TRANSACTIONS

OF THE

Astronomical and Physical Society of Toronto,

FOR THE YEAR 1898

INCLUDING NINTH ANNUAL REPORT.

PRICE ONE DOLLAR.

TORONTO:
ROWSELL & HUTCHISON,
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[Authors are alone responsible for views expressed in papers or abstracts of papers published in the *Transactions.*]

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TRANSACTIONS

OF

The Astronomical and Physical Society

OF TORONTO,

DURING THE YEAR 1898.

FIRST MEETING.

January 20th; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

Mr. D. J. Howell, Director of Photography, presented a full report of work done in connection with the arrangement of the Society's lantern slides, reproductions of photographs, etc. The catalogue now included:

Sixteen slides, illustrating the Sun and solar phenomena;

Fifteen photographs of the Moon, three of which are reproductions of the work of Messrs. Henry Bros., of Paris;

Five photographs of drawings of Mars, Jupiter and Saturn;

Fifteen photographs of stars, star clusters and nebulæ, some of which are reproductions of work done by Dr. Isaac Roberts, F.R.S.;

A collection of photographs of observatories, great telescopes, etc., including a print from the original negative of the portrait of Miss Draper.

Mr. Howell's report and his recommendations regarding the preserving of the slides, were adopted, the special thanks of the Society being due to him for the pains he had taken to put his department in perfect order.

A letter was read from Mr. David Brown, of Port Elgin, asking some information regarding the positions of the minor planets throughout the year. The Secretary had extracted from the pages of the ephemeris, and had forwarded to Mr. Brown, the information required. A cordial letter was also read from Mr. Charles Clark, of London, Ont., who had kindly forwarded to the Treasurer a substantial sum towards the Society's general purposes. Mr. Clark referred to the project for the establishment of a popular observatory, and intimated his willingness to subscribe towards this purpose whenever called upon. The thanks of the Society were due to Mr. Clark for his donation and kindly interest in the general work.

Observations were reported by Mr. G. G. Pursey and Mr. A. Elvins. Some discussion arose regarding observations of the faculæ on the disc of the Sun. The President proposed that such members as could conveniently do so, should make drawings of the faculæ on all favourable occasions, in order possibly to determine whether there is anything like wave motion observable. Mr. Elvins thought that it would require very careful work, indeed, to detect such variations in the appearance of the faculæ as there may be, but that it was an important question and well worthy of study. He would endeavour to make drawings whenever possible.

The President reported having recently visited the Toronto Observatory, where he had been shown the tracings made by the seismological instruments recently erected under the direction of Mr. R. F. Stupart. Upon special request Mr. Stupart had undertaken to present to the Society at a future meeting a full description of the instruments and an explanation of their use.

Mr. Thos. Lindsay then read some letters received from Prof. Story-Maskelyne, F.R.S., of Basset Down, Eng., bearing upon the life work of Dr. Nevil Maskelyne, the founder of the *Nautical Almanac.* The information was so complete as to permit of a sketch, in considerable detail, of the early computers of the ephemeris. The following was then presented as a continuation of the

HISTORICAL SKETCH OF THE GREENWICH NAUTICAL ALMANAC.

V. *Dr. Maskelyne's Assistants.*

Before presenting some information regarding those who assisted Dr. Maskelyne in his labours at the Greenwich Observatory, and in the great work with which we are here specially concerned, it is necessary to explain whence came this information to our hands. A century and a quarter is a long time in these fast living modern days; a thousand leagues is a long stretch even for ocean greyhounds; so it did not seem an easy task, here in Toronto, to collect details of work done in the early days of the *Nautical Almanac.* Indeed, it would have been an impossible task, but for the kind assistance of Prof. Story-Maskelyne, the custodian of all his illustrious grandfather's original notes and memoranda, and of Mrs. Story-Maskelyne, who has been at the pains of transcribing from these notes the particulars which are here presented. We have several most excellent libraries in this city, and many of us know with what success we are sometimes able to verify some point of historical interest, by reference to the rare volumes in one or other of these. But when the matter we are in search of has never been printed at all, it is then we feel there are some disadvantages in living even in such a glorious country as this, so far away from the Motherland, where *our* treasures are preserved.

This chapter, then, is not mine, except that I have collected the material into a form in keeping with the general tenor of the sketch; and taking this opportunity to express my sincere thanks to Prof. and Mrs. Story-Maskelyne, who have enabled me to do so, I have a great deal of pleasure in here presenting for the first time publicly, some account of those who aided Nevil Maskelyne in the labours of his life.

Nevil Maskelyne had taken his M.A. degree at Cambridge about seven years before his appointment as astronomer-royal. He was, therefore, a ripe scholar when he took charge of the observatory, and being anxious to spread such knowledge as he possessed, he lost no time in announcing that he would undertake, without extra emolument, the astronomical education of a junior. It appears, however, that the Admiralty had appropriated only a very modest sum for observatory maintenance, so that an assistant to Maskelyne, after having had the advantage of living with him and studying under him for a time, was then obliged to seek more remunerative employment elsewhere. This was the routine for many years, and perhaps after all it was not a bad plan. Maskelyne could not be expected to teach many at one time, and the more young men there were here and there through the country having had the advantages of exclusive intercourse with him, the better was the case for astronomy.

Among notes made in the early days are found the following, on the "requirements for an assistant":—

To understand arithmetic, geometry, algebra, plane and spherical trigonometry and logarithms; to have a good eye and good ear; be well grown, and have a good constitution to enable him to apply several hours in the day to calculation, and to get up to the observations that happen at late hours in the night; to write a good hand and be a ready and steady arithmetical computer. If he knew something of astronomy and had a mechanical turn, so much the better. To be sober and diligent, and able to bear confinement. Age from twenty to forty.

I venture to say that these requirements stand to-day as they did in the last century, and fortunately there has never been any lack of young men able to fill them. Those of us who know something, however little, of practical astronomical work, can appreciate the words "mechanical turn"; I wish I could impress upon every smart mechanic a full understanding of the power that is in him. It was evidently not necessary that the assistant should have been engaged in astronomical work before coming to the observatory. If he had the elementary mathematical knowledge expected of him, he would be pretty nearly ready to take up astronomy.

And now to give you the names of the favoured ones and some particulars about them. The following is taken directly from Dr. Maskelyne's note-books; the form in which he has made the entries is quite in keeping with the method shown in all his work:—

Date of my assistants' coming to the Observatory and going away, with the time they staid:

	CAME.	WENT AWAY.	STAID.
Joseph Dymond	Lady Day, 1765	Nov. 14th, 1766	$1\frac{5}{8}$ years.
William Bayly	Nov. 14th, 1766	Lady Day, 1771	$4\frac{3}{8}$ years.
Reuben Burrow	Lady Day, 1771	Michaelmas, 1773	$2\frac{1}{2}$ years.
John Hillins	Michaelmas, 1773	Lady Day, 1776	$2\frac{1}{2}$ years.
George Gilpin	Lady Day, 1776	July 30th, 1781	5 yrs., 4 mos.
Joseph Linly	July 30th, 1781	Sept. 29th, 1786	5 yrs., 2 mos.
Thomas Horrox	Sept. 29th, 1786	Dec. 9th, 1786	6 weeks.
Robert Gooch	Dec. 9th, 1786	Jan. 3rd, 1787	25 days.
George Flowman	Jan. 5th, 1787	Jan. 26th, 1787	21 days.
William Malachy Hitchins	Feb. 10th, 1787	June 23rd, 1787	4 mos., 13 days.
John Brinkley	June 23, 1787	Nov. 9th, went to Cambridge	
Returned	Jan. 27th, 1788	March 28th	6 mos., 2 wks.
John Burnstead	Oct. 16th, 1787	Dec. 3rd, 1787	6 wks., 6 days.
Joshua Moore	Dec. 11th, 1787	Jan. 29th, 1788	7 weeks.
Wm. Garrard	March 25th, 1788	July 1st, 1789	1 yr., 3 mos., 1 wk.
Wm. Smith	July 1st, 1789	July 16th, 1789	2 weeks.
John Crossley	July 16th, 1789	April 1st, 1792	2 yrs., $8\frac{1}{2}$ mos.
Benedict Chapman	April 1st, 1792	July 1st, 1793	1 yr., 3 mos.
Joshua Garnett	July 1st, 1793	May 23rd, 1794	10 mos., 22 dys.
David Kinebrook	May 23rd, 1794	Feb. 12th, 1796	1 yr., 8 mos., 20 dys.
Thomas Evans	Feb. 12th, 1796	July 1st, 1798	2 yrs., 4 mos., 17 dys.
William Garrard	July 1st, 1798	July 21st, 1798	20 days.
John Crossley	July 21st, 1798	Sept. 22nd, 1798	2 mos., 1 day.
Robert Wallace	Sept. 22nd, 1798	Oct. 17th, 1798	25 days.
Francis Nisbet, *ætat.* 27	Oct. 17th, 1798		1 year, 1 month.
Thomas Ferminger, *ætat.* 24	Dec. 17th, 1799		Till Dr. Maskelyne's death in 1811.

The most notable among these assistants in point of subsequent attainments is probably John Brinkley, afterwards astronomer-royal for Ireland. Brinkley was twenty-four years of age at the time of his going to Greenwich, and had already "seen service" in connection with the mathematical pages of the *Ladies' Diary*. You will remember that in a former chapter we were interested in this notable work, and the special connection between it and the *Nautical Almanac* was just this, that when a young man applied for a position under Maskelyne he did not forget to state, among his other qualifications, that "he had been able to solve many questions in the *Diary*." In Dr. Maskelyne's notes references are found which establish this fact. Brinkley took the high standing of Senior Wrangler at Cambridge in 1788; that would be, I presume, just after leaving Greenwich the second time. He was appointed Andrews professor of astronomy at Dublin in 1792; this meant also the directorship of the observatory at Dunsink, and subsequently the office of astronomer-royal for Ireland. In the Andrews chair Dr. Brinkley was the predecessor of Sir William Hamilton. He was appointed Bishop of Cloyne in 1826, and died in 1835. Our Vice-President, Dr. Meredith, remembers the Bishop very well. A son and daughter of the latter were married to an aunt and uncle of Dr. Meredith.

William Bayly was a Wiltshire boy. The four years spent under Maskelyne proved a valuable experience for him. In the year following his departure from Greenwich he was appointed to sail with Captain Cook on the second voyage. He served most creditably on this and also on the third voyage, fatal to the great navigator. Bayly was subsequently Master of the Royal Academy at Portsmouth. He died in 1810.

Reuben Burrow was a Yorkshire boy. Subsequent to his engagement at Greenwich, he was employed by Maskelyne while conducting the famous experiments at Mount Schehallien, so we may judge that his apprenticeship had been very creditable to him. Burrow was another *Ladies' Diary* man, being editor for several years. Leaving his native land for India, he was one of the first members of the Asiatic Society at Calcutta in 1782. Later, in 1791, he was connected with the great trigonometrical survey of Bengal.

Thomas Simpson Evans was just of age when he went to serve at Greenwich, and on leaving two years later was appointed in charge of a private observatory at Blackheath, owned by Mr. W. Larkin, of the East India Company. Evans collected a most valuable library of mathematical works. He was subsequently mathematical master at Christ's Hospital, and died in 1818, still a young man.

W. M. Hitchins, who appears in the list as coming in 1787, was a son of the life-long colleague of Maskelyne, whose work we will review later. The young man appears to have taken up the study of law after his short sojourn at Greenwich.

It will be noticed that in 1787 there was a break in the continuity of service, and it appears also that Joshua Moore was contemporary with John Brinkley and engaged on special work. The following extracts are taken directly from Maskelyne's notes and are interesting, in that they show what these young men were doing :—

1787, August 15th.—Mr. Moore came here and was employed till September 19th inclusive, in transcribing rules and papers, and making calculations relative to the *Nautical Almanac* ; from September 20th to October 12th in transcribing reductions of my observations, viz., twenty-two days ; from thence to October 16th in copying papers relative to the *Nautical Almanac.* He went away October 16th, and Mr. Burnstead came the same day. Mr. Burnstead went away December 3rd, and Mr. Moore came here.

1787, December 11th.—Employed in calculating refractions, and bringing up reductions of right ascensions and Sun's longitude from observations, to the end of 1787, till January 2nd, 1788 ; also a table giving deviation in N.P.D. He then began reductions of Moon's longitude and latitude compared with *Nautical Almanac*, from beginning of 1783, and was employed therein till January 29th, viz., twenty-seven days, and computed twenty-one places of Moon, and prepared the remaining calculations to make up a whole book, viz., 176 in all....He took the book with him to complete the calculations. He went away January 29th, 1788.

February 5th, 1788.—Mr. Brinkley began reducing Moon's places from July 5th, 1784, and comparing them with the *Nautical Almanac.* On March 25th, or in seven weeks, he had done fifty places, or as far as January 31st, 1785, and prepared sixteen more from February 1st to March 23rd, 1785.

We see from the above that the assistants were employed in continually verifying the ephemeris, and the minuteness with which Maskelyne records the work done is an evidence of the care that was taken with the work itself. It will be noted that the comparisons were made for intervals of a few days.

Joseph Linley was one of the few that remained a good long time in harness at the observatory, and had made himself well nigh indispensable. In a letter to Sir Joseph Banks, Maskelyne says, "Having parted with Mr. Linley, I at present make all the observations myself, and cannot attend the meeting of the Royal Society," a clear case of duty first.

John Crossley appears twice in the list. He also must have served faithfully and well, for he was subsequently appointed to the position of "astronomer," in the *Investigator*, on her voyage of discovery in 1801.

The last name on the list is that of Thomas Ferminger, who came in 1799. By this time Dr. Maskelyne's efforts to obtain a reasonable grant for the maintenance of the assistants had been fairly successful, and Mr. Ferminger was enabled to remain at Greenwich for many years. It is related of Mr. Ferminger that on the occasion of an accident which happened to him on the street he was only concerned with the thought "who will make the observations to-night," so absorbing had the tie to the observatory become.

Dr. Thistleton Dyer, the present Director of Kew Gardens, is a grandson of Mr. Ferminger. One special duty which devolved upon this valued assistant was that of entertaining the King and Royal Family when they came to the observatory. Dr. Maskelyne's quiet and retiring disposition led him rather away from duties of this character.

Now, I have not been able yet to give you sketches of the lives of all the assistants, but I have not quite exhausted my material, and hope to fill in what is left blank at some future time or times. We leave the assistants then, and pass on to the other co-workers with Dr. Maskelyne in the production of the *Nautical Almanac*.

VI. *Computers and Comparers.*

When Dr. Maskelyne undertook to give to England an astronomical ephemeris, and this was immediately on his appointment to office, he was the only astronomer in the country thoroughly capable of executing such work, from all standpoints. But there were some very bright mathematicians throughout the kingdom quite capable of working efficiently under his direction. Such special instruction as they might require Dr. Maskelyne undertook to give, "without extra emolument," as usual.

The names of those who were engaged in the mathematical work during the early years of issue were

George Witchell,
Israel Lyons,
William Wales,
John Mason,
Richard Dunthorne,
Malachy Hitchins,
Charles Barton,
Reuben Robbins,
Joseph Keech,
Walter Steel,
Henry Andrews.

Just at this point, and by way of a change, let us see what were the princely sums wrung from the British taxpayers to pay these gentlemen for their work. The following is a copy of the "little bills" rendered to the Board of Longitude for the calculation account :—

1766, June 18.—	To pay 4 computers of the *N. A.* of 1767 and 1768 at rate of £70 per ann. each, Mr. Witchell having already received a quarter's salary, or £17	£262	10s.	0d.
1767, May 6.—	To pay Mr. Dunthorne for comparing and correcting the calculations of 1767 and 1768 of the *N. A.* at £70 per ann	140	0	0
1768, Feb. 18.—	To pay the computers and comparers of the *Naut. Alm.* of 1769 and 1770 at the rate of £75 per ann. each for a whole ephemeris, £450 and £50 for other expenses incurred on acct. of the Board	500	0	0
1769, Oct. 9.—	To pay the computers and comparers of the *N. A.* of 1771 and 1772	450	0	0
1770, Sept. 6.—	To pay for incidental expenses on acct. of the Board	150	0	0
1771, Jan. 20.—	To pay the computers and comparers of *N. A.* of 1773 and 1774	450	0	0
1772, Feb. 11.—	do. do. 1775 and 1776	450	0	0
1775, April 6.—	do. do. 1777 and 1778	450	0	0

Here we have 12 volumes, and the average cost about £240 ; while all that one man could earn at the work was about £75 per annum.

This does not seem a large amount for the work done, but astronomy never has offered very high monetary rewards to its votaries. Probably everything was gauged, so that there would be no loss in the publication of the ephemeris. It is not likely there was any profit.

In the early prefaces special mention is made of some of these computers. George Witchell, F.R.S., had been engaged with Maskelyne in the production of the *Mariner's Guide*, and was highly esteemed by the astronomer, whose senior he was in years. Witchell was born in 1728, and died in 1785. He was master of the Royal Academy at Portsmouth at the time of his death.

Israel Lyons was the son of a Polish Jew, and was born at Cambridge in 1739. His father was a man of high attainments and was well-known as a botanist. Israel had a particular bent for mathematics, and ranked among the first in England in his day. Credit is given to him for having improved upon methods of working the lunar distance problem. In modern works on navigation Lyons' method will be found. He died in 1775, while in charge of Lord Mulgrave's Observatory.

William Wales was a Fellow of the Royal Society, and Master of the Royal Mathematical School in Christ's Hospital. He and Witchell were actively engaged in the construction of the tables for the 2nd edition of the *Requisite Tables.*

Richard Dunthorne was, I think, the oldest of this array. He was born in 1711, the son of a gardener in Huntingdonshire. He was an example of one holding an inferior position, as the world has it, but enjoying the companionship and confidence of the most brilliant men of the day. He was butler to Dr. Long (one of the Admiralty Board, you will remember), and at the same time an intimate friend of the Lowndean Professor. Dunthorne is specially mentioned in the early prefaces as having worked with Lyons in the perfecting of the lunar distance problem. He died in the same year as his friend, 1775.

Henry Andrews, born in Lincolnshire, 1743, was, perhaps, the most notable figure of the last century, and beginning of the present, as a computer, for that was his special work. He was connected with all the almanacs of his time, and was practically a servant of the Board of Longitude all his working life. He was drawn to the study of astronomy by becoming interested in the eclipse of April 1st, 1764, and his profession of schoolmaster was, of course, likely to keep him in the track. Andrews was the recipient of a testimonial from the Admiralty on his retirement. He died in 1820, at Royston, Herts.

Malachy Hitchins, born at Gwennap, Cornwall, in 1741, was the life-long friend of Maskelyne, and it is by all authorities recorded that his is the name which must be specially linked with that of the astronomer-royal in the production of the ephemeris. He was introduced at Greenwich in 1767, and from that time till his death in 1809, was the most noted of the computers. We have already seen in what high regard he was held by Dr. Maskelyne. A full account of Hitchins' life and labours will be found in the *Dictionary of National Biography.*

These, then, were the men who were engaged in making England a mighty nation, in giving her seamen the data enabling them to navigate the ocean fearlessly, and gradually bringing within easy reach a perfect record of the movements of the heavenly bodies. I have not given you particulars of all, and there are more yet to be mentioned, those who were engaged at a later period; but in the meantime, perhaps, this much will do. I thought it a pity, as stated in the beginning, that nothing should be recorded of those who racked their brains with formulæ and little else. If by bringing together these notes even a little has been added to the history of the *Almanac* in an easily accessible form, I shall be very well pleased indeed. Some of us do not care about these old stories, and others do. I suppose it all depends on how much of the spirit of the antiquary one possesses. Need I say, that this means the spirit of perfect peace and good-will?

SECOND MEETING.

February 3rd; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

This was an open meeting, held in the Theatre of the Normal School, and to which the public had been invited. On calling the meeting to order the President ruled that routine business be suspended, the special object of meeting being to hear the address by Mr. John A. Paterson, the retiring President, on "The Progress of Astronomy in 1897." After reminding the members of the very great pleasure which had been afforded by the previous annual addresses, and would undoubtedly be experienced on this occasion, the President called on Mr. Paterson to address the Society.

Mr. Paterson then proceeded to deliver the address, the full text of which forms the appendix to the Society's *Transactions* for the year 1897.

On the conclusion of the address, which was most enthusiastically received, the President conveyed to Mr. Paterson the hearty thanks of the audience, and called upon the Secretary to read the text of the resolution, adopted at the annual meeting, expressing the thanks of the Society to the retiring President for the energy and zeal displayed during his term of office. An illuminated copy of the testimonial was then handed to Mr. Paterson by Mr. A. Elvins, who, in a few well-chosen words, expressed the very great pleasure he had in so doing. Mr. Paterson replied, thanking the members for this mark of their favour, and assuring them that he would continue to take the most active interest in the affairs of the Society.

After adjournment the members and friends present spent some time in inspecting the portfolios of lunar photographs recently received from the observatories at Mt. Hamilton and Paris.

THIRD MEETING.

February 17th; the Vice-President, Mr. E. A. Meredith, LL.D., occupied the chair.

A communication was received from the Hon. Secretary of the Royal Society of Canada announcing the date of meeting, May 25th, at Ottawa. The Secretary was instructed to prepare a sketch of the work done during the year past, for presentation among the reports of affiliated societies.

A cordial letter was received from Mr. G. F. Rogers, B.A., Corresponding Secretary of the Orillia Astronomical and Physical Society. Mr. Rogers reported great success in the meetings held and asked for some information regarding the establishment of a library in connection with the Society's work.

Reports of observations were received from Mr. Lumsden, Mr. Pursey, and Mr. Blake. Mr. Lumsden referred to the distinguishing brightness of Aristarchus, on the lunar surface, and stated that it had been quite observable recently by the aided eye, as a specially bright spot. The Sun had been observed by Mr. Blake and Mr. Pursey, the former using the large telescope of the Toronto Observatory. Drawings were presented by both observers, made on February 11th and 16th; magnetic disturbances had commenced on the morning of the former date and at a time when the large group of February 16th must have just been about to appear on the eastern limb.

The Librarian presented his report of exchanges and presents. Among the latter was a copy of Sir Norman Lockyer's *Recent and Coming Eclipses,* presented by Mr. D. J. Howell. In reply to a question Mr. Howell stated that he was giving his attention to the methods adopted by recent observers in photographing the corona, and would present some notes on the subject at an early date. This special work would be allotted to Mr. Howell when the expedition would be in the field for observing the total solar eclipse of May 28th, 1900.

The Secretary then read a translation by the President, of a paper by M. Triboulet, of Blida, Algeria, which dealt with the possibility of applying very great magnifying power to small objectives. The paper was discussed by several members, the result being that no one could understand how M. Triboulet had allowed himself to be so deceived in matters pertaining to elementary optics. Mr. J. R. Collins said that he would be glad to follow any reasonable suggestions regarding improvements in telescopes, but he thought it a little too much to spend time in constructing an instrument designed to show a fixed star as a planetary disc !

Mr. John A. Paterson made some remarks upon the ideas of those, not accustomed to observational work, regarding the size of objects seen in the telescope ; "size" being in this case the exact word to use. Further, it was remarkable how differently people would speak regarding the apparent size of the Moon's disc, or the Sun's ; the difficulty being that the mind is not always trained to geometric ideas. Thus one would say that the Moon looked as large as a "dinner plate" ; another that it looked as large as an orange, and so on. Even after it was shown how nicely a lead pencil at arm's length would cover the Moon's disc, the false impression remained.

FOURTH MEETING.

March 3rd ; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

Cordial letters were read from Mr. Charles Clark, of London, and from Mr. David Brown, of Port Elgin. Mr. Clark gave an account of the various efforts made to popularize the study of physical science in London, Ont. ; considerable interest had been taken in the matter but he had not yet succeeded in forming a branch society. Mr. Brown gave a report of some naked eye observations, in reply to a request for a list of objects visible to good normal sight.

The Secretary read some extracts from a paper by Captain W. Nelson Greenwood, delivered before the Manchester Chamber of Commerce, and dealing with the Unification of Time at sea. Captain Greenwood had reviewed the whole question and presented the case for the proposed change in time reckoning, so as to call forth the hearty approval of the Chamber of Commerce, and also of the Manchester Geographical Society, under whose auspices the lecture had been arranged.

Mr. A. Elvins presented a sketch of a very beautiful parhelion which he had observed on the morning of February 25th about 8 o'clock. Several other members had seen the phenomenon, all agreeing that it was a remarkable appearance, and proving that the drawings made in the Arctic regions and reproduced in books of travel are not in the least exaggerated.

Mr. Pursey presented some drawings of the solar disc, showing sun-spots and faculæ.

A short paper was then read by the Secretary, contributed by Mrs. George Moore, of Surrey, Eng., descriptive of a visit to the Naval Observatory, of Washington, D.C. Mr. R. F. Stupart, who had been on several occasions at the Washington Observatory, thought the description very accurate indeed. He added some remarks descriptive of the mechanical contrivances employed in the motion of the floor of the dome.

FIFTH MEETING.

March 17th; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

Captain W. Nelson Greenwood, of Lancaster, Eng., was duly elected a corresponding member of the Society.

An encouraging letter was read from Mr. H. E. S. Asbury, of Seaforth, Ont., who had succeeded in forming an association for the purpose of systematically observing the heavens. The prospects were bright for a continued interest in astronomy in that town, and it was hoped that a regularly organized society would soon be an accomplished fact. Mr. Asbury forwarded a sketch of a parhelion observed on the morning of March 7th, and which had remained visible for an hour. Mr. T. S. H. Shearmen, of Brantford, wrote in reference to his coronal work, stating that he was more confident than ever of his final success in photographing the corona in full daylight. Dr. Harrison, of Keene, Ont., forwarded a description of a brilliant meteor seen in his locality.

Several of the members reported having observed the brilliant aurora of March 14th; Mr. Pursey reported a paucity of sun-spots, and the President called attention to the non-coincidence of spots and auroræ on this occasion.

Mr. R. F. Stupart forwarded some notes from Toronto Observatory as follows:—The most pronounced magnetic disturbance since 1892 began at 7h. 50m. p.m., on Monday, March 14th. The maximum activity was recorded between 4 p.m. and 8 p.m., Tuesday; the greatest westerly swing of the declination needle (6° 7′ W.) occurred at 5h. 36m. and the greatest easterly (3° 9′ E.) at 6h. 45m. A fine aurora was visible Monday evening. A press report stated that in Maine earth currents interfered with the telegraph and wires were worked without batteries. The most marked meteorological feature of the two days was the development over the Dakotas of a very severe cyclone in which the barometer fell unusually low; it moved northward into Manitoba and thence, during Wednesday, eastward with diminishing energy across northern Canada.

The Secretary stated that he had received from Mr. David E. Hadden, F.R.A.S., of Alta, Iowa, a full report of his observations of Mira (*o* Ceti), between October 24th and March 2nd. Commencing with magnitude 4·4 on October 24th the brightness had increased to magnitude 3 on December 7th; then gradually decreased to magnitude 6·8 on March 2nd. The colour was a "deep orange tint." Another correspondent of the Society, M. Lucien Libert, of Havre, France, had also been engaged in the study of "the wonderful star," and had forwarded the results of his observations between September 25th and February 14th. The fairly close agreement between the estimated magnitudes as recorded by both observers will be seen upon inspection of the following table, the dates given being those on which both reported.

	D.E.H. Mag.	L.L. Mag.
Oct. 25	4·4	4·8
" 28	4·1	4·7
" 29	4·0	4·5
Nov. 1	3·9	4·0
" 2	3·8	4·0
" 5	3·7	3·8
" 11	3·6	3·7
" 17	3·5	3·5
" 20	3·3	3·3
Dec. 7	3·0	3·3
" 17	3·5	3·6
" 20	3·5	3·7
" 21	3 6	3·7
" 24	3·8	3·9
Jan. 2	4·0	4·3
" 7	4·1	4·8
" 21	5·5	5·8
" 23	5·5	6·0
" 30	6·0	6·4

After some discussion on matters of general scientific interest Mr. D. J. Howell, by special request, projected on the screen a number of the Society's lantern slides. These included the series of lunar photographs taken at the Lick Observatory and several pictures of the solar corona. One obtained during the recent total eclipse in India, showed the coronal streamers most beautifully; the Chairman pointed out the significant fact that these appeared to be extensions of the spot zones, chiefly. Mr. Howell also showed some drawings of the planets and several of his own reproductions of photos of star clusters and nebulæ.

The thanks of the meeting were due to Mr. Howell for the pains he had taken to make the exhibition of pictures instructive and entertaining.

SIXTH MEETING.

March 31st; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

Mr. Robert Wallace, of Toronto, was duly elected an active member of the Society. Rev. Norman Russell was duly elected a corresponding member. Mr. Russell's future address would be some point in India, to be communicated later.

Letters were read from several correspondents. Mr. A. B. Thompson, of Orillia, had written in regard to procuring books and periodicals for the library of the Orillia Astronomical Society, which was now actively engaged in observational work. Mr. H. E. S. Asbury, of Seaforth, also reported the encouraging progress made by the Society in that town.

Observations of the Sun were reported by Mr. A. Elvins and Mr. G. G. Pursey. Mr. Lindsay had made observations of Jupiter with the 4-inch Gregorian reflector, which had been shown to the members at a previous meeting.

Referring to the magnetic storm of March 15th and 16th, 1898, the President said:—

Mr. Stupart, Director of the Toronto Magnetic and Meteorological Observatory, sends out notice that on March 15th and 16th there occurred a magnetic storm, the most severe since 1892. The latter was a much disturbed year, several such storms having occurred. The storm of March 15th and 16th occurred on the 7th and 8th days of solar rotation, taking the period and its commencement as given in my paper published in our *Transactions* for last year, and is the same storm (admitting recurrence in that period) which showed itself with much violence on the 17th, 18th and 19th May, 1892. It was first noticeable on January 30th and may be traced by a slight dip on April 20th and June 14th *et seq.* It is an intermittent storm, connected in some way with a disturbance manifested on the 10th day of solar rotation, which very often shows itself as even more important than its predecessor.

It had been announced that Mr. R. F. Stupart had acceded to the request of the Society to read some introductory notes on seismological observations at Toronto Observatory. Being called upon Mr. Stupart reviewed the events which, culminating about 1880 in Japan, led to the establishment of systematic methods of observation, in order that as much as possible might be learned of the phenomena of earthquakes. Knowledge was sought regarding the very minute tremors only discernible by the most refined instruments, as well as of those calamitous upheavals which have destroyed whole cities. In Japan, more than in any other country these phenomena had been studied, with the result that, while it has been impossible to erect buildings that would withstand heavy shocks, certain forms of architecture have been devised that are best adapted to stand the strain of the less violent but frequently recurring tremors of the Earth's crust. A hope had been entertained that the rate and direction of transmission of earthquakes might be determined, and with this in view the co-operation of observatories in other parts of the world had been sought.

Prompt action had been taken on Mr. Stupart's recommendation to the Dominion Government, and a set of the instruments necessary for recording minute tremors, ordered for the observatory at Toronto. These arrived on the morning of the day when Prof. Milne, the great authority on this subject, gave his lecture in Massey Hall, before the British Association, during the visit of that body to Toronto. The principal instrument, the horizontal pendulum, was shown on that evening. Mr. Stupart now gave a full description of the instrument and its use, a diagram assisting the members to follow the plan of the work. It was worthy of note that on the day when the horizontal pendulum was first set up there had been a severe shock at Toronto, and the curve recording the movement showed, that just about the time when the tracing pen began to work, the disturbance was very marked, but soon subsided. The details of observation on several recent occasions were given, from which it appeared that a shock originating many thousand miles from Toronto is felt here, and, affecting the pendulum, is made to write its own history on photographic paper. In some cases the records compared with others from various places showed that the tremor had been felt at Toronto first; again, that the wave of motion had traversed a great distance before passing this point. There seemed no doubt that valuable service would be rendered to seismology by careful attention to these records, and it was the intention to make the work a special feature of the meteorological department.

An interesting discussion followed the reading of Mr. Stupart's notes, bearing partly upon such correlated phenomena as tidal waves and land slides. Some interest was also taken in what had been said regarding the extreme delicacy of the measurements made by the seismological instruments. It was startling, but true, that millimetres were quite gross measures and easy to make. Mr. Stupart in closing the discussion said he would be pleased to show the instruments at work to any of the members who came to the observatory. He stated also that before the end of the year he would probably be able to present a paper reviewing the more marked disturbances recorded at Toronto, with diagrams in illustration.

The Chairman thanked Mr. Stupart on behalf of the Society for his kind invitation and hoped that the Society's volume for 1898 would contain reproductions of some of the more important earthquake curves.

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SEVENTH MEETING.

April 14th; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

The presents received since the last meeting were laid on the table. Among these was the first volume of a collection of lunar photographs by Herr Fauth, of Landstuhl, Prussia; also a volume of drawings of Jupiter and Mars by Herr Kreiger, of Trieste. These were much admired by the members present and the special thanks of the Society were due to the donors.

Some notes of observations, etc., were read from Mr. T. S. H. Shearmen, of Brantford. Commenting upon the published report of Mr. Lumsden's observation of the "black aurora," Mr. Shearmen stated that he had noted a similar phenomenon on April 7th, 1891, and in his journal had described it substantially as described by Mr. Lumsden on February 27th, 1897. Referring to work upon Saturn, Mr. Shearmen stated that since making the observation of a partial division in ring B., he had corresponded with Prof. Schaeberle and had learned that the same observation had been made at Mt. Hamilton. Mr. Shearmen thought it was wrong to credit any observer of the present day with priority in this connection. He considered that the division was the same as observed by Sir William Herschel, but not actually accepted by him as evidence of the *occasional* multiple character of the rings. Mr. Shearmen reported a conspicuous white spot on the central meridian of Jupiter at 9h. E. S. T. on April 8th, and a number of bright and dark spots near to the central meridian on April 5th at 9h. 28m.

Mr. George E. Lumsden presented a sketch of the lunar craters Reinhold and Lansberg, with a small craterlet between them. This last had been referred to by some observers as being difficult to observe. It had, however, been well seen in Mr. Lumsden's 10 inch reflector.

Mr. Lindsay reported having observed the occultation of Jupiter's first satellite on the evening of April 8th. In a 2-inch telescope the satellite when at a little distance from the disc was a mere star point. It had been interesting to note the effect of the phenomenon of irradiation when the satellite was just upon the limb of Jupiter and about to disappear. It then had the appearance of a round bead of light attached to the planet.

Mr. G. G. Pursey presented his report of sun-spot observations with diagrams for the past three months.

Some discussion arose regarding the visibility of the zodiacal light in this latitude. Mr. Lumsden had quite recently observed the phenomenon on a clear evening in the north-east part of the city. He stated that it was so marked as to be quite noticeable to other observers who saw it unexpectedly. Mr. Elvins remarked that he had never successfully observed the zodiacal light in Toronto, since the electric system of lighting had been established.

Mr. Lindsay read some notes in review of the theory recently announced that the so-called doubling of the "canals" on the planet Mars was due to errors in focussing the telescope. It had been stated by several English observers that by racking the eye-piece within or without the focus, all the phenomena that had occasioned so much dispute could be produced. Mr. Lindsay had repeated the experiments using a white disc of paper with lines drawn upon it and placed at about 100 yards from the telescope. In considering the case of Mars, however, two difficulties arose: how was it possible that all the observers had their telescopes unadjusted, and if any one had, would he not be immediately aware of it? Mr. Lindsay thought that the theory was too obviously opposed to the simplest kind of common sense to merit a moment's consideration.

Mr. A. Elvins then read some notes descriptive of some experiments in colour, as follows:—

A piece of black cardboard is pasted to a window pane through which the sky can be seen, and viewed through a prism; at the upper part of the card we see blue above and violet underneath; at the bottom of the card are red and yellow. The arrangement of the colours shows that those above and below are not two parts of the same spectrum, but parts of two spectra. We now take a second card and paste it below the first, say two inches apart, when the blue of the one will be a little below the yellow of the other. Then we slide the lower one up gradually, still looking through the prism, and the blue overlaps the yellow; the yellow and blue become narrower and a beautiful green is seen. We have now a perfect spectrum as we see it in the spectroscope. To me this seems to show that blue and yellow light will blend and form green.

If the colours seen through the prism at top and bottom of the cards are primary colours, and I think they must be, then the primary colours are red, yellow, blue, violet; four instead of three. Orange and indigo are mixtures of red with yellow, and blue with violet, while yellow and blue form green, seven colours in all.

If we so arrange the cards as to cause the red to fall on and mix with the violet, another colour is seen, a beautiful rose, or magenta, a colour which is not seen in the spectroscope and which is as far removed from any other colour as the blue is from the green.

We can produce this overlapping of the two ends of the spectrum by cutting the card so narrow that the violet from the top comes down so low as to fall on the red at the bottom; both the red and violet then disappear, and the rose becomes visible. And again; if we cut a white card about a quarter-inch wide and fasten it on a black card, and look at it through a prism, we find that blue from the top edge falls on the yellow from the bottom; the yellow and blue then disappear and green becomes visible. I shall not enter on the cause of these phenomena; but it is well to notice that but for the cutting off or stopping some white light, so as to cause darkness, before the light reaches the prism, we should get *no colour*; and whether the red end of the spectrum or the violet end is seen, depends on the position in which we place the prism in reference to the opaque edge which cuts off the light.

When blue and yellow light are thrown on a screen from two lanterns, green is not produced; they are complementary colours and we see a grey, without colour; but if we place blue and yellow glass behind each other in the same lantern, and project the light on the screen, we find the colour green. Similarly, if we look at diffused light, the sky, through blue and yellow glass, the light reaching the eye is green. And again, in the first experiment, if while looking at the blue above the card we place yellow glass between the card and the prism, the blue disappears and green is visible.

I wish only to refer to the experiments and the facts which they present. The causes you can study for yourselves and you will find it pleasing and instructive.

EIGHTH MEETING.

April 26th; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

This was an open meeting, held in the Physical room of the University of Toronto, and to which the public had been invited. It had been announced that Prof. Alfred Baker, M.A., would deliver a lecture on "The Nebular Hypothesis." A large audience attended.

The Corresponding Secretary read a letter received from the editor of *Whitaker's Almanac* explaining the omission of the pages relating specially to predictions of phenomena in the volume for 1898, and promising to consider the re-insertion of these pages in subsequent issues.

Dr. J. J. Wadsworth, of Simcoe, had written at some length on his observations of Neptune during the winter of 1897-8. He had been specially drawn to this work by Mr. Herbert Sadler's chart published in *The English Mechanic* and showing the path of the planet among the stars. Between December 3rd, 1897, and April 15th, 1898, ten observations had been made. The Doctor wrote to Mr. Lumsden :—

Each night I laid down his position among the small stars that were near him, and his motion even within 24 hours was distinctly perceptible. His R.A. on Dec. 3, was 5h. 22m. 40s. From this he retrograded to about 5h. 16m., thus passing through an arc of 1½ degrees. This does not seem much, but he sailed by a large number of telescopic stars in this short voyage, stars with which I of course became very familiar. By April 15 he had *advanced* nearly half a degree. As to his appearance in my telescope: His light being equal to that of a star of the 8th magnitude he is a pretty conspicuous object. He presents a distinct disc, wholly different from the image of a star. I saw this disc with a power of 120, but better with 315. On two nights when the air was especially good I could hold the disc with great satisfaction with a power of 560. Still there was a sort of nebulous look about him with all powers. His light seems pale, there is nothing intense about it.

But why should there be any vividness in reflected light from a planet that is probably shrouded in a nebulous envelope, and from which the sun appears to be only twice the diameter of Jupiter as we see him? For we must remember Neptune is thirty times as far from the Sun as we are. His diameter is 35,000 miles, yet his angular diameter is but 2¾ seconds of arc, about one-tenth that of Jupiter. Still we can see him better than he can the Earth; for from Neptune, Jupiter is never seen to recede from the Sun more than ten degrees, Mars only three degrees, and the Earth, Venus, and Mercury still less. Possibly we may be seen to transit the Sun if he keeps a Lick telescope.

Now as to his satellite. You will remember we said we would try to detect it, as no one had ever seen it through a telescope in Canada as far as known. It is a small object certainly, as it is rated at the 14th magnitude on Argelander's scale, equal to 13.8 photometric, from observations on the satellites at Mt. Hamilton. But it recedes to an angular distance of 16″ from its primary. You will remember we had no difficulty in seeing the companion of Beta Aquarii, which is of the 15th magnitude. Well, I looked every one of the ten nights for it, and saw what may have been the satellite. But how can I be certain without seeing it regularly on consecutive nights? The clouds prevented this, and I cannot assert *positively* that I have seen the satellite of Neptune. Next winter or before I will try again. He is getting too near the Sun now.

It is so easy to mistake fixed stars for satellites that I regard with suspicion some printed observations I have seen regarding this satellite; I doubt if he can be seen with a less aperture than 9 inches.

The President then called upon Prof. Baker who proceeded with his lecture. The hypothesis as given by La Place was very lucidly sketched, Mr. Baker stating that it was his object to treat the subject in a popular way. The history of the hypothesis, the objections that have been urged against it, the many points in its favour, the recent work of Darwin and See, in the investigation of double star evolution, were all in turn referred to. The conclusion was reached that in general outline the theory as announced by the great French astronomer, stands to-day, with but little modification, as he gave it a century ago.

The cordial thanks of the meeting were presented to Prof. Baker by the President, who added his own hearty appreciation of the lecture and of the spirit which animated generally the professors of Toronto University, always willing to assist in popularizing the various branches of the physical sciences.

NINTH MEETING.

May 10th; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

The Secretary announced that an abstract of the Society's *Transactions* for 1897, had been forwarded to the Secretary of the Royal Society of Canada. A short paper calling attention to the eclipse of May, 1900, had been prepared by Mr. Lindsay, and would be presented by the Honorary Secretary, who had kindly arranged to represent the Society in this matter.

A request having been received from the U. S. Naval Observatory for the earlier volumes of the Society's *Transactions*, the Librarian was requested to make up a complete set and forward to the Director, who had on all occasions favoured the Society with the publications of the observatory. A cordial letter was also read from Miss Mary Proctor, of New York, and asking for a copy of the verses on "The Midnight Sky," written by Mrs. Manley, of Meaford.

The Corresponding Secretary read a communication received from Mr. A. F. Hunter, M.A., of Barrie, Ont., as follows:—

BARRIE, April 19, 1898.

GEO. E. LUMSDEN, ESQ.

DEAR SIR.—As bearing on the interesting papers on November meteors in the last two annual reports, I find in Samuel Thompson's "Reminiscences of a Canadian Pioneer," the author notices (at p. 73) a November display in 1834, which he observed in this (Simcoe) county. He is so precise as to the year, and his book generally is so accurate, that I do not think he has mistaken the date for the display of 1833. It lasted from eleven p.m. till three. Be kind enough to lay this before any member of the Astronomical Society who may be pursuing this subject, as Thompson's book is accessible in the Public Libraries.

Yours very truly,

A. F. HUNTER.

Mr. Lumsden had referred to the work mentioned and had made the following extract which was read:—

It was one night in November following, when our axeman, William Whitelaw, who had risen from bed at eleven o'clock to fetch a new log for the fire, shouted to us to come out and see a strange sight. Lazily we complied, expecting nothing extraordinary; but, on getting into the cold frosty air outside, we were transfixed with astonishment and admiration. Our clearing being small, and the timber partly hemlock, we seemed to be environed with a dense black wall the height of the forest trees, while over all, in dazzling splendour, shone a canopy of the most brilliant meteors, radiating in all directions from a single point in the heavens, nearly overhead, but slightly to the north-west. I have since read all the descriptions of meteoric showers I could find in our scientific annals, and watched year after year for a return of the same wonderful vision, but neither in the records of history nor otherwise, since that night, have I read of or seen anything so marvellously beautiful. Hour after hour we gazed in wonder and awe, as the radiant messengers streamed on their courses, sometimes singly, sometimes in starry cohorts of thousands, appearing to descend amongst the trees close beside us, but in reality shooting far beyond the horizon. Those who have looked upwards during a fall of snow will remember how the large flakes seem to radiate from a centre. Thus I believe astronomers account for the appearance of these showers of stars, by the circumstance that they meet the Earth full in its orbit, and so dart past it from an opposite point, like a flight of birds confronting a locomotive, or a storm of hail directly facing a vessel under full steam. No description I have read has given even a faint idea of the reality as I saw it on that memorable night. From eleven p.m. to three in the morning, the majestic spectacle continued in full glory, gradually fading away before the approach of daybreak.

Continuing this subject Mr. Lumsden stated that he had received a letter from Mr. W. F. Denning, F.R.A.S., of Bristol, who had been much interested in the paper contributed by Dr. Meredith. Referring to this Mr. Denning wrote :—

I notice in the report that Dr. E. A. Meredith in discoursing on the November meteors of 1832 and 1833, says (page 11), that he observed the shower of 1832 at Castlenock School just outside the Phœnix Park, Dublin, but there must be some mistake in his description for he says that "it was shortly after eight o'clock that we boys were amazed and awestruck by the extraordinary spectacle which the heavens presented." Now the radiant of the Leonids does not rise until about 10h. 20m. p.m., and the shower observed by Dr. Meredith must have represented some other system. A rich display of the Leonids is rarely seen before midnight, and none of the meteors can possibly be observed before 10 p.m.

Possibly Dr. Meredith witnessed a return of the Andromedes of Biela's comet for the circumstances were exceedingly favourable for the appearance of this shower early in December, 1832. The Earth passed through the comet's track only about a month after the comet had itself passed through the same section. A brilliant shower of meteors ought therefore to have occurred though there appear to be no existing records of it. Dr. Meredith's description favours the inference that the meteors he saw were Andromedes for he says the display "looked like a shower of fiery snow flakes so thickly and so gently did the falling stars seem to come down." The Andromedes fall slowly and almost vertically, the radiant being high in the evenings, whereas the Leonids between about 10h. 20m. and midnight shoot along with great swiftness in apparent courses either horizontal or ascending and would not appear to "come down" as described by Dr. Meredith. If Dr. Meredith's notes really refer to a display of Andromedes, they are very valuable as supplying a missing link in the chain of Biela's showers. It would be well to consult the newspapers of the period to see if they contain any reference to the phenomenon in the first week of December, 1832.

Dr. Meredith had been made acquainted with Mr. Denning's views and had stated his intention of making a search for records bearing on the point in question.

Mrs. J. Fletcher then addressed the meeting on the subject of popularizing astronomical studies. It was thought that popular lectures might be given by members of the Society, and that occasionally an opportunity might be afforded those interested to use the telescope in making observations. A lengthy discussion followed in which several members took part. The Chairman finally stated that as a beginning he would be glad to meet Mrs. Fletcher and her lady friends at his residence on a day which he would name, when he would arrange for several telescopes to be placed at their service.

Mr. Lumsden then read a paper on "Phenomena to be Observed," naming all those of interest which it would be possible to see during the next few months.

Special mention was made of the eclipse of Jupiter's third satellite on May 16th and of the close approach of the Moon to Venus on May 22nd. It was hoped that as many as possible would try to observe these phenomena.

TENTH MEETING.

May 31st; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

The President read a brief account of an interview had with a committee of the City Council since the previous meeting and in reference to a money grant to the Society. The sum of $100 had been voted, it having been asked for the purpose of providing opportunities for the general public to view celestial objects with the telescope.

Communications were read from Dr. T. J. J. See, of Flagstaff, Arizona; Miss Mary Proctor, of New York; and Dr. Joseph Morrison, of Washington.

Mr. David Brown, of Port Elgin, wrote a brief account of some observations made by him. Noticeable among these was an observation of Venus with unaided eye, when the planet was 36 days past superior conjunction. Mercury had also been seen when 13 days past superior conjunction. Mr. Brown enquired regarding naked eye observations of Jupiter's satellites. Some discussion followed this, during which the President stated that he had observed on one occasion in Toronto, an elongation of Jupiter's light which he interpreted as caused by the satellites being on one side, and this proved to be the case.

Mr. D. J. Howell reported having observed a meteor on the evening of May 30th at 22h. 43m. the peculiarity of which was its very slow motion; the trail remained visible for quite an appreciable time. Dr. Wadsworth had observed the close approach of the Moon to Venus on May 22nd. Mr. Lumsden had observed the interesting occultation of Jupiter's third satellite on May 16th.

Mrs. J. Fletcher read some notes descriptive of a meeting of ladies held at Mr. Harvey's residence, for the purpose of observation. The day had not been very favourable for telescopic work, but views were had of the solar surface and a short paper by Mr. Harvey on the phenomena of the Sun had been much appreciated.

Mr. J. Phillips made some references to published statements regarding the parallaxes of the fixed stars, particularly of Arcturus. This occasioned some discussion during which one member stated that the extremely small parallax of Arcturus announced by Dr. Elkin, of Yale, could hardly be accepted as accurate. Calculations based upon this quantity had shown that the star must be large enough to fill the whole orbit of the Earth, a result which was quite too sensational. Mr. Phillips was requested to prepare a paper on the subject of parallax generally, for a future meeting.

Mr. Lindsay then read a continuation of his

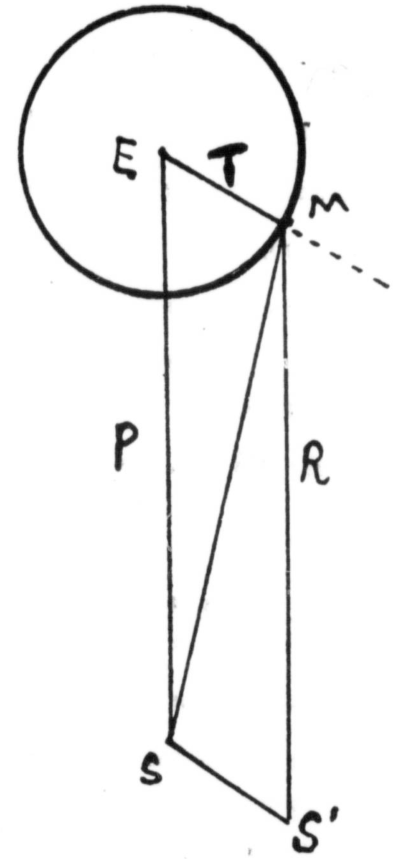
HISTORICAL SKETCH OF THE GREENWICH NAUTICAL ALMANAC.

VII. *The Lunar Ephemeris.*

After this long digression, but without promising that such ramblings will not be repeated, we turn again to the subject-matter of the first issues, having now reached page 5 of each month. This and six pages following were devoted to data concerning the Moon, and for the first time in the history of astronomy there were given with sufficient exactness for all practical purposes the places of this object in the heavens day by day throughout the year. First we have on page 5 the Moon's longitude and latitude for each noon and midnight, computed to seconds of arc. Mayer's tables admitted of computing these places to seconds though that degree of accuracy was not strictly claimed. When it was necessary, as of course it would be often enough, to find the longitude for a time between noon and midnight, the astronomer had to resort to interpolation by second differences. Examples of this were given in the explanations, and assistance was to be had from tables specially constructed by Michael Taylor, having for arguments the time and the mean of the second differences. The subject of interpolation had been taken up by Newton in the form of a problem to draw a curve through any number of given ordinates. Maskelyne discusses this very fully in the explanations. [I should say here, lest I forget it, that the prices of these volumes of extra tables were rather high. While the almanac itself was sold for 3*s.* 6*d.*, and the *Requisite Tables* for 5*s.*, the proportional tables of Taylor were published at 15*s.*, and a volume of logarithm tables by the same author was later published at 3 guineas.] Page 6 gave five columns; the time of the Moon's passage over the meridian to the nearest minute of time; the R. A. for noon and midnight to the nearest minute of arc; and the Decl. for the same hours, also to the nearest minute; when we say to the nearest minute, that means within a possible error of half a minute, so that the R. A. was named within 7½ seconds of time. Page 7 gave the semi-diameter and the horizontal parallax for noon and midnight to the nearest second, with proportional logarithms for readily interpolating.

Now these data which are so quickly enumerated were based on the fundamental tables of Tobias Mayer and for which the British Government had paid a very substantial reward. All the corrections to the Moon's mean motion, known at that time, were taken into account in the computation of the ephemeris, while Maskelyne himself was continuously engaged in observational work that the tables might be rendered still more perfect. [This work has been carried on uninterruptedly ever since and the Greenwich observers are the great authorities on the Moon.] I think it is correct to say that at this particular time the perturbations due to the Sun only were considered. Later in the century the number of corrections was about 40, applied to the Moon's mean place in its theoretical orbit. Then the planets were taken into account. We have then at this stage the first application of the problem of three bodies, to the needs of the navigator and explorer.

You will remember that in discussing the solar ephemeris we were interested in Kepler's problem, that is, to divide an ellipse into equal areas by lines drawn from the focus. The solution of this is of course required for constructing the column giving the Moon's longitude, but every moment there is a force disturbing the mean motion and changing the direction of the path, so that if the Moon's orbit could be seen from a point in space, a bird's eye view as it were, it would be just about as zigzag a line as we could well imagine. And yet how small are the perturbations and how regular from lunation to lunation. Employing the mean period alone we can name the recurrences of eclipses, times of new and full, etc., for thousands of years, and will never be astray more than an hour or two. But an hour or two might as well be half the orbit for the purposes of the ephemeris, what is wanted is the place to a second or two. It has never been required of the amateur that he should have an extensive knowledge of those operations that enter into the approximate solution of the problem of three bodies, but there are several writers who have given some details of the work in such a way that they can be readily followed. I take for granted you will agree with me that when not more than an elementary mathematical knowledge is required we should try even as amateurs to follow the masters. The columns of the ephemeris will thus be in some degree more intelligible to us. The chapter on perturbations by Dr. Norton, in his text book, is a special instance of plain treatment in a general way of some of the corrections to the Moon's mean motion.



Let *SE*, *EM* and *SM*, respectively represent the force of the Sun upon the Earth, the Earth upon the Moon, and the Sun upon the Moon. Complete the parallelogram. Then the force along *SM* is decomposed into two forces, one acting along *S'M* and one along *ME*. Now, if the force along *S'M* were equal to the force along *SE* the Earth-Moon system would not be disturbed internally. We might suppose it simply drawn through space in a direction parallel to *SE*. But if there is difference between these two forces that will clearly be the disturbing force in the direction *MS'*. The other component, the force along *ME*, will also be a disturbing force, and will evidently increase the gravity of the Earth for the Moon.

Denote the force of the Earth upon the Moon by $\frac{1}{y^2}$; the Sun upon the Earth by $\frac{m}{a^2}$; and the Sun upon the Moon by $\frac{m}{z^2}$, and let the force $\frac{m}{z^2}$ be decomposed into R along MS' and T along ME.

$$\text{Then } \frac{\frac{m}{z^2}}{T} = \frac{MS}{ME} = \frac{z}{y}; \ T = \frac{my}{z^3}.$$

That is, the disturbing force tending to draw the Moon toward the Earth is $\frac{my}{z^3}$. Turning these symbols into figures we have: Call the distance y, unity; then z = about 400. Call the mass of the Earth unity; then $m = 355000$, and the fraction becomes $\frac{355000}{64000000} = \frac{1}{179}$. This is the amount by which the gravitational influence of the Earth upon the Moon is increased under these conditions.

Similarly the force along MS', or $R = \frac{ma}{z^3}$. Then we have the force along $ES = \frac{m}{a^2} = P$.

Now these fractions may be equal to each other, or either one may be greater than the other, but in any case the difference between the two forces $R - P = \frac{ma}{z^3} - \frac{m}{a^2} = ma\left(\frac{1}{z^3} - \frac{1}{a^3}\right)$ and this is the disturbing force acting along the line MS'.

We have the disturbing force acting along ME already.

Now the components of this force along MS' may be resolved into three, not easily represented on a plane surface, but here is something that will serve for a model. Here we have the line MS' making an angle with the radius vector of the Moon, with a tangent to the orbit, and with a perpendicular to the plane of the Moon's orbit, which, of course, we know is inclined to the ecliptic. The cosines of these angles have for a common denominator the disturbing force along MS', and for numerators, respectively, the forces along the radius vector, along the tangent, and along the perpendicular; so that, for example, the force along the radius vector, pulling the Moon straight out is

$$ma\left(\frac{1}{z^3} - \frac{1}{a^3}\right)\cos\beta$$

and the actual radial force is the difference between this and the force pulling the Moon in, that is,

$$\frac{my}{z^3} - ma\left(\frac{1}{z^3} - \frac{1}{a^3}\right)\cos\beta$$

and here we see that the angle β is equal to the elongation of the Moon.

Now, we need not go much farther with this. I have merely introduced it to show that so far the work is all straight, beginning with simple equations it gets more and more difficult until—but I will speak of that presently. The inequality which the tangential force produces is called the Moon's variation, that produced by the radial force is the evection. It changes the eccentricity of the orbit, literally carries the Moon out, hence the term. A change in the eccentricity of the orbit affects the equation of the centre necessarily, and as this is going on all the time, Kepler's problem has a pretty hard time of it.

These inequalities were known from very early times, although of course not their causes. Hipparchus knew that the equation of the centre varied; Ptolemy in the first century of our era found the maximum value for the evection; Tycho Brahé discovered the variation; but of course in all these matters Tobias Mayer, armed with the results of Newton's labours, gave tables much more accurate than any of the old astronomers could have possibly compiled. Maskelyne's own additions to the lunar theory were almost immediately of service. A few years after the first issue of 1767 his perface reads, referring to the calculations of the lunar ephemeris, "were made from new tables, improved from Mayer's tables, composed by Mr. Charles Mason, under my direction, upon the series of lunar observations made by the late Dr. Bradley." From these words we would scarcely gather, what was the fact, that Maskelyne was the guiding spirit of the whole work.

Maskelyne and all the rest, before him and after him, from Newton till the present day, have broken lances against the difficulties of the lunar theory. We read a sketch of the life of any of the great mathematicians of the last century and a half, and when we come to a list of his works, there stands out a little "contribution to the lunar theory." Not early in life, but after all is mastered that is already known in mathematics, then comes the battle with the Moon's motions. This is for the man in the very fulness of his powers. We must all have heard at one time or other the view expressed that the Moon is placed just where it is by a beneficent Creator, knowing the needs of His creatures. The inclination of the orbit is just so; the declination of the full Moon is apparently designed to relieve the long arctic night; the nodes of the orbit whirl round and by and by it is to southern observers that the Moon "runs high"; the orbit is yet not so greatly inclined but that it skirts the horizon in our harvest time and allows the Moon to rise almost with the stars for a few nights. And the tides; are they not truly the servitors of man? Is it unphilosophical to say that the Moon is thus specially placed for the benefit of mankind? Possibly; but it is for the philosopher. to prove that these things are not evidences of design. Others accept them, and even if pressed hard by some illustration contrasting the littleness of man with the immensity of the universe, may rest secure upon the unanswerable argument, "I am open to conviction, but who will convince me"! For myself, if I see evolution somewhere, I yet see design everywhere, and it is not I will dispute that the first push upon the Moon was in a direction and with a force which designedly brought about the present conditions. So far from disputing this let me add to the argument. Who can say that the insuperable difficulties in the complete analysis of the Moon's motion were not designed as a whetting-stone for the mathematician? As he attacks it new beauties are revealed, and new difficulties arise. By the aid of processes thus discovered he carries his mathematics beyond the region of application in other directions; then back to the lunar theory now doubly armed and yet to find that still there are truths to discover. As I have said it is not for the amateur to follow the masters of mathematics into these realms, but we can all read history, and we all do know that the complex movement of the Moon in its orbit, has, more than anything else, been the fuel to fire the imagination of those devoted to that science which more than any other has enabled man to delve into the mysteries of the Creator's handiwork.

VIII. *The Lunar Distances.*

We have now four pages of the ephemeris for each month, giving the distance of the Moon's centre from certain fixed stars for every three hours. These were the tables which were at this time the pride of the British Admiralty; they gave the navigator data by which he might determine his longitude at sea within very much closer limits of error than by any other method. This was the one great object of the *Nautical Almanac* it having been long recognized that the Moon's rapid motion among the stars would afford a means of solving the problem. We know that Newton was the first to show how the Moon's path was to be computed, and this was the first step towards making that body do duty as the minute hand of the celestial clock. But Newton himself was forever acknowledging the assistance he had had from the work of his predecessors, so, to roughly sketch the history of the longitude problem, we must go back long before the immortal philosopher's day.

It did not escape the notice of Hipparchus, the father of astronomy, first that east and west distances could only be satisfactorily determined by comparing local times, and secondly that the relation of these to each other could only be known by comparing them with a signal given by a body in the heavens. And it appears that Hipparchus did endeavour to lay down the relative positions of a few places by noting the times when the shadow of the Earth crept upon the Moon during a lunar eclipse. But we can readily understand what difficulties present themselves in this method and are prepared for the very erroneous estimates of distances that appear in all the old maps of the world. The idea, however, that the Moon was the object to be studied was in the minds of all astronomers; in fact one could not be an astronomer and not be aware of the possibilities in the case. But while from an inadequate knowledge of mathematics, and very poor instrumental means, the lunar method made no advancement for many centuries, the spirit of research was yet leavening the work of a few master minds, and finally it dawned upon statesmen that it would not be altogether a bad thing to encourage some one in the work of assisting the navigator. But this was not until the beginning of the 17th century, long after the opening up of the western hemisphere, so that if we begin astronomy with Hipparchus we have 18 centuries during which it was not possible to map out east and west distances with anything like accuracy at all. It is said that Columbus thought he had hit upon an easy method of solving the problem when he discovered the variation of the compass; he thought that the needle would be found to vary regularly as he passed westward; this we know was not the case.

At the end of the 16th century, Spain, poor Spain, had seen her best days and there had come to the throne Philip III., a prince of whom the historians have little either of very good or very bad to tell, except that he helped his country along a little in her process of decay by losing the Netherlands. It comes readily to the tongue to say that she deserved to lose them, but in this unhappy hour it is not I who would press poor falling Spain too far. I will leave that to some one who can boast of a long line of saintly ancestors who never hunted the heretic, burned the witch, or starved the North American Indian. Not being interested then in what Philip did that was bad we still find that he has a little place in the history of astronomy so far as it relates to our present subject. He it was who first offered a money reward to the navigator who would find a convenient method of determining the longitude at sea. Perhaps Philip dreamed of Spain's recovering her once proud eminence as a maritime nation, and he would lend his captains such aid as he could, while navigators yet reckoned their longitude from—not London, or Paris, or the Hague, but, alas for the changes of time—from the Grand Canary Island. We have to record no success following the proclamation of Philip III., but let us not forget to give due credit to the Spanish navigators for what they had done even without a knowledge of how to determine longitude accurately. They certainly knew well that if they steered far enough to the south-west they would strike—Mexico.

Then Philip's proclamation had opened the eyes of other governments, and soon the Dutch Republic, looking around for worlds to conquer, saw that navigation was an important science, and the ministers of that already thriving state also offered a large reward for a solution of the great problem. We are approaching a time now of great intellectual activity in Europe, the days of the consummate Huyghens, as Newton called him; of Fermat, propounding problems that are yet among the unsolved; of the courtly Pascal, prince among mathematicians; and although we have more than a hundred years before us until the problem in all its details was made simple of solution by Nevil Maskelyne, it is to be remembered that the century was one of continual progress; true, much slower than during the 19th century, but yet a continual and healthy progress. The Dutch Republic seems not to have been any more successful than Spain in assisting the navigator, who was still obliged to keep to his old methods. In passing I may say here that Marryat's *Phantom Ship* deals with the period of which we are speaking and references are made there to the difficulty of finding the longitude, dead reckoning alone being employed by the Dutch captains of whom he writes.

England does not figure in this prize problem competition during the 17th century, but it must have been known that she was willing to take the matter up, because, in 1674, a Frenchman, the Sieur de St. Pierre, presented himself before the ministers of King Charles II. and announced that he had discovered a method by which the longitude at sea might be readily determined. This man is referred to by one writer as "an indigent Frenchman," and it is said that he gained a hearing through the influence of the then Duchess of Portsmouth. But, at any rate, what he had to say was important enough to occasion the forming of a Royal Commission, composed of Lord Brounker, then President of the Royal Society, John Flamstead, already an enthusiastic astronomer; and some others. Flamstead's opinion was that St. Pierre's method would not serve in practice to solve the problem, and indeed that no method could solve it until accurate tables of the Moon and certain fixed stars were made available. There had been many efforts made to find the longitude simply by observing the Moon and a star, and computing the R. A. of the former. St. Pierre's method seems to have had for its peculiarity the observing of two stars and the Moon at the same time.

We may here stop a moment to consider the theoretical solution of the problem in question. To be as brief as possible; the Moon changes very rapidly in R. A., and if these changes were tabulated with the corresponding times at one selected zero point, all we would have to do at some other place would be to observe the Moon's R. A., and find the local mean time of the observation. Suppose we find that the R. A. of the Moon is 9hrs. when the mean time clock shows 5hrs. p.m., and then turn to an ephemeris and find that 9hrs. is the R. A. of the Moon at 11hrs. p.m., at, say Greenwich, as the selected zero point, why, then, there is a difference of 6 hours in time. A complete turn of the Earth occupies 24 hours, so that one quarter of its circumference intervenes between Greenwich and our station. Now this is elementary—we may make it still more so by saying, determine the R. A. of the Moon which moves reasonably fast, and you have the longitude by comparison with the Greenwich tables.

Now, St. Pierre assumed, first, that the almanacs of the day were pretty accurate, secondly, that the local mean time of any place could be readily determined, and the R. A. of the Moon he proposed to determine in something like this manner:—Having given the Decl. and R. A. and the altitudes of two stars, there are sufficient data to determine the R. A. of the meridian and the co-latitude of the place. Then in the triangle formed by the co-latitude, the zenith distance and polar distance of the Moon, the hour-angle of the Moon was computed, and its R. A. thus directly. Now, to clear all this elementary work of the corrections for parallax and refraction seemed to Flamstead to be a too difficult matter for the ordinary navigator; coupled with this were the very inaccurate tables of the Moon and the stars, and so he did not recommend the method. But the leaven was fairly working, and what happened after the St. Pierre episode we all know. The King decreed that an observatory should be established, Flamstead placed in charge, and that he should diligently apply himself to the task of correcting astronomical tables.

Then Sir Isaac Newton appears on the scene, the astronomer in the study working with the astronomer at the telescope. Flamstead's observation supplied the data which Newton required to trace out the lunar orbit, and these data were the basis of the 3rd book of the *Principia.* This was the beginning of the study of the lunar theory on the principles of the Newtonian law of gravitation. Flamstead published an ephemeris which was a great advance on all preceding, but his time was still not long enough for such observational work as would enable the mathematician to perfect the lunar tables. Then Edmund Halley takes place as astronomer royal; in his time, in 1731, John Hadley presented to the Royal Society the memorable paper descriptive of his quadrant, for taking observations at sea. Halley saw at once the possibilities of the new instrument, and among these, its aid in effecting a solution of the longitude problem. He it was who hit upon the plan of measuring the distance of the Moon from a star with the quadrant, a work for which the old cross staff was quite too clumsy, and comparing this distance with a table of distances specially prepared at Greenwich. In the meantime there was a standing offer of a reward, instituted in 1714, by the British Government for the most perfect tables of the Moon. We have already seen that Mayer eventually won the prize, and now we are concerned with Nevil Maskelyne's work in giving the results of nearly twenty centuries of research to the British sailor, and the public generally, whom he appears always to have had in his mind.

The lunar distances were given to seconds of arc from the following stars: Alpha Arietis, Aldebaran, Pollux, Regulus, Spica, Antares, Alpha Pegasi. The *Requisite Tables* contained additional matter simplifying very much the problem of correcting the observed distance, for the tabulated distances were, of course, computed for the centre of the Earth, the astronomer's imaginary observing station.

An elementary presentation of the problem as now proposed, it is not difficult to give: The zenith distances of the Moon and a star, and the distance between them, are observed; in the triangle thus formed the angle at the zenith is computed; the sides of the triangle are now changed by applying the corrections for refraction and for parallax in altitude; specially note that parallax in R. A. which spoiled St. Pierre's method, does not enter here; the angle already found at the zenith we take to be common to the two triangles, so that now we have two sides and included angle, to find the third side or true distance. The rest was simple enough, having the lunar distance tables at hand. Using the old familiar notation for triangles we have for the first operation:

$$\cos \tfrac{1}{2} A = \sqrt{\sin s \sin (s - a) \operatorname{cosec} b \operatorname{cosec} c}$$

requiring five references to the logarithm tables. The next operation we regard as an independent one, and we have

$$\tan \varphi = \tan a \cos C$$

$$\cos c = \frac{\cos a \cos (b \pm \varphi)}{\cos \varphi}$$

or seven more references, twelve in all.

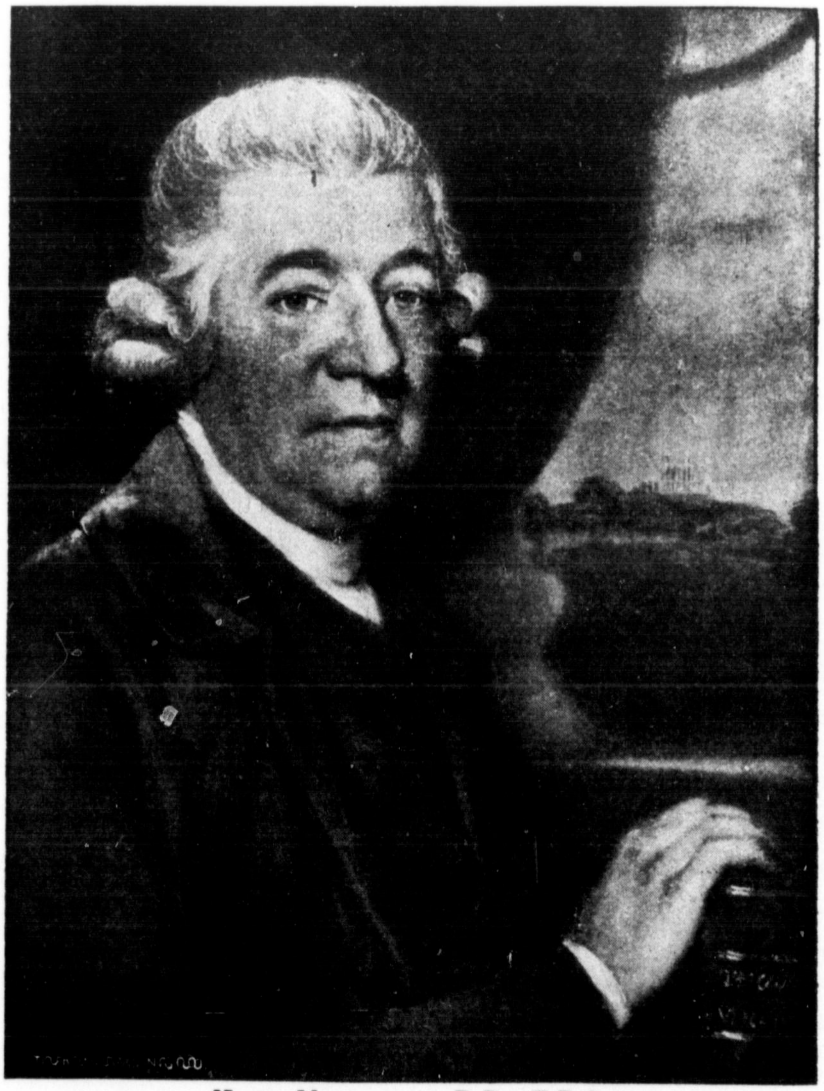
By the aid of special tables the work was reduced to seven references, but of course the tables were elaborate and covered up a good deal of the work, so that without any tables but the logarithms the above solution is the shortest. And it would be perfectly rigorous but for one correction, which, however, is much smaller than the limit of error in the observation by the instrument. This is due to the fact that the position of the Moon is given as seen from the true centre of the Earth, and the zenith from that point is not the same as the zenith of the observer. The result is that the angle which we have taken to be common is not strictly common to both triangles. All corrections of this kind were, of course, well known to the astronomers of Maskelyne's day, but this minute source of error was not considered in presenting the problem to the navigator. The latter was now quite happy; with the true distance of the Moon from a star, and the local mean time, he turned to his almanac and found the Greenwich time corresponding to the distance, and thus had his longitude.

What the founder of the *Nautical Almanac* himself thought of the longitude problem I am able to tell you. Prof. Story-Maskelyne has kindly sent me an extract from a letter written in 1766 by the Astronomer-Royal at Greenwich to Capt. Edmund Maskelyne, then in India, with Lord Clive:—

* * * * * I have full employment here. I have lately received Mr. Harrison's watch here to try its going, agreeable to the resolutions of a late Board of Longitude, and shall soon have his other three timekeepers. The Board have engaged persons to compile a very complete nautical and astronomical ephemeris which will come out next September, for the year 1767, to be continued annually.

> There will be twelve pages in every month. All the lunar calculations for finding the longitude at sea by that method will be ready performed, and other useful and new tables added to facilitate the whole calculation ; so that the sailors will have little more to do than to observe carefully the Moon's distance from the Sun or a proper star, which are also set down, in order to find their longitude. You may, perhaps, meet with some of my pupils in India. They will tell you this is not a project in vain. The Board of Longitude are also desirous to encourage the making of watches after Mr. Harrison's method. They have engaged a person to make one. I have had the drawings engraved here under my eye, and shall publish them in a short space of time. * * * * *

And we may imagine the shades of Hipparchus and Ptolemy peering over Maskelyne's shoulder as he wrote, and rejoicing that now, at last, the orbs of space were to become truly subservient to the toilers of the sea !



NEVIL MASKELYNE, D.D., F.R.S.

Having followed so far the description of the *Nautical Almanac*, I am sure you will be pleased to learn that there has been presented to us a reproduction of the portrait of Dr. Maskelyne. Our thanks for this favour are due to Mrs. Story-Maskelyne, from whose sketch of the life of the Astronomer-Royal I quote here. Speaking of existing portraits it is said :—

> The portrait of Dr. Maskelyne, presented by his widow to the Royal Society, was painted by Vanderpuyl in 1785 [said to have been painted by Vanderburgh, but the name is spelled Vanderpuyl in Dr. Maskelyne's account books].
>
> The crayon portrait at Basset Down, executed in 1804, is by John Russell, R.A., and was a gift by the artist to him.
>
> There are two engravings published from portraits of Dr. Maskelyne, one from the portrait at the Royal Society, and another engraving like Russell's crayon, but omitting the observatory.

We have here a photograph of the Russell crayon at Basset Down. This I will hand to our Librarian, to be placed among the treasures of our Society.

ELEVENTH MEETING.

June 14th ; Mr. John A. Paterson, M.A., occupied the chair.

Encouraging letters were read from Mr. H. E. S. Asbury of Seaforth, and Dr. J. J. Wadsworth of Simcoe.

In reporting the receipt of presents and exchanges since last meeting, the Librarian stated that he had recently found in an old collection of books offered for sale, a copy of Tobias Mayer's *Lunar Tables*, first edition, 1770, and bound up with this, the *Tables* as corrected by Charles Mason, and published in 1787. This had been bought for the Library. The purchase was now heartily approved of.

Mr. Geo. E. Lumsden read some notes on phenomena to be observed, and illustrating the present position of Jupiter, Saturn and Uranus. Mr. G. G. Pursey in reporting his solar observations stated that he had recently noticed that small spots would break out and quickly disappear. Mr. Elvins thought this class of phenomena generally accompanied the minimum of solar spot activity Mr. Lumsden had observed the approach of Jupiter to a small star in the neighbourhood, and its regression from the same star. The time of passing from direct to retrograde motion had been compared with the time as predicted in the ephemeris and found to agree exactly. Dr. J. J. Wadsworth had also observed the exact time of change successfully.

The Chairman then announced that the special business of the evening would be the discussion of a plan for the establishment of a "People's Observatory" in Toronto. At a meeting of council held June 7th, the President had presented a draft prospectus for discussion by the council. At that meeting there was not a large attendance and it had been moved and carried, that the subject be brought up at the next regular meeting of the Society, and it was therefore now in order.

In opening the discussion Mr Sparling stated that in the absence of the President who had brought the plan in its present state before the council it would be impossible to satisfactorily discuss it. He stated also that although the matter had been referred to a regular meeting of the Society and was of such importance that only at a full meeting could it be disposed of, it would still be more satisfactory to have a full council report before action by the Society.

Mr. Sparling then moved that the discussion of the plan for the establishment of a "People's Observatory" be referred to a special meeting of the council.

Some discussion followed: Mr. A. T. DeLury, B.A., thought that in considering the matter it would be well to take full account of possible assistance from the University of Toronto. Mr. Lumsden stated that in his opinion success could only be assured when such an institution as the University of Toronto lent its hearty aid to the scheme finally adopted.

Mr. Sparling being asked to add to his motion that Mr. DeLury be specially invited to attend the council meeting, it was seconded by Mr. G. G. Pursey, and carried.

TWELFTH MEETING.

June 28th; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

This was an open meeting, to which the public had been invited, it having been announced that Mr. Napier Denison would deliver an illustrated lecture on meteorology.

A letter was read from M. Lucien Libert of Havre, who forwarded a series of observations of falling stars and a continuation of his study of the fluctuations of Mira.

The Secretary announced that the Lords Commissioners of the Admiralty had placed the Society on the exchange list for publications authorized by them, and had forwarded three most valuable volumes, one the catalogue of stars photographed at the Cape of Good Hope, and two containing the observations of Iris, Sappho and Victoria, made in 1888 and 1889 for the purpose of redetermining the Sun's distance and other constants. The sincere thanks of the Society were due to their Lordships for this very great favour.

The President submitted the following note on the researches of M. Deslandres:—

The Society will remember that in my paper on the periodicity of magnetic disturbances on the Earth, I was driven to attribute them to some force transmitted from the Sun, in direct lines, and was obliged to differ from Prof. Frank H. Bigelow, who thought them connected with the solar magnetic field, and considered that the magnetic force emanating from the solar north pole, returned to the solar south pole after a course of spherical shape—thus reaching the planets (which revolve in nearly the plane of the Sun's equator) about the middle of this widely extended course.

In the *Comptes rendus de L'Academie*, No. 19, 1898, M. A. Deslandres comes to my support with the theory, that the repellent force of the Sun is due simply to the well understood repulsion which the primary cathode rays exercise on matter they strike. While the Sun's attraction is proportional to the mass of any given particle, the Sun's repulsion, *i.e.*, the repellent influence due to cathodic rays emitted by him, is proportional to surface, and, with a very small particle, he says the repulsion may exceed the attraction. Thus the minute particles which occupy the upper portions of stellar atmospheres, repelled by cathodic rays, give rise to the rays of the solar corona and the tails of comets.

The cathodic rays, he proceeds to remark, heat and illumine by phosphorescence the bodies they encounter—whence comes in part, the proper light of the solar corona, also that of comets.

Cathodic rays carry with them a negative electrical charge, which modifies the electrical and magnetic field of the bodies they encounter, producing in the case of solar cathode rays, electrical discharges, auroræ and terrestrial magnetic storms.

M. Deslandres says the spectroscopic study of the chromosphere, or lower part of the Sun's atmosphere, shows it to be an electrical phenomenon, comparable to terrestrial atmospheric electricity. The upper portion of the chromosphere, being rarified and electrified, must emit cathodic rays. Being about normal to the solar surface, they are necessarily more intense where the chromosphere is most brilliant, viz., above spots and faculæ. This explains the rays seen in the corona, the multiple tails of comets, and the relations between the Sun and terrestrial magnetism.

Cathodic phenomena, therefore, occur in space between the upper parts of stellar atmospheres and those of planets, and, in accordance with this theory, even planets ought to emit cathodic rays, and present in a slight degree, the phenomena of cometary tails.

Mr. Denison was then called upon to deliver his lecture on

OUR ATMOSPHERIC OCEAN.

Mr. Denison began by explaining the construction and use of the various instruments in use in the meteorological service and showed diagrams of these. Then followed remarks upon the primary circulation of the atmosphere and the general upper poleward drift; the return surface current opposes the upper drift and sets up secondary movements, which are again divided into cyclonic and anticyclonic. A series of diagrams projected on the screen served admirably to illustrate the atmospheric currents, while several specially prepared slides of the weather charts showed how storms pass over the North American Continent, areas of high and low pressure being marked by the irregular curves of the barometric readings. Several of these slides represented recent storms, remembered by most of the audience, so that they were particularly interesting. The effect of atmospheric waves upon the surface of our lakes was also shown, and a diagram of the extremely sensitive instrument set up at the mouth of the Humber river, recording most minute changes in lake level, was projected on the screen. The series of slides included several comparison tracings of the instrument records at the Humber and at the Observatory ; the extreme delicacy of the former being very easily seen.

In referring to the changes of atmospheric pressure and their results, Mr. Denison stated that these had quite recently been shown to have a direct influence upon the muscular activity of animals. An ingenious apparatus was described which had been devised for the special purpose of recording what may be called the "curve of activity," and slides illustrating these were shown.

An interesting discussion followed the lecture and the exhibition of the slides. The hope was freely expressed that Mr. Denison would be able to continue the very valuable original work on which he had been engaged. The President called special attention to the instruments which the lecturer had himself devised and which it was certain would be found of good service on the Pacific coast whither Mr. Denison was shortly to proceed.

A hearty vote of thanks was accorded Mr. Denison, coupled with best wishes for success on the Pacific.

THIRTEENTH MEETING.

July 12th ; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

An interesting communication was received from Dr. Ludwig of Port Dalhousie, in reference to the forming of a society in that locality. The corresponding Secretary had replied to Dr. Ludwig and given him some information as to the manner in which other branch societies were conducted, and assuring him of the hearty support of the Toronto Society. Mr. Arthur Cottam, F.R A.S., wrote in reference to his star chart, the terms of sale of which had been reconsidered.

Among predicted phenomena was noted a close approach of Mercury to Regulus on the evening of July 27th. Attention was called also to the remarkable announcement by Herr Waltemath, that a second satellite to the Earth would be seen to cross the disc of the Sun on July 30th. While there was no astronomer of note who had any belief in the existence of this object, it was still thought to be due to the self-styled discoverer that observers be made acquainted with what he had announced.

In reporting observation Mr. G. G. Pursey stated that since July 1st, the Sun had been perfectly free from spots. Observations of Jupiter and Saturn were reported by Mr. R. Wallace. The President stated that there had been an earthquake disturbance recorded at Toronto Observatory on May 28th, at 3 p.m. The trace had been shown him. This differed from other traces in a marked degree; thought to be due to distance traversed by the wave. In this case probably the origin was in Japan.

Considerable correspondence and several reports from members were received relating to a remarkable meteor which was widely seen in Ontario on the evening of July 5th. This had been the most noticeable object of the kind ever recorded in Canada except possibly a meteor described by the late Mr. Chas. Carpmael as having been seen on July 3rd, 1884. The President stated that he was now analyzing the correspondence and would present to the Society at an early date a summary of the whole with a view to tracing as accurately as possible the path of the meteor and determining details of its form, etc.

Mr. Geo. E. Lumsden then read, by special request, the following paper on

A POPULAR ASTRONOMICAL OBSERVATORY.

The expediency of establishing and maintaining a popular astronomical observatory at Toronto, is a subject which may be discussed under two heads, arranged as questions:—

"Of what may a popular observatory consist?" and

"How may such an observatory be acquired and maintained?"

We shall simplify matters if we clear the ground by stating that a popular observatory to be a success must be intended for instruction only and not for research, at least not for research that demands very powerful telescopic assistance. Except in certain branches, original research may be left to great refractors and reflectors, remote from the smoke and heat of cities, the glare of electric lights, and the vibrations of rushing trains. Large instruments are sadly out of place in the immediate neighbourhood of cities, and are useless for the purposes of popular instruction. At seats of learning fully equipped for astronomical observation, the practical, every-day work is done with telescopes of moderate aperture, though more powerful instruments be available.

Every astronomical observer finds himself beset by two classes of local conditions, which must be taken into account: meteorological and atmospherical. The former class has to do with the clearness of the skies; the latter with the steadiness of the air. The one may keep the observatory closed, the other, to a greater or less degree, may interfere with sharpness of definition.

If the meteorological conditions at Toronto were such that telescopes could be used every night, one might be able to be more patient under the pressure of a demand in certain quarters for large instruments. But the records of the Observatory show that, in every year, the percentage of cloudy skies at Toronto is always greater than the percentage of clear skies. In 1896, the last year reported, there were but three months in which the clear weather was even slightly, if at all, in excess. The average of cloudiness in 1896 was 60 per cent.; in 1895, 57 per cent.; in 1894, 60 per cent.; in 1893, 59 per cent.; in 1892, 61 per cent.; in 1891, 59 per cent.; and in 1890, 62 per cent. The average for the past forty-three years was 61 per cent., so that 1896 was not a very bad year. During that year, however, 55 days were entirely clouded, and, of the 365, there were only 74 which could be reported "fair," a term which does not indicate that the skies were even clear. If, therefore, we are to make the most of our opportunities, we must have recourse to small telescopes, which are less exacting as to atmospherical conditions, and can be used during nights when, by reason of haze, cloudiness and air-currents, large instruments must perforce stand uncovered in their domes.

The atmosphere is ever in a state of unrest.* Terrestrial objects radiate heat, which rises in waves and floats with the wind. Vapours and air-currents possess peculiar properties of refraction. By them, celestial objects are distorted. Outlines suffer from tremors and a rippling effect technically known as "boiling." The larger the telescope the more are these atmospherical disturbances magnified and exaggerated. When present even in a slight degree, they are troublesome. When pronounced and persistent, the only value of great light-gathering power is counterbalanced, if not destroyed. Images must be well defined;

* See, generally, "*Telescopic Work for Starlight Evenings,*" by W. F. Denning, F.R.A.S., p. 20, *et seq.*

mere brightness counts for nothing. Large telescopes are invariably designed for the discovery of unknown orbs. But obstacles of a grave nature too frequently confront the observers who use them. The comparatively tranquil and sharply defined images seen in small instruments are not present in very large ones. Objects are much more brilliant, but are involved in glare, and subject to constant agitation. The finer details are often obliterated. Another serious difficulty is due to the flexure, or "sagging," of the heavy discs forming the object-glasses or mirrors of great telescopes. For these reasons, there have been many failures. The list of "disappointments" includes the Lord Rosse 6 and 3-feet reflectors, which, owing to the climate, can be used "at their best" only during a few hours annually, and the 4-foot Paris reflector, which, on the average, can be employed advantageously not more than one night in the year. The Herschel 4-foot, the Lassell 4-foot, and the Melbourne 4-foot reflectors, and the Vienna 27-inch, the Leander McCormack 26-inch, the Washington 26-inch, the Gateshead 24-inch, the Princeton 23-inch, and the Nice 30-inch refractors have not, by any means, realized anticipations. Usually, observers with these instruments are conscious that the advantage gained in light has been lost in definition. On rare occasions, perhaps once in fifty times, results are different. The atmosphere is approximately at rest. Objects are sharply defined, as in smaller telescopes. The astronomer realizes that his instrument, though generally ineffective, is itself not at fault, and that it would do valuable work were the conditions of the air always, or more often, suited to the exercise of its full powers. Dr. Kitchener, after testing 51 instruments, held the opinion that large telescopes were as useful as the enormous spectacles suspended over the doors of opticians, and asked, "What good can a great deal of bad light do?" His conclusion was that amateurs of Astronomy should seek perfect, rather than large, telescopes. Prof. Young, of Princeton, who has charge of the great refractor of the University, probably said for large instruments as much as could be safely said, when he wrote: "I can almost always see with the 23-inch everything I see with the 9½-inch under the same atmospheric conditions, and see it better; if the seeing is bad, only a little better, if good, immensely better." During the spring of 1885, Young, while observing with the 23-inch, was able only twice to use on Jupiter a power of 1,200 diameters, but he then succeeded in detecting delicate details in and near the Great Red Spot, and in seeing the true forms of certain white dots on the belts of the planet. In perfect air his telescope should easily bear a power of 100 to the inch of aperture, or a power in excess of, at least, 2,000, but, ordinarily, a much lower power than 1,200 must be employed. It is this absence, at most places, of proper atmospheric conditions which has driven several observatories to mountain heights, where the air is always pure and often free from cloud and vapour. Harvard College, which possesses the most complete observatory in the world, has a branch in the mountains of Peru. The Percival Lowell Observatory, at Flagstaff, Arizona, and the Swift Observatory in Southern California, are two others which claim to possess the advantages of clear mountain air.

Small instruments have done a vast amount of useful work in every field of astronomical observation. Even as to nebulæ, which require great space penetrating power, D'Arrest shewed what small apertures can accomplish. Every department is indebted, more or less, to common telescopes. Their good work is due to the efficiency with which they can be used despite conditions that very often render great instruments valueless. Nearly all the comets and double-stars were discovered with them. With the exceptions of the discovery of the moons of Mars, the fifth satellite of Jupiter and the motion of nebulæ in the line of sight, very little that is noteworthy, can, of late years, be credited to great telescopes. Herschel said that an object may be seen with less optical power than was required for its discovery. And this is true. Only after a long and arduous search, which would have been given up but for his wife, was Hall able to satisfy himself that Mars has two moons, though he employed the 26-inch telescope of the Washington Naval Observatory, the largest refractor then in existence. These moons, which had escaped Herschel with his 4-foot reflector, are now comparatively easy objects in a good 7-inch refractor. After a prolonged search, Barnard, using the 36-inch Lick telescope, espied the fifth satellite of Jupiter, but, once discovered, the moon was found to be visible in much smaller telescopes, including the 18-inch at the Dearborn Observatory, Chicago. Burnham's glory, as a discoverer of difficult double-stars, will be associated, not so much with the 36-inch at Lick Observatory, as with the 6-inch telescope with which, as an amateur, he whiled away his evenings, and with which he made discoveries which astonished observers with better facilities. Langley with a 13-inch made his reputation as a solar observer, and Dawes, one of the most successful amateurs in England, never used a telescope larger than 8-inches in diameter, and usually employed a 4-inch. Schiaparelli, with a 9-inch, discovered the "canals" of Mars, which some very reputable observers cannot see with telescopes two or three times as great in aperture. Satisfy all the conditions as to time, place, position and readiness she demands, and the first-class battleship becomes a terrible engine of destruction, but under average conditions, the trim cruiser can fight all around her, and go where she dare not. At Alexandria, Admiral Seymour, on his flag-ship, was compelled to stand off in deep water, while Charley Beresford, on the *Condor*, ran in shore, silenced the batteries, and did effective work. Satisfy all the conditions as to sky and air that it demands, and the giant telescope becomes a powerful accessory of the astronomer, but instruments of one-half, or even one-third of its size can, under average conditions, do effective work while it must stand idly by.

An observatory which would answer very perfectly the popular purposes in view, may, in the writer's opinion, consist of a low, rectangular frame building, equipped with several telescopes of moderate aperture. So far as a building is concerned, all that is absolutely required is a structure which will protect instruments from weather and from dampness. There can scarcely be a greater mistake than that of mounting a telescope in a small building of heavy stone, or brick. It is impossible to maintain the temperature inside and the temperature outside of such an observatory at the same height, an indispensable requisite, if the telescope is to give satisfactory definition, at least, as soon as it is placed in use. Except on account of dampness, which has a tendency to rust its polished metal parts, it would be best to leave every telescope out of doors, because then the temperature of the air and of the telescope would always be uniform. This uniformity allows the instant use of an instrument at any favourable moment. As is well known, glass quickly responds to changes of temperature, expanding under the influence of heat and contracting under that of cold. Owners of dome-protected telescopes, after uncovering them, are compelled to wait, often through annoying intervals, until the various lenses have cooled sufficiently to enable them to recover their true forms and give the best results. Some astronomers allow their telescopes no other protection than canvas affords. Others do not hesitate to leave their instruments in the open air, unprotected save by a heavy coat of paint.

Under ordinary circumstances, the temperature within a stone or brick observatory is some degrees, and in warm weather many degrees, higher than the temperature outside. When the shutters of the dome are opened, counter air-currents are set up, as a matter of course. While these continue, fine definition is simply impossible of attainment—even if the optical parts are in a normal condition. The difficulty, in this respect, is further increased if a telescope, as is often the case, be perched in the top of a tower with an inner stairway leading to it.

A low frame building can be made roomy, cool and convenient. Ingress and egress would be easy; there would be no stairs to climb and visitors, as well as observers, could move about freely and with comfort. If sufficiently large, the building could, without much additional expense, be made to provide necessary rooms and even a public hall for small audiences. A rectangular structure would furnish corner spaces for four domes, under which could be set up at once, if funds allowed, one first-class refractor of, say, eight or ten inches aperture for solar and stellar work, and two first-rate reflectors of, say, fifteen or twenty inches aperture, for lunar, planetary and photographic work, the remaining dome to be reserved for a transit instrument. Great observatories are exceedingly expensive to erect, equip and maintain. Each of them swallows up several average fortunes. On the other hand, it is possible to erect, equip and maintain a popular observatory at a cost which, comparatively speaking, would be a mere bagatelle. For instance, a first-class Brashear or Alvan Clark 8-inch refractor can be bought for $2,600; a 10-inch for $3,300, and a 12-inch for $6,000. A Brashear reflector, of the highest quality, and 12½ inches in aperture, would cost $1,550; a 15½-inch, $2,000, and a 20-inch, say, $3,000. Its mounting is often a very expensive part of a telescope, especially if it be of moderate size; this is always true if the instrument is provided with circles engraved on silver, and with other, partly necessary and yet partly luxurious, conveniences. For a popular observatory, great refinement of equipment is not really needed. If omitted from the instruments mentioned, their respective prices would be materially reduced. A 3-inch transit would cost $1,000, a chronograph $400, and necessary clocks $500 more. To these could be added a photographic-doublet, costing about $350, and a spectroscope costing somewhat less. If a site could be secured, $10,000, certainly less than $12,000, would be a sum sufficient to put up the building and set in working order by far the best popular astronomical observatory on the continent. If arrangements could be effected by which such an observatory would be taken over by one of the Universities as some return for its use for the purposes of instruction, the maintenance need be of small cost, as the director, himself a professor, could derive ample assistance from his staff and students.

The writer's view has been that, from the standpoint of the public interest, it is better to expend a comparatively large sum upon several instruments of small aperture than upon a single instrument of large aperture. This he knows is, popularly speaking, the view of a heretic. But for the information of those who, in good faith, differ from him, he must add that the cost of large telescopes, whether refractors or reflectors, grows by leaps and bounds as aperture is increased. For instance, as has been shown, a complete 12-inch refractor may be purchased for $6,000, yet the two 36-inch glass discs for the Lick telescope, alone and unmounted, had cost $50,000 before they left the workshop; the incidentals connected with the mounting and housing of the telescope were all extra, and have absorbed nearly $700,000. Reflecting telescopes are, relatively, very much cheaper. The 20-inch reflector, already referred to, would cost $3,000, and, all things being equal, would be an instrument superior to the 12-inch refractor costing $6,000, a sum that would itself go a long way towards paying for a 30-inch reflector, which, when the elements permitted, would do superb work, and would bring to Toronto, even as a matter of possession only, credit and renown. The mounting and housing of these instruments would require additional expenditures of money on a scale rapidly increasing in proportion to size of aperture, but still moderate as compared with those of refractors. On the ground, among others, of expediency, the writer has consulted several directors whose testimony cannot be questioned, some of them having, or having had, charge of telescopes of the largest size and of the highest excellence. These gentlemen all agree that for usefulness and, certainly, for the purposes of instruction and popular work, an observatory similar to the one above described is undoubtedly best. Dr. Keeler, the eminent spectroscopist, now director of, and for the second time connected with, the Lick Observatory, writes as follows:— " My experience with visitors is that they prefer one large telescope to a number of small ones. They may *see* better with the latter, but it is the size which attracts and satisfies them. Perhaps it is not worth while to humour a notion having so mistaken a basis." Dr. Keeler may have been reflecting upon scenes said to be witnessed on Saturday nights at Lick Observatory and described some years ago by Mrs. Proctor, who has counted as many as two hundred persons waiting their turn to look into the great telescope. One minute's time only was allowed to each visitor. Without practice, this is an opportunity certain to be wasted. Unless one knows what to look for and how to look for it in a telescope, little can be done in one minute. Dr. Holden and his assistants endeavoured to reduce to a minimum the disappointment often felt by visitors, but after the trials attending a long drive over a mountain road, and an enforced return at night by stage to hotels fourteen miles from the Observatory, the disenchantment in cases, must have been complete. A gentleman, who was no astronomer, but who had been induced by curiosity to make the long journey to Mount Hamilton, told the writer that on one of these occasions all he was able to see was "the planet Mars shining like a red-hot plate." But how different was the result under other circumstances—the crowd being away, the conditions being good, and the time of the observer being at his own disposal! Mr. Serviss, the author of that charming book, "*Astronomy with an Opera Glass*," has described to the writer the delight he experienced when, in company with Prof. Barnard, he was permitted to observe, at his leisure, and with the great telescope, the fifth satellite of Jupiter, an object up to that time, December, 1893, seen, perhaps, by less than a dozen human beings.

So much as to what a popular observatory may be, and now as to the sources from which to provide for and maintain such an observatory.

There are various sources. There is the general public. There is private munificence. There are our universities, which are teaching institutions of which much is expected, and which might take up the matter wholly, or in part with the assistance of the public, a society, or a company, or, as is the most popular way in the United States, of money supplied by wealthy men desirous to assist in disseminating useful knowledge among their less favoured fellow-citizens. The ideal public observatory would be an observatory equipped and maintained as the public library is equipped and maintained, that is, at the public charge, so that every ratepayer, under certain conditions, might enjoy equal rights of admission, if he chose to exercise them. This suggestion may seem to be odd, but such a suggestion will not always be odd. The day may not be far distant when even Legislatures will authorize, if not require, school boards to provide astronomical instruction for the young. There can be no harm, at least, in permissive legislation, similar to that respecting libraries. The cost distributed over a municipality would be very inconsiderable, while the benefits to be derived would be very considerable. The day has come when no seat of learning, certainly no university, or college worthy of the name, can afford to treat Astronomy and the physics related to Astronomy with disdain, real or affected, or to remain unable to gratify students who take, or could be induced to take, an intelligent, practical interest in the science, but who are deprived of work at the telescope, the charm of which is beyond expression. No man can boast a liberal education and, at the same time, be ignorant of the fundamental principles of Astronomy, a science whose influence, especially on its practical or observational side, has a wholesome, animating, and elevating tendency. As years pass, more and more time is devoted in Europe and in the United States to this subject, not that every man shall be an astronomer, but that he shall have the opportunity, if he choose, to make some acquaintance with the science. The apathy in this respect now marking educational institutions in Canada was once but too apparent in the United States. In 1825 John Quincy Adams was ridiculed in Congress for urging that a national observatory be founded. In 1832 Airy told the British Association that, so far as he knew, there was not one observatory in the Republic. Airy's remark, however, was not without effect. Ormsby MacKnight Mitchell, then professor of mathematics and astronomy in Cincinnati College, it is true, partially for the purpose of increasing his own information, prepared and delivered a course of lectures which created sufficient local enthusiasm to bring into existence the Astronomical Society of Cincinnati, which, in a few years, numbered 800 members. Out of the pioneers, Mitchell, at the very start, formed a joint stock company with a capital of $7,500. This amount was subscribed in three weeks. Mitchell was sent to Europe for a telescope to cost $10,000. Though less than 12 inches in aperture, it was to be the largest on this continent. The instrument was eventually erected in a building whose corner-stone was laid by ex-President Adams, then of an advanced age, and as the last public act of his life. Mitchell, full of enthusiasm, offered to act as director of the observatory for ten years without salary, depending upon his income from the college. Almost as soon as this magnanimous proposal was agreed to, he was driven again to the lecture platform, fire having destroyed the Cincinnati College and, with it, his means of livelihood. But Mitchell's personal loss was the country's gain. His manly eloquence and sterling qualities as an exponent of science secured for him crowded audiences in all parts of the States, and especially in the east. The results were really astonishing. In ten years ten observatories had been erected and opened. In 1882, fifty years after Airy's comment, there were 144 in existence. Now there may be 200, three of them outrivalling any others on the face of the Earth. Airy's praise of English munificence, such as it was in 1832, led to that munificence being exceeded one hundred fold in America. An enormous impetus and popularity were, by these means, given to the study of astronomy everywhere. Even women have vied with men in giving lavishly of their money for equipping observatories, for teaching the science in schools and for assisting in sending out scientific expeditions.

Several practical schemes, each differing a little from the other in the principle which has been worked out, may here be mentioned.

Returning for a moment to the Cincinnati Observatory, it may be stated that after languishing during the Civil War, Cleveland Abbé became its director. In the meantime, the city had encroached upon the observatory, and, a gentleman having come forward with the offer of a new site and $10,000 for a building, the proceeds of the old site, which was sold, were devoted to endowing a School of Art and Design in connection with the university, the city, as a condition of the gift, agreeing to sustain the observatory, which was also attached to the university. The State Legislature passed an Act requiring the Board of Education to assess and levy annually on the taxable property of the city not less than three-one-hundredths, nor more than five-one-hundredths, of a mill, a levy which, at the lower rate, though infinitesimal, yields annually about $5,000, a sum which has answered every necessary purpose. In a letter to the writer of this paper, the present director says the observatory is now an integral portion of the educational system of the city, and, in reply to an inquiry as to the method by which the observatory is conducted, adds: "Our present plan, which works well, is to admit visitors on twelve evenings in each month, these being selected by the director and furnished to the university office. Tickets are then issued gratis by the clerk to any one applying up to twenty for each evening. Sometimes the whole number will be taken for a single party, but more often two or three smaller parties are admitted on the same night. As nearly every one wishes to see the Moon, the public evenings are chosen from a couple of days after New Moon to Full Moon. There is no provision for school children, but the classes in Astronomy from the different schools often obtain permits and come under the same regulations as other parties. I have a special assistant to take charge of this work. Of course, students who take Astronomy in the university, have a little more freedom and have the theory and the uses of all the instruments explained to them. The public understand that the main object of the observatory is scientific research and that no privileges are granted which will seriously interfere with this." Here we have worked out the principle of the State recognizing an astronomical observatory as an integral portion of the educational system of a city similar to Toronto in many respects.

Take another instance, that of the Chabot Observatory at Oakland, California. This ideal public and educational institution, the result of private munificence wisely directed, has recently become a worthy monument to the memory of a worthy citizen. Twelve years ago Mr. Anthony Chabot, a wealthy resident of Oakland, a small city, was induced by several gentlemen, including the school inspector, to found a popular observatory which, on completion, was presented to the School Board in trust for the city and was directed to be used to educate the general public and the pupils in the public schools. In 1892, Mr. Chabot was so pleased with the results of his gift that he donated a further sum, in all about $25,000, in order that the observatory might be rebuilt and improved. The frame building which was erected, in addition to other necessary apartments, includes a lecture-room, 20 by 30 feet in size. The equipment consists of an 8-inch Clark telescope, with micrometer and spectroscope, a mean-time clock, a sidereal clock, a sidereal break-circuit chronograph, a 4-inch transit, a complete set of meteorological instruments, and a seismograph for determining the direction and intensity of earthquakes. The lecture-room is fitted up with folding opera-chairs and table-rests, and two lanterns for the projection on screens of spectra and of slides. The rules governing the observatory are as simple as possible. Mondays and Tuesdays are set apart for high and grammar school pupils, Fridays for observations, and the remainder of the week for visitors and private schools. Admission is by card obtained from the school inspector, who is also the director, a happy combination which exists in another and much larger American city. The public attendance increased from 1,644 in 1886, to 2,240 in 1892, the year of rebuilding, since which event it has been found to be impossible to keep an accurate record, but the estimated annual attendance is not less than 5,000.

Take, from many which could be cited, another case where intelligent generosity has asserted itself to some purpose, that of the Smith Observatory, Geneva, New York, the director of which is the famous discoverer of comets, Prof. W. R. Brooks. In this instance, a retired capitalist, desiring to do something for his fellows, erected, in his spacious grounds, a residence for his director, and an observatory in which he mounted a 10-inch Clark telescope, a 4-inch transit, the necessary clocks, etc. Mr. Smith's purpose in erecting the observatory was announced to be "the increase and diffusion of astronomical knowledge." Hence, the public is welcomed every clear night, and all-comers are instructed by Mr. Brooks, who shows them fine views of celestial objects. Visitors come from Geneva itself, from the surrounding towns, and from all parts of the country, and, as Prof. Brooks says in a communication to the writer of this paper, "freely express their thanks and appreciation for the rare privileges afforded them." Illustrated lectures are given to the public and to the schools.

The last instance to which your attention shall be invited is that of the Gesellschaft Urania of Berlin. This scientific society was founded in 1888 as a joint stock company, with a capital of 300,000 marks, about $100,000. In 1896 there were nearly 400 shareholders, who possessed a fine two-storey building, fitted with all sorts of astronomical and physical apparatus, and erected in one of the public parks on a site presented by the Government. Shareholders have free admission to all the spectacular and special exhibitions and receive a copy of the magazine, "Heaven and Earth," published by the society. The success of this purely scientific undertaking has been phenomenal and, notwithstanding the necessarily great initial outlay and some difficulties, not anticipated by the founders, is now on a paying basis and in possession of a fine property. From the report for the year ending March 31st, 1894, the last in possession of the writer, it may be gathered that 25,210 family tickets were issued (5,043 to new applicants), and that the public attendance, which reached 117,617 paying visitors, included 26,400 visitors on special occasions and 10,000 pupils from the city schools. The income derived from all sources was more than $30,000. The astronomical equipment includes one reflector and the following refracting telescopes: one 12-inch, one 6-inch, one 5-inch, and one 4-inch. Complete details may be obtained from the literature issued by the Managing Committee.

We see what is being done in Europe and in the United States by public spirited men and women. Their example can and ought to be followed in Canada. In the United States, from the very public schools of the higher grades to the most ambitious colleges, there is rivalry in this field. The great universities are vieing, each with the other, in the splendour of their astronomical and astro-physical equipments, due, in some part, to the open-handed generosity of opulent men desirous to see in their own day some of the results of munificence wisely directed into popular educational channels. Munificence of this kind is royal, whether the patron be prince or private citizen. Science owes much to munificence, and nobly are her professional votaries striving to repay the debt. Her scrolls are rapidly filling with names illustrious by gifts. The glory of the Ptolemies is associated with patronage of literature and science. When all else that he did shall have been forgotten, it will be remembered that Frederic II. of Denmark, was the friend and protector of Tycho Brahé, and while the name of the astronomer lives, so shall that of his king. The name "Lick" will never be blotted from the page of Astronomy. If munificence becomes princes, how much more does it become rich men who, in giving, are giving that which is theirs by right of their own energy and thrift.

So far, munificence has done nothing in Canada for Astronomy. Not a public telescope pierces the Canadian skies, pure as those of more favoured lands. But the day is coming when this reproach will be wiped away. When once they understand the needs of learning, wealthy men will come forward with substantial assistance. We are hopeful for the future. There *is* a demand in Canada for astronomical knowledge, and that demand will be supplied.* So far as Toronto is at present concerned, the interests of observational astronomy are practi-

* Since the above was written, it has been announced that Mr. Wm. Macdonald (recently deservedly knighted) has purchased twenty acres of land on Mount Royal, and that he will, on behalf of McGill College, Montreal, erect thereon and equip and endow a first-class astronomical and astro-physical observatory. As an evidence of the completeness of the equipment, it may be added that the principal telescope will be a 20-inch refractor of the highest quality.

cally relegated to this Society willing enough, but utterly unable to give full scope to its plans, conceived in the interest of the public. If this Society had the observatory and the apparatus it requires, it would give freely of its time and abilities to make the best use of the equipment. It is prepared to work with any corporation, or other body, or individual, who will submit and support any feasible scheme. Most of our members are beginners. Every one is a learner. We embrace all classes. Some of our members are teachers in the city schools, where they have practical experience that our otherwise laudable system is defective in that it causes neither the teacher nor the scholars to be taught anything worth knowing of Astronomy. Any member of this Society who has a telescope will vouch for the truth of the assertion that there are in this city and in this country many people who are intensely interested in Astronomy, and who wish to acquire sufficient practical knowledge to enable them to appreciate the descriptive statements contained in books and in magazines, and in the newspaper articles which, on special occasions, the best edited sections of the daily press supply to their readers. Children have sufficient imagination to be apt pupils in Astronomy. No youth ever refuses an opportunity to look into a telescope. During the last transit of Mercury, and the last partial eclipses of the Sun, groups of children were noticed, in many parts of the city, paying fixed attention to these events. This Society, alive to its duty, placed, on these and other occasions, in some of the schools, portable telescopes loaned by members, or by opticians. These were taken in charge by teachers, anxious to be of assistance to their pupils. One member of the Society, who, at his house, showed some bright boys from an adjoining school the planet Mercury on the solar disc, was well rewarded when he saw their countenances light up with intelligence as the phenomenon was explained to them, a phenomenon easy enough to explain under the circumstances. In a few moments the lads understood that which, without practical work, no elucidation could have made clear to their minds. Of lads like these, will come the Canadian astronomers of the future who, we may be sure, will prove to be the equals of any, once they have the opportunity to learn. At present they have none.

Comparisons are odious and should not be made. But let us, for the sake of contrast, conceive one of these lads, with locks then whitened by Time, standing here and addressing the Astronomical

Society of 1950 on the subject of the growth and cultivation of Astronomy in Canada, and speaking to an audience drawn from a city and from a country where the science shall be loved and cherished for its own sake, and where, instead of being neglected, as now, it shall be in as thriving a condition as anywhere else in the world. Fancy this successor of mine painting, in words, some such picture as this :—"Ladies and gentlemen, imagine, if you can, a civilized nation, whose shores were washed by three great oceans, but within whose coasts, when I was a boy, there was not one telescope worthy of the country, and not any instrument of any kind for the use of the public. Imagine, if you can, a Province claiming to be the brightest gem in an Imperial Crown, but in whose public schools the only instruction in Astronomy was limited to a few paragraphs scattered through the pages of the common school geography. Imagine, if you can, a metropolitan city of 200,000 people, asserting herself as the centre of the intellectual life of the land, and boasting the excellence of her academies and colleges, but without one class in Astronomy, or a single telescope. Imagine, if you can, two universities, in the Calendar of one of which the word 'Astronomy' was not to be found at all, and in the Calendar of the other it appeared only to refer to special work in the last year, the practical part of which could not be done on the university grounds for want of apparatus. Imagine, if you can, an examiner compelled to admit that he had set papers for fourth year men who, from memory, were able to explain the theories of certain instruments and describe their uses, but who would not have recognized them had they been shown to them, and could not have used them had they been placed in their hands." Nothing in this conception is to be understood as, in any manner, reflecting upon the Faculties of the Universities which, as is too well known, are crippled by want of funds, or upon the provincial head of our educational system, who cannot move faster than public opinion will allow. For that Minister it must be said that he came readily and cheerfully to the practical assistance of this Society, and those who have met him know how deep an interest he takes in the subject, and how much he wishes that matters, in respect of the science generally, were on a better footing in Ontario.

If it may be permitted to add a word upon the attractiveness of the subject we have at heart and which we, apart from any selfish motive, desire to see brought in a practical way within the reach of our people, the writer would crave to be allowed to close with the eloquent words once uttered by Mitchell of Cincinnati, who, whether as college don, whether as astronomer, or whether as general in the armies of his country, never flinched from duty. In cheering on the plodding student and in defending the spirit of inquiry and the interest which should be taken by the public in Astronomy, he exclaimed: "In this boundless field of investigation, Human Genius has won its most signal victories. Generation after generation has rolled away, age after age has swept silently by, but each has swelled by its contribution the stream of discovery. One barrier after another has given way to the force of Intellect; mysterious movements have been unravelled; mighty laws have been revealed; ponderous orbs have been weighed, their reciprocal influences computed, their complex wanderings made clear until the mind, majestic in its strength, has mounted step by step up the rocky height of its self-built pyramid, from whose star-crowned summit it looks out upon the grandeur of the Universe, self-clothed with the prescience of a God. With resistless energy, it rolls back the tide of Time, and lives in the configuration of worlds a thousand years ago; or, more wonderful, it sweeps away the dark curtain from the Future and beholds those celestial scenes which shall greet the vision of generations when a thousand years shall have rolled away. To trace the efforts of the Human Mind in this long and ardent struggle, to reveal its hopes and fears, its long years of patient watching, its moments of despair and hours of triumph, to develop the means by which the deep foundations of the rock-built pyramid of Science have been laid and to follow it as it slowly rears its stately form from age to age until its vertex pierces the very heavens; these are the objects proposed for accomplishment, and these are the topics to which I would invite your earnest attention. The task is one of no ordinary difficulty. It is no feast of Fancy, with Music and Poetry, with Eloquence and Art to enchain the mind. Music *is* here, but it is the deep and solemn harmony of the spheres. Poetry *is* here; but it must be read in the characters of light written on the sable garments of Night. Architecture is here; but it is the colossal structure of Sun and system, of cluster and universe. Eloquence is here; but there is neither speech nor language; its voice is not heard. Yet its resistless sweep comes over us in the mighty periods of revolving worlds. Shall we not listen to this music, because it is deep and solemn? Shall we not read this poetry, because its letters are the stars of heaven?

Shall we refuse to contemplate this architecture, because its archways seem ghostly from infinitude? Shall we turn away from this surging eloquence, because its utterance is made through sweeping worlds? No; the mind is ever inquisitive, ever ready to scale the most rugged steeps. Wake up its enthusiasm, fling the light of Hope on its pathway, and no matter how rough and rocky it may prove, ONWARD is the word which charms its willing powers."

COUNCIL MEETING.

July 19th; held at the residence of the President, Mr. Arthur Harvey, F.R.S.C., who occupied the chair.

On calling the meeting to order the President stated that the question of the establishment of a popular observatory was open for discussion. Requesting Mr. Vice-President Stupart, to take the chair, Mr. Harvey briefly stated his views, which were that an effort should be made with the assistance of the ladies of the Society to raise by popular subscription a sum sufficient for the purpose in view. Mr. Harvey then resumed the chair.

The provisional programme which had been presented at the previous meeting, was then read by the Secretary.

Mr. John A. Paterson reviewed the subject generally, and stated that in his opinion a system of canvassing for subscriptions would not succeed where the object was a scientific one. He differed from the President in this, while acknowledging his energetic action in bringing the question so prominently forward. Other members present then entered into the discussion. Mr. Elvins thought that it was only by the aid of the University of Toronto that the object could be accomplished. Messrs. Lumsden, Stupart and DeLury, were of the same opinion. Mr. DeLury spoke at some length to show that unless an observatory were directly connected with an educational institution it would be impossible to make it a success.

The President, while stating that he had not at any time proposed a house to house canvass, called for a formal expression of the wishes of the council.

Mr. Elvins then moved, seconded by Mr. Paterson, that the President appoint four members of the Society to confer with the authorities of the University of Toronto and the Minister of Education to discuss joint action in connection with the establishment of an observatory. This was carried.

The President at the request of the meeting then named as members of the committee, Messrs. Elvins, Paterson and Lumsden and Mrs. Craig.

Mr. Elvins then stated that in the meantime a step should be taken towards regular observation work, and moved, seconded by Mr. Sparling, that the alternate Tuesday evenings between the regular meetings be devoted to observation at the Technical School or other suitable place, and that Mr. Lindsay be appointed to take charge of the instruments and conduct the meetings, which would be open to all who wished to attend under regulations to be made. This was carried and the meeting adjourned.

FOURTEENTH MEETING.

July 26th; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

The report of the meeting of council held July 19th, was read and formally adopted.

Mr. J. W. Ney of Bracebridge, Ont., was duly elected an associate member of the Society.

The President announced that he had received several supplementary reports of the meteor of July 5th. It had been much more widely observed than at first supposed. Some discussion arose in regard to the sound of explosion of these bodies. Mr. J. Phillips remarked that in no case were the senses so easily deceived. A meteor might be seen to explode and one might easily imagine a sound when really nothing of the kind followed at all.

A piece of what was supposed to be a fragment of the meteor had been forwarded by Rev. Dr. Caswell of Meaford. This was examined closely, but the concensus of opinion seemed to be against its genuineness.

In reporting observations, Mrs. Geo. Craig stated that on July 13th, she had observed an aurora about 9 o'clock in the evening, and which she seemed to be able to identify as what had been seen as a cloud during the afternoon. Mr. Elvins had observed a similar phenomenon on July 19th, and had named it "a daylight aurora." He had learned that there had not been any unusual magnetic disturbance accompanying. A general discussion followed on the subject of daylight appearances of the aurora, after which the menbers spent some time in inspecting the annual volume published by the Royal Society of Canada. The beautiful reproductions of the Cabot maps were admired by all.

FIFTEENTH MEETING.

August 9th; the President, Mr. Arthur Harvey, occupied the chair.

Mr. Geo. Craig, of Toronto, was duly elected an active member of the Society.

A cordial letter was read from the Director of the Royal Alfred Observatory, Mauritius, who had kindly forwarded a copy of the *Annual Report of the Director* for 1896, and the *Magnetical and Meteorological Observations* for the same year. The Librarian was instructed to transmit copies of the Society's *Transactions* as published, and to convey the thanks of the Society for this valuable addition to its Library.

Referring to the meteor of July 5th, the President said he would require a further time to make a final synopsis of the facts. On a recent journey through Hastings county he had found nobody who had seen it, or knew of its being seen in the locality. The inference, therefore, seemed fair, that the easterly limit of its visibility was near Peterboro'. The substance said to have scaled off it, shown at the last meeting, though unlike other meteorites, was believed in the locality to be the material which had fallen, and further enquiry into this was needed on the spot, *i.e.*, a close examination of the witnesses to make sure they were not deceived themselves.

The Librarian's report, read by the Secretary, included the announcement of tbe receipt of Herr Leo Brenner's monograph on Mars, containing eighteen drawings of the surface made during the last opposition, and a map of the entire surface on a Mercator projection. The special thanks of the Society were due to the donor.

Mr. T. Lindsay then read a report of the first meeting for popular observation, held August 2nd. The weather had not been favourable during the early part of the evening, but towards nine o'clock the sky cleared and a very enjoyable time was spent. Several ladies, members and friends, were present. Mr. Lindsay thought there was no reason why these meetings should not be successful. The Moon was the special object on this occasion. There were three refracting telescopes of 3-inch aperture placed on the lawn.

The President reported his observations of Venus, markings on which were plainly visible in his 3-inch, though no details could be observed.

After some discussion the members adjourned to the lawn and spent some time in telescopic work.

SIXTEENTH MEETING.

August 23rd: the Vice-President, Dr. E. A. Meredith, occupied the chair.

Letters were read from Prof. Griffith, Assistant General Secretary of the British Association; from Prof. Brooks, of Geneva, N.Y., and from the Astronomer-Royal of Ireland. Mr. Griffith invited the Society to appoint a delegate to the Bristol meeting of the Association.

On motion of Mr. Lumsden, seconded by Mr. Elvins, it was decided to request Mr. W. F. Denning, F.R.A.S., to act as the representative of the Society.

The Astronomer-Royal had written Dr. Meredith to say that he had not been able to find any other record of the meteoric display of 1832 than the one published in the Society's *Transactions* for 1897, as given by Dr. Meredith himself.

Further business was curtailed in order to afford time to Mr. W. B. Musson, who by special request had prepared the following account of

A VISIT TO THE YERKES OBSERVATORY.

Having occasion to visit Chicago about the beginning of August, I determined if possible to avail myself of the opportunity to see the Yerkes Observatory, our President kindly agreeing to furnish me with a letter of introduction to the Director, Dr. Geo. E. Hale.

Upon arrival in Chicago, the intending visitor to the great telescope should proceed to the depot of the C. & N. W. R. R., and buy a ticket for William's Bay, Wis., a small town situated at the western end of Lake Geneva, about seventy-five miles from Chicago. A run of two hours and a half accomplishes the journey, after which a walk of one mile along a country road brings one to a pretty piece of woodland, and upon emerging from this the great dome of the famous observatory is seen rising from the clearing beyond.

The building is of the Romanesque style of architecture, is built of a stone coloured Roman brick, and presents an imposing appearance. A push of the electric button quickly brought a lady attendant to the door, and upon enquiring for the Director I was shown into an ante-room, upon the table of which were various evidences of photographic and spectroscopic work.

Dr. Hale received me with great kindness, and after a few moments' conversation conducted me to a room where he had been arranging a number of negatives showing the spectra of various stars of the fourth type. It was most interesting to note when the negatives were placed one above the other, the lines of identification running through the series, the most prominent of which is a bright line in the yellow. From this room we proceeded to visit the other departments of the observatory.

The general form of the building is that of a cross, the four points being terminated by the three towers and the meridian room. On the main floor are situated the lecture, computing, and reception rooms, the chemical and spectroscopic laboratories, the library, general offices, enlarging and instrument rooms.

We first visited the laboratories, where work with very sensitive radiometers and bolometers is now in progress. The problem specially engaging attention at the present time is that of trying to determine whether or not any heat radiations can be detected from the stars. Observations have been in progress upon Sirius and Arcturus, and it is almost certain that some results of a positive character have been obtained. The radiometer employed is probably the most sensitive ever used, and is capable of registering the heat of a candle at a distance of six miles. This work is carried on by Prof. Nichols in the heliostat room. This room occupies that part of the attic floor lying between the two small towers, it is 104 feet in length, and is provided with a sliding roof and walls which can be pushed back, exposing the mirror to the light of an object at the lowest declination.

Here we met Prof. Nichols who went to a great deal of trouble in explaining the apparatus in use. He is very enthusiastic over this investigation, and very sanguine of success. I might here remark that Prof. Nichols is not attached to the permanent staff of the observatory, but is spending some two months there for the purpose of conducting these investigations.

The heliostat is mounted upon a brick pier rising from the ground, and carries a flat mirror, silvered on the surface, from which the light is reflected to a 24-inch concave mirror of 8 feet focal length. This mirror was made by Mr. Ritchey—optician of the observatory. Here, also, is situated the very sensitive radiometer, the fans of which are of infinitesimal weight, and suspended by a fine quartz fibre produced by a special process designed by Prof. Nichols. This apparatus is in part the same used by Dr. Hale in some of his attempts to map the solar corona without an eclipse, by the aid of a bolometer. The heliostat at present in use is one loaned by Prof. Keeler, and has a mirror of 17-inch, though a much larger one is employed for the measure of stellar heat radiation. A new instrument, with a mirror of 24-inch aperture, is, however, being designed in the instrument shop of the observatory.

The ground floor contains the optical shop, physical laboratory, instrument shop, and photographic dark rooms. It is also intended to arrange a constant temperature room, in which the temperature can be maintained at any desired degree for months at a time, if necessary. Here, also, is situated the concave grating room. In the latter is now mounted a 4-inch concave Rowland grating of 10 feet focus, together with the necessary apparatus for producing the spectrum of any substance desired. Arrangements are also made whereby an image of the Sun, or of an arc light, may be thrown on the slit, and any desired apparatus used in conjunction with the grating.

From this room we proceeded to the optical shop, where we found Mr. Ritchey busily at work. Lying upon the grinding machine was the immense disk of glass from the works of St. Gobain, France. This disk, 5 feet in diameter, 8 inches thick, and weighing nearly a ton, is in a fair state of completion.

The large grinding machine is based upon the Draper model, but with some very important improvements. Two cranks with adjustable stroke give the required motion to the grinding tools, the mirror of course revolving beneath. The arms guiding the motion of these cranks can be lengthened or shortened at will, thus allowing any change in the position of the tools to be made whilst the machine is in motion, and modifying the stroke from a circle to an ellipse of any desired degree of eccentricity. As the grinding tools are very heavy, weighing several hundred pounds each, some means had to be devised for controlling the pressure. This was accomplished by a system of counterpoising, which allows the adjustment to be made to a nicety.

Mr. Ritchey is highly pleased with the result, and considers it a very important feature of his machine. Another very great improvement consists in the mounting of the glass disk upon trunnions. This allows the figure to be tested by the Foucault method without removing the glass from the machine. In dealing with disks of such great weight this is almost indispensable.

Every precaution has been taken in this room to avoid trouble from dust, and the walls are lined with a double thickness of building paper, having air spaces between, in order to secure as far as possible, constancy of temperature.

Mr. Ritchey uses eight grades of emery between the flour and the polishing, and finishes off quickly with a polisher of resin and beeswax. This is a slightly different plan from that adopted by Dr. Brashear, who uses fewer grades of emery, and takes longer in the final polishing.

When completed, this five foot mirror will be mounted equatorially, and used for astro-physical investigations.

The machine shop contains lathes, drill press, planer, milling machines, and various other pieces of machinery. The Director informed me that the advantages arising from having their own instrument shop were almost incalculable. Repairs can be made quickly, and apparatus modified in the course of construction as desired.

The next visit was to the north-east tower. In this dome is mounted the 12-inch refractor, formerly in use at the Kenwood Observatory. This telescope is furnished with two objectives by Brashear—one visual, and one photographic. When it is desired to transform the instrument into a photo-heliograph the photographic objective is attached to a side bracket at the upper end of the telescope.

We now proceeded to the other end of the building, and in another moment were in the huge dome of the great 40-inch. This dome is sixty feet high, and ninety feet in diameter. It is quite unnecessary for me to give any description of the telescope itself, as you are all familiar with it. Its sixty-two feet of focal length certainly produces the impression of a giant instrument. A photographic lens and enlarging camera have here also been attached to the tube.

Busily at work, making micrometrical measurements of the disk of Venus, was Prof. Barnard, the famous discoverer of the "5th Satellite." Dr. Hale favoured me with an introduction, and I had the pleasure of spending some considerable time with him in the dome, and afterwards in his office, where he showed me a large number of his photographs, and discussed many questions of interest. Prof. Barnard's conversation lead me to the conclusion that so long as amateurs work earnestly and carefully, they may expect every encouragement from the *professional* men.

Whilst upon this subject, I might say that Dr. Hale impressed upon me the fact, that if our Society desired to attain the greatest degree of usefulness, it is very desirable that its members should choose each some special line of work, and follow it up persistently and systematically.

Prof. Barnard invited me to meet him in the dome again in the evening, which I did, and had the pleasure of a view of Saturn, and of one or two star clusters.

The seeing was, unfortunately, very poor, so it was quite impossible to form any opinion as to the power of the instrument to show planetary detail. Its light-gathering qualities, however, were well demonstrated. The powers used were as high as 460.

I also had the very great satisfaction of watching Prof. Barnard at work on his micrometrical measurements of the positions of stars in cluster No. 5 M., and was favoured with several views of this object, which must be superb on a fine night.

The following morning I enjoyed a further conversation with Dr. Hale, and looked over a number of his negatives of solar spots, prominences, and faculæ, of which there are some 3,500. These negatives were extremely interesting, several of them showing enormous areas of disturbance, which would have been impossible of detection by visual means. In two instances eruptions on sun-spots had been photographed. Dr. Hale thought these were, in all probability, "end-on" views of prominences. Such photographs are extremely rare.

An instrument is now being devised for determining photographically the different rates of motion of different elements in the prominences.

While discussing the subject of instrumental power with Dr. Hale, he expressed himself very strongly in favour of very large reflectors (say ten feet diameter) for spectrographic work. He thought great results might be expected from the use of such instruments. For all round work he considered refractors the best, but thought the telescope should always be chosen to suit the special class of observations it was intended to pursue.

The principal work intended to be carried on at the Yerkes Observatory includes visual and photographic studies of the solar spots, faculæ, chromosphere, and prominences, bolometric, and photometric investigations, micrometrical observations of double stars, nebulæ, and planets, general photographic work, and researches in stellar spectroscopy, also laboratory work of various kinds.

A 24-inch reflector, now nearing completion in the observatory instrument shop, will soon be placed in the south-east tower. An additional building has also been erected in the grounds with a light dome, in which will be placed an equatorially mounted portrait lens for photographic work on the milky way, nebulæ, and comets.

After taking leave of the Director, I returned to Chicago, where I had the very great pleasure of meeting Prof. Burnham. This gentleman received me with the utmost kindness, and I spent some two hours in his company with the greatest pleasure and profit.

In conclusion, I desire to express my sense of the extreme courtesy and kindness extended to me by Dr. Hale, by Prof. Barnard, and all members of the observatory staff, whom I had the pleasure of meeting.

A lively discussion followed the conclusion of Mr. Musson's paper. The opinion was freely expressed that the authorities of the Yerkes Observatory had conferred a favour on the whole Society in having so kindly entertained its representative. The Secretary was requested to convey to the Director an expression of this general feeling.

Mr. J. Phillips then delivered, by special request, a short lecture on Parallax. The subject was treated in a most lucid manner, the mathematical formulæ involved being clearly explained, with the assistance of numerous diagrams. Mr. Phillips dealt with the Moon's parallax and gave all the details of the calculations by which the distance of that object is determined. He was requested to prepare for future meetings similar papers on stellar parallax and related problems, to form a series of short mathematical papers, instructive to all studying practical astronomy.

SEVENTEENTH MEETING.

September 6th; Mr. G. G. Pursey, occupied the chair.

Letters were read from Mr. Arthur Cottam, F.R.A.S.; the Ward Institute, of Rochester, N.Y.; and from Mr. Geo. Papps, of Hamilton, Ont.

Mr. Geo. E. Lumsden stated that he had had a brief visit from Dr. Brashear, of Allegheny. The chief subject of discussion had been the notable aurora of September 2nd. Dr. Brashear had not been able on this occasion to meet the members of the Society, his time not permitting. This was much regretted.

The Corresponding Secretary introduced the subject of representation at the Bristol meeting of the British Association for the Advancement of Science. It was explained that owing to the brief notice received action had to be taken before the Society could meet, and that, after consultation with members of the council, the following letter had been sent to Mr. W. F. Denning, F.R.A.S., who, it was hoped, would be able to represent the Society at the meeting referred to:

TORONTO, August 24th, 1898.

DEAR MR. DENNING,—After the meeting of the British Association in Toronto, the subject of becoming a Corresponding Society was mooted, and from time to time was under the consideration of this Society, its hope being that, at the meeting at Bristol, itself a seaport town, and for centuries a centre of ocean-going shipping, an opportunity would be afforded of presenting a paper or taking further action with respect to the Unification of Time at Sea, a matter which this Society, in connection with the Canadian Institute and the Royal Society of Canada, has been actively promoting for some years, and which it brought before the Association last year.

Somewhat unfortunately, certain members of this Society could not, apparently, rid themselves of the impression that the Association, at its meeting here, by no means did what it might well have done for the advancement of a movement which, in the opinion of hundreds of astronomers and navigators, is in the interest of ocean commerce and seamen. Nor could they understand why the chief representative body of the first commercial power should have hesitated, as it did, or should have put forward such a plea for inaction as that its astronomical members were not in attendance at Toronto, and could not advise.

However, a formal application was made, with the intention of going on, and of asking you (if you had no objection) to read a paper on the Unification of Time, drawn up and based on new material. But when the printed matter supplied by the Committee on Corresponding Societies arrived and was examined, it seemed, from the absence of their names on the list, either that the Association did not care to establish relations with British Astronomical Societies, or that the Astronomical Societies had, for reasons of their own, held aloof from the Association. As a result of the circumstances I have mentioned, no further action was taken, and thus matters stood until a few days ago, when I received from Mr. Griffith (the Assistant General Secretary of the Association) a kindly letter, stating that this Society had been placed on the list of Corresponding Societies, asking for papers published since June, 1897, and requesting the appointment of a delegate to attend the meeting of the Association to be held at Bristol.

Upon submitting the matter to the Society last evening, a resolution was adopted, approving of its election as a Corresponding Society, and appointing you to be its delegate, if you find yourself able to act; if not, I was authorized to request Mr. B. E. Walker, F.G.S., General Manager of the Canadian Bank of Commerce, Toronto, and President of the Canadian Institute, who will be at the meeting, to exercise his good offices in our behalf; this being the suggestion of Mr. Griffith, who was not aware that we had a member in Bristol, and who knew that Mr. Walker was in Europe partly for the purpose of attending the Bristol meeting.

Owing to the lack of time, the Society will not be able to furnish a paper to be read before the Association, or to suggest a line of action with respect to any matter which has occupied its attention. It may, therefore, prove that your duties as delegate, if you accept the position, will be perfunctory in character. Nevertheless, I can assure you that it will be no small matter of congratulation among the members of the Society if it should prove that you have taken charge of its interests before the Association.

I have deemed it proper to be frank with you, so that you may understand the situation. I do not know that they will be of any use, but I have sent to you under separate cover a copy of our last Report, and certain printed matter dealing with the subject to which I have referred.

The sending of the letter was formally approved of by the Society.

The Chairman reported observations of the large spot then upon the Sun's disc, and which he thought was the largest seen since 1893.

The report of the observation meeting of the previous Tuesday evening was then read :—

It had been announced that at this meeting there would be an opportunity to observe the occultation by the Moon of θ Aquarii, a star of 4·4 magnitude. Preparations were therefore made to observe accurately. Several visitors and members were on the grounds. Mr. Wallace's watch was taken over to the Observatory, where Mr. Davidson kindly compared it with the standard clock and gave us the correction. We had four telescopes: the Dollond of the Observatory, and three others. The time predicted for the occultation was 8h. 37m. 37sec. standard time. That being early in the evening there was just time to show all the friends present the Moon coming up to the star. They could thus understand just what we were looking for. All saw the star easily in the telescopes. It was not visible to the unaided eye. As the time approached, Mrs. Craig held the watch and counted the seconds. At the moment of disappearance, which was instantaneous, as observed in the Dollond, Mrs. Craig noted the time, and on making the necessary correction, it was found to be as nearly as possible to the predicted time. A revision of the calculations has shown that at 8h. 37m. 37sec. the conditions for immersion were almost exactly filled.

The Secretary then stated that he had received from Mr. Arthur Harvey, President of the Society, the following summary of reports regarding

THE METEOR OF JULY 5TH, 1898.

The Society has received a great many accounts of the remarkable meteor which was seen by hundreds of persons at various points of the western peninsula of Ontario at about 20.40 o'clock on July 5th. A summary is given of the most interesting and exact. These accounts are arranged in geographical order, from east to west, and it will thus be seen that the meteor first appeared to the north of Belleville, vertically over Blairton, at such a height—perhaps 120 miles—that it could be seen from Geneva, N.Y.—20 miles south of Lake Ontario. It moved almost due west, passing a little north of Peterborough and Barrie, immediately over Stayner, and a little to the south of Meaford and Collingwood. When over Lake Simcoe it came near enough to the Earth to allow of the noise it caused being distinctly heard, and it was in strata of air sufficiently dense to hasten its disintegration and lead to final explosions. If any important fragments remained in being, they fell in Lake Huron. Further discussion of some of the principal points involved will be attempted in the President's annual address.

PETERBOROUGH.—Between sunset and dusk my attention was attracted by a bright light at an elevation of about 60° to the west. I at first mistook it for the last effort of a rocket, and looked to see it burst, but as it increased in brilliancy and descended slowly towards the Earth, I suddenly understood that I was looking at one of the most beautiful meteors I could ever hope to see. It flamed in my view for at least six or seven seconds, and descended obliquely to the westward, leaving behind it a trail of whitish grey vapour which I watched for seven or eight minutes as it slowly gathered up and disappeared in the dusk. The trail of smoke or vapour was left in a zigzag line behind the meteor and afterwards appeared to dissolve very slowly.—*G. A. Stathem.*

BELLEVILLE.—A brilliant meteor passed over Belleville and was observed by a number of citizens. From the centre of the city it seemed to pass over Albert College.—*Belleville Sun.*

BEATRICE, MUSKOKA.—I did not see the meteor myself, but the light from it was sufficiently great to cast a very distinct shadow of the window frame on the floor of the kitchen where I was at the time. Our hired boy was outside and saw it. His description is a large ball of fire (red), with a long tail of fire, falling on a slanting direction from east to west. When apparently a little above the top of the trees it burst asunder into many pieces, with a noise sufficiently loud for him to hear it distinctly.—*J. Hollingworth.*

(Mr. H., on being written to, gives exact particulars of the movement of the shadow, the height of the window and the size of the kitchen, from which it is calculated that the meteor was about 50° above the horizon when first seen.)

SMITH OBSERVATORY, GENEVA, N.Y. (from the *English Mechanic*).—A really magnificent meteor was observed here this evening, while it was still high twilight. It was very large in apparent diameter, about one-half that of the Moon, and intensely bright. It slowly descended the western heavens, at an angle of thirty degrees from the perpendicular, leaving a trail of white light, at first straight and equal in breadth to the diameter of the meteor. Then it became bent and twisted into fantastic shapes, remaining visible several minutes.—*W. R. Brooks, D.Sc., F.R.A.S., Director.*

FENELON FALLS.—The meteor seemed to descend from half way from the zenith towards a point a little south of north-west. Before disappearing, large balls of light were discharged, larger than the largest stars; the colour was a soft golden red. It left in its course a granulated line of light which seemed to descend, gradually assuming a zigzag form, and was visible for several minutes.—*Walter H. Stevenson.*

BRACEBRIDGE.—The meteor appeared to strike the atmosphere about three parts of the way up between the horizon and the zenith, and to explode about the same distance down between the zenith and the horizon. When it exploded I could see the pieces fly in every direction like the explosion of a rocket. It lit up the place like a heavy flash of lightning. The smoky track was visible fully five minutes after the meteor fell.—*J. W. Ney.*

(In a subsequent note, Mr. Ney thinks the smoky track may have lasted ten minutes, and says the band of smoke would not be of greater breadth than one-eighth of the diameter of the Moon.)

PARRY SOUND.—The meteor, which appeared here on the evening of the 5th July, was travelling in a south-west direction, and appeared to go down on land a short distance from here. The whole heavens were lighted up. It was visible about fifteen seconds, and travelled like a huge serpent in a zigzag fashion across the horizon.—*Thos. R. White.*

BARRE CENTRE, N.Y. (South of Port Hope).—A large meteor was observed here on the evening of July 5th, at about 8.50 p.m., 75th meridian time. Apparently starting just below Polaris, in Cepheus, it traversed the sky in a south-westerly direction, crossing the constellations Camelopardalus and Lynx, and finally burst near the horizon in Canada. Its lustre far exceeded that of Venus when at her greatest brilliancy, leaving behind it a fiery train which was easily visible a greater part of its flight for three or four minutes after the meteor had disappeared. A feeble line of light was lastly seen, which, serpent-like, drifted from its direct course into wavy parts, but they gradually faded away and vanished from sight. The space of time occupied in its flight was about four seconds. —*Weston Weatherbee* (from *Popular Astronomy.*)

ST. CATHARINES, ONT.—Somewhere about sunset, I was in the house, and was looking on a shelf for some things, the light not being very good, when there came a flash as of lightning which lighted everything with a very green pale light. I knew it to be a meteor from the color of the light. I went to the door, but it had disappeared. It brought to my mind very vividly one I saw at Niagara Falls in 1866, which had the very same kind of light.—*George Henderson.*

WHITBY.—Many citizens observed the brilliant celestial visitor because of a zigzag streak that looked like steam in the track of its passage, about half the distance from the zenith to the horizon.—*Associated Press Report.*

Miss Violet M. Harvey was bicycling on Roxborough avenue, Toronto, where the view of the meteor was unimpeded, and, after an exact observation, went home and gave the following account—the region of the sky pointed out by her being translated into astronomical language :—

The meteor appeared about 40° above the horizon, where the constellation Cepheus shortly afterwards became visible. Its appearance was as if an electric arc light had been suddenly lighted. It was far brighter than any star or planet, and was of appreciable size. It fell at an angle of 45° from the perpendicular, its path inclining towards the west. This path seemed wavy, the motion appeared slow, so that the meteor itself was visible for three or four seconds. It seemed bluish white at first, becoming reddish towards the end of its course. It disappeared about 20° above the horizon. It left a luminous track, like steam and smoke commingled, greyish white, which remained visible for four minutes, and was being influenced by aerial currents, so that it became wavy, but not what is understood by zig-zagged.

Mr. Walter Cassels' account agrees with the above, but he adds that the trail was smooth, of soft black smoke, like a small cloud. Curls were noticeable, like the steam from a locomotive, but darker. Mr. Cassels saw the meteor well, from near Toronto Junction.

Mr. Sydney Crocker and his children, at North Toronto, saw the meteor, and his account agrees with the two previous descriptions, but a barn prevented his seeing the light disappear; though it had turned reddish before hidden from view. The children thought it must have fallen close by and wanted to organize a search party. Mr. Crocker listened for fully ten minutes for the noise of an explosion, but heard none, though the locality is a quiet one, and the evening was favorable.

Mr. G. D. Bruce, on Homewood avenue, saw what seemed to be a star, moving very rapidly. It got larger and larger as it came nearer—when closer, we could see a ball of fire, red in front, the meteor itself a brilliant bluish white, with a trail of fire streaming out behind for some distance. Four other persons besides himself saw it for several seconds, until it disappeared behind some trees, leaving a trail of smoke that could be seen for some minutes.

Mr. B. Leonard Thorne was on the Humber river, and to him the meteor had the appearance of a ball of electric flame, about the size of a football, or larger, which left in its wake a path of luminous matter which at first followed its direct course, but before vanishing became wavy and irregular. Mr. Thorne at first thought it fell into the Humber valley, but recognized later that he must have misjudged its height and velocity.

Mr. H. B. Denovan had a full view of the meteor from Bank street, and thinks it was an irregular oblong in shape, followed by two smaller bodies or reflections.

AURORA.—I was two miles north of Aurora and was standing facing the north-west, on the lawn of the Grange Hall, where there was a garden party. The meteor started directly over Yonge street, or straight north of where I stood, about 65° or 70° high, and shot in a west by south (very little south) direction and exploded at about 30° high. Its appearance was like a very large sky rocket, very brilliant and clear, and when it exploded was very bright, throwing out six or seven distinct and separate balls of light, and like a flash of lightning, and died away, leaving a streak of fire in the sky along its course, which was visible for three or four minutes.—*R. S. Rowman.*

LLOYDTOWN.—Through Mr. Napier Denison, *Mrs. Armstrong*, who lives 14 miles from Aurora, sends a sketch of the meteor in three stages showing the meteor as it exploded, marked "vivid lightning at time of bursting," the line of smoke as left by the meteor, and the same when blown by wind.

STAYNER.—I was driving along the second concession of Nottawasaga, near town, when I saw the meteor. It was almost directly overhead—the slight divergence being to the north. I watched it go in a westward course over the Nottawasaga mountain, apparently miles high. It could hardly have dropped this side of Lake Huron. There was a report, several minutes after it passed. My horse, going at a gentle jog, covered 2,640 feet, according to the town map, between the first flash of light and the noise. Many people in Stayner thought there was an earthquake, as the windows shook and the crockery rattled.—*Dr. C. E. Jakeway.*

(If a gentle jog be six miles an hour, the time was five minutes exactly.)

Through Mr. Joseph Wallace, of Orillia, a letter from his son who was at Penetanguishene has come into our possession :—

PENETANGUISHENE.—I had a short but good view. Its direction was due west as near as one can tell. Its angle toward the Earth was so acute that one would have thought it would strike it within a mile. Its appearance was something like this :

The front end seemed like molten metal at a white heat, with a vicious looking eye of a dark metallic colour, which seemed to be revolving at a tremendous rate, and emitting numerous sparks which gave a sharp crackling sound, something like immense fire crackers. The rear end was of a decidedly yellow colour, as also the tail, and the material gave one the impression that half of it would drop off if it did not keep moving very lively. Some say the meteor exploded with a short cracking noise, but I believe the only explosion was a continuous one, and produced the swishing sound of which they speak, but, coming on the ear of the observer suddenly, it might convey the impression of an explosion. I believe the report, which resembled the roar of a large cannon, was heard about four minutes after the wonderful stranger had passed.—*J. B. Wallace.*

ANTEN MILLS, SIMCOE COUNTY.—A small star gradually rose in the air, shot across the sky, lighting up the landscape as if by an intense electric light, finishing its course by an explosion, followed by a loud detonation, as of a cannon, in the distance, which caused several buildings to shake.—*Barrie Examiner.*

TOWNSHIP OF ESSA, COUNTY SIMCOE.—I was driving north on the town line, between Essa and Tossorontio, when, it being yet quite light, my attention was suddenly aroused, first by the back of my horse and the roadway being brightly lighted up, then by a hissing noise, louder and more intense than that produced by a large rocket.—*John W. S. McCullough, M.D., C.M., Alliston.*

BARRIE.—I was indoors when the meteor passed, but I saw a fragment of its zigzag track three minutes later. This fragment was 35° above the horizon, in a north-westerly direction, and made an angle of 52° with the pole star, measured approximately with a graduated circle.—*A. F. Hunter, M.A.*

ORILLIA.—A low rumbling noise resembling thunder. A white streak about a mile long.—"*Mirror.*"

MARCHMONT.—The track of smoke and sparks, which was at first perfectly straight, after a few minutes became zigzag. The break-up of the meteor was clearly visible, and was accompanied by a beautiful and brilliant display of colours, such as accompanies the bursting of a rocket. —*Mr. Nelson*, in the *Orillia Packet.*

LOVERING.—Two neighbours and I were sitting close to my house looking towards Orillia, or east by south-east, when a magnificent light appeared in the heavens which lighted up the grass around us. All exclaimed they felt the warmth. It made a sound as of the quick passage of the flight of a bird, and burst into magnificent colours. In about one or two minutes after we distinctly heard a report as of the discharge of heavy artillery, such as I have heard on board H. M. men-of-war, the sound dying slowly away as if over water.—*E. W. Kitchen*, in the *Orillia Packet.*

WALTER'S FALLS.—I was at Walter's Falls (near Chatsworth) and saw it from start to finish. It travelled from east to west, a little north, and looked exactly like a sky rocket, and exploded in just the same way, leaving a trail behind which spread out the longer it lasted, and about one minute after came the thunder—a rumbling noise, much the same as a waggon going over a bridge, getting louder as it came, and lasting about one minute.—*Jas. Paterson, Elmvale.*

OWEN SOUND.—With reference to a point in your letter, viz., the possibility of there having been two smaller meteors following the main one, I may say this hypothesis agrees remarkably with the first description I received of the phenomenon. My brother, Mr. W. J. Tucker, of Manitowaning, who takes a keen interest in matters of this kind, and is accustomed to making close observations, was visiting in Owen Sound, and was rowing on the bay at the time the meteor appeared. He said there were three distinct and separate balls of fire, which seemed to be connected by a band of intense light. He was the only one in this locality who gave such a description of the meteor. As to the pieces said to have been picked up in Euphrasia—an item in the *Weekly Sun* gives particulars of the finding of pieces on the farm of Mr. A. C. Paterson, Blantyre, ten miles south of Meaford.—*Jas. A. Tucker, Ed. Owen Sound Sun.*

I was driving through Sullivan township, about 20 miles south of Owen Sound. It was travelling towards the north-west, in the direction of Lake Huron. In colour it was yellow, and resembled a street electric light. It was wonderfully brilliant while it lasted. When it exploded, it made a large flash, but the noise was distant and resembled the report made by a sky rocket bursting. The meteor passed through the air with a whizzing noise before it burst. The trail it left was a long thin streak of smoke of a wavy appearance, the front half being dull red and the other half blue. The smoke disappeared gradually, and no trace remained at the end of half an hour.—*S. Eagleson, Owen Sound.*

COLLINGWOOD.—I intend to prepare a statement respecting the meteor. I visited the place where it was supposed to have fallen, but I guess it didn't fall. Opinions are so varied that it is no easy matter to digest and arrange them.—*Wm. Williams, Ed. The Bulletin.*

PRESQU' ISLE.—I beg to enclose a rough draft of the position of the meteor when first seen. At a rough guess it must have travelled 30 miles after it was seen before the explosion took place.

The apparent course was southerly, with a decline of about 30° towards the Earth.—*J. Mackenzie, Tp. Clerk, Sarawak.*

BRUSSELS, HURON COUNTY.—My wife had a very good view of the meteor, here in Brussels. She was coming home that evening when she saw a flash, and, looking up, she noticed a large ball of fire. As it descended, it became still larger, when it appeared to break up into pieces, leaving a vapour which seemed to float in the air for some minutes. A whizzing noise followed the meteor as it was descending. It seemed to fall very slowly and afforded ample time for close observation. The vapour was as plainly observed as smoke from a chimney.—*Dr. F. H. Kalbfleisch.*

(This Brussels' observation is valuable, for Brussels is 50 miles from the track of the meteor.)

MOOREFIELD, WELLINGTON COUNTY.—At 8.40 or 8.50 p.m., of July 5th, I was on the platform of the G.T.R. station at Moorefield, when a strong light on the side of that building attracted my attention. On looking round, I saw what I supposed was a very large rocket, which just then burst with a loud report, throwing out several streams of fire.—*E. Overell, Hamilton.*

PORT ELGIN.—The meteor was in view to us here ten or fifteen seconds. The body was a bright reddish colour, the trail was lighter. The trail was visible about ten minutes. I saw an explosion, and in a few minutes after I heard a heavy roll like thunder, in the north-east, which lasted for about two minutes. It appeared to be descending very rapidly and travelling at a great rate.—*Augustus Smith.*

BLANTYRE.—1. My son John (aged 13) saw the light from the portion of the meteor which was found the next day. There were perhaps 15 or 20 pieces, all of which would go into a tea cup, therefore we did not get very much of it. We gave so much away we have little left.

2. This portion passed overhead, it did not seem to go any further. They went out as they fell to the Earth, and as they were not found till the next day we could not tell their consistency when they fell. When found they were about the colour of a brown egg shell, and not unlike it in shape and consistency, only about half an inch thick, and soft, like white chalk with small yellow specks like sulphur all over it. In the inside of this was black sooty-looking stuff. It was luminous till within 25 feet of the Earth, when it gave a sound of a stone being thrown swiftly out of a sling.

I cannot give any more information, but having heard there were larger portions fell near Collingwood and Craigleith, would advise you to write to parties near there.—*A. C. Paterson.*

(Similar information from Mr. R. C. Gillies, of the same place.)

MEAFORD.—I have for you a fragment of what is said to be meteoric stone. Large pieces were found, but were broken up.—*Rev. D. J. Caswell, President Astronomical Society, Meaford.*

This ends the account we have to give, and we think they are very full. The Rev. Dr. Caswell took many pains to collect and verify accounts of the phenomenon as seen near the Georgian Bay, and defines the track as passing between Meaford and Rocklyn. The sample of stone does not seem to be of extra terrestrial origin. Mr. Paterson is an intelligent gentleman farmer, and will, perhaps, find, some day, under the surface of the farm, the pieces his son saw fall.

EIGHTEENTH MEETING.

September 20th; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

Letters were read from Sir John Bourinot, Hon. Secretary of the Royal Society of Canada; from Dr. J. A. Brashear, and from Mr. W. H. S. Monk, F.R.A.S.

Some time was agreeably spent in discussing observations of

THE GREAT SUN-SPOT OF SEPTEMBER 4-15.

Mr. A. Elvins, who presented several sketches, said: I first saw it on September 4th, it being at that time a short distance from the eastern limb, having probably appeared on the 1st or 2nd. There were three or four nuclei; and the penumbra, which was quite distinctly seen, was of about the same width on the preceding and following side, and was in form a long ellipse. On the 5th it was wider and four nuclei could be traced, or perhaps it might be described as a large black nucleus with bright lines or bridges, which seemed to divide into four. There were also two groups of spots following, one small spot preceding and two others just within the northern end of the penumbra. The spots became more distinctly seen as they approached the Sun's centre, and both the large spot and the train of spots which followed underwent great and rapid changes. It must have passed over the limb on the 15th, as it was near the limb on the 14th and I failed to see it on the 16th. We should look for its return on the 28th or 29th, for it is not likely to disappear in one solar rotation.

Mr. Geo. E. Lumsden, who also presented sketches, said: The length of the disturbed area was about 150,000 miles; breadth, 75,000; the length of the great spot was about 65,000 miles, the whole forming a magnificent spectacle in the telescope. No drawing can adequately show its beauty of shape and contrast, its delicacy of shading, or indicate the minor changes of detail continually going on about the fringes of this enormous solar storm area. Some idea of the size may be gained by saying that, without touching their sides, the Earth might be dropped through either of the upper two spots in the central group of three. The great group has been visible since Saturday, September 3rd, having come over the limb on Friday night, when there was an aurora.

Several sketches were also received from Dr. J. J. Wadsworth and one made by Miss Helen Stennett of Simcoe. Dr. Wadsworth had observed in his large reflector. He wrote: The spots are most awfully grand, perfectly sublime; no sketch can give an idea of them. The penumbra is a reddish brown and has numerous extensions of wedge shape. The group is easily seen with unaided eye.

After an inspection of the several drawings by the members, Mr. W. B. Musson was called upon to read a paper on

SOME ANCIENT THEORIES REGARDING MOTION AND THE COSMOS.

Should an astronomer or physicist of the present day be asked to express in one word the basis of all physical phenomena, he would probably answer—motion. That mysterious force manifested in the dance of atoms, and in the roll of Suns, that

> * * * "Along their fiery way
> All their planets whirling round them,
> Flash a million miles a day."

Although the term *Primum Mobile*—or first mover—has been more particularly applied to the outer sphere of Ptolemy, the problem of motion was one which had to be faced by every philosopher who undertook to formulate a theory of the cosmos. It is the purpose of the following notes to briefly review some of the ancient conceptions of the universe, and to trace through them down to recent times, the various ideas obtaining in regard to motion.

We know that the earliest astronomers are supposed to have been the Egyptians and Babylonians, but it is doubtful as to how far the science had progressed before it passed into the hands of the Greek philosophers, and to what extent—if at all—the latter were influenced in their speculations by the former. Indeed, with the Greeks themselves, we must search for the birth of such inquiries in the dim mists of mythology. For example, Hermes, the shepherd of the skies, signified by his name—impulse, and came to be regarded as the spirit of movement in the heavens.

The earliest conception of the Earth was that of a circular plane, surmounted by a solid concave vault, and surrounded by the ocean, the stars rising from, and setting in the waters. Thus Homer, in the fifth book of the *Iliad*, describing the rising of the dog star (I quote from Pope's translation),

> "Like the red star that fires the autumnal skies,
> When fresh he rears his radiant orb to sight,
> And *bathed in ocean*, shoots a keener light."

And again—

> "To which around the axle of the sky,
> The bear revolving, points his golden eye,
> Still shines exalted on th' ethereal plain,
> Nor *bathes his blazing forehead in the main.*"

It will be sufficient for the purpose of the present paper, however, to begin with the primitive Ionic philosophers, and to endeavour to trace from that school the development of modern ideas. The first name of importance connected with astronomical research in Greece is that of *Thales*, a citizen of Miletus, who lived about 639 to 546 B.C., and who was the founder of the Ionic school. He taught that the Sun, Moon and stars were composed of a solid substance, but that the stars partook of a fiery nature, that the Moon received her light from the Sun, and was eclipsed by the Earth, which floated upon the water. The fire of the Sun, he thought, was sustained by aqueous exhalations. Water or a humid substance was the origin of all material things. Whether he considered this humid mass to be animated by some external influence is a matter of doubt, but he believed all nature to be full of demons or intelligences proceeding from the Divinity, and this idea, very probably, was to him a sufficient explanation of physical motion.

Following Thales came Anaximander, a disciple of the former, and about thirty years his junior. He was the first of the Grecian philosophers to adopt the method of recording his teachings in writing. He held all things to be produced from, and terminated in "infinity." The exact signification of this term is a matter of dispute, but as he was a follower of Thales it is not unreasonable to suppose that he intended to express by it the humid mass which was regarded by that teacher as the foundation of the material universe.

Hermias asserts that he supposed an external mover prior to this humid mass, and Aristotle refers to the infinity of Anaximander as directing all things. His exact meaning, however, is vague. He further held that the stars were globular masses of air and fire, and derived their motion from moveable spheres to which they were attached, and that they were inhabited by animated portions of the Deity. He assigned the Sun to the highest place in the heavens, the Moon next, and the planets and fixed stars to the lowest. The Earth he placed in the middle of the universe. The movement of the Sun he ascribed to an opaque ring by which it was surrounded.

The third of the Ionic philosophers was *Anaximenes* of Miletus. He is said to have been a companion of Anaximander, and may be placed about 475 B.C. According to his philosophy, the Earth was a flat trapezium supported by air. The Sun was also flat, and consisted of fire. The stars were aqueous in nature, and were fixed in the crystalline sphere, revolving around (not under) the Earth. The solsticial movement of the Sun was caused by the pressure of the air against the stars as it approached the poles, their resistance to this pressure driving the Sun back again in his course. Air, he believed to be the first principle of all things, being infinite in its nature, diffused through all matter, and perpetually active. About this period may also be mentioned *Heraclitus*, an Ephesian. He was known as the "obscure philosopher" from the manner of his written style. The following doctrines concerning celestial matters are attributed to him :—

The stars are formed of compressed air, and are fed by earthly exhalations, the Sun being a hollow hemisphere. Fire or an ethereal exhalation is the principle from which all things are produced. This principle, he held to be composed of small indivisible parts or atoms, simple in their nature, and eternal. These invisible particles were always in motion, and by combining produced fire and all natural forms. This primary fire was possessed of intrinsic motion—the force producing nature. It was made by neither gods nor men—it always was and always would be. The eternal motion was caused by "fate." The rational principle animating the eternal fire pervaded the universe, forming, preserving, and dissolving the visible world. The atoms moved in various directions, causing constant collisions, collecting in masses, and producing natural bodies. The motion of these atoms produced fire —the elements collected in one mass or chaos, from which was ultimately evolved the forms of nature. Divested of its metaphysics the foregoing is not at all a bad anticipation of the atomic and nebular theories of to-day.

Although Heraclitus speaks of the cause of motion as fate, he held this principle to be inherent in matter, and it corresponds very closely to the modern atomic motion.

Next in order of the great teachers comes *Xenophanes*, the founder of the Eleatic school. He lived, roughly speaking, 500 B.C. Closely connected with his doctrines are those of Parmenides, but they have no special bearing upon the subject in question. Xenophanes considered the universe to possess within itself a Divine force. Parmenides regarded this force more in the nature of an external principle, *pervading* the universe, but confined more especially to the extreme sphere of the world. The latter is noted as having been the first to teach the spherical form of the Earth (520-460 B.C.). *Empedocles* of Agrigentum, who lived about 450 B.C., held that the Earth was motionless at the centre of the universe, attributing its state of rest to the rapid movement of the heavens surrounding it. The stars were fixed in the crystalline heavens, the planets wandering freely beneath. The active principle of nature he considered to be a subtle and intelligent fire which animated all nature. The ultimate constituents of material bodies were atoms, round, and indefinitely small.

Matter in this condition was possessed of the qualities of friendship and discord, which produced the first agitation, or movement, of the original mass, while in a state of chaos. This conception of the properties of matter might be considered to dimly foreshadow the modern doctrine of chemical affinity. The first cause of motion in these atoms was held to be the Divine mind. The first principle of the elements Empedocles taught to be eternal. Nothing had a beginning or an end. In the formation of the world the ether was first secreted from chaos, then fire, then Earth.

We now come to the period of *Pythagoras*. The history of this philosopher is to a great extent obscure, the very time and place of his birth being matters of dispute. The best authorities, however, suppose him to have been a native of the island of Samos, and to have lived between 569-470 B.C. He was exclusively an oral teacher, and left no written records. Following is a brief summary of his astronomical doctrines. Plutarch tells us that when Numa built the temple of Vesta, where the perpetual fire was to be kept, he intended to represent by its form the frame of the universe, in the centre of which, according to the Pythagoreans, is placed the element of fire. The Earth, he states, "they suppose not to be without motion, nor situated in the centre of the world, but to make its revolution round the sphere of fire, being neither the most valuable nor principle part of the great machine.' Around this central fire, which was termed "the hearth of the universe," revolved in circular orbits, ten bodies.

In the highest place was the heaven containing the fixed stars, then came in order the five planets, the Sun, the Moon, the Earth, and lastly the antichthon. It is to be noted that this system regarded the Earth as moving in an orbit through space, and thus, although Pythagoras did not form his system upon a scientific basis, he may be credited with being the first speculator to give the Earth this motion. The tenth sphere he *supposed*, in order to complete the harmony of nature, in correspondence with the decad which made the harmony of numbers. The music of the spheres must not be forgotten in considering the distinguishing features of the Pythagorean philosophy. The intrinsic cause of all motion Pythagoras taught to be mind—universal, omnipresent and invisible. To those, however, desiring to study more closely the teachings of this philosopher, I would recommend the paper entitled "The Pythagorean Philosophy," by Mr. Harvey, and printed in the *Transactions* of this Society for 1893.

We now come to a name marking an important period in the history of philosophy. *Leucippus*—belonging to the Eleatic school, and the founder of the atomic theory, was the first investigator to throw away the old metaphysical style of reasoning, and to endeavour to account for observed phenomena by purely physical causes. In astronomy he held the universe to be a sphere whose outer coat attracted foreign bodies by the nature of its movement, that these bodies, at first moist, became hard, and were ignited by the rapid movement, ultimately forming stars. His physical doctrine was to the effect that the part of the universe containing matter was composed of innumerable atoms, of different figures, which struck against one another and produced a variety of motions which continued until atoms of similar forms came together and *bodies* were produced. Although Anaxagoras, Empedocles, Heraclitus and others, had regarded matter as composed of infinitely small particles, Leucippus and Democritus were the first to teach that these atoms were destitute of all attributes but figure and motion.

It must be confessed, however, that the great advance made by these philosophers consisted in the realization—to quote the words of a recent writer,—"That it is better not to know so much, than to know so many things that are not so."

Democritus, born about 459 B.C., followed closely in the footsteps of Leucippus. He developed the atomic theory as follows: Nothing can be produced from nothing, nor can anything be annihilated; thus reaching the modern conclusion regarding the conservation of matter. The first principles are atoms and vacuum, both infinite. The atoms have been eternally moving in space, colliding, combining, and producing natural forms. Space, he believed to be filled by many worlds, all subject to the law of growth, decay, and destruction. Like Leucippus, he held the animating principle of nature to consist in the intrinsic motion common to matter, and believed all things to be moved by "the rapid agitation of atoms." The atomic theory of Epicurus did not differ essentially from that of the two preceding philosophers. He held the internal energy of matter, which he termed gravity, to be the cause of all motion. His conception of the formation of the world was as follows:—

A finite number of atoms falling fortuitously into the region of the world by their inherent motion would collect into one mass or chaos. In this chaos the heavier atoms fall towards the centre, producing the Earth; the next lighter rising higher, forming the air, and the lightest particles form the stars. This incessant motion of the atoms will also tend towards the dissolution of the world, when once more, nothing will exist but infinite atoms and infinite space.

The true theory of Epicurus was first fully stated by the Roman Lucretius in his *De Rerum Natura*. The atomic theory, however, was first placed upon a scientific base in 1804, by John Dalton.

We now approach the period when Greek astronomy began to assume the importance of a science founded upon observation.

Eudoxus, a disciple of Plato, who lived about 406-350 B.C., formulated a theory of the motions of the planets, which ultimately developed into the Ptolemaic system. He was a practical observer, and left a written record of the results of his observations. He is supposed to have visited Egypt, where he received instruction from the priests.

The general theory of Eudoxus, according to Aristotle, was as follows: The Sun and Moon are each borne by three spheres, one of which is that of the fixed stars, one moves along the ecliptic, and a third obliquely to the second. Each of the five planets has four spheres, two being the spheres of the fixed stars, one having its pole in the Zodiacal circle, and one being oblique to that circle. The Ionic philosophers regarded the stars as being imbedded in a solid sphere and turning with it, but it was necessary to increase the number of the spheres when the theory came to be applied to the planets.

In the year 384 B.C. was born one of the most illustrious of the ancient philosophers, and the founder of the Peripatetic sect, the immortal *Aristotle*. He regarded astronomy as a science founded on observation and mathematical calculation. The heaven he conceived to be without beginning or end, to be endowed with the form of a sphere and to move perpetually in a circle.

In this spherical heaven the celestial bodies are fixed, their motion being due to the spherical orbs to which they are attached. To account for the complex motion of the planets, he assumed these bodies to have will and power to act, each one completing its circuit, and surmounting obstacles "in the best possible manner."

He thought the complex motions of the inner orbs was a compensation for their having a less number of stars than the outer sphere. He mentions the theory of Eudoxus, and the modifications of his theory by Callippus. This theory agreed with the opinions of Aristotle in supposing all the heavenly bodies to move in circular orbits about the Earth, which was at the centre of the universe. Callippus added an additional sphere, over the Earth, to Venus and Mercury, and two additional ones to the Sun and Moon, making a total of thirty-three. Aristotle assumed a separate set of spheres for effecting the retrograde motions of the planets—six for the two outer, and sixteen for the other three, or fifty-five in all.

The spheres of Eudoxus, Callippus, and Aristotle are solid, transparent substances, to which the stars and planets are affixed, and are the sources of motion. The outer sphere, or the *Primum Mobile*, revolved with the greatest velocity, from west to east, the inferior spheres turning from east to west. The velocities of the spheres of the planets were inversely as their distance from the first sphere. We must remember that it was some such method of reasoning as this that suggested Bode's and Mendelejeff's laws. It is to be noted that both Eudoxus and Aristotle make the Earth immovable at the centre of the universe. The earliest writer who is supposed to have introduced the idea of the movement of the stars being only apparent and caused by the rotation of the Earth, was *Hicetas* of Syracuse, a Pythagorean. The time of his existence is doubtful, but is supposed to have been about 450 B.C.

Heraclides, 410-340 B.C., held the same doctrine, namely, that the Earth turned from west to east on its axis, at the centre of the universe, and that the heavens were at rest.

Ecphantus, another Pythagorean, is supposed to have had substantially the same idea.

Aristarchus of Samos, 320-250 B.C., rejected the geocentric doctrine common to most of the Greek astronomers, and proposed in its stead a theory almost if not quite identical with the Copernican, namely, that the Sun and stars are immovable, that the Earth moves around the Sun in a circle (with the Sun in the centre). He is also said to have given the Earth an axial as well as an orbital motion, thus accounting for the diurnal and annual motions of the Sun and stars. The words of Plutarch, that "he accounted for these appearances by supposing the heaven to be motionless and the Earth to turn in an oblique circle, revolving at the same time about its axis," show that he believed the orbit of the Earth to be inclined to its axis.

According to Plutarch Aristarchus was threatened with the same fate as Galileo, as Cleanthes tried to have him prosecuted for impiety for declaring that the "hearth of the universe" moved. Fortunately for Aristarchus, however, thought among the Greeks was more tolerant than in the time of the great Italian, and Cleanthes was obliged to content himself by writing a treatise against the heretic.

Apollonius of Perga, who lived about 200 B.C., belonged to the Alexandrian school, and may be mentioned as the first to discard the theory of spheres, and to introduce that of epicycles and eccentrics to explain the motions of the planets. This theory, developed and elaborated by Hipparchus and Ptolemy, held its ground until eventually displaced by the Copernican system. Hipparchus (150 B.C.) made a great advance in astronomical science by reducing the motions of the Sun and Moon to equable circular movements. He did not extend this system to the planets, however, as he was not in possession of the necessary data upon which to work, and in this fact we may see an indication that the value of the inductive method of reasoning was beginning to be recognized.

Claudius Ptolemæus—100-170 A.D.—now took up the science where it had been left by Hipparchus, and applied the latter's theory to the planets.

According to the Ptolemaic theory, each planet was supposed to be set in a crystal sphere, which revolved, carrying the planet with it. Outside the seven planetary spheres—arranged one within the other—was a larger sphere carrying the stars. This was believed to turn the others, and was called the *Primum Mobile.*

The motion supposed to be communicated from the *Primum Mobile,* however, was modified in the following manner :—

The stations and retrogressions of the planets had to be accounted for. It was, therefore, supposed that the main sphere carried the centre of axis of a subordinate sphere, which latter carried the planet, the minor sphere revolving at a different uniform rate.

The curve described by a point on the circumference of a circle which is itself travelling along a straight line is called a cycloid, and when the centre of the circle is carried around another circle the epicycloid is produced. This would account fairly well for the stations and retrogressions of the planets, but the system was a clumsy and inaccurate one.

The next great advance was made in 1500 by Copernicus, who gave the Sun his true place in the centre of the universe, and paved the way for the discoveries of Galileo, Kepler, and Newton.

In 1600 Descartes propounded his theory of vortices, by which space was regarded as being filled by an all-pervading fluid, portions of which were in a state of whirling motion, which was communicated to the planets, each planet being carried around in its own particular eddy.

Kepler's laws, which swept away all theories of epicycles, are :—

1st. The planets move in ellipses, with the Sun in one focus.

2nd. The radius vector describes equal areas in equal times.

3rd. The square of the time of the revolution of each planet is proportional to the cube of its mean distance from the Sun.

Newton founded his reasoning upon the following laws of motion :—

1st. If no force acts upon a body in motion it continues to move uniformly in a straight line.

2nd. If force acts upon a body it produces a change of motion proportional to the force and in the same direction.

3rd. When a body exerts force on another, that other reacts with equal force upon the one.

These laws, although giving us a clearer knowledge of the phenomena of motion, do not assist us in the search for its first cause.

According to the Newtonian philosophy the motions of the planets depend upon two causes, viz., gravitation, and the original tendency to move in a straight line. Space will not permit a consideration of the various opinions which have been advanced in regard to the nature of gravitation,—I cannot do better than refer anyone desiring to pursue this subject to the admirable paper by Mr. J. R. Collins in our *Transactions* for 1895.

Regarding the original impulse imparted to the planets, we must turn once more to chaos, to the dim and distant nebula that, revolving and contracting under the influence of the gravitation of its particles, "cast the planets"—the *Primum Mobile* of modern astronomy.

Should we desire to follow the mystery still farther, we must appeal again to physics, but whether we question the atoms of Dalton, the force centres of Boscovich, or the vortex rings of Lord Kelvin, the reply is still "behind the veil."

Of the laws under which the phenomena of matter are produced we have a more accurate knowledge, but of the ultimate cause of motion we know no more than did the Greek philosophers 2,500 years ago.

NINETEENTH MEETING.

October 4th; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

Mr. W. H. S. Monk, F.R.A.S., was elected a corresponding member of the Society; Mr. J. D. Warren, of Toronto, was elected an active member.

A communication was received from Mr. B. E. Walker, President of the Canadian Institute, who had just returned from the meeting of the British Association in Bristol. Mr. Walker stated that Mr. W. F. Denning, F.R.A.S., had represented the Society at that meeting.

From Mr. D. E. Hadden, F.R.A.S., of Alta, Iowa, the following notes on the great sun-spot of September were received; Mr. Hadden wrote under date of September 9th:—

The following observations in connection with the large solar spot which appeared by rotation at the Sun's eastern limb on the morning of September 2nd inst., may be of interest. When I first observed it, but a mere line of light separated it from the edge of the limb, no penumbra being visible except on the north and south edges of the long umbral line. A bright aurora was seen the same evening. On the following day penumbra was visible on all sides of the umbra and the spot promised to be interesting, the changes from day to day since, being quite marked. Owing to atmospheric conditions, the spectroscope could not be used until the 6th, when but little or no disturbance could be noticed in the vicinity of the spot. On the 7th, however, a sudden outburst occurred. When the spectroscope was adjusted at 11.40 a.m. central time, the entire region just preceding, and for some distance following, and also north and south of the spot, was greatly agitated; the Hα line being reversed and distorted; small black jets projecting from either side of the line were noted in several places, and on opening the slit slightly, the flame and spike-like form of the disturbances could be clearly seen. At 12 m. intensely brilliant flames were observed over the large spot, extending from the umbra to the edge of the penumbra on the east side. This phenomenon was particularly striking; the intensely bright scarlet flame nearly in the centre of the dark absorption band of the spot spectrum, being very interesting. The D_3 line was bright; while D_1 and D_2 and many other lines were widened. At 12h. 5m. p.m. a small dark line attached to the Hα line extended obliquely towards the red end of the spectrum, in the region just preceding the main spot. Observations were interrupted at 12h. 10m., and could not be resumed until 1h. 40m., but the entire disturbance had then almost ceased, only a few slight reversals being noted. A 2-inch diffraction grating, attached to a 4-inch telescope, was used.

Mr. Elvins agreed with Mr. Hadden that the spot had appeared by rotation. He had noticed the second return on September 28th. Some sketches of the disturbed region were received from Dr. J. A. Brashear, who had been summering in Muskoka.

The President called attention to the recent discovery of a new minor planet, one which came, at perihelion, between the orbits of the Earth and Mars, and would at the most favourable opposition be visible to the unaided eye. This object would eventually, it was said, prove the one by observation of which the best determination of the solar parallax would be obtained.

Mr. John A. Patérson, who had just returned from a holiday trip, spoke enthusiastically of the serenity of the skies in the Muskoka district:—

Last August I visited a pleasantly-sequestered nook in the Georgian Bay bearing the mellifluous name of Honey Harbour, and there the summer evening sky was to me a revelation. We have been told of the murky Toronto sky and of the metropolitan smoke, which with the mists and vapours of Lake Ontario mars the glorious effulgence of the overarching firmament. But there the transparency of the air is such that the ordinary eye is as good as a telescopic eye of moderate power here, and seems about as strong as the "double-million magnifier with hextra power" of Mr. Samuel Weller. I remember one occasion especially well when almost unconsciously I found I had an audience of some ladies and gentlemen who were hotel summer visitors. It was an enchanting twilight and "heaven's husbandry" was not shown, for all her candles were growing aflame, and as the darkness stole round us

> "Silently one by one in the infinite meadows of heaven
> Blossomed the lovely stars, the forget-me-nots of the angels."

The day had been warm, although tempered by the cooling, bracing breezes of the Georgian Bay, and now, these "being up gathered like sleeping flowers," in the Sun's shadow the firmament had put on her finest and bravest apparel. Looking to the east there Andromeda, the bride of Perseus, displayed her trembling jewels, and next her Cassiopeia, her mother, gracefully seated on her golden chair, seemed to beckon to her for forgiveness to atone the wrong she had done by boasting of her daughter's beauty. The great nebula of undigested world stuff (if such it be), held in the left hand of Andromeda, was too close to the edge of the horizon to be seen. Further to the east, close to the horizon, Pegasus seemed lifting himself with ponderous wings from the bosom of the lake.

Along the line of the ecliptic low down, Aquarius, Capricornus, Sagittarius, Scorpio, Libra and Virgo, belted the sky. Antares, with its red flashing fires, beamed with remarkable brilliancy away to the south in the middle of the Scorpion's back. Just east of the meridian the Swan, with her flashing wings, the Dolphin and the Eagle, blazed so beautifully as if indeed these creatures, ancient dwellers in the ever circling menagerie of the old astronomers, had been brightened and whitened as they shook off the waters of the Georgian Bay. Altair, that first magnitude star, flamed on the neck of the Eagle like a blazing jewel. On the west of the meridian we saw Hercules the "kneeler," the Northern Crown with its glittering circle, the Herdsman, with the flashing eye of Arcturus, like a diamond on his knee, watching Polaris and off to the north the Hunting Dogs bore on their necks Cor Caroli, far, far brighter than ever we see it here, and the Great Bear, with its pointers and tail-stars more dazzling, seemed mightier than before. But what shall we say of the Great Galaxy? We never see that in Toronto unless we call a sort of slight hazy gleam that glorious circle; but there it was a thing to be set down and thought over; the white parts near Sagittarius and in Cygnus where it divides into two mighty arms as if lifted up in silent praise, were indeed in that calm and cloudless night a marvel, and eloquent with wondrous beauty. It seemed as if the glorious stars were gathered in the crowded sky and listened in breathless silence to the litany of the universe led by the solemn uplift of the Great Galaxy. Venus and Jupiter hung like great globes over the western horizon, and as the silent footfall of the evening stole on and the darkness deepened, these silver-fair planets seemed to chase each other to their rest. There we sat on the rocks and studied the great book of the firmament spread before us emblazoned with shining letters that shone the more brightly as the purple evening wore on and dark night followed. We in Toronto do not and cannot see the glories of the heavens as they look down on us, but there and in Muskoka the bosom of old night seems on fire and sparkles with as many coloured glories as the hilt of King Arthur's sword *Excalibur*, which "twinkled with diamond sparks, myriads of topaz lights and jacinth work of subtlest jewelry." Should it ever come—and I trust the time is not far distant—that a first-class astronomical observatory be built in Ontario, I fear Toronto cannot claim it, as the power of a first-rate objective would be sadly crippled by the mist and the smoke that hang about it. "Go west" is an advice often given to young men who pursue Hope's golden dream; "Go south" leads the invalid to strength and health; but "Go north" will lead my hearers where they may see God's sky without a telescope, and will show the astronomers where they may plant their instruments most effectively.

TWENTIETH MEETING.

October 18th; Mr. A. Elvins occupied the chair. This meeting was held at the Toronto Observatory.

Letters were read from Prof. W. W. Payne, of Northfield, Minn., and from Dr. J. J. Wadsworth, of Simcoe. Miss Mary Proctor, of New York, had kindly forwarded a copy of her work, *Stories of Starland*, which was found to be a delightful little volume and specially adapted to young seekers after knowledge.

Mr. R. F. Stupart, Superintendent of the Meteorological Service of Canada, being present, an interesting discussion arose regarding the recent removal of the magnetic instruments to Agincourt, about 14 miles from Toronto. Mr. Stupart had been aware, ever since the establishment of the trolley system of railway in Toronto, that the magnetic observations were seriously affected by the electric currents, and the removal to a point free from these disturbances, had been freely advocated.

Regarding the amount of the disturbance caused by the trolley system, Mr. Stupart said:—

Electric cars first ran in Toronto on August 17, 1892; the line first put in operation was that on Church street, which was followed on September 5 by King street, between George street and Dufferin street. During the first few weeks, while a very small vibration of the needle was discernible on the V. F. curve, it was generally almost inappreciable, and it was not until September 20 that the movement increased to an extent sufficient to really impair the value of our magnetic curves; a marked increase of current must have been used on that day and afterwards. On October 10 the cars first ran on Yonge street, and there was only a very small increase in vibration, but a decrease of about .000070 of a dyne was observed when the current was on. About 10 a.m. on the 14th January there was a marked increase of vibration, and the vertical force increased about .000200 of a dyne. This disturbed period was only temporary, and shortly after 5 p.m. of the 17th there was a reversion to the smaller vibrations, which continued until May 15, when very small vibrations began again and continued with varying intensity during the summer, while the decrease of the V. F. with the current ranged from about .000200 to .000500. This disturbance was very great between September 12 and October 17, and at intervals during the following year, but there was no radical change in conditions until December 17, 1894, when a decrease of V. F. while the current was on was changed to an increase, this occurring when the cars first ran on McCaul street. Throughout 1895 the vibration and amount of permanent deflection was very nearly as it has been since, but on October 15 the increase of V. F. with the current was again changed to a decrease, this occurring at the time that the railway company made certain changes in the feed wires. It is noticeable that although several changes occurred in the V. F., it at times having been less with the current on and at other times greater, the horizontal force showed a steady decrease on all occasions with the turn on of the current, which during the past two years has been .000200 to .000500. No appreciable deflection of the declinometer magnet can be noted, the only effect being a continuous vibration which has rendered the curves very ragged and difficult to read with accuracy. A study of the traces during the times that the various electric lines were put in operation shows that with the currents ordinarily used there is little effect at three-quarters of a mile, and a further survey with a portable instrument affords further evidence in the same direction. It has, therefore, been determined to remove the magnetic instruments to a point distant two miles from any probable trolley route, and about nine miles from the present location, and continue what is certainly the most valuable and extended magnetic record outside of Europe.

The long desired removal of the instruments was now an accomplished fact. Mr. Stupart gave the following brief description of the building :—

The new observatory, which was commenced in June and finished during the early days of September, consists of two parts, a circular stone cellar nineteen feet in diameter, the walls two feet in thickness, the floor concrete and the roof covered with felt and gravel, in which, on stone piers sunk in concrete to a depth of six feet below the floor, are placed the self-recording photographic instruments, namely, the declinometer for recording changes in the direction of the magnetic needle, and the bifilar and vertical force instrument, for registering respectively changes in the horizontal and vertical components of the Earth's magnetism ; above ground and connected with the cellar by a flight of steps is an erection which is divided into two portions, in the larger of which absolute magnetic determinations will be made, piers being provided on which to place the necessary instruments, and an adjustable opening on the roof for transit work—and the smaller, an office, which will be heated by a copper stove. Observations were first made in the new building on September 10, and all the instruments have now been adjusted in their new position, and everything is running smoothly. Results already obtained have shown that values will differ but slightly, from those obtained at the old observatory, and it is proposed to make a very careful comparison before dismounting the old eye-reading instruments in Toronto.

Very great care has been taken in selecting material for the building, every stone used was tested for magnetic effect, and none but copper or zinc nails and fastenings have been used.

There appears to be every prospect that the new observatory will be admirably suited for the purpose for which it has been designed, and there is strong reason to think that the series of observations at Agincourt will be practically a continuation of the old and valuable series of observations made in Toronto. All the photographic records will be sent for development to the Toronto Observatory, which continues to be the central office of the Dominion Meteorological service.

TWENTY-FIRST MEETING.

November 1st; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

This meeting was held in the Lecture-room of the Canadian Institute. It had been found impossible to secure the necessary accommodation in the Technical School on account of certain changes which had recently been made in the building. The council of the Canadian Institute had, therefore, been asked to provide accommodation and had kindly arranged for the regular meetings of the Society to be held in the Lecture-room and had set apart a room for the library. The members generally were much pleased with the present arrangement.

Letters were read from the Secretary of the Rochester Academy of Sciences, and from Mr. J. C. Vandyke of Rutgers College, New Brunswick, N.J.

Mr. R. F. Spence, of Toronto, was duly elected an active member of the Society.

Reporting observations Mr. Elvins stated that there were now very few spots on the Sun. It was noted that the observatory record had been broken on account of the work of moving the magnetic instruments in September. The regular work of solar observation had, however, been carried on by Mr. Blake during October, and would be continued. The President called attention to the somewhat unsatisfactory state of solar photography. In this connection Mr. Lindsay stated that he had compared several of Mr. Elvins' drawings with photos published in *Knowledge*, and had been struck with the similarity.

Further business was then suspended in order to afford time to Dr. E. A. Meredith, who had prepared, by special request, the following paper on

THE EXPECTED METEORS OF NOVEMBER, 1898.

To assume the role of a prophet is rather a risky thing, especially so when a day or two must show whether the prediction is true or false. Notwithstanding this, I am bold enough to predict that we may expect two remarkable meteoric showers in the month on which we have just entered; one about the middle and the other towards the end of the month; subject, however, be it understood, to the three following provisoes: 1st. That the calculations of astronomers on this subject are correct; 2nd. That the weather is propitious; and 3rd. That Toronto is in that part of the globe favoured on this occasion by our celestial visitors. As Vice-President of this Society I am prepared to guarantee the correctness of the calculations of the astronomers; I must leave to my brother Vice-President, Mr. Stupart, as director of meteorology, to see to it that the weather conditions are as they ought to be on such an occasion. As regards the *third proviso,* I fear that neither of your Vice-Presidents can be held in any way responsible for Toronto being in the proper place to witness the expected spectacle. These meteoric displays, it must be remembered, are not seen at the same time in all parts of the globe. The most splendid are visible only on certain portions of the Earth's surface, the favoured region being that which the stream of meteors happens to cross in its path. The great display recorded by Humboldt in South America, in 1799, is, so far as I know, recorded in only one other place—Cape Florida. The famous showers of 1832 and 1833, though widely extended, were confined to certain regions of the Earth, and the same was the case with the subsequent showers of 1866 and 1867. It is, therefore, quite possible that even with fine weather we in Toronto may see few or no meteors on either of the occasions I have referred to, while we may hear that they have been witnessed elsewhere by others more fortunate than ourselves.

The story of this famous group is a fascinating one, so marvellous and sensational that it reads like a chapter of interstellar romance. As, however, this story has been told to the Society at least twice during the past year, once very fully and eloquently by our ex-President, Mr. Paterson, and subsequently more briefly by myself, I must not by repeating it again this evening make it a *thrice told tale* for the Society.

I cannot, however, refrain from giving a very brief outline of the story, what may possibly be new to some of my audience. It seems then, that in the year of grace 126, our giant outlying planet Uranus, then on the marches of our solar system, when nearing his aphelion, encountered a mighty cluster of meteors, boldly intruding into our system, and incautiously grazing almost the surface of the planet. Angry at their "molesting his ancient solitary reign," Uranus turned the cluster out of the path it had been moving in, and swung it into the new orbit in which it has ever since continued to move like any ruly and well conducted planet, another vassal to our Sunking.

The diagram on the blackboard shows the relative positions at the critical time of the encounter of Uranus, the cluster and the Sun ; it also shows the orbit in which the cluster had been moving, and the new orbit into which it was swung by Uranus.

I may notice here that the orbit of the cluster, while it intersects as you observe the path of Uranus, does not intersect the paths of any of the other large planets—Jupiter, Saturn or Mars. It does, however, meet the path of the Earth at the point which the Earth passes about the middle of November, and it is to this fact that we are indebted for the magnificent spectacle which we witness in the heavens every thirty-three years for two or three and sometimes even four, five or more consecutive Novembers. Were it not that the Earth meets the stream of the meteors they might revolve in their mighty orbit for ever, like myriads of other cosmical bodies unseen by us.

Our real acquaintance with these meteors dates from the years 1832 and 1833 of this nineteenth century. In the former year the old world was *startled* and amazed by a magnificent meteoric shower in the middle of November, and in the following November there was a still more magnificent display in both the old and new world, but especially in the new. These were followed by less brilliant displays in different parts of the world in succeeding Novembers until 1839.

Pictorial representations of the meteoric display in 1833 on this continent will be found in *Chambers' Encyclopædia*, and other popular works. I say advisedly that the world was *startled* by these celestial spectacles—for they were wholly unexpected—a veritable bolt from the blue. As I said last year the marvellous phenomena in 1832 and 1833 form an epoch in the history of meteors. "They heralded," as Mr. Denning says, "the dawn of meteoric astronomy. The event was so striking and the cosmical associations so important that astronomers for the first time devoted earnest attention to the subject of meteors." As a result of the investigation which followed and especially of the researches of Prof. Newton of Harvard, Olbers and others, and the laborious mathematical calculations of Prof. Adams of Cambridge, it was established that these meteors, which had so surprised the scientific world, were moving in a mighty orbit round the Sun, in an orbit extending beyond that of Uranus, which at aphelion is nineteen times more distant than the Sun ; that they took thirty-three years to complete their journey ; and further, that we might expect similar brilliant mid-November displays every thirty-three years for two or three consecutive Novembers. The scientific world was consequently quite prepared for the next displays which occurred in 1866 and 1867, after the first cycle of thirty-three years from 1832 and 1833. And now in 1898, after the second cycle of thirty-three years, we are confidently looking forward to a similar display about the middle of this month.

Since 1832 and 1833 meteoric astronomy has in fact for the first time been placed on a scientific basis. When it was clearly established that these meteoric phenomena could be counted upon every thirty-three years in future, the enquiry naturally suggested itself as to whether any trace could be found in the past of earlier displays of these particular meteors, and the resulting investigations brought to light records of no less than ten brilliant displays before the famous one in 1799, witnessed by Humboldt and his companion Bonplant in South America. These displays occurred in the years 902, 931, 934, 1002, 1101, 1202, 1366, 1533, 1692, 1698. All these different displays are said to have been of extraordinary brilliancy, and most of them were associated by the superstitious and ignorant contemporary chronicler, and by the people generally, with some remarkable historical event which occurred at the time. It will be seen at a glance that all these displays took place at intervals of one or more periods of thirty-three years; and oddly enough it happens that they occur at the beginning and the end of every century with two others in the middle of the century. Mr. Denning calls attention to a remarkable distinction between the three successive returns we have referred to, those of 1799, 1832 and 1833, and 1866 and 1867. The first display was apparently confined to *one night and one year* only, while the second were seen during nine successive years from 1831 to 1839, and the third for six successive years, namely, from 1864 to 1869, and he might have added on many of these occasions the display lasted for several nights. The inference drawn from this is that the group of meteors were in a more condensed form in 1799 than at their subsequent returns, an inference, I may add, amply justified as we shall see by other considerations.

These outbursts of mid-November meteors occur, as we have seen, in cycles of thirty-three years, and last then sometimes two or three or even eight or nine consecutive years; but it may naturally be asked why, as the orbit of the meteors meet the path of the Earth *every year* at the point where the Earth is found about the middle of November, why have we not equally fine displays *every year?* The answer is simply because the meteors are not distributed uniformly throughout their orbit. On the contrary, they are largely gathered together in a mighty shoal extending over, it may be a sixth or seventh of the orbit, and through all the rest of the orbit they are scattered comparatively sparsely. The great dense shoal or stream of meteors takes two or three years, possibly more, to pass the point where the orbit of the meteor meets the Earth's path in November. After the passage of the shoal the Earth meets in other years comparatively few meteors, sometimes more and sometimes less.

Mr. Stoney in his *Story of the November Meteors* explains the cause of the unequal distribution of the meteors and why it is that they are constantly becoming more and more scattered in the orbit.

"They seem," he writes "to have passed Uranus while they were still a *small compact cluster*. Those members of the group which happened to be nearest the planet as they swept past would necessarily be attracted with more force than the rest; the farthest members of the group with the least. The result of this must necessarily have been that when the meteors was soon after left to themselves, they did not find themselves as closely compacted as before, moving with an absolutely identical motion, but with motions which differed, though perhaps very slightly, from one another. These are the conditions which would have started them on those slightly differing orbits round the Sun which would cause them, as time wore on, to be drawn out into the long stream in which we now, after seventeen centuries, find them." Sir Robert Ball illustrates very happily the results which must necessarily follow from the fact that the members of the group of meteors after their encounter with Uranus travel in slightly differing orbits with slightly differing velocities. "The case," he says, "is exactly parallel to that of a number of boys who start for a long race in which they have to run several times round the course. At first they all start in a cluster and perhaps for the first round or two they may remain in comparative proximity; gradually, however, the faster runners get ahead and the slower ones lag behind; and so the cluster becomes elongated. As the race continues the cluster becomes more and more dispersed round the whole course, and perhaps the first boy may even overtake the last. Such seems the destiny of the mid-November meteors in future ages. The cluster will in time to come be spread out around the whole of their mighty track, and no longer will we witness a superb display every thirty-three years." I think, however, even the youngest of my audience need not be much distressed at this announcement of Sir Robert Ball, as the superb displays are not likely to be seriously impaired during his time.

Besides the gradual dispersion of the mass of the meteors, of which I have just spoken, there is another cause which is operating, surely if slowly, to diminish the brilliancy of future November displays. It is this that in every November when the stream of meteors is passing through the Earth's atmosphere millions of them perish. Mother Earth exacts a heavy toll from these trespassers on her domain. We must remember that it is only when the meteors are perishing that we are sensible of their presence. We see them for the first and last time for the few seconds or minutes when they are *passing through our atmosphere, a festal blaze in darkness.* We must bear in mind that the orbit of these meteors is retrograde or directly opposite to that of the Earth. Consequently they pass through the Earth's atmosphere with a velocity compounded of their own proper velocity and the velocity of the Earth. As the velocity of the meteors is twenty-four miles a second, and that of the Earth eighteen miles a second, it follows that they pass through the Earth's atmosphere with the inconceivable velocity of forty-four miles a second. The resulting atmospheric friction produces such intense heat that the meteors blaze up and are consumed and reduced to dust, which falls in quantities to the Earth. Some scientific men maintain that the meteors, which are only partially consumed, fall to the Earth as aerolites or meteoric stones, while others are of opinion that the meteoric stones have quite another origin. However that may be, there is abundant evidence everywhere of the presence of this meteoric dust, but few probably appreciate the extensive and important part it plays in this little world of ours. In a lecture on Shooting Stars, delivered by Sir Robert Ball within the last few weeks before the Berkpeck Institute in London, "he assured his hearers," as the London *Spectator* informs us, "that at a most moderate computation scores of tons of meteoric matter are added each day to the previous mass of the Earth. Meteoric particles are found on Arctic and Alpine shores, in the Atlantic ooze and in the motes of the sunbeam. Grains of corn owe something to the gentle rain of meteoric matter, as well as to the rains of a more familiar kind. The loaf as it comes to the table contains within it particles which had voyaged for uncounted centuries of time through illimitable millions of miles of space. Thus, to provide the actual material of our bodily frame, the remotest realms of space have been laid under contribution. The life of everyone present," he adds, "was at that moment in intimate association with particles brought to us by shooting stars." This certainly is a startling statement which we should hesitate to accept did it not come to us with the high authority of Sir Robert Ball. Notwithstanding, however, the destruction annually of so many meteors and their conversion into dust, I may again inform the youngest of my hearers that he may comfort himself with the assurance that the splendour of our November displays is not likely to be sensibly diminished during his time, for if millions of meteors perish every year, many hundreds and hundreds of millions still remain to astonish and delight the world for centuries of Novembers.

When we reflect that the meteoric bodies which our atmosphere turns into dust are counted by hundreds of millions, averaging a marble in size, but many very much larger, we must feel that our atmosphere, in addition to its many other invaluable services, performs an important function of which possibly we may never have dreamt before. It is clear that, but for its kindly protecting mantle, on the occasions of our annual visits from our meteoric friends, instead of enjoying as we do a magnificent spectacle of celestial fireworks, we should be pelted with a pitiless rain of stones, compared with which our most terrible hailstorms would be as nothing.

A word as to the size of the enormous stream of meteors of which we have been speaking. Here we are dealing with large figures, and our estimates are necessarily somewhat conjectural. The breadth of the stream, Sir Robert Ball tells us, is very small in comparison with its length. Its width cannot be less than 100,000 miles, although astronomers, I may remark, make it much more. Its length may be estimated from the circumstance that although its velocity is about twenty-six miles a second, yet the stream takes two or possibly three or more years to pass the point where it crosses the Earth's path. A simple arithmetical calculation shows that assuming the time of passing to be two years the length of the stream must be at least two-thirds of the distance from the Earth to the Sun.

A careful comparison of the various showers which took place at the maximum time in 1866, brings out the fact that the central and densest part of the stream is flanked on each side by lateral and somewhat less dense but wider meteoric currents at some distance from the main stream. We might illustrate the condition of the stream by a vast shoal of herrings in which, side by side with the central and densely packed shoal, there were other shoals on either side, wider, but not so closely packed with herrings.

I have occupied a great deal of time in speaking of the Leonids, and yet before quitting this part of my subject I must ask your consideration to one or two other interesting facts connected with them. If you look at the diagram on the blackboard you will see that there are two orbits of the meteors marked out on it—one with a dotted and the other with a continuous line. The former is the orbit into which the meteors were swung after their first encounter with Uranus in 126; the latter the orbit in which the meteors are now moving. Why this displacement of the orbit? It results, Sir Robert Ball informs us, from the fact that at each successive return of the meteors they cross the Earth's track at a point slightly further on in the direction in which the Earth is moving. The amount of change thus produced in seventeen centuries in the plane of the orbit is shown on the diagram.

The other point which I wish you to notice is the position of Uranus and the meteors at the time of their encounter in 126 A.D. You will observe that Uranus was nearing but had not reached his *aphelion* at the critical moment; the attraction of the giant planet (sixty-four times larger than our Earth) pulled the meteors, then dangerously near him, out of their course, and sent them moving in a new orbit, but on in the same direction as before, and consequently in an opposite direction to that in which Uranus himself was moving. This, it seems to me, is manifestly the reason why the motion of the stream is retrograde or opposite to that of the planets. Had Uranus passed his aphelion when the encounter occurred he would necessarily have drawn the meteors towards him, and they would then have moved on in the same direction with Uranus; in other words, their motion would have been direct.

But it is time that I should leave the Leonids and direct your attention to the other group of meteors which we look for in the latter part of the month, the Andromedes, about which I propose to say something this evening.

This shower of meteors derives its name from the fact that the "radiant" or point from which the shooting stars diverge is found in the constellation.

Andromeda will be situated near the zenith. Great scientific interest attaches to this group of meteors in consequence of the very close connection between it and Biela's comet, a connection which gives this stream of meteors special value in discussing the interesting question which now engages so largely the attention of astronomers—the connection between comets and meteors.

Biela's comet is called after the astronomer whose name it bears and who re-discovered it in 1826. Its history has been a most strange one. I cannot do better than quote Sir Robert Ball's remarks on the intimate connection between the comet and the Andromedes:

"We find," he writes, "that the direction in which the comet moves and in which the meteors move are identical. We have, therefore, learned that the orbit in which the Andromedes move, and the orbit in which Biela's comet moves are coincident. This is in itself a strong and almost overwhelming presumption that the comet and the shooting stars are connected; but this is not all. This comet was observed in 1772, and again in 1805-6, before its periodic return in six and a half years was discovered. It was again *discovered* by Biela in 1826 and was observed in 1832. In 1846 the astronomical world was startled to find that there were now two comets in place of one, and the two fragments were again perceived at the return in 1852. No trace of Biela's comet was seen in 1859 or in 1865-66 when its return was also due. It therefore happens that at the end of 1872 the time had arrived for the return of Biela's comet, and thus the occurrence of the great shower of Andromedes took place about the time when Biela's comet was actually due. The inference is irresistible that the shooting stars, if not actually a part of the comet itself, are at all events most intimately connected with it." As it is now four times six and a half years since the shower in 1872, we are confidently expecting its return as due this year. Hence the interest with which the return of the meteors this November is expected, as helping to solve the question as to connection between the meteors and the comet.

There is, I should mention, a marked difference in the appearance which the Leonid meteors and the Andromedes present when passing through our atmosphere; a difference which is due partly to the very different velocities of the two streams in the transit, and partly to the position of the radiants. It will be remembered that the direction of the Leonids is retrograde or exactly opposite to that of the Earth, consequently they move through our atmosphere with their proper velocity of twenty-six miles a second plus the velocity of the Earth, or eighteen miles a second. They consequently pass through our atmosphere, as I have already said, with the prodigious velocity of forty-four miles a second. The motion of the stream of Andromedes, on the other hand, is direct, like that of the Earth, and consequently the velocity with which they pass through our atmosphere is only the difference between their velocity and that of the Earth, or about eight or ten miles a second.

I may repeat here what I stated in my paper last year on the November meteors of 1832 and 1833, that when we are on the lookout for the Leonids on the night of the 15th November we must remember that there are several other meteor streams which usually are seen at that time. Among these are the Perseids and the Taurids. In ordinary years these latter groups frequently quite outnumber the Leonids, but in the years of the great Leonid display, the other meteors are relatively so few in number as to be almost inappreciable. The Leonids can, moreover, be readily distinguished, even by an ordinary observer, from the other meteors, not merely because they diverge from a different radiant, a different point in the heavens, but also because they are, as we have stated, so much more rapid in their flight and different in appearance.

In conclusion, may I add a personal word, first to express my fears that I have exhausted your patience by the length of my paper, and, secondly, to say that if after all that I have said you should fail to see either or both of the celestial phenomena about which I have been speaking, or if you should be disappointed in the splendour, I pray you to lay the blame as you may think right, either on the astronomers or the weather, but not on your Vice-President, the lecturer of this evening.

TWENTY-SECOND MEETING.

November 15th; Mr. Geo. E. Lumsden, F.R.A.S., occupied the chair.

This was the second meeting held in the Lecture-room of the Canadian Institute. The room set apart for the Library was being made suitable for the purpose, and it was expected that at an early date the books and apparatus of the Society would be brought from the Technical School, and the removal thus made complete.

A letter was read from Mr. E. W. Maunder, F.R.A.S., calling attention to the work which ladies might accomplish in the field of astronomy. Prof. E. C. Pickering, LL.D., had kindly forwarded a number of star maps and forms upon which to record observations of the Leonid meteors.

The Librarian reported the receipt of the first volume of the *Annals* of the Lowell Observatory, containing a series of drawings of Mars and a full discussion of these by the Flagstaff observers. The special thanks of the Society were due to Mr. Percival Lowell for this most valuable work.

In discussing phenomena to be observed, Mr. A. Elvins called attention to the great probability that the Andromedes would be seen earlier than the 27th of the month, this year. A movement of the node of the orbit might bring the Earth and the swarm together earlier and earlier, year by year. It was noted also that Mr. Elvins, at the previous meeting, had cautioned the members not to be too sanguine about observations of the Leonids this year. He thought it not at all likely that many would be seen. The Chairman then called upon the members for reports of observations.

Mr. Elvins stated that he had made arrangements with Mr. J. R. and Mr. Z. M. Collins to observe during the whole night, but he had been disappointed in the weather and had really nothing to report bearing on the Leonids. He had, however, certainly noted some meteors radiating from a point near Capella, in Auriga, and thought it might be worth while to enquire whether there was not a radiant in that region. Several of the ladies present had made arrangements to observe, and had seen a few meteors which were probably Leonids. Miss Elliott and Mrs. Merrishaw made short reports.

After a short discussion of these isolated observations, Mrs. Craig read some notes from recent popular writings by Mr. E. Maunder and Sir Robert Ball.

The Secretary then read a communication received from Mr. T. S. H. Shearmen, of Brantford, on the connection between different classes of solar disturbance and terrestrial magnetic disturbance :—

The great group of sun-spots of September, 1898, and the aurora that followed its arrival at the Sun's C. M., has again caused general attention to be drawn to the fact, that there is a connection between the *position* a spot (or other seat of solar disturbance) occupies between the east and west limbs, and the occurrence of terrestrial magnetic disturbances.

As there appears to be a general misapprehension or oversight regarding a connection between these phenomena which I announced many years ago, I will take the present occasion to state anew some of my results and conclusions, reached after a careful study of auroral phenomena.

One main result has been so well expressed by Prof. C. A. Young in the last edition of his admirable work, *The Sun*, that I quote it here: "Now, when we come to collate aurora observations with those of sun-spots, as Loomis has done with great care and thoroughness, we find an almost perfect parallelism between the curves of auroral and sun-spot frequency.

"We find also, as Shearmen, of Toronto*, * * [has] pointed out, that auroras often run in series, so to speak, following each other for several months at nearly regular intervals of [27-28] days, which is very closely the period of the Sun's apparent equatorial (synodic) rotation; this, of course, makes it more or less probable that their appearance is connected somehow with the way in which certain portions of the Sun's surface present themselves to the Earth."

The conclusion to be drawn from this is (again in the words of Prof. Young), "that disturbed regions upon the Sun are specially influential upon the Earth's magnetism at the moment when they are near the eastern edge of the Sun, and just coming in sight to us on the Earth. There is no obvious reason, however, why a disturbance on the Sun should thus propagate itself more vigorously in a direction tangential

* This was prior to Mr. Shearmen's removal to Brantford, which has been the scene of his astronomical work for some years past.—Ed.

to the Sun's surface and in the plane of the Sun's equator than in any other direction."

Whilst in many cases disturbances of the Earth's magnetism can be traced to the arrival of a solar disturbance (not necessarily a dark "spot") at the Sun's eastern limb, it is also true that there are great—and in many cases, abnormally great—disturbances of terrestrial magnetism, when a very large spot-group is near the Sun's C. M. This fact has been used to throw doubt upon the eastern limb connection; but, as I long ago pointed out, very large disturbances and certain other classes of spots behave differently to the majority of normal spots. In other words, *solar disturbances must be divided into classes, each class having a special influence on terrestrial magnetism.* It is a neglect of this fact (which I pointed out several years ago), that has led many recent investigators into a misapprehension of the subject, and, in some cases, to a denial of any connection whatever between sun-spots and terrestrial magnetism!

Much remains to be said, but I hope the above outline sketch will show that I have been able to harmonize apparently dissimilar phenomena.

A brief discussion followed the reading of Mr. Shearmen's communication. Mr. Elvins referred to the different views held by students of the subject, and testified to the great pains taken by Mr. Shearmen to establish his point, which it was most gratifying to know had been conceded by several most eminent authorities.

TWENTY-THIRD MEETING.

November 29th; Mr. Geo. E. Lumsden, F.R.A.S., occupied the chair.

This was an open meeting, to which the public had been invited, it having been announced that Rev. C. H. Shortt, M.A., would address the Society on "What an Amateur can do without Tools."

The meeting was well attended and Mr. Shortt's address thoroughly enjoyed. The very wide field open to the amateur in the study of astronomy, yet working without any apparatus at all, was specially referred to. A most happy method of constellation study was clearly out-lined, which, followed up, would enable the student to become perfectly familiar with the stars visible in northern latitudes.

Mr. Alderman Davies, seconded by Mr. John A. Paterson, M.A., moved the cordial thanks of the meeting to Mr. Shortt for his most interesting address. Several of the members present acknowledged having received much instruction from the address and hoped that lectures of this character would be more frequent. They would tend directly towards the main object of the Society, namely, the popularizing of scientific studies. In presenting the thanks of the meeting to Mr. Shortt the Chairman expressed his own appreciation of the instructive address.

TWENTY-FOURTH MEETING.

December 13th; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

The proceedings at a recent meeting of council were discussed at length. It had been proposed to ask Prof. E. E. Barnard of the Yerkes Observatory to give a public lecture in Toronto. The desirability of such an event was acknowledged by all; there was no doubt that a renewed impetus would be given to astronomical work among students of science if such an eminent observer as Prof. Barnard were to publicly lecture in Toronto. It was accordingly proposed to appoint a committee having for its work the interviewing of other scientific institutions in Toronto, in the hope that they would lend their aid to making an event of the kind a pronounced success. The President with Mr. John A. Paterson and Mr. Geo. E. Lumsden would form the special committee.

Part of the evening was taken up in a discussion of the recent observations of the planet D.Q., after which the President read a short paper on the *Primum Mobile* suggested by Mr. Musson's paper on the ancient theories regarding motion and the cosmos.

TWENTY-FIFTH MEETING.

December 27th; Mr. John A. Paterson, M.A., occupied the chair.

It having been announced that nominations for the various offices to be held during 1899 would be received, this business was proceeded with.

For the office of Hon. President, the Hon. G. W. Ross, LL.D., Minister of Education, was nominated unanimously and declared elected. For the office of President, Mr. Arthur Harvey and Mr. Geo. E. Lumsden, were nominated. For Vice-Presidents, Dr. E. A. Meredith, Mr. R. F. Stupart, and Mr. John A. Paterson, M.A., were nominated. Nominations for the other offices were unanimous as follows: Treasurer, Mr. Chas. P. Sparling; Corresponding Secretary, Mr. J. R. Collins; Recording Secretary and Editor, Mr. Thos. Lindsay; Librarian, Mr. W. B. Musson; Director of Photography, Mr. D. J. Howell; other members of Council, Messrs. A. T. DeLury, B.A., C. A. Chant, M.A., A. F. Miller, G. G. Pursey, and Rev. C. H. Shortt, M.A.

Reports of observations were then received. Mr. Pursey stated that there had been little disturbance on the solar disc for some time past. He would shortly present his quarterly series of drawings.

Some notes on the planet D.Q. were read from the pages of *Popular Astronomy.* Mr. Lindsay referred to an able article by Dr. Morrison, published in the same periodical, on "The Sun-dial of Ahaz," and thought the subject had been treated in a masterly manner. Mr. J. R. Collins called attention to a report that the bright condensation seen by several observers in the nebula of Andromeda, had not been seen at the Yerkes Observatory.

Mr. J. R. Collins had been requested to prepare a series of experiments in the reproduction of mirage effects. The apparatus necessary had not yet been procured, but it was expected that at an early date the difficulties would be overcome. Mr. Collins then read a short paper on the construction of the reflecting telescope.

NINTH ANNUAL MEETING.

January 10th, 1899; the President, Mr. Arthur Harvey, occupied the chair.

The business of the election of officers was at once proceeded with.

Mr. Geo. E. Lumsden addressed the meeting on the subject of his nomination for the office of President, and desired that his name be withdrawn.

Several members recalled the services rendered to the Society by Mr. Lumsden, and supported him as one eminently qualified for the office of President. Mr. Harvey stated that he would be glad to retire in favour of Mr. Lumsden, and give him an enthusiastic support if he were willing to accept the office.

Mr. Lumsden thanked the members for their good opinion of himself, but again declined the nomination. Mr. Harvey was thereupon declared elected President for the ensuing year.

Mr. John A. Paterson, M.A., desired his name withdrawn as a nominee for the office of Vice-President. Thereupon Dr. E. A. Meredith and Mr. R. F. Stupart were declared elected.

Mr. J. R. Collins wished to resign the office of Corresponding Secretary to which he had been appointed. Mr. Geo. E. Lumsden was then nominated for the office. At this point Mr. Lumsden rose to say that he wished to be relieved of the office of Corresponding Secretary, and that there was no one who could better fill that position than Mr. Collins. On being specially requested to continue in the office which he had made all his own since the incorporation of the Society, Mr. Lumsden finally consented to the nomination, and was declared unanimously elected.

Mr. G. G. Pursey, who had been elected as member of the Council, desired to withdraw. Mr. J. R. Collins was then unanimously elected to a seat in Council.

Mr. W. B. Musson, who had been unanimously elected to the office of Librarian, had not wished to continue in office for reasons which he had on a former occasion explained. It was moved by Mr. John A. Paterson that Mr. Z. M. Collins be appointed to assist Mr. Musson. This was carried, Mr. Musson consenting under these conditions to continue in office.

The Treasurer then presented his report, as follows:

Receipts:

Balance on hand, January 1, 1898	$321 34
Received for Fees	113 00
" " Interest	5 95
The Chas. Clarke Donation	5 00
Municipal Grant	100 00
Provincial "	200 00
Total	$745 29

Disbursements:

Publication Account	$211 30
Expenses	237 15
Balance on hand	396 84
Total	$745 29

On motion the report was adopted.

Mr. Lindsay presented a brief report of the work done during the year, the meetings held, and members elected. A satisfactory increase was shown in the membership.

Mr. Musson regretted that he was not yet in a position to make a report on the Library.

This concluded the business of the Annual Meeting; the remainder of the evening was spent in a general discussion on the best means of still furthering the interests of the Society, and in making popular those branches of science with which it was always specially concerned.

RECENT DEVELOPMENTS IN THE BY-WAYS OF ASTRONOMY AND PHYSICS.

[*Address delivered before the Astronomical and Physical Society of Toronto in the Theatre of the Normal School, January 25th, 1899, by the President, Mr. Arthur Harvey, F.R.S.C. The Hon. President, Hon. G. W. Ross, LL.D., etc., Minister of Education, occupied the chair.*]

The four annual addresses of our Past President, Mr. J. A. Paterson, were the most charming astronomical discourses it was ever my good fortune to hear. In eloquent words he brought his facts before us, accurately stated and logically arranged, and those who possess a series of our *Transactions* have treatises which they can read again and again with pleasure and profit. Such addresses are *hors concours*, and in following the custom established by Mr. Paterson of closing a Presidential year by a public speech, I deprecate comparisons other than those I make myself. He, like St. Paul, is full of faith and valiant in its defence. With a rich store of personal magnetism and an unusual command of graceful diction, he touches the heart as well as the head. I, like poor St. Thomas, incline to be critical and sceptical, and am an unsympathetic delver into facts. He lucidly explains new and lofty theories; I recognize no comparative values in truths. As in biology I dislike to think of some forms of life as high and others low, so in astronomy I hold that a small satellite is as worthy of a man's life-work as a giant planet or a huge sidereal orb.

If I could learn all the laws which govern the being of the little snow crystal which floats down from the upper air on a calm, cold winter day; if I could come to know fully and exactly why it has grown into the particular and beautiful shape I see when I examine it with a lens of sufficient power—I should deem I had gained as much as if I had mastered the laws which rule the ice caps of polar regions, which are thousands of feet in thickness and thousands of miles in area, and send valleyfuls of icebergs to the ocean. On this principle I will try to lead you into some of the by-ways of astronomy and physics, by which I mean roads little frequented of the public. Treasures are to be found there, as in the broader paths travelled by the throng, and as in the old imperial days men truly said, "All roads lead to Rome," so in science, all her paths have a common end. But if you are expecting the eloquent speech to which in annual addresses you have become accustomed, you will be disappointed. I will not try to play Acestes to Mr. Paterson's Eurytion.

The one who might have done so, to whom I desired to hand over this night the responsibilities of my office, was Dr. E. A. Meredith, a Vice-President at the time of his decease. We stand by a grave so recent that the star we placed upon it in testimony of our love has scarcely had time to fade. He was indeed advanced in years, but as active as a young man, in mind and body, and a paper from his graceful pen is to be printed in our next *Transactions*. He was long my personal friend, and of late years has been my neighbour. Though a science medallist of Trinity, Dublin, his chief delight was in the classics. He would sometimes challenge me to a competitive metrical version of some ode of Horace or Anacreon, and whenever I found a delightfully obscure passage in a Greek play, I could rely on his scholarship to help me out of the difficulty. I think I never puzzled him except with the page of Carthaginian, found in Plautus, and I believe he would have tried that, if there were such things as Punic grammars or dictionaries. One of the passages I drew to his attention, as extremely beautiful, is in the last Rhapsody of the Iliad, and describes the grief of Achilles for his friend Patroclus. This I translated for him into hexameters, and repeat, as the lines are apposite to this occasion :—

> "Sleep enfolded the rest, but soothed not the mourner, Achilles.
> There stood Patroclus, the manly, the brave, still present before him.
> All their mutual pleasures and pains, their wars and their wanderings
> Passed in review, that restless night, as he tossed on his pillow.
> Tears would start now and then, amid sighs, and finally, rising,
> Down to the shore he strode, and paced up and down to the wave-beats.
> When, at length, shimmered the dawn, alone he harnessed his horses,
> Three times drove them around the funeral pile of Patroclus,
> Threw himself then on his couch again—but was sleepless as ever."

So does the dear heart, cultured, gentle man, peace-loving, kindly soul, lost to our assemblies, live on for each of us who knew him, in affectionate regard.

The most remarkable astronomical event of the past year is undoubtedly the discovery of the planet Witt, DQ (433). The past

President treated the planetoids on several occasions to gentle sarcasm, and dismissed them with a rippling smile. He told us how they are now usually caught, how they sometimes get lost for a while, and how their names read like the class lists of Ladies' Colleges. But was it quite fair to joke about these "pygmy children of the Sun," these "erring children in a crowded street," to make light of them because some prosaic astronomers have labelled them Bettina or Clementina, or to impute loose morals to Menippe because they had not kept track of her from 1878 to 1896? Surely not, for the asteroids could not well retort.

It was in 1891 that the photographic way of searching for these little bodies was introduced by Dr. Max. Wolf, of Heidelberg. A camera, attached to an equatorially mounted telescope, is pointed to the place where a planetoid is expected, when its proper celestial meridian corresponds with the midnight meridian of the observatory. The plate is exposed for three hours, in which time the heavens appear to have moved 45°. Then it is developed and examined with a lens. The stars, with whose motion the driving clock has made the telescope keep time, appear as points, but the planetoids, moving in their orbits, leave trails, of about one minute of arc.

Now Ennecke, discovered by Peters in 1878, had not been seen since 1889, and astronomers wished to know if it had been captured or had gone to pieces, so after calculating that it ought to be near *β Aquarii*, they sent out notices to be on the lookout for it in the middle of August of last year. On the 13th, Mr. Charlois, an assistant at the Bischoffsheim Observatory at Nice, and Mr. Witt, the chief of the Urania Observatory at Berlin, both photographed the sky in the proper region, and both found Ennecke as well as two other asteroids. One of these was Althæa, Watson's discovery in 1872, which has been regularly observed since then, but the other had made a trail just twice as long as any asteroid had been known to do before. Thinking it might be a comet, Mr. Witt turned the big telescope upon it, found it was an asteroid, and telegraphed to Kiel, which is the central repository for all such astronomical news. Two days later, Mr. Perrotin, the chief director of the Nice establishment, was reminded of his assistant's discovery, and he, too, telegraphed—but, of course, too late, and Mr. Charlois has to be content with such fame as the numerous asteroids he has previously discovered reflect upon him.

It seems almost like one of Jules Verne's inventions to hear of a joint stock company's observatory making astronomical discoveries, but this one "find" is really a magnificent dividend.

When the photographic method of search was introduced, it was arranged that new planets should be provisionally lettered, and no names given until it became quite certain they were new. DQ means that the D series is complete, that is, a hundred, and that this is the seventeenth of the next alphabetical lot. It is the 433rd asteroid, but is possibly No. 1 of an entirely new set. For the nearest asteroid previously known is Adalberta, which revolves around the Sun in 1,103 days, but DQ revolves in 645 days, in a curiously eccentric orbit.* The mean distance from the Earth to the Sun being taken as unity, our perihelion distance is, in round numbers, 0·98, and our aphelion distance 1·02. The perihelion distance of DQ is 1·12, and the aphelion distance 1·70. The perihelion distance of Mars is 1·38. Thus DQ comes a long way within the nearly circular orbit of Mars at one time, and goes a long distance beyond it at another. Very few of the other asteroids swing within the orbit of Mars, and that but a little, at perihelion.

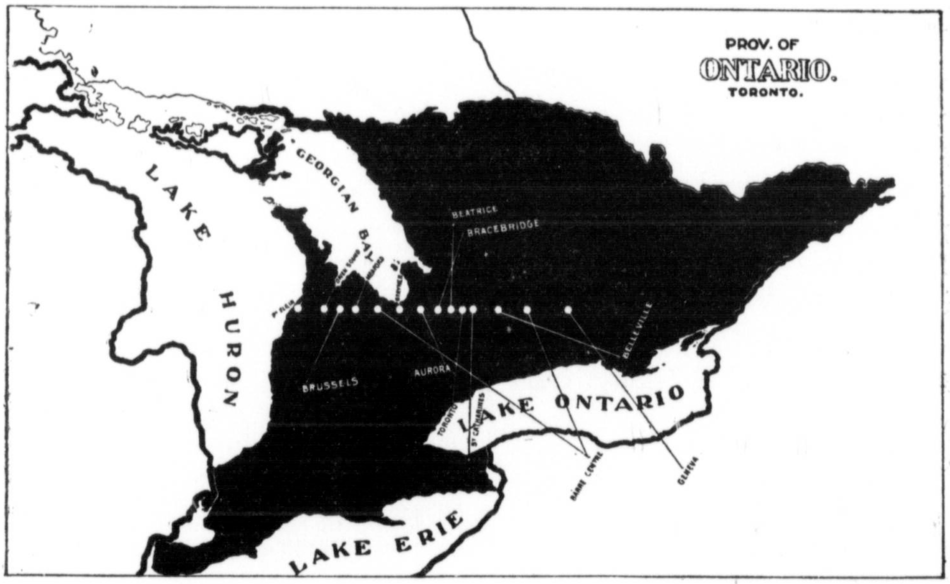
Now the nearest possible approach of the Earth to Mars is when they are both on the same side of the Sun; Mars in perihelion, the Earth in aphelion. Assuming these conditions realized, and taking no account of the different planes of their orbits, their distance would be $1{\cdot}38 - 1{\cdot}02 = 0.36$. Similarly, the nearest possible approach of DQ to the Earth is $1{\cdot}12 - 1{\cdot}02 = 0{\cdot}10$, or less than a third of our nearest approach to Mars. In like manner it can be shown that DQ occasionally comes within half our nearest approach to Venus, which is 0·27, so that this new asteroid is really our very next-door neighbour. Unity being 92,874,000 miles, or thereabouts, DQ may come within the trifling distance of ten millions of miles, though it may be æons before the aphelion of the Earth corresponds with DQ's perihelion. Meantime, at the next conjunction, it will be about 13,000,000 miles away—quite close, in fact. Not the least valuable result of its discovery is, that it will allow of a more accurate estimate of the fundamental astronomical measure, the distance, namely, from the Earth to the Sun. Astronomers have not long finished calculating it by means of measurements involving Iris, Victoria and Sappho, but by using DQ it is thought the limit of error can be reduced by fully two-thirds.

* The asteroid has since been called Eros (the Greek god of love, whom we call Cupid), a particularly happy name in view of its singular movements.

In 1894, DQ was in opposition, and in a favourable position, and was probably as bright as a sixth magnitude star, yet it escaped observation. When Mr. Witt first saw it, it was a little above the eleventh magnitude. In 1900 it will be of the eighth. Not until 1924 will it again reach the sixth magnitude, and be just visible to the unaided eye. We have been eloquently told by the late Richard Proctor, and the mathematics have been beautifully worked out by Mascart, of the harmonious way in which the hundreds of minor planets, revolving between Mars and Jupiter, have been sorted into groups by their attractive power. Here, at length, we find one which is well within the sphere of influence of the Earth, and we shall, no doubt, find many curious and beautifully harmonious relationships between its times and ours. I forbear to speculate on the question whether there are other such bodies circling between Mars and ourselves, and whether all the spaces between the orbits of all the planets are not inhabited, so to speak, by groups of tiny worlds, though the phenomenon of the *gegenschein*, or counter glow, gives plausibility to the belief. To see either the *gegenschein* or the Zodiacal light you must make a pilgrimage to a region where electric lights are not, and, as to the former, you must select a moonless night. Then, as far above the horizon as the Sun is below it, and on the ecliptic opposite that place, you may see a considerable area shining with a mild light, like a very faint nebula. It is so diffuse that if there are bright stars in that part of the heavens you may miss it, wherefore September and October are the best months. Then, too, it is more circular than at other times, when it expands into an ellipse. It may be the light reflected from a belt of asteroids so small as to be separately imperceptible. It has long been said that Saturn was a microcosm of our system, and the recent discovery that his rings are composed of millions of small bodies circling around him, seems to require that there should be rings around the Sun also, of similar nature. The little things swing accurately too. Prof. Barnard, once of Lick, now of the Yerkes Observatory, favoured some of us with an interview last week, in passing through Toronto, and he informed us that Prof. Chandler had calculated the orbit of DQ by the aid of recent observations, and that on the photographic plates of Harvard University this little body had several times been found, so far back as even 1883, when its position corresponded with the calculation to one-half second of arc. Though this accuracy in the movements of the cosmic clock is wonderful, astronomers are really looking not for exactness so much as for disturbance. Like other scientific men they rebel against the soul-benumbing idea that any of the so-called works of the Almighty are in the common sense complete. "He looked upon His work," said the wise Jew, "and saw that it was good." "He looked upon his work," says the flighty expositor, "and saw that it was perfect." That is not the scheme of genesis. No definitely final creation confronts us anywhere. Once, indeed, men thought this system of ours was the only changeable part of the universe. The planets wandered, but they were only scurrying about from their desire to arrive ultimately at a higher sphere, the rest of God, among the patient stars which were fixed aloft, the ideal of purity and repose. But the new astronomy has shattered this belief. The stars are not in the least sense fixed. In the heavens, as on the Earth, everything is movement, activity, a striving for progress, a reaching out towards perfection. If material things were perfect, they would be unchangeable, which implies either divinity or extinction—neither of which is the lot of animals, vegetables or celestial bodies.

The transition from planetoids to aerolites and shooting stars is easy. The former are, however, *ex hypothesi*, parts of the original Sun-nebula, the latter may be bodies which have come from interstellar space into the influence of the Sun and Earth. There is possibly a connection between what we call falling stars and aerolites, but be not unmindful that there may be great differences as to their origin, their physical constitution, and the laws which govern their movements. One of the earliest studies I made in meteoric astronomy, communicated to this Society, and afterwards in fuller detail to the Royal Society of Canada, was a simple statistical enquiry into the distribution of aerolites in space. The collection of the dates of known falls of stones from heaven shewed that it is not uneven, that as many fall in one month as in another, and that their distribution even by days is quite as regular as with a limited list can be expected. This is not the case with shooting stars. Leaving these, however, for a time, your attention will be invited to some deductions from observations of a very beautiful meteor which was seen over a large part of the peninsula of Ontario on July 5th of last year. These observations it was my duty to collect, and all that possess importance are being printed in our *Transactions* for the year.

In a map of part of our Province, at several places from which we have reliable records I have stuck in wires, at the angles at which the observers saw the meteor. This defines its track with considerable accuracy, and the heads I have put upon the wires will enable you to mark with ease the path of this wonderful bolide.*



Prof. Brooks, the director of the Smith Observatory, Geneva, N.Y., saw it descend the western heavens at an angle of thirty degrees from the perpendicular. When he first saw it, it must have been about over Peterboro', which is 120 miles from Geneva. It was then about 100 miles above the Earth, as shown both by scale and calculation. At Toronto it was seen at an angle of fifty degrees from the horizon, a little east of north ; at Beatrice, Muskoka, at an angle of forty degrees, nearly south. The distance between the two places is 120 miles, which gives to the meteor a height over the intermediate town of Barrie of about 70 miles. At Bracebridge, the angle of elevation when the meteor was first seen was noted at sixty-six degrees, which would increase the height over Barrie to 77 miles, but the difference is not material. From that place westward we get some guidance from the noise. Dr. Jakeway's horse, at a gentle jog, went 2,640 feet between the flash and the sound. If "a gentle jog" means 6½ miles an hour and the rate of sound travel-

* The diagram shows the position on the Earth's plane, but not the height of the meteor, which the model does.

ling downward through the air be 1,085 feet a second, that gives an altitude at Stayner of 57 miles, it being there directly overhead. Mr. Parlane, of the Hermitage, Collingwood, says the explosion was heard four minutes after it was seen, which means 49 miles of distance or about 40 in height. It was then rapidly approaching the Earth. The estimate of time between the flash and the noise, as communicated by Rev. Dr. Caswell is given by Dr. Danard, at Rocklyn, 11 miles south of Meaford, at two minutes, and by Mr. F. Abbott, at Owen Sound, at one minute and a half. That means, in distance, 25 miles and 27 miles respectively, the meteor passing between the two places at a height of about 15 miles. The Port Elgin observation corroborates this, and whether the meteor became dissipated or passed on into Lake Huron is uncertain and immaterial; the Port Elgin observer could perhaps determine the point, were it worth while.

Thus we have a well defined visible course for this meteor of about 200 miles, in a direction almost due west, beginning at a height of 100 miles, or, allowing for the distance travelled before an observer's notice would be attracted to it, perhaps 120 miles, and declining in a parabolic curve to an observed height of 15 miles.

It is not easy to estimate the velocity with which it moved, because time-pieces are not set with sufficient exactness. If Mr. W. Weatherbee's account is correct, he must have seen it cover 180 miles in four seconds, or 45 miles a second, but the usual estimate of the limit of its visibility is about five seconds, and it is very unlikely that any one observer would note both the first moment of visibility and the time of its disappearance. If 100 miles of its course were seen by those who estimate five seconds, that would mean 20 miles a second over the ground or 23 miles a second through the air.

At the height of 120 miles, the atmosphere is almost inconceivably tenuous. A single volume of air at sea level, would at that height expand to the 44th power of two, or say a thousand millions of million times its original size. Resistance there would seem to be nothing, but the curious law in aerodynamics discovered and enunciated by Prof. Langley, of the Smithsonian Institute, doubtless comes into play—*i.e.*, the *vis inertiæ* of air, its extraordinary power of resistance to being pushed out of its place by a sudden impulse. This property is what gives the air at our level the carrying power needed by the bird, it helps the boy's flat stone to skim, and buoys up the moving aeroplanes of

Langley and of Maxim. I cannot understand how a meteor can incandesce in such extremely rarefied air on any other ground than that this unwillingness of air to be made vacate its situation on short notice forces the meteor to heap up a cushion in front of it, dense enough to cause a great deal of friction and supply oxygen enough to make its crust, heated by that friction, flash into brilliant light.

When Prof. Brooks saw the meteor, its apparent diameter was about one-half that of the Moon, that is, about 15 minutes of arc. If we take its height to be 100 miles, the distance from Geneva to Peterboro' being as above mentioned, 120 miles, the meteor was 150 miles from the observer, so that, not allowing for irradiation, its real diameter was over six-tenths of a mile. Other observers note its great size, "as big as a foot-ball," "half as large as the Moon," "the size of a plate," "resembling a huge electric arc light,"—all this over a hundred miles away from the object. Nor do they seem likely to have been led into much exaggeration by the dazzling brilliancy of the apparition, for they speak of the breadth of the trail of smoke as equal to that of the meteor itself, and I think the breadth of the trail is a good measure of the diameter of the meteor. To be half the apparent size of the Moon at 100 miles away it must have been 0·43 of a mile across, and to be a quarter her size 0·20 of a mile. At 60 miles away these figures would become 0·26 and 0·12 respectively. Perhaps great meteors like this do not come to us unattended. They have not sufficient mass, according to the kinetic theory of gases, to hold to themselves any known gaseous elements, but they may have collected a quantity of denser matter on their way through the ether. This may have been a swarm, half a mile across, for swarms of that magnitude are not unknown, one may even say not uncommon, and in that case this would be its history :—So soon as it encountered enough friction to take fire, the whole assemblage of hundreds or thousands of stones, big and little, flashed into light. The great trail, "like the steam and smoke of a locomotive," showed how rapid the combustion was. The smaller stones were speedily burned up, but the larger ones continued on their fatal course for a few more seconds, until they were either dissipated or became so hot that they cracked, exploded, and came to a sudden end in a blaze of coloured glory. Probably at some points of the track, part of a bursting stone would diverge from the course of the main body, which would account for a couple of otherwise aberrant observations.

That these "explosions" caused the noises heard, does not seem certain. The rapid movement through the air would cause a thrust, which, followed by the inrush of air to fill the vacuum left by the rapid passage, would set up vibration. At the highest elevations mentioned, these waves would be too much dispersed to cause much effect upon the ear, but as the bodies came within about 50 miles, the swish or hiss first heard would grow into a roll like thunder, which would be the sharper the more vertically it passed.

If, instead of skimming through our air on its way towards the Sun, at a considerable angle with the vertical, this meteor had plunged in upon us about midnight, coming from a radiant near the zenith, all its substance would not have been sublimed, and parts, of considerable size, might have reached us, as aerolites have reached us before. I do not consider the specimen sent us, said to have fallen from the meteorite, to be extra-terrestrial. It shows signs of stratification, which meteoric stones do not exhibit, and the crust, with which part of it is covered, is too thick in places to have been formed while the molten surface was being washed by air.

But what a fine protecting cushion the air is to us. Great masses may rush at us, but in most cases the atmosphere proves an efficient shield. Showers of smaller stones, or lumps of metal, may cannonade us, but they seldom pass the friction belt, or what military men might call the zone of fire. We live secure, quite reconciled to the celestial bombardments which are constantly going on.

The wavy streak left by the meteor is an interesting feature in this connection. The trails of shooting stars, which have heen known to last from ten to fifteen minutes, have not seldom shown a similar wavy appearance, which proves that, high up in the sky, where we might imagine a reign of eternal calm, there is often violent disturbance. When I was at school, the text books used to give 40 miles as the upper limit of the atmosphere. In one respect they were not far wrong: at 40 miles high the air is so rarefied that 32,000 volumes only contain as much gas as one at sea level. At that height the column of mercury in a barometer instead of standing at 30 inches, would only be one-thousandth of an inch above the level of its reservoir, a quantity entirely undistinguishable by the unaided eye. Clearly, then, the aerial waves which disturbed the meteor streak cannot be measured by any barometrical instruments we have, not even Mr. Napier Denison's gigantic water barometers, which indicate the great waves in what he calls the upper air, meaning the stream which steadily flows north-east, above the local currents and clouds which fill the air for a few miles up with their attendant rains and snows. But his waves are only 5 or 10 miles above us, while the zigzag meteor trail tells of storms a hundred miles higher, whose waves, as I calculate them from the observed undulations of its track, are 5 miles long by 2 in depth, and scatter far and wide the fine dust into which it was resolved. There must be many analogies between the movements on the limits of our air and the fierce winds we observe upon the Sun.

Comets, as you know, are bodies of unknown composition, which have been generally thought to come from interstellar space, and to return whence they came, except when they stray within the attraction of some planet, which twists them from their hyperbolic orbits and by compelling them into ellipses, prevents their ever again leaving the solar system. But now comes Fabry, the director of the observatory at Marseilles, who has been closely examining in groups the orbits of all known comets. He finds no evidence that the motion of the Sun through space among the stars has had anything to do with these orbits, as would have been the case if by means of comet-catching planets, or by his own powerful influence he had called them to him as he rushed along. Fabry proves, by an examination of the elements of their paths, that they all are of the proper family of the Sun, which of course extends his sphere of attraction far beyond the furthest planet yet discovered. However this may be, I think that meteors such as we have been discussing are truly comets, perhaps not large enough to be visible at any considerable distance, and perhaps exhausted of the vitality which makes some comets shine—dark comets, as there are dark stars. This is only an "aside" to introduce the subject of shooting stars, which are thought by many to be the discards of comets—a word which I shall presently show good reason for calling a misnomer. You have, doubtless, all become familiar with the term radiant, *i.e.*, the point among the stars from which the meteors of the separate swarms appear to fall. It is not easy for an inexperienced observer to locate the course of meteors among the stars, and many plans have been adopted to help the work. An invention of the past year consists of a ground glass hollow globe, on the outside of which the constellations are depicted, and within which are incandescent or other lights. It is mounted on an axis pointing to the pole, adjusted to latitude, and a moveable quadrant is provided to be placed on the meteor track observed, which is then to be marked in pencil. After each night's observations are copied off, a sponge prepares the globe for further duty. The ordinary requisites for observation of this kind are a thorough knowledge of the constellations, a stellar map of the part of the sky visible at the period, a lamp, a pencil, a quick eye and a ready hand. Now, while there are hundreds of known radiants, there are a few streams which are especially noticeable by their brilliancy or numbers. Chief among these is the great swarm which intersects the Earth's path in the middle of November, and which seems to come from a point in Leo. This year we shall pass through the part of the Leonid swarm which is usually most crowded, though the expected display will be dimmed by the light of the Moon. Last year it was thought there might be a brilliant fall, but observers in Toronto looked for a display in vain, and I, who was star gazing on the height of land west of Lake Superior, from 2 to 3 a.m., on the 13th, 14th and 15th of November, with a clear sky, never saw less meteors in the same space of time. In most parts of the world only a few Leonids were noted, but one observation deserves especial record as showing the devotion of astronomers to their science, and the importance now attached to meteoric astronomy. Lest the weather should baulk the observers at Meudon (Paris), a balloon was provided for their use by the Aeronautical Society of France. Balloons are now measured by their cubic contents, just as ships are measured by tonnage, and this one was of 1,200 cubic metres, which equals 130,000 cubic feet. A Mr. Cobalzar was told off to take charge of the ascent, and when it was known that the heavens at Paris and vicinity would be overcast, Messrs. Dumontet and Hansky took their place in the car. They started at 2 a.m. on the 13th. The balloon had only risen 500 feet when it shot into a beautifully clear sky. Mr. Hansky devoted himself to observing Leo, the others to the heavens at large. From 2.45 to 4.30 Mr. Hansky registered fourteen meteors, of which thirteen were in the region of the radiant. The other observers saw ten to twelve Leonids and about as many sporadic meteors. At dawn the aeronauts descended in a forest, and, some damage having been done to the balloon, involving loss of gas, they were debarred from repeating the observations the next day, which is regrettable as, judging from the observations at Lyons, they might have seen a fine display. There, on the night between the 13th and 14th, there were two observers, the first being on duty from 8 to 12.15, the second from that time until dawn. Mr. Luizet saw three Leonids shoot up before the radiant rose above the horizon at 10.30. After that he noted thirty-one meteors, of which nineteen were Leonids, and the others chiefly Geminids or Perseids. Mr. Guillaume in the three morning hours saw a hundred and thirty-four, which he thought were only two-thirds of the number that fell. They were generally orange yellow, and left a trail. Those without a trail were bluish and belonged to other swarms. Mr. de Fonvielle and Mr. Janssen, who are in control of the Aeronautical Society of France, state that three balloons will be used this year for observations of the Leonids—one in Europe, one in America, and one in Central Siberia. They will be made to hold 50,000 to 60,000 feet of gas, and observers will be able to reach an altitude of 10,000 feet. Each party will make an ascent on the 13th, two will repeat it on the 14th, and the other on the 15th.

While observers have thus been busy, mathematicians have not been idle. The most lucid and complete papers on the orbits of various meteor-streams I have read, are those printed in the *Transactions* of the Imperial Academy of Science, St. Petersburg, from the pen of Mr. Th. Bredikhine. He refers to the drawings and descriptions of the great comets, such as the older folks among us have seen, and to the accounts of the smaller ones, more lately scrutinized with telescopes. The consensus of opinion is that the velocity, length and direction of the streams of matter they emit, both before and after perihelion passage, both towards the sun and away from it, not always even in the plane of their orbits, prohibit the thought of such matter ever being gathered up again by the parent comets. But of all the meteor streams whose orbits he patiently examines, there are but two that seem to be connected with any known comet. He does not refer to the Bielids, which, from their name, must by some one of reputation have been reasonably well identified with Biela's comet, but of the Leonids all he can prove is that they have the same perihelion distance as comet 1866 I. The Perseids only "seem" to be connected with comet 1862 III., and the Aquarids' orbits "have some resemblance" to the orbit of Halley's comet of 1686. It will take half a century at least to accumulate observations and calculate and arrange the orbits so as to speak with any certainty about the connection alluded to, for, of the Geminids, Orionids, Quadrantids and Leonids, all Mr. Bredikhine can tell us is that "the generating comet is unknown." It seems quite evident that if falling stars are the discards of comets, their substance must be tenuous, and they can have little in common with the aerolites which strike us now and then. There is much confusion yet about the whole subject of meteoric astronomy. Perhaps the photographic eye will help us in the study. By long exposure the sensitised plate is made to show more details of nebulæ and comets than we can see by the natural eye, though aided by the finest glasses. Thus the camera, some one suggests, may even be used to catch for us a glimpse of the Leonid stream. True, the radiant of these and other meteors is rather an area than a precise point. Within such areas there are really several radiants. But great numbers of the Leonids do rush in a regular path, from their principal radiant towards the Sun, and while their whole road is broad enough to envelop the Earth for days, the part where they are thickest may impress a plate, if they are in a condition either to reflect or to radiate light, and the luminous trail may tell its story as plainly as did that of the planet Witt DQ.

When Küstner of the Berlin Observatory, discovered that the pole of the Earth did not steadfastly point in the same direction, there was much consternation in the astronomical world, which spread in ludicrous ways to non-scientific men. It is seven years since that discovery, and during those seven years of observation the pole has returned very nearly to its mean position. Fears of change of climate have therefore all subsided, but there remains a lingering doubt whether this twelfth known movement of the Earth may not in some way place a stress upon the substance of the Earth and cause the earthquakes which are always vexing us. Though the question involves latitude upon the Earth, it is largely astronomical, but it is taking up much of the attention of the International Geodetic Association, which met at Stuttgart in October last, to consider questions connected with the measuring and the weighing of the Earth. Six stations are to be equipped this year—three in the United States (at Gaithersburg, Md., Cincinnati, O., and Ukiah, Cal.), one each in Sicily, Turkestan and Japan. It is proposed to buy the land on which the observatories are to stand, though the period of observation now provided for is only five years. The method to be employed is visual, which seems a pity, as the personal equation enters very largely into observations near the zenith. The instrumental outfit will, however, be much less costly than if photographic registry were resorted to. It will consist merely of a zenith telescope and an astronomical clock. Twelve groups of stars, each comprising eight pairs, will be selected—six for the latitude determinations proper, the other two, with greater zenith distances, will throw light on the question of refraction. In fifty years, when the pole will have completed half a dozen cycles, we may expect by these means to know something definite as to its mean path. The Geodetic Association, which occupies 1,228 different gravity stations, has been busy with correcting the formula for L, that is, the length of the seconds pendulum at sea level, into which a spherical function of the third order is now introduced, which infers the determination of a different curvature for the northern and southern hemispheres of the Earth. The society considers that one of the most pressing needs of the day is the re-determination of the lengths of the arcs measured more than a hundred years ago, in Ecuador and in Lapland, at the instance of the French Academy. These ought to be resurveyed with the most modern instruments, for they are confessedly inaccurate, and have, nevertheless, been continuously employed in the determination of the Earth's figure. Owing to political revolutions in Ecuador the measurement of the arc there, miscalled the Peruvian arc, may have to be postponed for a few years. Meantime the Russians and Swedes are measuring an arc in Spitzbergen, between the parallels of seventy-seven and a half degrees and eighty-one and a half degrees. The field work will be finished in 1900, and the computations two years later. This will make the sixth or seventh determination.

We have all heard of the attempts to gather knowledge of the condition of the upper air by means of kites which carry up recording instruments, and of stations on lofty mountains. Mr. Rotch, of the Blue Hill Observatory, has been the pioneer of this work in America, and I am told this is a private observatory, maintained by his own private means. The newest successes in this line are French, and the means used are small balloons, called *ballons sondes*. They are filled with pure hydrogen, and carry a parachute from which hang registering thermometers, barometers, etc. This has so far proved a very satisfactory, and is a comparatively inexpensive, way of exploring at great height without danger to life. The traces are very clear, though complaints are made that the rotation of the balloons causes some irregularity on the thermometrical registers, which I suggest may be obviated by attaching to the apparatus a magnetized tube in a horizontal position. There are also combinations of the kite and the balloon tried at Strassburg, which may be very useful. The Americans, too, have gas kites and sky-cycles, not yet adapted to scientific uses.

But ascents in large balloons for scientific purposes have not been neglected in France and Germany which have for the time displaced England as an aeronautical centre, and means have been found to diminish the risk of visiting high altitudes. One great obstacle was that there is not enough oxygen in highly rarefied air to carry off the ponogenes of the body, when poisoning, and consequently stupor, ensues. The æronauts now carry a store of powerfully compressed oxygen which is at the proper time released through a tap into a reservoir in which the pressure is of two or three atmospheres only, from which it is led by tubes into the mouth and swallowed.

The brilliancy and steadiness of celestial objects seen from balloons are remarkable—the sky becoming blacker by day from the absence of diffused and reflected light, while by night the glare of the full moon seen through an opera glass is quite intolerable. There are those who believe that at great altitudes it may be possible to photograph the Sun's corona without an eclipse.

The study of earthquakes has been extended to Canada and two seismographs have been put up, one at Toronto, the other at Victoria, B.C. They are in charge of Mr. Stupart, the director of the magnetic and meteorological observatory of Toronto, and are part of the series reporting to Prof. Milne, at Shide, in the Isle of Wight. The Toronto instrument has been in working order since last spring, the other since October only, but I learn that several earthquakes have already been recorded both at Toronto and Victoria, and I have seen the record of one which was probably a Japanese earthquake; the traces at both the Canadian stations are similar, and the time at Toronto is ten minutes and a few seconds later than at Victoria. Whether the shock is conveyed by the Earth's crust, around the globe, or directly through it, is not yet certain. In this connection the last paragraph of the seismological report to the British Association at its meeting here is of importance:—

"The greatest result which it is hoped may be achieved" (by a seismic survey of the world) "is to accurately determine the rate at which earthquake motion is propagated over long distances. In some instances the rates which have already been determined are so high, reaching 12 and more kilometres ($7\frac{1}{2}$ miles) per second, that the supposition is, that motion does not simply go round our Earth, but that it goes through the same : and if this is so, then a determination of these rates of transit will throw new light upon the effective rigidity of our planet."

If the tremor alluded to above came from Japan and precisely the same shock is timed at Victoria and at Toronto, the rate of transmission through the arc is less than four miles a second, while through the chord it is slower still. This instance is only quoted, therefore, to show the need for continuous careful examination. In science, a lifetime is but a brief span, and each generation can but add one layer to the pyramid of knowledge, which, though it continue to rise, unchecked by national and international catastrophes, will never in this world receive its golden capping. What, indeed, are the so-called triumphs of science, of which we are considering a few, but revelations of previous ignorance? Even yet the sum of what we do not know is to the sum of what we have learned, as the whole circumambient air is to a summer catspaw which just ruffles a small area of our sleeping lake. Still, we all abhor the vague and long for the definite. Given a problem, and we crave for its solution. Thus the search for more light is and ever will be insatiate, and we must, as a need of our nature, be adding here a little and there a little to the general aggregate of what has been ascertained, which is called science.

It is by no means literally true that the foundation of the world cannot be moved at any time; nay, the Earth is never at rest for a single day. When I last visited Mr. Stupart, a fortnight ago, there had already been thirty-seven earthquakes registered at Toronto, of which fifteen had been also observed at Shide. The times of transmission varied far more than expected, even allowing for the relative distances from the supposed earthquake centre. The only reason I could assign was that the particular portion of the quake most felt in one place was not the same that was registered as the main shock in another. The words quoted from the British Association report also came forcibly to mind: the "effective rigidity" of the Earth. What must the Earth's interior be like? In some places miners have reached a depth where the heat is too intense for them to bear, and reckoning from the ascertained rate of increase in temperature as depth is gained—an increase well established on the average, though not uniform in all localities—the rocks must be in a state of fusion at 60 miles down, while at 600 the temperature is usually considered to be from 15,000° to 25,000°, so that from such a depth to the centre of the Earth there may be nothing but the vapours of elements in a state of the most intense compression. Could we bring a ton of such gas suddenly from the Earth's centre to the surface, it would expand with violence to which dynamite explosions are but toys, for the pressure must be two millions of pounds to the inch. Rock matter has its fusing point raised under pressure, and it is conceivable that under the enormous pressure spoken of it may be virtually solid—which is one of the things we should like to know. Now, the crust may or may not rest conformably on a fluid core. If not, there may be cavities, in places, and the falling in of solidified matter or the slipping of one stratum upon another may produce a series of violent tremors. If it does rest conformably, the infiltration of water, through deep and devious channels, until it reaches the inner fires, may cause tremendous pressures, and earthquakes such as destroy lives by the ten thousand may be the serious result. We have few earthquakes in Canada now that exhibit features of violence, but at a remote time the whole country was terribly and continuously shaken, to which the geological features bear evidence, but this branch of the subject is not for us to enter into here.

The mention of Mr. Stupart's name recalls many happy hours spent among the records of the Toronto magnetic and meteorological observatory, which with unvarying kindness and patience he has made available to me for my favourite study, the Sun and his connection with terrestrial magnetism. The installation of the electric street railway system interfered so much with the working of the magnets that no amount of care in applying corrections sufficed to make them tell their tale with accuracy. A new house for these delicate instruments has accordingly been built at Agincourt, nine miles distant to the north-eastward, where the trolleys cease from troubling and the restless bars are undisturbed by artificial attractions. For three months, while they were being moved, the photographic register was broken, and the record kept by the old imperfect system of eye observations.

From the Sun there is always something new. We have long known that the spots upon his surface are larger and more active at some times than at others, and that a maximum occurs about every eleventh year. Somewhere near the time when there is a maximum of spots, there is also a maximum of the protuberances which are seen on the edges of his disc, from which the great prominences shoot up, which spectroscopists can now observe at any time, though in the pre-spectroscopic period they were only visible during total eclipses. At these times, also, the great white clouds upon his yellowish gray surface, which are called faculæ, shine most intensely, and it is conjectured that the corona then attains its greatest extension, though the point is as yet uncertain, for the corona can only be observed when, during total eclipses, the moon blots out the rays of his glowing disc. Thus the Sun is in all likelihood a variable star, though not from the same cause which makes Algol and some others variable, viz., the rotation around them of huge dark bodies which cut off portions of their light. What the cause may be of the periodical outburst on the Sun is a mystery awaiting solution. There is no warranty for presuming the existence of an invisible mass, swinging somewhere in space, and approaching him more nearly every eleventh year, to call his fires into renewed activity. Nor can one well imagine an internal cause for the regular throbbing of the mass of the giant orb. There is surely no Titan imprisoned within him, as there once was under Ætna; the Titans are as dead as Hecuba.

The spots only appear in the equatorial zones, further from the equator at maxima and nearer at minima. Protuberances and prominences are seen much further north and south, and sometimes even near the poles. For some years I have charted on maps the prominences recorded in the *Transactions* of the Italian spectroscopists, and to show you how fierce is the solar activity even near a minimum, I invite your inspection of the chart (on a Mercator's projection) of the prominences for 1897. These are the prominences of the year shown as in a composite photograph and they are not all active at the same time. However, the Sun may be considered as belted with these flames, as Jupiter and Saturn are belted with clouds, and for that matter the Earth also. There seem to be regions on the Sun which are the scenes of many such outbursts in the year, while other regions are quiescent. The main belt of 1897 was between 60° and 50° north latitude. Between 45° and 30° there were fewer eruptions, but a second fiery zone existed between 30° and 20°, and of this three portions were more active than the intermediate parts. In the southern hemisphere there was a belt between 50° and 55°, less defined than the northern belts, and most of the prominences where in one part of this hemisphere, covering about 100° of longitude. I have transferred half the chart to a hemispherical map, which will show these features in a simple way.

Spots are no sooner well formed than they tend to diminish and disappear, though they are sometimes seen during a second and third solar rotation. But as they change their form, and have different rates of rotation in different latitudes, and have sometimes proper motions of their own, there is difficulty in deducing from them the exact rate of solar rotation. I have therefore tried another method, based on magnetic disturbances on the Earth.

Remarkable concordances between the years of sun-spot maxima and those when our magnets are most disturbed have long been known to exist. Prof. Garibaldi, at Geneva, brought out this fact in his paper printed in the *Atti dei Lincei*, 1890, basing his argument on averages. Taking the bifilar magnet as a guide, which indicates the variations of horizontal magnetic force, the following relations exist :—

Years of sun-spot maxima.	Remarks on magnetic conditions.
1848.8	The beginning of 1847 shews much disturbance, and there is much irregularity towards the end. The beginning of 1848 is a disturbed period too, especially in April. We have no observations for the end of this year.
1860.2	A disturbed year, violent magnetic storms at the end of March, the beginning of July and the middle of August.
1871.0	The year 1872 is the year of the most marked disturbance.
1883.2	The year 1882 seems more disturbed than the next.
1893.0	The year 1894 is the year which shows the greatest disturbance.
Sun-spot minima.	
1844.0	A very quiet year.
1856.2	No observations for this year but 1857 is very quiet.
1867.2	A very quiet year.
1878.0	A quiet year.
1887.0	A quiet year.
1898.0	Quiet, except one storm on September 9th and 10th.

The precise period of sun-spot maxima and minima is not easy to ascertain ; the area on the Sun covered by spots is taken as the criterion, but it may not quite correspond with the intensities of solar action. So, too, I take the magnetic data from the curves which show the daily means of magnetic force, but its actual amount and its variations have not been computed. Some aberration may therefore be found in the statement, but on the whole it is certainly correct, and the conclusion is undoubtedly true, that in some way solar outbursts influence the magnetism of the Earth.

In 1872, Prof. Young was looking at the Sun and saw a spot break out. At the same time a magnetic storm began, and the inference was drawn that particular spots cause special storms. Few, if any, recurrences of this coincidence have been observed, and the theory which would invariably connect spot formation with magnetic outbursts needs further proof. Some spots, however, do influence us, and the question arises, do the storms occur when those spots are formed, when they appear upon the eastern edge of the disc, or when they directly face the Earth. However this may be, it is difficult to believe that an intensely heated body can be magnetic at all, for, in the laboratory, magnets lose their power as temperature increases. Terrestrial magnetism may, therefore, be an effect induced by some undiscovered form of vibration communicated through the ether, and it certainly seems likely to be most effective when the solar disturbance is central as regards our planet. I believe our corresponding member Dr. Veeder's theory is, that some cool envelope of the Sun is magnetic, and that there are particles of meteoric matter distributed throughout his system in sufficient quantity to convey that magnetism, by induction, to every planet.

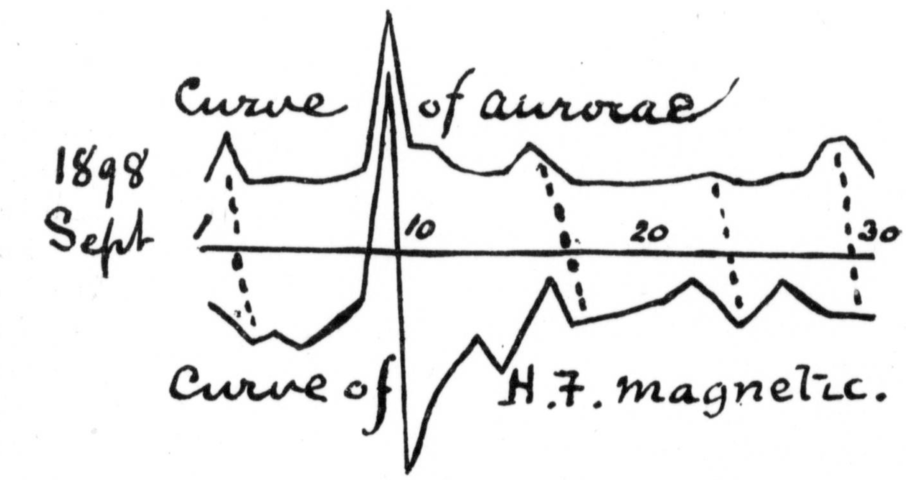
On endeavouring to find the period for the recurrence of particular storms, it occurred to me that there might be particular areas on the Sun from which eruptions intermittently take place, and a paper in our last year's *Transactions* tracks with some plausibility the recurrence of magnetic depressions for fifty years, at intervals of which 27·24575 days or multiples thereof are on the average the measure. This then should be the mean rotation period of the Sun, and it agrees very closely with the rate of rotation given by Carrington. I have even ventured to predict periods of magnetic disturbance, not without success, but much more work has to be done to prove or disprove the theory. The Sun's atmosphere is flaming fire—incandescent hydrogen, helium, carbon, lime, vapour of iron and all the other elements, metallic and non-metallic—one of the last discovered by its spectrum being vanadium.

There can be no nucleus in the ordinary sense of something that is solid, though under the enormous pressure it may behave as a solid, and if eruptions are due to chemical changes, the disturbed portions of the huge globe must be numerous and in many cases very large. For it is no slight cause that throws up great volumes of the Sun's envelopes a hundred thousand miles in a few minutes, to be quickly deformed and dissipated by the furious furnace winds which attend such upheavals. Nor is it a slight cause which in the spot zone tears away millions of square miles of photosphere and chromosphere and lets us look at the filamentous formation of the penumbra, and at the yawning depths where the umbra shows black by contrast—depths within which, as Prof. Barnard tells us, he can see with the great Yerkes telescope still deeper and darker chasms.

The interferences of such eruptions with each other, and the changes constantly going on, make it very difficult to trace their separate effects.

A fine illustration of the connection between sun-spots and magnetism occurred last year, though a quiet year for both phenomena, with the one exception I am about to mention. On the 1st of September the magnetic curve began to show signs of depression, and dipped a little more on the 2nd and 3rd, but not so much as to be called a storm. On the 2nd the greatest sun-spot of the year appeared on the eastern limb. It was the principal spot of a group, which proved to be, according to Mr. Elvins' calculations, 150,000 miles in length, and 40,000 miles in breadth. It was central on the 9th, and on that day as well as the next the magnetic disturbance was very violent, a sharp rise occurring on the former day, and a still sharper fall on the latter. The spot disappeared by rotation on the 15th. There was a magnetic dip on the 14th, and a rise on the 15th and 16th—these changes seeming to have no connection with the spot. It should have reappeared on the 29th, but Mr. Lumsden thinks he observed it a day ahead of time. On the 29th there is a dip, which is a periodical recurrence of that on the 2nd, but if the spot came into view as Mr. Lumsden says, that and the dip are not connected, nor can any other magnetic variations be connected with it. Its final disappearance after the third rotation is given by Mr. Denning as November 8th. As calculated, the time should be November 10th, which bears out Mr. Lumsden's observations, for there seems to have been some current impelling the spot ahead of solar rotation. This spot was caused by some extremely violent commotion on the Sun, of which no previous indications were given, nor did it leave any permanent traces.

There was at the same time a beautiful example of the connection between magnetic storms and auroræ, for on the 9th and 10th auroræ were reported from every part of the Dominion—"brilliant" at Pembina crossing, "of the first class" at Quesnelle forks in the far west, as well as at Cape Magdalen and Cape Chatte in the St. Lawrence gulf. In Europe the aurora of the 9th was the finest seen for many years, the English, French and German journals were full of notices about it, the illustrated papers gave pictures of it, it was reported upon in detail by observatories, and I do not doubt that the Russians have continued the chain of observations through Asia, while we shall hear of it from the southern hemisphere as well. To make the connection between the vibrating magnet and the dancing northern lights clear to the eye, I have made an auroral curve for September from the *Weather Review*, a publication we owe to Mr. Stupart's initiative, combining by means of its reports both frequency and intensity. This I have placed in juxtaposition with the magnetic curve for the same period, indicating by dotted lines the corresponding phenomena. If these lines vary from the vertical, it is because auroræ are only observed at night, while magnetic observations include the day.



I also present the curves for the whole year, and the same correspondence is noticeable, though the auroral observations are subject to many corrections, as they do not include arctic regions. The most numerous and brightest auroras are almost invariably coincident with the principal dips of the curve of horizontal magnetic force. This is no new subject of discussion in Toronto (see pages 80 and 81 of our *Transactions* for

1897), but I now advance the theory to its conclusion and say that observations indicate that the whole of the magnetic force from the Sun finds immediate expression in auroræ, and that when we obtain an auroral record for the whole inhabited world, we shall find that the auroral displays correspond as to their sum with the magnetic aberration from average. They are not of universal distribution, except in a few isolated cases.

It is, perhaps, to be noted that in 1892, a spot appeared in February, which was central on the 13th, the date both of the magnetic storm, which is the frontispiece for that year's *Transactions*, and of the celebrated Rose Aurora. Later, in July, a spot appeared as a notch on the limb on the 7th, was central on the 14th, and passed off on the 21st. There was no depression on the 7th, and a very trifling one on the 8th, but on the 14th a great magnetic storm burst out and literally broke the record. Mr. Miller micrometrically measured this group of spots at 147,000 miles. Mr. Elvins described the auroræ accompanying it at centrality. In 1894 a spot came over the limb on February 15th, which proved to be easily visible to the naked eye. Coincident with its centrality on the 22nd was a remarkable aurora, described for us by Messrs. Copland and Collins. Mr. Carpmael furnished us with a record showing an intense magnetic storm on that same date. I then made a series of magnetic charts, and showed the Society that the storm had given signs of its approach by a slight depression in the curve on December 28th, 1893, which appeared more clearly on the 26th January, 1894, and that after the three great outbursts between 21st and 25th of February it could be traced on March 22nd, April 18th, May 15th, and June 10th. I now add that it can be seen in the spring months of 1895 and 1896, for it causes depressions on the exact days expected. On the other hand, on February 4th, 1897, I figured a spot, or rather a group, which involved $\frac{1}{13}$ of the diameter of the Sun, or say 66,000 miles, but there was only a slight magnetic depression then. That slight depression was repeated several times, but there was no great magnetic outbreak until 16th March, 1898, which at all corresponded with the day of solar rotation, and as to the identity of that there are special reasons why one cannot speak with certainty. Such indications led me to the theory of areas of continuous disturbance on the Sun. They must be deep-seated, in cases which produce great spots, and it is not the spot but the explosion or condition of the part of the Sun where the spot occurs which makes the magnetic storm. The spot, like the storm, is only an effect. Prominences often accompany spots, but I do not think they are such deeply seated disturbances as spots must be, and I find no evidence that they materially affect the magnets, nor do I yet find auroræ to follow protuberance or prominence effects.

I wish I could give you the completed results of an examination I have begun, of which the present result is that the sudden changes noticed in comets' tails are synchronous with outbursts of solar energy as shewn by terrestrial magnetism. Astronomers have been more careful to ascertain the elements of comets' orbits than to give daily accounts of their constitutional changes, and while I find in the transactions of scientific societies plenty of mathematical calculations, it is difficult to unearth the precise data needed for my purpose. I think, however, there is little doubt of the correctness of the statement I believe to be a new discovery. We shall have to wait for the appearance of another great comet to study thoroughly this interesting and important question.

Encke's comet, 1871, was globular, but on the 9th November "it exhibited a new aspect, anything but globular." On that day the principal magnetic depression of the month occurred, though it was not an important one.

Coggia's comet, 1874, had a tail which "became exaggerated" on July 13th. There was a noticeable depression on that day.

Brooks' comet of 1893 showed nothing remarkable until October 22nd, when a photograph disclosed the fact that it was broken up into irregular masses of cloud, and had the look of a lighted torch waving in the wind. On the 23rd (which owing to the difference between the astronomical and civil day may mean the 22nd) a magnetic disturbance began, which reached its acme on the 25th, while another raged violently on November 1st. The end of October was the most disturbed period of the autumn.

Comet 1861 II. suffered a change, possibly on July 2nd, on which day there was but a slight depression. If, as I believe, the Earth passed through its tail on June 30th, it is worth noting that there was no magnetic disturbance then.

I have not the magnetic records of 1836, when Halley's comet returned to us, but let us examine the facts about Donati's, which spanned the sky in 1858—the most beautiful and wonderful object it has ever been my delight to observe. In Dunkin's "Midnight Sky" it is stated that "on October 3rd the matter comprising the nucleus and envelope was evidently in a continual state of local excitement." We have no records from the Toronto Observatory for 1858, so I turned, with some excitement also, to the records of the observatory at Bombay, which the Canadian Institute possesses, and you can judge of my satisfaction when I found that in this critical case the curves shewed that the greatest dip of the month—a fortnight before and a fortnight after—occurred on that very day. The curves at Bombay follow, as you are aware, if you have paid attention to previous papers, the same rule which these at Toronto obey. Wherefore I say, thus early in the inquiry, which I hope others will take up and aid me in, that whenever a comet is near the Sun, and a solar outburst occurs which causes a magnetic storm, the influence of that storm is felt in the rending apart of the material, whatever it be, of which the comets' tail is composed, in the excitement of the nucleus and the ejection of shining substance.

What if the next eclipse of the Sun should be photographed in colours? The new process which consists of taking three photographs with an ordinary camera, through glass screens of yellow, blue and red, transferring them to stone and reproducing the original by three successive printings in the same three colours, is fairly successful. Here is a label for packages of starch, made by this means—a beautiful reproduction from a larger picture. I have seen examples taken from nature, and there seems no reason why a triple camera, or a single camera adapted for rapidly changing the coloured screens, should not bring out for us in its true colours the next Sun eclipse, and show the dark disc of the Moon, the carmine of the prominences, the sealing-wax red of the chromosphere, the orange glow surrounding it, the silver sheen of the corona and the blue of the sky. Mrs. M. E. Dignam has been so kind as to paint for me the Sun eclipse of 1896, as seen in Turkestan, from the photographs and drawings, and the admirable description of the colour phenomena given in the reports of the Imperial Institute of St. Petersburg.

The customary time limit for an address has been reached, which is also that for which an audience can give attentive thought to any subject, however engrossing. But I must follow precedents and say something to our visitors about this Society.

There are among our members, as in most associations of the kind, two schools of thought. We have the proselytising section who desire to go out into lanes and by-ways and invite their fellow men to join them in admiring the features of the Sun and Moon and the beauties of the wandering and other stars. They call upon all of scientific tastes, especially the young, to engage in the particular studies in which they themselves delight. We also have those who, having gained some insight into the first principles of astronomy and physics, wish to get further knowledge for themselves, and find, in meeting other like-minded people, incitement and encouragement in the patient and pleasurable work. These members refuse to think that the cause of science is served by flaunting her achievements and chanting her praises after the manner in which the attractions of a circus are paraded; they think her beauty and dignity will of themselves attract votaries, as ardent and more constant than these who, under temporary excitement, join her train. But these differences do not interfere with our internal harmony, and there is room among us for many more of both orders. I have heard that some persons fear to join us lest our discussions should be too abstruse for them to understand. To show how slender is the basis for this apprehension is in part the reason why to-night I have led you among some of the least popular problems, and you have listened in a way that convinces me you have your feet so planted on the steps that you can climb yet higher up the golden stairs. Not a quotation have I given you from any major or minor poet, secular or sacred, but I judge that you have been all the time aware of the harmony and rythm which prevade and conjoin astronomical and physical facts. Discussion on such subjects and reports of observations occupy us at our meetings within walls, but they do not constitute all our practice; we meet on roofs, in observatories, on lawns—wherever we can find an outlook to the sky—and every one of us who owns a telescope delights to show to friend or stranger whatever it can reveal. We received last year a kind and thoughtful intimation that the city council would give a small sum to aid us in extending such facilities to the general public, and we have found that public interested and appreciative. This induces us to look for additional means of supplying the craving for such knowledge which undoubtedly exists. Toronto is not an ideal place for an observatory, its skies are too often clouded, especially in winter, owing to its situation between the lakes. An Ontario observatory, designed for scientific work with telescopes of the highest power, should not be near the lakes but on the height of land; while a Dominion observatory of that kind should, perhaps, be on the higher slopes of the Rocky Mountains. But we have in this city many nights in winter, and more in summer, so clear that the stars hang like jewels from the sky, tempting one to reach out but a little and seize them. We have, indeed, a better climate for observation than any British observatory, a clearer sky than Paris, where the brothers Henry cannot use more than five out of thirty of the lunar negatives they take. We are in a better situation than the fine observatory of the Vatican, the Urania at Berlin, and many others in Europe, while we are in no worse plight than some of the best observatories of the States; those, namely, which are near the Atlantic coast. So as we do want to see the nebulæ, the planets, and the comets, now and then, to fair advantage, though we may not make them the study of our lives, and as we cannot do so if we have to go to Wabigoon, or Medicine Hat, or Banff, we wish to have a good equatorially mounted telescope in or near Toronto, accessible to the public at reasonable times for purposes of observation, and we could find uses for it too on sundry special scientific lines, though it were not possessed of the light-collecting power of the Yerkes or the Lick. It would cost $10,000, be as valuable and useful to the public as a library or museum, and a source of just pride to every citizen.

To be ready to appreciate such a telescope and to help the project by your influence, join our ranks. The annual subscription has been placed at a nominal sum so as to keep no one out who cares for knowledge of this kind, while the possession of our printed *Transactions* and the use of our already valuable library are concomitants of membership. Like many who put their hands to the plough, you may soon tire, but on the other hand you may become sun-worshippers like Mr. Pursey or be moonstruck like Dr. Wadsworth and Mr. Lumsden, you may find delight in thoughts on the origin of the solar system and the cause of gravity like Mr. Elvins, or become spectroscopists like Mr. Miller. You may take to theoretical and practical optics like the Collins Bros., or be attracted to the mathematical side of science like Messrs. Phillips and Lindsay. With Mr. Musson you may take up historical astronomy, or seek for fossils in meteorites like Dr. Hahn. You may help Mr. Howell in his photography of celestial objects, or with me persecute for meteorological records the officials in the park. But you will not have the melancholy fate of my old acquaintance who, speaking of the wakeful hours at night which usually accompany increasing years, complained that they were always a burden and a weariness. His assertion was not unchallenged, for to me there are no hours more delightful, and I said that if one tired of writing or reading one could always think, which was even better. "Oh," said he, "but one must have something to think about. I know little outside the common affairs of trade, which are but worries, and I often have recourse to a sleeping draught, which brings oblivion but not refreshment." Thus he; but to others the glorious, ever-restless Sun, and the silvery, silent, almost changeless Moon are never shut out by the drawn curtains of a bed-room. For some the sapphires, emeralds, rubies and diamonds which gem the sky are ever glittering, meteors rush past in squadrons to receive the question, "whence and whither?" and return the same reply. The heavenly arc displays to them its sweet and lovely tints in every kind of weather and renews the pledge that sunshine will always follow showers, redress the balance of the rains and beneficently distribute them over the whole world. At their will the heavens blush into dawn and at their command the Sun sets in ruby glories. They make vivid lightning flash from the darkened sky, and at their bidding the bright silver clouds are heaped up. Thousands of other beauties and wonders recur to their memory and lead to reflection on the laws which govern the being and the movements of all matter, which the highest authority on Earth declares must lead to a due recognition, not of the conflict but of the concord between knowledge and faith.

At the conclusion of the address the Minister of Education, who, upon rising, was received with applause, said :—

"MR. PRESIDENT, LADIES AND GENTLEMEN,—This is the first time since my appointment as Honourary President that I have been able to occupy the chair at any of your meetings, or in any way to identify myself personally with the splendid work which you have been doing for science. From year to year I enjoy the pleasure of reading the Presidents' addresses at the Annual Meetings, being, as they are, always carefully prepared, and showing, as they do, succinctly, the progress of astronomical and physical science. I have, indeed, read the annual reports of your proceedings, not as a matter of official duty, or simply as a matter of routine, but with a great deal of interest and profit, and I am pleased to say that your Society is one of the handmaidens of the great scientific investigations which are now being carried on in this country, and in all lands where science has her votaries, and is doing a grand work. The excellent address to which we have listened this evening is an illustration of what a Society which makes no pretensions can do through its officers and through its members. I think the paper which Mr. Harvey has read would be a credit to the presiding officer of any society, not excepting even such a body as the British Association, evidencing, as it does, wide range of knowledge, and accuracy and extent of observation, and expressed, as it was, in language clear and felicitous."

Having alluded to the present Government grant to the Society, and having added that, if he had his own way, he would be pleased to double, or to treble it, Dr. Ross proceeded :—"I think it is a pity that we in this Province, with our excellent educational facilities, and with considerable knowledge of scientific matters, generally, do not devote ourselves more to special lines of work. 'Everybody is a faddist,' somebody has said. Banker though he is, Sir John Lubbock was contented, and found time to amuse and instruct himself, and as events proved, others as well, by observing the habits of ants and bees—a very dull and monotonous study one might think, looking at the matter cursorily, but one in respect of which that now famous amateur naturalist and investigator has succeeded in making observations of a high order, and has contributed to Natural History some splendid chapters as a result of his pursuit of this 'fad.' Lord Salisbury as an electrician, Mr. Chamberlain as a cultivator of orchids, and Mr. Balfour, in other ways, devote themselves in their leisure moments to what some people might call 'hobbies,' and it is said that Mr. Gladstone, when he used to get tired of Statecraft, translated Homer or Horace. Our politicians, I am sorry to say, do not get time outside their political duties for anything but political meetings. I am glad that Mr. Paterson and Mr. Harvey and Mr. Lumsden, and a good many other members of this Society have time to occupy themselves in studies of practical utility, which are to them, at the same time, a source of great pleasure. I congratulate the Society on the splendid work it has done, and thank you for the honour you have conferred upon me from year to year of electing me to be your Honorary President. I hope Mr. Harvey will continue his investigations, and that we shall all be contributors, more or less, to the interesting and instructive subjects embraced in the terms 'Astronomy' and 'Physics.'" (Applause.)

APPENDIX.

CORRECTION FOR "SCHAEBERLE ABERRATION" IN THE GREGORIAN AND CASSEGRAIN TELESCOPES.

BY J. R. COLLINS.

In a paper appearing in the *Transactions* of this Society for last year, dealing with the "Schaeberle Aberration" in the telescope, I endeavoured to show that the error thus designated could be entirely eliminated from the Gregorian form of telescope by manipulating the curvatures of the surfaces of both reflectors in such a way as to neutralize the errors of each.

Since that time I have, with the assistance of my brother (Z. M. C.), gone carefully over the subject, and we are now able to state the figure and ratio of the curvatures of the reflectors and their relative position to each other, that will bring about the correction referred to.

We find that if the surface of the large mirror be a paraboloid of the same figure as that requisite for a Newtonian, and the small mirror an ellipsoid, the diameter of available aperture of each to the other being as six is to one respectively; the ratio of the radius of curvature of surface of the small mirror being 1 to $6\frac{5}{8}$ of radius of curvature of large mirror; the small mirror being placed $\frac{1}{6}$ past the focus of the large one will give a resultant focus of the combination at a point situate on the axis behind the surface of the large mirror, a distance equal to $\frac{1}{11}$ the focus of the large mirror.

In the former paper, it was stated that the Schaeberle aberration was aggravated in the Cassegrainian form of telescope. While this is true when dealing with the curvatures usually employed in that instrument, we find that if special curves are employed it is possible to eliminate the error as effectually from the Cassegrainian as from the Gregorian telescope, thus: the surface of the large mirror to be the figure of a hyperboloid, and the small convex mirror also to be hyperbolized, with diameter of available aperture of small mirror to large mirror in proportion of 1 to 6; radius of curvature of small mirror to radius of curvature of large mirror 1 to $4\frac{1}{2}$; the small mirror to be placed $\frac{1}{6}$ inside the focus of large one, giving a resultant focus, as in the former case, at a distance behind the reflecting surface of large mirror, equal to $\frac{1}{11}$ of its focus. That is to say, if we suppose the focus of the large mirror to be 33 inches, the resultant focus would be formed 3 inches behind its surface, through the opening in front of the eye-piece at F, as in Fig. 1, the correction for the large mirror being carried twice as far as with the ordinary parabolized Newtonian reflector.

This is shown in Fig. 2, where C is the centre of curvature of spherical surface of large mirror, f, the focus of central portion, for parallel incident light. As the curved surface sweeps outward it cuts the parallel lines at angles becoming more and more acute as the aperture is increased, and the angle of reflection being always equal to the angle of incidence, the focus gradually shifts successively inward to f', the focus point of the extreme outside portion of the mirror's surface. In parabolizing the reflector for a Newtonian the point to be obtained is to cause the scattered points from f' to f to advance and concentrate on the point f, and to do this it is necessary to gradually lengthen the focus of the successive portions of the reflecting surface from the centre outward. Such a figure, of course, must necessarily be a paraboloid. Now, to obtain the correction we desire, it will be required to extend or push back this figure still further successively until the extreme outside ray is brought to a focus at f'', a distance beyond f equal in amount to its former displacement inside that point from f to f', leaving the central rays still focussed at f, thus producing the figure of an hyperboloid.

The same holds with the small convex mirror, with the exception that the hyperbola is carried still further until f'' is extended 50% further beyond f, than f' is inside f, the proportion of overcorrection being as $1\frac{1}{2}$ is to 1 as in Fig. 3.

When we refer to radius of curvature in any of the above, the radius of the spherical surface before it is parabolized or hyperbolized, as the case may be, is intended.

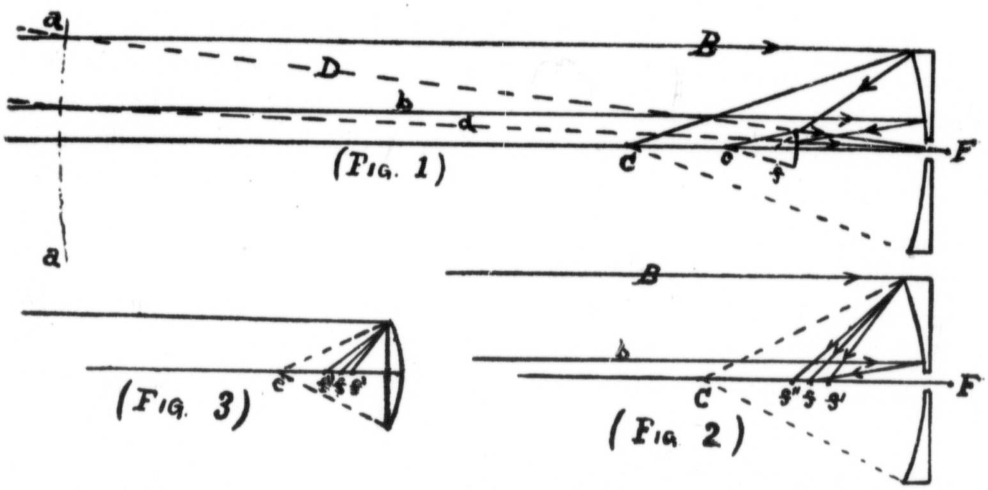


Figure 1 is a graphic demonstration of the correction for the Cassegrainian form of telescope that can be followed by any one familiar with the elementary rules of optics.

If the incident ray B with resultant focus at F in Fig. 1 be projected forward along D until it cuts B at *a*, the total distance from that point to F is the equivalent focal length of the combination; and for all parallel incident rays reflected by the combination as with *b*, *d*, etc., so that if the size of the images from all portions of the reflectors are uniform, all the reflected lines when projected backwards will cut its parallel incident ray precisely on the arc *a*, *a*, which arc is centred on F. With the explanations given of Figs. 2 and 3, it will be seen that all the rays projected backward cut their incident parallel on the arc *a*, *a*, consequently all portions of the compound reflecting surface are of equal equivalent focal length and must produce images of the same diameter. The demonstration also applies to the Gregorian.

If "I" be the central portion of large mirror whose parabolic focus would be *f*, and "*i*" the central portion of small mirror placed either outside or inside of "*f*," and F *a* be the equivalent focal length of the combination, then as *f i* is to *f* I, so should F *i* be to any line from F cutting its parallel incident ray (or equivalent parallel incident ray) on the arc *a*, and the correction is attained. When the mirrors are closer together than this, in the Cassegrainian, the hyperbolic correction required, is less for both mirrors, and when further apart, the required correction is greater.

The ordinary refractor can only be corrected for a portion of the spectrum at any one time, and even then absolute correction is not attained for that particular part; the colour images for the corrected parts being of unequal size, and though the error may be minute, it leaves a blurring effect to be dealt with as well as that due to the Schaeberle aberration, which is also present. So it will appear that, with these defects eliminated, the Gregorian and Cassegrainian reflectors accurately figured, and of maximum brilliance, for the wave fronts of light it is possible for them to reflect, other things being equal,—aside from the diffraction effects of secondary cell, and its supports—are capable of forming an image more sharply defined than most of the instruments considered to be their superior.

THE MEAFORD ASTRONOMICAL SOCIETY.

(INSTITUTED 1893.)

Affiliated with the Astronomical and Physical Society of Toronto.

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The Meaford Astronomical Society.

Transactions of 1898.

The first meeting of the year was held on January 6th at the residence of Mrs. H. Manley, Vice-President, and was well attended, three visitors being also present. Under the head of communications, a letter was read from Mr. Wallace of Orillia, stating that there were a number in that town desirous of organizing an astronomical society, and asking for suggestions as to procedure. Miss McRae reported having observed a very brilliant sun-dog on evening of January 3rd and another the following morning, both of which had also been observed by Dr. Danard. An interesting discussion took place in reference to a meteoric stone, which the newspapers reported having fallen November 24th last, at Birmingham, N.Y. A chapter from the text-book was read and discussed.

A large attendance was present at the meeting held at the residence of Mrs. W. Moore, jr., on the evening of February 10th. An article was read on the subject of the Total Eclipse of the Sun as observed in India on January 22nd. Miss Shortt read a selection from Sir Robert Ball's writings on "The Material of a Comet," and a long discussion followed on the subject of comets generally. A portion of the text-book was read, dealing with the phases of the Moon.

The next meeting was held at the Society's rooms on March 3rd, and a further communication was received from Orillia, telling of the organization of an astronomical society there and asking for advice regarding text-books and magazines. The President called attention to some coming eclipses of Jupiter's moons, and gave dates and hours on which, if the weather was favourable, members ought not to fail to watch the interesting phenomena at the eye-piece of the telescope.

Mr. J. S. Wilson handed in a newspaper article giving account of a new moon described by Dr. Waltemath, and supposed to be Dr. Wiggins' dark moon, which was to cross the Sun's disk on 30th July.

The ninety-fifth meeting of the Society was held at the residence of Mrs. Fuller, on Bridge street, March 17th, and the meeting was a large one. Copies of the annual *Transactions* for 1897 were placed on the table, and examined with interest and satisfaction. The President exhibited many drawings of 'sun-spots' which he had observed of late. Mrs. Manley read an article entitled "Life on the Planets," by Mr. Percival Lowell. Dr. Caswell then read a paper in form of a popular lecture on the Moon, and a vote of thanks was passed to the writer.

The next meeting was held at the Society's rooms on the evening of March 31st. Several members had observed a large halo around the Moon that evening, and the subject was discussed. The Rev. A. H. Wright, of Stayner, who was present as a visitor, and who had resided for many years in the Saskatchewan district, gave a very interesting description of the brilliant auroras seen in the great North-West, with the beautiful prismatic colours and active motions observable. Mrs. Manley read an article by Sir Robert Ball on "Recent Discoveries about the Sun." A portion of the text-book was read and discussed dealing with the Moon. Arrangements were made for the holding of a public open meeting of the Society in some suitable hall, and a committee appointed for the purpose.

The ninety-seventh meeting was held at the residence of Mrs. H. Manley. A communication was read from Henry Harrison, Esq., of Jersey City, informing us that he was sending a gift of his telescopic picture of the crescent Moon.

The ninety-eighth meeting was held at the Society's rooms, April 29th, and a communication was read from Henry Harrison, Esq., of Jersey City, describing his private telescope, the method of its mounting, powers, etc. A resolution was passed thanking Mr. Harrison for the telescopic picture of the crescent Moon which he had kindly presented to our Society, and a copy of this hearty resolution was directed to be published in the local newspaper and forwarded to the donor. The President called attention to the favourable position in which the planet Venus was now situated for observation. It was also mentioned that Saturn was now in the eastern sky and its rings rather more open than last year. Miss Shortt read an article of much interest entitled "The Stars in April." Dr. Caswell read an article written by Mr. Thos. Lindsay, of Toronto, in the *Canadian Home Journal* entitled "Astronomy as a Recreative Study."

On May 12th a public open meeting was held in the hall of the Ancient Order of Foresters, kindly placed at our convenience for the evening. The chair was occupied by Dr. Hamill, mayor of the town. Some of the lady members and visitors furnished a short programme of instrumental and vocal music. A lecture on "The Moon as a Neighbour and Friend," was given by the Rev. Dr. Caswell, President of the Society, after which a series of lantern views on astronomical subjects, kindly supplied by the Astronomical and Physical Society of Toronto, were exhibited by Mr. S. Huff, Science Master of Meaford High School, and explained by the President. The hall was well filled by an intelligent and appreciative audience, and a vote of thanks was moved by the Rev. S. H. Eastman, B.A., and seconded by James Cleland, Esq., ex-M.PP., expressing the gratitude of those present to the Meaford Astronomical Society for furnishing them with an evening of such great interest and instruction in a field of study out of the usual order of things and altogether new to many of them, and wishing the Society for the future much prosperity.

The one hundredth meeting was held in Miss Paul's drawing room on the evening of May 26th. The Corresponding Secretary reported having received a copy of a quarterly journal published by the Astronomical Society of Wales, and entitled *The Cambrian Natural Observer.* The President called attention to some of the coming phenomena in connection with Jupiter's moons in May and part of June. Dr. Danard gave a description of a beautiful lunar rainbow which he had observed. Mrs. Manley read an interesting article on the subject of "Double Stars," and Mr. Thos. Lindsay's article on "Astrology" in *Popular Astronomy* was read and very much enjoyed. A portion of the text-book was read and discussed on the subject of the Moon's surface, as to its so-called lakes, and its mountain ranges, etc.

The next meeting of the Society was held at "The Rectory" on the evening of June 9th. The President gave an account of two large sun-spots which he had been observing, and also a drawing of the Moon showing the lakes, mountain ranges, and prominent features. A portion of the text-book was read, dealing with the inferior and superior planets and their phases, followed by a long discussion and the examination of several drawings made to illustrate what had been read. The members then adjourned to the lawn, where by aid of the telescope Jupiter's moons were observed, but the condition of the atmosphere was not favourable to make observations satisfactory.

The one hundred and third meeting was held at the Society's rooms on July 7th. Observations made by several members of lunar rainbow, auroræ, and a large meteor which had passed over the town on the evening of July 5th, led to a long and interesting discussion. Dr. Danard read a very valuable paper on "Earthquakes," and by resolution he was requested to allow it to be published in a local newspaper. Dr. Caswell had hurriedly prepared a paper on "Meteors," and had gathered as much information regarding the recent brilliant one as possible, and was requested to send it to local newspaper for publication, as it would serve to answer many questions which were constantly being asked.

At the Society's rooms on the evening of September 8th, a communication was read from Mr. G. E. Lumsden of the Toronto Society on the subject of the recent brilliant meteor, and several further items of interest were gathered to be transmitted to Toronto.

Under the head of observations several members mentioned a very beautiful sight afforded on the evening of August 18th by the conjunction of Jupiter and Venus in the western sky. On September 2nd the aurora was seen through shifting clouds, and on September 7th a very beautiful rainbow with reflection of remarkable brilliancy. A chapter of the text-book on the Sun was read and discussed, and several selections from Prof. Young's book were also read by the Corresponding Secretary on the same subject.

The next meeting was on September 26th, and was held at the residence of J. S. Wilson, Esq., M.A. A copy of Poole Bros.' Map of the Full Moon, which had been ordered, was much admired by all present. Mr. Huff, in a brief address, explained the "Metric System" at the request of some members present. Dr. Caswell read a newspaper account of the fall of a large meteor in Mexico on 22nd July. A chapter from text-book was read on the physical and chemical condition of the Sun, and Mr. Huff, by some drawings, showed the scientific nature and use of a *prism*.

The one hundred and sixth meeting of the Society was held at the residence of Mrs. H. Manley, on Thursday, November 10th, at eight o'clock. Mr. J. S. Wilson gave a reading from the *Daily Bulletin* relative to a recent electrical discovery, in which it is claimed the inventor is enabled to transmit electrical energy through the atmosphere by means of a transmitter and receivers, without the necessity of metallic wires. The paper of the evening was furnished by Dr. Caswell, who had recently returned from a holiday trip to Washington, D.C. In his paper, which was very interesting and instructive, he described his visits to the Naval Observatory at the American capital, giving a description of the new buildings and the splendid instruments in use, and especially the perfection of all the appointments in connection with the 26-inch refractor, one of the largest telescopes in America.

A resolution was passed expressing the heartfelt regret and sorrow of the Society in the loss which they have sustained in the death of Miss Shortt, who for several years was a member of this Society, and took a deep interest in its transactions and in the study of astronomy, and that a copy of this resolution be transmitted by the Secretary to Mrs. Sheppard, the sister of the deceased.

The one hundred and seventh meeting of the Society, and the last for the year, was held in the drawing room of Miss Paul, Librarian, on December 1st. Dr. Danard sent in a communication suggesting the idea of inviting a lecturer from one of the Toronto colleges to deliver a lecture under the auspices of our Society on some astronomical subject. It was thought that this might be done in May, when we could hold another public open meeting. Mr. G. G. Albery, Corresponding Secretary, read an article respecting the giant telescope now under construction for the coming Paris World's Exposition.

The work of our Society has been greatly hindered during the present winter season by the sickness of some of the members, and by many other matters which have interfered with the regularity of our meetings, but we enter upon a new year with the same affection among our members for our favourite science, and the desire to advance ourselves in the knowledge of the same.