, 1.27 a.m. Monday, February 10th. A brilliant meteor in the north, travelling west. Body in sight about 12 seconds. When nearing the horizon it broke into many pieces, which died away in 2 or 3 seconds. Whole phenomenon lasted about 15 seconds. No sound heard.

Vittoria (Norfolk Co.).

JOSEPH A. MONTROSE.

When about four and one-half miles southwest of Vittoria, at about 1.30 a.m. (Monday) I saw a single meteor. It lasted about 3 seconds, in which time it lighted up the earth with a dazzling brightness. It was to the northward at an elevation of about 45°. It was travelling with a westward motion and coming down at an angle of about 53°, as nearly as I could guess. It had a long tail. I heard no sound.

Windsor.

GEO. A. DEANE.

The meteor I saw was a remarkable one. I have seen one or two meteors in a rather long life, but never before one like this. In size it appeared about that of the full moon, but it was not round in form, being a long oval. The accompanying sketch (Fig. 13) I made next morning.

It was descending (apparently) directly to the earth. At first glance I took it for a collapsed balloon, but only for the instant, as I at once recognized it as a meteor. I expected to hear in a few days of some damage it had done at no great distance from here.

The outline was very clear and distinct, with no "rays" or "nebula," such as usually attend a very distant bright light.

The time was exactly 1.23 a.m. (Monday). I looked at my watch, as I fully expected to hear more of it. It was in the north-northeast. It

did not appear to me like a swiftly falling body, but appeared to travel toward the earth in a very slight curve.

In color it was the red of the setting sun, denser at the bottom (large end), running to a yellowish flame color at the top. Time body was in sight, I should judge about 1½ seconds.

MR. F. P. GAVIN, M.A., Principal of the Collegiate Institute, reports as follows:

Mr. A. W. Brown, of Windsor, railroad man, on Sunday evening, February 9, was left as watchman on a wrecked train on the C.P.R. about one mile west of North Newberry (just the other side of Bothwell).

Mr. Brown states that he was awake and observant all night and noticed the following: Some time about 9 o'clock he saw the largest meteor, bluish white, very bright, and travelling in a northeast to south-



FIG. 13.—From a sketch by Mr. George A. Deane, Windsor, of the meteor seen by him at 1.23 a.m., February 10th.

west direction. Again at about 2.20 a.m. he saw a series of meteors, smaller than the one seen earlier, apparently following the same course, but visible somewhat longer, possibly 4 or 5 seconds each. There were about 18 or 20 of them and the whole display lasted about 20 minutes, sometimes several minutes elapsing between successive meteors. They appeared brightest about 70° to 80° above the horizon, and seemed to travel right down to the earth in the distance. Mr. Brown says he got the impression that they were heading towards Detroit from where he was stationed. This would give a west to southwesterly direction.

All the meteors seemed to have a stream behind them like a rocket, and brightened up the whole air. The large one in the early part of the evening was illuminating enough to attract the attention of one not watching. No sound was heard.

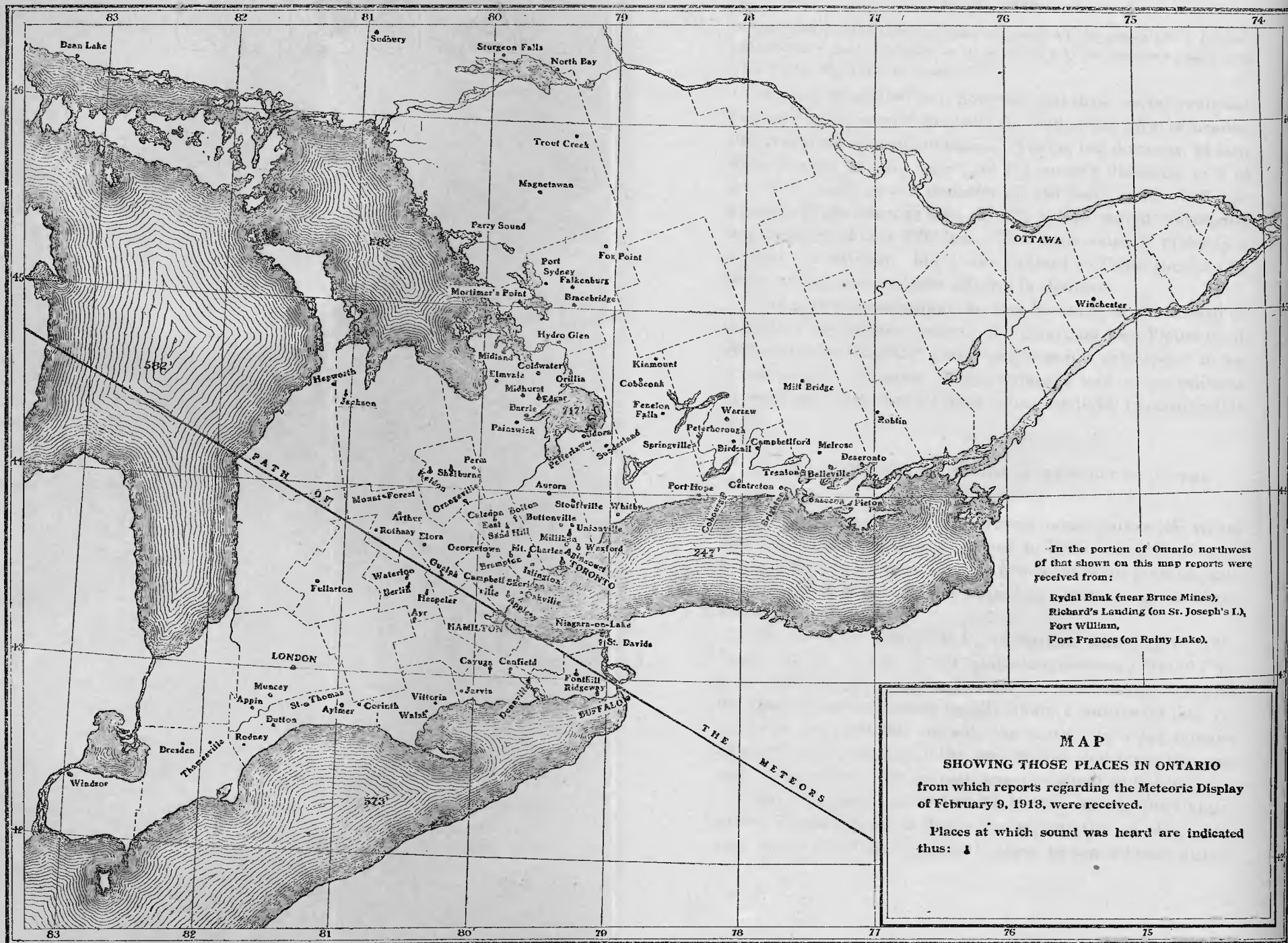


FIG. 1.—MAP SHOWING STATIONS IN ONTARIO FROM WHICH REPORTS WERE RECEIVED.
 When crossing the 80th Meridian the path made an angle of $31^{\circ} 14'$ with the E. and W. line.

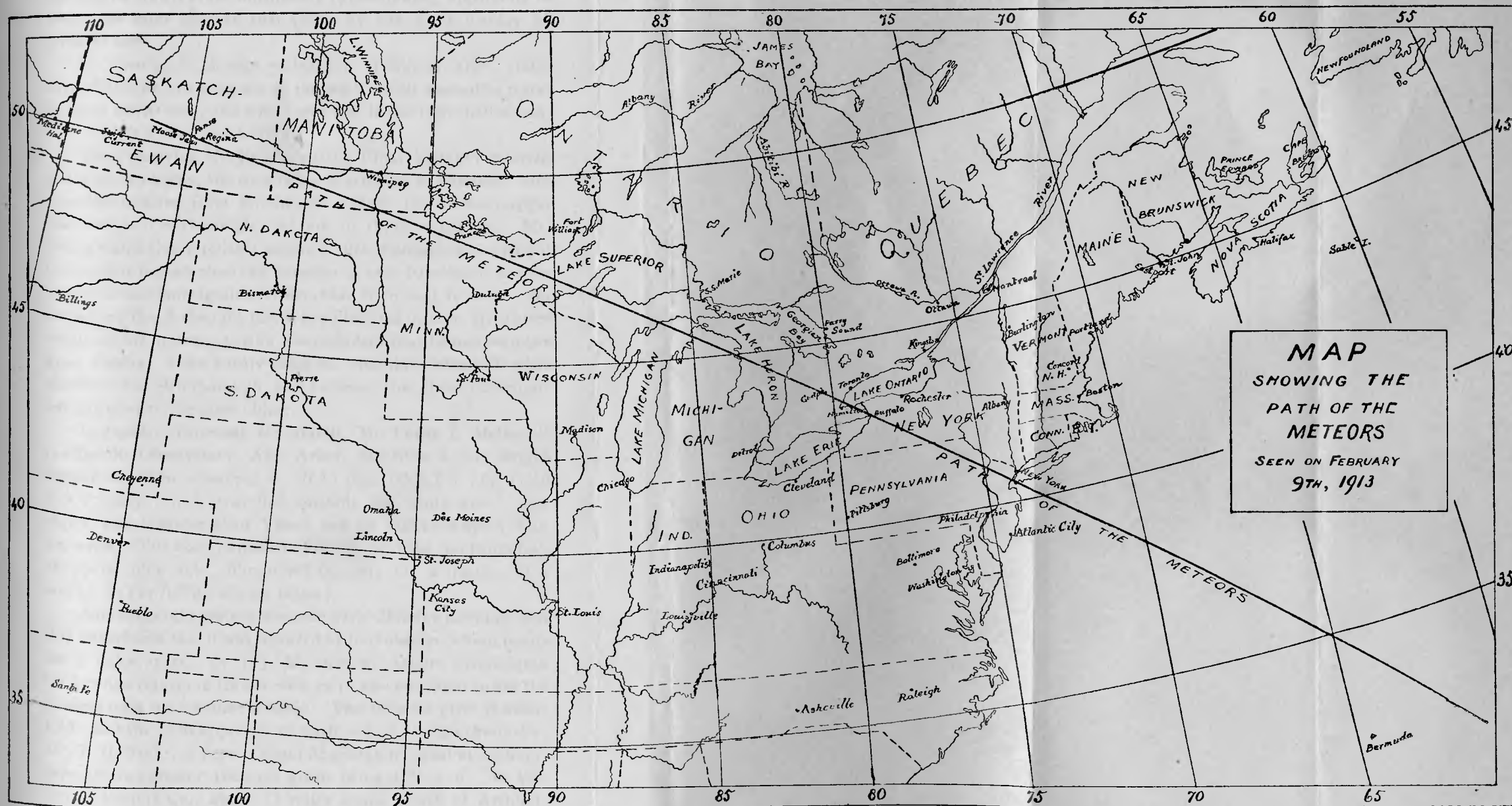


FIG. 2.— MAP SHOWING THE COURSE OF THE METEORS FROM SASKATCHEWAN TO BERMUDA, NEARLY 2500 MILES

NOTES ON THE GREAT METEORIC STREAM OF
1913, FEBRUARY 9TH

SEEN IN CANADA AND THE UNITED STATES

BY W. F. DENNING

PROFESSOR CHANT, in the JOURNAL of the Royal Astronomical Society of Canada, for May-June, 1913, has given us an extremely interesting and valuable paper on the extraordinary flight of meteors witnessed across Canada and the United States on February 9, 1913. That meteoric exhibition seems to have been unparalleled in two respects *viz.*:—(1) Its multiple nature, consisting as it did, of a long procession of meteors. (2) The great length of its observed luminous flight extending over more than one-tenth of the earth's circumference.

I have been in the habit of watching the heavens since 1865 and have never noticed anything similar. There are meteors occasionally seen with multiple, crumbling heads and broad spark trains, but the wonderful stream of successive meteors seen on February 9 seems, like Saturn's rings, without a parallel.

Professor Chant has made some useful deductions concerning the real course of the meteoric stream, and of its height as it passed between the eastern border of Lake Huron and Buffalo, but the data, upon which he necessarily had to rely, are rather contradictory, and absolutely accurate results cannot be obtained from them. I have partially gone over the work again, and the results obtained exhibit a good general agreement with those derived by Professor Chant. I am, however, disposed to give the objects a rather greater elevation than that assigned by him. Taking the whole of the estimates of the altitude, I should ascribe a height of about 38 miles as the meteors passed over the region near Toronto. There are a few significant observations indicating the lower elevation mentioned by Professor Chant,

On the Great Meteoric Stream of 1913, Feb. 9th 405

but there are also a great number supporting the conclusion that the objects were decidedly more than 30 miles high. Several reasons support this, *viz.*:—(1) The great improbability that the stream could have prolonged its flight so far in a fairly dense region of air only 26 miles above the earth's surface. (2) The red or yellow, slow meteors, moving in horizontal flights, are usually more than 30 miles high, and generally between 26 and 40 miles. In cases of very slow fireballs, falling at a slight angle towards the earth, they frequently penetrate deeper, collapsing between 26 and 32 miles, and rarely go farther. I have computed the heights of a considerable number of meteors, moving in long horizontal paths and they have almost invariably been more than 40 miles above the earth's surface. The objects seen in February last may, however, have been abnormal in their elevation as well as in their distribution.

The data are of such a character that everyone studying them may derive a different result according to his interpretation of the records. The following remarks are, therefore, merely intended as independent views, and are in no sense offered in the light of criticism.

The mean height of the objects from many observations in the region between longitude 82° and 78° West was 38 miles. Some of the components seemed higher than others, and ranged, perhaps, up to 44 miles. But the observed differences in the apparent altitude of the meteors may have been possibly induced by considerable width in the stream rather than by actual differences in height of the particles.

The velocity was about 8 miles per second. The motion of the meteors was direct like that of the planets, and comets of short period.

If we adopt three minutes as the period occupied by the whole stream in passing a given spot, its length must have been 1440 miles. The earth was running away from the meteors at the rate of about 18 miles per second.

The observed path of the stream extended over 2,600 miles from N.W. of Mortlach, Saskatchewan, to E. of Bermuda.

The position of the "trace" or track over which the meteors passed is, no doubt, well placed by Professor Chant. The writer would be inclined to locate it two or three miles south of the line adopted, but there are uncertainties due to the conflicting evidence, and the positions shown in Professor Chant's maps, probably represent the best deduction that can be made.

The stream must have had a curved flight, fairly concentric with the earth's surface. Had it been travelling in a straight horizontal line without any curve or deflection, and 38 miles high near Toronto — it would have had a height of 250 miles at the beginning and end of its observed luminous flight owing to the earth's curvature. Of course it could not travel in any such straight line owing to air resistance and gravitation. There is no well attested case of a meteor ever having been seen at anything approaching the latter elevation and it is probably far outside even the rarer limits of our atmosphere.

The stream seems to have consisted of from ten to twenty groups, or meteors with fragments in the form of spark trails, including in all several hundreds of particles. The larger ones were probably traced over 180 miles by individual observers, and the duration was 23 seconds.

Had the stream met the earth in her orbit and moved east to west the velocity would have been about 44 miles per second, and the interval occupied in passing a given point 33 seconds. The motion at the end does not appear to have been very different to that remarked at the beginning. Judging from the aspect of the swarm as viewed from Bermuda it was not nearing exhaustion, but apparently quite capable of a further 1,000 miles or more flight across the North Atlantic Ocean.

It is probable that the stream may have developed from one mass originally, and that it was formed by one of the largest bodies of the kind we have ever encountered. The disintegration of meteors is a well attested fact of observation. The meteoric stones of L'Aigle, April 26, 1903, numbered two or three thousand, and their fall was distributed over an ellipse, of which the larger axis was 6.2 miles and the smaller 2.5 miles,

The meteorite of May 12, 1861, at Batnera, descended in fragments which were picked up several miles asunder, and they fitted precisely.

In any case the vanguard of the meteors of February 9 must have been of enormous size to have sailed with astonishing brilliancy, and retained their compact form, along a curved path of some 2,600 miles. Even after this extensive flight, Col. Winter, at Bermuda, where the last observation was made, says its diameter was equal to that of the moon. The testimony of various observers was that the chief bodies were subject to explosions scattering fiery sparks behind them in long trains. There was evidently a great expenditure of material going on along the whole line. The low velocity would certainly cause a vastly slower rate of combustion than that of meteors which dash into our atmosphere like the Leonids at 44 miles per second and acquire a white heat, destroying them instantly.

These meteors were red or yellowish-red and their color sufficiently showed the very moderate rate of combustion. It is generally the case that the apparently slow meteors overtaking the earth, and moving in nearly horizontal flights, last a long time, and travel over very lengthy paths. I found a path of 611 miles for the meteor of August 21, 1902, and a path of 590 miles for that of February 19, 1911, and they were probably much longer. The small area of England is not suitable for the determination of these long flights.

At Pense, the second station from whence the meteors of February 9 last were observed, the phenomena were described as a "procession of stars" lasting about two minutes.

At Bermuda, where the final view was obtained, Col. Winter estimated that the meteors occupied two minutes in passing a given spot, so that their enormously lengthy flight had certainly not extended the stream. This string of newly-made terrestrial satellites maintained the same relative distances from each other, without any lagging behind of the tail, even after encountering all the vicissitudes involved in a journey of one-tenth the distance around the earth. The times occupied in their passing

were not very exactly recorded, but no material lengthening out could have occurred. Probably the meteors existed in nearly the same distribution before their immersion, and combustion in our atmosphere. The resistance of the air, and terrestrial attraction, would seem to have counteracted the effects of the earth's curvature, and to have kept the stream well in tow, at a pretty equable height.

The tail end of the stream certainly did not consist of the same objects all along the flight, but was formed of burning fragments peeling off from the leading meteors. At Toronto, Mr. H. D. Asibley says that the last four meteors were extremely dim, and that two of them, observed to rise in the north-west, became invisible before passing over. Several of the larger meteors of the group doubtless existed all along the observed flight, while the smaller, scattered particles at the end were reinforced by luminous debris from the leaders in numbers sufficient to compensate for disappearances.

The reports from Fort William, Richard's Landing and Bermuda give evidence that the height was 60 to 80 miles when passing near these places. At Thamesville the swarm was seen below Cassiopeia and the polar star. The distance between these is about 28 degrees and taking $42\frac{1}{2}^\circ$ as the altitude of Polaris, and that the meteors as shown in the sketch were as much as 12 degrees less, the resulting height must be 64 miles, the distance being 107 miles to the point on the earth underneath the meteors, and the altitude 30° . If we infer very considerable error in the proportions of the sketch and decrease the elevation to 25° we get a height of 51 miles, which seems probable.

As seen from Sudbury, about 190 miles north of the place under the southern point of the meteors' flight, they must have been quite 40 miles high, for there was a hill between the observers and the meteors which probably cut off fully 10° from the horizon.

At Winchester, some $5\frac{1}{2}^\circ$ east and $1\frac{1}{4}^\circ$ south of Sudbury, the distance was 221 miles, and the altitude said to reach 15° . Taking the altitude as only 10° the height would be 45 miles.

There is decided evidence that the meteors were higher in the air, in the earlier and later part of their visible display, than in the middle section of their flight but not very considerably so.

In deriving the mean height near the middle part of the stream, (Toronto region), I deducted one-third of the estimated altitudes. In some cases this may not be sufficient, for there is a general propensity to overstate the elevation. But in other instances it is certainly taking off too much, for the given altitude is probably just about correct, and there are several descriptions where the estimate is obviously too high!

I believe that reducing altitudes by one-half the estimated values is too great. The difference between 45° and 23° is enormous, and few observers of ordinary intelligence, and exercising a little care, could make such an error. If a number of people are asked to give the altitude of an object 30° high, they will often say 45° —but 23° is so obviously nearer the horizon than the zenith, that very few estimate it as midway.

At Caledon East special weight has been given to the statement that "the meteors went over, or nearly over, the belt of Orion." They may, however, very likely have passed above it, and some of them certainly did, for they were at different altitudes.

There were two observers at Bolton, a little farther from the meteors than the Caledon one, and the independent estimates of altitude are:—"Some of them died out just as they passed over, though they were not directly over me, but a little to the south-west." "They appeared in the western sky about four-fifths of the way up from the horizon."

At Jackson, further west, but at nearly a similar distance from the meteors they were said to have passed nearly over head, but a little to the south-east. These statements indicate a path far above the belt of Orion even allowing for excessive estimates.

At Parry Sound Mr. W. L. Haight and a companion fixed the elevation as 35° to 33° after going back and determining its position from their point of view. Taking the altitude as really only 22° the resulting height will be 51 miles.

On page 157 of the article in the *JOURNAL*, Professor Chant gives nine values for the height, with a mean of 33.8 miles, after deducting half the estimated altitudes. I find that on computing from the same data, and correcting for earth's curvature, the mean comes out 35.8 miles, and I cannot explain the discrepancy. If one-third instead of one-half of the altitudes is deducted, the mean height is 51 miles, which certainly appears too great.

With regard to the thunder-like detonations, it is to be feared that endeavors to deduce the height from the time intervals elapsing between the appearance of the meteors and the reports, cannot lead to very certain or exact conclusions. The velocity of sound in ordinary air at 32° Fahr. is 1,088 feet per second or $12\frac{1}{2}$ miles per minute, but we do not know accurately the velocity in the upper, colder and rarer regions of the atmosphere. We know that sound travels slower at low temperatures, and that loud explosions travel faster than faint ones. If computed on the basis of temperature at the earth's surface, the distance and heights of meteors determined from the noise of their bursting would be much too small.

At Mount Hamilton, California, a detonating fireball was very accurately observed in 1894, (July 27), and it was concluded that the sound was transmitted through an air medium with a mean temperature of — 193° Fahr. and sound velocity of 800 feet per second. The meteor exploded at height of 28 miles. The distance from Mount Hamilton was 59.25 miles and the noise occupied 390.7 seconds in reaching the observatory.

Mr. John Butterfield, at Toronto, heard the rumbling or thunder-like sound at 9^h 12^m on February 9, or seven minutes after the big leader of the meteor swarm had passed. If it was 38 miles high the observers distance from it was 47 miles. From the experiments made and knowledge gained, with regard to the decrease of temperature relatively to height it appears probable that the velocity of sound would not be more than 640 feet per second for a mean height of 19 miles which would give a distance of 51 miles — nearly agreeing with that observed by Mr. Butterfield. The data upon which these conclusions are based

cannot, however, be said to afford anything more than a rough approximation to the truth.

The radiant point of the meteors is uncertain. We know the direction of flight in azimuth, when the meteors were first seen from Mortlach and Pense, but do not know the inclination at which they were descending. If they were moving horizontally even at that probably very early period of their display, the point about 328°, + 9° — a few degrees east of ϵ Pegasi, was on the horizon in the direction 15° north of west indicated by the "trace" given by Professor Chant. If the meteors were in view before coming within range of the observer at Mortlach, it is certainly strange that there are no records from westerly towns in Alberta and British Columbia.

I draw the inference that the meteors first became visibly luminous in the region of Mortlach, Saskatchewan. As seen there, if they were falling a little towards the earth, the radiant must have been in the western region of the Square of Pegasus. I saw a meteor with extremely slow motion and a yellow train directed from this point on February 8 last, about 30 hours before the great display, and the fact has some interest as suggesting that there was certainly a meteoric shower in Pegasus at the time. But I can find no mention in former records of such a shower or of any fireballs from this quarter in the second week in February. The region sets soon after the sun.

Meteoric astronomy has, however, been sadly neglected in the past, and there are comparatively few accurate data available for reference. Of the myriads of fireballs which are annually displayed in the earth's atmosphere, not more than about a score are well observed and properly investigated.

There are probably more than a million meteors brighter than Venus appearing every year in the night skies of various parts of the world. If but twenty of these are subject to proper study we may form some conception as to the very few drops we gather of the great and continuous storm of meteoric fireballs.

February is becoming a notable month for abnormal meteors. Though August brings us its abundant Perseids, and November

its occasional brilliant showers of Leonids, February seems in recent years to have provided marvellous fireballs of a unique pattern, and quite unmatched in the history of meteoric astronomy. On February 8, 1894, there was a great daylight fireball, appearing in the sunshine soon after noon. On February 22, 1909, a fireball left a streak several hundreds of miles long which remained visible two hours, and drifted about 236 miles to the north-west over the English Channel and south-west of England.

Could photography have been applied and furnished a number of views of its path-position, the wonderful planetary swarm of February 9th last might have taught us some new and important facts. Its visit has certainly provided us with a great novelty among the transient phenomena of our skies. We must evidently be prepared to view the incursion of a strange object into the firmament at any time. The various forms of meteoric apparition are so extremely diversified that past researches have not nearly exhausted them. Observers are practically non-plussed by the surprise visits of remarkable meteors, and they ought to be better prepared and more alert, if they would improve upon the very defective observations made of past phenomena. The unique object of last February will direct a useful attention to the subject, and if it leads up to the making of but one new observer it will not have come in vain.

BRISTOL, ENGLAND,
September, 1913.

REMARKS ON MR. DENNING'S PAPER

The chief discrepancy between Mr. Denning's conclusions and my own is in the height of the meteors when passing Toronto.

In obtaining my result I used only observations on which I thought I had especial reason to depend. Mr. Hahn, who supplied the drawing for the frontispiece, besides being an artist is an amateur astronomer. He is the son of the late Otto Hahn, of Toronto, who possessed a large and valuable collection of

meteorites. Mr. Hahn's observation was closely corroborated by Messrs. Herman and Marsh, while four others, whose estimates appeared to be especially trustworthy, indicated a height not much greater.

In some of the other cases I had correspondence regarding the altitude, and I found the observer so often in doubt as to the value to be assigned that I decided to depend almost entirely on those few observations which appeared definite and certain.

As to the values in the table on page 157, I may say that in calculating them no account was taken of the earth's curvature. I thought them hardly deserving such refinement, but as the correction for curvature is always additive it would have been wiser to have allowed for it.

Mr. Denning, however, has had such a long and active experience in handling meteoric observations that his interpretation of the evidence is particularly valuable.

C. A. CHANT.

THE GREAT METEOR OF 9TH FEBRUARY, 1913

BY W. H. S. MONCK

IN the Session of 1902-3 I laid before the Society in conjunction with the late Mr. Arthur Harvey, a catalogue of ærolites or meteors that had fallen to the earth in the solid state, and we both expressed our opinion that they came in recurring showers like ordinary meteors, though the richest meteor-showers seemed to be unproductive of ærolites, while much fainter ones were often accompanied by ærolites or fireballs. It was natural under the circumstances to refer to this catalogue in connection with the great meteor of 9th February, 1913, and I found there three actual stone falls on the 10th of February, one at Nanjemoy, Maryland, in 1825, another at Girgenti, Sicily, in 1853, and a third at Madrid, Spain, in 1896, besides which Mr. Harvey has in the supplemental list one at the Isle of Oleron, France, in 1875. There are, likewise, two falls on the 12th of February and two more on the 13th, one of the former pair being at Homestead, Iowa, in 1875, just two days after the fall at the Isle of Oleron, France.

Turning back to the *Monthly Notices* of the R.A.S. for the year 1865-6, I find the late Mr. A. S. Herschel writing, "Detonating Meteors were observed on the 10th February, 1772, by Brydone; on the 11th of February, 1850, by the present Astronomer Royal, and on the 9th of February, 1865, by a friend of the writer at Bangalore, S. India, all of which probably belonged to the zone of meteors circulating round the sun." (XXVI. p. 211).

A list of eight American meteoric fireballs, an account of which was given by Professor Daniel Kirkwood, in 1877, included one on February 8, 1877, but as he had only one observation of this fireball he was unable to make his computations with regard to it. A brilliant day-light meteor was seen 17 years later on February 8, 1894. It was seen almost at noon by Dr. A. A. Rambant, Astrono-

mer Royal of Ireland, at Dunsink, near Dublin, and also by Mr. Wood, near Birmingham, and others. Its path was calculated by Dr. Rambant and also by Mr. Wood, according to both of whom it was first seen at a height of about 80 miles over the Irish Sea and was lost sight of over Yorkshire after descending to less than one-fourth of that height. This is not a bad collection and could no doubt have been added to if I had pursued my inquiries farther; but I may give one more example. On February 11th 1905, three bright meteors were doubly or more than doubly observed and paths determined for them by Mr. Denning, but they do not seem to have been as brilliant as most of those already referred to. There were, however, material differences between their radiants as computed by Mr. Denning. Two meteor-showers active on the same night is not unusual but it would be unusual to find both of them rich in fireballs. Yet there is some reason for thinking so in the present instance. There is certainly no fireball shower in February previous to the 8th of that month, but the ending is much less definite than the beginning and those on the 12th and 13th may perhaps have had a different source from those on the 8th, 9th and 10th.

The multiplicity of the fireball of 9th February, 1913, is not unusual though with the ordinary small meteors it seems to be unknown. Mr. Harvey in his article accompanying the catalogue already referred to mentions that a swarm that fell at L'Aigle on the 26th April, 1803, included 2000 or 3000 stones, that 700 or 800 were recovered from the fall of an ærolite in Iowa, U.S., on the 2nd May, 1890, and 100,000 (there seems to be some exaggeration here) from one at Pultusk on January 30, 1868. There was however, a very conspicuous example of the same kind of multiplicity that the great meteor of February 9, 1913, exhibited in a famous English meteorite of 18th of August, 1783. The *Annual Register* for that year contains a full account of it as seen at Greenwich Observatory, and the resemblance will at once strike the reader. The Madrid meteorite, I may remark, left a train which was long visible as a cloud. It was a day-light meteor seen in the sunshine at about 9h 30m a.m.

Reverting to the multiplicity of some of these meteorites, a question arises as to how it is to be explained. Did all the company of meteors originally form a single body which afterwards became split up and divided, or had they always a separate existence though travelling together? Their condition is quite distinct from that of what is called a meteor-swarm. In the latter case though the meteors succeed each other at very short intervals of time, when we consider the speed at which they are travelling, the distance between any pair of them evidently amounts to several miles. If a number of them fell to the earth simultaneously they would be scattered over several square miles of the earth's surface. But when these multiple meteors fall we have hundreds or thousands of them scattered over a very small district. This could hardly occur if they were originally a solid body which was afterwards broken up by one or more explosions. The fragments would not keep in such close company at any considerable distance from the place where the explosion occurred. Perhaps some light may be thrown on the subject by a theory of my late friend Sir Robert Ball, though I do not know whether he modified it before his death. These *aerolites* or meteorites—stones that actually fell—were, he thought, projected from terrestrial volcanoes at a time when they were more active than at present. If projected with sufficient velocity they would commence revolving in independent orbits, instead of falling back to the earth as they do when projected at present; and while travelling in these orbits they would be liable to encounter the earth and thus return to us after a long interval. Here it is evident that a number of stones projected from the same volcano at the same time might travel in close company for a considerable distance. And I know of no reason why other celestial bodies might not have something analogous to our volcanoes still active and capable of ejecting companies of small bodies. There seems indeed to be reasons to believe that the sun is constantly ejecting matter though not perhaps in the solid or liquid form. An explosion or some kind of collision at the outset would probably prevent the bodies from keeping close

together during a course of any considerable length, but an action of a volcanic kind might perhaps remove this difficulty.

Another puzzle is this. These detonating meteors are sometimes of dazzling brilliancy and appear at great heights in the atmosphere, moving with great velocity. Yet the stones that fall are often but slightly heated and are sometimes seen to fall very slowly and almost perpendicularly. How can both of these characters be ascribed to the same meteors? Or are these two distinct species of fireballs, one of which only fall to the earth on rare occasions?

Let us then consider the conditions under which a falling meteor will reach the earth in the solid form. What usually happens when it enters the atmosphere is this: Entering with a high velocity, the air resists it and diminishes its speed, the motion thus lost being converted into heat, which raises the temperature of the meteor and renders it first red-hot and then white-hot after which it melts and finally evaporates when the vapor of the meteor gets mixed with the air and we cease to be able to trace it. Except the melting-point (or rather the evaporation-point) of the meteor, the only elements involved here are its size and its velocity, but when it has penetrated so far that a combination with some of the elements of the air may take place this possibility may also require consideration. But in the first place the greater the velocity the less chance there is of the meteor remaining solid until it reaches the earth, because the greater the velocity the greater is the amount of heat developed by destroying its motion. And this is probably the reason why no meteor belonging to the great Leonid or Perseid streams seems to have fallen to the earth. The meteors are travelling with a high velocity and they are also as a rule very small—which brings us to the next point, *viz.*, a large meteor is more likely to reach the earth than a small one. Perhaps I should rather say that a part of it is more likely to reach the earth; for part may be vaporised or melted, while another part remains solid till it encounters the earth. The centre of a large meteorite might still remain cool after the parts near the surface had been

fused and evaporated. Large size and slowness of motion are thus most favorable for the production of ærolites, but unusual size on the one hand or unusual slowness of motion on the other might suffice where the other element differed little from the average.

These large fireballs, however, are usually explosive or detonating and it is usually after an explosion that an ærolite is seen to fall and is picked up. What effect has such an explosion on the meteorite which is thus separated into parts? Much evidently depends on the force of the explosion, regarding which little is known, but plainly a number of parts are driven out of their former course into a new one resulting from the explosion; and assuming that this new force is not insignificant when compared with the meteor's velocity at the moment of the explosion, the previous velocity of some fragments may be almost annihilated while that of others is increased. The explosion may thus cause some parts of a detonating meteor to fall to the earth while the main body escapes into space to visit us again on some future occasion or perhaps is dissipated in the air. This seems to have occurred in a few instances, but they are hardly sufficiently ascertained to be relied on. One of these is the great meteorite of 18th August, 1783, referred to by Mr. Harvey in the Catalogue.

There is evidently a good deal still to be discovered with regard to these meteorites or ærolites and their connection with the earth, and it is much easier to ask questions than even to suggest answers to them. I hope, however, that the entire subject will receive more attention from astronomers than it has usually received of late years, and that none of these elements, which I may call observation, calculation and speculation, will be wanting. The progress in this department during the last quarter of a century has been very slow. I hope some of our leading astronomers will devote their attention to the subject and ascertain the problems to be solved and the direction in which we should look for a solution of them.

DUBLIN, IRELAND,
March, 1914.

MEETINGS OF THE SOCIETY

AT TORONTO

March 10, 1914.—The meeting was held in the Society's Rooms, 198 College St., at 8 p.m. Mr. H. B. Collier occupied the chair.

The Chairman gave an account of recent observations of the planet Mercury.

Dr. R. E. DeLury, of the Dominion Observatory, Ottawa, gave the lecture of the evening on "Recent Solar Investigations." With the assistance of slides the modern apparatus for solar research was described. The results obtained by direct photography and by spectrum investigations were made the topic of the lecture; the measurement of the rotation of the sun by the successive changes of the sun-spots was given. The reflecting telescope and the spectrograph which are in use at the Ottawa Observatory were described in detail. Then the method of measurement of the rotation of the sun by the shift of the spectrum lines due to the Doppler effect was outlined, and with the aid of slides showing the shifts, the method of calculation was clearly presented, together with the refinement in methods made within recent years at Ottawa. Dr. DeLury pointed out how certain anomalies in the measurements indicated disturbances probably due to convection or pressure conditions which are being investigated at present.

The spectroheliograph of the Yerkes Observatory was described and photographs of the sun with calcium light and hydrogen light were shown, giving the difference in appear-

W. H. Pickering in Jamaica. The excellence of the atmospheric conditions permits valuable observations to be made visually. The principal investigations undertaken were the periodic changes in ellipticity of the disks of Jupiter's four larger satellites, an application of the same method to very close double stars, bright streaks and evidence of present activity in craters of the moon, and the meteorological and seasonal changes of Mars. An interesting conclusion is that Jupiter's satellite's like Saturn's Ring consist of meteors. The changes in shape of the first satellite indicate the existence of two sets of tides.—From *Director's Report* for 1913.

THE ZEEMAN AND STARK EFFECTS.—The important discovery by Stark of the effect of an electric field on radiation is of the greatest interest to the physicist, and may prove of equal value to the astronomer. Although the observed phenomena are in some respects closely analogous to those of the Zeeman effect, there are significant points of distinction which makes it possible to determine with certainty whether an electric or a magnetic field is the producing cause. The most important criterion, in cases where the magnetic or electric fields are too weak to produce complete separation, is afforded by the fact that whereas in the Zeeman effect the outer components of a magnetic triplet are circularly polarized when observed in the direction of the lines of force, the components of an electrically resolved line are unpolarized under similar conditions of observation. Thus, disregarding other points of difference, the presence of circularly or elliptically polarized light, if not of instrumental origin, will serve as a sufficient criterion.

At present it can only be said that if the Stark effect exists in the sun its magnitude appears to be so small that special methods, similar to those employed in the study of the general magnetic field, will be required to detect it. Polarizing apparatus suitable for this purpose is described in a paper read before the American Philosophical Society on April 24th.—GEORGE E. HALE, *Publications Astronomical Society of the Pacific*, No. 154.

J. R. C.

NOTES AND QUERIES

Communications are invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

QUERY

It is well known that potter's clay is magnetic with a north and south pole thrown in by the magnetic currents of the earth. This line of poles will remain constantly parallel to these currents no matter how, by handling, you may twist around the mass of clay. But, if you bake the latter, the poles become permanent, registering the declination and the inclination of the magnetic currents of the epoch. Consequently, I would believe that in a contact of diabase (which is a lava) with a clay bed, we may expect to find a certain thickness of baked clay registering the exact position of the currents of the date, supposing the strata are undisturbed. Would there be there an indication of the diabase irruption? It might be objected that the cycle of variations of the magnetic needle has been covered over and over again. Granted, but nevertheless, in accordance with some personal ideas of mine, you might have here a surprise: you may register some great and quite unexpected declination. Now, if I am right, what I wish to know is this: Will our present delicate instruments permit us to read this contact so as to find scientifically accurate data on the existence and direction of the magnetic currents of the date of irruption of the diabase?—ANDRÉ, (Ottawa).

ANSWER

I have been unable to obtain any information relating to the subject of this query. A competent expert on clays questioned the correctness of the statements in the first few sentences, and would be greatly obliged to learn on what authority they are made. Perhaps "André" would give further information.

AN EXTENDED METEORIC DISPLAY IN 1783

In his interesting article in the last issue of the *JOURNAL* Mr. W. H. S. Monck, of Dublin, Ireland, referred to a meteoric

display in 1783 which in some respects resembled the notable display of February 9, 1913. At my request Mr. Monck has sent me an account of it, as follows:—

EXTRACT FROM *ANNUAL REGISTER*, 1783

18th August,—At eleven minutes past nine in the evening, a very singular phenomenon was seen at Greenwich. It being rather dark a sudden and uncommon light appeared, without any cause then visible, for full two minutes; then appeared this phenomenon coming from the N-N-W perfectly horizontal in its course and without any vibration continued to S-S-E. It passed over Greenwich and near the Royal Observatory till the elevated trees in the park took it from the sight. Though it was transitory the motion was not rapid for you could distinctly discover its form, colour, etc. Its duration was near two minutes during which there was no variation in its lustre. Its magnitude and animated effect made it appear near our earth. Two bright balls parallel to each other led the way, the apparent diameter of which appeared to be about two feet, and were followed by an expulsion of eight others not elliptical seeming gradually to mutilate, for the last was small. Between each ball a luminous serrated body extended and at the last a blaze issued and terminated in a point. Minute particles dilated from the whole. While this luminary was passing the atmosphere was exceedingly bright but immediately after it became dark though the moon was up. The phenomenon which appeared in 1716 and continued from eight in the evening to three in the morning was like the present not local, for it has been seen in most parts of the Kingdom, notwithstanding it was not subject to the great vibrations of the former. The balls were partially bright as imagination can suggest, the intermediate spaces not so exquisite in their colourings. The balls were tinted first by a pure bright light, then followed a tender yellow, mixed with azure, red, green, etc., which with a coalition of bolder tints and a reflection from the other balls gave them the most beautiful rotundity and variation of colours that the human eye could be charmed with. The sudden illumination of the atmosphere, the form and singular transition of this bright luminary rendered much to make it awful; nevertheless, the amazing vivid appearance of the different balls and other rich connective parts not very easy to delineate gave an effect almost equal to the rainbow in the full zenith of its glory. It appeared also almost all over the island of Great Britain, nearly at the same time, as well as France, Flanders, etc.

In a note accompanying this Mr. Monck makes some interesting remarks which I take the liberty of quoting:—

“There is plenty of fine words but I don't think you will be able to follow it very closely but some of the agreements may strike you. See a note in the ‘Supplemental Catalogue of

Ærolites,’ for August where Mr. Harvey inserted a fall of an ærolite at Shetland on August 18, 1783. Shetland would be pretty much in the N-N-W line, from Greenwich, but I do not know what Mr. Harvey's authority for the fall was. I think the path of this meteor of 1783 was computed from observations.

I don't know what the phenomenon of 1716 referred to in the *Annual Register* was, but I think from the description that it must have been an aurora, not a meteor. The volume for 1783 has another interesting article in it—the discovery by Mr. William Herschel of a new star called *Georgium Sidus*—the name which he originally gave to Uranus.”

ROTATION IN A NEBULA DETECTED

One can hardly look at the beautiful photographs of spiral nebulae which have been made in recent years without being impressed with the notion that they are in rotation. The graceful arms encircling the mighty central mass must surely be moving about it, and perhaps, a hundred or a thousand years hence, a comparison of direct photographs taken then with our own will easily reveal this motion.

But there is another way to detect motion of the heavenly bodies, namely by the spectrograph. It was applied with great success to determine the rotation of the sun, Jupiter and Saturn, and, a few years ago, Uranus was shown by photographs taken at the Lowell Observatory to have a rotation period of about ten and one-half hours, a result agreeing well with what had long been surmised.

It has fallen to Dr. V. M. Slipher, of this same observatory, to make the important discovery of rotation in a nebula. Such bodies are so faint that it is extremely difficult to obtain a spectrogram, but with an especially efficient spectrograph attached to the 24-inch refractor photographs were obtained showing unmistakable inclination in the nebular lines, and hence demonstrating rotation.

The nebula which has yielded this result is one in the con-

published. When I wanted to fix up a plan with him, he thought we ought to wait till his observations on the dynamics of the universe could also be included; "for," he said, "if these are not correct, the rest is not worth reprinting either." These words we hear from the mouth of a man of whom it has been so repeatedly—and rightly—testified that he saw his scientific wishes fulfilled more than anyone else! Could it be otherwise? Whoso has seen the ideal—and few have seen it as purely as Kapteyn—feels himself little before the Truth he desires to master.

THE METEORIC PROCESSION OF FEBRUARY 9, 1913.

By WILLIAM H. PICKERING.

PART I.

This remarkable phenomenon was in no sense a meteoric shower. It was a different kind of event altogether, and while undoubtedly much less spectacular than a great shower, such as that of Nov. 1833, was in some respects more interesting and instructive. It consisted of a procession of fire balls and meteors all moving very slowly, in practically the same path across the sky, from horizon to horizon. It was first seen near Mortlach, 65 miles west of Regina, Saskatchewan, lat. $50^{\circ}.5$ N., long. 106° W. It traversed successively Manitoba, Minnesota, Michigan, Ontario, New York, Pennsylvania, and New Jersey a few miles to the south of New York City. It then went out to sea, and appeared next in Bermuda, was seen from the steamship *Bellusia*, lat. $17^{\circ} 35'$ N., long. $51^{\circ} 11'$ W., and last from the steamer *Newlands*, lat. $3^{\circ} 20'$ S., long. $32^{\circ} 30'$ W. The distance between the first and last stations is 5659 miles. Computation indicates that the meteors traversed several thousand miles more, while still within the limits of the earth's atmosphere, thus forming prior to their final destruction a series of minute temporary terrestrial satellites.

There appear, when first and last seen, to have been some 40 to 60 fire balls, arranged at first in 4 or 5 separate groups. Several of these had long tails. In part of the route they were accompanied by innumerable finer particles that were swept off of them in their rush through our atmosphere. The interval during which the larger fire balls were visible under favorable circumstances seems to have been from 30 to 40 seconds, and the duration of the display about 5 minutes. In Canada their color was usually described as yellow or reddish, but not white. Generally they were compared to bright stars, sometimes to Venus, but in Bermuda the two leaders looked like large arc lights, slightly violet in color and of diameter equal to the moon. Their true angular diameter was of course much less than this. An incandescent steel globe 0.2 inches in diameter, at a distance of one half mile was

found by Professor I. L. Smith in 1857 to appear of the moon's diameter (*Jour. R. A. S. Canada*, 1914, 8, 109). This would correspond to a diameter of 24 feet. It therefore appeared 1400 times its true size. If the meteors were at a distance of 70 miles from Bermuda, this would indicate that the diameter of the two leaders was about 28 inches.

A very full description of them, with a computation of their path, and estimates of their height, speed, and size is given by Professor Chant in the *Journ. R. A. S. Canada* 1913, 7, 145 (See also 404, 438; 8, 108, 112; 9, 287, and 10, 294). The last two papers are by Mr. Denning, and are particularly valuable as giving the data of the two observations made at sea. These were not available when Professor Chant made his calculations, and they not only permit us to correct them, but they serve to give us much more definite information regarding the height, speed, and size of the meteors, regarding which his paper left us in considerable doubt.

The path of the meteors across the United States was about as long as it was in Canada, and they must have been visible over an area of rather more than a quarter of a million square miles, including all the large cities and observatories of the important states of Michigan, New York, Pennsylvania, New Jersey, Delaware, Maryland, the District of Columbia, and southern New England. In fact if the skies were clear they might have been seen by over 30,000,000 people. It is regrettable that it did not occur to any one in this area that this very unusual phenomenon was worth investigating. A collection of observations might at that time have been made, culled from newspapers and by private correspondence, similar to that secured by Professor Chant. His collection is most valuable and unique, and it is proper to say that all that we know about the meteors is really due to him, since it was his work which called Mr. Denning's attention to the matter. My own first knowledge of the phenomenon was due to reading his papers. The total number of reports on which our knowledge is based is 141. Of these 135 came from Canada, 1 from southern Michigan, 1 from a lady in New Jersey, 2 from Bermuda, and 2 at sea. It is gratifying to find that America is not left out entirely in the investigation.

It is certainly unfortunate for our scientific reputation however that the most important and interesting meteoric event of the past ninety years, visible in the early evening, and to more advantage in our country than in any other, should be described by us in only two very brief reports. From these two the most important information that we gather is that the sky was clear in those two regions.

In Professor Chant's first paper he gives the height of the meteor stream in Ontario as 26 miles. In a later paper he modifies this statement to 34 miles. Mr. Denning believes it from the data to have been 38, and Mr. Davidson from other considerations, 45 miles. The last value seems to me irreconcilable with the observed facts, but if, follow-

ing Mr. Denning, we believe that the track of the meteors in Ontario lay three miles south of the course laid out for them by Professor Chant, the two best observations, as well as the average of all the others, some of which are however rather divergent, appear to agree fairly well with an altitude of 35 miles. We shall therefore adopt this altitude for the meteors in Ontario, and shall assume that their track crossed longitude 80° in latitude $43^\circ.35$. This we shall call the Ontario station.

After passing this point, as we shall see presently, the meteors, by following a curved course, continued at practically the same elevation above the sea until they had passed the Bermudas. They then rose slightly, and we shall therefore take their height for a considerable distance to be about 35 miles. They traversed during this portion of their path several thousand miles in what was exclusively the earth's gravitational field. If not interfered with, they must necessarily have moved in a great circle over its surface. The only interference was that due to the atmospheric resistance to their motion, and to the pressure due to the rotational velocity of the earth's atmosphere. The former would not affect the direction of the path. The latter would tend to push the meteors to the eastward. We shall find in a later paper that this deviation would amount to only a fraction of a mile, so that we need not consider it, but shall assume that the course of the meteors was that of a great circle. Accepting the well known law that the density of our atmosphere is approximately halved for every ascent of 3.5 miles, we find that at 35 miles it would be $1/1024$ of what it is at sea level, or 0.8 mm. Making certain corrections for the presence of water vapor, the change of gravity for altitude, etc., this value is reduced about one-half (Humphrey's Physics of the Air. p. 69).

TABLE I.

No.	Azimuth	COURSE OF THE METEORS.					
		Bermudas		Bellusia		Newlands	
		Distance	Height	Distance	Height	Distance	Height
1	54°	35	20	59	28	91	39
2	$54^\circ.5$	46	28	74	36	62	25
3	55°	57	36	97	45	35	14

Regarding the course of the meteors, according to Professor Chant, at the Ontario station it was towards the south-east, in azimuth $58^\circ.8$ measured from the south. The observations from the Bermudas and at sea indicate that this value is somewhat too large. Fortunately the meteors passed to the east of the steamer Bellusia and to the west of the Newlands, so that we are enabled to locate their path quite closely. If their azimuth had been as great as 56° they would have passed on the wrong side of the Newlands, if as small as 53° they would have passed through the zenith of the Bermudas. We shall see now however, that even azimuth 54° is impossibly small. Three azimuths have been computed, 54° , $54^\circ.5$, and 55° , and the distance of the course de-

termined in each case, from the Bermudas, from the Bellusia, and from the Newlands, in statute miles. The results of these computations are given in the third, fifth, and seventh columns of Table I. The apparent altitude for the Bermudas was given at first roughly as 35° by Col. Winter. He refers later to an observation by a Mr. Gosling, who from a known position saw the higher of the two larger meteors go just over the top of a tree, whose altitude proved to be $30^\circ.5$. He gives a sketch, and I have taken the altitude of this meteor to be 32° . It cannot well have been less, nor is it likely to have been very much more. Ship's officers are used to estimating altitudes at sea, and I have taken their estimates exactly as they gave them, 25° for the Bellusia, and between 20° and 23° for the Newlands. I have taken the last at $21^\circ.5$. The corresponding heights of the meteors in miles, corrected for the curvature of the earth, are given in the fourth, sixth and last columns. We see at once that the heights of the meteors at the Bermudas are rather low. With azimuth 54° or even $54^\circ.5$ they could hardly have reached the Newlands, 3,000 miles distant. With azimuth $55^\circ.5$, they would have struck the sea within a few miles of the ship, or passed through its zenith. It therefore seems clear that the azimuth of the course of the meteors from our adopted station in Ontario can have differed little from S $55^\circ.0$ E.

The error of $3^\circ.8$ in the azimuth as given by Professor Chant is due to his having accepted the statement of the observer at Pense that the meteors passed "directly overhead." This statement certainly seems definite enough, but in point of fact they actually passed, according to the course as we have determined it, 108 miles to the north of him, at an altitude of 26° ! Our determination is confirmed by the observer at Fort William, located just to the north of the Minnesota line, and about half way from the Ontario station to Pense, who says they passed to the south of him at a zenith distance of 30° . Had he been in the town itself, the zenith distance would have been just 15° , but it seems he was out snow-shoeing in the open. His exact location is therefore unknown, probably even to himself, but his observation would locate him some twelve miles to the north of the town. This furnishes a pretty accurate check on the course. At Fort Francis on Rainy Lake, 100 miles farther west, an indian reported that the meteors passed to the north of him. According to Professor Chant the meteors should have passed to the south, and he states that he thinks the indian must have been confused as to his direction. Indians are usually not very likely to be mistaken in matters of that sort, and it seems that he was right after all, for the meteors did pass to the north of him.

As an illustration of the curious numerical errors that sometimes occur in the observations of meteors, the observer at Richard's Landing on Lake Huron, who seems to have been in general a careful and competent witness, states that the meteors passed $22^\circ.5$ to the south of his zenith. They actually passed 56° to the south, at a horizontal

Our work on the meteor of July 25, 1929, revealed this error quite definitely. Professor Olivier, in his computation, carried the path down to an altitude of only about seven miles. His determination of the path was based altogether on information obtained from correspondence, and chiefly on information obtained from Chicago. In our own determination of the path, we found considerable discordance in the reports, although practically all used were obtained by personal interview. However, where the point of disappearance was well marked for an intelligent observer, the reports agreed well. The selected reports included accounts of disappearance over the middle of a street known to run east and west, disappearance in a small area of sky between two buildings, observations through a window, and other similar observations, from which the psychological element was presumably almost entirely absent. These reports agreed also with the only report which we were able to obtain from an observer within a few miles of the point of disappearance. Our adopted height at disappearance is twenty-five miles, which agrees better with the fact that no detonations were heard.

A similar discordance appeared in the interviews concerning the Paragould meteor. For the interviews near Paragould most of the observers did not have the point of disappearance marked as well as one could wish. Not many persons were about at four o'clock in the morning. But fortunately, from locations so close to the real end point, the psychological error had little effect, and the end point determined was near the place where the meteorites were found. For the more distant interviews the effect was quite noticeable; for example, all of the St. Louis interviews carried the path well past Paragould.

The only meteor listed in Farrington's catalog of meteorites, for which the approximate path was computed, is the Amana, or Homestead, Iowa, meteor. The meteorite fell about twenty miles west of Iowa City on the night of February 12, 1875. The path was computed at once by University of Iowa men, and was continued about twenty-five miles beyond Amana. Consequently, considerable time was spent in searching twenty-five miles beyond where meteorites (more than eight hundred pounds) were later recovered. The logical explanation is that the observers continued the apparent path of the meteor too far, as we find to be the case in modern times, and so misled the University men. From the published articles on this meteor, it appears that the investigators did not know of the effect, and naturally made no effort to correct for it.

For the recent Harding County meteor, it appears that Mr. Nininger has found the same effect. A few days after the fall of the meteorite, he made a preliminary estimate of the height of the end point of the path of the meteor. This estimate, sent in a personal letter, was six to eight miles. Later, from personal interviews, Mr. Nininger computed the height of the end point to be seventeen miles—more than twice as great as the original estimate.*

The University of Iowa Observatory, Iowa City, Iowa.

The Meteoric Display of February 12, 1934: A Preliminary Report

By H. H. NININGER

A remarkable meteoric display occurred about 9:20 o'clock, M.S.T., on the evening of February 12, 1934, visible from the States of Nebraska, Wyoming, Montana, Idaho, Utah, Colorado, Kansas, Iowa, and South Dakota. This flight was unusual in several particulars as follows:

*See the first article in these *Notes* in the February, 1934, number, pp. 105-6.—Eds.

1st: The meteor or meteors continued luminous through a much longer arc than is commonly the case, coming into visibility at least as far west as eastern Idaho or southwestern Montana and continuing visible as far east as eastern Nebraska—over a distance of not less than 700 miles. The extreme limits have not yet been definitely determined. The meteor may have come into view at a point even farther west than has been indicated.

2nd: The flight was peculiar also in its multiple nature. It consisted of not less than three distinct units during the latter half of its visible course. These units traveled, not in a procession, but in a more or less fixed formation.

3rd: The flight was much slower than is the movement of ordinary meteors, being only about $3\frac{1}{4}$ miles per second in the middle part of its visible course, where it was timed very carefully by a competent observer through a distance of about 160 miles.

4th: All observers who have been interviewed agree that the meteor was not sufficiently bright to light up the landscape noticeably. Even those who were near the course compare the light to that of Venus at her best, but state that the meteors were apparently larger than the planet. This circumstance seems a bit strange in view of the fact that the flight was visible from points as far as 400 miles south of its course. It is probable, indeed almost certain, that the earlier half of the flight was more brilliant than the latter half. It is probable also that the three fireballs seen by the observers interviewed, had resulted from the disruption of a single mass, the disruption occurring at about the mid-point of the luminous flight; however, this matter has not yet been settled.

5th: No noise was heard by the numerous witnesses interviewed along the line of flight between Torrington, Wyoming, and Burwell, Nebraska, with the exception of two persons in Burwell.

The three meteors which traveled together through the last 200 miles gradually grew dimmer until their redness faded out at an altitude which has not yet been definitely determined but which is known to have been several miles above the ground. A bright moon and the meteor's slow movement would certainly in part account for its reduced luminescence.

As he interviewed the numerous witnesses to this phenomenon, the writer was impressed by its resemblance to "The Meteoric Procession of February 9, 1913," as reviewed by William H. Pickering in *POPULAR ASTRONOMY*, Vols. 29 and 30, 1921 and 1922. Both phenomena resemble each other very closely as concerns the time of year, time of day, direction of flight, velocity, luminescence, and angle of descent. Both were multiple meteors and both were of unusual duration.

No fragments from this fall have as yet been reported.

Do the unusual displays of February 9, 1913, and of February 12, 1934, have any special significance, or do they bear any relation to each other?

A Growing Interest in Meteorites

By H. H. NININGER

In February and early March, the Secretary of the Society for Research on Meteorites made a tour of several Eastern States, visiting a number of universities, colleges, and museums, in the interest of meteoritic research. Six public lectures were delivered, and in twenty-four institutions the Secretary conferred with the heads of departments where interest had been shown in meteorites.

Lack of time and severe weather conditions prevented his reaching a number of institutions which had been originally included in the itinerary; but in those institutions visited there was evidenced a growing interest in the program of re-

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Correction.—*Instead of the line above the figure on page 259, read*
 — —3 —2 —1 0 1 2 3 4 —

The principal articles of this magazine, beginning with Volume 15 (1907), are listed in the INTERNATIONAL INDEX TO PERIODICALS.

Popular Astronomy

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The Radiant and Orbit of the Meteors of February 9, 1913

By C. C. WYLIE

The meteors of February 9, 1913, are among the best known of modern times, being mentioned in general textbooks, books on meteors and meteorites, encyclopedias, histories, and popular books. More than 140 reports are available,¹ nearly all having been collected and published by Professor C. A. Chant, of the University of Toronto. Had he not made that prompt investigation, this study would have been quite impossible.

THE POPULAR EXPLANATION IS UNTENABLE

The popular explanation of the phenomenon is that a cluster of fireballs travelled from Saskatchewan across North America, and over the Atlantic to the equator, a distance of some 5700 miles. Several considerations, of which we will mention four, make this explanation untenable.

First, the letters give the descriptions we would receive from intelligent people on a shower of meteors with a radiant in the north-northwest. They do not describe what the popular explanation assumes—a cluster of fireballs rising from behind objects on the horizon in the west-northwest, crossing the sky on a great circle, and going behind objects on the horizon in the east-southeast.

Second, the disappearance of a shadow-casting meteor behind objects on the horizon is impressive, and observers who see it comment on the spectacle when they write. The fact that no observer reports seeing this shows that few, if any, bright meteors went behind objects on the horizon for the more than 140 observers reporting. This, in turn, shows that the paths cannot have been especially long, for we have received such reports on several meteors.

Third, only shadow-casting meteors come low enough for detonations. The shooting stars coming from the same radiant must have ended twenty-five or thirty miles higher than the detonating meteor. Any conclusions based on the assumption that the shooting stars and the detonating meteor were at the same height when brightest must be erroneous.

Fourth, the kinetic energy of a meteor about as bright as the full

¹ *Journal of the Royal Astronomical Society of Canada*, Vol. 7, pp. 145-215, 383, 404-413, 438-447; Vol. 9, pp. 287-289; *Journal British Astronomical Association*, Vol. 24, pp. 101-111; *POPULAR ASTRONOMY*, Vol. 30, pp. 632-637; Vol. 31, pp. 96-104, 443-449, 501-505.

moon, and travelling at a speed of seven miles per second at a height of about twenty-five miles, is sufficient to maintain that velocity against the air resistance for eight to ten miles. A drop in speed lessens the air resistance, but it also lessens the kinetic energy, and the meteor drops into denser air. When a meteor no brighter than the full moon has dropped to a speed of seven miles per second, and a height of twenty-five miles, the end of its path is very near.

The popular explanation has been quite generally accepted,² but Fisher and Hoffmeister³ have questioned whether it is completely correct. Neither, however, appears to challenge the assumption of long paths extending from horizon to horizon and neither makes any determination of the radiant or a calculation of a real path.

THE FIREBALLS OF FEBRUARY 9, 1913

The following are the more important fireballs which probably fell from the leading radiant on that night:

First, a detonating meteor which fell over Ontario at 9:06½ P.M., 75th meridian time.

Second, a shadow-casting meteor observed from Ann Arbor, Michigan, at 10:15 P.M., C.S.T. (11:15 P.M., 75th meridian time).

Third, a spectacular fireball⁴ observed from Bermuda at 10:00 P.M., Atlantic time (9:00 P.M., 75th meridian time).

Fourth, a shadow-casting meteor observed in Ontario at 1:25 A.M., 75th meridian time, February 10.

Fifth, a daylight detonating meteor which fell in Patagonia at 6:00 A.M., February 10.

In addition to these spectacular meteors, several groups of shooting stars were observed, among them the following:

Fort Frances, Ontario, 9:00 P.M., C.S.T. (10:00 P.M., 75th meridian time). A string of forty or so meteors, followed after five minutes by a string of eight, passed north of overhead.

Mortlach, Sask., 7:10 Mountain time (9:10 P.M., 75th meridian time). "Must have been hundreds."

Watchung, New Jersey. (Time not given, returning from church). Saw seven distinct meteors, two burst.

Pense, Sask., 7:00 M.S.T. (9:00 P.M., 75th meridian time). Considerable number of meteors seen singly and in groups.

Ontario. Shooting stars unusually bright, or in unusual numbers, were reported at various times from 7:30 P.M., February 9 to 2:20 A.M., February 10. The greatest number were noticed immediately after the fall of the detonating meteor, as people were looking up then. Only two or three were definitely not from the leading radiant.

² Baker, *Astronomy*, (third edition), p. 249; *Encyclopaedia Britannica*, Vol. 15, p. 339; Fath, *Astronomy*, (third edition), p. 229; Hutchinson, *Splendour of the Heavens*, Vol. 1, p. 441; Jones, *Worlds Without End*, p. 139; Newcomb-Engelmann, *Populaire Astronomie, Siebente Auflage*, p. 515; Nininger, *Our Stone-Pelted Planet*, pp. 85-86; Olivier, *Meteors*, p. 242; Russell-Dugan-Stewart, *Astronomy*, Vol. 1, pp. 453-454; Waterfield, *A Hundred Years of Astronomy*, p. 481.

³ Fisher, *POPULAR ASTRONOMY*, Vol. 36, pp. 398-403; Hoffmeister, *Die Meteore*, p. 78.

⁴ The report indicates that a single fireball, which burst, was observed in Bermuda.

Atlantic Ocean. Five ships reported meteors in unusual numbers, at times varying from 8:51 to 10:01 P.M., 75th meridian time. For one ship the shower continued thirty minutes. Three of the five ships reported the general direction of motion as follows: "from north to south," "from west by north to southeast," and "from west of the constellation Orion toward the south." These directions are all in general agreement with the leading radiant.

England. Bright meteors were unusually numerous according to Denning. No time or radiant is given.

THE APPARENT RADIANT

To determine the apparent radiant the reports were examined to find those giving the apparent path of a meteor or fireball in the sky. Reports giving merely an estimate of the general altitude and direction of the path are of no value. Neither are the numerous reports giving the observer's guess as to the real direction of travel of the meteor. Two references suggest that the radiant was under the constellation Cassiopeia. One observer reports that a bright meteor appeared "right under Cassiopeia" and travelled northward. Another reports that the meteors came from 5° west of Cassiopeia and travelled southward.

Three reports were selected as of value in determining the apparent radiant. First, an astronomer at the University of Michigan gives the right ascension and declination of the points of appearance and disappearance of the Ann Arbor meteor, a shadow-casting fireball. Second, Colonel Winters, who observed a fireball in Bermuda, reported that it appeared in Ursa Major and went across the eastern sky. A measured altitude of 30½° is given as its apparent height in the eastern sky. Unfortunately, the azimuth of this point is not given, but as the altitude changes rather slowly, the error in assuming a due east direction probably is not great. Third, an observer at Dunnville, Ontario, reported that meteors passing exactly overhead were travelling in a due east-southeast direction. For overhead meteors the apparent direction of travel is the real direction, and so this report can be used. Probably these are the only reports from which one could hope to determine the radiant directly with an uncertainty of less than 20°.

Using these three reports the apparent radiant was determined as, approximately, in right ascension = 21^h 30^m, declination = +61°. It is interesting to note that a detonating meteor which fell in Europe on January 25, 1894, had an apparent radiant in right ascension = 22^h 1^m, and declination = +55°. In this preliminary determination of the radiant,⁵ the zenith attraction has not been allowed for, and the error due to that might be more than 10°.

The radiant can be determined more accurately by computing the path and apparent radiant of the detonating meteor and then obtaining the zenith attraction on the assumption that the Ann Arbor fireball, reported

⁵ From the more accurate work of the following paragraphs, the apparent radiant of the Ann Arbor meteor was determined as R. A. = 21^h 25^m, Decl. = +60° 43'. The agreement with the approximate determination is excellent.

by the University of Michigan astronomer, came from the same radiant and with the same velocity. The 140 reports collected by Professor Chant are sufficient for a reasonably good path of the detonating meteor, but the report of the astronomer is the only one giving the coördinates for even a single meteor.

THE PROJECTED PATH OF THE DETONATING METEOR

To determine the projected path, let us consider the Ontario reports stating that the meteor (or meteors) passed to the one side or the other of the zenith. We find the following:

Berlin — east
 Brampton — little west of point overhead
 Caledon East — toward Orion (southwest)
 Campbellville — *directly* overhead
 Dunnville — directly overhead (one report), 10° southwest of zenith (other report)
 Elora — right overhead
 Georgetown — little to west
 Guelph — slightly to northeast of zenith
 Hespeler — overhead, or little to north
 Jackson — nearly overhead but a little to the southeast (*i.e.*, east rather than west)
 Mt. Charles — directly overhead
 Sheridan — southwest
 Toronto — southwest, or west
 Waterloo — east.

For many of these, the report indicates that the detonating meteor was seen. It is a safe assumption that it was seen by most of the others, as its light would have caused most persons outdoors to look up. Such persons would notice the shooting stars in the same general region as the path of the detonating meteor, and very few others would notice any shooting stars. We can assume that in nearly all cases, the reported direction from the zenith is that of the detonating meteor.

A projected path was drawn⁶ passing a little east of Jackson and exactly over Campbellville, in perfect agreement with those reports and in general agreement with all others given above except Dunnville. The Dunnville reports are brief, and one of them is "second-hand." There is nothing in either report to indicate that the detonating meteor was seen by the observer. Reports from other communities indicate that the detonating meteor did not go as far south and east as Dunnville. Presumably the Dunnville reports refer to smaller meteors which passed through, or near, the zenith.

⁶ The direction in which an observer guesses a meteor is travelling cannot be used in drawing the projected path unless the meteor passes practically overhead. The Campbellville observer saw the meteor directly overhead, but he gives only the general direction "northwest to southeast." There is only one apparently careful estimate of direction from overhead meteors, the Dunnville report, which we used in determining the approximate position of the apparent radiant. The azimuth of the adopted path is in good agreement with this report.

THE REAL HEIGHT OF THE DETONATING METEOR

We have two measurements on the apparent height of the detonating meteor. This is good for that number of reports, and it is enough to fix the real height of the path. The first measurement is from Mill Bridge. As Mr. Norman stepped out of a door at the southeast corner of his barn, the bright meteor flashed past the eaves of the roof on the southwest corner. Mr. Norman measured 20 feet from his head to the eaves and 50 feet to a point under the eaves, so the altitude of the meteor must have been the angle whose tangent is 20/50, or 22°. In our calculation, we assume that Mr. Norman did not see the meteor instantly but that the head of the meteor was 5° to the south of due west when he saw it on a level with the eaves of his barn.

The other measurement is from Springville. Rev. D. B. Marsh noticed that the head of the large meteor was eclipsed by the top of a telephone pole. He set up a transit instrument where he had been standing, and measured the azimuth as 49°, and the altitude as 14° 58'. The measurements determine the real height of the meteor above the projected path at each of the two points, and consequently the real height at all points.

THE POINT OF APPEARANCE

In fixing the points of appearance and disappearance, one must keep in mind that most of the directions refer to the apparent direction of travel rather than to the points of appearance and disappearance, that many of the reports are on the fainter meteors rather than on the detonating meteor, and that there is a psychological tendency to lengthen the path. We selected the reports on the detonating meteor which appeared to fix the direction with the greatest care, and obtained for the point of appearance the following:

Bolton — a little west of northwest
 Melrose — west or slightly north of west
 Toronto — 34° west of north (but states he did not see the beginning because of a building)

To these we can add the Jackson report, that the meteor was first seen in the northern sky. We have adopted a point a short distance northeast of Jackson and at a height of 67 miles above the projected path as the point of appearance.

For most spectacular meteors the point of bursting, or disappearance, is fixed much better than the point of appearance. The meteor appears unexpectedly, and when an observer looks up his eyes follow the meteor in its motion across the sky. When it disappears, there is nothing to distract his attention and that point is remembered rather well. The Ontario detonating meteor, however, was an exception. About the time it disappeared the attention of observers was distracted by the smaller meteors coming into view. A very small number report the direction of the big meteor at the time of its disappearance. Several comment on the bursting, but without giving the direction more definitely than "nearing the southeast," for example.

We have selected the following three reports to fix the point of disappearance, which must, of course, lie on the projected path.

Edgar — nearly due south
Falkenburg — south southwest
Campbellville — when half-way to the horizon

From these we adopted a preliminary point about ten miles north, and a little east, of Dunnville, at a height of 17 miles. We deliberately carried the path farther south and east than the reports indicated, to show how the error could be corrected and the endpoint fixed more accurately from the reports on detonations.

THE ENDPOINT FROM DETONATIONS

We assumed 995 feet per second as the velocity of sound. This corresponds to an average temperature of approximately -50° F. On calculating the interval which should have been required for detonations to reach the persons in the various communities we found that for the great majority of observers who reported a time interval, the interval was too great. The result shows a systematic tendency to overestimate the duration of the display. Perhaps the unusually slow motion of the meteors was responsible.

The greatest discordance was for Toronto where the time for the detonating meteor was given as 9:05 and the time for hearing the detonations was given as 9:12. This is an interval of seven minutes whereas a computation of the approximate travel time for the detonations gave $3^m 28^s$. Closer examination of the times for the detonating meteor shows that persons who report looking at a watch give the following 9:04½, 9:05, 9:06, and 9:08.

For the 9:06 and 9:08 times it is stated that the watch usually is correct within a few seconds. No such statement is made for the 9:04½ and 9:05 times, so those should be given less weight. Another consideration is that persons who saw the meteor were outdoors, in general in dark surroundings. No doubt the watch was looked at some time after the fall of the meteor, and an allowance made for the estimated time interval since. This interval was overestimated more than underestimated, as we have said, which would make the watch time, as given, too early. From these considerations we have adopted 9:06½ as the time of fall.

The reports from Toronto show that many persons heard two rolls of thunder separated by an interval of about two minutes, or the time in which one man walked two short blocks on that cold winter night. The time 9:12, which is given twice, refers to the second roll of thunder in both cases. What this second roll of thunder was we cannot say. It was not so loud as the first report, which did come from the meteor. There is a reference to Humber Bay and another reference, not from Toronto, to the thunder sounding like ice cracking. Perhaps, this second roll of thunder was due to ice cracking in the bay; or it may have been an echo of the detonations of the meteor. The wind velocity in

Toronto at that time was 24 miles per hour, which presumably is sufficient to crack ice.

The reports indicate, as we have said, that the first detonations reached Toronto about two minutes before 9:12. This means that they arrived at about 9:10. We now have the discrepancy in the Toronto times removed, for from the fall of the detonating meteor, 9:06½, to the arrival of the first detonations, 9:10, is 3½ minutes, agreeing with the calculated travel time of $3^m 28^s$.

For a considerable number of communities we are told whether the detonations arrived during, or after, the display of shooting stars which followed the fall of the detonating meteor. The following are some of these communities, together with the travel time for the detonations computed from the path of the meteor as drawn.

Place	Travel Time		Detonations Heard
	m	s	
Sheridan	2	50	During display
Georgetown	3	01	Few seconds after
Springbrooke	3	04	During display
Brampton	3	15	After display
Hespeler	3	19	After display
Mt. Charles	3	22	After display
Toronto	3	28	After display

The Springbrooke and Georgetown reports indicate that the noticeable display continued for about three minutes after the fall of the detonating meteor. There was a small discrepancy in that the Georgetown report indicates the display was ended $3^m 01^s$ after the fall of the detonating meteor, while the Springbrooke report indicates it was continuing $3^m 04^s$ after the fall of the detonating meteor. As one observer can watch only a small part of the sky, it is quite possible that the last meteor (or group) seen by the Springbrooke observer was missed by the Georgetown observer. However, our data on the detonating meteor, on air conditions, and on the location of observers are not accurate enough to justify any concern over such a small discrepancy.

There was a real discrepancy, however, in the reports from Cayuga, Dunnville, and St. Davids. The thunder was heard after the close of the display at all of these places while, according to our preliminary path, it should have reached Dunnville $2^m 03^s$ after the fall of the detonating meteor, or well before the close. This indicated that our preliminary path was carried too far to the south and east.

To remove this discrepancy, the adopted bursting point was moved back along the path to a height of 25 miles over a point about eight miles east of Hamilton. This gives a travel time for the detonations of $3^m 26^s$ for Dunnville, of $3^m 8^s$ for Cayuga, and of $3^m 52^s$ for St. Davids. This adopted endpoint agrees better than the preliminary with the directions reported for the detonations,—from the north for Cayuga, the direction of Hamilton for Canfield, and from the west for St. Davids. It also agrees better than the preliminary with the reports on the point of dis-

appearance from Edgar, Falkenburg, and Campbellville, as given previously.

The only real discrepancy remaining, in either time or direction in the reports on detonations, is from Oakville. The observer reports that the detonations came from the north, whereas the shock wave should have reached him from the southwest. Probably this observer was standing in the "sound shadow" of some building, or was indoors, so that an echo coming from the north was the first loud sound to reach him.

WIND DIRECTION FROM THE DETONATIONS

The dotted line on the accompanying map encloses the area within which practically all observers reported detonations, and outside of which only one reported detonations, an observer from Edgar. This is indicated by the small dotted circle north of the main area. There is a possibility that the noise heard at Edgar was not from the meteor, as a

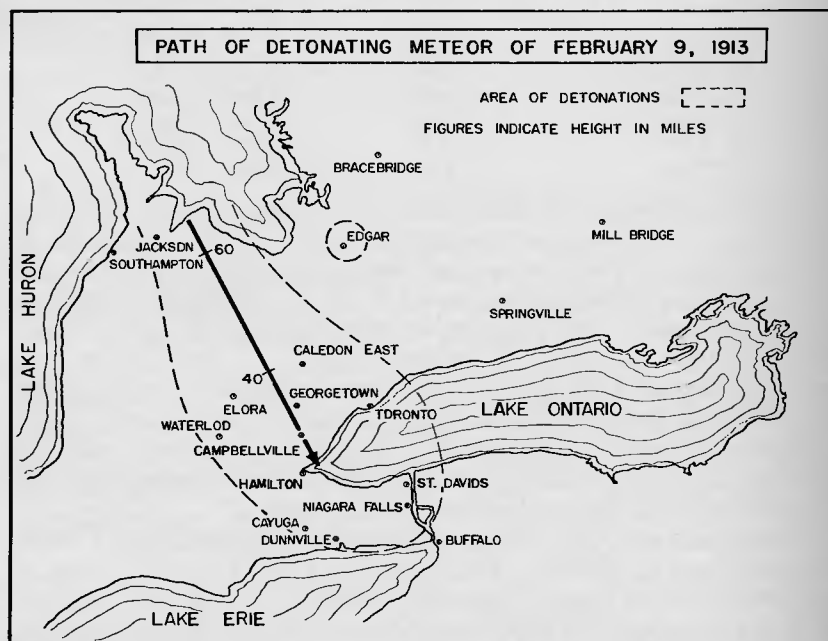


FIGURE 1

considerable number of observers nearer to the main area reported hearing no sound, and the detonations were not heard by the observer at Edgar who sent in the report. However, it is possible that the person who heard the roll of thunder was in open country, and in exceptionally favorable surroundings for hearing relatively faint detonations.

A casual inspection of the area within which the detonations attracted general attention shows that it is not symmetrical. It is distinctly to the east and south of the path of the meteor. Edgar is to the east of that

area so if that observer heard real detonations the lack of symmetry is even more pronounced. This suggested that at the time of the fall of the meteor, northwesterly winds were prevailing over that part of Ontario. We, therefore, wrote to Mr. J. Patterson, Controller of the Meteorological Division of the Air Services at Toronto, Canada. Mr. Patterson replied that "at 8:00 P.M., a cold wave was advancing rapidly from northwestern Ontario with westerly winds." At 9:00 P.M. the winds were north and northwest, in general, for the area of detonations. This accounts for the area lying farther to the east and south than is normal for a detonating meteor.

PRELIMINARY DETERMINATION OF THE VELOCITY

Estimates for the duration of the detonating meteor ran from a few seconds up to three minutes. No doubt the higher estimates were due to the observer's confusing the duration of the entire display with the duration of the detonating meteor. From celestial mechanics, the minimum velocity with which a meteor can enter the earth's atmosphere is seven miles per second. The path length was 116 miles, so even making allowance for atmospheric retardation, the duration could hardly have exceeded 20 seconds. Estimates of 30 seconds and above were rejected as impossible. Using the nine lower estimates which appeared to refer to the detonating meteor, we obtained $12\frac{1}{2}$ seconds for the duration, corresponding to a velocity of 9.3 miles per second. This was only a preliminary figure, and it was rounded off to $9\frac{1}{2}$ miles for obtaining the more exact value of the velocity from the zenith attraction.

THE VELOCITY FROM THE ZENITH ATTRACTION

It was assumed that the meteor reported from Ann Arbor came from the same radiant and with the same velocity as the Ontario detonating meteor. The procedure for obtaining the accurate velocity was as follows: With the preliminary value for the velocity (9.5 miles per second), the altitude of the radiant of the detonating meteor was corrected for zenith attraction. The corrected radiant was reduced to right ascension and declination. The right ascension and declination of the corrected radiant were reduced to altitude and azimuth for Ann Arbor at the time of the fall of the Ann Arbor meteor. With the preliminary value of the velocity, the zenith attraction was computed, and the altitude and azimuth of the apparent radiant were obtained for Ann Arbor. These coordinates of the apparent radiant were reduced to right ascension and declination, and checked against the great circle of the Ann Arbor meteor. If the correct velocity had been assumed, the radiant of the detonating meteor would seem to fall on the great circle of the Ann Arbor meteor as seen from Ann Arbor.

The work was carried through graphically for the assumed velocity, 9.5 miles per second, and it was found that the radiant missed the great circle by some two degrees. The graphical work indicated that the correct velocity was about 10.2. Computation using a slide rule and four-place

logarithms indicated that this should be adjusted to 10.1 miles per second, which value was adopted. This method of determining the velocity from the zenith attraction is reasonably accurate for velocities and radiantants as low as this.

We can now assemble the results on the detonating meteor in tabular form:

Time of fall	..... (75th meridian) 1913, February 9, 9:06½ P.M.
Longitude of appearance	..... 80° 48' West
Latitude of appearance	..... 44° 41' North
Height of appearance	..... 67 miles
Longitude of bursting	..... 79° 46'
Latitude of bursting	..... 43° 23'
Height of bursting	..... 25 miles
Length of path	..... 116 miles
Projected length	..... 109 miles
Apparent velocity	..... 10.1 miles
Geocentric velocity	..... 7.33 miles
Heliocentric velocity	..... 21.11 miles
Azimuth apparent radiant	..... 151° from south
Altitude apparent radiant	..... 20°
R.A. apparent radiant	..... 327° 15'
Decl. apparent radiant	..... +56° 40'
Altitude corrected radiant	..... 7° 18'
R.A. corrected radiant	..... 315° 15'
Decl. corrected radiant	..... +46° 16'
R.A. heliocentric radiant	..... 32° 0'
Decl. heliocentric radiant	..... +31° 22'

COMPARISON WITH REPORTS OF OBSERVERS

The Ontario reports are typical in that most give what the observers thought was the direction of travel, rather than the directions of appearance and disappearance. For some, fictitious lengthening along an almucantar of altitude is very great. Making due allowance for these psychological errors, however, the agreement of the computed path with the reports is very good.

The adopted radiant and velocity fit the Ann Arbor report perfectly since that was used in deriving them. A graphical check showed good agreement with the Bermuda fireball, and satisfactory agreement with the rather indefinite reports on the second Ontario fireball, the fireball from Patagonia, and the showers referred to earlier in this paper as reported from Canada, the United States, and the Atlantic Ocean. No doubt, nearly all the meteors reported on that night were from the same shower, and the radiant and velocity must have been very close to that which we have adopted. While the path of this detonating meteor cannot be considered as well determined as those from modern measures, the reports are so numerous and complete that we believe it is determined much better than most paths based on the older observations.

THE ORBIT

From the heliocentric radiant and velocity the orbit about the sun was computed. The orbit is direct, and it resembles the orbits of the small asteroids which come close to the earth, rather than those of comets.

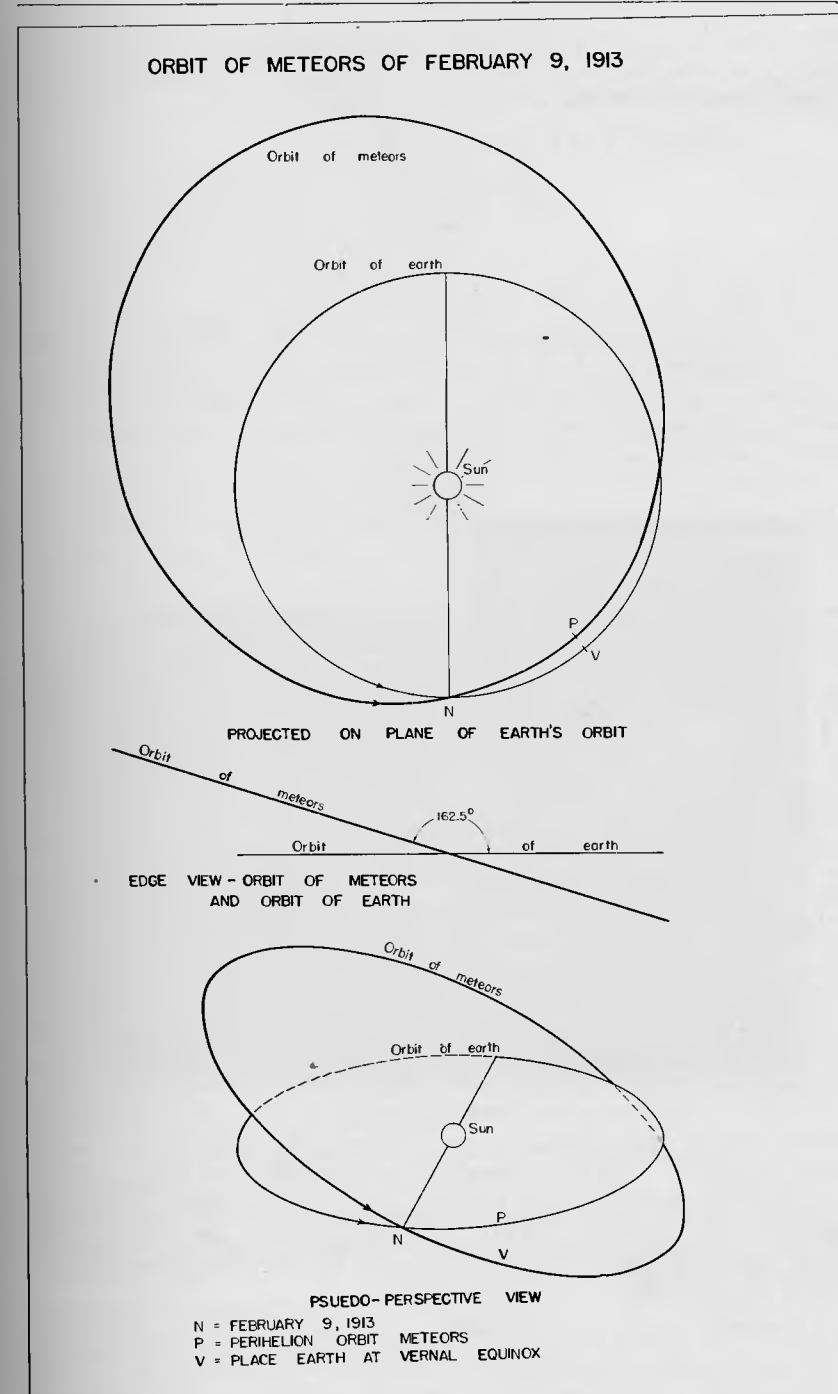


FIGURE 2

However, the shower of shooting stars in connection with this fall indicates a swarm of small particles which is characteristic of comets rather than asteroids. The following are the elements obtained.

$$\begin{aligned} a &= 1.38 \\ e &= 0.328 \\ \omega &= 220^{\circ}3 \\ \Omega &= 320^{\circ}8 \\ i &= 17^{\circ}5 \\ P &= 1.62 \text{ years} \end{aligned}$$

SUMMARY

The meteoric display of February 9, 1913, was a shower of fireballs and shooting stars from a radiant in the north-northwest. It was not a procession of fireballs moving over an unusually long path. The most spectacular meteor of the display was a detonating meteor which fell in Ontario at 9:06½ P.M., 75th meridian time.

The approximate radiant is indicated by three references to Cassiopeia, and it was computed from the paths of the Ann Arbor and Bermuda fireballs, together with the direction of travel of overhead meteors in Ontario.

The true geocentric radiant was computed from the detonating meteor, and the Ann Arbor meteor observed by an astronomer, as follows: the projected path of the detonating meteor was drawn using reports which gave the direction of the path from overhead. The height of the real path at various points was obtained from two measurements of the apparent height. The directions of the points of appearance and disappearance were obtained by selecting the reports which appeared to give these directions the most carefully. The endpoint was obtained more accurately from the detonations as follows: without using any estimates of time this point was made to agree with the reports stating whether the detonations occurred during or after the display of shooting stars. The approximate velocity was obtained from the estimates of duration. An accurate value for the velocity was obtained on the assumption that the Ann Arbor meteor came from the same radiant and with the same velocity as the detonating meteor. With this value of the velocity, the altitude of the apparent radiant was corrected for zenith attraction and the right ascension and declination of the true radiant were obtained.

From the right ascension and declination of the radiant and the apparent velocity, the geocentric velocity and the heliocentric velocity were computed. The right ascension and declination of the heliocentric radiant were computed, and, following this, the elements of the orbit about the sun. The orbit is direct, and it resembles the orbits of the small asteroids which pass inside the orbit of the earth rather than the orbits of the comets.

UNIVERSITY OF IOWA, APRIL 27, 1939

A Vacuum Chamber for Aluminizing the 82-Inch Mirror of the McDonald Observatory

By ROBLEY C. WILLIAMS

Shortly after the signing of the contract for the McDonald Observatory by The Warner & Swasey Company in 1933, the late Mr. E. P. Burrell, Director of Engineering of the firm, became greatly interested in constructing a vacuum chamber in which the 82-inch mirror for this observatory could be coated with an evaporated film. Mr. Burrell was largely responsible for the final design of the equipment, although its construction was not completed until some time after his death in 1936. The general notions underlying the design and construction of the

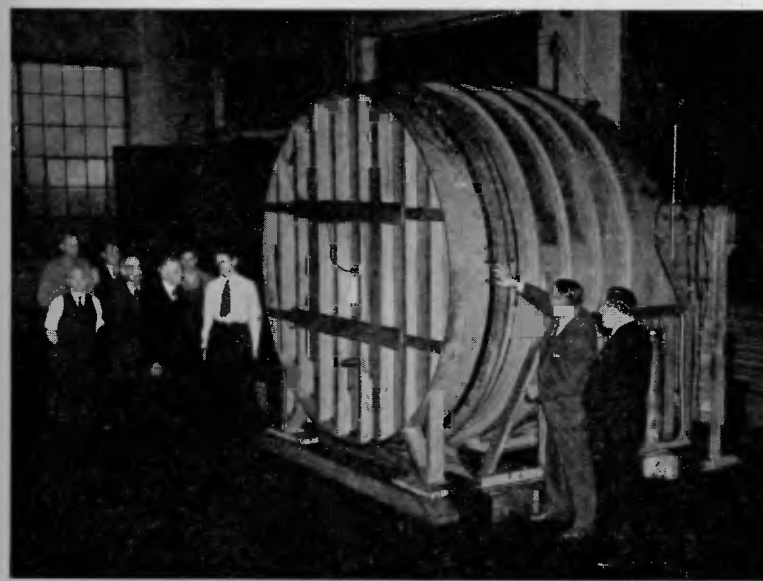


FIGURE 1
A GENERAL VIEW OF THE 109-INCH VACUUM CHAMBER
WITH THE LID BOLTED IN PLACE.

chamber were that it should be made extremely rigid, that it should be constructed to allow the insertion of practically any shape and size of mirror, and that it should be large enough to accommodate all the existing and proposed mirrors, with the exception of the two giants in California. The cell construction was completed in the spring of 1938, and its operation was considered satisfactory a few months later. Since the summer of 1938 a number of mirrors have been coated in the chamber,