TRANSACTIONS

OF THE

Astronomical and Physical Society of Toronto,

FOR THE YEAR 1893,

INCLUDING FOURTH ANNUAL REPORT.

PRICE ONE DOLLAR.

TORONTO:
ROWSELL & HUTCHISON,
Printers to the Society.

1894.

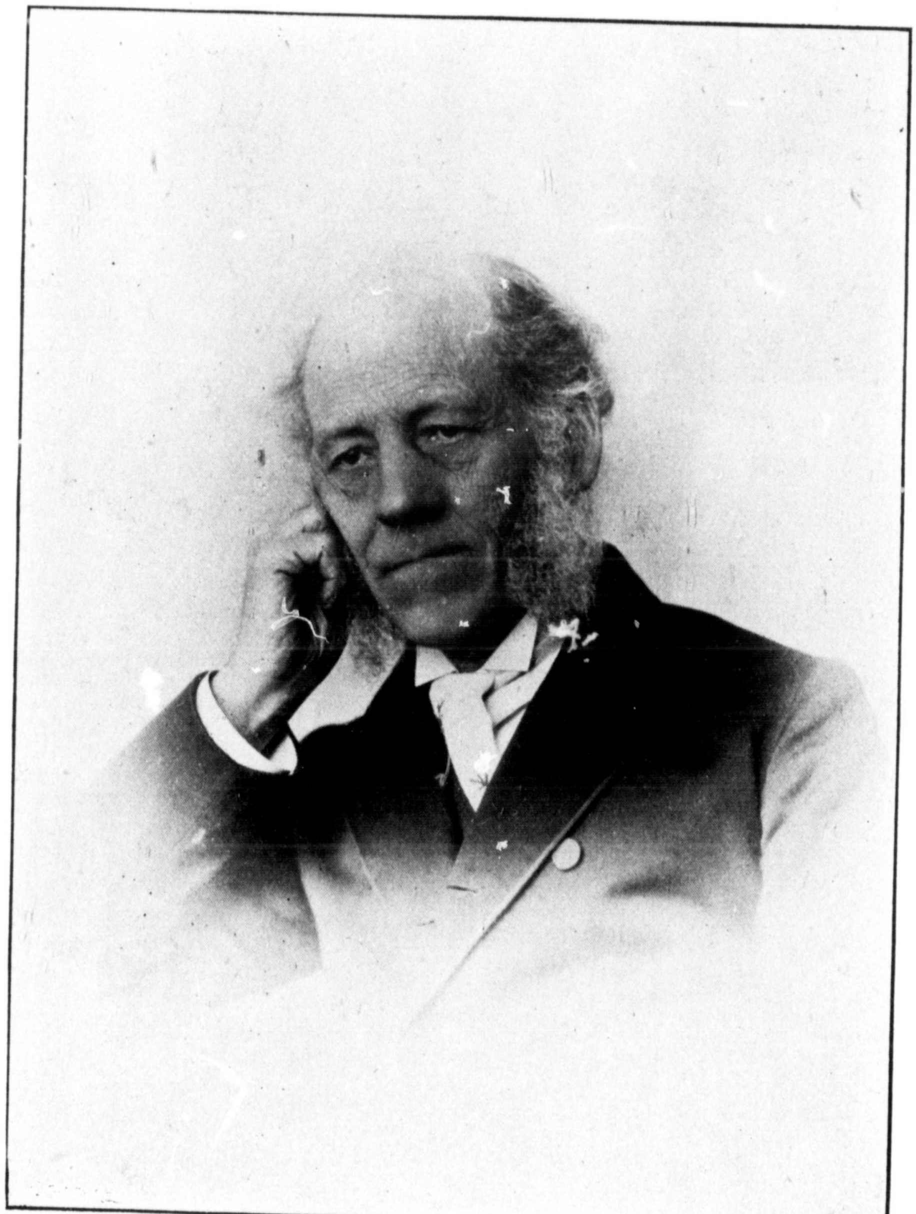
The

WITH COMPLIMENTS OF

The Astronomical . . .

. . . and Physical Society

OF TORONTO.



ANDREW ELVINS.

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The Astronomical and Physical Society of Toronto.

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TRANSACTIONS

OF

The Astronomical and Physical Society

OF TORONTO,

DURING THE YEAR 1893.

FIRST MEETING.

The first meeting of this Society during the fourth year of its incorporated existence, was held on the 24th of January, 1893, Mr. John A. Paterson, M.A., Vice-President, in the chair, but as the business done pertained to the annual meeting held on the 10th of January, from which it had been continued by postponement, the proceedings were published in the Report issued for the year 1892.

SECOND MEETING.

February 7th; Dr. Larratt W. Smith, Q.C., Vice-President, presiding. On taking the chair, Dr. Smith cordially thanked the Society for having again chosen him as one of its officers. He appreciated this mark of its renewed confidence, and would endeavor to do everything in his power to promote the prosperity of the Society which had been so signal in 1892. He had pleasure in reporting that the Council had decided to apply to the Ontario Government for an annual grant in aid of the Society's funds. That Government had ever manifested a disposition to foster and assist scientific bodies of a popular character, and he had no doubt that any representations that might be made would receive careful consideration. He suggested that the Council be authorized to prepare and send a respectful Memorial to the Minister of Education, who took a deep interest in the science of Astronomy, and who had willingly become the Honourary President of the Society (Applause). Dr. Smith's suggestion was formally approved of, and a special meeting of Council was called.

As some evidence of the willingness of members to render assistance where possible, and of the public appreciation of the efforts of the Society to fulfil its pledges, it was stated that during the year Miss S. L. Taylor, Dr. A. D. Watson, and Messrs. J. A. Paterson, A. Elvins, G. G. Pursey, D. J. Howell, and G. E. Lumsden had cheerfully acceded to requests to address, on the subject of Astronomy, audiences in various parts of Toronto, and that some of them had spoken on two or three occasions wher the Society's lantern and views had been used. Mr. Pursey added that he had been desired by a gentleman in Peterborough to assist him in getting together some material to be used in a lecture on the planet Mars, that he and other members had complied, and had received the thanks of the applicant.

Among the communications read by the Corresponding Secretary, the following note from the Honourable G. W. Ross, LL.D., Minister of Education for Ontario, was received with applause:

EDUCATION DEPARTMENT, ONTARIO.

Toronto, 26th January, 1893.

MY DEAR SIR,—Kindly accept my thanks for the honour done me by The Astronomical and Physical Society of Toronto, by appointing me Honourary President for the year 1893. I have read the proceedings of the Society with a great deal of pleasure, and regret exceedingly that I have not been able to attend its meetings. I hope when the Session is over, I shall be at liberty to enjoy the benefits of its discussions more directly than heretofore. Yours truly,

GEO. W. ROSS.

Publications received from the Royal Society of England, the United States' Naval Observatory, and The Astronomical Society of the Pacific were laid on the table by Mr. Pursey, the Librarian.

Mr. Arthur Harvey and Mr. Andrew Elvins reported that they had observed a fine aurora on the 4th of February. The arch rose above the horizon to a greater height than usual; the prevailing colour was light green, with blotches of pink. The night was an extremely cold one.

Mr. G. E. Lumsden read a memorandum dealing, in a general way, with certain of the more remarkable astronomical phenomena observed and discoveries reported in 1892, and with some of the phenomena predicted for 1893. References were made to the Sun, sun-spots, planets, comets, occultations of stars, and, at some length, to the Moon, which was described as one of the most interesting of the celestial objects and extremely well adapted for observation with almost any kind of magnifying glass. Some attempt was made to describe the lunar sky as it would appear to a terrestrial observer if he could take up a position near the centre of that side of the Moon which is always turned to the Earth.

The paper was followed by an animated discussion relative to the Moon, sun-spots, and other phenomena, and to the causes operating to make in Northern Europe, Asia, and America the winter of 1893 an abnormally cold one, and, at the same time, to make the summer in the Southern Hemisphere an abnormally hot one, with a remarkably heavy rainfall.

Mr. Harvey suggested that solar conditions, when a sunspot maximum is being reached, might have something to do with the cause, if themselves not the actual cause; but Mr. Elvins, who had exhaustively studied the subject, in an effort to ascertain the effect visible changes in the Sun have upon terrestrial meteorology, was inclined to think that, whatever the cause is, it comes from without rather than from within the solar system, and that the Sun, as well as the planets, are alike subject to it. He had failed to find that great cold in the Northern Hemisphere was accompanied by great heat in the Southern Hemisphere, but he had detected a correspondence in this respect between the Eastern and Western Hemispheres. The discussion was participated in by the Chairman, Mr. M. Turnbull, Mr. Pursey and others.

THIRD MEETING.

February 21st; Mr. John A. Paterson, M.A., Vice-President, in the chair. Miss Jessie Brodie, of Toronto, was elected an Active Member. Mr. Pursey, the Librarian, reported the receipt of a series of interesting publications from the observatories at Uccle, Berlin and Alleghany; also publications from various British and Foreign Societies.

The letters read included communications from Professor W. W. Payne; from M. L. Niesten, of the Royal Observatory at Uccle, Belgium; from Sir Robert S. Ball, LL.D., Lowndean Professor of Astronomy and Mathematics at Cambridge, England, who applied for a copy of the last Annual Report of the Society, and from Dr. M. A. Veeder, of Lyons, N.Y., with reference "to the interesting co-incidence that Holmes' comet should have rapidly increased in brightness on January 16th, at the time when the enormous spot area, near the Sun's meridian on the 27th of that month, was appearing at the eastern limb." At the previous return of this area on December 20th, there was a well defined auroral period. In the doctor's opinion, "the conditions on January 16th were favourable for the development of increased luminosity of comets' tails, if they are of electro-magnetic origin and auroral character, and the point had an important bearing upon the cosmical dust question and the part it plays as a conducting medium for electrical currents."

At the instance of Dr. Larratt W. Smith, Q.C., who was unable to be present, Mr. G. E. Lumsden read the following Memorial drawn up by Dr. Smith at a meeting of the Council in support of the Society's application to the Government for an annual grant, and the letter from the Minister, acknowledging its receipt :—

To the Honourable George W. Ross, LL.D., etc., etc., Minister of Education for the Province of Ontario, Toronto :

The Petition of The Astronomical and Physical Society of Toronto, respectfully showeth :

1. That the Society was incorporated in 1890 under the above name.

2. That it has a constantly increasing membership, now numbering over eighty, and has held fortnightly meetings throughout the whole period of its existence, besides many sectional meetings for observation and instruction.

3. That it is in constant correspondence with nearly one hundred Astronomical Societies and Observatories in different parts of the world, with which it exchanges printed Transactions.

4. That the papers read and the observations made by its members, are acknowledged by the Societies to be of value to science, and communications, embodying original observations, theories and calculations, are being constantly sent to it by Honourary and Corresponding Members, who are persons of eminence in Astronomical and Physical circles.

5. That the Society, with the design of attracting to the study of Astronomy and Physics, as large a number as possible, not only of residents in Toronto, but of observers throughout the Province, has placed its fees for membership at a small figure, which is found to be barely sufficient to meet the incidental expenses of the Society, yet difficult to increase, without limiting the Society's usefulness at home.

6. That the Society finds the cost of printing its Transactions, with properly engraved diagrams, and of preserving, in good order, the books and apparatus it

has been, and is constantly, acquiring (mainly through the liberality of generous donors) too considerable for its resources.

7. That it, therefore, respectfully prays for a liberal annual grant in aid of its funds to be applied towards the expense of printing, of acquiring works of high scientific value and, ultimately, of such instruments of observation as may be needed.

The Society proffers this humble request with the greater confidence, because there is no other Astronomical Society in the Province, and because it has reason to know that, by the liberality and publicity of its actions, it has largely contributed to the spread of an interest in Astronomy, to the diffusion of information respecting its principles and practice and to the cultivation of a taste for this, the noblest of all sciences.

8. The Society begs to enclose herewith, printed copies of its Transactions, and will be glad to submit copies of the Transactions of other Societies as models of the excellence which it hopes by the aid of the grant herein applied for, in due time, to attain.

And your Petitioners as in duty bound will ever pray.

LARRATT W. SMITH, *Vice-President.*

Toronto, February 9th, 1893.

EDUCATION DEPARTMENT, ONTARIO,
Toronto, 13th Feb., 1893.

MY DEAR DR. SMITH,—I shall bring the petition of The Astronomical and Physical Society before the Government when the Estimates are under consideration. If I think it is necessary, after I have discussed the matter with them, for a deputation from the Society to wait upon them, I shall let you know. I sincerely trust, however, that you will be spared this trouble, and that the grant will be cheerfully made.

Yours truly,
GEO. W. ROSS.

Larratt W. Smith, Esq., D.C.L., Q.C., Toronto.

After the Memorial and the reply of Dr. Ross had been read, the action taken by the Council was formally approved of, and fitting mention made respecting the active interest taken by Dr. Smith in promoting the application.

Mr. Lumsden read a Report from Council relative to the action to be taken by the Society in endeavoring to induce astronomers to reckon the Astronomical Day from Mean-midnight instead of from Mean-noon, as now. It was stated that on Saturday, the 11th of February, the Council met Dr. Sandford Fleming, C.M.G., an Honourary Member of the Society, who had for years taken a deep interest in the subject of Time-Reform, and who in 1892, was appointed by the Society to be Chairman of the Special Committee selected to consider this matter. The Report added that after addresses by Dr. Fleming and by Professor Carpmael, who presided, it was decided to seek the co-operation of The Canadian Institute, which had been successful in other branches of the subject, and to suggest the appointment of a Joint Committee to be charged with the issue to Astronomers the world over, and to other scientific men interested, of a circular briefly setting forth the advantages to be derived from the proposed change and inviting answers to a question prepared for eliciting every shade of opinion upon the subject. Mr. Lumsden intimated that Dr. Fleming, on the evening of the same day, brought the subject to the attention of The Institute, which heartily agreed to co-operate with the Society and authorized its Council to appoint the necessary Committee.

It was thereupon moved by Mr. G. G. Pursey, and seconded by Mr. James Todhunter, that the Report of Council be adopted, and that Messrs. Charles Carpmael, F.R.A.S., President of the Society, John A. Paterson, M.A., and G. E. Lumsden, be authorized to act in conjunction with three members of The Canadian Institute, as a Joint Committee, with Dr. Fleming as Chairman, to deal with the question.—Carried.

Owing to incessantly cloudy skies, few observations were reported, but reference was made by Mr. A. Elvins, Mr. A. Harvey and Mr. C. P. Sparling to a brilliant aurora visible on the 17th of February. A "mock sun," visible on the morning of the 20th, was described by Messrs. A. F. Miller, Harvey, Elvins, Lumsden and others. This apparition seems to have been best seen during the twenty minutes commencing at 9.10 o'clock. Around the Sun, at a distance of about twenty-three degrees, there was a halo, at times well defined. At three points in the halo, North, East and West of the Sun, there were bright luminous spots equi-distant from each other; no corresponding point South of the Sun was noticed. The Sun in the centre of a cross, the halo, the brilliant spots, and, more especially a short luminous arc North-west of the Sun, at a distance of about forty-five degrees, made up a most interesting object. The arc appeared to occupy a part of the sky otherwise clear, and was remarkable owing to the fact that in the course of a few minutes it disappeared and re-appeared some half-a-dozen times. The convex side of the arc was towards the Sun and, when at its brightest, was tinged with red; the Northern side was violet in colour. The phenomenon was observed by many persons in Toronto, and a diagram, showing most of the features described, was sent in by Mr. Christopher P. Sparling, a student at Trinity University.

The paper of the evening was entitled "The Telescope," and was read by Mr. Arthur Harvey, who, in terse language, sketched the history of the development of the telescope by means of discovery, invention and experiment and the application of the Laws of Optics, as they came to be understood. With the history of the instrument itself, were interwoven a narrative of the important discoveries made in the heavens, a description of the several kinds of telescopes used, brief references to the lives and work of the most noted observers, a rapid survey of the science of Astronomy, past and present, and an encouraging forecast of its future. The latest announcements from the more important fields were enumerated and some of the advantages yet to be derived from spectroscopy and photography foreshadowed. Interesting references were made to the Sun and the planets and to the present work of photographing all the stars down to the fourteenth magnitude. The paper was an exhaustive one, and was supplemented by numerous diagrams, some original, and by a working model of the great telescope in the Vatican Observatory. The following were the author's closing words: "Old, yet new! New, yet old! What a perennial attraction Astronomy affords! The Pope, in renovating the Vatican Observatory, quoted from Solomon, the Wise and Unhappy, who says that he 'studied and came to know how the world was made, and the operations of the elements, the beginning, ending and midst of the times; the alternation of the turnings of the Sun and the change of seasons, the circuits of years and the positions of stars.' From a passage in Amos, it would appear that he was a highly educated and well-read physicist, as well as a far-sighted politician and prophet, for all that he was a herdsman and fruit-picker. His words we might well adopt as a motto: 'Seek Him that maketh the Seven Stars and Orion, and turneth the Shadow of Death into the Morning and maketh the Day dark with Night; that calleth forth the Waters of the Sea and poureth them out upon the face of the Earth.' The parallelism of these passages shows, by the way, that both men had studied in the same University, or Temple School; so, clearly, Astronomy was one of the recognized branches of higher education in Syria twenty-five centuries ago. Of Chaldea and Egypt, we know the deep astronomical lore centuries before that. Yet we glory in the thought that it has been given to this generation to found a New Astronomy, in which there are yet space and room for the individual effort of everyone of us." The paper was discussed at some length by Mr. Elvins, Mr. Miller, and others, who complimented Mr. Harvey upon the manner in which it was prepared. The diagrams and working-model were examined and admired.

FOURTH MEETING.

March 7th; Mr. Arthur Harvey in the chair. The attendance of members was large. A Report was received from the Committee on the proposed change in reckoning the Astronomical Day. A copy of Mr. J. Ellard Gore's new work, "The Visible Universe," was ordered to be purchased. Mr. G. G. Pursey, the Librarian, presented a series of the publications of various British and foreign Societies and of The Canadian Institute; also an article on "Thunder Storms," by Dr. M. A. Veeder, of Lyons, N.Y.

Under the head of observations, Mr. Harvey read an interesting memorandum upon the spots visible on the Sun between the 1st and 7th of March. Diagrams made daily for the purpose of showing the position and detail of the spots were handed in. Dr. A. D. Watson described an observation made by him on the early morning of the 16th of October, 1892, when he was fortunate enough to see Jupiter, apparently, accompanied by only one moon, a comparatively rare phenomenon; two of the moons were invisible, owing to the fact that they were in transit, and a third was behind the planet.

The paper for the evening, "The Retrograde Motion of the Moons of Uranus," was read by Mr. John Phillips, whose main object was to prove, or, at least, to point out, the mathematical and physical possibility of a system of satellites being projected from the polar vicinities of spheroidal planets—especially from planets of great oblateness, such as Saturn, and finding orbits around them. The chief properties of the spheroid were dwelt upon and, by means of models, were contrasted with those of the sphere. Direct, or retrograde, motion, was said to depend on the angle at which the plane of a satellite's orbit cuts that of the ecliptic, whether acute or obtuse, the former causing direct motion, the latter retrograde. In polar projection, taking both polar regions into account, the chances were held to be equal whether those angles were acute, or obtuse. One thing polar projection failed to account for, and that was the revolution of all the Uranian moons in nearly the same plane. Equatorial projection accounted for such uniformity, but bodies projected from high latitudes would be more likely each to strike off in a plane of its own. In Mr. Phillips' opinion, this added to the probability that the plane of the equator of Uranus lies in that of the orbits of his satellites. The paper gave rise to a lively discussion, in which the Chairman and Messrs. Pursey, A. Elvins, C. A. Chant, R. Dewar, and others took part, and enunciated views, for the most part, hostile to the theory which had been advanced.

FIFTH MEETING.

March 21st; Dr. Larratt W. Smith, Q.C., Vice-President, in the chair. The attendance was unusually large. As the evening was to be devoted chiefly to a study of the planet Saturn, an orrery had been obtained and set up for use.

The communications included letters from Dr. M. A. Veeder, of Lyons, N. Y., and from Mr. S. R. Peal, of Sibsagar, Asam, India, enclosing a paper on "The Canals of Mars." Mr. D. J. Howell urged the revival of the Opera-Glass Section for the ensuing season, and the subject was referred to Council. Mr. G. G. Pursey, the Librarian, presented the publications received since the last meeting. These included the Annual Report of The Mathematical and Physical Society of University College, Toronto, and a paper by Dr. Veeder, on "Magnetic Disturbances Caused by Solar Influence."

Under the head of observations, of which there had been few, owing to the prevalence of cloudy skies, a letter from Dr. J. C. Donaldson, of Fergus, was read. That observer, when opportunity afforded, had been endeavoring to compare the light of Satellites III and IV of Jupiter, when sufficiently near together for the purpose, and to prosecute his double-star work. His observations on Saturn showed that the ring-system had opened out considerably, the dark outlines of the sky being clearly visible between the *ansæ* and the planet; observations which were confirmed by Dr. A. D. Watson and Mr. Arthur Harvey, of Toronto. Dr. Donaldson also enclosed a communication from Professor E. C.

Pickering, Director of the Harvard College Observatory, respecting certain double-stars in regions of sky containing *α* Capricorni and the bright star Castor, which had been photographed at the observatory during the past year, and concerning certain supposed variability in which, Dr. Donaldson had written to him. Mr. G. E. Lumsden and other members reported a parhelion, or "mock sun," observed between 5 and 6 o'clock on March 17th. The phenomenon showed the somewhat unusual features of double-rings around the Sun and of double-inverted arcs. The sky was very hazy, and in parts quite cloudy. During a portion of the time, the Sun itself was almost totally obscured by a small, dense cloud, yet the "sun-dogs" North and South of him, even badly defined as they were, were too brilliant to be steadily gazed upon. It was stated that the parhelion had also been seen at a point some thirty miles North of Toronto, indicating that the same atmospherical conditions prevailed there. Reports upon the planet Mercury and sun-spots were made by Messrs. Harvey, A. F. Miller, A. Elvins and others.

"Holmes' Comet" was the subject of the first paper, which was read by Mr. J. A. Copland, who had paid considerable attention to the observation of meteors. Mr. Copland reviewed the history of the comet since its discovery, quite accidentally, on the 6th of November, 1892, by Mr. Edwin Holmes, F.R.A.S., a well-known English amateur astronomer. At first, the visitor, which, almost at once, assumed startling proportions, was identified with the lost comet of Biela, and a German astronomer of reputation having announced that it would probably strike the Earth on Sunday evening, the 27th of November, much popular excitement was the result. But, before that date arrived, apprehension was removed by the discovery that the comet was really receding from, and not approaching, the Earth. The interest in the comet was heightened, however, by the magnificent meteoric displays witnessed in many places on Wednesday evening, the 23rd of November. Mr. Copland said that the chief point of radiation seemed to lie in the constellation of Andromeda, approximately ten degrees East and four degrees North of the position of the Holmes' Comet at the time, and that a noticeable feature of the rich shower was the paucity of really brilliant individuals. Some Toronto observers calculated that the numerical rate of fall was about twenty per minute. Professor Young, of Princeton, N.J., counted the meteors shooting downward at the rate of one hundred in four or five minutes; and, in his report, he calculated that within his range of vision the total number which fell during five hours was over thirty thousand. Other observers recorded from fifty to sixty every five minutes. This would correspond to a deluge of four hundred million meteors descending upon the half of the Earth's surface turned toward the radiant. If each meteor be averaged as being fractionally over one cubic inch in bulk, there was a mass of thirty-four million cubic feet of matter deposited upon one hemisphere of the Earth, which, it was calculated, must have moved across a meteoric stream three hundred and sixty thousand miles wide. In the course of his paper, Mr. Copland discussed the peculiar variation in the brightness of the comet, referring specially to the outburst on the 16th of January, 1893; its orbit, its period, it having proved to belong to Jupiter's family, and its connection with a meteoric stream having, apparently, a shifting radiant-point. The paper was illustrated by several large diagrams, carefully drawn to scale, and was deeply interesting and instructive.

With a view to interesting the members generally in the special study of the planet Saturn, then well situated for observation, a series of "Five Minute Papers," each dealing with some planetary feature, had been invited. The response was hearty, and more were offered than could be read, several being reserved for a future occasion. The object in view was accomplished, as it was evident that the planet had received a good deal of attention.

Miss Sarah L. Taylor read the first paper, which included a terse account of the discovery of the planet, his rings and his moons, each new discovery marking some step in the improvement of the telescope. The work of Galilei, Huyghens, Cassini and others was touched upon, and the telescopic appearance of the planet, very probably the most interesting member of the solar system, was graphically described.

The second paper was read by Mr. G. G. Pursey, who took for his subject "Saturn as a Habitable Globe." Necessarily, the writer had to deal largely in speculation, which was, however, made highly interesting by the manner in which he drew deductions from facts, due to long years of patient observation, maintaining the nebular hypothesis. Mr. Pursey took opportunity to discuss several theories relative to the formation of Saturn's rings and moons, which do not accord with that hypothesis. He succeeded in making a very brief paper both entertaining and instructive.

The third paper was contributed by Dr. A. D. Watson, who rapidly described and discussed the causes of and the interesting phenomena connected with the disappearance, at certain intervals, of Saturn's rings, as viewed from the Earth—except in the more powerful telescopes. The doctor's own telescopic observations made during the previous three years, during which certain disappearances occurred, and his use of elaborate diagrams and the orrery, made very clear the various scientific points dealt with in his excellent paper.

The last paper read was by Mr. Arthur Harvey, and was entitled, "The Simple Mathematics of Saturn." This paper, which was profusely illustrated by diagrams, and contained numerous tables, calculated by the author, was accompanied by a representation of the planet beautifully drawn in coloured chalks. In rapid survey, Mr. Harvey described the appearance of the solar system as viewed from without; as seen from the Sun; as seen from the Earth; and the retrograde motions of the planets; explained how the periodic times of the planets are ascertained; how their distances are calculated; how their specific gravities are known, and referred to the dimensions of Saturn and of his rings and moons. The paper bore evidence of careful preparation, most of the equations made use of having been worked out by the author for the purposes of practically illustrating the *formulæ* employed by the mathematicians. As the various papers were read, questions were asked and answered, and observations upon them made.

SIXTH MEETING.

April 4th; Dr. Larratt W. Smith, Q.C., Vice-President, in the chair. Communications were read from Sir Robert S. Ball, Lowndean Professor of Astronomy and Mathematics at Cambridge University, thanking the Society for a copy of its Reports; M. L. Niesten, of the Royal Observatory, Belgium, thanking the Society for papers sent, and from Professor W. H. Pickering, Director of the Harvard Observatory, Arequipa, Peru, who intimated that his report on Mars would be published soon after his return, in a few months, to the United States, and that the nomenclature of the planet would probably receive attention at the meeting of astronomers to be held at Chicago.

Mr. G. G. Pursey, the Librarian, presented a number of publications, including "Terrestrial Atmospheric Absorption of the Photographic Rays of Light," by Professor J. M. Schaeberle, of Lick Observatory; "Solar-Electro and Magnetic Induction," by Dr. M. A. Veeder, of Lyons, N. Y., and the current issues of the Royal Society, the Royal Astronomical Society and other bodies. Considerable time was spent in discussing schemes having for their object the promotion of the best interests of the Society and the plan upon which the work of the Opera-Glass Section should be conducted. The reports included a series of solar, planetary and stellar observations by Dr. J. C. Donaldson, of Fergus.

Mr. Arthur Harvey read a description of observations made during the previous fortnight, for the purpose of showing how some of the apparently intricate problems of Astronomy may be simplified by a little practical work. The subject dealt with was the obtaining, by such ready and simple aids as are at the hand of every amateur, the distance of the planet Saturn from the Sun. By drawing maps of the region of the sky occupied by Saturn and three bright stars, on March 28th, at 4 a.m., and again on April 1st, 11 p.m., and adopting a rude method of triangulation, Mr. Harvey said he was able by means of a six-feet upright fixed in the ground and carrying a measuring bar, marked off into sixty inches and (by means of the screw fastening it to the upright at one side) swinging like the arms of a windmill, to ascertain the apparent distance moved over in two weeks by the planet, then retrograding towards the West. Having these data, a few easy calculations enabled him to compute Saturn's distance as 9.7172 times the distance of the Earth. The distance given by the authorities is 9.538, obtained only after the use of exact scientific methods. Mr. Harvey explained that he had not applied corrections for ellipticity, increased velocity of the planet in perihelion, aberration, etc.

Mr. G. E. Lumsden presented an interim Report from the Joint Committee on the Reckoning of the Astronomical Day. Mr. C. P. Sparling, the Recording Secretary, was authorized to extend to the members of The Canadian Institute an invitation to attend the next meeting of the Society, as a special paper, with experiments, on "The Polarization of Light," was to be read by Mr. C. A. Chant, B.A.

The paper of the evening was entitled

"THE CANALS OF MARS,"

and was contributed by Mr. S. E. Peal, of Sibsagar, Asam, India, a Corresponding Member. In the course of his paper, Mr. Peal said that among the most recent remarkable geological discoveries of modern times, according to the authorities, was the permanence of continents and of ocean-basins; that the continents and oceans have occupied the same general position they do now; that the solid crust of the Earth has always been subject to distortion; that the general trends of the coast-lines must have been modified from time to time by the movements of the lithosphere, due to the sinking in and crumpling up of the crust on the cooling and contracting nucleus; that the earliest wrinkles coming into existence would be meridional, or sub-meridional, and that such is the prevailing direction of the most conspicuous Earth features, such as mountain-chains and coast-lines; that these discoveries give the clue to the cause for the present distribution of land and water, and that they should be of the highest value in studying the permanent features of other globes. Tested by the Moon, Mr. Peal said these discoveries were borne out in the most remarkable manner; that the slow, persistent subsidence of ocean-floors, together with the North and South arrangement of the land and sea-areas, due to tidal distortion, or rupture, in the early stage of crust-formation, are common features of the Earth-Moon system, but that on Mars, which has no large satellite and whereon the effect of solar-tides, according to Professor Darwin, are "inconsiderable," one of these two features is practically absent, the result being a totally different distribution of land and water and a conspicuous absence of large equatorial oceans placed meridionally, as in our Atlantic and Pacific, and *in lieu* of them an equatorial girdle of land-masses and only two oceans, one on each pole; that this peculiar arrangement was, there could scarcely be a doubt, due to the following causes: (*a*) that on Mars the earlier phases of crust-formation began at the poles, which, as time passed, became sea-basins; that by the slow subsidence of the floors of these polar-oceans, which would be the coldest and densest portions of the crust, the emergence of the equatorial land-girdle would at last follow as a natural consequence; (*b*) that the comparative continuity of this latter would be assured by the absence of a large satellite causing tidal-rupture, as in our case, the solar influence being "inconsiderable."

Thus the two features, so conspicuously seen, as influencing the distribution of land and water on our Earth—*i.e.*, permanence and subsidence of ocean-floors, together with tidal-distortion, inducing a sub-meridional arrangement—would seem to be valuable aids in interpreting the distribution of land and water on Mars. But though "inconsiderable," the solar influence would yet cause limited tides, a little before, during and after the equinoxes and tend to cause an "over-spill" from one basin into the other when one of the poles was turned towards the Sun. Such tide-water passing across the equatorial land-girdle by the lowest levels would cause channels or "canals," which the "bore" would tend to straighten, especially, if in alluvial strata. At the equinoxes the tides would, during the day-time, be drawn up the canals from each polar basin on to the equatorial-region by solar attraction, the return flow taking place at night. Thus, even with limited tides, the effectual circulation of the water on Mars would probably much exceed that seen on our Earth and its heating by the solar rays to a large extent daily in the tropics would be greater than with us. The circulation of this heated water in each polar basin might well account for the smallness of the "polar-caps," the net-work of canals across the equator acting as an efficient water-heater, mitigating thereby the rigors of the arctic and antarctic climates. The occasional duplicity of the canals might possibly be due to the presence in them of a series of islands, like the sand "churs" of the Brahmapootra, a river which is very seldom, indeed, found to flow in one channel, and some of whose islands, like the "Majuli," or middle-land, are one hundred and thirty miles long by ten to twenty broad. From an elevation of twenty to thirty miles, in fact, this river would undoubtedly present the appearance of a series of long loops. Mr. Peal closed his paper by stating that if the geological axiom of the permanent subsidence of ocean-floors, so clearly seen on the Earth and Moon, applies to Mars, "we can see at once that the completeness of the equatorial land-girdle is due to the absence of tidal-rupture by a large satellite and also an intelligible reason for the origin of the 'canals' as tide-ways open to the polar-basins at each end."

The paper provoked a spirited discussion, led by Mr. Harvey, who warmly differed from those geologists who hold the views with respect to permanent continents and ocean-basins, and meridional and sub-meridional troughs and ridges, credited to them by Mr. Peal. He argued at some length in support of the contrary view, adding, however, that the writer of the paper did not require these alleged discoveries of the geologist to substantiate his theory. Dr. Smith (the Chairman), Mr. Elvins, and others also spoke on the subject.*

SEVENTH MEETING.

April 18th; Mr. Charles Carpmael, M.A., F.R.A.S., Director of the Toronto Observatory and President of the Society, presiding.

This meeting, which was an open one, was, by permission of Professor James Loudon, M.A., President of the University of Toronto, held in the Physical Department of the University, and was attended by one hundred and fifty members of the Society and their friends. On taking the chair, Mr. Carpmael announced that the routine business of the meeting would be transacted at a later hour, in order to secure for the writer of the paper the time required to read it and to perform the experiments by which it was to be illustrated.

Mr. C. A. Chant, B.A., Lecturer in Physics in the University of Toronto, was introduced, and read the following paper:—

THE POLARIZATION OF LIGHT.

The phenomena of light have occupied the attention of thoughtful minds ever since it began to hasten, on its errand of mercy, into every dark corner of the Universe; but only in quite modern times has any great advance been made in unravelling the mystery in which was wrapped its nature and some of its wonderful effects. Indeed, it is only in recent years that any serious progress has been made in any department of Science; but, of the different branches, Optics was the first to receive effective examination at the hands of eminent mathematical physicists.

In 1676, the Danish astronomer Römer demonstrated that light travels with a measurable velocity. He discovered this, as perhaps most of you already know, by observing that the time for an eclipse of one of Jupiter's satellites did not agree with the time predicted from calcula-

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* Mr. Peal's paper was, on application of the Editor, permitted to be published in full in the May number of *The Canadian Magazine*, Toronto.

tions based on its mean motion. This was explicable only on the supposition that light was propagated with a finite velocity, the difference in the times being due to the fact that, at some parts of her orbit, the Earth is farther from the planet than at others. This velocity he estimated to be one hundred and ninety-two thousand miles per second. Sixty years afterward, Bradley, the English astronomer, carefully measured the aberration of the fixed-stars (the maximum being little more than 20″, or the 64,800th part of a circle), and using the value then accepted for the solar-parallax, the resulting velocity of light was very nearly the same as that before stated. But, in our own times, apparatus of exceeding delicacy have been constructed, by means of which this amazing velocity has been directly measured, simply by calculating the length of time taken to travel a few feet, the whole experiment being performed in a darkened room. When we learn that to traverse the short distance used in the experiment less than $\frac{1}{10000000}$th of a second was required, we can, in some small degree, realize the immense difficulties to be overcome in the experiment. All the results agree very closely, and it is believed that one hundred and eighty-six thousand miles per second is pretty accurately the velocity of light.

But the nature of light itself is what I wish more especially to consider; and, after that, the explanation of some odd phenomena by using the accepted theory. We start with the fact that a mechanical influence emanates from one body, travels with a finite velocity, and influences another body. Now, we can conceive of only two modes by which this can take place. The influence is mechanical, and that implies the action of matter of some kind. This matter we may suppose to be shot forth in the manner of a projectile; or we may suppose that the matter which is influenced exists in the space between the influencing and influenced bodies, that the disturbance is made by the influencing body, and that one part of the medium passes it on to the next, till at last it reaches the body influenced. Bullets exemplify the first phenomena; waves on the surface of water, and sound passing through the air the second. The question then arises, which view shall we accept? The first, commonly known as the Theory of Emission, or the Corpuscular Theory, seems to explain many things well. Rectilinear propagation, rays, or pencils and shadows, aberration, the laws of reflexion and refraction, can all be easily explained on this hypothesis. To accept this theory, we must be willing to believe that matter is continually rushing into our eyes at the rate of one hundred and eighty-six thousand miles per second, and yet, without any serious injury. On the face of it, this seems preposterous, but we must not, on that account, cast it aside. There is not a single theory which aims to go to the root of natural processes in which there are not results equally astounding. We shall see this in the alternative theory, namely, that of waves. For the motion to be transmitted to us by means of undulations we must, at the outset, suppose that the interstellar, interplanetary and intermolecular spaces are all filled with some medium; this we call the *luminiferous ether*. It is commonly considered as imponderable, and yet it must possess inertia, that distinctive property of matter. By this, we mean that to produce a finite effect requires a finite time. Sir William Thomson has tried to determine the mass of this wonderful substance, and he declares that the whole of it in the visible universe contains no more matter than is in a half-pound weight. Now, which of these shall we take? If we can prove that one is wrong, we have no option; at least for the time being, we must accept the other. There is an experiment which determines which must go.

In explaining the phenomenon of refraction by the emission theory we are led to the result that the denser the substance, the greater must be the velocity of light in it; while, by the undulatory theory, in accounting for this same phenomenon, we reach a result exactly contradictory of the other, namely, that the denser the substance the slower must the disturbance travel through it. Now, at least one of these must be wrong, and only experiment can determine which. Foucault, the brilliant French experimenter, whose method of measuring the velocity of light I have referred to, made this determination. In his apparatus he made the light pass through a long tube of water, and the result clearly showed that it took the light longer to pass through this substance than through the open air. This, then, proves that the denser the medium the less must the velocity be, and as the emission theory predicted otherwise, we must conclude that it was wrong, and must be discarded. Of course, this does not prove that the other theory is the correct one, but it is the only one we have to fall back on; and, though it is to be feared that there are many points in it not perfectly satisfactory, we must make the best of it. However, the theory has been adapted to every circumstance, and now the evidence that it is the true one is very strong. Thus we are led to embrace the Wave Theory. Imagine now a column of ether reaching all the way from your eye to the Sun. It is plain that a wave-disturbance may travel along this to the eye, if the vibrations be either in the direction of the column's length, or at right-angles to that direction. In the case of sound, the air particles oscillate in the line of propagation; but it is very well proved that the displacements which produce the phenomenon light, at least the effective displacements, are perpendicular to the direction of propagation. Fix your eye as you stand on the shore upon that piece of wood floating out upon the surface of the water. You notice that the object seems to rise and fall continuously, but that it hardly approaches the shore at all. And yet, the wave-disturbance is transmitted with a regular velocity; there is a perpetual rolling and dashing of the breakers at your feet.

It may be well to give here one or two definitions. A *wave-length* is the distance from the crest of one wave to the crest of another; or, more generally, from a point on one wave to a similar point on the next one. By *amplitude* we mean the distance of the crest of a wave above the mean position of rest, or the distance of the trough below that position; or, if you consider a string vibrating, its amplitude is the distance it swings from its natural position. It is the distance, from rest, through which the individual particles oscillate.

Let us now take another step forward, and a most important step it is. A most wonderful phenomenon always present in wave-motion is that of *interference.* Drop a pebble into still water. It gives rise to a series of circular waves, each wave moving out from the centre of disturbance, until at last they die away. Now, drop two pebbles in at the same time, and a few feet apart. These will give rise to two sets of waves, which rapidly approach each other, and then mingle together. Each set of waves will affect every surface particle within their widening circles, and you at once see that there are particles which will be acted on by the two sets simultaneously. The invariable rule is, that the motion of every particle of the water is the algebraic sum of all the motions imparted to it. If one crest co-incide with another crest, the particles there will be raised to double-height, their amplitude will be twice as great; but if the crest of one series co-incide with the furrow of the other series, the one will quite destroy the other, and the amplitude will be zero, that is, at that point we shall have still water. Thus we see that under the action of one set of waves a particle cannot remain at rest, while, if acted on by two sets, one may quite oppose the other and produce quiescence. Indeed, the places where the particles are at rest under the action of water-waves can easily be noticed. Now, in the wave theory of light, quiescence means darkness; hence we see it is theoretically possible for two series of waves, that is two lights, to produce quiescence, that is darkness.

We can easily illustrate by means of sound. When two sounding bodies, differing slightly in pitch are sounded together, a peculiar throbbing sensation is produced. This is due to interference. Each sound wave consists of a condensation and a rarefaction, the former corresponding to the crest of a water wave, the latter to its trough. At one time, condensation co-incides with condensation, and we have a loud effect; then condensation reaches the ear from one source at the same time that rarefaction arrives from the other, the two motions destroy each other, and the sound almost dies away. Thus you see the cause of the throbbing sound; two sounds do produce silence, and, astonishing as it may seem, two lights can produce darkness.

You have all noticed the beautiful iris hues which are presented to the eye when oil is poured upon the surface of water in sunlight. These are undoubtedly due to interference. The brilliant colours of soap-bubbles are attributable to the same cause. The great philosopher, Newton, spent much of his time in examining these frail transparent films. Another method of producing these "Newton's-rings," as they are called, is by placing a lens of long focus upon a plate of glass, and then projecting light upon it. In this case, the light is reflected from the two surfaces near together. The waves from the farther surface have a slightly greater distance to go, and thus, on returning, they will be a little behind those reflected from the first surface. Whenever they are a half-wave-length behind there will be interference, and some of the colours will be left out. Hence we get coloured rings. If we use light of only one colour, or wave-length (such as red), we obtain simple darkness where the interference occurs. From this we deduce the rule that when two series of waves arrive at a point, the one half a wave-length behind the other, they will totally interfere and produce darkness.

I have just referred to a fact which might have been taken up earlier, namely, that white light is compound. The seven chief components are the colours of the rainbow, and we believe that the only difference between red light and blue light is in the length of wave, that of the former being much the greater. Thus, it would seem that pitch in music corresponds to colour in light, and, indeed, the analogy between the two has been pretty carefully worked out.

The different wave-lengths have been quite accurately measured, and are as follow:

LIGHT WAVES.

Colour.	*No. to Inch.*	*Oscillation per Second.*
Red	39,000	477,000,000,000,000
Orange	42,000	506,000,000,000,000
Yellow	44,000	535,000,000,000,000
Green	47,000	577,000,000,000,000
Blue	51,000	622,000,000,000,000
Indigo	54,000	658,000,000,000,000
Violet	57,000	699,000,000,000,000

We are now ready to consider that peculiar undulatory motion, possessing which, light is said to be polarized. A crystal of Iceland spar seems as clear as glass. But let us now project a beam of light through it. Strange to relate, it emerges as two beams, two bright spots appearing on the screen, apparently of equal intensity. Each of these two beams is found to have peculiar properties. One of the beams is called the ordinary, the other the extraordinary. The ordinary ray (or beam, as a beam is a bundle of rays), has peculiarities which are symmetrical with respect to a certain plane; the peculiarities of the extraordinary ray are symmetrical to a plane at right-angles to the former, and each ray is said to be plane-polarized. Newton conceived that the ray had two sides, and, comparing this to the two ends of a magnet, wherein is its polarity, he said the light was polarized. With our present theory, the analogy is certainly not a very good one, but the phraseology is continued. What then is polarization? It is believed that when light is polarized, its vibrations take place entirely within a single plane. Before entering the crystal, the directions of vibration were inconstant, first in this direction, then in that; but, on emerging, the vibrations of the ordinary ray are all, and continuously, in a single plane, the vibrations of the extraordinary being continuously in a plane at right-angles to the other one.

Many crystals have the power of polarizing light. Besides Iceland spar, tourmaline performs it well; but it is hard to secure a piece of this crystal suitable for a lecture experiment. There is another means, however, of getting the same effect. In 1808, Malus was examining, through a crystal, the light reflected from the windows of the Luxembourg Palace in Paris, and, to his great astonishment, he found that the reflected light was polarized. It has been found, following up this discovery, that when reflected from the surface of almost any substance, except metals, light is partially polarized, and that when the tangent of the angle of incidence is equal to the index of refraction of the substance, the reflected ray is totally polarized. Many are the reasons for believing that in this case the vibrations are parallel to the surface.

One difficulty in experimenting with this light is due to the fact that the unaided eye cannot detect any difference or peculiarity.

On passing through the Iceland spar we found the ray divided into two, the vibrations of the one being at right-angles to those of the other. Now, to examine one of these we must dispose of the other in some way. A Scottish optician, named Nicol, did this very cleverly. He took a long crystal of spar, cut it along a certain plane, and after polishing the two surfaces cemented the two pieces together again with Canada balsam. With this arrangement, it is found that the ordinary ray is totally reflected at the surface of the balsam, and is driven entirely out of the crystal, leaving us only the extraordinary ray which we can examine with more ease. The crystal so cut is called a "Nicol-prism," and is one of the most useful pieces of optical apparatus.

Now, let us take two Nicol-prisms. Project the light through the first; it emerges polarized; the vibrations are in a single plane. Then let us project this light through a second Nicol-prism. You can easily see that all vibrations passing through this prism must be in a single plane, too. If this plane co-incides with the similar plane in the other prism, the light comes through easily, but if we turn the second prism about, so that these planes are at right-angles, the light cannot get through the second prism at all, and we should have darkness. The first prism that the light is passed through is called the *polarizer*, the second one the *analyzer*. The duty of the former is to polarize the light; that of the latter to see if the polarizer has done its duty, or to examine the light on emergence from the polarizer.

Let us now consider our experimental disposition. First of all, we project the beam from the electric lamp against a pile of glass plates. These are placed at the correct angle, and thus the light reflected from them is polarized. Then, we make this pass through a Nicol-prism, and we examine the effect produced on the screen. In a certain position we find the analyzing Nicol completely shuts out the light, and the screen is dark. Now the glass and the Nicol both are quite as clear as water, and yet the light cannot get through them. At present, we have darkness on the screen. Introduce now between the polarizer and analyzer a sheet of mica. This mica, as you know, is quite clear. Before we put it in we have darkness; after we insert it, brilliant colours. Whence come these beautiful tints, far excelling any artificial pigments?

To explain this, we must examine the mica. It is known as a double-refracting crystal, and in it are two directions, at right-angles to each other, along which vibrations can be transmitted. Project light against the plate and it emerges vibrating in these two directions, but it is found that the light which vibrates in one direction travels in the crystal at a slower rate than that in the other. Now, on coming out of the polarizer, the light is vibrating in one plane. It strikes against the crystal. If this plane is parallel to either one of the mica's two directions, the light will pass freely through the mica, but can get no further; the analyzer stops it. But turn the mica. The incident vibration is now broken up, one part going through the mica in one plane, the other in a plane at right-angles to it. But one has gone faster than the other. The analyzer now takes hold of these two vibrations, and brings them together again in one place; but one is behind the other, and you know from the laws of interference that if one is a half-wave-length behind the other there will be interference, and the interfering light will be cut out and colour be produced. Hence, to obtain a blue colour, we must take a mica plate of such a thickness that one vibration when it gets through is just half a wave-length of red light behind the other. If this is the case, on coming together again the red rays will be cut out and blue produced. Thus, you see these results are produced by a combination of polarization and interference.

Exquisite colours can be secured by taking pieces of mica, or gypsum, of varying thickness. Placing them between the analyzer and polarizer, we find that this particular thickness gives red, another gives blue, and, taking all together, we have beautiful, brilliant effects. If now, when we have one set of colours, I turn the analyzer through 90°, complementary colours flash out. Here we have a rose with beautiful red petals and green leaves; turning the analyzer through 90°, we have green petals and red leaves. This action, then, is due to a peculiar molecular structure which the substance acquires on crystallizing. But similar colours may be reached with what is known as unannealed glass. A slab of glass is quickly cooled; the outside becomes rigid, and the inner part cannot settle itself naturally, but has to adapt itself to the rigid outside. Thus there are strains in the substance, and the molecules are irregularly arranged; and it exerts the same effect on the transmitted light as does a slice of mica. I have not even mentioned that, besides plane polarized light, we have circularly and elliptically polarized light, but I have not time to explain the terms.

To those of you present who have given this subject any study, I may say that I hope it has been somewhat refreshed in your minds; to the rest of you, I fear I have been somewhat tedious, and yet I trust that we all have a more definite conception of the exquisite, though intricate, mechanism of this wonderful thing light, so common and yet so intensely necessary for our very existence; and that we shall feel our interest somewhat quickened when, still further in our devotion to Science, we seek to worship at Nature's shrine, in

> "That cathedral, boundless as our wonder,
> Whose quenchless lamps the Sun and Moon supply
> Its Choir the Winds and Waves, its organ Thunder;
> Its dome the sky."

At the close of the paper, which had been illustrated by a series of most interesting and, in many instances, very beautiful experiments, a vote of thanks was heartily accorded Mr. Chant, and also to Professor Loudon, who had kindly placed the rooms and apparatus at the service of the Society. In moving the vote of thanks, Mr. John A. Paterson, M.A., referred to the pleasure which many of the audience experienced in renewing their acquaintance with a subject so instructive and so admirably presented by the lecturer, and recalled the days when, as undergraduates, he and others had, in those very halls, listened with delight to scientific lectures. In seconding the motion, Mr. A. Elvins dwelt on the many merits of the paper and the success which had attended the experiments, and said that a wish long entertained by him had been gratified by the meeting of the Society in the well-appointed lecture-rooms of the University. In presenting to Mr. Chant the thanks of the Society and visitors, Mr. Carpmael stated that not only had the paper been made highly interesting, but that Mr. Chant had succeeded in condensing into one lecture, and in making clear to a popular audience, subject-matter usually occupying many lectures, even as given by masters of physics, such as Faraday, Tyndall and Stokes, all of whom he (Mr. Carpmael) had had the pleasure of hearing speak on the subject of light.

Many of the audience remained to inspect the acoustic apparatus in the adjoining room, while the business of the meeting was continued.

Among the letters read was a communication from the Reverend T. E. Espin, F.R.A.S., of Wolsingham Observatory, England, announcing the discovery that Star No. 180 of Espin's Catalogue, was variable; one from Dr. M. A. Veeder, transmitting a paper on "The Source of Solar Heat;" one from Mr. S. E. Peal, of Sibsagar, Asam, India, enclosing a paper on "Selenology;" and two from Dr. J. C. Donaldson, of Fergus, describing a series of observations on Saturn and on some rather difficult double-stars, in which he had been successful. Dr. James McDermott, of Sunderland, Ont., was elected an Active Member. Five candidates for Active Membership were proposed.

EIGHTH MEETING.

May 2nd; Mr. John A. Paterson, M.A., Vice-President, in the chair. The attendance was large. The following Active Members were elected:—Messrs. A. T. DeLury, B.A., John Duff, B.A., G. F. Hull, B.A., W. B. Musson, J. W. Smith, M.D., and J. Von Sommer, of Toronto.

The Constitution and By-laws of the Society were amended and consolidated. Letters were read from Rev. T. E. Espin, F.R.A.S., of Tow Law, England, respecting the variability of Stars Es-Birm., Numbers 545 and 561, and from Dr. M. A. Veeder, of Lyons, N.Y., announcing that Lieutenant Peary, of the United States Navy, would, during his expedition to Northernmost Greenland, record observations of the aurora upon a plan that would enable comparisons to be made in detail with records from other localities. Observations on the Sun and Saturn were reported. Attention was drawn by Mr. Arthur Harvey to the prevalence of interesting sun-spots; also, to the fact that very shortly Saturn would begin to move again to the Eastward, and, in doing so, would pass the star γ Virginis so closely as to give, almost from night to night, evidence of motion. Dr. Donaldson, of Fergus, requested observers to examine the companions to the double-stars δ and κ Geminorum; with respect to the companion to κ variability had been suggested, but that is regarded as doubtful, even though he had not been able to pick it up with a $3\frac{1}{2}$ inch Cooke refractor, while he had no difficulty in seeing the comes to δ with the aperture of same telescope reduced to $2\frac{1}{2}$ inches. Mr. G. G. Pursey, the Librarian, presented a series of Reports from various Societies in England.

After routine business was disposed of, Dr. Veeder, who had spent a portion of the day at the Toronto Observatory in consultation with Professor Carpmael, was introduced and warmly received. Dr. Veeder said he had had occasion to visit Buffalo in connection with his investigations into the cause of auroræ, and had availed himself of the opportunity to come on to Toronto and make some inquiries respecting the invaluable magnetic records at the Observatory, extending, as they do, over a period of half a century. His visit had been a very agreeable one. He referred to Lieutenant Peary's expedition to Northern Greenland, and said he was confident that officer's observations, which would extend over two years, would go far to removing certain difficulties which now meet the investigator of auroræ. To these the doctor referred, and by using, as illustrations, the celebrated auroræ of the 13th of February and of the 16th of July, 1892, explained the value of the facts that it was expected the Lieutenant would establish. Many persons had been in the habit of observing auroræ for the purpose of predicting the weather. This was a mistake. Observers of auroræ should be meteorologists rather than weather prophets. The observations required most at the present time in this country were such as could be made by anyone. They consisted chiefly in recording at certain hours the fact of the presence or of the absence of auroræ. Except on the occasion of great and general displays, auroræ were usually local in their character. For instance, an aurora visible at Toronto might not be visible at Quebec. For this reason, it was possible, by means of observers widely scattered, to make observations by which the limits of a given display could be determined, and by which it could be ascertained whether auroræ frequented certain localities. He would be happy to supply blank forms to anyone who would undertake to make the simple entries required. From making these entries, one's interest in the work would grow, and the general result would, no doubt, be that many would be led to investigate the subject for themselves. He acknowledged the assistance the Society had rendered him, and, in a complimentary manner, alluded to its enthusiasm and work. Later in the evening the subject was again brought forward, and several members including Messrs. Harvey, A. Elvins and the Chairman, stated their views with respect to the causes, frequency and locality of auroræ, and suggested some theories for Dr. Veeder's consideration.

Mr. G. G. Pursey read a paper on

SOLAR HEAT,

of which the following is a synopsis :

The basic truth of the following remarks cannot be better expressed, perhaps, than by the words of a familiar writer, who says : "For the invisible things of Him from the creation of the world are clearly seen, being understood by the things that are made" (*Paul*). "The universe is the externization of the soul" (*Emerson*).

In a former paper, I made a feeble attempt to trace matter to its source. The subject is very much involved, and little satisfaction can be derived from the study of such an abstruse theme, yet I am persuaded that a glimpse may be obtained now and again into Nature's laboratory that, by-and-bye, shall expand and reveal something of a more positive character. It was attempted to be shown that what we call Matter is Incarnated Thought; Precipitate of Mind ; Crystallized Spirit ; that vital, spiritual substance, in assuming concrete forms, takes upon itself, or clothes itself, with these material crystals ; that the more tenuous or thin the covering of any particle, or series of particles, the more active that series, and it was suggested that magnetism, or electricity, may be of that character, polarization determining largely the modes of action ; that the more dense the covering of the particle, the more passive, as earths and metals, and that the particular form assumed by each series, or co-series of particles, or molecules, determines the consistency and use of the mass. The fluid molecule, it was said, must be perfectly globular and smooth so as to be easily mobile. The air globules must also be spherical, very light and very elastic. Under pressure, a volume of air will become hot, and, under sudden and intense pressure, will present that phenomenon we call fire. May it not be that in such a case the gross material coverings, enclosing, as they do by this theory, active, vital centres, become ruptured, thus releasing their contained vital principles, which, under such conditions, produce that sensation we call Heat ; light resulting from the excitation of the luminiferous ether? Immediately on the removal of the pressure, the molecules illapse into their former condition. Were it not so, a fire once kindled would be perpetual—if these air-globules were able to continue in an active state—but after having been drawn into the fire by the current which is always present, they hasten to escape, and retire into a state of passivity by again becoming enfolded in crass coverings, thus tending to restore and preserve equilibrium. The great solar-fire may be composed almost entirely of these actives, as they may be called, retaining their activity, on account of not being able to escape from the conditions by which they are held together, but when, from some extraordinary cause, portions of the Sun's mass are projected to a great distance from his surface into a cooler region, these actives hasten to encase themselves in protective envelopes, thus assuming denser material, passive forms, as dark cloud-like masses. These, when of sufficient magnitude to be discerned from Earth, constitute that nondescript phenomenon, sun-spots. From the nature of the case, these agitations are perpetually and increasingly taking place, through the invasion of colder waves from sub-zero space. The faculæ and willow leaves, or rice grains, on the Sun's disc, when seen on his rotating limb, appear like magnificent pyrotechnic displays, as seen during an eclipse; being nothing more than crested, rolling waves of white, or red-hot, matter, which literally cover the entire surface of the Sun; for it must be remembered that only the most extraordinary and colossal upheavals, or outbursts, reach the cooler breath of space, so as to congeal into opaque clouds. Such, then, in brief, may be the constitution (and shall I say by-laws?) of the great solar-fire. I do not think it proper just now to review other theories as to the nature or maintenance of solar-heat, but here boldly make this assertion, solar-heat is not maintained.

You have seen the sparks flying about the smith's forge; follow one of these to the ground, pick it up if you can find it for it will not burn your fingers, it is so very small that it parted with its heat all but instantly. With a cold-chisel the smith chips off the end of a rod of red-hot metal; it drops to the ground, but do not touch it just yet, although it may have lost its ruddy colour, it still retains sufficient heat to burn your fingers, for it is many times larger than the spark and requires just so much longer to cool. In 1819, Mount Ætna threw out large quantities of lava; the stream was several feet in thickness. After nine months, it was observed to be moving at the rate of a yard a day. An instance is on record of a flow of lava from the same mountain being in perceptible motion ten years after the eruption. I have read somewhere, that in South America some forty years after an overflow from a volcano, travellers boiled eggs in the crevices of the lava. Our Moon, a tolerably good-sized body, no doubt occupied many millions of years in cooling, and most probably had raised her family before the Earth had brought forth her first-born, and even now the centre may be in a state of incandescence. This globe, much bigger than its satellite, is following hard after in the cooling process, but on account of its volume will retain its heat a long, long time to come, as there must be 5,000 or 6,000 miles of molten matter inside of its crust. The Sun, more than a million times the size of this Earth, has so far resisted the attacks of the enemy as to maintain the supremacy, but Time will tell. Every now and again the antagonist scores one, leaving a tell-tale mark on his face; about that phenomenon we guess, and suppose, and assume, and theorize, but as surely as man dieth and wasteth away, a consummation prefaced by these wrinkles and these grey hairs, so surely is that spot on the Sun's face a precursor of total extinction, and so to the question "How is the solar fire maintained?" I simply say: It is not maintained, but is dying out just as rapidly in proportion to its size as the spark from the forge. If such be the case, there is no necessity for contraction theories, meteoric theories, or even that advanced by our esteemed fellow-member, Mr. Elvins, and supported by Mr. Kedzie, that the waste is made good to the Sun by interchange of material from other suns throughout all space. I have not taken sufficient interest in that theory to be able to pronounce definitely upon it; I simply have not room for it. The meteoric theory I just touched upon and will leave it there. The contraction theory demands a word. Miss Clerke says: "The production of heat by contraction exceeds the loss by radiation so long as a body is in a gaseous state, but falls short of it when the body has attained to a liquid condition;" evidently the Sun has reached that state. Contraction in the case of solid bodies is evidently a result of radiation, as may be seen any day. It may certainly be the means of concentrating heat, and causing local spurts to occur, not increasing the sum total, as in the case of the Sun. I doubt not but it is one of the chief agencies in squeezing out the bowels of that luminary in those magnificent eruptions which occupy the attention of astronomers the world over, just as by the compression of the crust of the Earth, the life-blood oozes through the pores of its thick hide in the form of boiling lava. If the Moon has cooled beyond the possibility of sustaining life, as we know it has; if the Earth is in the process of cooling, a fact about which, for my part, I have no doubt whatever, as there is overwhelming evidence tending in that direction, such as the existence of coal deposits in Arctic regions, that is, if coal be a product of vegetation at all, Precession of the Equinoxes, Glacial Eras, etc., etc., even so the Sun is finally destined to share the common fate. It was once a white star; now it is a yellowish star; by-and-bye it will be a red star, and then, like Algol's supposed companion, it will be a dark body. We may let our imagination go back to the time when the predecessor of our Sun, together with its inhabited worlds, occupied the vast area now filled by our solar-system; we may even peer through the vista of that long past era and see that remote system emerging out of nebulosity—to repeat the story of a still prior system which had run its course, raised its family, and matured its quota of human souls for higher spheres, and—bewildering thought!—there's an eternity back of that. Generation after generation of worlds and systems of worlds succeed each other, as surely and as orderly, although the epochs may be of almost infinite duration, as the Earth yields her annual supply for the sustenance of her offspring. Those suns and worlds in this and unknown systems are but the corpuscles in the vital fluid of the greater body of the Universe, whose arterial and nervous systems perform their peristaltic gyres with undeviating precision in the great vortical ocean of ether which fills all space. And just as in the microcosm, or little world, man, one effete particle is removed to make room for a newly created particle, so that the functions of the body may continue; so worlds and suns, after filling up the measure of their days, their energies exhausted in the service and interest of this great economy, return again to imponderable atoms to be again reclarified and prepared to enter into other combinations in the hands of the great, untiring Architect. I conclude with those two memorable lines of Pope, which express a true pantheism as well as a true cosmogony:

> "All are but parts of one stupendous whole,
> Whose body Nature is, and God the soul."

NINTH MEETING.

May 16th ; Mr. John A. Paterson, M.A., Vice-President, in the chair. Though from high wind and heavy rain, the evening was one of the most disagreeable of the year, the attendance, especially of ladies, was large and encouraging.

The correspondence read included a fraternal and very interesting letter addressed to Mr. James Todhunter, Treasurer of the Society, by Mr. W. D. Barbour, Secretary-Treasurer of the Leeds Astronomical Society, who asked for an exchange of Reports, and inquired into the work and methods of this Society, giving in turn a brief sketch of the life and work of his Society. The Corresponding Secretary was requested to answer Mr. Barbour's letter in the spirit in which it was evidently written, and to send a copy of the Reports.

Mr. G. E. Lumsden reported the progress made by the Joint Committee of The Canadian Institute and the Society in dealing with the subject of the proposed change in reckoning the Astronomical Day, and stated that he had received a letter from Dr. Sandford Fleming, C.E., C.M.G., the Chairman, stating that upwards of nine hundred circular-letters had been sent to the members of the staffs of public and private Observatories and to scientific men the world over, asking for their opinions on the question.

Mr. G. G. Pursey, the Librarian, reported the receipt, among other publications, of copies of Professor G. E. Hale's papers on "Photography of the Corona, without an Eclipse, with the Spectroheliograph," "The Probability of Chance Co-incidence of Solar and Terrestrial Phenomena," and on "The Condition of the Sun's Surface in June and July, 1892, as compared with the Record of Terrestrial Magnetism."

The following paper on

THE SOURCE OF SOLAR HEAT,

contributed by Dr. M. A. Veeder, was read by the Corresponding Secretary :—

It occurs to me that it may be of interest to communicate the conclusions to which I have been led in respect to the sources of solar, and related forms of activity. It has been shown in the course of the research in respect to the aurora, in which I have been engaged, that the forces concerned in the production of this phenomenon, are wholly internal to the Sun itself, in respect to their origin. It becomes an important question as to what is the essential nature of these deep seated solar activities, and as to the manner in which they are sustained. After an extended study of evidence, which it is not proposed to rehearse in detail at the present writing, my conclusion is that the molecular constitution of substances in the Sun is destroyed mechanically by pressure. In other words, the crushing force brought to bear in the interior of the Sun, is sufficient to destroy not merely gross forms, but the intimate molecular structure of substances there existing, leaving the ultimate atoms dissociated, and consequently in a fit state to originate the most energetic chemical and resultant activities possible. In this way, processes of vaporization, combustion, and the like, are instituted and maintained with evolution of heat, light, and electrical action. It is evident that this liberation of the ultimate atoms being dependent upon the mass of the Sun, will continue as long as that body remains as large as at present, unless, perchance, the atoms themselves may be worn out in the process. It is evident also that the radiation of heat will not result in any diminution of mass, it depending upon vibratory conditions, as is now generally believed, and not upon any dispersion and conveyance of the atoms themselves. This being the case, it is not necessary to look to any source external to the Sun itself for the replenishment of the solar fires. In like manner, volcanic activities and the heat known to exist in the interior of the Earth may depend upon a similar effect of pressure from superincumbent strata. If this be true, the larger the mass the greater the heating and other effects; and this appears to be the case generally throughout the solar system.

Thus, the planet Jupiter, though more distant from the Sun than the Earth, gives evidence of being in a molten condition, this being due simply to its relatively greater mass and the consequent greater crushing force brought to bear in its interior. The fact that volcanic activities generally underlie mountain ranges where the pressure is greatest, both laterally, because of plicating and folding, and vertically, thus acquires special significance. That the dissociation of ultimate atoms results in what is known in Chemistry as the nascent condition and energizes chemical activities requires no proof. Whether this dissociation can be accomplished mechanically by pressure is the only question involved. Manifestly, it is impossible to bring to bear pressures equivalent to those resulting from masses of soil and rock many hundreds of miles in thickness, as in the case of the Earth, or many thousands as in the case of the Sun. Still, something of the sort appears in a small way in the process of attrition, as commonly employed to facilitate chemical combination. Rubbing and pounding by the aid of mortar and pestle is nothing more or less than bringing pressure to bear in such manner as to facilitate the breaking up of the molecular structure, so that the component atoms may be liberated preparatory to entering into new combinations. In like manner, in the process of pounding a bar of metal until it becomes hot, we have direct evidence that the disturbance of molecular structure by compression is capable of originating heat. If such are the effects in the case of experiments on such a small scale, what must be the effect of the inconceivably great pressures brought to bear in the interior of the Sun? Under such conditions, if possible at all through the agency of mechanical pressures, the breaking up of molecules and reduction to ultimate atoms would seem inevitable. Thus, the forces concerned in the production of heat and light, as well as electrification, may be wholly internal to the Sun in respect to their origin, as we have been led to suppose in the latter case from the behaviour of the auroræ as above stated. It is evident that this view rests upon an altogether different basis from that involved in the nebular hypothesis of La Place, or the meteoritic hypothesis of Lockyer. To the writer, it has always seemed difficult to imagine that by any system of motions discoverable in the solar or planetary systems, there could be condensation of gases on the one hand, or of meteoritic masses on the other, as required by these hypotheses. Nowhere do we find any rushing together of planetary, or meteoritic masses in radial directions towards a common centre.

On the contrary, attractions and repulsions so counterbalance each other that collisions on any considerable scale appear to be impossible. If there is any contraction of the orbits of the bodies thus moving, or of the bodies themselves, it is so small that no certain proof of its existence has been secured thus far. How to obtain from contractures, whose very existence is in doubt, the tremendous activities exhibited in the Sun and elsewhere is, to the writer at least, an insoluble problem. It would seem, on the other hand, that such diffusion of gases and meteoric particles as is presupposed in the hypotheses in question would be the very means of preventing at once and for ever such intensity and violence of action as actually exists and is sought to be explained. To the writer, at least, the compression hypothesis appears to be much more nearly in accord with the most obvious facts of observation respecting the Sun, and likewise with fundamental principles of Chemistry and Physics. From this point of view, the forces concerned are not mathematical abstractions, but are those exhibited in concrete form in the workshop and laboratory. Instead of beginning with diffused gases and particles, as in the case of the nebular and meteoritic hypotheses, the point of departure is supposed to be exactly the contrary, namely, the existence of masses of matter of sufficient bulk to have the crushing effects to which reference has been made. As soon as such masses exist, no matter what their origin, the evolution of the activities that have been indicated follows in due course. This certainly affords a new point of view, and has the merit, at least, of yielding an alternative hypothesis.

The paper occasioned considerable discussion. Mr. A. F. Miller took exception to the theory of mechanical pressure destroying molecular structure as being contrary to experimental chemistry, a view also taken by the Rev. J. F. McBride, many practical illustrations being given. The views of Dr. Veeder were also criticised by Messrs. Arthur Harvey, A. Elvins, and the Chairman.

Rev. Father McBride read the following notes he had prepared on two interesting subjects :—

ON APPROXIMATIONS.

In looking over your Proceedings for 1892, I was struck by the close results obtained in eclipse calculations by the graphic method. I confess to a weakness for graphic work, and, in 1884, contributed to *The Canadian School Monthly* arbitrary, but very simple, methods for the construction of all polygons up to thirteen sides, the error being in every case less than the lowest possible instrumental error. People say such procedures are unscientific ; so is hanging, but it is very effective ; and that they are arbitrary ; so is the rule of three. A friend of mine objected that they are *slovenly*. By their fruits know them. They give fairly good results. And we must always remember that a good instrument does not make a good observer, and that seven-place tables are not needed in working out observations taken with an instrument reading only to half-degrees. That their use leads to slovenly habits, I absolutely deny. The fact of their results being mere approximations does not imply slovenliness, otherwise, the work of your Opera-Glass

Section would lie under the same imputation. In fact, I believe the contrary to be the case, and that those who devote themselves to graphic work do that work all the more carefully because they have at their elbow an accusing spirit in the shape of a book of tables to convict them of error, if they fall into it. Besides this, there are nearly always cross, or test, measurements easily applied and serving the purpose of independent computations in the ordinary methods. Slovenly work under the ordinary method will be more common with the careless computator than slovenly drawing with the graphicist. The argument in favour of graphic, or of empiric methods, is that they give a fairly good result and do not necessarily seclude the mathematical principles on which the process is based. They always remind me of the little tricks and schemes (perfectly legitimate and much admired) by which we extricate the *x's* and *y's* from obdurate bi-quadratics. As an example of an arbitrary formula of practical utility (though not precisely in the line of the Society's work), I submit the following which I evolved myself. For content of cylindrical vessels, let d = diam. in ft., then

$$5d^2 - 2 \text{ per cent.} = \text{gallons per ft. high,}$$

which is correct within an error of $\frac{1}{50}$ of an inch in measurement of depth.

THE SMALL MASS OF THE EARTH.

In Dr. Joseph Morrison's paper on Solar Heat, published in your Transactions of 1891, he states that the ultimate velocity of a body falling freely into the Sun from indefinite distance would be 382.6 miles per second. I am reminded, reading this, of a statement made by the late R. O. Proctor, that if a small body fell to the Earth from the nearest fixed star, its ultimate velocity would be as great "*as if it had been falling for all eternity.*" The statement (this was years ago) set me figuring, and I found, by elementary methods, that at the distance of the nearest fixed star the attractive power of the Earth would be so infinitesimally small that a body influenced only by that attraction would take one thousand four hundred and sixty-three millions of millions of years to fall the first foot. Proctor might well say if it had been falling for all eternity it would make no difference when it got to the Earth.

Mr. Thomas Lindsay read a paper on

PLANETARY ROTATION,

of which the following is a full synopsis :—

It is my intention simply to refer to one problem, not yet solved, and but little studied, which, having a certain fascination for me, may possibly interest others. Stated briefly, in question form it is this : Is there any connection between the rotation-period of a planet, or satellite, and the other elements of the body, such as mass, distance, periodic-time, etc. ?

This problem can scarcely be said to have a history ; so far as I know, only one writer has ever endeavoured to investigate it thoroughly, and it does not seem at the present time to attract much attention. Yet it cannot be said to be unimportant. We cannot say that of anything connected with the solar system, and it may be shown that planetary rotation is intimately connected with the nebular hypothesis itself. My attention was first called to this question on hearing a paper on the subject by Mr. A. Elvins, and seeing a little apparatus devised by him and intended to illustrate a theory accounting for rotation. To describe it briefly : A ball, nicely balanced on a pivot, was made to revolve as if in an elliptic orbit ; as it revolved, it took up rotation. Mr. Elvins held that the increased velocity of the outer particles at the perihelion passage might ultimately cause rotation. Some members here present may remember that the principal objection brought out in the course of the discussion which followed, was that an apparatus could not fairly represent the conditions, yet there was a question that seemed not very easily answered : Why did the ball rotate? What was the particular force tending to that result? The apparatus is in the possession of the Society, but the subject has not since been taken up. The model and the text of Mr. Elvins' paper have been in my hands for some time, and there has been ample opportunity for studying both. The conclusion I came to, tending to explain the rotation, was simply this : If a body revolve about another, it will take up rotation when the projectile force of the outer particles is just a little greater than the force which binds it towards the centre of revolution.

If we take a wheel and pivot it anywhere upon a rod, and fasten the inner spokes to the rod by a thread, then revolve the whole device rapidly, the string will break and the wheel will rotate. The rod is literally the force of gravity, and the strength of the string is the measure of the excess of the projectile force of the outer particles over this. But it would really appear that there is something in planetary rotation that apparatus cannot explain, and which even does not agree with mathematical analysis. It has been demonstrated, apparently conclusively, that if a spherical homogeneous body were sent revolving about another by one straight impulse forward, while gravity tended to draw it in, it would never rotate at all. Professor Coakley, in 1891, wrote a very exhaustive article on the possible rotation of Venus and Mercury. He investigated the tidal-influence of the Sun upon these planets as to whether it was great enough to draw out the diameters of the planets, making them slightly "egg-shaped," and holding them there, so they could not turn upon their axes, only once in a revolution, as our Moon does. The theory accounting for the non-rotation of the Moon is that while it was still plastic the gravitating force of the Earth set up great tidal action, retarding the rotation, ultimately reducing it to once in a revolution. Professor Coakley's conclusion was that the Sun's influence on Mercury and Venus was not sufficient to retard rotation; that those planets are not so held in, and that they probably do rotate on their axes as the Earth does. The paper will be found in *The Sidereal Messenger* for May, 1891. But, further, in that paper, the method was applied to all the satellites of the planets. And in Jupiter's case, it was shown that the influence of that planet in setting up great tidal action on his satellites was very much greater than that of the Earth on the Moon, and the decision reached was that the moons of the Jovian world do not rotate on their axes. Now observe: a most experienced astronomer, Professor W. H. Pickering, of Harvard, with an excellent telescope most favourably placed in the clear atmosphere of the mountains of Peru, sees Satellite I, "egg-shaped," agreeably with Professor Coakley's theory, but sees it, also, rotating on its axis, which is altogether against that theory; nor is that all, for its motion of rotation is retrograde; that is to say, it revolves in one direction while it turns end over end on its axis in the other direction. Now does this not prove that we can neither trust imitations by means of apparatus, nor the mathematics of motion to tell us much about planetary rotation, in the present condition of the solar system? With regard to Professor Pickering's observations, it is certainly strange that they are new, and that this peculiar rotation was not seen before, and the world of science will probably not accept his conclusions till they shall have been verified when Jupiter is again in good position. The drawing out of the diameter of a satellite by the great gravitating force of the planet is not difficult to understand, and without looking into the mathematics of the phenomenon at all, we can fancy a rigid bar, representing gravity, from the planet to the satellite keeping the latter in one position, facing one way as it revolves; but it is quite a blow to learn that this time, at least, the theory is astray. Now, there never was a discrepancy of this kind that could not be accounted for, but there are many which are still to be studied, and there certainly is here a wide field for study and for speculation. Professor Pickering ventures the theory that the satellites of Jupiter are composed of small bodies congregated together, so now we have the whole problem before us. We shall hear more about this probably, by-and-bye, but I am inclined to think that the observations are correct and that the mathematical theory requires investigation.

To investigate the possible connection between rotation and the other elements we note: The rotation of the Earth has not varied in the historic period, but its distance from the Sun and its orbital velocity are constantly changing, within limits, of course. The eccentricity of the orbit, the axial inclination, the perihelion point, none of these is constant, and the great precessional movement is going on all the time. It would seem, then, that rotation has nothing to do with these. But the mass and the periodic time are constant. May it not be that the rotation period of the resulting planet was decided in the moment when the vapour ring first slipped from the bulging equator of the primary? If so, then we would require to know the conditions of the parent mass before we could begin to study the ring or segment thrown off. Now, we are back to the nebula, and it is very probable that the proof of the absolute truth of the nebular hypothesis is only to be found by studying the rotation-periods of the planets. If it could be shown that, as planet after planet was formed at the distances as found, the rotation-periods should be as they are, surely no better proof of the hypothesis could be desired.

In 1849, Professor Daniel Kirkwood showed that there was an analogy between the distances of the planets from each other and their rotation-periods. This is scarcely ever referred to now, why, I do not know; while seeking to raise the nebular-hypothesis to the dignity of a law, it is strange that this is not considered. The analogy may be briefly stated thus: Between two planets there is a point where a particle would be equally attracted by both bodies. Professor Kirkwood, from this, deduced what he called the breadth of the "sphere of attraction." Then he found that the square of the number of times which a planet rotates in a revolution round the Sun is proportional to the cube of the breadth of the ring. With Venus, Earth, and Saturn, the law holds good, with the other planets there are difficulties. We cannot determine the breadth of the ring for Mercury, it being innermost, nor for Neptune, being outermost, nor for Jupiter and Mars, as there is no planet between them and the Asteroids are confusing. There are some points due to Professor Nichol which it is well to remember in this connection. The outer planets rotate very rapidly, the inner ones more slowly. The rings that formed the outer planets were broader than the others. The outer particles would move more quickly than the inner particles in either case, and according to this difference, would be the rate of rotation first caused by the increased momentum of the outer particles when the ring would break. Now, if this caused the greater velocity of the outer planets on their axes, and if, in general, the non-rotation of satellites is explained by the great tidal action of their primaries, there is something to work upon. If we are looking too far back into the æons of the past, be it so, but I do not see how, on any other line of investigation, the nebular hypothesis can be proven true beyond a doubt. Professor Kirkwood's analogy will be found in The Proceedings of The American Association for the Advancement of Science, 1849.

We may be assured that the planets do not rotate, as we find them, by accident; there are no accidents in Nature. The period is the result of some law, whether it be expressed by the analogy or not. We do not forget that as a body condenses it rotates more rapidly. When Jupiter was about to throw off Satellite IV, he rotated in sixteen days; now he rotates in ten hours. These little peculiarities of nebulous masses may help to make the problem of rotation still more difficult, perhaps beyond the reach of celestial mechanics, far-reaching as the science is. Still, we may speculate upon it; perhaps light may be thrown upon it here and there. There is one thing that may be said of this problem: if some one were to show just what the law is that governs rotation and prove all the cases, no one could say, "Oh, that was brought out a hundred years ago!" Professor Kirkwood's analogy is the nearest approach, and that is admittedly imperfect.

In drawing attention to this problem, I would say that it would seem necessary to reconstruct the nebula out of which the system was formed. This does not seem an easy task, but, even if it is impossible, an attempt may lead to other truths; certain it is we do not yet know all that is to be known of the solar system.

TENTH MEETING.

May 30th; Mr. E. A. Meredith, LL D., in the chair. Mr. J. M. Martin, of Toronto, was elected an Active Member.

Mr. G. E. Lumsden placed on the table, for the examination of members, a copy of Proctor's "Old and New Astronomy," and one of Niesten's excellent globes of the planet Mars.

The following letter from Professor S. W. Burnham, M.A., late of Lick Observatory, was read by the Corresponding Secretary:—"I have yours of the 9th inst. There has been no change in the distance of either κ or δ Geminorum since the first measures, and, therefore, they should be as easily seen at one time as another, so far as the position is concerned. I have not given these pairs any special attention, since I used a small aperture, as they are of no particular interest so far as the micrometer goes. There appears to be a little change in the angle of δ, but it is very slow. At one time, it was suggested that the companion to κ was variable from the different estimates of magnitude, but the evidence amounts to nothing. In seeing objects of this kind, everything depends upon the seeing. I have failed to see at all, or only with difficulty, half of the double-stars in the heavens at different times, but have never yet found a variable companion, or even suspected one."

The Secretary also read the following communication from Dr. Veeder, relative to the utility of his plan of having numerous observers of auroræ, so as to detect evidence of "locality," etc.:—"The availability of this plan of observation was finely illustrated in connection with the displays of May 7th, 8th, and 9th. Taking May 9th for example: at Yarmouth, Nova Scotia, there was an aurora of the ordinary type at 8.45 p.m., 60th Meridian Time, and auroral band extending East and West, just South of the zenith, from 9.15 to 9.45. Co-incidently at Lyons, N. Y., one observer verified the absence of the aurora at 8.50

and 9.11, and another at 9 to 9.10 and 9.29, and another at 7.56, 8.26, to 8.36, 8.39, 9.02 and 10.04 (75th Meridian Time). Also Bracebridge, Canada, reported that there was no aurora at that point that evening until 11 p.m. Thus, the Yarmouth display, although prominent, was utterly wanting in three localities, further Westward, at the same hour.

Mr. Arthur Harvey referred to the often observed fact that during the summer seasons there are certain days of the week upon which rain almost invariably falls. He had been looking for the cause of this periodicity, and was on the point of preparing a paper, when it came to his knowledge that he had been forestalled by a writer in *The Meteorological Journal.* Under the circumstances, he said he would be content with stating the fact that he had been studying the subject for some time past, and that the conclusion arrived at was that the periodicity was due to solar rotation, or was intimately connected with it. Though his data for the season of 1893 were not quite complete, he ventured to predict that the rainy day during the summer would be either Sunday, or Monday; possibly, the rain would fall during the night of Sunday. Remarks upon the subject were made by Mr. J. M. Martin, Mr. A. Elvins, and others.

As had been previously arranged, the major portion of the evening was given up to the discussion of various theories respecting solar heat and energy. Two papers were read by Mr. Elvins, the first in kindly criticism of the views of Mr. G. G. Pursey expressed in a paper read on the 2nd of May; the second, stating his own views. In the latter, which was entitled

MOVING MATTER III : SOLAR HEAT,

Mr. Elvins said :—Space is that in which bodies do, or can exist. In its nature, space must be a vacuum, except where matter exists in it, and, from its very nature, its extension must be infinite.

Matter is substance, having form and dimensions. [I regard the ultimate particles of matter as infinitely hard and impenetrable.] As to extension, all atoms and masses of matter must be finite.

Matter exists as ultimate atoms, or as aggregations of atoms; atoms unite and form larger bodies; these unite and form still larger ones, and thus they probably pass through several stages of evolution before they reach the chemical atom, or molecule of a chemical element.

Such molecules exist as separate bodies in gases, or, by the reduction of their free paths, they may exist as liquids or solids. In whatever form matter exists, it is always subject to the three laws of motion.

Heat, I regard as motion of particles comprising a mass; the vibratory motion produced by the impact of other moving bodies. A nail is made hot by blows from a hammer, and a ball of lead melts when it strikes an iron target.

Here, we see the motion of a mass changed into the motion of the particles composing the mass; the mass ceases to move; the molecules take up the motion. *This molecular motion is heat.*

Motion of matter as masses, molecules, or atoms, is *energy*, and this is a constant in Nature. We call it, Light, Heat, Electricity, Chemical Affinity, Mechanical Force, Magnetism, and so on, according to the quantity of matter moving, and the manner, or mode, in which it moves.

Now, when a large mass of matter is struck by a smaller one, both are translated through space in opposite directions; the rebound of the small one causes it to pass over more space than the large one, but still the large one moves. But if the mass (suppose a ball of steel) were struck simultaneously on opposite sides with the same force, the ball would remain stationary, though its molecules would be set in vibration by the blows. Every additional blow would increase the vibration. This vibration could be so increased that other bodies coming in contact with it would have their molecules set in motion, or be heated. We must never forget the fact, that a steel hammer striking a steel ball of larger size, rebounds, and that if the ball were struck by a vast multitude of hammers on every side, there would be a rebound from *every point* at every blow given.

Now, if two hammers were moving toward the ball, at the same rate, one a trifle behind the other, the second would collide with the first on its outward course or rebound; any number of hammers, following each other, would be similarly acted on.

Suppose such blows and rebounds to be existing at every point on the surface of the ball, the hammers would everywhere be rebounding from the ball and from each other; thus, the energy, or motion, of the incoming hammers would be radiated again into space.

Now, if the ether is, as I assume it to be, composed of the ultimate particles of matter moving with great velocity amongst themselves, and keeping up their motion by collisions (as the Kinetic Theory of gases supposes the molecules of gases to act), then large bodies in space are bombarded on every side by these small, but rapidly moving atoms. Such a body is our Sun. He exists in this boundless ocean of ether. The collisions of his molecules with the ether atoms must be without number, and the resulting molecular motion must be very great. The incoming ether atoms must strike the solar molecules and rebound according to the Third Law of Motion.

The rebounding atoms must receive and carry away into the ether a part of the motion of the solar molecules; moving faster, or slower, according as they have received more or less of the solar energy. *The length of the free path of the ether atoms*, after being charged with the plus of solar energy, may be what we know as a wave-length.* These are waves of energy, and may become manifest to us in different phenomena. Some enter our eyes, and we see them as light; some strike and set in motion the molecules of our muscles and nerves, and we feel them as heat. They cause our winds, our evaporation, our rain, and our storms. But by far the greater part of solar energy passes into the ether and keeps up the motion of that all-pervading medium, from which its own energy is derived.

Thus, ether and ether motion connect the entire universe into a harmonious whole; convey our Sun's energy far beyond the stars whose light can be seen by our giant telescopes; bend the paths of the planets and of many double-stars into orbits, for we may seek the *cause of gravitation* in this motion and receive a satisfactory reply.

Ether energy is scattered in every direction. The Sun takes it and scatters it radially to a comparatively small distance around himself; and this I take to be the chief cause of solar heat or energy. The fall of

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* I am not satisfied with the usual definition of a wave-length, as applied to solar energy, viz., the distance from one crest of a wave to the next crest preceding or following. A *single* wave may be conceived as passing outward from a centre, having no wave either preceding or following it. This wave moves on, but there is no distance between crests, for there is but one crest; the term "wave-length," as usually defined (distance from wave-crest to wave-crest), is clearly inadmissible. Oliver J. Lodge, in his work Modern Views of Electricity, page 317, says that when "we assert that the form of energy called light is *undulatory*, we by no means intend to assert that anything whatever is moving up and down, or that the motion, if we could see it, would be like anything we are accustomed to in the ocean. This kind of motion is unknown."

meteors on his surface is another cause, but I will reserve this for my next paper.

The papers were followed by a very animated discussion, participated in by Messrs. John Phillips, C. A. Chant, Thomas Lindsay, G. G. Pursey, G. F. Hull, Arthur Harvey, John A. Paterson, and Mr. Elvins. The meeting was one of the most interesting that the Society ever held.

MEETING OF COUNCIL.

A special meeting of the Council was held on the 5th of June; Mr. E. A. Meredith, LL.D., in the chair.

The accounts connected with printing the Report of the Society for 1892, and some others, were audited and ordered to be paid. Mr. G. G. Pursey submitted a proposal from the Lady Manager of the Toronto Woman's Christian Guild, for the use of rooms in their large new building, which also contained a hall suitable for open or other public meetings. After discussion, Mr. C. P. Sparling, the Recording Secretary, was authorized to call the next meeting of the Society at the Guild for the purpose of testing the suitability of the premises.

ELEVENTH MEETING.

June 15th; Mr. John A. Paterson, M.A., in the chair. The attendance was large and much interest was manifested in the proceedings. Several subjects, including the desirability of issuing half-yearly Reports, were referred to Council. It was announced that the publishers of *Astronomy and Astro-Physics*, if they received sufficient encouragement, would issue a 48-page monthly magazine, to be called *Popular Astronomy*, to be devoted to advancing the interests of teachers and students of astronomy and amateurs.

Mr. James Todhunter, the Treasurer, announced that the Legislative Assembly of the Province had granted the sum of $200 to the Society to be used in furthering its objects. (Applause.) He added that he had conveyed to the Hon. Dr. Ross, Minister of Education, the thanks of the Society for this recognition of its work.

In speaking of the books he had received, Mr. G. G. Pursey, the Librarian, dwelt upon the value of a recent Report of the Museum of the Smithsonian Institution. Observations on Jupiter were reported by Mr. J. A. Copland, of Toronto; on auroræ, by Dr. M. A. Veeder, of Lyons, N.Y.; and on γ Virginis and other pretty, though somewhat difficult, double, triple, and quadruple-stars, by Dr. J. C. Donaldson, of Fergus.

Mr. Sandford Fleming, C.E., LL.D., C.M.G., of Ottawa, Chancellor of Queen's University, Kingston, and an Honourary Member, was formally introduced by the Chairman, and spoke briefly upon the work of the Society and the interest he took in it.

Mr. Arthur Harvey read a paper on

THE PYTHAGOREAN PHILOSOPHY.

After a few introductory remarks, Mr. Harvey said:—The fragment of Cicero, called the *Somnium Scipionis*, contains a succinct account of Pythagorean Philosophy. This is usually printed next to the two famous treatises on Old Age and on Friendship, which have been the delight of almost a hundred generations, and there I found it, at school, half a century ago. Its conceit, that as the planets go whizzing round, each is attuned to a musical note, appealed to my boyish fancy, and the apparently easy Latinity somewhat captivated me, too. So, from time to time, I have turned to it as bringing up pleasant memories. I once thought it so dissimilar from Cicero's usual subjects that I shared the doubt which is occasionally hinted at, whether the work is Cicero's at all. But I now find that only one thoroughly trained in the best schools of Athens in their palmy days could have given us so complete a *prècis* of the tenets of the Pythagoreans, and none but a Roman of the Augustan age could have written such Latin. I also note some turns of speech which are peculiar to Cicero, and I rise from each re-perusal more convinced that in this fragment we have a gem of true classic origin.

Athens, in the time of Cicero, fulfilled the ideal of a University town. The States of Greece had been made to feel the strength of numbers at the hands of the conquering Romans. Sparta, whose every citizen had been worth a dozen warriors of other nations, had realized that every victory meant ruin, as the loss of hundreds was more disastrous to their closely inbred race than that of thousands to Persians or Egyptians. Macedonia had shattered itself during Alexander's life, and after his decease. Corinth and the Greek cities of the Ægean had yielded up their autonomy. All had lost their distinguishing characteristics but Athens. Athens, whose chief glory had always been spiritual rather than physical; Athens, noblest of all the European centres of human intelligence; Athens, the mother of Liberty, Philosophy, Art and Literature, had not lost pre-eminence in respect of mental acquirements and those polished manners which surely follow.

These things cannot come to a state without a national history, and what a noble background of history Athens had! Its very name is connected with that of the Goddess of Thought and Art, Athene, whom we poorly know under her barbarian title, Minerva. Athens was fabled to have met the Atlantides in conflict eleven thousand years ago. Athens was surely there when the Aryan of Europe met the Asiatic Turanian at Troy, or some where near it on the Hellespont, and flung him back. Athens was the moving spirit in the resistance to the hosts under Darius and Xerxes. The Athenian Miltiades led at the fight near Marathon which crushed the land forces of the Persians, while the Athenian Themistocles dashed into the hurry-scurry at Salamis which shattered their navy—a feat we once re-produced in the English Channel against the Armada. Athens, under Pericles, collected the works of Homer. What city but this could have been the home of Phidias, Apelles and Zeuxis? It was what Bulwer Lytton says Paris is—"*O mon Paris, foyer des idées et œil du monde.*" Where else could Socrates have questioned, Diogenes sneered, Sophocles and Euripides produced their perfect dramas, Aristophanes have laughed, Plato walked the grove? With the noblest of all buildings, the Parthenon, before their eyes; with the Acropolis there as a lesson that a country is glorified by a people who will dare to leave their homes and lose their worldly all sooner than their freedom; with a quick-witted population whose perfect language was an admirable vehicle for thought, knowing which they had the literary treasures of the world at their control—what wonder if the young patricians of Rome resorted thither, and made it what a combined Oxford, Paris and Heidelberg would be to-day. Such then, in the most flourishing time of its schools, though when riches and the loss of true independence were stifling original thought—when literature and philosophy had reached their local acme, and art, with religion, was decaying—such was Athens when Cicero was sent there to finish his education and become imbued with the tenets of the Pythagorean Philosophy.

Pythagoras seems to have held to the old world something like the relation which Newton or Darwin holds to this. Born in Samos, five or six centuries before Christ, he was a great traveller; we hear of his having gone to Egypt, and he finally settled at Crotona, one of the Greek towns of Southern Italy. Pythagoras brought forth Plato, as Darwin brought forth Herbert Spencer, and though we know but little of the exact tenets of Pythagoras himself, his teachings, as we may know them from his School, ought to be more familiar to us. I do not for a moment suppose that the disciples of Pythagoras knew more of his views than a university class of to-day knows of the views of its most distinguished professor. No books are left; the papyri are too fragmentary to help us out. I doubt if it was the method of the time to write one's knowledge down and claim the distinction which the discovery of a new moth, or fly, or microscopic bacterion now gives. The old philosophers were disposed to be secretive, to guard their knowledge from the herd; they were reflective; they condensed their thought, and none who remember the so-called Theorem of Pythagoras (Euclid I. 47) need be surprised at his motto: "Number is the Soul of the World."

(At this point, Mr. Harvey read his own translation of *Somnium Scipionis*, but before doing so made the following remark:—I may say that the Latin words are technical, yet technical in a science of which the conditions have changed, so that the spirit of them is apt to be misrepresented by the use of words current in the speech of to-day. I have had to eliminate such terms, for instance, as "rotation," "energy," "force," for evolutionary views and modern doctrines have already given special meaning to many of our common scientific words. Mr. Harvey went on to say that a great deal of light is shed on the brief fragment by reading Philolaus, Plato, Macrobius, and the *De Officiis* of Cicero himself.)

The metaphysical part of the argument resolves itself into this: That eminent men are so upright in their ways, so solicitous for the well-being of their country and their fellow-men, so dignified, yet gentle, in their manners, so informed with every virtue, that they seem to be of heavenly origin. They appear, indeed, scarcely to have left that happy abode, for, in a sense, they carry it with them, always and everywhere. To such men the return to heaven might well be thought easy! In the books and oral teachings of the Pythagoreans, careful classifications of the virtues and disquisitions thereon were not infrequent. The scheme of Plotinus I may thus condense:—

1. Political virtues were: To interest oneself in the country's behalf, in that of the city, too; to respect one's parents, love one's children, and show goodwill to neighbours; to guide all thoughts and acts by just reasoning, to do naught but the right, to be careful of duties to men and to the gods. Five classes of such political virtues might be named. *Prudence*, which includes judgment, understanding, circumspection, foresight, readiness to hear both sides, caution. *Valour*, to which belongs the duty of raising the mind above the fear of danger, and of everything but unworthy conduct, also of bearing with even temper adversity and prosperity. *Fortitude* begets magnanimity, trustworthiness, calmness, the power to do great or good acts, constancy, tolerance, firmness. *Temperance* subdues the desires within just bounds, prevents one's doing that of which one can ever be ashamed, and is accompanied by modesty, veneration, abstinence, chastity, honesty, frugality, soberness. *Justice* gives every one his due, and from it proceed friendship, innocence, concord, piety, religion, and humanity. By these virtues a man becomes the ruler of himself first, and afterwards of the State as well.

2. Purifying virtues, which are those of lovers of wisdom who are desirous of comprehending Divine law and of cleansing themselves from the grossness of things corporal. They are the attributes of men who withdraw from public affairs.

3. The virtues of the purified soul come next, and are followed, not from choice, but because no other course is possible. Lusts need not be kept in check; they are forgotten; passions need not be ignored or conquered, they are not felt; anger, envy, carnal desire, are never experienced; justice is known and done by intuition.

4. Exemplary virtues are like to these; those, for instance, of a man who is always brave, whose mind is god-like by first intention, who must be just by the eternal law of his being, who cannot be deflected from virtuous action.

The great result of all is the knowledge of oneself.

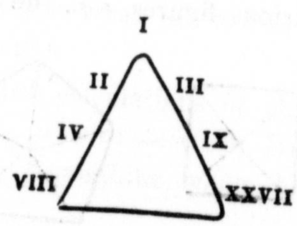
On the other hand, those who follow the desires of the body, or what we call the lusts of the flesh, make of themselves brute beasts, fear the dissolution of the body; their souls cannot, when the body dies, easily lose their connection with it, but linger about it and about the grave. Having chosen the life of the animal, they wish to follow the pursuits they chose, and their return to Heaven is blocked by many an obstacle.

The soul, or the principle of life, you will remember, is said in the

Dream to come to man from the stars. What that principle is was thus variously defined :—Plato, a moving essence ; Xenocrates, number, self-moving ; Aristotle, ἐντελέχεια, absolute being, or, as I make it, "uncreated existence" ; Pythagoras and Philolaus, harmony ; Poseidonius, idea, thought ; Asclepiades, the united exercise of the five senses ; Hippocrates, a tenuous spirit pervading all matter (*omne corpus*) ; Heraclides Ponticus, light ; Heraclitus the Physicist, a spark of the essence of the stars ; Zeno, a spirit united, concrete with the body ; Democritus, a spirit connected with atoms, so easily moved that all bodies are pervious to it ; Critolaus, quint-essence ; Hipparchus, fire ; Anaximenes, air ; Empedocles and Critias, blood ; Parmenides, the product of earth and heat, or fire ; Xenophanes, the product of earth and water ; Boetius, air and heat ; Epicurus, fire, air and spirit.

The abode of incorporeal souls is said to be the Milky Way, and this was defined as follows :—Theophrastus, "where the two Hemispheres of the Heavens are soldered, there being a noticeable brightness where the edges come together." Diodorus, "fire (by which, I think, is meant what we call inter-stellar ether) of a condensed and concrete nature, brought into one curved path (or definite place) by the dissociation of the material of the universe. The quantity thus collected makes it visible to the eye, though on account of its too great diffusiveness it cannot be seen elsewhere." Democritus, "innumerable stars so closely assembled, yet separated by such spaces, as to show light like one body, though really diffused." Poseidonius, "an infusion of sidereal light." In the Milky Way you may see two comparatively dark places. These were the two gates by which souls descended to Earth and returned to Heaven.

We have now to touch lightly on the Pythagorean view of numbers. Everything began from the monad or unit, which was both masculine and feminine. The odd numbers were considered masculine in their attributes, the even numbers feminine. Two and three were arranged on different sides of a triangle—squared and cubed—and this gave a key to numerous proportions.

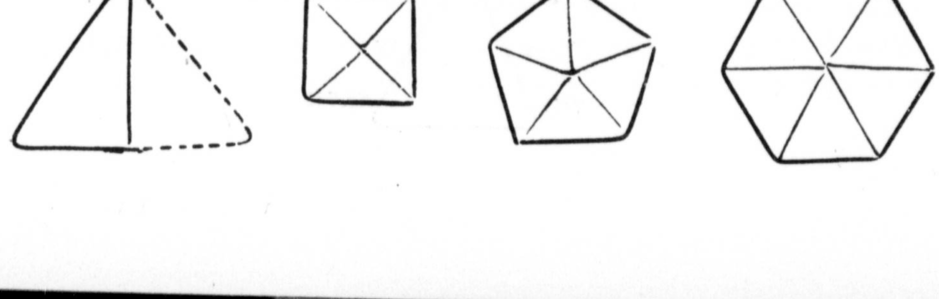


Then came a number of symphonies—the diapason, hemiolius, diapente, diatessaron, disdiapason and epogdoon. Mr. Martin has arranged these interstitial numbers or mean terms thus :—

$$\bar{1} : \tfrac{4}{3} : \tfrac{3}{2} : \bar{2} : \tfrac{8}{3} : 3 : \bar{4} : \tfrac{16}{3} : 6 : \bar{8}$$

$$\bar{1} : \tfrac{3}{2} : 2 : \bar{3} : \tfrac{9}{2} : 6 : \bar{9} : \tfrac{27}{2} : 18 : \overline{27}$$

Noting the many remarkable properties of numbers, Pythagoras conceived that numerical proportion was at the root of the order of Nature. As in the Heavens there can be nothing fortuitous, nothing tumultuary, musical sounds must be produced by the revolution of heavenly bodies, and the in-dwelling property of proportion must cause them to be harmonious. As a practical experimenter, we hear that Pythagoras weighed the hammers of the smiths at the forges and found their weights to correspond proportionately to the sounds they gave out. He suspended weights to the tendons of animals, and found the correspondence between tension, length and note (or particular sound). We use his monochord to-day. If we take Plato in his Timœus to be an exponent of the views of Pythagoras, we shall see how great a physicist he must have been :— His statement is that before the Heavens there existed Being, and Generation, and Space; that all matter, all the elements (fire, air, earth and water), were combined, no part being left out. Much idle talk is indulged in by careless readers and thinkers; they say we have progressed beyond these elements. But if we examine what was meant by the term, we may find ourselves not widely differing from the Pythagoreans. Fire, for instance, was considered under three heads—flame, light, and heat. If for their technical word Fire we substitute ours, Energy, the difference is resolved into the change of the scientific jargon of the time. The atoms were by Pythagoras (taking the same authority for his views), considered to be triangular in shape, and such as could be arranged in symmetrical ways, especially the equilateral triangle, and the right-angled triangle formed by dividing one of its sides into equal parts and connecting the middle point with the apex. In this triangle the hypothenuse is twice the smaller side. Triangles variously arranged around a point form various figures, *e.g.*, the square and parallelogram,



consisting of four; the pentagon, of five; the hexagon, of six; and what we easily see in the plane needs but a little more knowledge of geometry to comprehend in the solid. His views as to the fluidity and compressibility of substances, as influenced by the shape and disposition of atoms, their parts and proportionate fractions of parts in the interstices, deserve more consideration than we can now give. Pythagoras saw that the cosmos was one, ruled by one law—a conception we are just re-attaining; "one solitary Heaven, a circle moving in a circle," being his expression for the perfection of form which this unity must have. As for the Divinity, "He is" expresses Him, and, if I can glimpse aright his idea of the creation or the formation of things, it was the introduction into chaos of the principle of order. There is in this a reasoning in a circle—how, without a beginning, could chaos be—but the Mosaic Genesis or the scientific Nebular Hypothesis of to-day is no better, nor shall we ever get behind a First Cause. Some of the circles described by formed or forming bodies being larger than others, and their velocities differing, spiral motion followed (a conception re-adopted in the modern theory of vortices). "After this manner," says Plato, "came into being such of the stars as in their heavenly courses had times of change." Creation was pervaded by the *anima mundi*, and the author proceeds thus: "A soul was placed upon each star, and when according to law it animated a bodily frame, the consequence of virtuous life was a return to that blessed and suitable existence." But the Earth was not the only abode of life. "He sowed some in the Earth, some in the Moon, some in the other stars, which are the vessels of time." For us in the Earth "He invented and gave sight, to the end that we should observe the courses of intelligence in the Heavens"; but we are not the only beings with a divine essence. "The gods informed other natures akin to that of man, with various (other forms of) perceptions—these are trees and plants." Sound was an impulse; speech is defined as "a blow," as "strokes transmitted through the ears to the soul by means of the air and brain"—hearing being the vibration of these blows. Sounds which have swift impulses are acute, slow ones grave. Colours are flames (rays) which emanate from all bodies, having particles corresponding to the sense of sight.

Coming to the detailed calculations of this ancient school, we are much aided by Macrobius, who wrote when Honorius was Emperor, for the instruction of young Eustathius, whom he addresses as "my son, the delight and glory of my life," and "my son, dearer and more beloved than the light of day." They tabulated distances somewhat as follows:

From the Earth to the Moon =				1
"	"	Sun =	$1 \times 2 =$	2
"	"	Venus	$2 \times 3 =$	6
"	"	Mercury	$6 \times 4 =$	24
"	"	Mars	$24 \times 9 =$	216
"	"	Jupiter	$216 \times 8 =$	1728
"	"	Saturn	$1728 \times 27 =$	46656

The size of the Earth, Macrobius states at about 80,000 stadia, or 10,000 miles through, and the distance of the Sun was measured on the assumption that the Sun threw up darkness when it went below the Earth, 60 times this diameter. This gave 600,000 miles as the radius of the Sun's sphere. Thus the circumference of the circle of the Sun being 3,700,000 miles, a means was given of finding the size of that body, and the apparent size of its disc was compared with the circuit it described in the sky at the equinox. One method was to measure the depth of the shadow in a concave dial between its first appearing at sunrise and the end of the first hour of an equinoctial day. This was observed to be $\frac{1}{108}$ of the Sun's apparent course; the $\frac{1}{216}$ of the circumference of his circle, = 17,500 miles, or, in round numbers twice the size, or eight times the mass of the Earth.

In beginning this paper, I remarked that I did not think the Pythagorean school were complete exponents of Pythagorean doctrine. Macrobius occupies pages with the singular co-incidences of numerals with physical periods. Thus, in man, in seven months he gets teeth, in twice seven he sits up, in thrice seven he articulates, in four times seven he walks, etc. Pythagoras, we may be sure, never indulged in any such trifling. Grand as is the Timœus of Plato, a prose poem of the loftiest, I doubt if we can call even that an exposition of the views of this great master of natural science. Plato, whose very name expresses the breadth of his intellect, may have had a wider range of thought, but as a mathematician and original observer, neither he nor Cicero was in complete touch with Pythagoras. The *Somnium* seems to me a *précis* of the Timœus—the machinery of the dream being substituted for that of the dialogue.

But Egypt was the real and crowded repository of the best thought and science, and we must all feel the spirit of Old Nile behind that of Greece. Pythagoras, Plato, Herodotus, Solon, all drank in their lore from Egyptian sources. While Egypt was independent, her philosophers were the great thinkers and masters of science, understanding, as I believe, the true system of the stars and planets, but the fountains of knowledge dry up as national self-respect diminishes, and after she became subject to Persians, Greeks and Romans, faint echoes only of pristine teaching were heard in the land, and these only were repeated for our instruction by those who were privileged to visit the seats of decaying learning. We may, therefore, find Pythagorean views before Pythagoras, though we have to look into mythology to discover them. Having lost many of the keys of this symbolism, we have not the clear insight which belonged to these initiated at Eleusis or instructed at Sais.

Alas, that the gods have been struck dumb! Plato did not despise the imagery of the old religion. Hear his magnificent outburst:—

Ὁ μεν δε μεγα ἡγεμων εν Ουρανω Ζευς .... "First marches Zeus, the great ruler of the sky, driving swiftly his flying chariot, surveying and completely arranging all. Him, in twelve columns, follow the troops of gods and deified men—the Earth being, it would seem, the only body in the universe at rest."

That Zeus, to Plato, was the Sun, is evident; the twelve columns are the zodiacal divisions. He goes on to speak of the Earth as "clinging" or "circling" round the poles. The Greek word *ιλλουμενη* bears both meanings. If we could resolve the doubt—"which did he intend?"—we could tell if the rotation of the Earth was known to the highest minds of antiquity. But the gods were old in Plato's time, and if we can trace the same thoughts to the years when they were young, we shall have proved our point. We will look into Hesiod and Homer, who were to Greece what Gower and Chaucer are to the English language and its poetry. Hesiod symbolizes the Sun as Apollo, and so, too, by the way, does Æschylus. Apollo was the leader of the Muses, *i.e.*, the source of all knowledge and sensation. His silver bow was the course of the Sun across the Heavens; his swift darting arrows were the sunbeams, causes of health and of disease (*ἰατρος*); his name Phœbus indicated solar brightness, his title Delius (*δῆλος*) the light which makes all things manifest. The glorious rays of the Sun gave him his epithet the Golden Haired, and when, earliest of his works, he slew the Python and was called the Victorious, what else was meant than that the Sun, emerging from Chaos, rendered deformity in his system impossible, while his daily rising puts an end to Night, extinguishes the stars, and gives laws to all upon the Earth? His claim to be the patron of music rested upon this—that "the sunshine makes birds sing and all creation rejoice." "After the seven wanderers," says Hesiod, "the Heavens above all include and contain the rest." Therefore he calls his eighth Muse Urania, from *Ουρανος*, the sky, while the ninth in his Theogony, last and chief of the graceful throng, is Calliope, sweet voiced Harmony. Surely this, and Pythagoras' and Plato's views, had a common ancestry.

We must be brief with Homer, though full of scientific knowledge, showing through his myths.

Ζεὺς γὰρ ἐς 'Ωκεανὸν μετ' ἀμύμονας Αἰθιοπῆας
Χθιζὸς ἔβη κατὰ δαῖτα θεοὶ δ' ἅμα πάντες ἕποντο
Δωδεκάτῃ δὲ τοι αὖθις ελεύσεται Οὔλυμπόνδε.

For Jove is to a banquet gone, since yesternight,
Beyond the sea, among the Æthiops,
And with him all the Gods for company.
At the twelfth (hour) he'll come to Heaven again.

ILIAD I., 424.

Zeus, the All-Father, the Cloud-Compeller, is the Sun; the gods who went in his train the stars, the twelfth hour indicates the time between sunset and sunrise or the setting and rising of the principal stars. Again:—

All in gold
Himself arrayed, the golden lash he grasped
Of curious work, and, mounting on his car,
Urged the fleet coursers; nothing loth they flew,
Midway between the Earth and starry Heaven.

ILIAD VIII.

This is distinctly Pythagorean, as to the place of the Sun in the System, and as to Saturn's we have the following:—

The lowest deep
Of earth and ocean, where Iapetus
And Saturn lie....in Tartarus profound.

After Zeus, the Sun, or Fire, we have Here or Juno, the air or ether. She is said to be the sister of Jupiter, as having the same origin, and his wife, too—Macrobius says because air is subject to the sky, but possibly because the Sun generates worlds from the interstellar ether. Here is the Springtide—

Thus saying, in his arms he clasped his wife,
  The teeming Earth beneath them caused to spring
The tender grass, and lotus, dew besprent,
  Crocus and hyacinth, a fragrant couch
Profuse and soft, up-springing from the Earth.

ILIAD XIV.

To complete the four elements, we have Neptune, the lord of the water, and Pluto of the depths of the earth, brothers of Zeus and Juno.

ILIAD XV.

On the shield of Achilles were figured—

Earth and sky and sea,
The ever-circling sun and full orbed Moon
And all the signs that crown the vault of Heaven,
Pleiads and Hyads and Orion's might
And Arctos, call'd the Wain, who wheels on high
His circling course, and on Orion waits—
Sole star that never bathes in the ocean wave.

ILIAD XVIII.

Orpheus again testifies in similar strain—

Κέκλυθι, τηλεπορον δίνης ἑλικαυγεα κυκλον
Ουρανίαις στροφάλιγξι περιδρομον αἰὲν ἑλίσσων
Ἄγλαε Ζεῦ Διόνυσε, πάτερ πόντου πάτερ αἴης,
Ἥλιε παγγενέτορ, παναίολε, Χρυσεοφεγγές.

Hear us, glorious Zeus Dionysus, father of Ocean, father of Earth,
Sun, begetter of all, illumining all, golden rayed light,
Ever spinning thy course in celestial circles,
That whirling orbit of thine in the far stretching eddy (of space).

Oldest of all, perhaps, is the invocation of the priests—

Ἥλιε παντοκράτορ, κόσμου πνεῦμα, κόσμου δύναμις, κόσμου φῶς.

All-ruling Sun, thou soul of the world, might of the world, light of the world.

When great men like Pythagoras tell us God created the world by taking a part of the original firmament, then double that, and three times that, filling up the interstices with diapasons and diapentes, it indicates just conceptions of the wonderful harmonies in all created things. What else is Phyllotaxis, which gives us the elegant double spiral of the spruce, the perfect form of the rose, the sculptured column of the palm? What else is Harmony, as chanted in national anthems, or refined above common comprehension by Bach or Wagner? What else mean the wave-lengths of light which yield us the impression of colour, or the attuned electrical impulses which are revealing to us actualities in space which may hold great possibilities for us? Mendeljeff has taught us the complete harmonies of atomic combinations. Bode and Kepler's laws were found by following a Pythagorean lead, and the Asteroids are sorted into belts, following the nodal harmonies of the attractive powers of Jupiter and the Sun. The scales of reptiles and fishes, the feathers of birds, are arranged in numerical proportion, and the very hairs of our head are numbered—αριθμημὲναι. All honour, then, to the great minds of old; away with narrow sneers at Hesiodic and Orphic cosmogonies. Would that we could attain to the balanced equipoise of the old Egyptians, themselves, perhaps, reproducing an older civilization, which their fable of the lost Atlantis may imply; also the perfect art and philosophical mind of the Hellenes, while retaining and increasing the knowledge of and control over physical forces which we have recently acquired.

In conclusion, what would not Pythagoras have given for a night with a modern Astronomical and Physical Society—to view the Saturnian microcosm and hear about the complementary colours of double stars? But hush! At the time of the Trojan war he was, he claimed, Euphorbus. According to his doctrine, two thousand years having passed, he may be on Earth again, and who knows but that Pythagoras *redivivus* is our Secretary to-night.

In the discussion which followed, part was taken by the Chairman and Messrs. Pursey, Elvins, Van Sommer, Musson, Miller, Ridout and others.

TWELFTH MEETING.

This meeting, by previous arrangements, was held on the evening of the 27th of June, in the spacious grounds of Mr. W. P. Atkinson, M.A., where nearly a dozen portable telescopes, including three of 3-inch aperture, had been set up. Many members were present with field and opera-glasses, and the evening was given up to observation, Dr. A. D. Watson and Messrs. A. Elvins, T. Lindsay, A. Harvey, C. T. Gilbert and G. E. Lumsden and others, in charge of telescopes, taking the direction of groups on different parts of the lawn. Clouds along the horizon and a slight haze overhead for a time, combined with the light of the nearly full Moon to render invisible a number of interesting objects. Still, the subjects very satisfactorily examined included the planets Mercury, Venus and Mars, situated low down in the West; Saturn and Uranus in the South; numerous beautiful double-stars in Virgo, Cygnus, Scorpio and Ursa Major and Ursa Minor, and the Moon, which was not, of course, seen to the best advantage in her then phase. It happened that Mars and Mercury were in close conjunction in Gemini. They were, consequently, visible together either in an opera-glass or in a telescope armed with a low power. Mercury was seen to good advantage, a gratifying fact inasmuch as he was seen for the first time by a few of the members and by most of the visitors present.

Two hours having been spent in observation, the Society met for the transaction of routine business only, Mr. Atkinson in the chair. Mr. Pursey reported the receipt of publications from Great Britain, France and the United States. Several communications, including enquiries respecting the Society and applications for membership were read. It was announced that the Third Annual Report had been published, and that with the consent of the representatives of The Canadian Institute, each copy contained, as an appendix, the Circular-letter issued to Astronomers of all nations, respecting the proposed change, at the beginning of the new century, of the reckoning of the Astronomical Day. On motion of Mr. Elvins, seconded by Mr. Harvey, a vote of thanks to Mr. Lumsden for the manner in which the Report had been edited, was adopted.

The list of predictions announced was unusually full, and included a special reference to the occultation of Antares at 8.30 o'clock, July 23rd.

MEETING BY COUNCIL.

Council met July 3rd, Dr. Larratt W. Smith, Q.C., Vice-President, in the chair. A number of accounts were ordered to be paid; the renting of permanent rooms was considered, and the subject of the publication of the Semi-Annual Report was, after discussion, deferred to the Annual Meeting in January, 1894.

THIRTEENTH MEETING.

July 11th; Dr. Larratt W. Smith, Q.C., Vice-President, in the chair.

The Secretary read letters from Dr. E. S. Holden, Director of the Lick Observatory; Dr. E. C. Pickering, Director of the Harvard College Observatory; Professor W. W. Payne, Director of the Goodsell Observatory, Northfield, Minn.; Dr. M. A. Veeder, and others; also two applications for Associate-Membership, one from Philadelphia, the other from Rochester. The annual Reports of the Society seemed to be in some demand, as several applications for complete sets had been received. The current publications received by Mr. G. G. Pursey, the Librarian, included those of The Royal Society, The Royal Astronomical Society, and The Astronomical Society of the Pacific. The last mentioned contained some fifty views of the planet Mars, drawn during the summer of 1892 at the telescope by Professors Schaeberle and Hussey, of the Lick Observatory staff. All of the plates were interesting, and many extremely so, the work being beautifully done. Dr. Holden announced that it was his intention to issue a report of the work done on Mars at Mount Hamilton by himself, Professor Barnard, and the other observers using the great and the 12-inch telescopes. Mr. Pursey also presented a volume containing the Greenwich Observations for 1890, which was received from the Astronomer Royal, and was examined with much interest.

Professor T. H. Smyth, of Trinity University, Toronto, was elected an Active Member.

Under the head of observations, the first place was given to the Rordame-Quenisset Comet, discovered, on the 8th of July, at Salt Lake City, and then easily visible to the naked eye as a nebulous object. A telegram to Mr. A. F. Miller, announcing its position, was read from Mr. John Goldie, of Galt, who had independently discovered the comet on the 9th of July, not having heard of any previous discovery. Two letters were received from Dr. J. C. Donaldson, of Fergus, and Mr. J. R. Connon, of Elora. The latter gave an animated description of the comet, and added two drawings made at the telescope. He described the tail as being several degrees in length, and as presenting the appearance of a hollow-tube, or cone, and the nucleus as being of a pale electric-green colour. Mr. Connon added that the comet was distinctly seen on the night of the 8th, at 10 o'clock, by a farmer as he was driving home, Northward from Elora. As he did not take a daily paper, and as the object was a very easy one, he supposed it was no stranger to scientific men interested in such phenomena, and did not immediately report his discovery. Additional reports were made verbally by Dr. Smith, and Messrs. Miller, A. Harvey, G. E. Lumsden, and others. A description, with drawings, of a large bolide, or fire-ball, observed on the 7th of July, at 7 p.m., by Mr. R. A. Eaton, of Toronto, was received, and was ordered to be forwarded to Sir Robert Ball. This bolide appeared to pass very slowly Eastwards, a short distance below the dipper in Ursa Major, and to explode a little beyond a line drawn to the horizon from the Pole-star. Of the three large pieces into which the fire-ball separated, the smallest flew Northward in the line of the eye and disappeared apparently as a very bright point on the meteor's track, seeming not to change its position; a second portion dropped towards the Earth, and the third came towards the observer in the line of sight. A short paper was received from Rev. J. F. McBride, containing the details of some observations made with a portable transit for the purpose of determining the latitude and longtitude of St. Helen's Church, Brockton, in Toronto. These were deduced from the observed altitudes of Spica and Polaris. Mr. Harvey read a note on the appearance of the sky at three o'clock in the morning of the 10th of July. The atmosphere was unusually clear, and the Heavens, with Jupiter in his full glory, the rising Moon in her last quarter, various bright stars, and the Milky Way, hanging, as it were, with festoons of stars, formed, with the stillness of the night, an awe-inspiring subject for contemplation of the amateur. Mr. A. Elvins and Mr. Miller described the great activity going on in the Sun. Sun-spots had been numerous and extremely interesting, owing to rapid changes. Mr. Miller said he had again noticed that the breaking out of spots in one solar hemisphere was usually followed by the appearance of spots in the corresponding portions of the other hemisphere. Mr. Elvins presented drawings made of the disc of the Sun every day in July, together with enlarged representations of the chief groups of spots, showing accurately and graphically the alterations in their appearance. A long series of planetary and stellar observations by Dr. Donaldson, of Fergus, was read. This observer had been steadily observing the Sun since January 1st, 1892, and stated that on no day had his disc been entirely free from spots.

Dr. Donaldson also sent a series of diagrams representing the positions of various triple and multiple stars he had been examining in Leo, Hercules and Cygnus, and, owing to a published intimation that the green companion to Antares should be looked for on the occasion of the occultation, July 23rd, stated that at 4 a.m. on the 28th of March, 1893, he found the pair so easily divided by his $3\frac{1}{2}$-inch Cooke, that he tried smaller apertures, and was always successful in "clearly and distinctly" separating them until he reached $2\frac{1}{2}$ inches, when "the green star was visible as a thickening of the diffraction-ring."

Mr. Thomas Lindsay read the following paper based upon

THE OCCULTATION OF ANTARES,

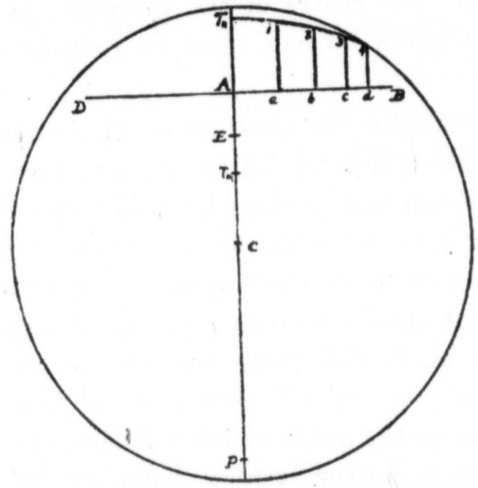
to be visible at Toronto, July 23rd, 1893. Mr. Lindsay said that in considering the phenomenon of the occultation of a fixed-star by the Moon, we may imagine an observer to be stationed at the star looking out upon the Earth, supposed to be projected upon space as a flat disc, and watching the disc of the Moon passing over it. He sees the edge of the Moon just touching the position of an observer on the Earth, and at that moment it is clear that the immersion of the star occurs to the mundane observer. If an observer were stationed at a star in the Pole of the Heavens, the circles of latitude supposed to be drawn upon the Earth's surface would truly appear as circles; the plane of the disc would be the plane of the equator.

If he were stationed at a star on the celestial equator, the circles would appear as straight lines, and the plane of the disc would be at right-angles to the equator. But if he were stationed anywhere between the Equator and the Pole, the circles would be foreshortened into elliptic curves, and the plane of the disc would make an acute-angle with the plane in which the axis lies. In this case, the semi-axis-major of the ellipse into which the circle of latitude is projected, is the cosine of that latitude, and the semi-axis-minor is the sine of the declination of the star, *not to radius unity of the disc,* but to radius cosine of the latitude; noting also that the inclination of the plane to the Earth's axis is equal to the declination of the star, or position of the observer in space.

The proportion between the Earth's disc and that of the Moon is as 1 to ·27227. The figure of the Earth being that of an oblate-spheroid, it is necessary to take into account the varying length of its radius as we pass from Equator to Pole, and also of the difference between the astronomical latitude, as measured from the zenith of the plumb-line, and the geocentric latitude, as measured from the zenith of a line passing through the true centre of the spheroid; in representing the disc of the Earth, a given latitude must be reduced to the geocentric latitude.

We may now consider the occultation of Antares of July 23rd. The declination of the star is 26° 11′ 53″ S., therefore, a line from it to the centre of the Earth, and produced, would enter the Earth in this latitude South, and leave it in the same latitude North. The disc of the Earth would appear as in the diagram. Let *C* be the centre, lat. 26° 11′ 53″ S. Then upon a meridian passing through it, the Equator would be projected at *E*, *CE* being the sine of the arc 26° 11′ 53″. The South-pole being 63° 48′ 07″ South of the point *C*, it would be projected on the disc in the point which measures the sine of this arc, at *P*. The arc from *C* to the latitude being 69° 39′ 48″, we measure the sine of this arc at *Tn* and have the position of Toronto at the upper culmination of the star. The difference between the latitude of Toronto and the star's declination is 17° 16′ 02″. The sine of this arc is *C Tm*, and *Tm* is, therefore, the position of Toronto at the lower culmination of the star; or, we may consider the globe transparent and say the observer would see the opposite point of the latitude-circle of Toronto at *Tm*. *Tn Tm* is then the axis-minor of the ellipse into which the latitude-circle is foreshortened. Bisect *Tn Tm* in *A*. Set off *AB*, *AD* at right-angles to the meridian, and each equal to the cosine of the latitude. Then *DB* is the axis-major of the ellipse. If now we suppose that Antares is on the meridian, Toronto will be seen at *Tn*; then the axial motion of the Earth carries it Eastward and when one-quarter-revolution is made, or in 6 hours sidereal time, Toronto is at *B*. Between *Tn* and *B*, the ellipse touches the circle and, at that point, Toronto is carried from the view of the observer at the star, or to the real observer the star sets. Six hours more and Toronto is at *Tn*; another quarter-revolution, and it is carried to *D* and between *D* and *Tm* the ellipse again touches the circle and the star rises. To mark the position of Toronto during the intermediate hours we note that, as it describes an arc of 15° in one hour, its place, referred to *AB*, will be in one hour at a distance from *A* equal to the sine of 15° to radius *AB*; in two hours the sine of 30° and so on. And its place referred to *A Tn*, will be in one hour at a distance from the axis-major equal to the cosine of 15° to radius

A Tn; in two hours, the cosine of 30 and so on. Dividing the line *AB* in this manner in the points *a*, *b*, *c*, *d*, and laying off the respective



cosines to radius *A Tn* at 1, 2, 3, 4, we have these latter points as those through which the ellipse passes, or the path of Toronto on the disc of the Earth as seen from the star.

We may now note the symbols in common use to designate the quantities we have so far considered :—Astronomical latitude, φ; geocentric latitude, φ'; log. radius of the Earth, ρ; the line *AB* or the semi-axis-major, $\rho \cos \varphi'$; declination of the star, δ; the line *A Tm*, that is, the sine of the declination to radius *AB*, $\rho \cos \varphi' \sin \delta$; the hour-angle, h; the co-ordinates of the place along the axis-major, $\rho \cos \varphi' \sin h = \xi$; along the axis-minor, $\rho \cos \varphi' \sin \delta \cos h = \eta$; the line *CA*, $\rho \sin \varphi' \cos \delta$.

We may now proceed to construct the diagram illustrating immersion and emersion. With centre *C* and radius unity (from any convenient scale) describe a circle. (The centre *C* is not shown in the diagram.)

On a meridian passing through it, take

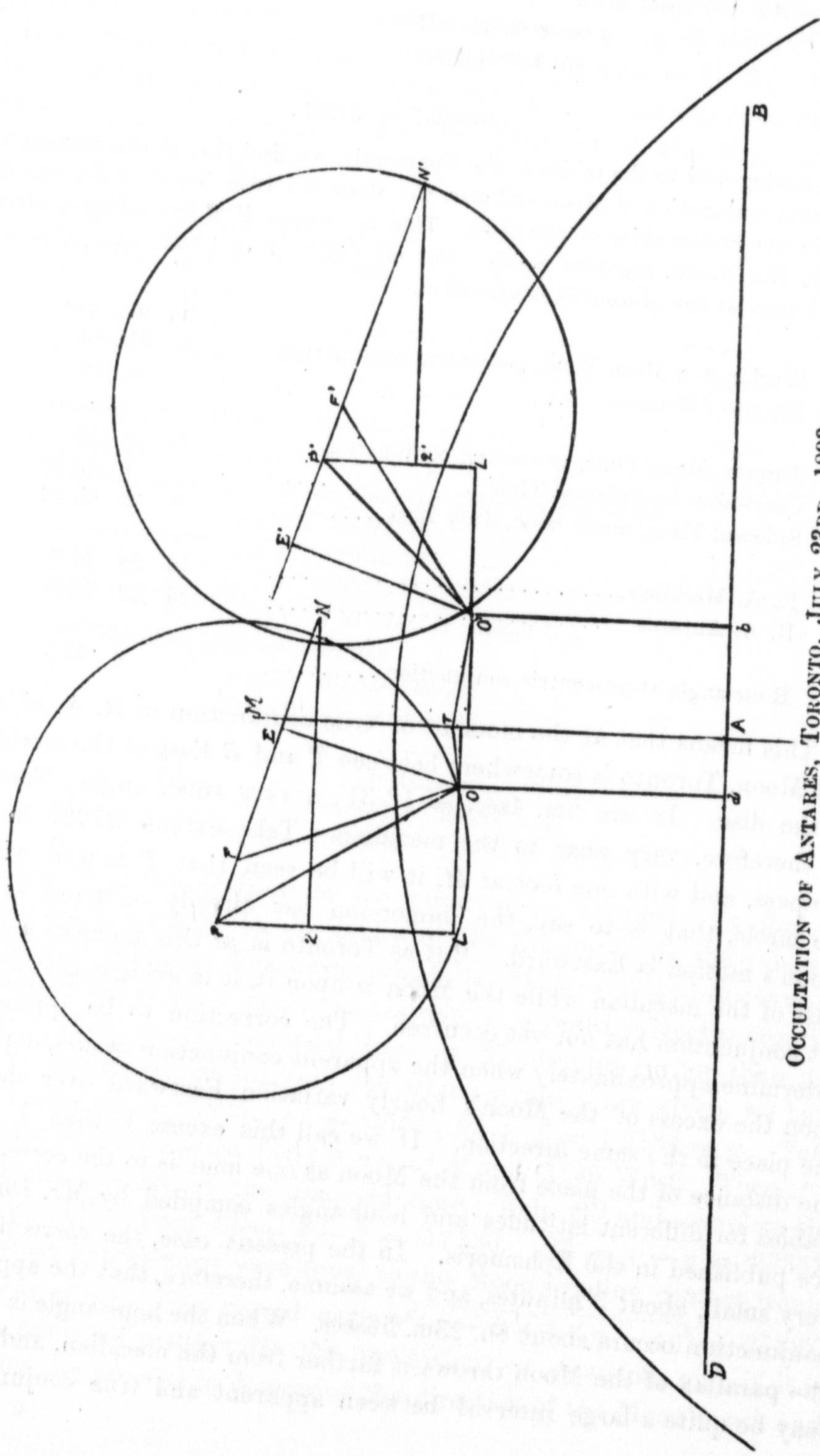
$CA = \rho \sin \phi' \cos \delta$ as follows :

$\log \rho$	9·9993104
$\sin \phi'$	9·8375347
$\cos \delta$	9·9529247
	9·7897698 = log ·61626 .

Take $AB = \rho \cos \phi'$

$\cos \phi'$	9·8608117
$\log \rho$	9·9993104
	9·8601221 = log ·72464 .

It will be observed that this value of $\rho \cos \phi'$ is constant for Toronto.



OCCULTATION OF ANTARES, TORONTO, JULY 23RD, 1893.

Take $AT = \rho \cos \phi' \sin \delta$

$$\begin{array}{rl} \rho \cos \phi' & 9{\cdot}8601221 \\ \sin \delta & 9{\cdot}6449066 \\ \hline & 9{\cdot}5050287 = {\cdot}31991. \end{array}$$

Referring now to the tables of the Ephemeris, we find that at the moment of geocentric conjunction of Moon and star, the Moon is 1·1630 North of the star (in terms of the radius unity of the disc). This is column Y of the tables, positive towards the North, negative South. Set off $CM = Y = 1{\cdot}1630$, and M is the Moon's place at the geocentric conjunction.

	H.	M.	SEC.
Washington Mean Time, geocentric conjunction	8	30	18
Toronto difference	—	9	22
Toronto Mean Time, geocentric conjunction.. .	8	20	56
Correction for Sidereal Time..................		1	22·28
Sidereal Time, mean noon, July 23rd..........	8	6	39·42
R. A. Meridian.............................	16	28	57·7
R. A. Antares	16	22	53·2
Hour-angle at geocentric conjunction		6	04·5

This means that at the moment of true conjunction in R. A. of star and Moon, Toronto is somewhere between T and B East of the meridian of the disc. In arc 6m. 4sec. = 1° 31′, a very small angle; Toronto is, therefore, very near to the meridian. Take extent ·27227 in the compass, and with one foot at M, it will be seen that T' is well within the circle, that is to say, the immersion has already occurred as the Moon's motion is Eastward. But as Toronto is at this moment a little East of the meridian while the Moon is upon it, it is evident that apparent conjunction has not yet occurred. The correction to be applied to determine approximately when the apparent conjunction occurs, depends upon the excess of the Moon's hourly variation Eastward over that of the place in the same direction. If we call this excess V, then V is to the distance of the place from the Moon as one hour is to the correction. Tables for different latitudes and hour-angles compiled by Mr. Downes are published in the Ephemeris. In the present case, the correction is very small, about 3 minutes, and we assume, therefore, that the apparent conjunction occurs about 8h. 23m. 56secs. When the hour-angle is large, the parallax of the Moon throws it farther from the meridian, and there may be quite a large interval between apparent and true conjunction.

Now, the duration of an occultation is usually about an hour, and we will, therefore, assume that immersion occurs about 30 minutes before and emersion about 30 minutes after conjunction in R. A. We will then have for immersion, 7h. 53m. 56secs. and for emersion 8h. 53m. 56secs., and will proceed to find the positions of the Moon and the observer for these times.

		M.	SEC.
Hour-angle at true conjunction	+	6	4·5
Add 3 mins. in Sidereal Time..................		3	0·4
Hour-angle at apparent conjunction	+	9	4·9
Deduct 30 mins. in Sidereal Time	—	30	4·9
Hour-angle at 7h. 53m. 56secs.	—	21m.	
In arc, h = ...	—	5° 15′,	

then the co-ordinate of the observer along the axis-major

$$\begin{array}{lr} \rho \cos \phi' & 9{\cdot}8601221 \\ \sin h & 8{\cdot}9614288 \\ \hline & 8{\cdot}8215509 = {\cdot}06630 = \xi, \end{array}$$

and the co-ordinate along the meridian

$$\begin{array}{lr} \rho \cos \phi' \sin \delta & 9{\cdot}5050287 \\ \cos h & 9{\cdot}9981743 \\ \hline & 9{\cdot}5032030 = {\cdot}31857 \end{array}$$

$$CA + {\cdot}31857 = {\cdot}93483 = \eta.$$

$$\text{Take } Ad = {\cdot}06630 = \xi;\ dO = {\cdot}31857.$$

Then O is the position of the observer at Toronto. To find the Moon's place, we refer to the tables of the Ephemeris for the values of the hourly variation Eastward, which is $\cdot5325 = x'$ and Southward, which is $\cdot1232 = y'$; x' is always positive, y' is positive North, negative South. Then, as the assumed time is 27 minutes earlier than the time of geocentric conjunction for which x' and y' are given, we have $t = 27$ mins. $tx' = \cdot2396$; $ty' = \cdot0554$; $ty' + Y = 1\cdot2184 = y$. Take the point P at a distance ·0554 North of M and ·2396 West. Then P is the Moon's position at the assumed time. Join PO and complete the triangle PLO. Then $LO = x - \xi = \cdot17330$. $PL = y - \eta = \cdot28357$. If now the hypothenuse were equal to the Moon's radius, contact would just take place. We should have $\sqrt{(x-\xi)^2 + (y-\eta)^2} = \cdot27227$. This is the proof position for the immersion, or emersion, and if it is not filled, we proceed to determine the direction of the Moon's path and the point upon it that is distant ·27227 from the observer. It will at once occur to us that if we draw the Moon's path through M and mark it off into spaces, and also mark off the ellipse, we might, by trial with the compasses, find the two points, one on the line and one on the ellipse, marked by the same times and at the proof distance from each other. The difficulty will be in marking off the ellipse; unless the scale be very large, the error will be quite appreciable. A graphic solution, however, quite rigorous, by a somewhat different construction that is here given, is due to Mr. W. F. King, C.E., Government Astronomer at Ottawa, a distinguished member of this Society, and will be found in the transactions of The Royal Society of Canada, 1888. To proceed with the present construction, we note that the difference between the hourly variations of the Moon and the observer will give us the relative path of the Moon, the point O being considered stationary. The hourly variation of the co-ordinate ξ is expressed by $[9{\cdot}4192]\ \rho \cos\varphi' \cos h$, the quantity in brackets being the logarithm of that part of the radius equal to an arc of one mean solar hour, or 15° 2′ 27″.

$\rho\cos\phi'$	9·8601221
constant	9·4191561
$\cos h$	9·9981743
	9·2774525 = log ·18943 = ξ'

The hourly variation of η is expressed by $[9{\cdot}4192]\ \xi \sin\delta$

constant	9·4191561
$\log\xi$	8·8215509
$\sin\delta$	9·6449066
	7·8856136 = ·00768 = η'

Then the relative motion of the Moon in one hour is expressed by

$$x' - \xi' = {\cdot}5325 - {\cdot}18943 = {\cdot}34307, \text{ and}$$
$$y' - \eta' = -{\cdot}1232 - {\cdot}00768 = -{\cdot}13088.$$

Take $PQ = {\cdot}13088$; $QN = {\cdot}34307$; join PN; then PN is the relative path of the Moon in one hour. From O draw OE at right angles to PN. With radius ·27227 from centre O describe an arc cutting PN in F. Then F is the position of the Moon's centre when O disappears, or to the real observer, the position at the immersion of the star. The line PF expressed in time as compared with PN which equals 60 mins. will give the time of immersion. The usual notation for the figure thus constructed is: angle $LPO = M$; $LPN = N$; $OPN = (M - N)$; $OFN = \psi$; line $PO = m$; $PN = n$; $OF = k$ the Moon's radius.

Then $\frac{x - \xi}{m} = \sin M$, $x - \xi = m \sin M$

and similarly $y - \eta = m \cos M$

$x' - \xi' = n \sin N$

$y' - \eta' = n \cos N$.

To compute the sides and angles we have

$\log m \sin M =$	9·2387986	$\log n \sin N =$	9·5353827
$\log m \cos M =$	9·4526603	$\log n \cos N =$	9·1168733
$\tan M$	9·7861383	$\tan N$	10·4185094
$M =$	31° 25′ 51″	$N =$	69° 7′ 6″
$\log \cos M$	9·9310865	$\log \cos N =$	9·5519853
$\log m$	9·5215735	$\log n =$	9·5648880
$(M - N) =$	37° 51′ 15″	$\log 60 =$	1·7781513
$\log \frac{m}{n'} =$	1·7348368	$\log n' =$	7·7867367

= variation in one minute.

Then to compute angle $\psi = OFE$ we have $\sin \psi = \frac{OE}{k}$; $\sin (M - N) = \frac{OE}{m}$; $OE = m \sin (M - N)$; $\sin \psi = \frac{m}{k} \sin (M - N)$; k being ·27227

comp. log. κ	0·5650002
$\log m$	9·5215738
$\sin (M - N)$	9·7862930
$\sin \psi$	9·8728670
ψ	= 48° 15′ 51″

To determine PE we have $\frac{PE}{m} = \cos (M - N)$; $PE = m \cos (M - N)$ or expressed in time $PE = \frac{m}{n'} \cos (M - N)$

$\cos (M - N)$	9·8983744
$\log \frac{m}{n'}$	1·7348368

$PE = 1·6332112 = 42·97\text{m}.$

If now we deduct FE expressed in time we have the final correction PF to be added to the assumed time.

$\frac{FE}{\kappa} = \cos \psi$; $FE = \kappa \cos \psi$ or in time $= \frac{\kappa}{n'} \cos \psi$

$\log \kappa$	9·4349998
comp. $\log n'$	1·2132633
$\cos \psi$	9·8232767

$FE = 1·4715398 = 29·61\text{m}.$

Then $PE - FE = 13{\cdot}36$m. =		13m.	21sec.
Add assumed time	7	53	56
Mean time of immersion	8h.	07m.	17sec.
Add		17	34
Standard time of immersion	8h.	24m.	51sec.

And the position-angle at immersion, measuring from the North-point, is evidently the supplement of the angle N added to ψ or

$$180 - 69° \ 7' \ 6'' + 48° \ 15' \ 51'' = 159° \ 8' \ 45''.$$

To compute the time of emersion, having assumed 33 minutes later than conjunction, we have

	M.	SEC.
Hour-angle at conjunction	6	4·5
33 mins. in Sidereal Time	33	5·4
$h =$	39	9·9

in arc $h = 9° \ 47'' \ 28''$

Then $\rho \cos \phi' \sin h = {\cdot}12323 = \xi$

$CA + [\rho \cos \phi' \sin \delta \cos h = {\cdot}31525] = {\cdot}93151 = \eta$.

Take O', the point whose co-ordinates are ξ and η; $t = 33^m$, $tx' = {\cdot}2928 = x$; $Y - ty' = 1{\cdot}0953 = y$; $(9{\cdot}4192)\ \rho \cos \varphi' \cos h = {\cdot}18746 = \xi'$; $(9{\cdot}4192)\ \xi \sin \delta = {\cdot}01428 = \eta'$. We have thus

$$x - \xi = O'L' = {\cdot}16955;\ y - \eta = L'P' = {\cdot}16379$$
$$x' - \xi' = Q'N' = {\cdot}34504;\ y' - \eta' = P'Q' = {\cdot}10892.$$

Take $O'E'$ perpendicular to n; take $O'F' = {\cdot}27227$, and solving the triangles we shall have

$$\frac{m}{n'} \cos (M + N) = 18{\cdot}61 \text{ M.}$$

$$\text{and } \frac{\kappa}{n'} \cos \psi = 29{\cdot}28$$

and the correction to the assumed time or $P'F' = 10$m. 38sec.; Eastern Standard Time of emersion, 9h. 22m. 8sec.; angle of contact, 137° 57′ 20″.

Though the hour was somewhat late, the Society listened with pleasure to a brief, but highly interesting description of the Yerkes' Telescope, written by Professor Barnard, and read by Dr. Smith, the Chairman.

FOURTEENTH MEETING.

July 25th; Dr. Larratt W. Smith, Q.C., in the chair. Mr. W. L. Dobbin, of Scottsville, N.Y., was elected an Associate-Member, and Miss Dupont, of Toronto, an Active Member.

A communication was received from Professor W. W. Payne, of Northfield, Minnesota, intimating that the first number of *Popular Astronomy* would appear in September. It was announced by Mr. T. Lindsay that the Society was especially indebted to Mr. Payne, and also to Professor E. C. Pickering, of Harvard College Observatory, for their courteous consideration in acceding to requests for and promptly sending the elements of Rordame's Comet, with an ephemeris, to the middle of August. Mr. J. R. Connon, of Elora, sent in several photographs of the comet and drawings of the aurora of 15th of July. Most interesting reports were received from Mr. A. Elvins and Mr. A. F. Miller. Mr. Elvins had several drawings of the comet made at a three-inch telescope, and reproducing the various changes of appearance it had undergone. Mr. Miller described at some length his spectroscopic observations. The spectrum showed the well-known three bright bands of the hydro-carbon comet, the middle band being the brightest. From a careful consideration of its appearance, he had arrived at the conclusion that the temperature of the comet was about equal to that of the spirit-lamp flame. He had noticed with much interest the occultation of a star by the coma of the comet on July 21st. Mr. Arthur Harvey said that he had been fortunate in seeing the comet clearly several times. It had a perceptible tail at first, as shown in the diagram he submitted, but on the 21st and 22nd of July he could distinguish none. On the 20th he still could define it, and saw through it some telescopic stars, undimmed and as sharply as if there were no comet between them and the eye. On the 22nd there was a seventh magnitude star, he thought, in close proximity to it, and there was much beauty in the view. Indeed, in his three-inch telescope, it was always an attractive object; its mild glow was that of a bottle of fireflies seen through a mist.

Commander W. A. Ashe, of Quebec, wrote to the Society in reference to the recently-discussed theories, including that of Dr. M. A. Veeder, accounting for auroral displays, and forwarded several copies of *Science*, containing controversial articles by him on the subject. He considered that the co-incidence of solar rotation and the appearance of the aurora had not been established.

The reports made of observations indicated that the occultation of Antares on the 23rd of July had awakened widespread interest among amateurs, and that it had been successfully observed by members of the Society in Toronto and elsewhere in Canada. At the instance of the Society, a delegation attended at the Toronto Observatory, where Mr. R. F. Stupart, of the Meteorological Service, put in readiness the 6-inch Cooke equatorial of the Observatory. Electric connection having been made between the telescope and the chronograph in the Transit Room, the times of contact were taken with extreme care. Mr. James Todhunter noted the instant of the star's disappearance, while Mr. W. Mitchell watched a second chronometer, close at hand, to make doubly sure of the time. The immersion was observed at 8h. 24m. 55s., and the re-appearance at 9h. 22m. Dr. J. C. Donaldson, of Fergus, gave an interesting account of his observations of the occultation, he having used a sufficiently high power to show the companion star to Antares. Dr. J. J. Wadsworth, of Simcoe, had also carefully watched the phenomenon, and made the time of immersion 8h. 24m. 10s. There was a slight difference between the times recorded by observers in different parts of the city. Dr. Smith, and Messrs. Arthur Harvey, G. E. Lumsden, and A. F. Miller, in the East, had not observed disappearance at the precise moment of the Observatory record, nor had Mr. J. A. Paterson and Dr. Watson in the West.

Mr. A. F. Miller read the following interesting note on

THE SPECTRUM OF THE LIGHT EMITTED BY INSECTS.

Through the kindness of Mr. Lumsden, who gave me two specimens of the small luminous beetle (*Photinus corruscus*) common in many parts of the country during the summer, I had an opportunity of examining this light spectroscopically on the nights of July 18th and 19th. The light emitted by the specimens I examined appeared to be of two different kinds, which I distinguished in my notes as "the steady light" and "the flash," or transient light. The "steady light" was emitted from the lower portion of the insect's abdomen pretty constantly, though not at all times. It was of a pale greenish tint, like that of phosphorus or a phosphorescent substance. It gave a pale, but still quite distinct, spectrum, consisting of a wide green band situate between λ 5160 and 5805 approximately. "The flash" was emitted for only a brief portion of time, generally about a quarter of a second, though sometimes the insect emitted several in quick succession. The source of the light is in the same region of the abdomen, but the luminous intensity is much greater than in the former case, the brightness being almost dazzling to a sensitive eye when the pupil is widely dilated in a darkened room. The color of the flash is a beautiful pale green, having a vividness suggestive of the small arc formed between brass terminals arranged as a spark-gap with a current of small quantity, but considerable intensity. To some eyes a redness is perceptible, due, perhaps, to the effect of contrast. The spectrum of the flash is perfectly continuous through the region it occupies, *i.e.*, from about λ 5000 to about λ 6605. Commencing in the bright red, we see in succession red, scarlet, orange, yellow, yellow-green, green, and possibly a very little blue-green. The specimens I examined did not seem to give any emission of blue or violet light, though there might have been faint radiations in this region imperceptible to the eye through the sudden character of the flash, and the overpowering preponderance of the less refrangible waves. This absence of blue readily accounts for the greenish tinge which the eye notices in the undivided rays, and I am not prepared to assert positively that the yellow and green regions are of greater relative intensity than the red, as compared with the emission spectrum of any luminous source capable of emitting rays mainly situate in the particular regions occupied by those under consideration. I must add, though, that my interest and attention being specially fixed upon the red region, I perhaps unduly accentuated its intensity and importance. It is quite plain that the whole energy devoted by the insects to light-production is expended in originating these rays which powerfully affect the visual organs. I am under the impression, however, that a certain small portion of heat rays must be formed at the same time, though probably little or no dark heat. I do not regard this conclusion as incompatible with physiological conditions, or the non-perception of any sensible heat. Owing to the loss of vitality naturally resulting from their captivity, it was difficult to obtain enough light from the insects to give a clear spectrum in an instrument of some power adapted to measurements, and the transient nature of the emissions also greatly increased the difficulty of the experiments. I therefore wish the above-mentioned extremes to be taken as approximate positions only, though I think the space between them represents quite well that in which the light radiations are contained. Some very interesting points suggest themselves in connection with a research of this character; for when we reflect upon the wide distribution, and the abundance of insects gifted with luminosity, it can hardly be doubted that very simple means suffice for the production of a selective radiation the equivalent of which we can hardly obtain except by complicated operations, or methods obviously in no way similar to those by which the insects originate light. There seems here an admirable opportunity for the microscopist, and it would also be of interest to test the action of this peculiar light upon the dry plate.

Reports of the recent auroral displays were so numerous that it was decided to devote the next meeting to their consideration, and the paper of the evening, by Mr. Andrew Elvins, a continuation of his former essay on

MOVING MATTER IV: SOLAR HEAT,

was read.

Mr. Elvins said:—I presume that those of you who read my paper on Gravity in our Transactions of 1891, page 28, and heard the first part of this paper on Solar Heat, will be somewhat prepared for the views to which I invite your attention.

You are aware that to account for the transmission of energy through space, physicists have agreed that a subtle, or rare, substance occupies every part of the universe. Some speak of it as an infinitely elastic fluid; it is said to be more "rigid than steel," and yet of a consistency resembling jelly. That a continuous substance as rigid as steel could permit the planets and comets to pass through it, without retardation, is to me inconceivable; I regard it as quite probable that the ether is simply the ultimate particles which exist in space and move in free paths; of which are composed masses of matter, as the Kinetic Theory of Gases supposes the molecules of gases to exist and move. Let us suppose this to be the nature of the ether of space, and endeavour to follow it in some of the changes it will undergo. First, I would notice the fact that these moving atoms would be constantly colliding with each other; that they could lose none of their motion, and that when they met centre to centre they would rebound; while, if they collided at any other angle than that of the line uniting the centres of both, they would be turned around on an axis passing through each of them. The motion of rotation thus brought into existence must be lost to translation; several collisions, indeed, might so diminish the translation as to bring two or more atoms nearer each other than they would have been but for their rotation, or but for the loss of translation, which has been changed to rotation. This would be a commencement of aggregation; it may be that the atoms of such a molecule may be brought still nearer each other by the impact of the ether atoms, which may carry into space some of the remaining translatory motion, and that they thus remain in each other's companionship for the future. Two such atoms may constitute a chemical molecule or element; three may constitute some other; four, still a third, and so on. Those gravitating toward each other would become small masses; these would unite and form larger ones, after which the masses themselves would move from the place in which they were formed and gravitate toward the solar system. It is interesting to notice how such masses would act when approaching the Sun. Those nearest that luminary would move a little faster than those more remote, the whole mass becoming an elongated swarm, which would move straight into the Sun, if the Sun were stationary—but, as we know, the Sun moves. The solar-system passes onward through space, probably in some mighty orbit. As it advances in its path, the direction of the incoming meteors must be continually changing. The straight line along which they moved when the mass was at A and the Sun at 1, cannot longer be followed when the mass is at B and the Sun at 2. This shows the course the meteors would follow, for they must sweep around the Sun in a hyperbola, and rush off again into space. From the Earth, such a swarm would be seen as a comet, which, if not retarded in its flight, would never return. Sometimes, however, in their outward flight, such swarms pass very near some one of the planets, and, being retarded, turn into a new orbit, in some cases forming ellipses and remaining permanent members of the solar system. Following this line of thought, it is easy to understand why comets and meteors come from all directions in space. But I want to show clearly why such swarms must move in different directions, some *direct*, others *retrograde*, and see what must be the result.

If the Sun be revolving around some very distant centre, its orbit must lie in some plane. Let us think and speak of space on the one side of this plane as above, and on the other side, as below. As the Sun moves in an immense orbit around this distant centre, we shall speak of that part of space between the orbit and the centre as the *inside*, and of that on the other side of the orbit, as the *outside*. Suppose a swarm of meteors to approach the Sun from any point outside the orbit ; it is clear that they will move in one direction, say, *retrograde*, and that meteors from the inside of the orbit will take up a *direct motion*. You will notice that meteoric orbits crowd together near the Sun. Now, as there are many millions of meteors in each swarm, and as the swarms move in opposite directions, *collisions must be frequent*. Meteorites will be shattered, their translation as masses will be largely stopped, any remaining motion being the motion of the molecules in the meteors. This molecular motion is *simply heat*, and it may be that it is sufficient to turn a large part of the meteoric masses into gas. As the colliding masses lose their momentum, they gravitate sunward, and, of course, fall into the Sun. Hence, the motion of the two masses becomes motion of molecules in the Sun. This motion is *Heat*.

But there is another means by which incoming meteoric masses will be projected upon the Sun. The action of the planets on incoming meteors must sometimes be such as to change both the rate of the meteors' motion and the direction in which they move. As an example, let us select one of the best known meteoric streams, that through which the Earth passes on the 12th and 13th of November. The period in which this stream passes around the Sun is about thirty-three years. Its perihelion is within the Earth's orbit, and its aphelion a little beyond the orbit of Uranus. Now, when this swarm has passed its aphelion, and is again moving sunward, it must cross the orbits of Saturn, Jupiter, and Mars ; if it happen that any one of these planets is a little inside the meteor track, or orbit ; it will draw the swarm somewhat inside the path in which it would have otherwise moved. The effect of this would be to scatter the members of the swarm more or less. If the planets were so situated as to cause the meteors in their flight to be scattered widely—some being diverted by one planet and some by another planet—some would pass nearer each planet, some more distant ; some would have their path changed but little, others a great deal. Amongst the many millions thus disturbed, many must fall on the Sun. The greater portion or part of the meteors of such a swarm would, probably, be very small in size, but their velocity would be very great, so that the arresting of their motion of translation when they fell on the Sun would cause molecular motion, *which is Heat*.

Gravitation, then, as I understand it, is the impact of ether atoms all around the Sun's mass; the fall of meteoric matter into the Sun is the factor, and, I think, a sufficient factor to sustain the Sun's heat indefinitely, and that, too, notwithstanding the fact that the Sun is constantly radiating heat. No contraction (which is a result of cooling) may take place in the Sun at all. That some natural force exists in the universe, and changes the Sun and star systems again into ether, I have no doubt; but I cannot try to show what this force may be, at least to-night. I hope some one will do this when I am gone; *better still* if they do so before that time arrives. I subjoin the following extract, page 376 of Proctor's last work, Old and New Astronomy, published and edited by Mr. J. Cowper Ranyard:—"On the whole, the evidence given by spectroscopic analysis of sun-spots appears to confirm the theory that dissociation by intense heat *might resolve the so-called elements into more elemental forms.*"

A short discussion, in which Mr. G. G. Pursey and Mr. Phillips took part, concluded a most interesting meeting.

FIFTEENTH MEETING.

August 8th; Dr. Larratt W. Smith, Q.C., Vice-President, in the chair. Messrs. A. J. Pattison and John Webber, of Toronto, were elected Active Members, and Dr. J. J. Wadsworth, of Simcoe, and Mr. Charles Clarke, of London, were elected Associate-Members of the Society.

The Committee having charge of the matter, reported that, agreeably with the powers conferred upon it, it had accepted the terms offered by the Lady Managers of the Y. W. C. Guild, with respect to rooms for the meetings, the library and apparatus of the Society. The action of the Committee was formally approved.

The communications read included applications from several parts of the Province for information concerning the Society, and a letter from Mr. W. D. Barbour, of The Leeds Astronomical Society, conveying thanks for Annual Reports.

Under the head of observations, a letter was read from Mr. David E. Hadden, of Alta, Iowa, an Associate-Member, who sent in diagrams illustrating the path of Rordame's Comet, and a sketch of the comet itself at 10 p m. (Central Time), July 9th ; also a representation of a spectroscopic apparatus of his own device, to be attached to his telescope. Mr. Hadden enclosed a transcript from his Observing Note-book, from July 7th to August 3rd, from which it appeared that he saw Rordame's Comet at 9.30 o'clock on the night of the 7th of July, at least one day before it was discovered by Rordame. Mr. Hadden saw the comet as a hazy star without a tail, but its true nature not being suspected, he did not examine it with a telescope. His letter also dealt with the astronomical exhibits at Chicago and other interesting matters. Mr. Andrew Elvins made a report upon sun-spots, giving particular attention to the Great Spot of August, 1893. Owing to cloudy weather, he was not quite certain when this spot appeared, but he thought it broke out on the side nearest to the Earth on the 2nd of August. With his report, Mr. Elvins handed in a series of drawings. Mr. A. F. Miller spoke of the great activity displayed in all parts of the spot, which had been easily visible to the naked eye, and dwelt upon the exceeding beauty of portions of the *penumbræ*. Accurate measures with the filar micrometer gave the spot a length of 92,000 miles, and a breadth of 52,000 miles, dimensions far exceeding those of the Great Spot of February, 1892, up to that time the largest one which had appeared during the prevailing sun-spot maximum. Solar observations were also made by Mr. Arthur Harvey and Dr. J. C. Donaldson, of Fergus, both of whom agreed that they had never seen so many spots as had been visible lately; Mr. Harvey said he had counted as many as forty-two at one time. Mr. Miller drew attention to the similarity in some respects between the Great Spot of February, 1892, and that of August, 1893. With the first there appeared the famous rose aurora of February 13th, and with the second the notable aurora of the 6th of August. With both there had been a low barometer and electrical and atmospherical disturbances. He also presented a photograph of that portion of the solar spectrum between G and H_1 and H_2. Interesting observations upon Jupiter, the aurora of the 6th of August, and some double-stars were also made by Mr. Harvey, Dr. Donaldson, and others.

THE AURORA OF JULY 15TH, 1893—ITS PARALLAX.

According to appointment, the evening was devoted to a discussion of the widely observed aurora of the 16th of July, 1893. A series of short papers were read.

The first was contributed by Mr. Arthur Harvey, who read the following paragraph from a Toronto paper: "The auroral display, on Saturday night, was one of the most magnificent ever witnessed. It began about 8.30 and increased in brilliancy up to 9.40, when a great white-coloured arch formed across the zenith of the Heavens clear from the North-western to the South-eastern horizons. Accompanying this beautiful arch, was a gorgeous display of auroral streamers in the North, North-west and North-east, which radiated from the Heavenly zenith, and were variegated towards the Northern horizon by prismatic colours, green and purple seeming to be predominant. The beautiful white arch moved bodily Southward from the zenith and began to wave and roll until at 10.30 it started to dissolve, and shortly afterwards disappeared altogether. The Northern Lights, however, kept their brightness nearly all night." Mr. Harvey then continued as follows:—During this aurora, which commenced at sundown, an arch of auroral light, about 10 o'clock, rolled up out of the North and passed the zenith, spanning the sky from East to West. It was of a yellowish cast: I noticed no rose or green tints. Its width was fairly uniform, from 5° to 7°. After lasting for several minutes, its continuity broke up in the East, it wavered at the zenith, and soon disintegrated. A beautiful feature was a fringe of auroral clouds, on the North side of the arch, very luminous and fleecy, for 20 to 30 degrees along its length; first on one side of the zenith, then on the other. I read in a newspaper, over the signature "Moses Oates," a reference to these clouds, and the idea was expressed that they were streamers of the usual kind, shooting from the arch towards the sky, but that as in this case the arch was overhead, not near the horizon, we saw the base of them only. At about midnight, the auroral disturbance, which had not finished with the vanishing of the arch, was again in full play. I went into the open meadow, behind my house, and saw the upward swishing impulses all about me. I could not perceive any light between me and the house or fences, 30 to 40 feet away, but I am persuaded it was there also, and I saw it up-rushing from the meadows and fields North, East and West. The streamers came from the Earth under my feet and the air around me. The zenith was the point they shot at, and very few came from the Southern half of the horizon—or the Southern half of the celestial hemisphere. I watched them for an hour. The same absence of rose and green was remarkable. From the observations made by Mr. G. E. Lumsden and myself, I have made some calculations of interest. It is to be regretted that the observations were not aided by instruments, so as to be accurate beyond a peradventure, but this often happens in the case of auroral views. The arch described in the preceding paragraph was stationary for some minutes before its disappearance. Mr. Lumsden saw it break up and vanish, as I did. He was at Bala, 110 miles North of Toronto (measured by map), and saw the arch, as it were, projected across Constellation Aquila, at a point some five degrees north of the celestial equator; in other words, at Bala the arch vanished 50° above the Southern horizon, or 40° South of the zenith. At Toronto, I saw the same arch at the same time, lying as it were across Constellation Lyra, at a point as I estimate it, from 8° to 10° South of the zenith. Supposing 10° to be correct, the perpendicular height of the arch was 166 miles; if 8°, 157 miles. Taking the former figures, the breadth of the arch overhead was 15 miles; or, including the cloudlets described, 20 to 25 miles. The ends of the arch, if it maintained an equal height above the Earth, would be 1,150 miles away, so that the magnificent vision was presented of an auroral belt in the sky 2,300 miles between its visible ends. It literally spanned the heavens from the Atlantic, outside Nova Scotia, to the head waters of the Missouri, in the Rockies, and beyond. At Washington, it would be seen nearly 40° above the Northern horizon. The parts near the horizon would be much broader than those near the zenith, and it would scarcely be seen as an arch more than a couple of hundred miles East or West of this locality. It would seem that the aurora may be a belt of molecular or magnetic disturbance, moving from the North Southwards, often at a height of 150 to 200 miles, with a breadth of 15 to 20, the disturbance pulsating from that belt into space. It appears to originate at, or near, the magnetic poles and to be intimately connected with magnetic outbursts, or terrestrial magnetic storms, which may be described as extensions of the activity of the terrestrial polar magnetic field. Its Southward movement is sometimes between a few meridians only and sometimes extends over many, even on opposite sides of the Earth. It appears to be unconnected with the atmosphere, or, at the least, to display itself most frequently at a height where the air is so rare as to be in effect a vacuum. The disturbance usually originates in far Northern latitudes, though in great storms it is possible that the energy may be re-inforced, or a secondary disturbance induced, even as far South as the latitude of Toronto, 44°.

After describing a peculiar parhelion and a mirage seen by him on the 12th of July, Mr. John A. Copland referred at length to the aurora of the 15th, which he observed all night long. In the course of his paper he said :—"I discerned at the North a peculiar greenness, while twilight still lingered in the North-eastern sky. As darkness fell, the display became magnificent. From a deep green arch in the North shot great streamers, sometimes purple at the base, whose flipping peaks invariably sought the zenith of the Heavens. About 9.40, an arch formed across the sky from the extreme North-west to the far South-east, and presented a most brilliant spectacle. At 10.15, while my wife and I were watching this nebulous arch, a meteor shot from near the 'Guardians of the Pole,' cutting into the great white roll in close proximity to the zenith. The meteor, which was palpably retarded in its course, passed through the diaphanous formation, and left an intensely white streak through the arch alone. The meteor was completely absorbed by the time it reached the South side of the arch, just a mere spark falling toward the Earth. A peculiar feature which I was careful to note was the dissolving and wavy motion of that portion of the arch at the meridian. At 10.30 the arch began to dissipate, the entire curtain moving bodily toward the South. By 10.47 it had entirely disappeared. But the streamers radiating toward the North, green at the base and in some parts purple, continued and were more magnificent than ever. The maximum of brilliance was from 10.30 p.m. until 1.30 Sunday morning, when there was a diminution for about twenty minutes. Brilliance and wonderful activity in the shooting toward the zenith was resumed at 1.50 a.m., and continued until 2.30. At this time the brightness began to fade, and finally died away in the North at 3.15 a.m. on the 16th, just before day-break. That surplus electricity is generated during these displays is evident from the fact that telegraph wires invariably become 'demoralized' on a night of brilliant auroræ, as we on the staff of *The Toronto Globe* well realize when we await important press despatches. The operator in our office informs me that on some of these magnetic occasions he detaches the battery and can work the 'ticker' with the electricity of the atmosphere. The current, however, is erratic."

An animated description of the aurora was also received from Mr. J. R. Connon, of Elora, who sent photographs of drawings made by him to show several phases of the display as well as photographs of Rordame's

Comet, of which he was a careful observer. In his paper, Mr. Connon said :—"The arch which passed overhead was about ten degrees broad from North to South ; its Northern side was a little to the South of Vega. Toward the West, the arch, it passed between Arcturus and the handle of the Dipper. At times, it was apparently steady, at others, moving clouds of light passed along it from East to West, like scud blown rapidly by the wind. In the course of ten minutes, streams shot out toward the North-east and began to swing around from East to West on the Northern edge like spokes of a wheel revolving with its rim nearly in the line of sight. This continued for about fifteen minutes, when two breaks in the arch were noticed. After this, bright streamers appeared and commenced to wheel around on the South side of the arch. The motion of the auroral light from East to West, whether going straight along the arch or wheeling around, occupied the same time, say, about ten seconds. As the rays or clouds of light reached the Western end of the arch, they moved more quickly. I have heard a sound produced by auroræ, but none this time, although I listened for it carefully, and there were no other sounds to prevent it being heard. My explanation of the peculiar appearances noticed during the display of July 16th, 1892, was, that there seemed to be something coming through the Earth and springing upwards like the flight directly toward the zenith of many rockets, which to the observer would appear to meet at a point overhead, as it were the vanishing point in perspective." Other interesting features were noted by Mr. Connon, as well as by Mr. W. G. Blyth, of Toronto, who paid especial attention to the appearance of meteors; some of which to him seemed to pass through the auroral matter. A report was also received from Dr. Donaldson. A very exact report, particularly as to instants of time, when changes were noticed, was read from Mr. J. Hollingworth, of Beatrice, Muskoka. This observer noticed, that in instances, the streamers, in moving from East to West, passed "apparently so low as to touch the house-tops." He also detected "the swishing sound heard during the magnificent aurora of July 16th, 1892 ; but not so loud, there being more wind." He added, that he now can "find at least half-a-dozen persons who distinctly heard the rustle of the aurora of that date."

Dr. M. A. Veeder, of Lyons, N.Y., reported that the "auroral band seen July 15th, was observed at all stations between Concord, Mass., and Miles City, Montana, while the aurora itself was seen still further Westward; that at the outset, the band seems to have extended from North-west to South-east at about the same angle and wholly irrespective of variations in magnetic declination at the different stations; that it appears to have reached the same phase of development in definite relation to local times rather than at the same instant of absolute time; that auroras have a tendency to exhibit certain individual characteristics—red auroras appearing red everywhere, and flickering auroras everywhere flickering, and that it would seem from this that the Earth at such times must enter into the midst of a conducting medium having special characteristics which modify the play of the currents which originate the auroral glow. At Lyons, N.Y., the band or arch, was seen fully developed at 10.20, and might have existed a few minutes sooner, while attention was being directed to the irregular patches and faint streamers then forming in the North. This band passed at that time through the Northern Crown, and very near Arcturus, but slightly North. Eastward, it was not so well defined. This band faded out at about 10.45. If the Crown and Horseshoe were the same as seen at Lyons and Toronto, it would seem that the former must have been at a vastly greater elevation than the latter. Perhaps, when further reports are at hand, it may be possible to determine the altitude of the lower margin of the curtain with considerable precision. This aurora is of interest also, because the 27-day periodicity again appears in connection with it. The only display of any prominence during June was on the 18th, the aurora of that date being very generally seen at all stations where it was clear. As regards the solar conditions, there were at the Eastern limb, at the June return, very extensive fields of faculæ, in which spots were forming, portions of which were near the Sun's equator. At the July return, this seems to be the case again, the faculæ being very bright, and a spot having formed in the midst of one of the portions of the field since its appearance by rotation."

The reading of the various descriptions was followed by an animated discussion, participated in by the Chairman, Messrs. T. Lindsay, R. B. Ellis, A. Harvey, A. Elvins, A. F. Miller, and G. E. Lumsden. Messrs. Elvins and Miller dwelt upon the lines and bands which characterize the spectra of auroræ, and referred to the various theories respecting their composition, their motions, their frequency and their cause. The evening proved to have been a most instructive one.

SIXTEENTH MEETING.

August 22nd; Mr. Arthur Harvey in the chair. The Reverend C. H. Shortt, of St. Cyprian's Church, and Messrs. J. R. Collins, Z. M. Collins and W. A. Douglas, B.A., all of Toronto, were elected Active Members, and the Reverend Canon Burke, of Belleville, and Miss K. E. Vale, of Davenport, Iowa, were elected Associate-Members.

The Society learned with much regret of the death of the Reverend J. F. McBride, an Active Member. Mr. Thomas Lindsay said the late clergyman had endeared himself to all with whom he came in contact, and, seconded by Mr. G. G. Pursey, moved a resolution expressing deep sympathy with his relatives and friends. The many excellent personal qualities of Father McBride were feelingly referred to by the Chairman and several of the members, and a short sketch of his work in the scientific world was read.

Mr. G. G. Pursey reported several valuable additions to the Society's Library, among them two volumes donated by a member who desired his name withheld, and a copy of the "Celestial Guide Book" and a Planisphere, donated by Messrs. Poole Bros., of Chicago, the well-known publishers. It was stated that these works had been recommended by eminent observers as admirably adapted for the use of those who desire a thorough knowledge of the constellations and all the objects of interest in the Heavens, praise which, an examination of the works presented, showed to be just. On motion by Mr. Lindsay, seconded by Mr. A. Elvins, a hearty vote of thanks was passed.]

It was announced that the books, apparatus, etc., belonging to the Society had been removed to its new rooms, 19 McGill Street, where access could be had to them at stated times.

Mr. David E. Hadden, of Alta, Iowa, an Associate-Member, reported that he had observed two very beautiful meteors on the evenings of August 6th and 11th, 1893; that of the 6th was pear-shaped, bright green in colour, and travelled swiftly from near Boötes, about 15 degrees in a South-west direction, exploding before disappearance a few degrees above the horizon: time, 11.03 p.m., Central Time. That of the 11th was also of a brilliant green colour, but travelled more slowly from near the 3rd mag. star 12 Canes Venatici, to a point about ten degrees South-west of Polaris, exploding into numerous reddish sparks. It was so brilliant that the whole landscape was lit up as if by a large arc lamp, and was noticed by people indoors: time, 10.06 p.m., Central Time.

Dr. Larratt W. Smith, Q.C., presented two drawings of sun-spots, carefully made at the telescope, on the 9th of August, at 6.45 p.m., and on the 28th.

Mr. A. F. Miller, reported a series of solar observations, and submitted a drawing by the spectroscopic method of hydrogen-flames at position-angle 258°, made August 13th, at 8h. 30 a.m., as a large spot was disappearing by rotation; he also, at some length, described his progress in photographing star-groups. The large telescope of the Observatory, through the kindness of Mr. Charles Carpmael, F.R.A.S., the Director, had been placed at his service, and very satisfactory photographs of the stars in the constellation of Cassiopeia had been obtained on the 15th of August, with an exposure of 45 minutes. Mr. Miller attached a camera to the telescope, and, after setting the driving-clock, made the equable motion of the instrument doubly certain by watching a star in the centre of the field of view of the eye-piece, preferably a high power. The telescope was thus used merely to guide the camera. Mr. Miller, who said he would continue the work as opportunity offered, presented to the Society copies of the work done on the star groups, and also photographs of the normal solar spectrum from F to H_2, taken August 13th, by apparatus which he had specially designed for the purpose and had used in his own laboratory.

Mr. Harvey read a paper on some experiments made by him in reflecting solar light.

A considerable part of the evening was taken up in discussing auroral displays and meteoric showers. Mr. J. R. Collins described the observations made by him on the 18th of August, when the "crackling sound" attributed to auroræ was heard by him with great distinctness, the impression made upon the senses being that it was exceedingly near. Messrs. Miller, Elvins and Z. M. Collins also spoke upon the subject. Mr. Pursey referred to the celebrated aurora of July 15th, which he observed at Kingston, and described several interesting features connected with that display.

SEVENTEENTH MEETING.

September 5th; Mr. John A. Paterson, M.A., in the chair.

Mr. G. G. Pursey, the Librarian, reported that he had received several volumes from kindred Societies, and announced that an Index of the subject-matter of exchanges was in preparation, and would shortly be completed. Letters were received from Dr. J. J. Wadsworth, of Simcoe, and from Mr. J. A. Copland. The latter reported at some length observations of auroral and meteoric displays made by him in North Wellington. Mr. A. F. Miller, in reporting his observations of the solar-surface, referred to the difficulty the amateur sometimes has in identifying a sun-spot from day to day, which, however, was not surprising, as it had been necessary during the past year at Greenwich, to employ extra assistance in compiling a complete record of the appearance of the Sun. Mr. A. Elvins presented several sketches of spots on the solar disc, some of which had been visible to the unaided eye. Mr. R. Dewar reported having heard the swishing sound of the aurora during the display of July 23rd. An interesting discussion arose in connection with photographic work on the heavens and Mr. Miller described some of the difficulties in the way of the amateur, one of which is the procuring of a suitable lens, the ordinary photographic lens not being quite adapted for the purpose. Mr. Arthur Harvey thought that the selection of plates was of even greater importance, and that ortho-chromatic plates solved the difficulty. Mr. Mungo Turnbull gave some practical illustrations of the method of using the celestial globe recently constructed and patented by him, using for the purpose the globe presented to the Society by Lady Wilson, in accordance with the wish of the late Hon. Sir Adam Wilson, Q.C.

Mr. Harvey read the following memorandum upon a subject in which the Society had been taking some interest, *i.e.*, the photographing of the sidereal heavens:—"I am permitted to bring for your inspection, from the Canadian Institute, the Third Annual Report of the Vatican Observatory, and I think the beautiful plates will interest you very much. Especially instructive is the plate of the star-cluster in Cancer, Præsepe or the Beehive. As you are aware, a photographic charting of the heavens is now in progress, in which several leading observatories are taking part. This is a reproduction of one of the standard plates. The faint lines—like those of latitude and longitude on an ordinary map—supply the means for comparing the places and movements of stars: in 10, 20 or 50 years, another photograph, on the same scale, will show the changes with much greater ease than any system hitherto adopted, however delicate the measurements or perfect the drawings may have been. The astronomer, with a magnifying-lens, will examine and compare square by square, note the proper motion of each star, see which are variable, which are the binaries and trinaries and the rate of their revolutions, while by a series of such plates we may hope even to approximate, by noting the inequalities or variations of motions, to an estimate of the number of dark stars—stars which do not emit light—which should be, if the nebular hypothesis has a basis in fact, far more numerous than the luminous or visible orbs. I have brought a magnifying-glass that you may see the beauty of the work, the admirable distinctness of the plate, on which you can note the several stars which appear to be connected with each other and not mere optical doubles. Thus you can, in a way, anticipate what the work of the astronomer is to be and enter into the observatory of the future, or at least an important part of it: a quiet room, with a good light, apparatus for super-imposing the image of one square from one plate on one from another taken years before, a note-book, a microscope, and no telescope at all."

The publication was examined by the members, who found the plate especially referred to by Mr. Harvey to be all he had said of it.

EIGHTEENTH MEETING.

September 19th, Mr. John A. Paterson, M.A., Vice-President, in the chair. The attendance was especially large. Professor Goldwin Smith, D.C.L., of The Grange, Toronto, was elected an Active Member.

It was stated that during the two weeks the Toronto Industrial Fair was open, visitors to the city from various parts of the Province had, for the first time, found their way to the Society's rooms and had examined the apparatus deposited there. Among the letters read were communications from Professor Newcomb, Superintendent of the Nautical Almanac Office at Washington, as to the computation of certain quantities published in the Tables of Star Occultations; from Professor G. E. Hale, Director of the Kenwood Observatory; from Professor Payne, editor of *Astronomy and Astro-Physics* and *Popular Astronomy*; from Sir Robert S. Ball, Lowndean Professor of Astronomy and Mathematics in the University of Cambridge, thanking the Society for a report of the bolide seen at Toronto, July 7th, by Mr. R. A. Eaton; from the Librarian of the Smithsonian Institution, and from inquirers as to membership in the Society. Mr. G. G. Pursey, the Librarian, reported the receipt through Mr. James Todhunter, the Treasurer, of a copy of Professor E. E. Barnard's "Micrometer Measures of the Fifth Satellite of Jupiter," and a photograph of a portion of the Milky Way, also made by Mr. Barnard. These were donated to the Society by Mrs. Todhunter, who, with friends, had paid a visit to Lick Observatory. Besides presenting to Mrs. Todhunter the photograph and book referred to, the Professor was assiduous in his efforts to afford the party an opportunity to look through the telescopes and to see the splendid apparatus of the Observatory. On the occasion of the visit, more than two hundred persons were patiently waiting, in turn, to gaze for a minute or so through the great telescope.

Under the head of observations, Mr. A. F. Miller reported that the Sun's disc appeared to be more free than usual from spots, there being, as it were, a period of quiescence. Usually, after a period of this character fresh outbreaks may be expected, and their appearance should be watched for. Mr. Miller presented a drawing, made by the spectroscopic method at 9.30 a.m., on the 17th of September, of a tree-like group of hydrogen flames, which extended for 15 degrees on each side of the Sun's North-point, and reached an altitude of 54,000 miles, being long enough to extend more than twice around the Earth.

Mr. Arthur Harvey, having handed in two excellent drawings of sun-spots in the Southern hemisphere, made on the 10th of September, read an interesting series of "Astronomical Notes" upon the Sun, his spots, their periods of maxima and minima, certain lines in the solar spectrum, the success achieved in photographing the spectrum and in photographing solar faculae and prominences, the daily work carried on in Greenwich and in Paris of photographing the Sun, the success in celestial photography and in discovering new stars attained by amateurs with modest appliances, the tracks of meteors found on plates exposed for photographing stars and nebulae, the discovery of Asteroids by finding the trails of stars on plates which had undergone exposures sufficiently long to show the proper motion of the Asteroids thus discovered, the theory that the peculiar shapes taken on by some of the satellites of Jupiter are due to their being composed of meteorites, and the theory that Jupiter's fifth satellite is an Asteroid forced by the planet's attractive force to join his system. Taking into account all the observations relative to sun-spots that are available, including those of the Chinese, Mr. Harvey said there appeared to be 66 or 83-year periods of intense maxima and of small intensity as well as the ordinary eleven-year intervals. This would seem to indicate that, according to one of these, the beginning of the next century will co-incide with a maximum of small intensity, and, according to the other, with one of high intensity. Having alluded at some length, to the thoroughness of the work being carried on by Dr. Gill and others in photographing interesting stellar-groups and clusters, Mr. Harvey closed his paper in the following words :—"In these stellar photographs, I find it is most important to focus properly for the chemical rays—experiment is the surest guide to a good result in this particular. We may practice very well with the ordinary landscape and portrait lenses and plates, but great progress has been made with the preparations of special films. I had the honour to bring before this Society two years ago, a specimen of Lippman's photograph in colours of the spectrum; great progress has been made since then. Lippman was at that time forced to use successive screens to prevent the too lengthened action of the more actinic colour-rays by shutting out these colours. Now the orthochromatism of the plates and their sensitiveness to the least active colour-rays have been much increased, the greens of trees, the grays of a stone building, the blue of the sky, have all been well brought out, and one of the finest experiments has been in the realm of Astronomy. Messrs. Fabre and Andoyer, of Toulouse, photographed the eclipse of the Moon of November 15th, using the plates of Lumière, sold as plates sensitized for red and yellow. Comparison was made between the results from plates prepared with collodion and gelatine bromided in the ordinary way and collodion plates made orthochromatic with eosine and cyanide solutions. Ordinary plates remained all but insensible to that part of the lunar disc immersed in shadow; the others came out with fairly satisfactory results as to this feature. These gentlemen purpose continuing their experiments upon Mars, upon Jupiter with his red spot, and on coloured stars."

Messrs. J. R. and Z. M. Collins exhibited negatives of the Sun recently made with an ingenious apparatus of their own construction.

Mr. W. H. Musson read several extracts from an article entitled, "Is the Universe Infinite?" by Sir Robert Ball. Several of the deductions of this mathematician and astronomer caused an interesting discussion. At the close of the meeting, Mr. Mungo Turnbull exhibited and explained a new altazimuth stand for telescopes recently devised by him, and intended for the use of amateurs.

THE NINETEENTH MEETING.

October 30th; Dr. Larratt W. Smith, Q.C., Vice-President, in the chair. The attendance was large, and included several strangers, who were made welcome. A new feature noted, was the presentation to the Society by outsiders of books and valuable papers, some of them rare. At a recent meeting, a copy of Ferguson's Astronomy, printed in 1758, in two volumes, became the property of the Society by purchase, but the third volume containing the plates was wanting. By a curious co-incidence, the volume necessary to make the set complete was donated at the last meeting by a member who was unaware of the earlier purchase. The first number of *Popular Astronomy* was laid on the table, and was much praised. Under the head of observations, Mr. J. R. Collins showed several sharp negatives, two inches in diameter, of the Sun and of the Moon taken with a two-inch telescope of a peculiar construction, and Mr. A. F. Miller handed in a drawing of the solar disc, September 24th, at 11 o'clock, showing accurately the position of the sun-spots and faculae, by projection, and, at the same time, the position-angles and shapes of the numerous red prominences scattered around the Sun's limb and visible by the spectroscopic method. The sketch was the first of the kind made in Toronto.

Mr. John Phillips read a paper on

THE VOLCANIC THEORY OF PLANETARY PROJECTION,

of which the following is a synopsis:

The volcanic theory of projection in relation to the satellites of the solar system, may be thus defined:—1st. Before any of the primary planets now accompanied by moons had any such attendants, each revolved in its orbit, rotated on its axis and was enveloped in and accompanied by an atmosphere which rotated along with it, and extended farther than the most distant satellite now revolving around it. 2nd. Each secondary planet was projected from its primary in a molten mass, by volcanic eruption, or some such agency. And, 3rd, the tangential force of each satellite is the unexpended force of projection, that explosive power by which it was first shot out from its primary, driven through the surrounding atmosphere and projected into a local orbit of its own,—the orbit in which it now moves being the original one, or a modification thereof.

This theory requires an atmospheric, or some similar, medium for the following reason:—Were the Earth, like the Moon, void of an atmosphere, a body projected obliquely from its surface at a velocity of from five to nearly seven miles a second, at any elevation above the horizon, would strike off in an elliptic path and return to the Earth again at the end of its sweep. The projectile could make but one journey off, and on its return, in trying to make its first perigee passage round the Earth, would be captured. If projected at a higher velocity still, it would go on increasing its distance and, of course, never return.

But were the Earth surrounded by an atmosphere several thousand miles high, and if the projectile on piercing through it and on entering the non-resisting medium beyond, had velocity enough in reserve, and if it were moving in the right direction, it would, at once, find itself an orbit, and revolve therein perpetually! The point in the upper air-limit where the projectile would break entirely clear of atmospheric entanglement would be the real point or place of projection. And to that point it would return, passing through it again, on completing its first journey in its elliptic orbit, and so keep on. Then, if the atmosphere were condensing down upon the Earth, the projectile would soon find itself high and dry off in the wide ocean of space, sailing round and round its primary perpetually, as our Moon and all the other secondary planets do.

An important matter lately established is that the resistance of the air on a projectile increases from the first to the second power, or to the *square* of the velocity, when the latter rises to between 900 and 1,100 feet per second, to the cube of the velocity when it rises from 1,100 to 1,350 feet, but rapidly falls to the *square* of the velocity again *after* it rises to more than 1,350 feet per second. This important fact, whatever its cause, scores many points in favour of the Projection

Theory. The force of gravity at the Earth's surface is 32 feet, a second or more; at the Moon's surface it is a foot and a half or less. Could we take to the Moon one of the guns of H. M. Warship Blake, we could send iron missiles flying round that planet. Those missiles, whilst moving, would be satellites of the *second order*, like the one supposed to have been seen during the total eclipse of the Sun in August, 1869. Were it possible to construct a ten thousand ton gun capable of projecting a one hundred ton ball, with a muzzle velocity of ten miles a second, iron-hail could be sent all round *this* world, but for its atmosphere, by giving to the missiles thrown in a horizontal direction, an initial velocity of nearly five miles a second. By projecting them at *any* elevation above the horizon, and with a velocity of nearly seven miles a second, they could be sent to twice the distance of the Moon, and would return again in about twenty-eight days, or during a lunar period. If the atmosphere extended only forty-five miles high, and the artillerist could so handle his gun that one of the balls, on passing the uppermost regions of the air, moved at the rate of four and nine-tenth miles a second, and in a direction at a right-angle to its radius-vector there, it would fly around the Earth in one hour and a-half. Not perpetually though, it being too near the Earth, for the tidal action of the Moon, or other causes, if no Moon existed, would soon ground it. Were the atmosphere to extend 4,000 miles instead of forty-five, and the projectile to be launched out there with the right velocity, it would probably be safe, though greatly perturbed in its orbit on account of the spheroidal figure of the Earth. It would revolve every four hours, and if seen from the Earth, would appear to have a retrograde motion, *i.e.*, to rise in the West and set in the East like the inner moon of Mars. If the atmospheric extension measured 15,000 miles, where there is more room, the gunner would not require to be so particular as to velocity and direction in launching the ball outside the air limit; but the more particular he was the more circular would be its orbit. The ball would revolve in twenty-four hours or so, and if its period corresponded precisely with the rotation-period of the Earth, the ball would be always over, or opposite, one-half of the Earth's surface, and, of course, could never be seen from the other. If thrown further than 15,000 miles, the projectile would appear to have a *progressive* motion round the Earth like the satellite we have. Thus the orbital distance of the projectile would fix its apparent motion, for the time of its revolution would depend on its distance; and its apparent motion, whether direct, retrograde, or, to all appearance, no motion at all, would depend on the time of its revolution, whether greater than, less than, or exactly equal to the time of the Earth's rotation. Lastly. If the air-limit extended 240,000 miles, our imaginary gunner could throw a projectile off into an orbit even there. He might not send it into quite a circular orbit so far off, but no matter. Nature and Nature's laws would conspire to help him. A velocity of 3,330 feet per second would give the shot a circular orbit if directed at a right-angle to its radius-vector there. But if the gunner could come within a couple of hundred feet of that velocity, it would do just as well if at an angle of ninety degrees or so. Even if a circular orbit were given at first, the Sun's perturbing influence would press it into an oval one afterwards. But there is a projectile already in that very vicinity; a huge spherical one over 2,000 miles in diameter, and known to be a projectile these last two hundred years. Now, the questions are, how came it there? Whence came it, and how could it have been projected? It is evidently a piece of Nature's handiwork. It must have been projected by one of Nature's big guns, and how this may have happened, I shall now show.

One of those guns, situated on the island of Krakatoa, an island 25 square miles in area, had been silent a long time, but on the 27th of August, 1883, a big shot was fired from it; the island was shattered and uncapped, and the whole charge of the gun, island-cap and all, was blown sky-high—shot up into the elements to an altitude of 23 miles, with a report heard 3,000 miles away. The quantity of material ejected is estimated in hundreds of billions of cubic feet, which would form a cubic mile of matter, or a globe a mile and a-quarter in diameter. Some of the *debris* from that eruption floated in layers in the upper-air in the form of pulverized dust for years, giving to the Sun a red appearance the world over, and producing the Krakatoa Sunsets. But the Krakatoa eruption was but a small affair when compared with other events of the kind. In 1815, the volcano Tomboro, in Sumbana, another island in the Indian Ocean, had an eruption, which was in full blast while the battle of Waterloo was raging. During that eruption, 34 cubic miles of solid matter was ejected, or *over 25 times* more than at Krakatoa, equal to a solid globe of more than four miles in diameter, and, in all probability, equal in size to one of the Martian moons.

In 1783, Hecla, in Iceland, boiled over and ejected *20 cubic miles* before it quieted down. During that eruption, the great fire-ball, the largest ever seen, estimated at from half a mile to a mile and a-half in diameter, swept from the direction of Iceland over Scotland, England, France and Italy, and probably then plunged into the Mediterranean, or grounded on the sands of the great African desert. That fire-ball, as it was called, whatever it was, made a good attempt at finding itself an orbit. Were it not for the resistance of the air, it might have done so. And, if it had, it would have revolved around the polar regions of the Earth with a retrograde motion, like that of the moons of Uranus. Now, is there any more rational, scientific or certain way of accounting for the existence of the two small moons of Mars than by supposing them to have been projected from their primary by forces akin to those brought into play at Krakatoa, Sumbana and Iceland, forces which have been stored or pent up within the Earth ever since she took upon herself the form of a planet and which were thousands of times more active and powerful in the early stages of her history than they are to-day? For to compare *any* historic eruption with some pre-historic ones, would be like comparing a pop-gun to a Krupp gun in calibre, range and power.

Let us now take the most difficult case of all, that of our own Moon, the greatest and most massive satellite in the solar system, when compared with its primary. It may seem that if an eruption like those contemplated ever occurred, this planet would have been burst into bits, and have given origin to a zone of planetoids, like the supposed planet Pluto was thought by Olbers to have done between Mars and Jupiter. But there is *another* side to this question. The Earth is much more massive than any planet in the system attended by a satellite; this massiveness would stand it in good stead in making a great physical effort. Then the mass, weight or quantity of matter in the Moon is, after all, only the one-eightieth of that in the Earth. Supposing the Moon to have been thrown off from the Earth by volcanic forces, there would still remain in the Earth sufficient material out of which eighty more Moons could be formed. An eighty-ton smooth-bore, short-barrelled gun could, without bursting, easily throw a ton weight shot, though not far or with good aim. But the projection of the Moon would more nearly resemble the action of a mortar than that of a gun. The eruption must have shaken the Earth severely, for she recoiled about 2,700 miles, the distance between her present centre and the combined centre of gravity of herself and the Moon. As to distance projected, that counts but little a few diameters away from the Earth, owing to the diminution of gravity. For instance, a missile projected from the Earth at an initial velocity of about 36,400 feet a second would go to the distance of the Moon, leaving the resistance of the air out of account. An initial of 153 feet a second greater would send it twice that distance, and one 152 feet greater still would send it to the distance of the Sun.

And now let us take a hasty glance at that luminary himself, with his spots, those great whirlpool openings in his disc, often hundreds of millions of square miles in area and of unknown depth. Let us think of the huge masses of ponderable matter, equal in bulk to some of the larger planets, now and then projected out through his luminous envelope, with initial velocities of *three or four hundred miles a second!* which, after sweeping partly around him, fall again upon some other part of his surface, more distant than the Moon is from us. Let us conceive this Earth, before she was attended by her satellite, to have been in that state or condition so aptly described by Sir Humphry Davy—a condition something like that in which the Sun now is, but lacking his brilliancy—a globular-shaped body, composed of liquids and gases expanded by heat, all in turmoil, and having now and then disturbances and eruptions such as occur in the solar surface in our day, and surrounded by a heated atmosphere extending farther than the present lunar orbit, but partly cooled near its outer limits. Conceive our Earth in this primitive condition, "the most primitive," according to Sir Humphry, "in which we can yet venture to consider it—rotating on an axis and winding its lonely way around the Sun," and let us imagine that, at last, a successful effort was made, and our Moon-matter was shot out at such a velocity, and in such a direction, that, on reaching the outer air-limit it set off in an orbit of its own, in which it still revolves, though probably in a much more eccentric orbit then than it has to-day, the Earth's rotation from West to East and the resistance of the air on the projectile while passing or pressing through it, having each played an important part on the final result. Thus, we may conclude that the happy effect of many causes all uniting on one occasion, and only on one, gave this Earth one satellite, and only one, our faithful attendant the Moon—Man's greatest instructor in the science of the starry vault above him—and but for which we would know little of the outside Universe to-day.

And now it is for the world to decide whether we have discovered how all the satellites of the system, rings of Saturn and all, have originated as separate bodies and found their orbits. For whether they revolve faster or slower than their primaries rotate, whether they revolve round the equatorial or the polar vicinities of those primaries, and whether their motions in their orbits are direct or retrograde, this theory accounts for them all—what no other hypothesis or theory before it ever did. Those destined to flourish in the Twentieth Century, a period now hastening on, will have no choice but either to adopt the theory just sketched or else fall back on the old notion that each planet was projected into its orbit with the required velocity, and in the right direction, by the Hand of the Creator—a supposition, by the way, which, however unsatisfactory to the philosopher, is beyond the scope of the *Calculus*, and cannot be disproven by the most refined analysis. But if this theory of ours, founded on mathematics and physics, stands the test as well as that, built on miraculous interference, ours must bear off the palm by its appealing to reason, by its convincing the judgment, gratifying the understanding, and, at last, laying hold on and captivating the mind itself, despite its resistance at first—arming it with fresh resources to make new discoveries and more conquests over matter in regions we have now no conception of.

Considerable discussion followed the paper. Mr. John A. Paterson said the theory made very great demands upon those who subscribe to the generally received conception of the Cosmogony as based upon observed facts, and held that the probability of our Moon being projected while yet fluid and from a fluid parent, to such a distance, and then taking up revolution in the same plane nearly as the revolution of the Earth, and keeping always the same side to the primary, was so extremely unlikely as to verge directly upon the impossible. Mr. Robert Dewar and Mr. Thomas Lindsay argued that even if such an explosion were to occur now, when the Earth is rigid, the Earth would be rent asunder, but Mr. Dewar did not consider it impossible for a fluid mass to eject matter with very considerable velocity. Other members continued the discussion, which was closed by Mr. Phillips, who offered several explanations, and held that his theory is unassailable from any mathematical or physical standpoint.

Mr. Elvins read the following paper on

TERRESTRIAL MAGNETISM.

It is almost certain that you, in common with myself, have often asked, Why does the needle point North and South? Why do not the magnetic and the terrestrial poles co-incide? Why does the direction of the needle point in slightly different directions, daily and yearly? And why is the vertical force greater at one period than another?

In seeking to solve such questions, I have noticed a co-incidence which I cannot think has been unnoticed by others, but which I have never seen referred to; and as I think it may aid us in our search after the cause of terrestrial magnetism, I shall call attention to this co-incidence to-night.

The magnetic pole is not at the terrestrial pole, but something more than twenty degrees from it. It has been found difficult to fix this point with great exactness, but it cannot be far from twenty-three degrees from the pole, and it is here that the co-incidence occurs, the equator being inclined to the ecliptic at nearly the same angle, twenty-three and a-half degrees.

This, of itself, is an interesting fact. Can we advance one step farther in our search after the cause? Iron is the element which most strikingly exhibits magnetic properties when properly treated for that purpose. A piece of soft iron is not a magnet, but if we cause a current of electricity to pass around it, it becomes one. If a ball of iron have wound around it a copper-wire connected with a battery, it becomes magnetic, with its poles at right-angles to the coil; if the current cease, the magnetism of the ball ceases also. If steel be used, instead of soft iron, the magnetism is permanent, and from steel our magnetic needles are made. We suspend such a needle above the coil of our ball, and the needle obeys the magnetic law, viz., opposite poles attract each other; the plus pole of the needle attracts the minus pole of the ball, and the needle points to the magnetic pole. Of course, it is probable that the molecular structure of the iron makes it possible for electricity to produce magnetic phenomena in it, and a further modification exists in steel, making its magnetism permanent. Of the nature of the iron molecule we have no certain knowledge, and we have no time to follow speculation to-night on this point. Experiments prove, then, that electric currents produce magnetism.

But what is electricity, and what is an electric current? My reply is an assumption which I cannot demonstrate, but, following the views expressed in my papers on Gravity and Solar Heat, I define electricity as matter existing in its atomic condition; when these physical atoms are moving onward in the same direction, we have an electric current. A current of air causes a vane to point in the direction of the wind; but if the air be stationary and the vane be placed on the top of a railway carriage, and the train be moved rapidly through the still air, the effect on the vane will be the same as if it were motionless and the air moved. Whilst the tendency of the vane, however, is to set itself in the direction of a current of air, the tendency of a magnetic needle freely suspended is, as is well known, to settle itself at right-angles to an electric current, and it would do so at once but for the fact that it is acted on at the same time by the attraction of the magnetic pole of the Earth. The Earth moves through space, which is filled with the ether; and the motion, in its orbit, of the Earth (and the motion of the solar system through space in a plane not far removed from the plane of the ecliptic), rushing through the ether, will produce a current the same in its effects as if the Earth were stationary and the ether rushed in a current across it. As the Earth moves in the plane of the ecliptic, the current produced by its motion must be in that plane, and the magnetic poles must be at right-angles to that plane, which we have seen is the fact. If the Earth, rushing through the ether, produces the current which makes the Earth a magnet, we should find the magnetic force greater than the mean when the Earth moves with greatest velocity, that is, during the winter months, and less during the summer months, when the Earth moves more slowly; this, I believe, is true in fact. I do not think, however, that this varying motion of the Earth in its orbit must necessarily be the only cause of the annual variation of the magnet; the motion of the solar system through space may be an important factor in producing this result, as I believe it to be in the case of the revolution of the magnetic pole. From the preceding, it is clear that if we have suggested the true cause of polar magnetism, the axis of the Earth's rotation must have been originally at right-angles to the plane of the ecliptic, and such I think possible and even probable. We have seen that certain forms of iron, as a mixture of iron and carbon, retain magnetism, once imparted, and become what we call permanent magnets. If now we assume that the Earth, while its axis was still at right-angles to the plane of its orbit, was capable of becoming a permanent magnet and did so become, then a subsequent change in the direction of the axis of rotation would not affect the magnetic axis, the pole of which would make a daily revolution around the terrestrial pole. Towards the magnetic pole the needle would invariably point. Geological evidence points strongly to such a change in the axis of the Earth's rotation; traces of a tropical *flora* and *fauna* are imbedded in the rocks of the Arctic regions. During the tertiary period the polar regions were evidently much warmer than they are at present, and it is also clear that from some cause not yet demonstrated, an exceedingly cold period followed, known as the Glacial, or Ice Age. Such a change as we have suggested in the direction of the axis might possibly have caused the great climatic changes referred to, and this is held by several writers on Geology. The general direction of the needle is towards the magnetic pole, but there are variations daily, monthly, and of longer periods. These will form the subject of a paper which I hope to lay before the Society at some future time.

So novel was the theory propounded and so interesting was the subject thus opened up, that Mr. Elvins was pressed to continue his investigations. In the near future, a continuation of the paper will be read, and experiments introduced by Mr. Elvins, who expects to trace the cause of all the variations in terrestrial magnetism.

TWENTIETH MEETING.

October 17th; Mr. John A. Paterson, M.A., Vice-President, in the chair. Mr. James McDougall, C.E., of Toronto, was elected an Active Member. The Ladies' Committee, appointed for the purpose, having completed their labours, presented to the Society a very handsome cover, ornamented with Astronomical designs skilfully worked in silk, to be used for protecting the Sir Adam Wilson Celestial Globe and other apparatus. On motion of Mr. E. A. Meredith, LL.D., seconded by Mr. Robert Dewar, the cover was formally accepted, and the lady members cordially thanked for their gift.

Arrangements were made for collecting notes of observations, etc., from the many Associate-Members and correspondents of the Society engaged in telescopic or photographic work. While the meeting was in session, a telegraphic despatch was received from Geneva, N.Y., announcing the discovery by Professor Brooks of a new comet in R. A., 12h. 21m., Declination, 12 deg. 55 min. N., motion, North-east. From Mr. J. A. Copland, were received copious notes on meteoric observations made on various evenings between and including those of September 30th and October 12th.

THE CHEMISTRY OF THE ATOM.

was the subject of the paper for the evening, which was read by Mr. Thomas Lindsay. The following is but a brief synopsis :—

The various theories which, as working hypotheses, have been advanced to account for chemical affinity and the many mysteries pertaining to the world of the infinitely minute, were reviewed ; the theory was held as most probable, which accords to the elementary atoms of matter definite geometric forms, the forms resulting from the various groupings of the ultimate atoms of one primordial element. It was held, that if we conceive this primal base to have been created by the Omnipotent and endowed with motion, and, at the same time, admit the existence of a medium through which forces would act, all that follows is the result of physical laws ; no other act of Creation need be postulated. A number of examples were given tending to strengthen the theory that shape alone determines the properties of the atom and molecule. The graphic symbols of the modern chemistry were employed to show the atomic linking of compounds, thus giving a clear idea of the valency or combining power of an atom. The magnetism in iron, nickel and cobalt, was held to be solely the result of the molecular structure, which might be of such a nature as to impart to the all-pervading ether, which flows through the densest solids, a peculiar motion which permits of the attraction of the needle to the magnet, or rather permits the needle to be literally pushed against it. (A difficulty was here pointed out by Mr. John A. Paterson, however, in view of the fact, that magnetic action is exhibited even in a vacuum). Continuing, it was held that, if there were no ether, this phenomenon would not be possible, and that the theory was probable which regards magnetism and chemical affinity as being precisely the same, two factors only being concerned, namely, the form of the atoms and the motion of the ether. It was suggested as a profitable study a system of experimentation, which might lead to a determination of the form of the atoms in magnetic substances. The isomerism of certain compounds was referred to as the strongest evidence that molecules of matter have absolutely no attribute but that of form. The case of butyric acid and acetic ether is most remarkable; these have the same vapour density and the same composition, that is four atoms of carbon, eight of hydrogen and two of oxygen; yet one is entirely different in properties from the other; the difference in odour is especially marked, butyric acid having the disgusting smell of rancid butter, while acetic ether has the pleasant fruity smell of apples. Passages from Professor Cooke's work on the New Chemistry were read in support of the theory that molecular structure determines the difference between these compounds; although they have the same composition, the atoms in one are not linked as in the other. The theory which considers atoms of matter as being endowed with spirit life was reviewed, as well as the single argument against it that there is absolute uniformity among the atoms of any given element; an atom of hydrogen here is precisely the same as an atom of hydrogen in some distant star, and this admits of direct proof by the spectroscope. It was held to be too great a demand upon Creation to endow every atom of hydrogen in the universe with the same spirit life or power. Experience teaches that Mind never acts twice in exactly the same way, and Nature always accomplishes her work in the easiest manner possible. The connection between life and matter was briefly referred to; it was stated that Man has made no progress in the investigation of the phenomenon of life since the dawn of Creation; definitions of life are quite unsatisfactory, particularly the one which states that an organism lives because it constantly adapts itself to its environment. The dead organism does that also, chemical action never ceases. It was held, however, that it would meet observed facts to say that life ceases to be when a certain molecular arrangement of the organism is disturbed. The action of poisons was instanced, particularly prussic acid, the molecule of which is composed of one atom each of the harmless elements, hydrogen, carbon, nitrogen. Yet, when these three are combined, their structure is such that a most minute quantity causes death instantly. This was thought to be the result of the peculiar form of the molecule, and the consequent power it had to destroy the normal shape of the molecules of the living tissues. In concluding, Mr. Lindsay said, there is no reason to doubt that Science will yet fathom every law in the physical world, but that the line is sharply defined beyond which we can never expect to pass, and that he believed that if, in the future, some philosopher should announce the law which governs all these mysteries in Nature, it will most probably be a law so simple that a child may understand it.

Considerable discussion followed the reading of the paper. Mr. J. Van Sommer very graphically described the Howard Theory of Atomic Energy, the various properties of molecules being supposed to depend upon their motions of rotation and oscillation, and showed how differently shaped molecules would result from a combination of atoms of the same shape, but having different motions. Mr. Robert Dewar referred to the theory of spirit life in the elementary atoms, and said that the chemist, working in the laboratory, is brought so directly face to face with the mysteries of chemical action that he does really feel he is looking upon matter endowed with volition. He stated also that many of the most gifted physicists of the day find a difficulty in rejecting altogether the theory that there is something more than purely physical force at work among the atoms of matter. Mr. G. B. Musson also took part in the discussion.

TWENTY-FIRST MEETING.

October 31st; Dr. Larratt W. Smith, Q.C., Vice-President, in the chair. The meeting was unusually well attended. Mrs. Ella Bogart, of Belleville, was elected an Associate-Member. Encouraging and cordial letters were read from Miss Agnes M. Clerke, of Redcliffe Square, London; Mr. J. Ellard Gore, F.R.A.S., M.R.I.A., of Ballysodare, Ireland, and Mr. W. F. Denning, F.R.A.S., of Bristol, England, Corresponding Members of the Society, who each transmitted a paper to be read. In a circular, Rev. T. E. Espin, F.R.A.S., of Tow Law, England, announced that a fine red star (observed at R. A. 20h. 46m. 59s., and N. D. 46° and 47m.), is a variable, and was then fading.

Under the head of observations, Mr. A. F. Miller and Mr. A. Elvins referred to the large sunspot, visible to the naked eye, which passed off the solar disc October 28th. Mr. Arthur Harvey described a peculiar aurora observed by him at Manitowaning on the 7th of October. Messrs. J. R. and Z. M. Collins exhibited several photographs, including one of the full Moon, very sharp and clear. Dr. J. C. Donaldson, of Fergus, reported an interesting series of observations upon the Moon, some close double-stars, and the satellites of Jupiter. Mr. Harvey presented a small stone sent to him from a distance as an aerolite, but which had proved to be a nodule of iron-pyrites. He said he had been informed that a meteorite weighing several tons, which had, some years ago, fallen on Cockburn Island, in Lake Huron, had been built into a wharf on the North side of the Island.

After routine, Dr. Smith, the Chairman, with a few well-chosen remarks, introduced a feature of special interest in the evening's proceedings. He said that the Society had desired to do honour to one of its most worthy members, and that the present occasion had been selected as a suitable one on which to bestow upon that member some mark of appreciation, after which the ladies would take charge of the meeting.

Mr. John A. Paterson, M.A., on behalf of the officers and members, then read the following

ADDRESS :—

THE ASTRONOMICAL AND PHYSICAL SOCIETY OF TORONTO,

TO

G. E. LUMSDEN, ESQ., *Corresponding Secretary.*

SIR,—Services well rendered deserve well rendered thanks ; and if the thanks of this Society are as well expressed as your services have been performed, then indeed may it be said that our expressions are more than usually eloquent, and that they are prompted by hearts more than usually grateful. Your voice has been heard in the councils of this Society since its inauguration, and whenever wise and sagacious guidance was required, our experience invariably recalls your presence as its very embodiment. Your contributions to the astronomical and physical researches of the Society have been many and various; even in the scientific magazines of foreign lands, we read the name of our Society, and that name is a mere nebulous appendage to your own, which shines as the nucleus. For all this take our words of gratitude, accept our expressions of praise. But not only has this Society profited by your words; it has gained much by your deeds, as shewn in the able and labourious editing of our Transactions, in the large correspondence you so industriously carry on for its benefit, and in the carefully prepared published accounts of our meetings, which have made our Society a distinct feature of the scientific character of our Province—this foremost Province of Britain's Western Empire. For these things, take our deed of gift. Appreciative words are jewels gathered up from the yesterdays of life, and we offer these to you. The yesterdays of our Society through you have been made brighter and happier. This gift is an appreciative act with which to make the to-morrows of your life more joyous, and thus your past, present and future days have our appreciation living throughout them. We have some members who are self-luminous, others of us from our thought-discs only act as good reflectors; mayhap in the future, by a continual absorption of light-waves, we may all be like you, self-luminous—although we do not recall any physical law which is the exact counterpart of this. But not only *that*; your regular attendance at our meetings convinces the observer that you must revolve in a circle of perpetual apparition. Modesty is a noted attribute of Science; we know that because we know you, and we have some knowledge of ourselves but an uncompromising devotion to Truth is also a noted attribute of Science, and that must be our apology for expressing our minds to you so freely, even if it may cause you some embarrassment. When deciding upon the form of our gift we had in mind the estimable lady who makes your house into a home, and whose path does not as often, as that of her binary, make a node at the place of our meetings. In conclusion, we trust that the golden sands of your life, and of her life, may flow joyfully onwards, and that the glass of Time that day by day makes your life record may be often turned by Him whose name is Love, who, while tenderly guiding us here, yet omnipotently sways the Universe everywhere. Yours very sincerely,

CHARLES CARPMAEL, *President.*
LARRATT W. SMITH, D.C.L., *Vice-President.*
JOHN A. PATERSON, M.A., *Vice-President.*
CHARLES P. SPARLING, *Recording Secretary.*
JAMES TODHUNTER, *Treasurer.*

As Mr. Paterson concluded the Address, the Chairman uncovered, and, amid applause, formally presented to Mr. Lumsden a beautiful silver urn and a silver inkstand, specially selected by a Committee. These handsome gifts bore suitable inscriptions, which were also read.

Mr. G. G. Pursey also read a short Address in verse in the form of an acrostic, which was most suitable to the occasion, and which was warmly received by the members. Mr. J. A. Copland, by letter, expressed his high appreciation of Mr. Lumsden's labours in giving to the public from time to time information which very materially assisted the amateur engaged in astronomical work.

In reply to the Address, and in returning his heartfelt thanks for the manner in which it referred to himself and to his wife, who had been of the greatest assistance to him in his work, and who deserved all that was said of her, Mr. Lumsden explained that when, by the merest accident, he learned that the event then transpiring was in contemplation, he protested that if the Society felt it to be fitting to make some acknowledgment of services it was good enough to regard as useful, he would be more than satisfied if the expression of acknowledgment took the form, as hitherto, of a few words, or, at most, of a resolution to go on the Minutes, and that he would be equally gratified if the tangible portion of the acknowledgment consisted of some book or instrument to become the property of the Society for the use of its members. But he found that the projected presentation had passed the stage at which changes could be made. Since then he had, with many misgivings, been looking about for something meet to say for himself on that occasion. The more he had looked about the greater had grown his difficulties. That he had tried to serve the Society was true, but he could not convince himself that he had succeeded in serving it so well as to deserve, even in the remotest degree, the warm expressions of appreciation introduced into its far too flattering Address. Assuredly he had not deserved any tangible tokens of their kind-heartedness; nay, for anything he had done, or tried to do, he had been already thrice repaid. In the first place, the honourable office conferred upon him had enabled him to experience the pleasure of correspondence with kindly men and women of high scientific attainments, who, as was to have been expected, had been courteous and forbearing to him and eminently sympathetic in so far as the objects and aims of the Society were concerned. In the second place, partly owing to the office he had held, he had been, for his own sake, compelled, not always he apprehended with the best results, to make of Astronomy a much more serious study than otherwise might have been the case. While, in the third place, he had become intensely interested in and, he hoped, profited by, a species of mental relaxation of a most inspiring, elevating, and, therefore, valuable kind. The older he grew, the more did he believe that every one, be his or her duties what they might, was the better for some intellectual relaxation of the character to which he referred. There appeared to him to be nothing so wearing as a ceaseless daily "grind" at one and the same wheel, or round of daily work. He had heard from others what he now said for himself, paradoxical as it might seem to some, that after business-hours the mind is often, if not always, rested by being, for a reasonable time, actively employed in some manner or pastime that is peculiarly agreeable. Relaxation might be found in some one of the many avenues open to everybody. One might find it in music, another in painting, another in reading in some favourite subject and in reflection, another in the works of benevolence, and yet another in some one of the almost innumerable fields of scientific investigation within the reach of amateurs. Of these fields, he knew of none more inviting than those of Astronomy and of Astro-Physics. He knew of none more elevating in influence and surroundings; of none more attractive, if only from the side of the Mysterious, a side which ever finds a response in the human breast; of none really more easily accessible, if approached from the right direction. Having entered upon one of these fields (though but a little distance truly), he repeated that he had been already more than repaid for what he had, in good earnest, tried to do. He had heard others declare that an evening spent at the telescope, or over some astronomical task, had often refreshed a mind weary with the performance of daily duties, and he believed this would be found to be true of every one who took up Astronomy as an intellectual recreation. Of a truth it seemed to him, if there were a debt of gratitude resting anywhere, it was on his side and not on the side of the Society. So that, under these circumstances, he was much touched by their too kind words. More, he was encouraged by them, and therefore, in the future, so long as he was enabled to do so, he would strive more than ever to merit some little portion of the praise accorded to him. After their markedly handsome treatment, it would be little creditable to him were he even by implication to permit anyone not familiar with their work to leave the room under the impression that he was willing it should be thought that to him in any special degree was due the prosperous condition of the Society, for the contrary was true. That the Society occupied an enviable position he trusted all would agree. That it was doing a good work and was awakening a widespread interest in Astronomy and Astro-Physics, would, he thought, be readily admitted, for there was evidence of this at every meeting. That it had made a fairly creditable appearance in the Observatories and Sister Societies of two continents, went, he hoped, without saying. But this was due not to one of them (certainly not to him), but to them all. Hearty co-operation had distinguished every one. Business ability, tact and judgment had been manifested on every side. Few scientific societies even of a popular character could boast the energy, the steady purpose, or the cheering attendance at their meetings that characterized the assemblages of this Society. All this had been the result of united effort. By the wisdom and distinguished administrative ability that had marked the occupants at all times of the chair of the presiding officer, whether in the Society or in Council; by the arduous services rendered at the

Recording Secretary's desk; by the patient services rendered in the Library; by the able services rendered in the conducting of their finances; by the ardent interest constantly taken by every one in the proceedings of the Society; by the papers which had been read and by other means highly creditable to the Society as a body, and to each individual member, the Society found itself comfortably housed and able to do work and to issue Reports which had been commended in high quarters, and which, it was trusted, would be succeeded by others still more calculated to add to the Society's prestige abroad as well as at home.

Under the auspices of the ladies, the proceedings were brought to a close in a very fitting manner, coffee, cake and other refreshments being served to the members of the Society and their friends and a very pleasant hour being spent in social intercourse.

TWENTY-SECOND MEETING.

November 14th; Mr. E. A. Meredith, LL.D., in the chair. A. Sinclair, M.A., and Mrs. F. Merrishaw, of Toronto, were elected Active Members. As some evidence of the increasing interest taken in Astronomy, it was stated that Miss Sarah L. Taylor had recently been invited by the Toronto Woman Teachers' Association to speak on the subject; that Mr. G. G. Pursey would address an open meeting to be held under the auspices of a Benevolent Order; that Mr. J. A. Paterson, M.A., would read a paper before a Society in Deer Park; that the Society would take charge of an open meeting shortly to be held by The Young Women's Guild; that, in compliance with suggestions made from time to time by the Society, and a demand from the public for fuller information, *The Canadian Almanac* for 1894 would contain some twenty-five pages of matter intended to be of use to amateurs, and that the Society was gratified at the publication of this material, to be added to as required, because these predictions would fall into the hands of thousands of people it could never hope to reach by its Annual Reports, from which, for the present at least, would be excluded the Tables published the last two years. Mr. J. Von Sommer read a letter from the Secretary of The Victoria Institute, London, England, inviting, on behalf of Sir George Stokes, the President, the Society to become an Associate-Member of the Institute. Mr. J. A. Copland was appointed British and Foreign

Correspondent of the Society, the editors of certain magazines having asked to be regularly supplied with reports of the Society's proceedings. Several members reported having observed for Leonid meteors on the night of the 13th, but with poor success. Dr. Larratt W. Smith and Dr. Meredith each, however, saw a very bright meteor; that of Dr. Smith rivalled Jupiter in brilliance. Mr. Thomas Lindsay made some interesting remarks upon and described some experiments in magnetism, the result of the discussion at a recent meeting. In reply to Mr. Arthur Harvey, the Chairman stated that he had carefully examined the reports of the Toronto Observatory to ascertain whether there was periodicity in so far as wet weather was concerned. He had failed to find evidence that was definite, but there appeared to be some to support the theory. The subject had been brought forward at Chicago, and warmly debated, but without satisfactory result. Mr. Lindsay suggested that an examination of the statistics of many years might show there was a ten-year or even longer period. Following up the subject, Mr. Harvey said he understood there was a theory that in order to secure good harvests, seeds should be planted while the Moon is waxing. Mr. J. Von Sommer and others spoke on the subject. Observations on the Sun, Jupiter, and some stars, and an aurora, visible November 1st, were received from Dr. Donaldson, of Fergus.

It was announced, that a large number of replies had been received from all over the world to the question asked by The Canadian Institute and The Astronomical Society, relative to changing the beginning of the astronomical day.

After an unusual number of predictions had been announced, Mr. W. B. Musson, by request, read the following paper on

THE DISTANCE OF THE NEBULÆ,

contributed by Miss Agnes M. Clerke, a Corresponding Member of the Society.

Sidereal science has scarcely yet fairly grappled with the problem presented by the distances of the shining bodies projected indiscriminately upon the face of the sky. It is indeed a most arduous one. The heavens are of such abysmal depth that they nearly everywhere defy our utmost efforts at sounding them. About a score of stars, however, are known with tolerable certainty to send their light-messages to us in periods comprised between four and twenty years; and at least as many others seem to be not more than twice as remote. But the distance of no nebula has been even approximately determined. Triangulating experiments have so far been completely baffled by the apparent insensibility of such objects to the perspective effects of the earth's perennial journeyings round the sun. They lend themselves, it is true, with great difficulty to such experiments; and negative results, though instructive, are not inspiriting. Consequently, very few trials have yet been made.

Measurements of nebulæ for such a purpose are both difficult and insecure. They can only in fact be attempted upon such of them as possess sharp central condensations. Other embarrassments supervene. The measurements can only be carried out with reference to one or more stars external to the nebula; and there can be no certainty that the stars chosen are really independent. Small stars in the vicinity of nebulæ are often, there is reason to suspect, physically associated with them; and no means are at present available by which to discriminate between those that are, and those that are not, bound by such ties. The only safe criterion would be proper motion. If a nebula could be found to move onward across the sky irrespectively of the surrounding stars, then no doubt would remain of its total detachment from them. But no nebula, with the exception of those involving the Pleiades, has an ascertained proper motion; hence, the systemic connections of cosmical clouds are undefined; and attempts to elicit from them signs of parallactic shifting relative to neighbouring stars may chance to be no less futile than labour bestowed upon drawing water in a sieve.

Moreover, certain indications of nearness to the earth as regards stars are all but completely absent in the case of nebulæ. Thus, rapidly moving stars are apt to have measurable parallaxes; but nebulæ, since they do not visibly travel either fast or slowly, stand, in this respect, all at the same zero-level. Again, wide stellar pairs in brisk mutual circulation intimate their comparative vicinity to ourselves. Double nebulæ, however, although sufficiently plentiful, preserve an inflexible rigidity of relative position. Revolving nebulous systems are unknown. Then the brightness of nebulæ, unlike that of stars, is independent of distance. A luminous *surface* retains its intrinsic lustre unchanged however far back it may be thrust into space. It shows, of course, smaller in proportion to the inverse square of the distance, the sum total of light received from it diminishing, accordingly, by the same gradations; but an equal apparent area shines always with unchanged brightness. The only criterion left is that of extent; and it is a very dubious one. Yet the chance of success in a search for parallax is certainly better with a large, than with a small object of the same kind, especially if it shows distinct structure.

These conditions are fulfilled by the "great round planetary" in Draco, numbered 6543 in Dreyer's New General Catalogue. Its diameter is nearly one-fiftieth that of the full Moon; signs of a screw-like, or "helical" conformation were clearly recognized in it by Professors Holden and Schaeberle, and an eleventh magnitude star stands in an evidently nuclear relation to the convolutions diversifying its sea-green disc. To measure the star is then to measure the nebula, and its perfect sharpness renders accuracy in so doing feasible. That this central point of light is no mere nebulous condensation is shown by its genuinely stellar spectrum, distinguishable as a variegated thread crossed by the three green lines from the surrounding gaseous area.

The object thus constituted has been subjected to various trials for parallax, an external tenth magnitude star 162″ from its centre, serving in each case as a reference-point. But without result. No inference was possible from a comparison of the measures executed by D'Arrest, at Copenhagen, by Brünnow at Dunsink, near Dublin, and by Bredichin at Moscow, except that of the indefinite remoteness of the nebula.

The truth of this inference can be otherwise attested. There are very few nebulæ in which the absence of sensible proper motion is so well-established as in the Draco planetary*. For Lalande happened to observe it on the meridian, July 26, 1790, and it still, after the lapse of a century, occupies the place in the heavens which he then assigned to it. Now this apparent immobility furnishes a direct proof of remoteness. The Sun, by its never-ending advance through space, furnishes, as it were, a base-line indefinitely extended by the mere efflux of time for trigonometrical operations upon the celestial objects around. Thus the effects of what Herschel called their "secular parallax" must eventually be brought to light, and even the imperceptibility of such effects during a given interval supplies a measure of the least distance compatible with the circumstances of each case. That is, provided the velocity and direc-

* Mr. Burnham believes that he has detected signs of relative motion between the central star of this nebula and the star used for comparison with it in parallactic determinations. But even if the fact prove to be as he supposes, the probability is strong that the movement belongs to the star, not to the nebula.

tion of the Sun's translation be approximately known. Accepting Otto Struve's conclusions on the latter points, d'Arrest showed in 1872, that on this principle, the largest admissible value for the annual parallax of the nebula in Draco was about 0″07. In other words, its distance could not well be less, and might be a great deal more, than that corresponding to forty-five years of light-travel. And his calculation allowed an ample margin of some five seconds of arc for uncertainties of observation.

We, at the present time, can push d'Arrest's reasoning a good deal further than he was able to do. In the first place, Struve's estimate of five miles a second for the speed of the Sun may now safely be doubled. Hence, the length of the line from the opposite extremities of which the nebula was viewed in 1790 and 1872 respectively, was fully twice as long as d'Arrest took it to be. On this ground alone then, the minimum distance of the object must be doubled. Again, one hundred and three years have now elapsed since Lalande's observation, yet the nebula still remains fixed. The extent of solar displacement, accordingly, to which it fails to respond by the slightest symptom of apparent mobility, is greater in 1893 than it was in 1872, in the proportion of 103 to 82. And in the same proportion, evidently, d'Arrest's value for its least possible distance must be enlarged. The upshot of these corrections is to show that the largest parallax that can be conceded to this mysterious object falls short of three-hundredths of a second (0″028); that, in fact, a stretch of at least 116 light-years intervenes between the emission of its rays and their reception on the Earth. The grounds of this inference, indeed, as d'Arrest did not omit to remark, would fail if the nebula shared the Sun's motion—if it travelled abreast of it towards the same goal. But this is in the highest degree improbable. All the more so that the body is approaching the Sun, according to Professor Keeler's determination, at the high rate of forty miles a second. This very large radial component is likely, on the face of it, to absorb by far the larger part of the motion inherent in the nebula.

Almost as a matter of course, photography, the factotum of Astronomy, has begun to lend its aid towards overcoming the difficulties connected with nebular parallax. Professor Holden pointed out in 1890 that the images of planetary nebulæ, obtained with sufficiently short exposures, are as small and as sharp as stellar images, and are hence equally capable of measurements delicate enough for the detection of parallactic shiftings on the scale of those displayed by the nearer stars. Sensitive plates, in fact, to which glimpses (comparatively speaking) are permitted of these complex structures, take notice only of the central stars forming perhaps their corner stones, and ignore their filmy developments.

This promising expedient has hardly yet received a fair trial; for the nebula lately experimented upon by Dr. J. Wilsing, of Potsdam, is not really planetary, although it has often been called so. Discovered about four degrees North of the famous double-star 61 Cygni by the late Prebendary Webb in 1879, and independently by M. Stephan, of Marseilles, it closely resembles a miniature comet, with a double, imperfectly condensed nucleus. Its catalogue number is N. G. C. 7027. The main part of its light is concentrated in the fundamental nebular line, which shines with surprising vividness. The nucleus, however, emits several additional rays, including that representative of the solar element, helium; but shows only a very feeble continuous spectrum. It is thus still far off from the stellar stage attained by the glittering point marking the centre of the Draco planetary.

Of Webb's nebula, Dr. Wilsing obtained, with the Potsdam spectrograph, between June, 1892, and June, 1893, one hundred and four impressions on thirty-four plates, each triply exposed during eight minutes. A series of thoroughly satisfactory, because almost perfectly concordant, measures were then executed of the principal nebular nucleus referred to two adjacent stars of the eleventh magnitude. But from each of the pair only a negative parallax was derived. The stars, that is to say, appeared to be nearer the Earth than the nebula, the latter remaining sensibly fixed, while the objects compared with it manifested a trifling change of place with the circling of the Earth in its orbit. The ostensible result was to locate one of the stars at forty, the other at only nineteen light-years' distance from ourselves. These positive data, indeed, are far from being definitively ascertained; but the negative significance of the enquiry is unmistakable. The nebula is shown by it to be immeasurably remote.

Nebular parallax, then, seems to be an unpromising subject for direct investigation. Yet nebular proper motion must, in course of time, prove determinable. Nebulæ, as a class, are without doubt, in rapid movement. The mean velocity in line of sight of eleven measured by Professor Keeler, comes out no less than sixteen miles a second. And it cannot for a moment be supposed that they possess, on the whole, a greater speed along than across the line of sight. Their motion relative to the Sun may be resolved into three components, corresponding to the three dimensions of space; one directed (say for convenience) towards or from the North-pole of the Heavens, another co-inciding with the plane of the celestial equator, and the third with the visual ray. Now it may fairly be assumed that a number of sidereal bodies sufficient to give a fair average, possess, on the whole, an equal velocity along each of these several lines.* We, at least, are aware of no reason for a systematic difference. Hence, if a mean rate of motion along one of the three axes be known, an identical value may safely be assigned to that along each of the others. Let us apply these considerations to Professor Keeler's eleven nebulæ, inadequate though the number be for the balancing of individualities in the mode of travelling. Their average radial speed, as just stated, is sixteen miles a second. By sixteen miles a second, then, they must also be considered to progress North or South, as the case may be, and East or West. Their mean distance could then at once be inferred, if only the corresponding angular displacements were determined. Attempts at such determinations have, it is true, proved unsuccessful. But let us assume, just for the sake of illustration, that the eleven nebulæ in question, taken one with the others, have a secular proper motion of three seconds of arc of declination, and as much in right ascension.† This is the outside of what is probable, yet it amounts to saying that a line of journey, pursued during one hundred years at the rate of sixteen miles a second, contracts, as viewed from the mean distance of the nebulæ, into the tiny span of three seconds. The remoteness implied is unimaginable. It is easy to say that light spends five hundred and eighty years (parallax = $0.''0056$) in travelling thence to our eyes, but the figures convey little impression. The mind fails to grasp the corresponding idea. Obviously, however, the inchoate systems separated from us by such formidable intervals, must be constructed on a scale of proportionate vastness. A globular nebula, only $10''$ across, if placed at the distance indicated, would occupy a sphere 600 times wider than one that could be girdled by the orbit of Neptune, and should exceed it in volume the cube of 600, or nearly 217 million times.

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* The late Dr. Kleiber originated this method of ascertaining the average parallax of collections of stars. See *Astronomische Nachrichten*, No. 3037.

† Reduced, of course, to the equator by multiplication with the cosine of the declination.

But before these provisional calculations can be either accepted or corrected, much has to be done, and much time must elapse. The proper motions of the nebulæ cannot, like their radial velocities, be determined off-hand. Professor Keeler's success in the latter department, however, lends fresh hope and interest to investigations in the former. The precise measurements, for instance, of a considerable number of nebulæ, lately executed by Mr. Burnham and Dr. Spitaler with the great refractors of Lick and Vienna, respectively, as well as by Professor O. Stone at the Leander McCormick Observatory, may in a few decades begin to bear fruit. Their repetition by astronomers of the next generation is not unlikely to disclose incipient traces of genuine progress across the sphere. As these develop and certify their character, knowledge regarding the scale of the Universe will become extended and solidified.

It would be hazardous (to say the least) to assert, at the present initial stage of enquiry, that nebulæ are absent from the region of space occupied by the three or four hundred stars nearest to our system; yet there are some grounds for holding that this may really be the truth. For Professor Kapteyn has shown that the Sun is placed within a cluster mainly composed of solar stars—of stars, that is to say, belonging to the second spectral type; and no instance has yet been adduced of the association of solar stars with nebulæ. An intimation seems thus to be conveyed to us that we are placed in a non-nebulous region of the Universe, far beyond the boundaries of which lie the vast, unsubstantial masses more or less dimly descried in our telescopes. Everything, indeed, leads us to suspect the prevalence of varieties of organization in the different parts of the sidereal world—varieties, however, emphasizing rather than impairing the fundamental unity in which the Unity of the Maker is dimly reflected.

After some discussion, Mr. Arthur Harvey said that while it was, in a sense, against the rule that a member should not be given a vote of thanks for a paper, he was sure that in the case of a lady, of a lady so distinguished, and one who had afforded them so much pleasure, not alone by the merits of her paper, but also by the clearness and felicity of style which made all her writings and her larger works so attractive to the student, he would be allowed to move that a vote of thanks be tendered to Miss Clerke for her admirable paper. Mr. Thomas Lindsay, in seconding the motion, reminded the Society that the contribution of such a paper was no small compliment. The motion was carried with applause.

TWENTY-THIRD MEETING.

November 28th; Mr. E. A. Meredith, LL.D., in the chair. From Rev. T. E. Espin, F.R.A.S., was received a report respecting the discovery of variability in certain stars which had been under examination at his Observatory in Tow Law, England. Owing to cloudy weather chiefly, no observations were reported. It was impossible to state whether there had been a shower of meteors visible on the 27th, heavy continued rain having entirely prevented observation. Adverting to some remarks upon a previous occasion regarding the proper time for the sowing of seed, Dr. Meredith said "Mr. Harvey referred to the belief, prevalent in some countries, and especially among Teutonic races, that seed should be sown when the Moon is waxing—not when it is waning. The question was asked if Virgil, in his Georgics, said anything on this point. I promised to look up the matter. In the opening lines of the Georgics, I find Virgil proposes to treat of the proper times for sowing seed and planting trees. He tells us that the farmer should watch the constellations, and the risings and settings of the stars as carefully as the sailor, that the position of the Sun in the zodiac determined *messis diem tempus qui secundi*, *i. e.*, the times of harvest and the season for sowing. In other words, the proper time for sowing seed was regulated solely by the Calendar. In one passage only, so far as I can find, is any reference made to the Moon (I Geo. c. 276), where he says that the fifth day after New Moon was unlucky, while the seventeenth was lucky for planting the vine and other things." Translations of these passages were read by Dr. Meredith.

Mr. W. B. Musson, referred to an article on Nova Aurigae, recently contributed by Dr. Holden, Director of the Lick Observatory, to *The Forum*, and called especial attention to the assertion that observation indicated that the star was being resolved into a nebula. Mr. A. F. Miller, briefly reviewed the history of this celestial object, and pointed out that associated with it were some novel and very peculiar features, not the least interesting of which was the fact that its spectrum before it faded away was different to the spectrum shown now that it had brightened again, there being lines, the meaning of which was not clearly understood. As a result of changes in the appearance and in the spectra of the Nova, certain very ingenious theories with regard to it would have to be materially modified, if not abandoned altogether.

Mr. T. S. H. Shearmen, of Brantford, sent, as an addition to the Society's Collection, an excellent photograph of the house in and around which Professors A. M. and A. G. Bell conducted the experiments which resulted in the perfecting of the principle underlying the telephone.

By request, Mr. C. A. Chant, B.A., read the following paper on

THE LUMINIFEROUS ETHER,

contributed by Mr. J. Ellard Gore, F.R.A.S., M.R.I.A., a Corresponding Member of the Society.

The hypothesis that light is transmitted by means of wave motion—a theory now universally accepted—evidently necessitates the hypothesis of a medium in which these waves are propagated through space. Various views of the constitution of this medium—known as the luminiferous ether—have been advanced by eminent physicists. Some of the properties attributed to this hypothetical fluid are so anomalous that it is almost impossible for the mind to conceive the existence of such a medium. Sir John Herschel says: "Every phenomenon of light points strongly to the conception of a solid rather than a fluid constitution of the luminiferous ether, in the sense *that none of its elementary molecules are to be supposed capable of interchanging places*, or of bodily transfer to any measurable distance from their special and assigned localities in the universe." The famous Dr. Young also says: "The luminiferous æther pervading all space is not only highly elastic, but absolutely solid."

Now, as our finite minds cannot grasp the idea of a solid which is impalpable to touch, and invisible to our sight—as the ether evidently is—any theory which would relieve us from the necessity of imagining, or rather trying to imagine, such an anomalous substance should be very acceptable. Such a theory was advanced a few years since by Professor de Volson Wood, and as his views, which are very carefully worked out, seem to be mathematically sound, some account of his hypothesis may prove of interest to the reader.

Professor Wood assumes that the ether is gaseous in its nature, and consequently molecular in structure, a conception evidently more probable than the hypothesis which ascribes to it the properties of a solid. He starts with two assumptions, both of which are known to be true. These are, that light is transmitted through space with a velocity of 186,300 miles per second, and that the ether also transmits 133 foot-pounds of heat energy per second per square foot from the Sun to the Earth. There is no doubt whatever as to the velocity of light, which has been determined by various methods, all of which give results in close agreement. With reference, however, to the heat energy transmitted from the Sun to the Earth, Herschel found 71 foot-pounds, and Sir William Thomson (now Lord Kelvin) assumed 83·5 foot-pounds per second in his calculations with reference to the density of the ether. Recent researches, however, by Professor Langley, show that the value is considerably higher, and his results indicate the number 133, the value adopted by Professor Wood. I may here remark that any theory which takes into account the limited velocity of light—for, although very high, the velocity is evidently limited—commends itself at once to our favourable consideration. For no other theory of the constitution of the ether attempts to explain—so far as I know—the limited velocity of light. Were the ether an *absolutely* perfect fluid—as some theories suppose it to be—we might reasonably expect that the velocity of light would be infinite, or in other words, that its propagation through space would be instantaneous. The fact that this is not so suggests that the velocity is limited by the constitution of the ether, in the same way that sound is limited in velocity by the constitution of the Earth's atmosphere, or of the substance along which the sound is conducted.

Starting with the above two assumptions, Professor Wood computes from the known properties and laws of gases that the density of the ether is such that the weight of one cubic foot is a fraction of a pound represented by 2 divided by 10^{24} (1 followed by 24 cyphers). In other words "a quantity of the ether whose volume equals that of the earth would weigh about $\frac{1}{20}$ of a pound." With this density, a cubic foot of the most perfect vacuum which has yet been obtained by air-pumps would contain a quantity of matter "some 200 million million times the quantity in a cubic foot of the ether."

Professor Wood also calculates that the pressure of the ether would be very small, about one pound on a square mile. Far, therefore, from being a solid, the ether is, on this theory, an excessively attenuated gas, and such an hypothesis of its constitution certainly seems more probable than the anomalous theories which have been hitherto maintained.

The chief objection which has been advanced against a gaseous constitution of the ether is that even with a highly rarified gas a retarding influence would be produced on the motions of the planets which, in the course of ages, would be easily detected by astronomical calculations. But Professor Wood shows clearly that, with his computed density for the ether, its resistance to the motions of planets and comets would be absolutely insensible even in the course of ages.

According to the Kinetic Theory of Gases, the number of molecules even in a small volume of an ordinary gas is enormous. According to Thomson the probable number in a cubic foot of air is 17×10^{25}, an immensely large number. Even for such a rarified gas as the ether is supposed to be on Professor Wood's theory, the number would be very great. He computes the number at about 10^{16}. Large, however, as this number is, the number given above for air is about 17,000 million times as large.

Assuming that the Earth's atmosphere is subject to terrestrial attraction—as it evidently is—and that it obeys the well known gaseous law of Boyle and Marriotte, namely, that the density is proportional to the pressure, we can find the law of the decrease of density with distance from the Earth, and hence the density at any given height above the Earth's surface. At a certain point the atmosphere will become so rarified that it will have the same density and the same tension as the ether. Professor Wood computes this height at about 127 miles. This should be the extreme limit of the Earth's atmosphere. By another method he finds 169 miles as the extreme height of the atmosphere. Both results are, however, uncertain; for a uniform temperature is assumed for the whole height, and as we know that the temperature diminishes as we ascend, this assumption is incorrect. Assuming a probable law for the decrease of temperature, and considering the temperature observed by Mr. Glaisher in his famous balloon ascents, he finds a height of 86 miles. Under certain conditions, however, he finds that this height might be increased to 110, and possibly to even 120 miles. Observations of the height at which meteors become visible indicate, in some cases, a height of 100 miles or more, but the usual height is between 70 and 80 miles.

Although considering the constitution of the ether to be gaseous and molecular, Professor Wood thinks "that the æther is a substance entirely distinct from that of the atmosphere—that the former cannot be considered as the latter greatly rarified, as some have supposed." He finds by calculation that the density of the ether at the surface of the Sun and at an infinite distance from that luminary is sensibly the same, and considers that—unlike the Earth's atmosphere—"the density and tension of the æther may be considered uniform throughout space." It would be impossible for a wave of light to be propagated in air with the known velocity of light unless we suppose the temperature of the air to be raised enormously—something like 400 billion degrees of the Fahrenheit scale. Professor Wood also computes the specific heat of the ether, and finds it more than a billion times that of hydrogen, which has the greatest specific heat of all known terrestrial gases. He finds the ratio of the elasticity of the ether to its density to be very great compared with the same ratio in the case of air. His result is 8 followed by 11 ciphers. He also shows that the Earth's attraction for the molecules of air lying near the limit of the atmosphere "will exceed 500,000 times the resistance of the æther; hence the molecules of air accompany the Earth in its orbit as certainly as does the Moon, and are far more rigidly bound to it than is its satellite."

From these results it will appear that Professor Wood's hypothetical medium fulfils all the required conditions.

A similar theory of the constitution of the ether has been advanced by Mr. S. Tolver Preston. He shows that the resistance offered by the air to a body moving through it is due to the comparatively slow motion of its molecules—about 1,600 feet per second, or about that of a rifle bullet—and that consequently, even if its density were as low as that of the ether, it would still offer great resistance to bodies moving with planetary velocities. If we suppose the molecules of the ether endowed with a very high velocity, this resistance would vanish, as the equilibrium of the medium would not be disturbed. He therefore concludes that the molecules of the ether are extremely minute and moving with a high velocity. Professor Wood estimates the mean square velocity at 286,000 miles per second. Their minuteness "is absolutely necessary to enable the ether to penetrate with freedom the molecular interstices of matter." Their high velocity is consistent with the hypothesis of a large amount of energy being stored up in the ether, for the energy of a moving body varies as its mass multiplied by the square of its velocity. A small body moving with a high velocity may therefore possess more energy than a much larger body moving with a small velocity. As, according to the Kinetic Theory of Gases, the pressure exerted by a gas depends on the velocity of its molecules, the ether may have a high pressure without being dense, or solid, as some have supposed it to be.

The low density of the ether found by Professor Wood has an important bearing on the hypothesis of the extinction of the light of very distant stars by absorption in the ether, an idea advocated by the elder Struve and other astronomers. I have shown elsewhere that telescopic observations yield strong evidence against the existence of any extinction of light, at least so far as our largest telescopes can penetrate into space. Let us see what effect the ether of Professor Wood's theory would have on the light of very distant stars. We can solve this problem by comparing its effect with that of the Earth's atmosphere on the light of the stars. Measurements with photometers of the same star at different altitudes above the horizon have shown that the absorption of light by the atmosphere amounts, in the case of a star in the zenith, to about a quarter of a magnitude. In other words, if the Earth's atmosphere were removed the light of a star in the zenith would be increased in the proportion of 1 to 1·26 or 100 to 126. Now, although the atmosphere extends with constantly diminishing density to a height of 100 miles or more, its total effect may be assumed to be equal to that of a homogeneous atmosphere of about 5 miles in height, and of a density equal to that of the air at the surface of the Earth. Assuming, as we are justified in doing, that the absorption of light is proportional to the density of the medium through which the light passes, and taking the density of the ether as computed by Professor Wood, I find that the thickness of ether which would absorb the same quantity of light as the Earth's atmosphere would be about 2×10^{23} miles, or 2 followed by 23 ciphers, an enormous distance. Let us see what this distance implies compared with the probable distance of the faintest stars. Measures of parallax have shown that the average parallax of stars of the first magnitude is about one-tenth of a second of arc. Hence the parallax of stars of the sixteenth magnitude—about the faintest visible in the great Lick telescope—would be (if their faintness is due to distance) about $\frac{1}{10000}$ of a second. This indicates a distance of 2,062,650,000 times the Sun's distance (about 93,000,000 miles) from the Earth, or nearly 2 followed by 17 ciphers. Hence it follows that the thickness of ether necessary to reduce the light of a star by a quarter of a magnitude only would be about one million (10^6) times the distance of stars of the sixteenth magnitude! We may, therefore, conclude that, on Professor Wood's theory of the constitution of the ether, there would be practically no extinction of light due to the ether *alone* as far as our largest telescopes can penetrate into the depths of space. So far as our limited range of telescopic vision extends we may therefore consider the ether as perfectly transparent, the total loss of light being wholly due to our own atmosphere. Of course, there may possibly be some extinction of light caused by meteoric dust in space, but this hypothesis has nothing to do with the ether, or with the question of its constitution which we have been considering.

In the course of a kindly criticism of the paper, Mr. G. F. Hull, B.A., pointed out the difficulty of forming anything like an adequate conception of the ether supposed to fill all space and to be a substance, solid, yet invisible to human eyes, and to be elastic, yet impalpable to the touch, and said that Mr. Gore had adopted the view, advanced by Professor Wood, that the ether is gaseous in its nature. After some reference to the extremely tenuous character of the ether, a pound weight of which, according to the Professor's hypothesis, would occupy a space 640 times the space occupied by the Earth, and whose density would be 1/200,000,000,000,000th of the density of the air reduced to 1/39,000,000th of an atmosphere, Mr. Hull said that inability to conceive such a gas as these conditions required, had, in some quarters, led to a rejection of the results flowing from any investigations of the Professor's, and that if these must be rejected, so must the theory upon which they were founded. There was, however, one result at which the Professor arrived which was not mentioned by Mr. Gore, and that was that the specific heat of ether is about 4,600,000,000,000, that of water being unity. This result apparently staggered the Professor himself, who, however, found consolation in what is generally accepted as a fact, that every particle of ether makes about 590,000,000,000,000 vibrations per second, a result, in his (Mr. Hull's) opinion, quite as difficult to receive as were the others. The facts concerning the velocity of light and the heat energy conveyed from the Sun were well known. The formula $V=\sqrt{\frac{\delta e}{\delta \rho}}$, used by Professor Wood, was applicable to all elastic media when the proper meanings were given to e and ρ. But the Professor assumed that the Kinetic Theory of Gases was applicable, which led to the form $V=\sqrt{\frac{\gamma . e}{\rho}}$ where γ=ratio of the two specific heats of air = 1.410. He also assumed that a quantity which he calls the modulus of the gas—which is nearly constant for ordinary gases—has the same value for ether. But, if we work on these assumptions, we arrive at a gas possessing properties differing so widely from ordinary gases that we have every reason to doubt the validity of the assumptions. Mr. Gore stated that the chief objection which had been advanced against a gaseous constitution of the ether was that a retarding influence would be produced on the motions of the planets which, in time, could be detected by astronomical observation. This was not usually regarded as a chief objection; though there was an objection with which it could not be compared. It was conceded by all physicists that plane-polarized light possesses a property vectorial in its nature, that is to say, it has magnitude as well as direction, and that this direction lies in one of two planes at right-angles to one another, and passing through the direction of propagation. This directed magnitude could have no component in the direction of propagation of the light, and, therefore, is transversal to that direction. This directed magnitude is called "a vibration." But all that is known is that it has a periodic change, and that the direction of the change is at right-angles to the direction of propagation. Now, in all the gases with which we are acquainted, the only possible form of wave-motion is produced by the motion of the particles backward and forward in the direction of propagation. Evidently, such longitudinal motion can have no particular relation with regard to any single plane through its direction. In brief, the phenomenon of polarization cannot be explained if we have longitudinal vibrations. Wave-motion in gases can not be propagated by means of any other vibrations, consequently a gaseous medium can not transmit the wave-motion producing light. This was the objection which, in his (Mr. Hull's) view, was insurmountable, and which had led such men as Fresnel, Neumann, MacCullagh, Green, Cauchy, Rayleigh, Kelvin, Helmholtz, and Maxwell, to adopt some form of the Elastic Solid Theory. In this theory, the compression was taken to be zero, or an exceedingly small quantity, and, therefore, the wave-motion produced by longitudinal vibrations to be infinite, or very large. This was probably what Mr. Gore had reference to when he stated that theories other than the one he had advocated do not take into account the limited velocity of light. Mr. Gore must have forgotten that this velocity appears as the result of analysis, and was never taken to constitute light. No difficulty had been experienced in arriving at a limited velocity for the wave-motion produced by transverse vibrations. In fact, it was assumed at once, as in Professor Wood's case, that this velocity was equal to that of light, and the arbitrary values for elasticity and density were deduced therefrom. Mr. Hull said he had attempted to show that Professor Wood's mistake lay in neglecting to add to his two assumptions a third, viz., that, as far as is known, the ether is incapable of transmitting longitudinal vibrations. This was the known property of an elastic solid, and had Professor Wood taken account of it he would hardly have represented the medium as a gaseous one. There was another theory, advanced by Maxwell, analyzed and extended by Helmholtz and Kelvin, and, lately, verified by Hertz: the Electro-magnetic Theory of Light, which was receiving much attention at the present time. It was an inviting subject, and was one which at some future time might be brought by him (Mr. Hull) before the Society.

Mr. Hull's views were supported by Mr. Chant, and the discussion which followed was taken part in by many members, who, whether they accepted or rejected The Gaseous Theory of the Ether, spoke highly of the value of Mr. Gore's paper in exciting physicists to a careful consideration of the subject.

TWENTY-FOURTH MEETING.

December 12th; Mr. John A. Paterson, M.A., Vice-President, in the chair. Interesting letters, on various subjects, were read from Dr. Joseph Morrison, M.A., Ph.D., F.R.A.S., of Washington, D.C., and Messrs. W. F. Denning, F.R.A.S., of Bristol, and J. Ellard Gore, F.R.A.S., of Ballysodare, and others.

It having been decided to ask Mr. Andrew Elvins to accept Life Membership in the Society, the pleasant duty of formally proposing the motion was entrusted to two intimate friends, Mr. G. G. Pursey and Mr. A. F. Miller. Mr. Pursey, who was received with loud applause, said that he moved the motion in full confidence that it would meet with the hearty support of every member. He thought that the Society was tardy in doing something like justice to his old friend, and that in thus making this recognition of his services, it was a question whether the Society was not really more honoured by Mr. Elvins in accepting the position than it was in conferring it. He had known

Mr. Elvins many years, and at a time, indeed, when he (Mr. Elvins) stood almost alone in Toronto as a student of Astronomy, and when the facilities for study were not what they are now. In all these years, Mr. Elvins had been the same honest, earnest and modest votary of Science, ever ready to impart all he himself had learned, ever ready to encourage the beginner, ever ready to give of his time and means to assist in furthering any scientific object. He (Mr. Pursey) had been, perhaps, more intimately, though less usefully, associated with the few devoted men who formed the nucleus of this Society through many years of its pre-natal and incipient existence than any other person, and, therefore, knew somewhat of the unselfish, untiring exertion of those men, and of one chiefly, in furthering the project of establishing this Society, which had outgrown even the most sanguine hope of the liveliest imagination. Were he (Mr. Pursey) to ask any person acquainted with the evolution and history of this Society, who, above all others, was the means of placing it on the path towards its present high standing, he was sure there would be but one answer—there could not be two opinions on the subject. And now as Time was fleeting, it was well that they defer no longer their important duty. He had, therefore, much pleasure, and honour, too, in moving: That The Astronomical and Physical Society of Toronto do confer upon Andrew Elvins, the esteemed and venerable father and founder of Amateur Astronomy in Toronto, the highest gift in its power to bestow upon an Active Member, viz., Life Membership. (Applause.)

In seconding the motion, Mr. A. F. Miller said he did so with peculiar and heartfelt satisfaction. His acquaintance with Mr. Elvins had extended over a period of thirteen very pleasant years, and dated from the time when a small party of amateurs met occasionally, from house to house, to discuss scientific matters and papers under Mr. Elvins' leadership. Mr. Miller referred to many interesting incidents in the early history of the Society, and said that he was not a little indebted to its founder for assistance when he, at his instance, took up the subject of spectroscopy, and for kindly guidance in many of his own investigations in Astronomy and Physics. The motion should, and no doubt would, be carried with every mark of appreciation. (Applause.)

Mr. Thomas Lindsay desired to add a word to what had been so happily said by Mr. Pursey and Mr. Miller. He had been one of the members present on the memorable occasion when Mr. Elvins read his paper announcing confidently that other satellites in the system of Jupiter existed and would be found. He himself had written the few lines handed to the press, epitomizing the paper; all the world now knew that one satellite had been found, and he (Mr. Lindsay) considered the Society was highly honoured in having on its Life Membership Roll the name of the astronomer who had first called the attention of other observers to the importance of studying closely the Jovian system.

The resolution was then put and carried amid loud applause, which was renewed when the Chairman rose to formally instruct the Recording Secretary to enroll Mr. A. Elvins as a Life Member. Then, addressing Mr. Elvins, Mr. Paterson, in eloquent language, paid a high tribute to the zeal and untiring energy displayed by him in the cause of the advancement of Science, and said it was but necessary to look around to see the fruits of his labours—they would be seen while this Society existed. He hoped Mr. Elvins would long be spared to continue his noble life work.

Mr. Elvins, who was very much moved, was warmly received on rising to thank the Society for conferring upon him Life Membership, an honour of which, he said, he was very proud. In the course of his remarks, he alluded, at some length, to the past, and spoke, with some feeling, of the days when he, Mr. Pursey, Mr. Mungo Turnbull, Mr. Robert Ridgway, and Mr. D. K. Winder, now of Detroit, had, with one or two others, worked together and had tried to keep alive public interest in Astronomy. He said that if he had been instrumental in leading others into scientific pursuits, it was from his own love of such work, and he considered his greatest achievement consisted in having directed the steps of some who had subsequently taken a very high standing in different branches of Science. He had tried to direct his fellows to the study of Nature as a means of recreation and relaxation from toil and worry; to view the Eternal Mind through the medium of Matter, and to regard all men as the children of a common power, which all men reverence—which we call God. Though now a Life Member of the Society, he would not cease to be an active one or to take a lively interest in its welfare. (Applause.)*

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* ANDREW ELVINS was born May 4th, 1824, at Polgooth, near St. Anstle, Cornwall, England. A boyhood amid the tin and copper mines of Cornwall afforded opportunities to cultivate in a mind, sedulously studious, a taste for geology and mineralogy and that love of Nature always characteristic of the

By request, Mr. J. Von Sommer read the following paper contributed by Mr. W. F. Denning, F.R.A.S., of Bristol, England, on

THE RADIANT POINT OF THE PERSEID METEOR SHOWER.

The Perseid Meteor Shower is undoubtedly cometary in its physical relations and its radiant-point exhibits a comet-like motion of about 1° of R.A. per day to the ENE. This motion was for many years enabled to escape detection, though Le Verrier, from theoretical considerations, had intimated that it must exist. Mr. Greg and others found the radiant-point apparently diffused over a considerable area in the Northern region of Perseus, but the position does not appear to have been determined with sufficient exactness, on single nights of observation, to prove

subject of this sketch. The lad's zeal for knowledge was greatly quickened by an acquaintanceship formed with the late Charles Peach, of Goran Haven, by whom he was induced to study Natural History. In 1845, being just of age, Mr. Elvins came to Canada to carve out his own fortune, and settled at Cobourg, where he married Miss Alice Rundell. Though actively engaged in business pursuits, time was found for the study of palæontology chiefly. For this purpose, numerous excursions were made to quarries in the County of Northumberland, and a large and valuable collection of Silurian fossils was formed. Assisted by a few friends, Mr. Elvins started a museum in connection with the Cobourg Mechanics' Institute. In 1860, having removed to Toronto, he became a member of The Canadian Institute, to which he presented some of his best specimens, and before which he has read many papers on Archæology, Astronomy and Meteorology. Having gathered about him a few friends, with similar tastes, he organized The Recreative Science Club, which, for some years, met every Tuesday evening at his dwelling. Reports of its meetings appeared in various journals, including *Scientific Opinion.* The Club eventually became merged with the Natural History Society, an incorporated body, and finally both became the Natural History Section of The Canadian Institute. In 1884, with two or three others, Mr. Elvins founded The Astronomical and Physical Society of Toronto, which became incorporated in 1890. To *The Astronomical Register* and other scientific journals, and to the Toronto daily press, he has been an active contributor upon such topics as "The Sun and the Worlds Around Him;" "The Sun-spot Period and its Relation to Terrestrial Meteorology;" "The Toronto Rainfall and the Fluctuations in the Height of Lake Ontario," etc. In "The Sun and the Worlds Around Him," published in 1872, Mr. Elvins expressed the view that the outer planets are still throwing matter from their surfaces, and when the Great Red Spot on Jupiter appeared in 1878, he thought the planet was ejecting matter which might become a satellite. This view was emphasized in a paper read before this Society early in 1891. Since then, the fifth satellite has been discovered.

the motion. The value of the materials suffered detraction from the following causes :—

1. Inaccuracy in registering the path-directions of the conformable meteors.

2. Errors in including the paths of meteors really belonging to neighbouring showers.

3. Interruptions, by cloudy weather, moonlight or other circumstances, to observations during a number of successive nights.

It will be evident to anyone who reflects on the nature of the research, that it is impossible to entirely eliminate the inaccuracies and hindrances alluded to.

I began observing the Perseids in 1867, but it was ten years later, viz: in 1877, before I first gained a distinct view of the motion of their radiant-point. In that year I derived positions as follows :

August	3-7	40° + 56°	40	meteors.
"	10	43° + 58°	285	"
"	12	50° + 55°	14	"
"	16	60° + 59°	5	"

In the following year, 1878, from July 26 to August 2, I saw 403 shooting-stars and the richest shower proceeded from a point at 32° + 53° which supplied 63 meteors of the swift streak-leaving class. The position of the radiant and the visible aspect of the meteors afterwards led me to the unavoidable conclusion that this strong shower was really formed by early Perseids. Careful observation, directed to this special point in subsequent years, absolutely settled the question and removed all doubt as to two important features in the observed character of the great August stream, viz :

1. The rapid motion of the radiant to the ENE at the approximate rate of 1° of R.A. daily.

2. The long duration of the shower, certainly from about the middle of July to the end of the third week in August.

The late Joseph Kleiber took up the mathematical discussion of the question in 1891, and a very useful paper of his was published in *The Monthly Notices* for March, 1892, in which he concisely showed that observation and theory were satisfactorily in harmony as to the shifting radiant. His computed positions for the Perseid radiant exhibited a mean difference of only 1°·32 when compared with 49 determinations of the place made at Bristol between July 8 and August 16 in various years. The agreement (as in nearly every case where observation and theory are matched for the first time) was not, however, perfect, especially as regarded the beginning and ending of the shower, but as the observations at these limits were extremely meagre and uncertain no other result could have been reasonably expected. It remained for future observations to correct those previously obtained and to bring about a still closer analogy between the observed and calculated radiants.

An excellent opportunity occurred in the present year which has been exceptionally favourable for the English astronomical observer for he can now (September 30) look back to about seven months of summer weather, and a proportion of clear nights far in excess of the average. I watched the progress of the Perseid display on ten nights between August 4 and 16 and obtained results in remarkable consistency with Kleiber's computations. It is evident that my observation on August 16, 1877, of a shower at 60° + 59° is too far East to represent the true Perseids on that date, and that Kleiber's position at 54° + 59° more nearly accords with its actual place. I am fully persuaded of this by several observations secured here since 1877. Thus on August 16, 1884, I recorded a brilliant Perseid close to its radiant, and with a path very accurately observed from 52° + 63° to 51° + 67° and therefore directed from a point at 53° + 58°. On August 16, 1892, I noted a pretty bright meteor apparently from the same centre. On August 16, 1893, I saw 4 meteors under the best conditions and obtained a good radiant at 52° + 57°. As to the Camelids seen on August 16, 1877, they represented a distinct system as I fully realized from evidence gained in August, 1893, for I saw 11 meteors from a radiant at 61° + 60° August 8-15, while at the same epoch the Perseid radiant was definitely manifested several degrees to the Westward. Quite possibly, the Camelids seen in 1877 and 1893 may be a continuation of a shower which I distinguished in 1878, July 30-August 1, at 65° + 60°.

For the guidance of future observers, I give an ephemeris of the Perseid radiant during about one month of its activity. It is based upon the most reliable of my observations:—

EPHEMERIS OF THE PERSEID RADIANT-POINT.

Date.	Radiant. α	δ	Date.	Radiant. α	δ	Date.	Radiant. α	δ
July 19	19°	+ 51°	July 29	32°	+ 54°	August 8	42°	+ 57°
" 20	20°	+ 51°	" 30	33°	+ 55°	" 9	44°	+ 57°
" 21	22°	+ 52°	" 31	34°	+ 55°	" 10	45°	+ 57°
" 22	23°	+ 52°	August 1	35°	+ 55°	" 11	46°	+ 57°
" 23	25°	+ 52°	" 2	36°	+ 55°	" 12	47°	+ 57°
" 24	26°	+ 53°	" 3	37°	+ 56°	" 13	49°	+ 58°
" 25	27°	+ 53°	" 4	38°	+ 56°	" 14	50°	+ 58°
" 26	29°	+ 53°	" 5	39°	+ 56°	" 15	51°	+ 58°
" 27	30°	+ 54°	" 6	40°	+ 56°	" 16	53°	+ 58°
" 28	31°	+ 54°	" 7	41°	+ 57°	" 17	54°	+ 58°

The shower needs attentive watching before July 19 and after August 16, though it is undoubtedly very feeble at those times, the Earth being probably situated only just within the outlying borders of the stream.

It is perhaps a little singular that, though half a generation has passed since the moving radiant was discovered, no adequate meausres have been adopted to confirm the fact observationally. It is true that it has received a certain amount of corroboration from observations by Mr. Booth and some others in England, but the point is one of so much significance and interest that it needs thorough ventilating, and this we may confidently expect it to receive at the hands of competent and energetic observers in future years.

Several members spoke of the value of the paper just read, and praised the steady application and patience which had placed Mr. Denning in the front rank of observers.

THE ASTRONOMICAL AND PHYSICAL EXHIBITS AT THE WORLD'S FAIR,

was the subject of a paper by Mr. G. E. Lumsden, who said that one of the difficulties attending a satisfactory examination of the scientific exhibits at Chicago was due to the fact that they were not gathered under one roof, but were widely scattered in various buildings. Those pertaining to Astronomy and Physics were found, some in the United States' Government Building, some in the State and Colonial Buildings, some in the Agricultural Building, some in the Mining Building, others in the Electricity Building, and more in the Manufactures and Liberal Arts Building. In this respect, the rule seemed to be for each country, and, indeed, each institution, educational or otherwise, to collect into one place all the exhibits which by any manner of relationship could be arranged together. For instance, the very complete collective exhibition of German scientific instruments and appliances, in charge of Dr. A. Westphal, was hived away in a gallery in the Electricity Building, where, under ordinary circumstances, no one would dream of finding it. This collection reflected great credit upon the Germans generally, and especially upon the Deutsche Gesellschaft für Mechanik und Optik, an association of mechanicians and opticians formed to encourage and support the manufacture of scientific apparatus of every description. Even a cursory examination of the numerous cases filled with instruments and appliances was sufficient to show that the members of the Association strove to attain to a very high standard of excellence. It was contended by Dr. Westphal that the entire development of German mechanical art, "admittedly not always equal to the development in England and France, had emanated from the full appreciation of the principle that the practical maker must know the intentions of scientific men which are to be realized by the instruments, and, also, the limits of the required exactness, and, *vice versa*, that the investigator must not be an entire stranger to the manufacture of his instruments, but must know their theory, and, with critical knowledge, only demand that degree of exactness which is necessary for his work, or which is attainable." This principle had been mutually cultivated by the Deutsche Gesellschaft, the philosophers working in unison with the mechanicians. Pages could be written upon the subject of the completeness and general excellence of the display which included astronomical and physical, as well as surveying, metronomical, hydrometric, meteorological, optical, chemical, electrical, electro-therapeutical, physiological, didactic and horological apparatus, the mere enumeration of the varieties of which would be tedious. Some idea of the quantity of scientific instruments manufactured in the Empire could be gained from the official statement that in 1892 there were 526 establishments, each employing not less than ten skilled persons, and that the aggregate number of individual employees was 7,614, and further, that, in all, there were more than 1,500 places, including shops and private houses, where workmen were busy in the construction of scientific apparatus of a high order. Consequently, there were many exhibitors at Chicago, but time permitted reference to but three of the makers of optical instruments. Merz, of Munich, showed two superb refractors, equatorially mounted on iron pillars, one 6-inches, the other 5-inches in aperture. The 6-inch was a perfect beauty in finish, and was complete at all points, possessing every known appliance, as well it might, its price being $5,000, though in the closing week of the Fair perhaps $4,000 in cash would have purchased it, as Merz did not wish that it should return to Germany. The 5-inch was for sale at $2,000, and though a much plainer instrument, was doubtless a very fine one. Besides these, Merz exhibited ten first-class object-glasses, ranging in diameter from five to eleven inches. Franz Schmidt and Haensch, of Berlin, exhibited spectroscopic appliances in profusion, all exquisitely finished and of great excellence. But, perhaps, the most interesting display was that of Schott & Genossen, of Jena. The exhibits of this firm consisted of finished discs for telescopic objectives, including one set of ordinary silver flint and ordinary silver crown lenses, 23-in. in diameter (since purchased by Dr. J. A. Brashear), besides smaller ones; polished slabs of optical glasses, ordinary crown-glasses, heavy and heaviest baryta crown-glass of high refractive power, crown-glass of high and of low dispersion, phosphate and borate-glasses free from silica, baryta light flints, etc., etc. Some of the specimens of densest silver flint-glass were like rich amber in colour. All the samples were beautifully polished, and seemed to be of the highest order of excellence. After some further references to the German exhibit, Mr. Lumsden described, at considerable length, the extremely interesting display of meteors, including siderites, siderolites and aërolites, either in their original form, or with polished surfaces showing the Widmannstätian figures, faults, etc., in one of the galleries of the Mining Building, made by Ward's Natural Science Establishment, Rochester, N.Y. Some of the largest known individuals were represented by casts hung from the ceiling or arranged on shelves so as to be easily examined. The writer dwelt upon the more notable Canadian specimens on exhibition and their analyses, etc. Many plates illustrating these and other meteors and their polished surfaces were shown to the members, and it was stated that the Rochester collection now includes the famous Knyahinya and other specimens, slides, etc., purchased from Dr. Otto Hahn, of Toronto, a member of the Society. Allusion was next made to the astronomical exhibit of the American manufacturers, including the fine displays severally shown by Dr. Brashear, Warner & Swasey, Saegmüller, and others. This exhibit was arranged on the floor of the North Gallery in the Liberal Arts Building and overlooked the Yerkes glass, itself an object of ceaseless interest to the thousands who, day after day, thronged that building, at once magnificent in its proportions and in its exhibits, the latter occupying forty acres of floor-space. Even when the great tube was motionless there was to the awed on-looker something uncanny about it, for it was not difficult to imagine the telescope to be a Thing of Life with a sleepless eye, oblivious of that which was around it, and ever trying to pierce the remotest depths of Space. But this sensation, due to this pardonable personification, was vastly increased when, apparently without a human being near it, but really when electrically controlled by an assistant seated at a small table close to its gigantic base, it began and continued to move on its axes, slowly, gracefully, silently, and without a jar, as if in search of something hidden in the far distant Beyond. Truly this mighty instrument is a splendid, nay, a princely, gift to Science. The telescope was in charge of Messrs. Warner & Swasey, who took great pains to explain its mechanism to every astronomer, and who presented to the writer a very fine photograph of it taken by Mr. S. W. Burnham, and shown to the members. Recent letters from the firm and from Messrs. Alvan Clarks' Sons respecting the instrument and the excellence of the lenses, now being figured, were read to the Society.

Dr. Brashear's exhibit included a beautiful 18-inch objective, worked after the mathematical formula of Professor Hastings, of Yale University. This objective was from glass made by Mantois, of Paris, and, after polishing and figuring, was tested by Professors Keeler and Leuschner, and pronounced to be "as perfect as could be made from the material at hand." The exhibit embraced other object-glasses of great optical perfection; plane and parallel surfaces for the Michelson and Jamin refractometers; grating-plates (Reseau) polished and corrected by Dr. Brashear, and ruled by Professor Rowland; prisms of the highest excellence, siderostat-mirrors of large diameter, silvered glass specula of great beauty; the large star-spectroscope for the Yerkes telescope; standard spectroscopes, telespectroscopes, two-mirror heliostat, and a 6-inch silvered-glass reflecting telescope complete. Dr. Brashear might well be proud of his display, and yet, in a letter, he stated he had been too busy to attempt to make a special one. In the California State Building there was shown a fine series of most interesting and valuable glass transparencies of the Milky Way, the planets, the Moon and comets, which reflected great credit on the staff of the Lick Observatory, by which they were made. In the Government Building, the Smithsonian Institution made a display of engrossing interest, including a series of very large photographs and glass transparencies, which challenged the admiration of everybody; they were not, however, all in respect of astronomical and physical subjects. Some drawings of Jupiter and Saturn made by Professor James E. Keeler, and shown in the Liberal Arts Building, were entirely worthy of that eminent astronomer. The French exhibit of scientific apparatus was, for the most part, grouped in a small section in the same building, difficult to find, as it was surrounded by exhibits of various kinds, including cases of silks, ribbons, and laces, and exquisite creations of the milliner's art, etc. The telescopes were few in number. One of the exhibitors was the firm of Vion Freres, of Paris, whose portable instruments are being introduced into this part of Canada by their agents, Messrs. Michael Brothers, of Toronto. Telescopes made in Great Britain and Ireland were conspicuous by their absence, not one instrument being on the grounds. Sir Howard Grubb had intended making an exhibit, but finally decided not to do so. Dr. Ainslie Common exhibited his splendid unsilvered 5-foot parabolic speculum, but it was placed practically by itself in the West Gallery of the Liberal Arts Building, just behind Watson & Son's microscope exhibit and in front of York's lantern-slide exhibit. Unfortunately, the Secretary of the British Commission had overlooked putting a legend upon it, so that it was, no doubt, thought by hundreds to be merely a very pretty piece of heavy circular plate-glass. Twice Dr. Brashear tacked an explanatory card upon it, and many times directed astronomers to it, as did also his representative, thus affording another instance of that good nature which has made the Doctor very popular. Another unfortunate error of the Commission was the neglect shown Dr. Gill's beautiful star photographic transparencies. These exquisite plates were not only placed—of all places in the world—in the exhibit of the Cape of Good Hope, in the Agricultural Building, but were not even hung up, the man in charge stating to some of the privileged few who found them, that he could not get from his Commissioner the £2 necessary for a frame. At least one kind-hearted American who loves Science for her own sake, would have furnished the means had he learned the humiliating facts in time, but he did not make the discovery until shortly before the close of the Fair. In inconsequential corners, and sometimes on the dark sides of partitions in sundry parts of the West Gallery in the Liberal Arts Building, were suspended the exhibits of those famous British bodies, the Royal Astronomical Society and the British Astronomical Association. In spite of the drawbacks, every scientific Canadian gazed long and lovingly upon the work of his British relatives, and much of it was very fine indeed. The Royal Astronomical Society exhibited, in brief, fourteen exquisite plates by Dr. Isaac Roberts, two large photographs of composite drawings made from all the negatives of the total solar eclipse of 1882, photographs of eclipses of 1870, '71, '82, '83 and '86, photographs of compared spectra of the Sun and meteorites from D to K, series of nine photographs of the great Sun-spot of February, 1892, spectra of the Sun, Arcturus and Nova Aurigæ, thirteen photographs of stellar spectra, photographs from Greenwich Observatory including chart plates of the Pleiades, catalogue plate with trail for orientation, ω^2 Cygni (7 exposures), photographs of the Sun, photograph of Great Comet of 1882, by Dr. Gill, and Captain Abney's photograph of the infra-red solar spectrum. The British Astronomical Association made a very fair exhibit for so young a Society; and showed that it is a virile one. The display included various fine drawings and publications. Four drawings of the Milky Way, made by Dr. Otto Bœddicker, were justly admired. Not far off was Professor Lippmann's very instructive and interesting exhibit of photographs of spectra and other objects in colours. The venerable and worthy Vatican Observatory was represented by a set of valuable publications. The College displays were all interesting and some absorbingly so. The people of the United States had reason to be proud of the exhibits made by their greater seats of learning As one gazed upon the splendid showing of the American and German Universities, one, if he were from the Canadian side of the border, at least, saw reason for regretting that not one British or Canadian University was represented at Chicago. It is, however, gratifying to know that the system of public education in Ontario received ample justice at the hands of the Government, and of its head, the Minister of Education, there being an extensive and, perhaps, unrivalled exhibition of books, apparatus, etc., which, it may be mentioned for the purposes of this paper, included the following specimens of the handiwork of Mr. Mungo Turnbull, of Toronto, a venerable member of this Society:—An 18-inch terrestrial globe, specially adapted for use in Public and High Schools; an 18-inch celestial sphere, so constructed that the student, having the whole combination of the stars and constellations before him, can carry on his studies within doors, and a 12-inch orbital moving globe, constructed to illustrate the four motions of the earth in its annual course round the Sun, and also the beam of light constantly flowing from the Sun whose rays illuminate that portion of the Earth's surface which faces the Sun's disc. Astronomical displays, more or less elaborate in various, if not in all, departments, were shown by the Universities of Harvard, Yale, Princeton, Johns Hopkins, and the City of New York, and the Western University of Pennsylvania, while more or less ambitious efforts were made by the State Universities of Michigan and Wisconsin, by the Clark, Lehigh and De Pauw Universities (this latter showed one of the two Chandler almucantars in existence), and by Amherst, Carleton, Beloit, Mount Holyoke, Smith, Vassar and other Colleges. Though others competed in the modern astronomical field, Harvard came first with the largest display, which included several hundred interesting photographs of instruments and observatories in Cambridge, Colorado, California, Chili and Peru; of stellar spectra, double-stars, star-trails, comets, clusters, nebulæ, solar corona, the Moon, Jupiter and his satellites, Mars, Saturn and satellites, Uranus and three moons, Neptune and moon, etc. But as one passed from case to case, from alcove to alcove, one could not help taking a deep interest in the exhibits eloquent of the labours of philosophers, some of them long since dead and gone to their rewards. There seemed to be, after all, some evidence that in this busy world there are many bosoms in which, on occasion, can spring into existence lively sentiments of profound respect for and even something of gratitude to those who, for the love of Science, pure and simple, spent many a weary hour in endeavouring to unravel her mysteries, and arrive at the truth. Not infrequently, over some battered box, some rusty mass of broken and bent wires, magnets, coils and cells, or over some conglomeration of rods, glass and wax, or over a puny thermometer embedded by loving hands in cotton-wool, or over some faded daguerreotype, or print, might be seen men, standing in that attitude of respectful sympathy (too often reserved for the side of the grave of departed worth), for the moment appreciating that they were in the presence of some precious relic of a Henry, a Draper, an Agassiz, a Franklin, a Priestley, a Kirchoff, a Guericke, a Magnus, a Helmholz, and even of a Fraunhofer. A Philadelphia High School master, interested in Astronomy, to whom the writer was introduced in Warner & Swasey's section, asked the latter if he had seen the Magdeburg Cups shown in the collective exhibit of the German Universities. On being answered in the negative, the Philadelphian, with a tremor in his voice and a fervor that did him credit, exclaimed, "I have had that honour. The cups have actually been touched and even lifted by *these* hands. Be sure and see them," an injunction which the favour of Dr. O. Lassar, the superintendent, enabled the writer to do to his full satisfaction. Venerable Princeton, among an endless variety of exhibits, showed an electrical machine devised by Franklin and used by Priestley; an electro-magnet, made by Henry, which had sustained a weight of 3,500 pounds; Agassiz's thermometer used by him in Switzerland; Fahrenheit's original thermometer, a glass-rod, still spotted by red sealing-wax, used by Franklin in his electrical experiments; Henry's original electro-magnetic motors, and a Rittenhouse orrery in very sad repair, and bearing a legend to the effect that it was made in Philadelphia in 1768, was bought by the President of the College for £300, and was injured by the British troops when quartered in Nassau Hall during the Revolution. The Western University of Pennsylvania exhibited Langley's bolometer in its original form as invented in 1881, and described as "an instrument for measuring heat-radiation of feeble intensity such as the determination of wave-lengths in the extreme lower end of the spectrum, the distribution of energy in the spectrum of the Moon, and the radiation of heat by gases;" also photographs of the infra-red solar spectrum and of bands in the solar-spectrum determined by the bolometer at Allegheny Observatory by Langley in 1887. The display of the University of the City of New York was rich in the relics of the elder Draper. There was his original iodine-box, his chlor-hydrogen photometer, afterwards adapted by Bunsen and Roscoe in their photo-chemical researches at Heidelberg, his camera, with a spectacle-lens, copied from the segar-box camera (used in taking the first daguerreotype portrait) with holes in front and sides for experiments in researches in light, his ammonia-sulphate of copper cell (glass three and one-half inches square, with cell two inches in diameter) used in getting the chemical focus in micro-daguerreotypes, his microscope, his mercury-box, his camera with one achromatic convex and two plano-convex lenses with adjustable diaphram, his daguerreotype plate of the solar-spectrum taken, in 1844, in Virginia, with a triangular aperture one-fourth of an inch on base and three-eighths of an inch on each side, fifteen seconds' exposure, and showing one straight line or band diagonally left to right, length of spectrum about three inches, and (possibly most interesting to the passer-by) the first daguerreotype picture of a human face taken (in 1840) by Draper of his sister, the exposure (of ninety seconds) being made in full sunlight on the roof of a building, and the lady's face being dusted over with white powder to aid the Sun in making an impression on the plate. The University sold artotype copies of this picture, whose authenticity was formally certified by the present representative of Sir John Herschell, to whom the picture was sent, and in whose family it remained until last year. The University showed the Morse battery by which, within its walls, was sent the first telegram, and also the original of the following, the first public message ever telegraphed : January 24th, 1838 : " Attention ! the Universe by Kingdoms, Right-wheel," a message stated, by the appended legend, to have been almost prophetic in the words that had been associated, as it were, by inspiration. Another deeply interesting exhibit was that of the Henry Draper Memorial, which included photographs of that lamented astronomer as well as of the Moon (1863) greatly enlarged, and of the instruments with which he took photographs (1872) of stellar-spectra and of the nebula in Orion, which were improved upon in 1881 and in 1882, the year of his death ; also the photograph of the comparison spectrum by which he discovered the existence of oxygen in the Sun, the upper part of the spectrum being that of the Sun, the lower being that of oxygen and nitrogen of air and showing the co-incidence of bright oxygen lines with bright solar-lines. As it was in the German Scientific Instrument Department, so was it in the German University Department, which occupied a large space in the Liberal Arts Building. The display was very elaborate. The astronomical and physical exhibit was especially interesting, not only because it was very complete, but because it also contained precious momentoes recalling the past. For instance, one might see Kirchoff's original spectral apparatus, Fraunhofer's terrestrial telescope, Helmholz's electrometer, Magnus' apparatus for the expansion of gas by means of heat, etc., Fraunhofer's heliometer, used by him in 1814, and, having been reconstructed, used again for the transits of Venus in 1874 and 1882, rusty instruments, wire, etc., used by Gauss and Weber in their electro-magnetic telegraphic experiments, and last, but not least, the original Magdeburg Cups constructed by Guericke, to show the pressure of the atmosphere, and to which reference has already been made. Among the exhibits in the War Department was the original specimen of the class of telescope invented in 1834 by Captain Andrew Talcott, U. S. Corps of Engineers, for the purpose of determining latitude by his method. The instrument was about three inches in clear aperture, and had a focal length of forty-two inches. It was intended to substitute for absolute zenith measurements in the determination of latitude, the differences of zenith meridional distances of two stars on different sides of the zenith, the stars being so selected that this difference may be less than the arc embraced in the field of view of the telescope to avoid the necessity of changing the position of the telescope in altitude. Tacked to the telescope was a description of it, and inserted in the War Department Catalogue was a remark by Colonel King, the exhibitor, to the effect that Captain Talcott's "has long been recognized as the most accurate method for the purpose of determining latitude known to astronomers."

One of the most interesting as well as instructive exhibits was that made by the United States Navy, including, as it did, the model of an armoured line-of-battle ship, which, as a compliment to the State where the Fair was held, was called "Illinois." Under the auspices of the Navy Department, the Naval Observatory at Washington made a display of astronomical and meteorological and time-keeping instruments. These were in the charge of Lieutenant A. G. Winterhalter, U. S. N., who proved himself to be a very efficient and courteous superintendent. The exhibit was distributed in three or four small, but suitable, buildings near the lake shore and in the vicinity of the battle-ship. The main building had two rooms. The smaller was a dark room where could be shown the solar image on a disc four inches in diameter as formed thereon by the photoheliograph placed at a distance of about forty feet. In the larger room was the display of the Observatory's time, chronometer and magnetic services with various objects of astronomical and nautical interest. Certain instruments in the room were connected with the Observatory at Washington, from which every day at noon (Central Standard Time) a signal was received by telegraph. Around the room were suspended clocks showing Greenwich, Paris, Berlin and Vienna Times, as well as other clocks indicating Eastern, Central, Mountain and Pacific Standard Times. Around the walls were also suspended a series of beautiful original drawings of celestial objects. These included Trouvellot's famous drawing of the solar eclipse of February 29, 1878, made at Creston, Wyoming; Trouvellot's drawing of the Omega nebula, September, 1875, as seen in the great 26-inch telescope at

Washington; Trouvellot's drawing of the Orion nebula made at the same time and at the same telescope; Trouvellot's drawing of Saturn made with the same instrument during the month of September, 1875. This drawing shows not only the shadow of the planet on the ring-system, but certain notches in the ring, the accuracy of which has been questioned. The photoheliograph shown was one of eight used during the transits of Venus, and had an aperture of 5 inches and a focal length of 38 feet. There were also a transit instrument and a 5-inch Clark equatorial telescope, the latter in continual use by the public, and both mounted under suitable domes. While the Lieutenant and the writer were in the Transit House, in which, in addition to the instruments, were suspended various large photographs taken by him, a captain in the French navy, one Count de Ballancœur, was introduced. The ensuing few moments' conversation, respecting various astronomical instruments, was conducted in French, in which language, as well as in the general subject, the Lieutenant showed himself proficient. No doubt this proficiency had much to do with the selection of Mr. Winterhalter by his Government some years ago to make a tour of inspection of all the Observatories in Europe, the results to be used in placing the new Naval Observatory at Washington in the most efficient condition possible. There were also in the main building astronomical, sidereal and controlled clocks, chronographs, chronometers, eclipse-cameras, instruments for correcting sextants, sextant-mirror testing apparatus, thermostats, etc., etc., and photographs of observatory and other appliances in use in Washington. The exhibit had also a pathetic side. For instance, there were two of Captain Hall's aneroid barometers which were buried in the Arctic ice for four years, and were recovered by Sir George Nares' Polar Expedition and returned to the United States Government. These instruments had been exposed to temperatures of cold as low as 104 degrees below zero. There was, also, a marine chronometer taken from the ship Florida, when captured at sea, also Perry's astronomical clock which had been exposed to the viscissitudes of three years' service at various points on the shores of the China and Japan Seas; also one of the chronometers taken out by the ill-fated Jennette Arctic Expedition, the Jennette having been crushed in the ice in the Arctic Ocean in June, 1881. This chronometer had been used by Commander de Long to navigate his boat to the delta of the Lena River in Northern Russia, and was found among his effects at the place where he and his party succumbed to the rigours of a Russian winter. There were also six chronometers which were ruined during the dreadful hurricane at Samoa which, on the 16th and 17th March, 1889, sunk the United States Ships Vandalia and Leipsic and drowned many brave seamen. Mr. Lumsden dwelt upon various other matters connected with the Exhibition, and closed his paper by saying that not by any means the least enjoyable portion of the visit paid to Chicago was the delightful half-hour spent with Mr. S. W. Burnham, who, though the Clerk of the United States Court, and a busy man, finds time to keep in touch with his beloved Science, and to whom the writer expressed his regret that among the interesting exhibits at the Fair was not found the 6 inch telescope, which, with himself, had grown famous.

TWENTY-FIFTH MEETING.

December 26th ; Mr. Robert B. Ellis in the chair. There was a fair attendance of members. Among the letters read was one from Dr. Joseph Morrison, M.D., Ph.D., etc., of Washington, promising papers. Mr. Mungo Turnbull, of Toronto, was elected an Active Member. The next meeting of the Society being the annual one, several important notices of motion were given. Mr. Pursey, the Librarian, presented an unusual number of publications, which included a copy of Prof. J. E. Keeler's admirably illustrated paper, "Physical Observations of Mars during 1892"; a set of *The Sidereal Messenger* and of *Astronomy and Astro-Physics*, covering several years, and several volumes on various subjects, the gifts of Mr. G. E. Lumsden and other members. On motion of Mr. Thomas Lindsay, seconded by Mr. D. George Ross, all the officers of the Society and members of the Council for 1893 were re-nominated for 1894. Mr. Lumsden handed in a photograph of a pretty specimen of frost tracery on a window-pane, and rough drawings, made at the telescope on the 26th, of Venus and of Jupiter, as seen in bright sunshine, about 4 p.m., both planets being visible on the clear sky. Mr. A. F. Miller reported the presence on the solar disc of many interesting sun-spots. Seven groups, three in the Northern hemisphere and four in the Southern hemisphere, were especially noteworthy. Mr. Lindsay called attention to the very valuable scientific papers made available by the recent binding of the reports received from the Royal and other Societies. In reply to a question, Mr. Elvins stated that many years ago, in the course of a long series of solar observations, he came to the conclusion that there was some relationship between the frequency of sun-spots and the rainfall, and he undertook to predict the rainfall for each of the years 1870 and 1871; the results were that he was out only about one-quarter of an inch in 1870, and less than an inch in 1871.

Miss A. A. Gray read from *Popular Astronomy* a most interesting article by Professor E. E. Barnard, of Lick Observatory, descriptive of the very peculiar appearances presented on the mornings of October 21st, 22nd, and 23rd, by Brooks' Comet (d 1893), and shown by photographic plates taken by a long-focus Willard lens in a camera strapped to the 12-inch telescope. On the dates mentioned, the comet's tail, previously a straight and graceful one, appeared on the negatives to be shattered, distorted and deflected by some agency at present not understood. The comet had evidently collided with some resisting medium, though probably of "extreme unsubstantiality," the detection of which was, in Mr. Barnard's opinion, of great importance. As these phenomena were wholly invisible in powerful telescopes, this was but another hint of the greater disclosures to come from the systematic application of photography, "revealing to us wonders of a startling nature where the unaided eye looks upon blank space." Mr. J. A. Copland also contributed a paper on the same subject, founded upon a special communication sent by Mr. Barnard to Mr. E. W. Maunder, F.R.A.S., of Greenwich Observatory, who published it, with observations of his own and copies of Mr. Barnard's negatives, in *The London Daily Graphic*. Mr. Copland's terse paper was illustrated by these plates.

THE FOURTH ANNUAL MEETING

was, on the 9th of January, 1894, held in the Society's Rooms, 19 McGill street, Mr. John A. Paterson, M.A., Vice-President, presiding. The attendance was unusually large, and included many ladies. Mr. F. H. Young, M.A., of Belleville, was elected an Associate-Member.

In pursuance of notice given at the previous meeting, Mr. Thomas Lindsay, seconded by Mr. D. Geo. Ross, moved, That whereas much of this Society's prosperity during the past year has been due to the deep interest taken by its officers in all branches of its work, and whereas, some of the excellent measures for enlarging the Society's field of usefulness are still under consideration, therefore, be it Resolved that the best interests of the Society will be served by making no change in the list of Officers and Members of Council for 1894, and that the Recording Secretary be requested to prepare one nomination paper containing the names as they stand now upon the Roll, and that the election of these Officers be made unanimous. Carried, amid applause. Mr. Sparling thereupon cast a ballot, and the following

OFFICERS AND MEMBERS OF COUNCIL FOR 1894

were declared to have been duly elected :—Honourary President, the Honourable G. W. Ross, LL.D., Minister of Education for Ontario; President, Mr. Charles Carpmael, M.A., F.R.A.S., F.R.S.C., Director of the Toronto Observatory; Vice-Presidents, Mr. Larratt W. Smith, D.C.L., Q.C., and Mr. John A. Paterson, M.A.; Treasurer, Mr. James Todhunter; Corresponding Secretary, Mr. G. E. Lumsden; Recording Secretary, Mr. Charles P. Sparling; Librarian, Mr. G. G. Pursey; Council, the Executive Officers and Messrs. E. A. Meredith, LL.D., A. Elvins, A. F. Miller, A. Harvey, and D. J. Howell. Miss Sarah L. Taylor, was re-elected Assistant-Treasurer; Miss A. A. Gray, Assistant-Recording Secretary; Miss Jeane Pursey, Assistant-Librarian; and Mr. John A. Copland, British and Foreign Correspondent.

NEW HONOURARY AND CORRESPONDING MEMBERS.

The Corresponding Secretary stated that in compliance with instructions received at a meeting of Council held in December, he had communicated with certain well known scientific men with a view to ascertaining whether they would be willing to accept the relationship to the Society of Honourary and Corresponding Members, to which positions it was thought fitting they should be elected. In every instance, nomination had been gracefully accepted and in terms highly complimentary to the Society, a matter for great satisfaction as it indicated that the Society had succeeded in making for itself a reputation of which, it was to be hoped, it was not entirely unworthy, and which, now that further illustrious names were to be inscribed on its Rolls, it should do all in its power to deserve and to sustain. For instance, Sir Robert Ball, of Cambridge University, the well known writer and lecturer, had replied, "I shall, indeed, be proud to accept the very honourable distinction you propose to confer upon me. I esteem it a very high compliment, and I only wish I felt more worthy of it." Professor G. H. Darwin, F.R.S., also of Cambridge, author of several important works, wrote "I shall have much pleasure in accepting the Honourary Membership of the Toronto Astronomical and Physical Society if my nomination is accepted by the Society. I beg leave to thank the Society in advance for the honour which they propose to confer on me." Professor S. P. Langley, Secretary of the Smithsonian Institution, wrote, "I have pleasure in acknowledging the receipt of your communication in which you pay me the compliment of asking me to accept Honourary Membership in The Astronomical and Physical Society of Toronto. I beg to assure you of my sincere appreciation of the action of the Society in this connection and of my gratification in accepting the honour thus shown me." Professor E. C. Pickering, of Harvard, who had always taken a kindly interest in the Society and had laid it under obligations not only by donating the publications of his great Observatory but by promptly answering various questions submitted to him, said "Your letter asking if I should be willing to accept Honourary Membership in The Astronomical and Physical Society of Toronto is duly received. In reply, if I should be elected, I should accept with pleasure. With regards and pleasant reminiscences for Mr. Carpmael, I remain yours faithfully," and, later, after notice of election, "Please convey to the Society my sincere thanks for this honour." In his reply, the venerable M. Otto Struve, of St. Petersburg, wrote, "Only yesterday, I received your communication that The Astronomical and Physical Society of Toronto will honour me by nomination as Honourary Member. Probably my answer will come too late for the annual meeting; however, I will not let pass a single day without expressing my thanks to the Society for the intended honour. In fact, I shall feel proud to be made an Honourary Member in company of those men you named in your letter. Though, at my age, I can hardly expect to make myself essentially useful to the aims of the Society, I shall certainly do it if an occasion presents itself, and with the greatest of pleasure. With respectful compliments and thanks to Mr. Carpmael, very truly yours." Professor Doctor H. C. Vogel, of Potsdam, the celebrated spectroscopist, said, "I beg you to accept my very best thanks for the communication you kindly made me in your letter. The great honour The Astronomical and Physical Society is willing to afford me by a nomination to the Honourary Membership is to be estimated most highly and I shall be very glad to accept this honour. I beg you to transmit my very best compliments to Mr. Carpmael." The Reverend T. E. Espin, F.R.A.S., of Tow Law, Darlington, a frequent correspondent, said, "Your communication in which you inform me that The Astronomical and Physical Society of Toronto intend to do me the honour of making me a Corresponding Member, has just reached me. In accepting, may I ask you to convey to the members of the Society my sincere thanks and wishes that what I shall soon hope to call *our* Society may be as flourishing in the future as in the past. I have watched with great interest its progress and the increasing value to Science of its publications." Professor G. E. Hale, Director of the Kenwood Physical Observatory, wrote from Berlin, Germany: "Thank you for your very kind letter, which has just reached me *via* Chicago. Please convey to the Society my thanks for its offer to elect me a Corresponding Member. I highly appreciate the honour thus shown me, and shall take pleasure in accepting the relationship in case the election is made." M. Paul Henry, of the Paris Observatory, one of the justly celebrated photographers of celestial objects, wrote, "C'est avec la plus grande reconnaisance, quoique en etant bien indigne, que j'accepte la grande faveur que vous voulez bien me faire en me proposant de me nommer Membre Corspondant de votre Sociètè. C'est un bien grand honneur pour moi de voir mon nom auprès des noms illustres de Miss A. Clerke, Messieurs Gore, Denning, S. W. Burnham, etc. Je vous prie, cher Monsieur, d'agréer, avec tous mes remerciements, l'expression de mes sentiments très distingués." Professor James E. Keeler, of Allegheny Observatory, the spectroscopist and discoverer at the Lick Observatory of motion of nebulæ in the line of sight, said, "I beg to thank you very sincerely for your letter. It will give me great pleasure to become a Corresponding Member of your Society, the good work of which is known to me. I feel, however, this hesitation, that I am a member now of more Societies than I can do justice to, and my correspondence must be limited, but if you can overlook an apparent lack of interest due to this cause, I shall he glad to have my name enrolled in your list." In a later letter, the Professor, in returning thanks for election, expressed the hope that he would shortly be able to contribute a paper as a result of some discussions of matters relating to the theory of the telescope. (Applause). Mr. Edward W. Maunder. F.R.A.S., First Physical Assistant at Greenwich Observatory, said, "Please assure The Astronomical and Physical Society of Toronto of my sense of the honour they have done me in nominating me as a Corresponding Member and convey to them my grateful acceptance of the position. I fear my somewhat numerous duties will but seldom allow me to contribute to their proceedings, but should I be able, I shall endeavour to do so. The diffusion of a love for Astronomy and the organization of astronomical workers are objects I have much at heart, and I most sincerely congratulate the Toronto Society on the success they have already attained in these fields." Professor C. H. McLeod, of McGill College, Montreal, a well known Canadian Astronomer, wrote, "Please convey to the Society my sincere thanks for the offer to place me on its list of Corresponding Members. I need not say that I appreciate the compliment highly, and shall be glad to accept the position. The knowledge that the nomination comes at the instance of your President, Mr. Carpmael, with whom, I have, for many years, had such pleasant relations and for whose great ability I have the highest respect, very much enhances my pleasure in accepting." Professor W. H. Pickering, of Arequipa, Peru, writing from Cambridge, Mass., said, "I may say it will give me great pleasure to become a Corresponding Member of your Society. Thanking you for the honour done me." Professor William A. Rogers, of Colby University, Waterville, Me., who has taken a deep interest in Canadian scientific matters, said, "I should highly appreciate an election to your Society as a Corresponding Member." The reading of these letters was followed by loud applause. Each of the candidates was formally proposed by motion, duly seconded, movers and seconders introducing their motions with remarks of a character complimentary to their nominees and their work. Each motion was carried unanimously. After the elections were over, the Chairman reminded the Society that with such illustrious names on its Honour Rolls, it must strive harder than ever to sustain the reputation which had largely been instrumental in inducing the new members to accept the invitations which had been sent to them.

On motion of Mr. Robert Dewar, seconded by Mr. G. G. Pursey, the cordial thanks of the Society were directed to be tendered to the editors of *The Globe*, *The Mail* and *The Empire* for their unvarying courtesy and for enabling the Society, by a generous use of their columns, to reach the general public and, by means of reports of meetings, articles and notices, to awaken a wide interest in Astronomy and Astro-Physics. Two non-members presented plates, suitable for framing; the one showing the Yerkes telescope as it was to be seen at Chicago, the other showing the Lick telescope in its dome at Mount Hamilton.

Mr. Pursey laid on the table various publications, including the last reports of The British Astronomical Association and The Astronomical Society of the Pacific, as well as a presentation and advance copy of the first volume of the new edition of Webb's "Celestial Objects for Common Telescopes," published by, and received from, Messrs. Longmans, Green & Co., of London. In addition to the compliment thus paid by the publishers, Rev. T. E. Espin, F.R.A.S., the editor of the new edition, in his preface, credited the Society with having suggested valuable features to be introduced into the book, which is invaluable to the amateur astronomer. The first volume deals entirely with the solar system; the second with the stars.

Mr. Todhunter, the Treasurer, presented an encouraging annual report showing that the assets of the Society, including telescopes, globes, books, etc., etc., had been valued at nearly $1,100, that on the 31st of December there were 105 Active Members, 22 Life, Honourary, and Corresponding Members, and 17 Associate-Members, and that, after meeting all engagements, there was a small balance in bank. He pointed out that in the public interest, as well as in that of the Society, a larger revenue could be expended, partly for the purpose of paving the way towards procuring additional astronomical and physical apparatus, and ultimately for the establishment of a popular Observatory, where the interested public, under suitable guidance, might have opportunities to see, and even to study, the Sun, Moon, planets and stars under the best auspices. Mr. Sparling reported that during 1893, twenty-five regular meetings had been held, with an average attendance that indicated a well-sustained interest, summer and winter, in the work of the Society. On motion of the Treasurer, the annual fee for active lady members was placed at $1, and the Life Membership fee for a lady member, at $10.

Miss A. A. Gray read a list of phenomena predicted for the ensuing two weeks, special reference being made to Jupiter and to Saturn. A gyroscope was presented to the Society by Mr. A. Aronsberg, who, also, explained the means by which simple lenses could be made by any one.

A Special Committee, consisting of Messrs. G. E. Lumsden, A. F. Miller, A. Aronsberg and C. A. Chant, B.A., was appointed to consider and report upon the propriety of petitioning the Dominion Parliament to reduce or remove the duty upon astronomical apparatus not made in Canada.

A very interesting display of the aurora at 6.10 p.m., January 3rd., was described by Messrs. J. A. Copland, Pursey, Elvins, J. Hollingworth, of Beatrice, Miss Wilkes and Dr. Larratt Smith. Mr. Copland said when he first noticed the aurora all the streamers were deep crimson in colour, and seemed to roll into each other and then shoot towards the zenith. At 6.20, the deep red colour seemed to be rent in two places by white bars; white and red then kept interchanging, with crimson predominating, until 6.30, after which the display gradually died away. It was decided that the following meeting should be devoted to short popular papers upon Jupiter, the object being to elicit the interest of some of the younger members.

THE PROPOSED CHANGE IN RECKONING THE ASTRONOMICAL DAY

Was the subject of a short paper by Miss A. A. Gray, who had assisted in compiling the answers received from astronomers in various parts of the world.

Miss Gray said the Secretaries were still in receipt of an occasional reply to the Circular-letters sent out in May last for the purpose of eliciting the views of scientific men interested, to whom the following question had been put, "Is it desirable, all interests considered, that on and after the first day of January, 1901, the Astronomical Day should everywhere begin at Mean Midnight?" At the date of compilation, 170 answers had come in. These had been tabulated in a manner which would readily show the various opinions held. On the return to Canada of Dr. Sandford Fleming, C.M.G., the Joint Committee would, no doubt, take steps to issue an Official Statement. In the meantime, without detracting in any important degree either from the value of or the interest attaching to the Statement, it might be mentioned that while most of the replies were simply in the affirmative, or in the negative, there were many which were qualified in some respect. In some instances, reasons were given; in others the answer was accompanied by a statement more or less lengthy, and in one or two others, a carefully prepared paper was submitted. All the categorical replies were in English. Of the replies from foreign countries, with notes written in English, five were from Germany, four from Italy, four from Austria, and one each from Russia, France, Norway, Holland, and Colombia. Of answers, with notes to be translated, three were from Germany, and one each from Russia (in German), Belgium, France and Mexico. This was alluded to only to show that the English language seems to be rapidly becoming a medium for the communication of scientific information. Miss Gray then read the following

SYNOPSIS OF REPLIES RECEIVED.

COUNTRIES.	AFFIRMATIVE ANSWERS.	NEGATIVE ANSWERS.	TOTAL.
Austria	7	5	12
Australia	2	0	2
Belgium	6	0	6
British Islands—			
England	16	4	
Ireland	4	0	25
Scotland	1	0	
Canada	4	0	4
Colombia	1	0	1
France	4	0	4
Germany	7	31	38
Greece	1	0	1
Holland	0	1	1
Italy	8	3	11
Jamaica	1	0	1
Madagascar	1	0	1
Mexico	5	0	5
Norway	0	1	1
Portugal	0	1	1
Roumania	1	0	1
Russia	6	5	11
Spain	2	0	2
Switzerland	2	2	4
United States of America	28	10	38
	107	63	170

The following

ANNUAL ADDRESS,

embracing an Astronomical Review of 1893, was then delivered by Mr. Vice-President Paterson :—

The men of ancient Greece taught the fable of the Sphinx, a monster who lived on a mountain peak near the city of Thebes. She received from the Muses certain dark, mysterious riddles, which she propounded to wayfaring travellers whom she captured, and if they could not solve and interpret these riddles, then she fell upon them, as they stood appalled with their failure, and tore them to pieces. The Thebans, to rid themselves of this plague, offered the Kingdom to the man who could guess her riddle, for that was the only way the Sphinx could be destroyed. Œdipus, a far-sighted, thinking man, though lame in his feet, inspired by so great a reward, took up the challenge and presented himself to the monster, who directly asked him: "What creature that was, which being born four-footed afterwards became two-footed, then three-footed, and, lastly, four-footed again." Œdipus replied it was Man, and explained his answer. He then slew the monster, and laying the carcass upon an ass led her away in triumph, and so became King of Thebes.

In this fable the Sphinx is Science throned on a towering height because hard to understand—a lofty and mysterious creature, looking down upon the uncultured crowd from a pinnacle,—and a monster because looked at by the ignorant, and made, by the gulf of distance, a fearful wonder. The Muses of mere theory give their speculations to the Sphinx, that is, to the test of practice, which incites to thought and action the minds of men, and thus staggers and harrasses them. Œdipus, the lame and impotent man, conquers the Sphinx. Those who were conquered approached the solution of the problem with headlong haste and inexperienced zeal; but the conqueror, slowly, deliberately and thoughtfully. When the monster was conquered her carcass was laid upon an ass, for there is nothing so lofty or abstruse but, after being made plain and intelligible, it may be received by the dullest comprehension. The reward was a Kingdom, and so he who conquers Science acquires dominion, and wears a diadem brighter than that won by arms. "The pen is mightier than the sword." It was so taught by the philosophers of that rude age, long before Bulwer created Richelieu; and thus the march of

Science and Discovery was by these ancient men taught by this beautiful and ingenious apothegm.

From century to century, from year to year, men, ambitious for conquest and the dominion that knowledge gives, but with hesitating and humble approach, have solved the problems of the Sphinx—Science—and have presented the results to the less instructed and less gifted and, thereupon, have become stamped with the emblems of royalty. (Applause.)

The progress of Astronomy has been a progress of triumphs. The Astronomer has ever lived; he never dies. The palaces of Babylon, the plains of Shinar, the temples of India, the pyramids of Egypt, the schools of Greece, the deserts of Arabia, the rude cloisters and roofless temples of Druidic and Scandinavian Mythology, have been his observatories. From age to age the torch has been kept blazing. When Copernicus laid it down, Tycho picked it up and passed it on to Galileo, who, in turn, gave it to Kepler, and then Newton took it, and so the light has grown until the hands that are reached out to grasp the torch, circle the world. The watch towers of Science now cover the whole Earth and their sentinels keep an unbroken vigil; they are under the shadow of Eternity. No star or nebula can ever set; if it escapes the piercing gaze of one astronomer, it will meet the far-reaching scrutiny of another, and if any is so far buried in the depth of space that no human eye can reach it, then the eagle intellect of man has contrived means whereby the orb, or fiery haze, can record its own existence and measurement on a photographic plate. God's revelation of a Redeemer was complete nineteen hundred years ago, but the revelation of His wisdom and power as shown in the Bible of the Heavens around us, that Fifth Gospel, is not complete yet; it grows from century to century, and we read the hieroglyph more clearly blazoned on the sky as each January ripens into the following December. (Applause.)

We of the year 1894 are highly privileged. We stand on the crest of Science's continued accretions. Below us are the slopes that have led up to the apex through many a dark valley of disappointing theories that once cast a rainbow glamour round about; over many a rock of brain wearying problems that yet brought a noble fruition; across many a river that swept down false but once cherished discoveries and sifted the golden grains of Truth from the sands of Error. Under the light of this foremost century we stand, while above us yet tower the unscaled heights enveloped in the mists that the human mind is yet to scatter.

The mass of accumulations is growing into order with every year: with every advance in knowledge some apparent disorder becomes orderly, the disjointed becomes jointed. No matter how exceptional a fact appears, when closely studied and mastered it quietly takes its place as a link in the endless chain of law; it becomes at once the effect of some antecedent cause, and the cause of some subsequent effect. (Applause.)

The year 1892 boasted of the discoveries of the fifth satellite of Jupiter and Nova Aurigæ. The year 1893 has not had its remarkable discoveries, nor its prominent scientific events, but it has borne its share of interpreting those wondrous rhymes of the Universe which Nature sings to all her children. The arcana of the sky are still being searched, and its mysteries are year by year being revealed.

I. The giant member of our system has been receiving much attention from Professor W. H. Pickering at his Arequipa Observatory, in Peru. The mighty Jupiter, presenting as he does a system within a system, invites constant study, and, under the watchful eye of Professor Pickering, more of the Jovian secrets are being revealed. Laplace's "Ring Theory of Evolution," as first enunciated, has, under modern observations, developed a series of exceptions, and as *exceptio probat regulam*, the theory has become more thoroughly established. As applied to Jupiter, the following propositions are enunciated:—(1) Jupiter was formerly surrounded by a series of rings similar to those now surrounding Saturn. (2) The direction of rotation of these rings was direct, like that of the planet. (3) By some force, whose cause is not explained, they were shattered, their components uniting, but still retaining the same orbit. (4) Like the original rings, each satellite still consists of a swarm of meteorites, their consolidation having been intercepted by the enormous tides produced in them by their primary. These propositions are inductively established by various observed facts, all of which in turn are entirely consistent with these theories, and therefore it is concluded that the theories are true and scientific. These facts are the small density of the satellites, the retrograde rotation and elongated shape of the first, the small density of the first as compared with any of the others, the regularly recurring changes of shape of the discs of the other satellites, caused by a rotation about their major axes, and others, which time forbids me to mention. The Jovian system has, therefore, bodies that appear egg-shaped and go through, at regular intervals, changes of shape from elliptic to circular. Pickering concludes that if the rings had been solid bodies, each moving as one piece, their outer edges would evidently have moved faster than their inner ones, and had they later been shattered by some cause and converted into one or more satellites, that each satellite would have had a direct rotation like the ring from which it was framed. If, however, the rings were composed of meteorites, as has been shown is necessarily the case with the rings of Saturn, their inner edges would travel the faster, and, upon their breaking up, the resultant satellites would all have a retrograde rotation, and so Laplace stands impregnable. Extending the same reasoning to the solar system, Pickering concludes that the Earth and all the planets, at first, had a retrograde rotation, and being thus in a position of unstable equilibrium, the axes of rotation through immense cycles slowly shifted into the present position of stable equilibrium. So, at one time, terrestrial objects now situated to the South of us would have been found under the Northern stars, the Sun rising in the West and setting in the East, while the stars moved backwards in their nightly courses. This change of rotation from the retrograde to the direct is exemplified in the curious instrument known as the gyroscope. It is satisfactory to us to know that we are living in an age when there is nothing retrograde about our mother Earth, that she is stable and moving in a satisfactory manner, without a jar of continent, or swirling spill of ocean, and "direct" in her orbit. (Applause.)

II. As far back as 1891 attention was called to a suspected variation in the latitude of certain places where accurate observations for latitude had been undertaken, and investigation was forthwith commenced, but the honour of the discovery of the way to apply the key and open the lock was kept for 1893, and the discoverer was Mr. S. C. Chandler, of Cambridge, U. S., who has proved the occurrence of periodic changes in latitude, and more particularly of a rotation of the geographical round the astronomical pole, in 427 days. It had formerly been an accepted dogma that the axis of rotation of the Earth revolves relatively to the axis of figure in a direction from West to East, in a period of 306 days. This motion of the axis of rotation would, of course, reveal itself in a change of latitude, as determined by celestial observation, and the phenomena was generally referred to as the "10-month period in latitude." But now we must speak of the "14-month period in latitude," for so Mr. Chandler has discovered after discussing an immense amount of observations, 33,000, taken in seventeen observatories (four of them in the Southern hemisphere), with twenty-one different instruments, and by nine distinct methods of observation. Professor Newcomb turned his attention to it, and he found that a very plausible assumption as to the elasticity of the Earth would account for a 14-month period. The old 306 day period was based upon the hypothesis that the Earth is an absolutely rigid body; but, as a matter of fact, the fluidity of the ocean plays an important part in the phenomenon, as does also the elasticity of the Earth; and it is very satisfactory to find that theory and observation can thus be made to harmonize with what is, at all events, from the theoretical point of view, a very important matter. The expression, then, "as solid as the Earth," may be a misnomer; we may, after all, live and move, and have our being on an immense rubber ball, so to speak, that changes its shape. However, that may be, we may write Q.E.D. after the proposition that the axis of rotation of the Earth revolves round the axis of figure from West to East in about 427 days, the distance between the axes being about a quarter of a second of arc, or twenty-five feet on the Earth's surface. How marvellous is the skill, patience, and ingenuity of man to detect such an infinitesimal irregularity as a motion of a globe 24,000 miles in circumference round an axis that, if it could be located physically, would jut out through the surface only twenty-five feet from what we call the North Pole, giving our Earth a very slight sort of wobbling motion, or, as she is our mother, and therefore a lady, we should better say, undulating motion, and watched, as she floats through space in her graceful swing, on one side by the fiery god of War, and on the other by the goddess of Beauty. It is, of course, needless to remark, that this erratic twist is entirely different from the nutation of the Earth's axis, which completes its stately nod in nineteen years or thereabouts. For this discovery, Mr. Chandler was awarded a gold medal. (Applause.)

III. The roll call of the asteroids still continues to increase. Since Bode's law showed a gap between Mars and Jupiter and observation in that belt of the sky commenced, 346 have been discovered, and in 1893 fifty of this number have been catalogued, and thirty-eight of these fifty are credited to one astronomer, M. Charlois, of Nice. These pigmy children of the Sun are so numerous that the stock of distinctive names has been exhausted, and only one of these new strangers has been named, and she is "Dembowska," which name indicates surely, that the brain has grown weary of inventing names. Only one of these asteroids in 1893 was discovered without the aid of photography.

IV. The year 1893 has its share of new comets. Rordame's Comet was discovered, July 8th, simultaneously at two places, at Alta, Iowa, and Salt Lake City, Utah. Rordame was the Salt Lake City observer; Telegraphic announcements were made from both places. The comet appeared in the twilight of the North-west sky as a hazy third magnitude star, with a tail of about 1°. Its motion was very rapid owing to its proximity to the Earth, and its direction to the South-east soon carried it out of sight. Photography showed the tail to have four distinct branches, with an outward spiral motion. Finlay's Comet of 1886, revolving in an ellipse with a periodic time of nearly six and three-fourth years, was, on the morning of May 17th, searched for by its original discoverer at the Cape Observatory, and, true to its covenant to observe its law and period, it crossed the field of view of his telescope on time. Holmes' Comet belongs to 1892, but it chose 16th January, 1893, for a display of unusual behaviour. Instead of proceeding in its course, minding its own business, as a well trained comet ought to do, at 20.10 o'clock that evening, right before Professor Barnard's eye, it commenced to grow and grow until, at 22.43 o'clock, puffed up with pride and self-importance, it became nearly twice its original size. It first registered 29″.4 on the micrometer wire, and ended, with a registry of 47″.9. Barnard says "This is certainly the most remarkable comet I have ever seen." In explanation of the genesis and growth of this comet, S. J. Corrigan of St. Paul, Minnesota, offers a theory of a collision between two asteroids. The first effects of such a collision would be to expand the volume of the resultant body, some of the matter whereof would be thrown entirely beyond the sphere of attraction due to the mass of said body. This matter, thus diffusing in space, appeared as a rapidly expanding nebulous envelope seen shortly after the discovery of the comet. But probably the greater part of the matter did not pass beyond the sphere of attraction, and, if so, it must have fallen back towards the centre of gravitation of the mass. As expansion and separation of the matter diminish the brightness of the nucleus, so must the attraction above described have increased the brilliancy thereof, producing the effect observed. The fall of this matter must have generated heat, and so the nucleus became truly a flower in the sky, generated by heat and growing from bud to blossom by heat.

Holmes' Comet is within the belt of asteroids and it yet is a question whether Holmes discovered a comet or a new asteroid. If a group of asteroids could separate from a common origin, may not re-unions or collisions be also possible ?

V. The total solar eclipse of April 16th last, excited the greatest interest. Two British expeditions went forth, one to West Africa and the other to Brazil; two French expeditions were stationed on the West African Coast. The American astronomers, under Professor Pickering, were located in Chili. The study of the solar corona made a substantial advance. Whether the corona is subject to rapid changes of form, or not, will no doubt be answered from comparison of the photographic plates taken by the observers. One result is already obtained, viz., that the corona shares in the general rotation of the Sun's disc. Photography here asserts her claims as the most wonderful weapon of discovery since the inventions of the telescope and spectroscope with which Astronomy has been equipped. The corona has never been photographed without the accompanying eclipse, and if there was no camera we should yet know little, for all we know of the corona is told in the speeding moments of an eclipse, and strong must be the nerve and clear the judgment of the astronomer who can make his observations during the critical moments of darkness, with an undisturbed mind. Fortunately, however, for Astronomy "the camera has no imagination, and the imperfections of the photographic film, however numerous, are not of a nervous character."

VI. The Hungarian astronomers send their contribution to 1893. Late photographs of the Moon taken by the Astronomer-Photographer of the Pesth Academy exhibit some unaccountable peculiarities. The plates show hundreds of walls or embankments, seemingly about 200 feet high and from 125 to 200 yards in width on top. They run parallel to each other, and appear to be from 1,000 to 1,300 yards apart.

VII. The systematic study of auroræ has received in 1893 a new impetus. As we know, Dr. M. A. Veeder, of Lyons, N. Y., has given large attention to this study and he has formed a plan, in which our Society has taken its own part, by which observers in the United States and Canada may co-operate systematically in observing auroral displays. It is confidently anticipated that it will become possible to give a simple and complete explanation of the entire magnetic system of the globe, and of the changes which it undergoes.

VIII. The year 1893 has given birth to a new engine of discovery, the great Yerkes' Telescope, the 40-inch Chicago Telescope (four inches larger than the monster Lick Refractor), of which we received a full account from our Corresponding Secretary, Mr. G. E. Lumsden, not long ago. The total weight is 75 tons, and, when pointed to the zenith, the object-glass will be 72 feet up in the air, about as high as a seven-storey house. What it will discover for us, we shall watch and chronicle with interest.

IX. God buries his workers, but the work goes on. A noted man on the 28th May last, lowered his arms in life's conflict before the eighty-fifth year of his age had closed, and entered into his rest,—the Savillian Professor of Astronomy and Director of the Oxford University Observatory, the Rev. Charles Pritchard. It was not till he was fifty-seven years old that he took any active share in astronomical research, or gave signs of that energy and zeal which characterized his later years. We regret that in our own University of Toronto, there is no Astronomical Observatory, and no equipment, but we learn that the old University of Oxford possessed none until 1870. We trust our University will not let centuries go by, as did Oxford, before she becomes a student of the stars. For his photometrical research, Pritchard received the gold medal of the Royal Astronomical Society in conjunction with Professor Pickering, who had been engaged in stellar photometry about the same time. He determined the parallax of thirty stars of the second magnitude while at Oxford, and thus went far into the solution of a great cosmical problem. For this he received the medal of the Royal Society. Other problems were engaging his indefatigable zeal when he was called upon to solve the great problem of death and immortality.

Thus Time drifts on : the firmament above is old, but never ages ; and the Science that seeks its secret and writes its story is old, but yet ever has the bloom of youth upon her cheek. The research of 1893 is closed, and we almost hear the not far off triumphs of 1894. Man's active hand still works, his busy brain still throbs, his restless heart still beats for yet more glorious results, and these will yet fill a historic page and make it lustrous.

The delivery of the address was followed by enthusiastic applause and by a vote of thanks eloquently moved by Mr. Turnbull. After some further business, the proceedings for 1893 were brought to a close by adjournment.

OBITUARY.

Joseph Francis McBride.

JOSEPH FRANCIS MCBRIDE was born in Glasgow, Scotland, in 1855. His father died in 1860, and his mother shortly afterwards came to Canada, and took up her residence at Wilkesport, Ontario. After attending school at Wilkesport, the subject of this sketch was advanced to the Streetsville High School, where he studied Classics for some time under J. J. Wadsworth, M.A., M.B.

In speaking of his education there, Dr. Wadsworth says that "He was a clever, studious boy, to whom it was an easy task to impart knowledge. His mind was lighted up by a steady glow of enthusiasm, to which the average school-boy is a stranger. He could easily excel in any branch, but was best at Classics and English. He read authors in Latin, not on any curriculum for matriculation, for his own pleasure. His was, indeed, a very superior mind."

He left Streetsville to study for the Church, attended Niagara University and Laval University, and, completing his theology in the Grand Seminary, Montreal, was ordained by the late Archbishop Lynch in 1878. His first charge was at St. Michael's Cathedral; his second, St. Paul's Church, Toronto, whence he was removed to Penetanguishene, in connection with the Reformatory. While there he made systematic surveys of the neighbouring counties, being particularly interested in this class of practical astronomical work.

Subsequently Father McBride was pastor of the Church of Our Lady of Lourdes, and acted as Secretary to Archbishop Lynch.

His last charge was at Brockton, where he was curate to the Very Rev. Dean Cassidy. While at Brockton he became associated with The Astronomical and Physical Society of Toronto, and his genial companionship was enjoyed by many of its members.

The kindly priest, active in mind, varied in talent, a master student in theology, science, literature, and music, was still not physically very strong, and his health having been seriously undermined during the summer of 1893, he succumbed to a severe attack of Bright's disease on August 20th, at St. Michael's Hospital.

A most lovable feature in the character of Father McBride was his life-long tender devotion to his aunt, who had the care of his early training, his mother having entered a religious community shortly after coming to Canada.

These relatives and many friends mourn the loss of one whose life was a lesson in kindly love to all men.