TRANSACTIONS

OF THE

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FOR THE YEAR 1892,

INCLUDING THIRD ANNUAL REPORT.

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TRANSACTIONS

OF

The Astronomical and Physical Society

OF TORONTO,

DURING THE YEAR 1892.

FIRST MEETING.

The first meeting of this Society during the third year of its incorporated existence, was held on January 26th, 1892, Mr. J. A. Paterson, M.A., Vice-President, in the chair.

The Auditors, appointed at a previous meeting, having vouched for the correctness of his accounts, the Treasurer's Annual Statement for 1891 was received and adopted.

The Corresponding Secretary read the following letters from Lady Wilson, and from the Honourable G. W. Ross, LL.D., Minister of Education :—

SPADINA CRESCENT, January 13th, 1892.

Lady Wilson begs to thank The Astronomical and Physical Society of Toronto for their kind sympathy expressed in their resolution communicated to her on the occasion of the lamented death of Sir Adam Wilson. She can assure the members of the Society that she feels most grateful to them, and that she will always take a deep interest in the future proceedings and welfare of the Society.

EDUCATION DEPARTMENT, ONTARIO,
Toronto, January 15th, 1892.

MY DEAR SIR,—Kindly convey to The Astronomical and Physical Society of Toronto, my thanks for the honour conferred upon me in appointing me Honourary President for the year 1892. I shall be very glad to receive your Annual Report, and although I may not be of much service to the Society, I shall take a deep interest in its investigations and publications. Yours truly,

GEO. W. ROSS.

In presenting the publications which had reached him, Mr. D. G. Ross, the Librarian, stated that he feared his engagements would render necessary the resignation of his office, an intimation received with regret.

Mr. A. F. Miller drew attention to several sunspot groups, one of which was very near the solar equator.

Mr. G. E. Lumsden reported having observed at 6 p.m., January 7th, a bolide passing from the vicinity of Polaris North-westward towards the horizon. Its colour was brilliant white, heightened by a rich opalescent glow. It several times exceeded Venus in brightness. The sky was hazy, and all the stars excepting Capella, were invisible. The bolide seemed to descend below the haze, so clearly was it seen. Mr. Lumsden also reported that at 6.10 p.m. on the 14th, he observed the full moon some forty minutes after rising, occupying the centre of four well marked streamers of light arranged as a St. George's Cross. The sky was perfectly clear, except that along the horizon beneath the moon, were lying some light fleecy clouds. The upper band of rays was much the shortest of the four, the lower one was much the longest, and extended to the clouds on the horizon. The cross disappeared at 6.25, by which time the moon had, apparently to the observer, risen above the stratum of air loaded with the ice particles which caused the phenomenon.

Several selected papers were read. These included one by M. Trouvellot, entitled "Extraordinary Luminous Phenomenon on the Sun," and one from *The Popular Science Monthly*, entitled "Amateur Astronomers."

SECOND MEETING.

February 9th; Mr. Larratt W. Smith, Q.C., D.C.L., Vice-President, in the chair.

Before proceeding to business, Dr. Smith thanked the Society very cordially for electing him one of the Vice-Presidents for 1892. He accepted the position, fully appreciating its importance, and determined to do all in his power to advance the interests of the Society. In this, he knew he would have the active co-operation of all its members.

Mr. Wm. Houston, M.A., of Toronto, was elected an Active Member.

Mr. A. F. Miller, for the Librarian, reported the receipt of publications from The Royal Society and The Royal Astronomical Society of England, and from The Astronomical Society of the Pacific; also, a Paper from Professor G. E. Hale, Director of The Kenwood Physical Observatory, Chicago.

Mr. Miller drew attention to the fact that on the 6th of February the largest sunspot visible for some years had re-appeared by rotation. The group was so large that its presence could be detected by the naked eye, care being taken, of course, to protect vision by using smoked glass. The return of the spot had been marked by auroræ and a magnetic storm.

Mr. Miller, Mr. A. Elvins, Mr. A. Harvey, and the Chairman referred to the recent noteworthy conjunction of Jupiter and Venus, regretting that clouds obscured vision on the night of the 5th February, when the planets, had the sky been clear, would have appeared as a beautiful and most lustrous double-star. Mr. Miller stated that, with a sextant, he had made observations which proved that Venus was moving over about one degree of arc per day. The magnificent spectacle afforded by the apparent near approach of the new Moon to the planets on the night of Sunday, the 31st of January, was described by several members, some of them mentioning the fact that it was observed by thousands of church-goers, and was noticed in the newspapers of the following day.

Mr. Harvey read a telegraphed account of the discovery by some unknown amateur in Scotland of a new star in Auriga, to be temporarily known as "Copeland's Nova," the Astronomer Royal for Scotland having first made the discovery public. The account stated that Dr. Copeland's despatch to Professor E. C. Pickering, of Harvard, was received at Cambridge on the afternoon of the 2nd of February, which was cloudy, but that during a brief bit of clear sky at twilight the Professor, with an opera-glass, caught a glimpse of the stranger. The night of the 4th was fortunately clear, and a long series of observations was taken. Reference to the photographic library resulted in a striking illustration of its value. Eighteen photographs of the region about Auriga had been taken between November 3rd, 1885, and November 30th, 1891; on none of them did this star appear. The new star was not found previous to December 1st, 1891, but on December 10th it was present. The date of its appearance was, therefore, between December 1st and December 10th. Measurements of the plates showed that the star was at its maximum brightness on January 20th, and had since been slowly decreasing. There had been a great desire to obtain the spectrum of a temporary star, and now there was one, and it unique. No other star gave such a spectrum. It was not like that of the ordinary variables. Its essential feature seemed to be that the hydrogen lines were dark with bright edges toward the red. The visitor was apparently wrapped in a whirlwind of flames, due either to an explosion or to a collision with some giant orb.

Mr. Elvins read a series of communications from Dr. M. A. Veeder, of Lyons, N.Y., who in a very methodical and painstaking way has set about clearing up much that is at present doubtful as to the causes of auroræ, and who readily supplies to anyone who will make observations, blank forms upon which may be recorded not only the presence but the absence of auroræ. Dr. Veeder says this system is already bearing fruit, the fact having been brought to light that "at times auroræ may be seen at Southern stations, when recorded as positively absent from those further North." Comparisons with other meridians had shown that an aurora tends to reach its maximum brightness at the same hours of local time, rather than at the same hours of absolute time. A study of auroræ had revealed the fact that they are very largely of the nature of halos, their position depending as much on the position of the observer as upon the general source of illumination in the auroral mass; as in the case of a rainbow, each observer sees his own arch. Auroræ, it was stated, exhibit a tendency to frequent certain localities, presumably on account of the presence of iron, or other peculiarities of the soil. Copies of Dr. Veeder's forms were distributed to members, some of whom undertook to make observations, which consist simply of noting the presence or absence of auroræ at certain hours.

After some discussion, the Corresponding Secretary was instructed to apply for monthly reports, for Dr. Veeder, to the Director of the Toronto Magnetic Observatory, and also to the Headmaster of the High School at Port Arthur, on Lake Superior, the most Northern town in Canada and the centre of vast mineral deposits. Mr. Harvey had seen some exceedingly brilliant auroræ while at Port Arthur, and suggested the place as an excellent one for testing the value of Dr. Veeder's theory that auroræ exhibit a tendency to frequent certain localities.

Mr. Harvey read a selected series of extracts from a pamphlet on "Inter-stellar Ether," received from Mr. Alfred Senior Merry, of Wales, who divides this ether into thermine and electrine, and holds some novel views, which are entitled to consideration. An animated discussion followed, in which the Chairman and Messrs. Elvins, J. M. Clark, Miller, and Harvey took part.

THIRD MEETING.

February 23rd ; Mr. J. A. Paterson, M.A., Vice-President, in the Chair.

The resignation of Mr. D. G. Ross, as Librarian, having been received, was accepted, and Mr. G. G. Pursey was elected to fill the office.

Mr. John Hollingworth, Beatrice, Muskoka, a veteran observer of meteorological phenomena and of auroræ, was elected an Associate Member.

Letters from Dr. Veeder, of Lyons, New York, and from Mr. Hollingworth, on the subject of recent auroral displays, were read. Several members described at length the famous rose aurora of February 13th, which, during an hour or so, created a good deal of popular excitement in Toronto, and was the subject of wide and general comment in the press. The aurora offered a most magnificent spectacle, the whole Northern heavens being aglow with, at times, intensely vivid colours, and, at intervals, with brilliant streamers exhibiting great activity of motion.

Mr. A. F. Miller had remarked the varying spectrum of the aurora and had made careful spectroscopic observations. In the North-west, red and green lines were seen, and in the North-east, green lines only. To the unaided eye even, there was a greenish tinge in the East. Mr A. Elvins' observations agreed with those of Mr. Miller.

Mr. G. G. Pursey read extracts from the newspaper press advancing various theories for the phenomenon, and, in one instance, opening up the question as to whether in the Northern and Southern hemispheres, there is a coincidence in auroral displays.

While on the subject of the aurora, Mr. A. Harvey presented a series of carefully made drawings of the sunspots visible at the time. One very large spot he believed to have been very shallow from the appearance of the nucleus when the spot was just upon the sun's limb.

The paper for the evening was entitled

A PLEA FOR THE RETENTION OF THE TERMS "ATOM" AND "MOLECULE,"

and was read by Mr. Robert Dewar who said that the opinion had been gradually growing in the scientific world that owing to the advanced state of science it was necessary to dispense with the terms "atom" and "molecule" as being of no further use, but rather subvertive in their application to the elementary forms of matter. After defining an "atom" to be the smallest quantity of an element which can enter into chemical combination, Mr. Dewar contended that even were all the elements proved to be merely modifications of one primary element, the term "atom" would still be applicable to the ultimate result to be designated the "ultimaté atom." Reference was then made to the "atomic theory" as promulgated by Dalton and based by him principally upon the following laws of combining proportions :—Constant-proportion, multiple-proportion, reciprocal-proportion, and compound-proportion. The law of constant-proportion treated of the constant and unalterable weight of the atom in combination. For example, the atomic weight of oxygen is 16; that of hydrogen 2. The molecule of water is represented by the formula H_2O. In eighteen pounds of water there are sixteen pounds of oxygen and two pounds of hydrogen; taken in any quantity, the weights were always found to be in the same ratio. The law of multiple-proportion treated indirectly of the individuality of the atom. An atom of one element was the smallest quantity that could be added to a compound already containing an atom of that element, and the weight of that atom would be equal to the weight of the first atom. Thus the atom was indivisible; there could be no one-half, or one-quarter, or one-third of an atom; these proportions do not exist. The law of reciprocal-proportion asserted that an atom would exhibit the same relative weight, whatever might be the body with which it combined. That of compound-proportion declared that the aggregation of atoms did not alter their weight, and that the atom was not divisible by the forces which affected chemical analysis.

A molecule was the smallest quantity of a substance that could exist in the free state. For instance, a molecule might be composed either of two atoms of the same element joined together and acting as a single body, or else two or more different elements whose atoms combined to form the molecule of, say, water, H_2O, or of bichromate of potassium, $K_2 Cr_2 O_7$.

So that the atoms in a molecule might be many or simply two; but, as shown by the law of multiple-proportion, nothing smaller than an atom could be added to form a molecule, it being impossible to break the atom into fractions; for example, if another atom of oxygen were added to water, H_2O+O, we would get peroxide of hydrogen, H_2O_2. Well, then, what was the reason advanced in support of dispensing with the terms "atom" and "molecule"? Simply this, certain physicists held that all the elements, as now recognized, were merely modifications of one or two elementary or primary bodies.

Mr. Dewar then proceeded to discuss the terms "atom" and "molecule," having regard, first, to the elements as not susceptible of being resolved into further primary bodies, and, second, as affected by considering the present elements to be modifications of some primal matter. He explained that the atom of each element has a different weight, as compared with the other elements, known as its atomic weight. The atomic weight, for instance, of calcium was 40, of mercury 200, of silver 108, and of hydrogen (taken as unity) 1. The element whose atomic weight was heaviest was thorium, its weight being 238. Nickel and cobalt were the only two elements having the same atomic weight, but they possess other characteristics common to both. This, in his opinion, seemed to settle the point of the individuality of the atom.

Dealing with the other branch of the question, Mr. Dewar contended that even if all the elements were modifications of one substance or individual matter, that would not preclude the existence of atoms in these modifications. If these were merely modifications, as they must be, then they must retain some of the properties of the principal, and, as atomicity was a feature or property existing in all elements, it followed that it must still be retained by the modifications, as it was co-existent with the principal as a property of it. There were numerous examples which might be cited in support of the theory that the elements were modifications of a primal base, such, for instance, as the allotropic forms of sulphur, which went so far as to possess different densities; so, also, carbon, which exists in the diamond, in graphite, or plumbago, and in the different grades of coal and, in its organic form, pervades the animal and vegetable kingdoms. There were several other elements which had allotropic forms; but this property was not confined to single elements. It was extended to individual elements which were now recognized as simple. For instance, a resemblance could be traced between carbon, silicon and boron. Silicon, which pervades the mineral kingdom, as carbon does the animal and vegetable kingdoms, had for its amorphous state or condition, a dull brown powder melting at a temperature equal to the melting point of steel, and burning brilliantly when heated in air; there was also graphitoidal silicon in the form of lustrous hexagonal scales, which may be heated to whiteness in oxygen without alteration, and there was diamond silicon in the form of octahedral crystals, which would scratch glass. Likewise, there was amorphous boron, a dark brown amorphous powder, resembling, in its properties, lampblack, and insoluble in water; also graphitoidal boron in the form of dark brown scales similar to graphite, and diamond boron as hard as the carbon diamond. Their atomic weights were: B. 11; C. 12; Si. 28. The specific gravities of the diamond variety were: B. 2·63; C. 3·3, and Si. 2·49, respectively. Then there were other elements, such as that highly interesting group comprising Cl. Br. and I., which are remarkable for their resemblance. One could go further, and, by alloying metals, produce results possessing properties differing from those of their constituent parts. But that was not all. By combining certain elements, one could practically form new elements; for example, ammonium, which is NH_4, *i.e.*, one atom of nitrogen combined with three of hydrogen. This compound had almost all the properties of potassium or sodium; had alkaline re-action, acting as a base with the acids; was very volatile and was known as the volatile alkali.

There was also that base known as cyanogen CN consisting of one atom of carbon and one atom of nitrogen, but it was not necessary to enlarge upon the properties of that synthetical element.

Now, if it were possible for an element to have several allotropic conditions and still to have atomicity, Mr. Dewar submitted that it was possible for it to have atomicity with the elements as modifications. But it might be objected that these allotropic forms retained their individual atomic weights. Very true; but be it remembered that boron and carbon, whose atoms weigh 11 and 12, respectively, have very great resemblance, and that Co and Ni, each having an atomic weight of 59, still preserve their atomicity. CN. Cyanogen had an atomic weight equal to the atomic weights of its constituents, namely, 26, and ammonium NH_4 had the same character, its atomic weight being equal to the sum of the atomic weight of its constituents, 18. One was, therefore, able to make an element and practically to give it an independent, or rather an individual, atomic weight. If elements, considering them to be modifications of a primal element, were susceptible of modification in one character, were they not susceptible of modification in others? thus the atom might be so modified by changes that it would be lighter or heavier according to those modifications. It might be said that ammonium was not susceptible of modification; but, as a matter of fact, it was, in its various salts, and, as for it, it had even been isolated so far as to form a metallic amalgam with mercury. What had been advanced in support of his plea for the retention of the use of the word "atom" might be repeated in support of the word "molecule," as it was essential for the very existence of the molecule that the atom should pre-exist. That both of these did exist, Mr. Dewar had no doubt.

The reading of the paper was followed by an interesting discussion, in which Messrs. Miller, Harvey, Elvins, Pursey and others took part.

FOURTH MEETING.

March 8th; Mr. A. Elvins in the chair.

Mr. G. G. Pursey, the Librarian, in handing in a series of publications, announced that he would afford every facility to members desiring to make use of the books and apparatus of the Society.

In a communication the Rev. T. E. Espin, F.R.A.S., of Tow Law, England, announced the fact that a new edition of Webb's Celestial Objects for the Common Telescope was in course of preparation, and said he would be grateful for any corrections or suggestions that might be made. A Committee, composed of Messrs. A. Elvins, G. E. Lumsden, and A. F. Miller was appointed to take charge of the matter, it being thought that any assistance in the power of the Society, should be rendered.

Professor S. C. Chandler, LL.D., of Harvard College, Cambridge, Mass., kindly complied with a request made, by transmitting copies of his interesting and valuable paper on Novel Stellar Motions, which was appointed to be read at a future meeting.

Mr. W. H. Law, B.A., M.D., Headmaster of the High School at Port Arthur, wrote to say that he would be happy to prepare for Dr. Veeder, monthly reports upon auroræ visible from Port Arthur, the centre of a district containing vast mineral deposits. Dr. Veeder was notified of this, and desired to furnish the necessary forms.

Observations being called for, several interesting letters were read from Mr. J. C. Donaldson, LL.D., of Fergus, Ont., relative to auroræ, and to double-stars and to the great sunspot of February, which he had carefully observed. On several occasions, he had been able to see the spot with the naked eye, and once, on the 17th of February, without using a darkened glass, the necessary protection having been afforded by passing clouds. In looking for large-sized spots, it is his custom to use an opera-glass, both eye-pieces being protected by smoked coloured sun-caps of some density, this being a very convenient method of examining the sun's disc, and often rendering unnecessary the setting-up of his telescope.

Mr. A. Harvey reported numerous observations of the great sunspot which re-appeared by rotation on March 4th, and presented several carefully drawn sketches of it. He remarked that the re-appearance of the spot did not take place according to his calculations, it being somewhat retarded, an observation corroborated by Mr. A. F. Miller, who had also paid attention to phenomena associated with the spot.

Much that was interesting was read and reported with respect to Nova Aurigæ. Mr. Miller read an account of his telescopic and spectroscopic observations, and said that he considered the star to be a mass of glowing gas of very high temperature and low density, and one that would probably fade away and become invisible. He remarked particularly that the spectrum gave almost entirely bright lines with comparatively little continuous background.

Mr. Pursey read a report of the discovery by Professor Swift, of Rochester, N. Y., of a comet said to be visible in an opera-glass.

The paper for the evening was entitled

ENERGY,

and was read by Mr. J. M. Clark, M.A., LL.B. It appears in full and is as follows :—

Professor Tait, the eminent natural philosopher, in his valuable historical sketch of the Theories of Heat, says that in the physical world, besides the inevitable time and space, there are but four elementary ideas, namely, matter, force, position, and motion. This statement seems open to very serious objection. Though time may from one point of view be regarded as one of the conceptual elements of motion, and, as such, has been justly denominated the "great independent variable," yet to the physicist, it cannot be regarded as by any means an elementary idea. This will be apparent if we remember the conventional measure of time universally employed. That measure shows that time is recognised not as a primordial idea, but as a very complex conception involving *motion*, *position*, and *space*. Further, it seems utterly inconsistent with what is now known of the nature of *force* to regard it as an elementary idea. If matter be really inert, the only rational use of the word "force" is to denote certain mechanical facts of motion. This is not inconsistent with the usual definition of *force* as any cause which tends to alter a body's natural state of rest, or of uniform motion, in a straight line. And here permit me to remark on the prevalence of erroneous ideas as to the nature of force. Such vague indistinct and unscientific conceptions vitiate many hypotheses and a great deal of reasoning and speculation. We may therefore regard *space*, *matter*, *position*, and *motion* as the only elementary ideas in the physical world. In looking at these ideas as elementary, we must avoid the fallacy of regarding them as absolute and independent. This would be to run counter to the well established principle of Mental Science that all knowledge is *relative*. The nature of our mental constitution is such that nothing in and by itself can possibly become an object of cognition.

Hastening to obey Newton's precept, "Beware of Metaphysics," let us now proceed to analyse the idea of energy, and to determine its place in reference to the four ideas above mentioned. Before doing this, it is necessary to deal with the preliminary question, are there two essentially different kinds of energy, *kinetic* and *potential?*

If potential energy be defined (as it generally is) to be the energy of position, its existence is utterly inconsistent with the proposition that matter is inert, a proposition the truth of which lies at the foundation of modern Physics. Newton, in one of his celebrated letters to Bentley, has justly said: "That one body may act upon another *at a distance* through a vacuum without the mediation of anything else by and through which their action may be conveyed from one to another, is so great an absurdity that no man who has in philosophical matters a competent faculty of thinking can ever fall into it." From this, it inevitably follows that no body or system of bodies, can possess energy merely by virtue of its position; in other words, by virtue of the distances of its parts from all other bodies. In this sense, therefore, potential energy involves a contradiction in terms. But if we regard potential energy as a convenient name for those kinds of energy whose nature is not yet understood, the term is convenient and admissible, though liable to create considerable confusion. There are not, therefore, two distinct kinds of energy—energy of *motion*, and energy of *position*. The distinction can, in the nature of things, have no possible fundamental difference for its basis. But energy may be conveniently divided into two classes, namely, energy whose nature we in some measure understand called kinetic, and energy known on the other hand as potential, of whose nature we know comparatively little, but which we regard as dependent on position, not that this dependence is an ultimate physical fact, but because it is a secondary or conventional mark which, in the absence of more definite knowledge, it is convenient to adopt. Premising this as to the nature of potential energy, let us now address ourselves to the problem of finding in what relation the idea of energy stands to the four elementary ideas of space, matter, position and motion. A very little reflection on the nature of energy will make it manifest that the idea of energy involves as its conceptual elements matter and motion; or, to express the same thing mathematically, the energy of a body is a function of the quantity of matter or mass of the body and its motion, and is measured by the product of the mass and half the square of the velocity added to the quantity of energy generally called potential. It is not proposed here to discuss the various hypotheses which, from time to time, have been offered as to the ultimate nature of matter. Of these, four are considered worthy of discussion by the learned authors of the Unseen Universe.

1. The Atomic Theory, developed by the Greek Philosophers, and of which Lucretius is the recognized exponent.

2. The fantastical theory of Boscovich who discarded "atoms" and "molecules" and substituted "centres of force," which were geometrical points, *i. e.*, without length, breadth or thickness.

3. The theory which contemplates matter not as atomic in its constitution, but as possessing unlimited divisibility.

4. The Vortex-Atom theory of Sir William Thomson.

According to Sir W. Thomson's hypothesis matter may consist of the rotating portions of a perfect fluid supposed to continuously fill all space. Whether the correct explanation has or has not been given, the theory is an exceedingly interesting and important one; and whether ultimately accepted or not, it certainly has already fulfilled and will to a yet greater extent fulfil the recognized functions of a scientific hypothesis. It may be pointed out that the Vortex-Atom theory is consistent with the principle of the conservation of matter. Applying Cauchy's method of integration to Lagrange's Hyrodynamical Equations deduced from D'Alembert's Principle, it is proved that the motion of a fluid under the action of natural forces if once irrotational is always irrotational. Then from this, remembering that any vortex line, however it may be translated, is composed of the same elements, it follows that there can be no additions made to the quantity of liquid in the vortex filaments. Consequently, by natural causes or forces the total quantity of the rotating portions of the perfect liquid, *i. e.*, Thomson's matter, can neither be increased nor decreased.

From what has preceded, it will be seen that the all prevading medium unfortunately known as the luminiferous ether is regarded as matter, since it necessarily possesses inertia, the distinguishing test of matter. On account of the important part played in modern physics by this medium which prevades not only inter-stellar, but also inter-molecular and inter-atomic space, it is of the greatest moment that this fact which is so often disregarded with disastrous results should be clearly realized. Its name, which is derived from its connection with the theory of light, does not at all suggest the varied functions which this mysterious ether is now supposed to fulfil. The recent investigations of natural philosophers tend very clearly to show that it acts as a medium for conveying not only light but also various other forms of energy, such as radiant heat, magnetic disturbance, etc., and further that it plays a very important part in transforming one kind of energy into the various other forms. The well established fact that light is capable of producing various chemical changes shows that the vibrations of the ether particles in which consists light may be transformed into motions of the atoms of bodies since all chemical changes result from accelerations of these motions. So important are the properties of the all prevading ether becoming, that Tyndall predicts that the Physics of the future will be mainly occupied in their investigation. Before proceeding to discuss the laws of energy, it is well to mention the different forms in which it appears. There is first the form of energy of which we become immediately cognizant by direct observation, viz.: the energy which bodies possess by virtue of their translatory or rotational motions, or the energy of mechanical motion. Next, there is molecular energy or the energy which bodies possess on account of the relative motions of their molecules. Then comes atomic energy resulting from the relative motions of the atoms of a body. Speaking generally, it may be said that alterations in motions of the first kind produce mechanical changes; in motions of the second kind physical changes; while variations in inter-atomic motions produce chemical changes. Besides these, there is the vast amount of energy which consists in the various undulatory movements of the luminiferous ether. Then there is what is generally called potential energy, which is in all probability really kinetic in its nature, but whose nature is as yet inadequately understood.

It is now proposed to trace very briefly the history of the principle of the conservation of energy, which is perhaps the most magnificent reward of the researches of modern science. There can be now no doubt that the theoretical foundation for the modern doctrine was distinctly and clearly laid by Newton in his wonderful scholium to his Third Law of Motion. In this scholium and the commentary on it, Newton not only states the law of the Conservation of Energy so far as the state of experimental science in his day would permit, but also clearly anticipated the so-called modern principle of Vis Viva and D'Alembert's Principle. No further advance of any moment seems to have been made, till about a hundred years later, Davy proved by experiment that the production of heat did not involve the destruction of matter and that heat was therefore not a peculiar kind of matter but a form of energy. About the same time, Rumford effected an approximate calculation based on experiment of the mechanical equivalent of heat. Here, I may be allowed to remark that from the fact that there is a mechanical equivalent of heat, it follows that the quantity of heat is proportional not to the quantity of motion but to the quantity of energy. Tyndall's brilliant work "Heat as a Mode of Motion," would therefore have been more correctly and appropriately entitled "Heat as a Form of Energy." These experiments of Rumford and Davy conclusively established the immateriality of heat, and that since mechanical work and heat might be taken as the measures of each other they must be species of the same genus, and that genus we now know to be energy. The next important names in the history of the theory of energy are those of Fourier and

Carnot. The calculations and conclusions of these profound mathematicians were expressed, it is true, in terms which to a certain extent involved the now exploded corpuscular theories of heat and light, but their reasoning and results were to such an extent independent of any particular theory that the elements involving the truth of these untenable hypotheses are capable of being almost entirely eliminated, leaving results which have proved of the greatest use in the development of the true theory of energy. To Clausius is principally due the credit of having thus utilised the brilliant investigations of these master minds, and in particular of having so modified the theories of Carnot as to make them consistent with the doctrine of the equivalence of heat and work. To Joule, the great English Physicist, is undoubtedly due, as has been conclusively shown by Prof. Tait, the credit of having placed the grand law of the Conservation of Energy on a true experimental foundation. Joule determined by means of some of the most ingenious experiments of modern times, that 772-foot pounds of work if converted into heat, would raise 1 lb. of water 1° F., or that to produce a quantity of heat sufficient to raise 1 kilogramme of water through 1° C. work must be consumed to the extent of 424 kilogrammetres, and thus placed the truth of the dynamical theory of heat beyond all manner of doubt. In performing one of the experiments devised by him for the purpose of ascertaining the mechanical equivalent of heat, Joule discovered that current electricity was a form of energy and subject to the Law of Conservation. His results were extended by Helmholtz, Mayer, Clausius and Thomson till the law of conservation has been shown to govern all natural forces. Thomson demonstrated that Faraday's discovery of the rotation of the plane of polarization of a polarized ray of light produced by media under the influence of a powerful magnet, involved the dependence of magnetism on motion in the case of magnetic and dia-magnetic bodies.

To Helmholtz and Carpenter is principally due the credit of having extended the principles of the conservation and transformation of energy to physiological phenomena. There can be no doubt that Maxwell's electro-magnetic theory of light is destined to play no unimportant part in the development of the true theory of energy. From data supplied by Weber, Maxwell found that electro-magnetic disturbances were propagated with the same velocity as light. The explanation of this he held to be that electricity, like light, was due to the undulatory vibrations of the medium, which is beyond question necessary for the propagation of light. If this hypothesis be found to be a valid one, a very clear insight will be obtained into the real connection between light and electricity. The relation of heat to light is seen by considering the nature of radiant heat, but is best shewn by considering certain experiments of Leslie, which prove that bodies are heated by absorbing light. The fact that heat is developed in certain chemical transformations indicates the relations of the forces of chemical affinity to heat. Thus, by considering in succession all the so-called natural forces it will be seen that they are all simply manifestations of an unchangeable amount of indestructible energy. Every form of energy is capable of being transformed by suitable manipulations into all its other forms without in any case involving any increase or diminution of the total quantity of energy. But while the quantity of energy in the universe is invariable, yet by virtue of laws, of which we have a particular case in Clausius' Second Main Principle of the Mechanical Theory of Heat, the amount of what may be termed available energy is being constantly exhausted. The truth of this, together with many very important consequences which follow from it, was first clearly pointed out by Sir W. Thomson in a remarkably able paper "On a Universal Tendency in Nature to the Dissipation of Mechanical Energy." It is simply another method of saying that no known natural processes are perfectly reversible.

Having thus briefly discussed the conservation, transformation and dissipation of energy, we propose concluding by investigating the sources of energy available for man.

A few moments' reflection will suffice to show that the main sources of energy available for man are: (1) Food; (2) Fuel; (3) Water Power; (4) Wind. Of these, food and fuel are of the same nature, food being utilized by means of animal machines, such as men, horses, etc., while fuel is converted into mechanical motion by means of engines of various kinds. The mechanical energy which is thus produced by means of food and fuel, is evidently for the most part, derived from the heat and light radiated from the sun. Water-power and wind even more obviously obtain their energy from the same source. Solar radiation is therefore the grand source whence nearly all the energy available for man is derived. Proctor's designation of the sun as the "Ruler, Light, Fire and Life of the Planetary System," is therefore fully justified from a scientific standpoint.

Various theories have been advanced to account for the enormous amount of energy in the form of heat and light annually sent forth by the sun, and of which the earth intercepts a very small portion. It was, for instance, supposed by some that the sun's heat was produced by the combustion of its materials. A very few facts will show that this hypothesis is utterly untenable. The mass of the sun, estimated from the most reliable determinations of the solar parallax, has been found to be about $4(10)^{30}$ pounds. The consumption of a pound of coal is known to produce an amount of heat equivalent to 9,200,000 foot-pounds. Combining these, we see that if the materials of the sun were supposed to be capable of producing by their combustion as much heat as equal masses of coal, an assumption eminently favourable to the hypothesis in question, the total mass of the sun would be consumed in producing a quantity of heat whose mechanical equivalent is $368(10)^{35}$ foot-pounds.

In a calculation (by the writer) of the probable density of the luminiferous ether, published in a recent volume of the Transactions of the Canadian Institute, it was found that the quantity of energy radiated from the Sun was $4\pi\ (433)^2\ (10)^6\ (5{,}280)^2\ 55{\cdot}00000$ foot-pounds per second, or $(10)^{34}$ foot-pounds per annum.

It therefore follows that if the theory of the origin of solar heat under examination were the true one, the energy of the sun would be exhausted in 3,680 years, while we know that the quantity of heat radiated from the sun has been practically as great as the present for millions of years. The theory of combustion or chemical combination therefore falls to the ground, and it is now generally supposed that the perennial fountain whence flow the vast energies of the solar system is the potential energy of gravitation, which is converted into kinetic energy by its mass moving towards the centre of inertia of the solar system, and thence into heat by a mechanism indicated by the physical constitution of the fiery ruler of the day.

The following investigation will show that this now generally accepted hypothesis predicates a cause shown to be a *vera causa* amply capable of producing the results it is supposed to explain, and, therefore, that it is not inconsistent with the axiom that the cause must be equal to the effect.

Let ρ represent the density at distance r from the centre of a spherical mass, supposed equally dense at equal distances from the centre.

The elemental mass, therefore, between the spherical surfaces, whose radii are r and $r + dr$, is $\rho\ 4\ \pi\ r^2\ dr$.

Taking proper units of force, and remembering the theorem that the attraction of a spherical shell on an internal particle vanishes, it follows that the force acting on this elemental mass is measured by the quantity

$$\frac{4\pi\ \rho\ r^2\ dr \int_0^r 4\pi\ \rho\ r^2\ dr}{r^2}$$

assuming, of course, the Newtonian law of gravitation.

The work done by this elemental mass moving through an infinitesimal de, will consequently be

$$\frac{4\pi\ \rho\ r^2\ dr \int_0^r 4\pi\ \rho\ r^2\ dr\ dc}{r^2}.$$

Integrating with respect to dr we get as the total work done

$$\int \left\{ 4\pi\ \rho\ dr \int_0^r 4\pi\ \rho\ r^2\ dr \right\} dc$$

a formula which will be found to be of considerable use in solving certain important classes of problems, involving the potential. Supposing ρ to be constantly uniform, if the radius of the sphere be originally a and become $a - da$, dc will evidently be $\frac{r}{a} da$, and the total amount of work done on account of the contraction will consequently be $\frac{3}{5}\ M^2 \frac{da}{a^2}$, where $M = \frac{4\pi}{3} pa^3$, the mass of the sphere.

Integrating the expression between the limits a and b we get as the amount of work done by a spherical mass M of radius a (supposed uniform) contracting to a uniform sphere of radius b, $\frac{3}{5} M^2 \left(\frac{1}{b} - \frac{1}{a}\right)$

Applying these formulæ to the case of the sun whose radius is 433,200 miles, and whose mass is $4\ (10)^{30}$ lbs., the amount of work done, or in other words, the quantity of heat generated by a contraction of 1 foot in the radius of the sun (supposed uniform) will be found to be represented by $\frac{3}{5} \frac{16\ (10)^{60}}{(433200)^2\ (5280)^2}$

The unit of force used here obviously is the attraction of unit mass on unit mass at unit distance; so that the attraction of the earth on unit mass at its surface would be represented by $\frac{4}{33}(10)^{26}\frac{1}{(4000)^2(5280)^2}$ multiplied by the mass of the earth $= \frac{3}{33}(10)^{60}$ of these units.

Now this force is obviously the weight of 1 lb. Therefore, a contraction of 1 foot in the sun's radius will generate a quantity of heat equivalent to $\frac{3}{5}\frac{16\,(10)^{60}\times 33\times(4000)^2\times(5280)^2}{(433200)^2\times 4\times(10)^{26}} = \frac{2}{3}(10)^{32}$ foot-pounds.

If account were taken of the fact that the sun must become denser as its centre is approached, this quantity would be considerably larger.

Accordingly, a yearly contraction of 150 feet in the sun's radius would be amply sufficient to sustain its heat at the present rate of radiation.

A decrease in the diameter of the sun of less than 90 miles would keep up the supply for over 350 years. If on the same hypothesis, the sun's radius were to become one-half of what it now is, or the density of the sun eight times its present value, which would make its density about the same as that of lead instead of $\frac{3}{5}M^2\frac{1}{(433200)^2(5280)^2}$ for a contraction of 1 foot, we should have

$$\frac{3}{5}M^2\left(\frac{1}{\frac{1}{2}(433200)(5280)}-\frac{1}{(433200)(5280)}\right)$$

i.e., about 433200 × 5280 times as much heat would be generated.

This would be sufficient to sustain the present rate of radiation for 15,000,000 years. Similarly if the mass of the sun were equally diffused throughout a sphere having a radius of 276,000,000 miles, which is the distance of Neptune from the sun, and were to contract till it became uniformly as dense as heat, heat enough would be produced to meet the present demand for 30,000,000 years.

This amount would be naturally increased by taking account of the masses of the other bodies of the solar system and of the fact that the sun must become denser as the centre is approached. This vast quantity is sufficient to account for the heat which has been radiated into space by the sun and the other bodies comprising the solar system, for the thermal energy now possessed by all these bodies, and for the kinetic energy they have by reason of their revolutions in their orbits and on their axes.

If the solar system had the same specific heat as water and were raised to a temperature of 28,000°, it would contain a store of heat 2,000,000 times as great as the present yearly expenditure.

These figures, curious and instructive in themselves, derive considerable importance from their bearing on the problems of geological time when taken in connection with the vast eons considered necessary by most geologists for the formation of the different strata of rocks, and with the still vaster ages claimed by biologists for the evolution of the existing and extinct forms of life.

We are told that the palæontological evidence for the high development and wide dispersal of organisms, at least in later palæozoic times, is complete, and that to the existence of a flora and a fauna such as that indicated even in the Cambrian formations, a mild climate is absolutely essential. Now, the climate is profoundly affected by the presence of mountains and large bodies of water, and even more by winds and ocean currents, and by the quantities of the variable elements in the atmosphere, yet to maintain a mild climate the heat-giving power of the sun must have been materially as great as at present.

The heat generated by the sun in assuming its present density and conformation cannot be supposed to be greater than that produced by contraction from the limits of the solar system to a homogeneous sphere of one-half its present radius. This would make 30,000,000 years the limiting or maximum age which can be assigned to the Cambrian formations.

In a recent lecture delivered by Sir William Thomson at the Royal Institution, he expressed the opinion that the total age of the sun did not exceed 20,000,000 years.

On this basis, Sir William Dawson has pointed out that the whole of geological time since the formation of the oldest Laurentian rocks would not exceed 6,000,000 years, and of this period only about 50,000 years can be allowed to the Pleistocene and Modern Periods.

The paper was followed by a very animated discussion participated in by Mr. J. A. Paterson, M.A., who read a series of appropriate paragraphs from Langley's New Astronomy; by Mr. Harvey, who, while praising the paper, which he reviewed at length, criticised some of Mr. Clark's deductions; by Mr. Elvins, who referred to the views of Mr. J. H. Kedzie, of Chicago, who, in his work on Solar Heat, does not admit the contraction of the sun's globe to be a cause of solar energy, and by

Mr. Pursey, who also referred to the views of Dr. Joseph Morrison, Ph.D., of the Nautical Almanac Office, Washington, who discussed the subject in an able paper published in the Transactions of the Society for 1891.

Mr. Clark answered numerous questions and, at some length, reviewed the observations which had been made by members.

FIFTH MEETING.

March 22nd; Mr. J. A. Paterson, M.A., Vice-President in the chair.

In the interests of the writers of original papers, Mr. Arthur Harvey brought before the meeting the advisability of publishing, in pamphlet form, papers such as that of Mr. J. M. Clark, M. A., on Energy, which contain results different from those usually accepted, thus establishing for the authors the priority to which their investigations entitle them. The proposition was well received, but no immediate action was taken.

Mr. E. A. Meredith, LL.D., of Rosedale, Professor David R. Keys, M.A., of McMaster University, Mr. D. O. Cameron, B. A., Barrister, and Mr. Robert B. Ellis, of Toronto, were elected Active Members. Mr. Pursey presented the publications received by him as Librarian.

The Committee respecting the revision of Webb's Celestial Objects for Common Telescopes presented a report in which leave was asked to submit to the Reverend Mr. Espin, the editor, the advisability of inserting chapters affording for the use of amateurs, some general information on the subjects of Celestial Photography and of Spectroscopy. Several changes in the form of the work were also suggested. The report was adopted.

The receipt of a number of valuable publications from Germany having been announced, Mr. Stephen Huebner stated that he would be happy to translate for the members any of the papers these publications contained.

Mr. A. F. Miller read an extract from a private letter received by him from Mr. John Goldie, of Galt, a Life Member of the Society, intimating that he had donated the sum of ten dollars to the Society's fund for procuring Astronomical lantern-slides. Mr. Miller moved a cordial vote of thanks to Mr. Goldie for this, his second substantial gift, which was further evidence of his good will towards, and interest in, the Society. Carried, with applause.

In a letter, Mr. J. C. Donaldson, LL.D., of Fergus, stated that he had been carefully observing the fourth satellite of Jupiter; that he had noticed some of the peculiarities of colour referred to by Mr. G. E. Lumsden in the Transactions of 1891, and that he hoped members would take advantage of the opposition of 1892 with a view to determining whether differences of physical conditions exist in the Jovian system.

Mr. Miller read the following description by Mr. Goldie of a paraselene observed by him :—"At 2.20 a.m. March 19, I saw a fine instance of this phenomenon. The moon was South-east by South, and its altitude about 23°. At about a radius of 27°, there was a very bright semicircular halo or arch over the moon, each end of this arch resting upon a 'mock moon,' having the same elevation as the true moon, and shining brightly, more especially the Western one. Underneath the moon, the halo was continued so as to form the complete circle, but the lower part was so dim as to be only just visible. Immediately above the moon was an inverted arch, and the point of intersection was very bright, as if the light of both arches was added together. The upper arch faded from view about 30° on each side of the point of contact. A light streak passing through the true and mock moons extended to the North-west, where it faded away. Another streak passed upwards nearly to the zenith. The phenomenon continued to increase in brightness, and at 2.30 a.m. the mock moons shone with brilliant rainbow tints, the Western one being specially conspicuous. So bright were they that had the moon been obscured the false images would have cast well-defined shadows. The atmosphere at the time, though not quite clear, was transparent enough to reveal the brighter stars quite perfectly; nor was there any other condition of the air different in appearance from what is general at this season of the year."

Commenting upon the observation, Mr. Harvey stated the cause of these phenomena to be the dispersion of light by particles of ice in the upper regions of the air, which act as prisms; that at Ben Nevis, Scotland, paraselenes are very frequently seen and that instructive accounts of them may be found in the records of Edinburgh Observatory.

Mr. Harvey being anxious to see diagrams of the phenomenon, Mr. Miller said he would ask Mr. Goldie for a sketch.

The Corresponding Secretary read the following letter received from Professor George E. Hale, Director of the Kenwood Astro-Physical Observatory, Chicago, Ill., and editor of the Department of Astro-Physics in *Astronomy and Astro-Physics*, published at Northfield, Minn.

KENWOOD ASTRO-PHYSICAL OBSERVATORY, Chicago, March 7th, 1892.

DEAR SIR:—Your letter of March 3rd has been received, and I have also to express my thanks for a copy of your second Report, which you were kind enough to send me. The Report would be a credit to any society, and I have read with special interest the accounts of solar and spectroscopic observations carried on by your members. Perhaps some of the constant observers of solar phenomena may find it convenient to send me occasional notes on their work for publication in *Astronomy and Astro-Physics*. I am anxious to keep our readers fully informed, especially on spectroscopic investigations.

In regard to the great sunspot of February, I may say that a fairly complete series of photographs was obtained here during its transit. Of these, a number for position merely were taken at the focus of the 12-inch equatorial; 49 were secured with the new "spectro-heliograph," and these give a faithful history of the faculæ as well as of the spots. A photograph was also taken of the eruption over the spot as it entered on the eastern limb on February 4th. I hope to be able to send you copies of some of these plates soon, but cannot just at present because the image of the sun given by the spectro-heliograph is elliptical—flattened in the plane of dispersion—and I have not yet procured a suitable cylindrical lens to give a round image of the sun in copying the originals. Of course you would not care for distorted images, and I wish to remove this defect before sending any out.

I take pleasure in mailing you herewith a photograph of the spectro-heliograph, and also one of the spectroscope as it appeared before the new apparatus was attached. The spectro-heliograph consists in principle of two moving slits, one replacing the ordinary slit of the spectroscope, and the other at the focus of the observing-telescope. A modified form of clepsydra in connection with an hydraulic accumulator, supplies the motive power. The grating (Rowland 4-inch) is rotated by the slow motion rod until the K line in the fourth order passes through the second slit. The slits then move together in such a way that the first passes across the sun's image, while the K line constantly passes through the second. As K is bright in prominences, and also in faculæ (discovered here the latter part of December, 1891), and the absorption is more marked in spots, it follows that all these phenomena will be obtained in the photographs. As a matter of fact, the best results for faculæ are obtained with a shorter exposure than that sufficient to show the prominences, so it is usual to make two sets of photographs, one with narrow slit moving slowly for the prominences, and the other with more rapid motion for spots and faculæ. The advantage of this apparatus lies in the fact that all prominences around the entire circumference of the Sun are shown on a single plate, while faculæ are as well shown at the centre of the disc as at the limb.

Very truly yours, GEORGE E. HALE.

The paper for the evening was the essay by Professor Seth C. Chandler, LL.D., of Harvard College, entitled "Some Novel Stellar Motions," which appeared in *The Astronomical Journal*, copies of which, with notices and other material, the author had, upon request, kindly transmitted. The special theory, brought forward in an admirable manner and mathematically analysed, was that the star Algol is accompanied by a dark companion, both revolving about a dark central body, the plane of motion being inclined at an angle of twenty degrees to the line of sight from the earth's position in space. The bearing of this upon the nebular hypothesis was discussed at length.

Several of the members were of the opinion that the theory brought forward could not be reconciled with the nebular hypothesis which requires the controlling centre of a system to be hotter than its attendants, and consequently brighter. The revolving bodies would certainly become cold and dark before the primary, but here it was contended that the centre was a dark body and the satellite bright and glowing. It was easy to suppose a small dark, and therefore dead, body in rapid revolution about Algol, its primary, but it was not so easy to understand how Algol, in turn, could be in revolution around a body so small as to have become extinguished by age. The discussion was very animated. All the speakers praised the boldness and originality of Professor Chandler's theory, and the patience and labour he had expended in working it out.

SIXTH MEETING.

April 5th; Dr. Larratt W. Smith, Q.C., Vice-President, in the chair.

Mr. A. Aymong and Mr. Charles Cluthe, of Toronto, were elected Active Members of the Society.

Mr. A. F. Miller presented for the inspection of members, an excellent drawing representing the paraselene, or lunar halo, of March 19th, 1892, observed by Mr. John Goldie, of Galt, who had supplied the sketch by request.

The Corresponding Secretary read letters from the Secretary of the Royal Society; Professor A. Kirkwood, LL.D., of Riverside, California; Mr. J. Ellard Gore, F.R.A.S., of Ballysodare, Ireland; and Dr. Joseph Morrison, of Washington, D. C. Dr. Morrison gave some hints of practical value with regard to the publication of papers containing algebraic notation, etc. He referred to his work on Trigonometry, as one which had been well printed in Toronto. Of this book, he donated to the Society two copies. He also alluded to a treatise on approaching Transits of Venus and Mercury, prepared for the purpose of awakening interest in those phenomena while he was attending Toronto University.

The Librarian reported the receipt of publications of the British Astronomical Association, the Royal Astronomical Society and other Societies.

Interesting reports of observations were received from several members.

Messrs. A. F. Miller, A. Harvey, and G. E. Lumsden had been successful in observing Mercury at the recent eastern elongation. Mr. Miller compared the brightness of the planet with that of Aldebaran, which it exceeded.

Mr. Harvey stated that by observing Venus before sunset, he had succeeded in getting a telescopic image altogether free from the glare that surrounds that planet after nightfall.

The paper of the evening on the Zodiacal Light was read by Mr. A. Elvins, and was contributed by Dr. M. A. Veeder, of Lyons, N. Y. The views of Dr. Veeder were clearly stated and his theories had evidently been carefully worked out. After some discussion, the remainder of the evening was devoted to a lantern-slide exhibition by Mr. D. J. Howell. The slides included copies of some very fine views of the moon received from MM. Henry Freres, the famous photographers connected with the Paris Observatory. These had been photographed and prepared for the lantern by Mr. Howell.

SEVENTH MEETING.

April 19th; Dr. Larratt W. Smith, Q. C., Vice-President, in the chair.

Referring to a special lecture on Meteorology which he had delivered before the Young Men's Christian Association, Professor Carpmael announced that he would be happy to give the substance of it at any meeting of the Society that might be appointed for the purpose.

Lieut.-Colonel John I. Davidson, and Messrs. Samuel Nordheimer, German Vice-Consul, and Charles P. Sparling were elected Active Members of the Society.

The Corresponding Secretary read a series of letters, including one from the Reverend W. J. Murphy, O.M.I., of Ottawa, and one from Professor Edward S. Holden, LL.D., etc., Director of the Lick Observatory, as follows :—" I beg to acknowledge the receipt of the Transactions for 1891, which I have just read. It shows that the Society has all the vigour which goes with youth. I am proposing to send copies of a few of our Astronomical photographs to the Society, with the compliments of the Lick Observatory, as soon as they can be prepared. I shall be glad if you can make arrangements so that each member of the Society can make copies of these, should he desire to do so." Applause.

Mr. A. Aronsberg passed round for inspection a specimen of workmanship in aluminum, which, he said, is taking the place of the heavier metals in the construction of certain parts of scientific instruments.

Mr. G. E. Lumsden reported that he had observed the occultation of Uranus by the moon on April 12th, at 11.51.4 Eastern Standard Time (16.51.4, G. M. T.); that the conditions were excellent, the sky being clear, the air steady, and the definition very fine; that the planet was picked up when about half-a-degree distant from the brighter lunar limb, the moon being almost full; that its disc was very perceptible, and that Uranus was easily followed up to the point of disappearance, which was almost instantaneous; that, when first seen, the colour of the planet was precisely the same as that of the central portion of the lunar disc when the eye has become accustomed to its glare in the telescope; that as Uranus neared the moon, his disc became suffused by a greenish tint, which deepened in intensity until the moment of occultation, a tint which was quite as perceptible at emergence at 13.10 E. S. T., and which gradually disappeared as the planet widened its distance from the moon. The phenomenon was a singularly beautiful one, and was observed with the assistance of a $10\frac{1}{4}$-inch reflecting telescope. At no time was the planet perceptible in the finder, or in a very good 2-inch telescope, which was also in use.

This occultation was also well observed by Mr. J. C. Donaldson, LL.D., of Fergus, who used a $3\frac{1}{2}$-inch Cooke refractor.

Mr. A. F. Miller, in the course of his remarks upon his solar work, called attention to the fact that all the prominences he had examined had appeared in the northern hemisphere.

Mr. Andrew Elvins presented some drawings of sunspots made at a 3-inch Wray refractor.

Mr. G. G. Pursey read from the press an account by Mr. E. E. Barnard, of Lick Observatory, of his interesting observations upon Swift's Comet.

Mr. Clarence Bell read a very instructive paper on "The Construction and Theory of the Dynamo." A large number of carefully prepared drawings were shown for the purpose of illustrating the paper. The phenomena of magnetic-fields and magnetic-forces were clearly illustrated and described. A short history of the development of the dynamo followed. Drawings of the different types of armatures were shown and their theory and workings explained. The differences between a simple, shunt and compound wound dynamo occupied a large portion of the paper. The continuous and alternating-current dynamos were treated at length, and comments made on the different systems now in use.

As a chapter in practical science, the paper was thoroughly appreciated, and an interesting discussion followed.

The Chairman, Dr. Smith, read an extract bearing upon the magnetic-needle and its variations.

Mr. J. G. Ridout explained some of the difficulties in the way of surveyors by reason of the variation of the compass.

Mr. D. G. Ross read an extract referring to experiments recently performed before the Royal Society by M. Tesla, the Montenegrin electrician. Some of these were remarkable, it having been demonstrated that when the rapidity of alternation is very much intensified, compared to what is used for practical purposes, the electric current becomes absolutely harmless.

EIGHTH MEETING.

This meeting was held on the 3rd of May at the Toronto Observatory, Professor Charles Carpmael, M.A., F.R.A.S., Director of the Observatory and President of the Society, in the chair.

Mr. D. W. Alexander and Captain J. D. Hay, of Toronto, were elected Active Members of the Society, and the Rev. W. J. Murphy, of Ottawa, an Associate Member.

Mr. G. G. Pursey, the Librarian, laid on the table the publications received, including the issues of the Royal Society of England, the Royal Astronomical and other Societies.

Mr. G. E. Lumsden reported that at three o'clock on the morning of the 25th of April he caught sight, through a window, of a nebulous object in the eastern skies about four degrees south of a line joining α and β Pegasi. This proved to be Swift's Comet (B. 1892), then easily visible to the naked eye. Its appearançe was that of a bright nebulous star, with short hazy tail pointing southward. A few minutes later, in a 10-inch reflecting telescope, the comet formed a striking object, though daylight was breaking. The nucleus, which was large and well-defined, seemed to be composed of a bright point of light, surrounded by haze, with marked condensation towards centre and not dissimilar to certain parts of the great nebulæ of Andromeda and Orion. The tail was visible over an arc of twelve or fifteen degrees, though nothing could be seen of the branches from it, reported to have been observed about that time by Professor E. E. Barnard. The comet was again examined telescopically on the 2nd of May. It was apparently much less conspicuous than on the 25th April, and was presented as an irregularly shaped nebulous mass, slightly condensed near the centre. Mr. Lumsden also reported an observation, carefully made, of the occultation, on the 29th of April, of 125 Tauri. Disappearance took place at 9h. 41m. 25s. Eastern Standard Time, or nearly 9 minutes earlier than the predicted time. As the moon was new, the sky perfectly clear, and the conditions eminently favourable, the observation was a singularly interesting and satisfactory one. The same observer also produced drawings of the planet Saturn, showing that the rings were presented edgewise to the earth, and were nearly invisible in telescopes of small aperture.

Mr. Thomas Lindsay said that on the evening of the 29th of April he had observed the moon occult a star at 8h. 27m., and that he could find no prediction of the occultation in the nautical almanacs.

Mr. Robert Dewar described an interesting auroral display observed by him at 11 p.m., April 25th, from a station about 115 miles north-east of Toronto. He had also noticed magnetic disturbances occurring at the same time.

Mr. Andrew Elvins read the monthly report on auroræ, received from Mr. John Hollingworth, of Muskoka.

Professor Carpmael then invited the members to adjourn to the dome of the Observatory and, the large telescope being adjusted, the rest of the evening was spent in observing the Moon and Saturn. The night was not very favourable, but a good view of Saturn was obtained with a power of 80, the ring being seen as a shaded thread of light. The mechanism of the instrument was described and explained by Mr. Carpmael and Mr. William Menzies, of the Observatory Staff.

NINTH MEETING.

May 17th, Mr. John A. Paterson, M.A., Vice-President, in the chair.

Drs. Albert D. Watson and H. J. L. McKenzie, and Messrs. Frank U. Caswell, Publisher, Donald C. Ross, Barrister, of Toronto, were elected Active Members, and Mr. J. R. Connon, of Elora, was elected an Associate Member.

As the paper for the evening was to deal with the practical teaching of Astronomy in the Provincial University and High Schools, the Honourary President of the Society, the Honourable G. W. Ross, LL.D., Minister of Education, had been invited to preside. As Dr. Ross was unable to do this, he wrote the following letter:—

TORONTO, 10th May, 1892.

I am leaving town to-morrow morning for a month's holiday, and consequently cannot do myself the pleasure of presiding over the proposed meeting of the Astronomical and Physical Society. I sympathise very cordially with what I understand to be Mr. Houston's views on the subject of Astronomy in the Provincial University, and I am quite sure that it is only the lack of funds that prevents the Senate from giving the subject more attention than it has done so far. I would like very much if the Society could prevail upon the authorities at Ottawa to remove the Observatory to some more eligible site, and erect buildings worthy of the work done by Mr. Carpmael and his associates. The observations taken at Toronto are among the most valuable taken on this continent, and, with additional facilities, their scientific use would be much enhanced. When I return, call upon me for any service I can render. Wishing you success, I remain, yours truly,

GEO. W. ROSS.

Among the other communications read by the Corresponding Secretary, was one from Mr. E. W. Maunder, F.R.A.S., of Greenwich Observatory, editor of the *Journal* of The British Astronomical Association, requesting newspapers or cuttings giving accounts of meetings of the

Society, and memoranda respecting any points of astronomical interest, astronomical observations, movements of astronomers, development of observatories, etc. ; one from the Director of the Kew Observatory, and one from the Reverend T. E. Espin, F.R.A.S., of Walsingham Observatory, stating that star

D.M. + 55°, 1870 :—XVI.h. 39m. 49s. + 55° 12′ ('55);

9·2 had been found to be variable, with a spectrum like that of Mira.

Mr. J. C. Donaldson, LL.D., of Fergus, wrote to draw the attention of members to the nearest companion to Alpha Geminorum, which he had been observing during two years, and which, he thought, was brighter than in 1890. The Corresponding Secretary was instructed to bring the matter to the notice of Professor E. C. Pickering, LL.D., Director of the Harvard College Observatory, Cambridge, Massachusetts. Messrs. A. Elvins, A. F. Miller, and G. E. Lumsden, who had prior knowledge of the letter, reported they had been observing the companion to Castor mentioned by Dr. Donaldson in his letter, and would communicate with him with reference to it.

The Reverend W. J. Murphy, of Ottawa, forwarded a copy of the New Law of Planetary Motion, as enunciated by Mr. D. McDonald, of Montreal.

Mr. David E. Hadden, Iowa, U.S.A., forwarded a number of copies of *The Weather Review*, containing his observations of the sun. The Librarian laid on the table the current publications received by him.

Dr. A. D. Watson, referring to the appearance of Saturn in the telescope, expressed the opinion, concurred in by several others, that the ring would not be entirely invisible in May, even in small telescopes.

Mr. Miller and Mr. Elvins reported a series of solar observations, some drawings of spots being presented by the latter.

Dr. E. A. Meredith introduced a question which, he said, had been discussed by meteorologists, viz., whether there is a general lowering of the temperature between the 10th and 13th May in each year on account of the earth's position in its orbit, relative to the paths of certain streams of meteors. Mr. Elvins said he would look over some records to which he had access, and state the result at the next meeting.

The paper for the evening was entitled

ASTRONOMY IN THE PROVINCIAL UNIVERSITY,

and was read by Mr. William Houston, M.A., a member of the Senate of the University, and also a member of the Society.

After a few preliminary remarks on the attractions of Astronomy as a scientific pastime and its consequent popularity, Mr. Houston spoke more at length of the science as a means of intellectual culture. Referring to the two great logical methods of investigation of natural phenomena, the inductive and the deductive, he claimed for Astronomy an exceptionally high place as one of the most perfect combinations, as to its methods, of both. While the phenomena of the heavenly bodies lend themselves as perfectly as any other phenomena to observation with a view to the formation of theories, or the generalization of principles, they afford exceptional opportunities for the verification of theories by the precise tests of mathematics. No other physical science is so perfect on both sides, the experimental and the deductive, or affords so favourable an opportunity for the exercise of both methods of the search after truth. With a view to making clear the present position and treatment of Astronomy in the University of Toronto, the lecturer explained the general character of the University curriculum. Students are allowed to graduate in either two sets of "courses," one at present called "pass" and the other "honour," though the epithets "general" and "special" would more directly describe them. In a pass, or general, course there are more subjects prescribed, with less work in each subject. In an honour, or special, course the subjects are fewer in number, while more of each is required, until, in his last year, the student is permitted to limit himself to a single subject, on which his graduating examination is based. There are options allowed in the general as well as in the special courses, and, as a result, Astronomy is not obligatory on all. The amount prescribed for those who elect to take it is comparatively small, and its treatment in the lecture-room is necessarily slight, owing to the fact that no provision has been made for allowing the student to observe celestial phenomena for himself. He is expected to "get up" his Astronomy from a study of a treatise on the subject, supplemented by a few lectures to aid him in the more difficult parts of it. The work required of one taking a special or honour course is much more thorough. It involves the use of the higher mathematics, and, indeed, Astronomy is placed with pure mathematics in the graduating department. This arrangement has had the effect on the one hand of subordinating Astronomy to Mathematics, and, on the other hand, of making the treatment of the subject a mere combination of theoretical calculations with the memorization of descriptions of astronomical appliances and their uses.

Mr. Houston quoted from examination papers to show that they are framed as tests of the kind of teaching he described, but he was careful to explain that this was not due to any inefficiency on the part of successive teachers of Astronomy in the University. This state of affairs is the result of the long-continued policy of the University in leaving Astronomy so inadequately provided for. He pointed out that similar treatment was formerly extended to other subjects, but as the Senate is making, or has made, provision for the practical treatment of every other subject in the curriculum, he thought Astronomy should not be the only one left to be taught theoretically or by rote. He suggested a two-fold remedy for the admitted evil:—(1) The creation of a new graduating department, of which Astronomy would be the chief subject, having associated with it Optics and Heat from the Department of Physics; and (2) the establishment of an observatory of instruction, equipped with a considerable variety of instruments. The first of these proposals would be easily carried out if the observatory were provided and the services of a director or demonstrator were available. To make this clear, the lecturer explained that down to within a few years ago there was but one mathematical department for graduating purposes, which department included both Pure and Applied Mathematics. This department was divided into two, one containing Pure Mathematics and Astronomy, the other containing the remaining application of mathematics to physical phenomena. His suggestion was that the divisions be now made three-fold instead of two-fold, one department embracing Pure Mathematics only, one made up of Astronomy with Optics and Heat, and the third remaining substantially the same as the present Department of Physics. With regard to the second proposal, he expressed the opinion that the University would be willing to grant a suitable site and the hope that it would before long provide a suitable building. The chief difficulty would be the equipment, which, for a good observatory of instruction, would be varied and costly. The maximum amount required is about $25,000 for building and equipment, and he suggested that if the building were provided it might be possible to secure the equipment by appealing to the lovers of the science for aid. He explained that the University is at present in great need of funds, and this is one way in which its friends might usefully help it, while doing at the same time something for a science some of them have done much to promote.

At the conclusion of the address, Mr. J. M. Clark, M.A., moved a vote of thanks to Mr. Houston, which was seconded by Mr. Lumsden, who expressed the hope that some one or more of the many wealthy Canadians and graduates of the University able to do so, would provide the funds necessary to construct an observatory.

Mr. A. Harvey heartily supported the motion, but criticized some of the University methods of management, regarding them as evidence of a disposition to withhold from the general public the advantages of the library and some of the departments where instruction of a character interesting to the people was given.

Professor D. R. Keys, M.A., warmly dissenting, stated that the public could at any time avail itself of the advantages of the library and museum.

The motion was carried, with the expressed hope that Mr. Houston would be entirely successful in his efforts to promote the practical work he had so much at heart.

TENTH MEETING.

May 31st, Dr. Larratt W. Smith, Q. C., Vice-President, in the chair.

Adverting to the question asked at the previous meeting by Dr. E. A. Meredith, respecting the annual fall of temperature said to take place between the 10th and 13th of May, owing to the supposed passage, between the earth and the sun, of a swarm of meteors at a point in their orbit intersected by that of the earth, Mr. A. Elvins stated that he had examined some records to which he had access, and that he did not find that the temperature was affected in any particular manner. In the short discussion which followed, it was, however, brought out that there are single days in the year which are invariably marked by a fall of temperature, and that certain meteoric phenomena are, at least, co-incident.

Mr. David E. Hadden, of Alta, Iowa, was elected an Associate Member of the Society.

The Corresponding Secretary read the following letter, dated May 24th, 1892, addressed to the members of the Society by Lady Wilson, of Toronto: "It will afford me much pleasure if you will accept the telescope and celestial globe of the late Sir Adam Wilson, as it was his express wish that they should be offered to the Astronomical Society, in which he took so much interest."

The Chairman and several of the members having referred to the pleasant relationship which had existed between the late Sir Adam Wilson and the Society, and to the interest he had taken in its welfare, it was moved by Mr. Elvins, seconded by Mr. Harvey, and resolved "That this Society gratefully accepts the donation made by Lady Wilson of the astronomical telescope and the celestial globe of the late Sir Adam Wilson, a donation valuable not only as a prized memento of an esteemed friend and active member, but intrinsically as well, and as a nucleus around which, the Society trusts, the accessories of a popular observatory will be gathered in due time."—Carried.

It was moved by Mr. Miller, seconded by Dr. Meredith, and resolved "That as a slight mark of the Society's appreciation of the gift just received, Lady Wilson be requested to permit her name to be submitted for nomination as a Life Member of the Society, and that the telescope and celestial globe be known and inscribed as the SIR ADAM WILSON MEMORIAL."—Carried.

Appropriate remarks were made by the mover, the Chairman, and Mr. Lumsden, the latter pointing out that, in addition to other apparatus, the Society now had an excellent six-inch reflecting telescope, and also the use of an excellent refractor, Dr. Larratt W. Smith having placed one at its service. He considered that the outlook was bright, and hoped that the Society would yet be enabled to fill the position it had assumed to occupy, namely, the place of a popular educator in the subject of Astronomy.

Under the head of Observations, the Secretary read the following letter, dated 25th May, 1892, from Professor E. C. Pickering, LL.D., Director of the Harvard College Observatory, to whom had been referred the communication from Dr. J. C. Donaldson, of Fergus, who had come to the conclusion that the nearest companion to Castor had, during the past two years, exhibited evidence of variability:—"I have had an examination made of the photographs of the region containing Castor. The three stars marked on your sketch appear on all of them, and have the same relative brightness. The photographs were taken on March 27th, April 1st, April 5th, 1890; February 15th, February 17th, March 6th, and May 18th, 1892, and had exposures of 9m., 17m., 10m., 10m., 11m., 13m., and 11m. respectively."

The hearty thanks of the Society were voted to Professor E. S. Holden, LL.D., Director of the Lick Observatory and an Honourary Member, for a set of exquisite photographic plates, including the following positives on glass:—"The Transit of Venus, 1882," "The Transit of Mercury, 1891," "The Sunspot of February, 1892," and "The Cluster in Perseus," taken November 3rd, 1890. There was also an original negative of the moon, twelve days old, taken August 16th, 1891. As was to be expected of anything from Lick Observatory, the plates, 8in. by 10in. in size, were very fine. At the request of Professor Holden, copies will be made for members.

Mr. A. Harvey mentioned that on the evening of May 28th, he noticed the illumination of the dark edge of the new moon's disc due, possibly, to the effect of the twice-reflected light from both Venus and the earth, the former being very near the moon. Mr. Harvey presented a drawing of the moon and Venus as seen in the telescope on the night referred to. Mr. Elvins remarked that he had observed the phenomenon under circumstances quite different from those mentioned by Mr. Harvey, and some of the other members expressed doubt as to the possibility of Venus being sufficiently brilliant to cause the illumination observed.

Mr. Miller reported an observation of Venus made in the daytime, and said the planet was seen to better advantage than after dark. He also described the interesting group of spots upon the solar surface, which corresponded with the group seen in April; some of them had undergone rapid change. Mr. Harvey remarked that one spot had been very near the sun's equator, nearer than he had ever seen one or thought it possible for one to be.

Mr. J. G. Ridout, referring to the position of sunspots, doubted the accuracy of positions given in longitudes. Mr. Miller explained how this was arrived at. A table, showing when the chosen central meridian is in the centre of the sun's disc, and based upon the sun's rotation period, is given in the *Companion to the Observatory.*

Master F. R. Miller, a lad of twelve, presented a photograph of a seven-inch electric spark produced by a static machine. This was followed by an interesting discussion upon the work of photographing the electric current, whether as a spark or as the flash of lightning, and the appearance of such flashes as caught by the camera.

Mr. Lumsden reported observations of Winnecke's periodic comet (telescopic), which was passing in a South-westerly direction between

Ursa Major and Leo Minor. It was stated that at no time during the present "disappearance" of Saturn's rings, had they been invisible, even in two-inch telescopes.

Members were reminded that on the invitation of Dr. Sandford Fleming, C.E., C.M.G., an Honourary Member, the Society had been interesting itself in a movement to induce all astronomers to reckon the day from midnight instead of from noon, and it was announced that Dr. Fleming had been requested to prepare a paper on the subject.

The paper of the evening was read by Mr. G. E. Lumsden on "Planetary Motions," those of Mars during the opposition of 1892 being chiefly dwelt upon as illustrations. Diagrams were introduced to explain the apparent retrograde motion of a planet in the sky, and the loops or closed curves described among the stars. Observations extending over a long period were described, and the phenomena compared with the slow motion of one object seen from another object carrying the observer very rapidly.

ELEVENTH MEETING.

June 14th ; Dr. Larratt W. Smith, Q. C., Vice-President, in the chair. The attendance was large and much interest was manifested.

Miss Wilkes and Miss A. A. Gray, of Toronto, were elected Active Members of the Society. The Honourable Judge Clayton, of Clarence, Maryland, was elected an Associate Member.

In view of the steady growth of the Society, some time was spent in discussing the desirability of obtaining a suitable place in which the Society might hold its meetings and mount its accumulating apparatus for the convenient use of members. The chief requirement appeared to be a centrally situated room, or small building adjacent to an open space on the ground, where portable instruments might be set up as occasion demanded. A Committee was appointed. In speaking on the subject of the best method of making use of the telescope presented by Lady Wilson, Mr. G. G. Pursey pointed out the necessity of having the instrument mounted in some place accessible and commodious, and stated that Mr. C. P. Sparling, whose residence, 282 Victoria St., was opposite the Normal School grounds, and therefore very central, had offered to take charge of the instrument and to arrange that access to it should be had by the members at all reasonable times.

On the motion of Mr. Elvins, seconded by Mr. Pursey, Mr. Sparling's offer was accepted.

Notice was given of a motion for a Committee to collect information as to the teaching of Astronomy in the City and Provincial Schools, and to suggest means by which to promote the study of that science.

Letters were read from Dr. Sandford Fleming, C.M.G., of Ottawa, stating that he was in communication with the Astronomer Royal of England, on the subject of the change in time reckoning; from Mr. J. Ellard Gore, F.R.A.S., of Ballysodare, Ireland, offering to the Society a paper on "Stellar Distances and Motions," consisting of a chapter in "The Visible Universe," a volume shortly to be published; and one from Mr. D. E. Hadden, of Iowa.

The Librarian reported having received the Reports of The Astronomical Society of The Pacific, of The British Astronomical Association, and of other societies.

Mr. D. J. Howell laid on the table the negatives which had been received from the Lick Observatory, and, showing prints from some of them, stated that he would, for a small fee, make any copies that might be desired, the margin over the actual cost to be applied to the credit of the Lantern-slide Fund, an offer that was accepted.

At a previous meeting, Dr. E. A. Meredith had called attention to a published statement to the effect that on the 13th of May, in each year, the temperature is always found to be lower than on the days immediately preceding or succeeding that date; the reason alleged for this was that on that day a swarm of meteoric matter passes between the earth and sun in such a way as to reduce the solar heat. Having reference to this, Dr. Larratt Smith, who for very many years had been a careful observer and recorder of meteorological phenomena, handed in a tabulated statement covering the ten days between the 7th and the 16th of May for each of the years 1877 to 1892, inclusive, and stated that the observations, which were taken at 8 a. m. and 10 p. m. each day did not bear out the alleged regular fall of temperature on the 13th, at least so far as Toronto was concerned.

Observations having been called for, Mr. A. F. Miller made the following report upon a phenomenon observed by him in 1892, June 12th, between 7h. 45m. and 8h. 20m., Eastern Standard Time:—"I had just commenced examination of the solar limb in search of prominences, the instrument employed being a 4-inch equatorial refractor (Wray) and a diffraction spectroscope with Rowland grating. The slit was placed tangential to the limb at position-angle 300 approximately, and the focus adjusted for the C line. When the slit was opened, I, at once, noticed a glowing hydrogen cloud hanging suspended above the chromosphere and entirely detached from it. It was much brighter than such clouds usually appear and seemed to roll or move in a manner which made its outline indistinct, notwithstanding its vividness. At the moment, I attributed this to terrestrial atmospheric tremors (though I subsequently came to believe the motion real) and made several alterations of focus to improve the seeing. In about five minutes, the outlines became sharper and I saw that a sharp conical body like the upper portion of an eruptive prominence was now visible below the cloud, but still detached from the limb. Concluding that the change of aspect was due to the better seeing, I proceeded to sweep all round the sun's limb in search of other forms, and, after ten minutes thus occupied, returned to the first position to re-observe the object I had before noticed; but could no longer recognize it in the form which I then discovered: *i.e.* a tall shining pillar-like column very bright and sharply defined. About five minutes were occupied in carefully examining the limb all round the position where the floating cloud-mass had been seen, to assure myself that I had not missed it by an erroneous setting of the circle, but I was soon convinced that the bright pillar occupied the exact site of the other form. Continuing to observe this column, I found it rather rapidly becoming faint while, at the same time, it was declining or bending over. While its position-angle was being ascertained with more exactness, it rapidly diminished in brightness and five minutes later had vanished entirely. I, however, noticed that the chromosphere at that point and for some degrees on each side of it, was more brilliant and more sharply defined than elsewhere round the limb. I now feel convinced that the fluctuations noticed in the original cloud when first seen, were due to actual motions of the mass in the line of sight, and not to atmospheric tremor; and that the change in appearance also really took place and was not, as I at the moment supposed, an improved view of the original form. I greatly regret that I did not continue to study the changes it was undergoing, as this would have revealed whether the cloud became actually metamorphised into the pillar-like form. Of course, it may be said that the former simply faded away while an eruptive prominence shot up from just below its site; but, bearing in mind the size and density of the cloud, I cannot believe that this was what occurred. It seemed to be taking on a pillar-like form while I viewed it, an idea which passed through my mind at the moment, but, unfortunately did not deter me from prosecuting the preliminary sweep for other forms, so that no measurements or spectroscopic study with a narrow slit were made. In the ten years during which I have made spectroscopic examination of the chromospheric forms a special study (so far as my rather limited leisure will allow), I have seen many gaseous or metallic up-rushes gradually spread out into cloudy forms, but never the converse. However, in this instance, I almost believe that by a whirling action, the cloud was gathered together and drawn down to the solar surface." In describing the phenomenon, Mr. Miller made use of diagrams, in coloured chalks, drawn on a blackboard.

Mr. A. Elvins presented sketches of the sunspot groups recently seen on the solar disc, and said, like Mr. Harvey, he had noticed the unusual proximity of one spot to the equator.

Dr. Larratt Smith drew attention to the unusual occurrence of a tornado in Nova Scotia, a region generally free from such storms.

As Mr. J. G. Ridout was about to leave for Europe, the Secretary was instructed to furnish him with credentials from the Society, introducing him to the Director of the Vatican Observatory, Rome, and to Scientific Societies wherever he might be visiting.

A paper was then read by Mr. Thomas Lindsay on the approaching occultation of Mars. The graphic method of determining the time of contact was explained and illustrated by diagrams, and the times deduced were:—July 11th, 11h. 20m. 18sec. Eastern Standard Time, for first contact, and of moon's limb with planet's centre, 12h. 12m. 42sec. A letter from Dr. Joseph Morrison, of the Washington Nautical Almanac Office, was read, having some reference to the paper. It was stated by Dr. Morrison that the graphic method was inferior to the Besselian method in making these calculations. Mr. Lindsay said that the results deduced should be correct within a small limit of error; if the error proved large, it must be attributed to his own errors in computation, not to the theory of the method employed.

TWELFTH MEETING.

June 28th; Mr. John A. Paterson, M. A., Vice-President, in the chair.

Mr. G. E. Lumsden's motion to the effect that the President, Mr. A. Elvins, Mr. A. F. Miller, and the mover be a Committee to frame a series of questions to be submitted to astronomers respecting the change in the time notation of the Astronomical Day, was carried.

On motion of Mr. James Todhunter, seconded by Mr. A. Elvins, Lady Wilson, Spadina Crescent, Toronto, was elected an Active Member of the Society. It was then moved by Mr. G. G. Pursey, seconded by Mr. A. Harvey and resolved, "That as some recognition of the graceful act of presenting to The Astronomical and Physical Society the telescope and the celestial globe of the late Sir Adam Wilson, Lady Wilson be and is hereby elected a Life Member of this Society." Carried, with applause.

Mr. G. M. Miller, of Toronto, was elected an Active Member of the Society.

Letters were received from the Directors of Melbourne and Bothkamp Observatories; from Miss Agnes M. Clerke, of London, England, who transmitted a paper on Nova Aurigæ; from Rev. W. J. Murphy, Ottawa, intimating that arrangements would be made at the Observatory at Ottawa for the observation of the occultation of Mars on the 11th of July.

Mr. Miller read a letter from Professor G. E. Hale, Director of the Kenwood Physical Observatory, to whom he had written in reference to his solar observation reported at the previous meeting. Professor Hale stated he had not observed the solar prominences mentioned. Mr. Miller called attention to the fact that it is not only in well equipped observatories that important solar observations may be made, adding that amateur observers may, at times, observe phenomena well worthy of record.

Mr. Harvey presented a sketch of Mars showing markings on the disc, as seen in a 3-inch refractor; he also described a well-defined parhelion observed June 25th, as an unusual phenomenon in this climate in the summer season.

Sketches of solar prominences were handed in by Mr. Miller. To show how some apparently difficult problems in Astronomy may be simplified by a little practical work, Mr. Lumsden described an attempt made to find the angle at which the plane of the celestial equator cuts the ecliptic. At noon, on or about Midwinter Day he drew upon a North and South wall a line marking the shadow cast by the sun from the top of a fence abutting the wall. On Midsummer Day he drew a similar line. And on measuring the angle between the two lines he found it to be a little less than forty-eight degrees; this angle halved gave one of about twenty-three and-a-half degrees, representing the obliquity of the ecliptic, the dividing line, of course, pointing, sufficiently, for all practical purposes, to the celestial equator, which, by the diagram on the wall, could be found at any time. Though the observation was of necessity a rough one, it was exceedingly simple, and served to make clear the language on the subject used in the text-books, not always understood by beginners.

The paper for the evening, "Stellar Distances and Motions," was received from Mr. J. E. Gore, F.R.A.S. It was intended to form a chapter in his book, "The Visible Universe" (since published), and was sent in advance of publication by special permission of his publishers, Messrs. Crosby, Lockwood & Son, London, England, who own the copyright. In his lucid and attractive style, Mr. Gore showed that the determination of the distance of the stars from the earth has always formed a subject of great interest to astronomers, and that a knowledge of the relative distances of bright and faint stars is of the highest importance in the study of sidereal astronomy, it being evident that if we could accurately find the distance of every star, and also the distances of the brighter and fainter portions of the Milky Way, the problem of the construction of the stellar heavens would be immediately solved. Notwithstanding the use of modern instruments of precision, the distances of but few stars have been ascertained with any approach to accuracy. In the course of his paper, the author referred to the earlier astronomers, including Tycho Brahe, Kepler and Huyghens, some of whom thought the stars had no measurable parallax, and, others, that the determination of stellar distance by observations was impossible; to Sir William Herschell, who, while working vainly upon the problem, made the splendid discovery of binary systems; to the parallax of fixed stars and the method of determining it; to the methods of computing a star's distance in miles by simply multiplying the sun's distance by 206,265, and dividing by the observed parallax, and of reducing distances to "light-years;" to the fact that the brightness of a star is no test of its distance; to the use of the spectroscope in determining the motions of stellar objects moving in the line of sight, and, among other branches of his subject, to the discovery that the solar system is itself in motion towards a point in Hercules.

The meeting adjourned to the lawn of the Normal School, Department of Education, where several telescopes, including the Sir Adam Wilson reflector, were placed in position, and very satisfactory observations made of the moon, Saturn and some double-stars.

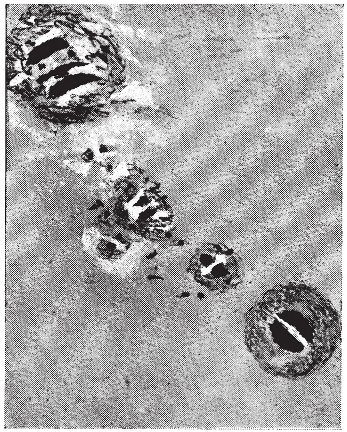
THIRTEENTH MEETING.

July 12th; Dr. Larratt W. Smith, Q. C., Vice-President, in the chair.

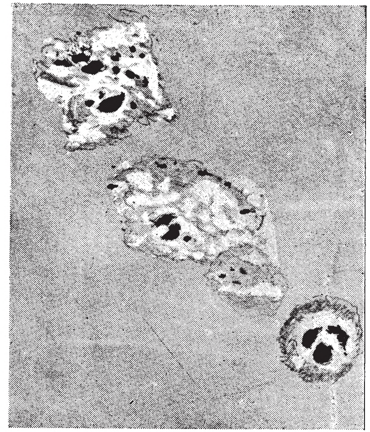
Rev. Father McBride and Mr. William Brett, of Toronto, were elected Active Members.

A communication was received from Mr. John F. Baker, of Kingston, who thought that the study of the elevating science of Astronomy was being practically denied to Canadians as a people, it being totally ignored by the various Departments of Education and, even in the Universities, being relegated to a comparatively unimportant position. Mr. Baker expressed the hope that the Minister of Education of Ontario, also Honourary President of the Society, would add Astronomy to the subjects to be taught in the schools, and urged the formation of classes for out-door work.

Messrs. A. Elvins and A. Harvey expressed the opinion that the elements of the science should be taught in all the High Schools and Colleges, but only to pupils desiring to study them. Mr. G. E. Lumsden stated that in most of the High Schools and in all the Colleges and Universities of the United States, instruction is given, and that the equipments of some of the Universities are among the best in the world, while some High Schools possess telescopes and apparatus of very great excellence. It was further pointed out that, in some instances, private munificence had enabled some of the colleges to purchase apparatus that made them centres around which societies could flourish and by which single observers could be much assisted. As but two of many instances that might be mentioned, it was stated that the great Lick Observatory itself is attached to the University of California, and that the Dearborn



JULY 7.



JULY 9.

JULY 15.

CHANGES IN SUN SPOT GROUP, JULY, 1892.

From drawing by Mr. A. Elvins.

Observatory and the Kenwood Physical Observatory form a portion of the Northwestern University at Chicago.

The Secretary read a reply from Lieut.-Col. McGill, of the Royal Military College, Kingston, to a query respecting Examination papers in Astronomy.

The Librarian reported the receipt of a paper " On the Orbit of the Binary Star ο Leonis," by J. E. Gore, F.R.A.S. (read before the Royal Irish Academy, June 22nd, 1891); Report of the Superintendent of the U. S. Naval Observatory for the year ending June 30th, 1891 ; various publications from Berlin, Germany, and The Proceedings of the Royal Society, May-June, 1892.

Mr. Lumsden, on behalf of the Committee on Change of Time-reckoning of the Astronomical Day, reported that it had met, and had considered a draft of a Circular Letter to Astronomers, which was amended in some particulars, and submitted to Professor Carpmael. The report recommended that Dr. Sanford Fleming, C.M.G., be added to the Committee, and that he be appointed Chairman thereof. The report was received and adopted on motion of Mr. J. A. Paterson, seconded by Mr. A. F. Miller.

Attention was called to the prevalence of sunspots, some of them only inferior in interest to the great spot of February. Mr. Elvins presented a series of fine drawings illustrative of the changes occurring in groups upon the solar disc. He also showed drawings of Mars and Jupiter. Mr. Miller considered that the Northern and Southern groups of July 3rd were re-appearances of two areas of disturbance which broke out on June 16th. Micrometrical measures gave 147,000 miles as the length of the principal group. On July 7th, at 8.30 a.m., he had seen the large spot of that date as a notch in the sun's South-east limb. This spot was the centre of an area of most intense activity, as testified by its spectroscopic peculiarities, many reversals and displacements of lines being recorded. Its approach was heralded on the morning of July 6th, by the appearance of a group of intensely brilliant prominences at position-angle 120 degrees. This spot, as well as the great Northern group, was visible to the unassisted eye July 9th and 10th. Solar observations were also reported by Mr. Arthur Harvey, Dr. Donaldson, of Fergus, and others.

The feature of the meeting under the head of observations was, however, the occultation of Mars by the, almost full, moon on the night of July 11th. This observation was successful in every respect, the occultation being easily visible even to the naked eye. Upon the invitation of Dr. Larratt Smith, a group of observers with portable telescopes and opera-glasses made the observation from his grounds, situated on an eminence near Rosehill reservoir, immediately North of the city. Great care was exercised in taking the times of contact. These were officially reported by Mr. A. F. Miller to have been as follows :

		Eastern Standard Time.
Immersion.	1st Contact,	July 11th, 11h. 18m. 37sec., p.m.
	2nd Contact,	" 11th, 11h. 19m. 45sec., p.m.
Emersion.	1st Contact,	" 12th, 0h. 14m. 2sec., a.m.
	2nd Contact,	" 12th, 0h. 15m. 1sec., a.m.

Dr. Smith, Mr. A. Elvins, Mr. Miller, Dr. A. D. Watson, Mr. A. Harvey, Mr. G. E. Lumsden, and others who were present, enlarged upon the official report, and mentioned many interesting features connected with the occultation.

Dr. Watson, who used a high power on his telescope, said that when Mars was about 70 seconds of arc distant from the bright limb of the moon, he noticed a gradual dimming of Martian detail, the South polar-cap and planetary markings seeming to be subject to a "shimmering," such as is seen when an object is observed through a heated atmosphere.

Mr. John Goldie, of Galt, reported that he made the observation with his 4½ inch equatorially mounted refractor, and that he took the times as follows:—First contact, 11h. 17m. 10 sec.; second contact, 11h. 18m. 18 sec.

Speaking of Mars, Mr. Lumsden reported that during an observation made between 2 and 4.30 o'clock on the morning of the 8th of July, a large dark marking near the South pole, by its motion, afforded evidence of the rotation of the planet. The South polar-cap was so conspicuous as to appear like a brilliant semi-circular object super-posed on the planet, rather than as forming part of it.

The paper of the evening on

NOVA AURIGÆ.

contributed by Miss Agnes M. Clerke, of London, England, a member of the Society, was read by Mr. A. F. Miller, and was as follows :—

Nova Aurigæ will always be memorable as the first temporary star to the investigation of which chemical methods were applied. Their application, moreover, had a special fitness to the nature of the apparition, since its most noteworthy feature was the spectroscopic display of motion in the line of sight, for the measurement of which photography offers particular advantages The spectrum of the new star was indeed of an extraordinary nature. It was two-fold. It included a long range of vivid lines extending very far into the ultra-violet, each with a dark line attached to its more refrangible side. The entire hydrogen-series from crimson C to the last of its rhythmically-disposed associates, were thus doubled, as well as the calcium line K, the sodium D and others. Many more, at the same time, belonging to the crowd of feebler bright lines, so to speak, threw no shadows; while every well marked dark line seemed connected with a bright one. All, however, that could be terrestrially identified proved to be displaced from their normal positions; the bright lines towards the red, their dark companions, to a still greater extent, towards the blue. Evidently, then, two oppositely moving bodies were concerned in producing a compound spectrum, the gaseous section of which testified to a recession from the earth of about 230 miles a second, while the juxtaposed absorption rays crossed the otherwise continuous spectrum of a mass advancing with the exceptional, though not altogether unprecedented, swiftness of 320 miles per second. Thus, a telescopically single star was resolved, by the analysis of its light, into two physically unlike, though chemically similar, components, accomplishing a daily journey of separation extending over close upon fifty millions of miles! Possibly even a good deal more. Spectroscopic estimates of motion are always minimum values. They take into account only that portion of velocity directed along the visual ray; they necessarily neglect the portion directed across it. We are, however, in absolute ignorance as to how much of the speed of Nova Aurigæ was thus directed. All that can be said is that the chances are enormously against the whole of it having been measured on the Potsdam and Tulse Hill negatives.

Nova Aurigæ was then really, though not optically, a double star; and there can be no question but that its luminous outburst sprang from its temporary duplicity. The outburst was very sudden. On December 8, 1891, Dr. Max Wolf, of Heidelberg, took a photograph of the sky around χ Aurigæ, showing stars to the ninth magnitude, on which the spot subsequently occupied by the Nova was blank. Yet it imprinted itself, forty-eight hours later, as a bright star of the fifth magnitude, on a plate exposed at Harvard College; and attained a maximum, similarly recorded, of about 4·5 magnitude, on December 20. But these photographic documents, as every one interested in the subject is aware, were only looked into after the visual discovery of the star by Mr. Anderson, of Edinburgh, on February 1, 1892. All the information collected about its spectrum, and the extraordinary revelations of movement afforded by it, were accordingly of a later date. This was unfortunate. One single determination of the kind in December would have been worth many in February and March. For it was then, presumably, at the time of the stars' abrupt leap upwards from obscurity, that they made their nearest approach to each other; and at that critical epoch, the changes in their velocities must have been comparatively rapid. Fifty days later they had, as it were, settled to their stride, and were rushing apart at a rate the variation of which from uniformity fell nearly, if not quite, within the limits of probable error in measurement.

One point, however, seems perfectly clear. Their velocity was hyperbolic. That is to say, it was not all due to the influence of their mutual gravitation. The bodies animated by it were very far from being relatively at rest when they began to fall together. Each, on the contrary, must have possessed a swift motion of its own pursued along a line nearly opposite to or intersecting that of the other. These assertions can be easily justified.

We may fairly assume that the components of Nova Aurigæ passed periastron about the time of their greatest brightness, that is, on December 20. They had accordingly been in course of recession from the scene of their close approach, for some forty-four days when they began to be spectroscopically observed; yet their relative speed can then scarcely have fallen short of six hundred miles a second. It kept, at any rate, well up to 550, on February 22—sixty-four days after periastron—when Dr. and Mrs. Huggins took a fine photograph of the spectrum so curiously significant on the point. Nor had it perceptibly slackened a week or more later, judging from the spectrographic determinations at Potsdam. But this high and lasting speed cannot have been parabolic—cannot, in other words, have been the speed due to the simple falling together, from an indefinite distance, of two gravitating bodies. A combined mass *ten thousand* times that of our sun would be inadequate to produce the observed relative velocity of the components of the Nova; the mass of ten thousand suns is not an approximate value, but merely a minimum estimate! An elementary calculation shows that no less enormous a power would be required to produce, at the end of sixty-four days' retreat from a grazing encounter, a parabolic velocity of 560 miles a second, diminishing, at the end of seven additional days, to 537 miles a second. Few, however, will be prepared to admit so extravagant a demand in the way of mass; and there seems no alternative but to conclude the orbits of the separating stars to have been hyperbolas. A very large proportion of their movement might, on this view, be original or inherent, and would hence persist irrespectively of the lapse of time; the changing element due to the accelerative force of gravity sinking, by comparison, into insignificance. Moreover, the ascending branches of the hyperbolas traversed may be assumed to have come near co-incidence with our line of vision. Otherwise, the measured velocities, extraordinarily high as they were, must have been considerably exceeded by the actual rates; which appears unlikely.

The meeting of the constituents of Nova Aurigæ must then have been casual (in our limited apprehension) and unique. It can never, in all time, be repeated. "Nulla vestigia retrorsum" is the inexorable law of hyperbolic travelling. And this is only what we should expect in the case of a temporary star, the distinguishing "note" of which is one solitary outburst. How such outbursts are occasioned is not indeed in all respects clear; yet the circumstances attending them have been rendered perceptibly less enigmatical by the recent apparition. This was certainly due to the mutual action of two cosmical masses, brought for a short time into close contiguity. Not into actual collision; since their motion survived, evidently without material diminution, an upspringing of incandescence which, accordingly, it could not have been spent in producing. Hence the manner of influence exerted has still to be defined and ascertained. Dr. and Mrs. Huggins incline to the view that it was of a tidal nature. And the bodily strains due to the pull upon each other of two voluminous spheroids, swinging round with possibly a bare escape of contact, must certainly have been of extreme intensity, and would be most likely to cause eruptions of heated gases from their interior parts, by which inert photospheric surfaces might be vivified to brief brilliancy. This hypothesis, too, would account, better perhaps than any other, for some of the minor peculiarities noted in the spectrum of the new star. Thus, the frequently multiple character both of the bright and of the dark lines contained in it, testified, it was plausibly argued, to the presence of "reversals," such as commonly occur above sunspots. They may be described as the dividing-up of wide bright lines by narrow dark ones, or of wide dark lines by fine bright rays; and they would be an almost inevitable accompaniment of enormous outpourings of ignited gases, ensuing upon tidal deformations. These were then presumably concerned—perhaps fundamentally concerned—with the phenomena of the Nova; but other causes may also have contributed to their production. The vividness of the transient illumination suggests, for instance, the agency of electricity rather than mere elevation of temperature; and electric forces of great potency can hardly fail to have been generated by the close approach, at high velocities, and violent mutual disturbance, of two more or less sunlike bodies.

Their solar nature was attested by the character of their spectrum. It was in the main that of the solar chromosphere, but displayed through the means of lines of absorption by the member of the pair advancing towards the earth, while the receding mass showed the same lines brilliant by emission. None of the destinctive elements of nebular or cometary light were detected; and an extreme degree of luminous excitement was certified by the strongly-marked presence of the entire ultra-violet hydrogen-series of rays, besides that of other groups still more refrangible, of unknown origin. The combined spectrum, in fact, rivalled that of Sirius in the extent and proportionate strength of its most refrangible section.

The question is one of much interest as to how far Nova Aurigæ might be regarded as a typical "new star." Was it an object so peculiar that reasonings about it could not legitimately be generalized, or were the discoveries it gave rise to capable of extension to other members of its class? There can be very little doubt as to the answer. Although the apparition had a *specific* character of its own, its *generic* character was that of a true Nova. Its visibility lasted, it is true, longer than that of any of its congeners in the present century. Nova Ophiuchi (1848), T Coronæ (1866), and Nova Cygni (1876), had each an exceedingly short maximum—to be counted, indeed, rather by hours than by days—while Nova Aurigæ did not enter upon its definitive and precipitate decline for nearly three months after its first manifestation. But the Pilgrim Star of 1572, and Kepler's Star of 1604, continued lucid during a year and a-half and two years, respectively, and the triple maximum of Anthelm's Nova of 1670, stretched over three years; so that the rule of speedy extinction admits of a fairly wide interpretation. Virtually the same range of bright lines seem, moreover, to have been observed in the spectra of the stars of 1866, 1876 and 1892. All three objects may, accordingly, be referred without hesitation to the same category; and all three must have attained brilliancy through the action of analogous causes. Nor can any valid distinction be drawn between these and other new stars, each of which must hence have represented the transitory conjunction of two bodies happening to pass very close by one another as they swiftly pursued their ways through space. But this state of things might not always disclose itself to observation. The velocities of the rushing masses might often escape even the detecting power of the most stringent light-analysis. If directed across our line of sight, they would be spectroscopically annulled; if much inclined to it, they would be so much reduced in amount as easily to evade notice. Further, there is no obvious reason why a gaseous should be strictly matched, as in Nova Aurigæ, by an absorption spectrum. But even if it were, the two might not be readily, if at all, distinguishable, since they would depend for their separate conspicuousness upon the oppositely displacing effects of rapid motion in the line of sight. It was this pushing apart of lines identical in origin that made the duplication of the spectrum, in the case of the recent star, so remarkable and unmistakable. Had radial movement been absent, the bright and dark series would have coalesced, and neither might have been distinctly perceptible. For in the integrated light, absorption would so nearly neutralise emission as to give the appearance, if not of a perfectly continuous spectrum, at least of one feebly characterised by those secondary bright lines which were uncompensated by dark ones. Thus, the spectrum of Nova Andromedæ (1885) was of this kind, and might conceivably have been so produced. The traces of bright lines noted in it might have represented, not the totality of emission, but only the excess of emission over absorption. They stood perhaps for the algebraic sum of many positive and negative quantities. This condition is periodically illustrated by the well-known short-period variable, β Lyræ, the only star yet known to exhibit a compound spectrum like that of Nova Aurigæ. It affords evidence, however, as might have been anticipated, not of hyperbolic, but of approximately circular motion. The bright lines, instead of remaining fixed beside the dark ones, shift to and fro, so as to be seen alternately on either side of them, conformably to the period of nearly thirteen days, in which β Lyræ varies in lustre. At intermediate epochs, moreover, when the orbital velocity of the star is tangentially directed, and its spectroscopic effects are consequently reduced to zero, the bright lines tend towards disappearance, overpowered by their dusky companions. In Nova Aurigæ, too, a similar effacement of mutually counterbalancing appearances should have marked (had observations then been practicable), the short interval during which its components wheeled round each other, preparatory to entering upon their endless career of separation. From a different point of view, indeed, this effacement would have been permanent. Had the orbit of the Nova been tilted up so as to lie nearly square to our line of vision, its spectrum would have borne a comparatively indeterminate character. The separate elements combined in it would have been inextricably confused; neither visual nor chemical methods could have afforded the means of reading its meaning aright.

FOURTEENTH MEETING.

This meeting was held on Tuesday, 26th July, at the residence of Mr. A. F. Miller, 280 Carlton street, it being Mr. Miller's intention, weather permitting, to place his fine telescope and spectroscope at the service of members for the purpose of showing some stellar spectra. Other telescopes were to have been on the ground, so that all present might be interested in making observations. As a cloudy sky prevented an open air meeting, the chair was taken by Mr. John A. Paterson, M.A., Vice-President.

Mrs. Margaret Fry Baldwin, Mr. James Foster, Mr. C. T. Gilbert and Mr. W. L. Gilbert, of Toronto, were elected Active Members of the Society.

The correspondence, which was voluminous, embraced further letters on the subject of teaching Astronomy in the schools. The larger portion of the evening was devoted to reporting and discussing observations. These included the recent occultation of Mars and two remarkable auroral displays on the 13th and 16th of July—displays which seem to have been widely observed and to have aroused much interest. Respecting the occultation of Mars, special reports were received from Mr. Thomas Lindsay, of Grimsby, Dr. J. C. Donaldson, of Fergus, and the

Rev. W. J. Murphy, of Ottawa, who, with Mr. Deville, Surveyor-General, and Mr. King, C. E., made very careful observations. The Ottawa group of observers reported the following :—

		Sidereal Time. H.	M.	SEC.
Immersion	1st Contact	18	45	43-37.
	2nd Contact	18	46	47-59.
Emersion.	1st Contact	19	41	24-22.
	2nd Contact	19	42	29-18.

AURORAL DISPLAYS.

With respect to the auroral displays, Mr. A. Elvins read the following memorandum: "Since our last meeting we have had two auroræ, both very instructive, though the second was far more grand and beautiful than the first. On the 13th of July, about 10 p.m., I observed between the horizon and the Pole-star, a bright, white, luminous cloud, which gave a bright line spectrum; other clouds were scattered East and West, but attention was paid to the first, it being the most striking in appearance. This auroral cloud drifted westward and passed over the lower stars in the square of Ursa Major; pursuing its westward course, it was soon lost behind some trees. When near the horizon, faint streamers rose from the cloud toward the great square in Hercules, then near the zenith; other faint streamers were visible in other parts of the heavens, and pointed to the same constellation. At 10h. 20m., a patch of white light appeared in the East; it was elongated, and a line drawn through its longer axis passed also to Hercules. This constellation seemed like the radiant of a star-shower, from which auroral streamers radiated on all sides. I cannot repress the conviction, that auroral displays and star-showers are very similar in their origin. The Eastern patch of auroral light became very bright, and passed upward in a Westward direction until, near Alpha Aquilæ, it bent and turned Southward. The Northern horizon was bathed in auroral light, but the usual dark bank was not present. All the patches gave auroral spectra, and I noticed that the auroral lines sparkled; appearing wider and brighter at some points than at others. For short periods, the lines seemed to have beads of light clinging to the more refrangible side. In some cases the line was certainly bent like solar lines in the spectrum of a sunspot; the light appeared to move in the line of sight, and the points of light seemed to be due to the luminous matter coming earthward. On this occasion, I saw only two lines, the more refrangible one was noticed only when the bright knots were visible. There was no sun-spot near the eastern limb on the 13th of July.

"The most brilliant display of aurora which I have seen since 1872, was visible on the 16th of July. I noticed it first about 10 p.m., as a broad, hazy stream of auroral light in the East, but it soon crossed the zenith and extended to the West, where it took on a purplish hue, the Eastern end remaining whitish but tinged here and there with green. When the spectroscope was pointed toward the West, the spectrum showed the two lines observed on the 13th, and also another far in the purple. While engaged with the spectrum the whole Northern heavens suddenly lighted up and, for a few minutes, presented a most gorgeous spectacle. It seemed as if the hitherto clear sky had become covered with patches of light cloud invisible except when, with a sort of electrical scintillation, they were, as if by sheet lightning, splendidly illumined by auroral light passing in rapidly succeeding rushes, or waves, or pulsations, from the North far towards the South. The Western sky was decidedly of a reddish-purple hue, while that of the East was more greenish white, though sometimes a reddish glow was visible even there. A corona formed near Vega, and all the rays radiated from that point.

"Electricity and Magnetism are doubtless disturbed when we have auroral displays, but the cause of the disturbance is far from being known. We get more auroræ at sunspot maxima than at the minima, but whether there is a real connection, or a co-incidence only, is not certain. Some observers think that spots coming over the Eastern solar limb cause an outbreak; it is certainly not always so. Others think auroræ are caused by some solar force when a spot crosses the central meridian. I should rather expect to find them caused by outbreaks of spots than by either of these, but I strongly suspect that when the cause and nature are really known, it will be found that synchronism of spots and of auroræ is a co-incidence only, and that one is not caused by the other, but that both are due to some cosmical cause which acts on both. In studying auroræ, we must remember that we *see* arches of *light*, streamers of *light*, flashes of *light*; that is, waves of ether vibrating at or above 500 million millions times per second strike our organs of vision. We cannot see electricity; its waves are too long. When waves of ether have lengths of from $\frac{12}{10000000}$ths to $\frac{16}{10000000}$ths of an inch, we have chemical energy; when they follow each other from $\frac{16}{10000000}$ths to one $\frac{20}{10000000}$ths of an inch per second, we see them as light; when they are but $\frac{12}{100000}$ths in length, we feel them as heat; and when they attain lengths which are measured by yards and miles, we have electrical phenomena. Clearly, we must cease to think of electricity as a substance, *i. e.*, a fluid. Ether fills all space, and light, heat, and electricity are movements of the ether. In auroræ, however, something disturbs the ether, causing it to move in light-waves; I hope the members of this Society will *find the disturbing cause.*"

The following description of the aurora was received from Mr. J. C. Donaldson, LL.D., of Fergus, a town five miles North and sixty-three miles West of Toronto: "The aurora which occurred on the 13th July was sufficiently remarkable, but the one to-night (July 16th) beggars all description." * * "About 10.30 p.m., I noticed a yellowish-white or gray coloured cloud coming from the North, and gradually stealing, as it were, from star to star, until it passed the tip of the tail of the Great Bear, reaching a point about overhead, I think, when it apparently stopped, and shortly afterward the display commenced, and it was a sight certainly never to be forgotten by any of those who had the good fortune to see it; no mere reflection from the polar ice about this display at any rate. Flames, rose, purple, amethyst, white, yellow, glorious, golden, darting from all points of the compass, North, South, East and West, with almost the rapidity of lightning, met at a point apparently just a little South of overhead. Anything more wonderfully beautiful than this, I have never seen."

The following description was received from a veteran observer of auroræ, Mr. John Hollingworth, of Beatrice, Muskoka, a point one hundred and thirty-six miles north of Toronto:—"On July 16th, at 9 p.m., a body of auroral light was observable down on the horizon at North and North-west. At 9.30, an irregular arch or band of light stretched from the horizon from North-east to North-west at an elevation of 45°, and from which streamers were issuing up towards the zenith; a smaller band or arch below this existed in the North, there being a clear sky below; and above this and between the upper one, stretching some distance in a Southerly direction from where the points of the larger arch touched the horizon, and rising to a considerable elevation were bodies of auroral light. The light at this time was of a pale green colour, with sometimes a tinge of red on streamers. This constituted the general character of the display until shortly after ten o'clock, at which time the light began to grow in intensity and spread in a direction South of the zenith, and at 10.30 o'clock, the whole sky from North to South, from East to West, was covered with such a body of auroral lights as I never before witnessed. From the horizon all around rose streamers, waves, and billows of light, leaping and dancing with lightning-like rapidity upwards towards the zenith, which seemed to be a gulf into which Nature might pour all her possessions and yet not fill it. I cannot compare it to anything more appropriate than the mighty Niagara running upwards, but without its thunder, yet not noiseless, *as the display was accompanied with a swishing, crackling sound, such as would be produced by the separation of two sheets of some light fabric whose surfaces were slightly sticky.* The culminating point of the display was about 10.30 o'clock, and lasted with full vigour for about fifteen minutes, after which time the pulsations became less violent for a time, and the sky cleared in parts; a further display, but not so extensive or violent occurred about 11 o'clock, and when I ceased to observe at 11.15 o'clock a considerable portion of the sky was yet covered with auroral light and bands. A distinguishing feature of this display was the well-defined bands of light running from North-east to North-west, those South of zenith being in the same direction. I think I have seen more brilliantly coloured light, but never anything so extensive or violently in motion as in the present instance. The time given is local, probably about twenty minutes later than Standard Time for Toronto."

Interesting reports were also made by Rev. R. C. Caswall, the Chairman, and Dr. Larratt W. Smith, and by Messrs. A. F. Miller, Arthur Harvey, D. J. Howell, R. Dewar, Clarence Bell, G. E. Lumsden and others.

Mr. Harvey vividly described a violent electric storm, accompanied by very heavy rain, which passed immediately north of Toronto, July 22nd. In the course of his report he said, that about five o'clock, a peariform mass of globular lightning fell, comparatively slowly, into the top of a tree about twenty-five yards from his house, in which he was sitting. It there exploded with great violence, doing considerable damage to trees near by. It was afterwards found that a telephone wire passed through the tree at the point where the explosion occurred. Other references to the great heat prevailing and to violent thunder-storms were made.

Dr. Donaldson transmitted a very creditable photograph of the sun, with spots, taken by Mr. John R. Connon, of Elora, near Fergus, at 3 p.m., July 9th.

August 9th, 1892. Owing to unfavourable weather, the special meeting to have been held on this date in the Queen's Park, for the purposes of observation with portable telescopes, was postponed.

FIFTEENTH MEETING.

August 23rd; Dr. Larratt W. Smith, Q. C., Vice-President in the chair.

Mr. J. W. Lee, of Toronto, was elected an Active Member of the Society, and Mr. W. F. King, of Ottawa, a Corresponding Member.

Further interesting reports, having reference to the auroral display of July 16th, were read. One from Mr. Robert Dewar was particularly graphic.

A letter from Dr. M. A. Veeder, of Lyons, N.Y., was read on the same subject. It stated Mr. John Hollingworth, of Beatrice, was the first to call attention to the peculiar crepitating sounds heard on that occasion.

On this point, the following extracts were read from an anonymous communication:

"I have been much interested by the communication by Mr. Hollingworth respecting the aurora seen by him in the Muskoka district in July last. My interest was chiefly occasioned by the crepitating sound heard and so clearly described. I remember that many years since scientific men were much interested in the question of any sound being heard. Inquiries were made in Europe and America, but the conclusion arrived at was that the auroral movements were too distant to be heard, and so the matter ended as an ascertained fact. I had good reason to be satisfied of the fallacy of the conclusion, as I had most distinctly and unequivocally heard them, many years before, in Forfarshire, Scotland. There, I saw an aurora that was remarkably bright and vehement, and seemed unusually low and near. The shifting bars were sharply defined, and seemed to come near the horizon. While I was going South with my back to the aurora, I was surprised by the hurtling, wing-like sound so aptly described by Mr. Hollingworth. I stopped and turned round to watch the aurora, and distinctly identified the hurtling sounds with the vehement shifting of the bars. The sounds lasted hardly two minutes. Several years afterward, my sister plainly heard them in the neighbourhood of Dumfries. This sound is a very important thing in the study of this difficult subject, and has now to be taken into account in spite of theoretical conclusions. The occurrence is very rare, and lasts only a few minutes, hence so few have heard the low, rustling quiverings as of wings."

A letter from Professor E. S. Holden, LL.D., was read, in which he disclaimed responsibility for any articles in the press that were not signed by some one of the astronomers engaged in the Lick Observatory. This was due to alleged discoveries on the planet Mars credited to Lick observers. Letters from Mr. S. E. Peal, of Sibsagar, Asam, India, and Mr. A. F. Hunter, of Barrie, were also read.

Photographs of the sun's surface were received from Mr. J. R. Connon, of Elora. They were excellent and were added to the Society's collection.

Mr. W. F. King, of Ottawa, wrote with reference to his paper on "The Computing of Occultations," read before the Royal Society of Canada, a copy of which he forwarded for the Society's Library. Mr. King's method is an application of diagram-work, with ruler and compass, to the rigorous analysis of Bessel. Mr. King said he would most heartily co-operate with any of the members in these observations.

The Librarian reported the receipt of a number of valuable works, among them a volume of reports from the Cincinnati Observatory, to which Mr. A. F. Miller called particular attention, stating that Professor Porter was engaged in a most important work, viz., that of observing stars for proper motions. He recommended the members to take advantage of the fact that this volume was in the Library.

Excellent drawings of Jupiter and Mars were presented by Mr. A. Elvins.

Mr. Miller reported the general result of his observations of the solar surface since July 26th. The most striking spot seen was the one which appeared on the Eastern limb, July 30th ; this was described minutely. Of the spectroscopic observations made, the most important was that of August 14th. Mr. Miller also presented a negative of the stars in the region of Alpha Aquilæ, taken by means of a home-made camera attached to a four-inch telescope. The negative afforded excellent evidence of the work possible with comparatively simple appliances, and was much admired. Mr. Miller said he had no doubt most excellent results might be obtained by using the telescope in the Toronto Observatory, even if only a common camera were employed.

The evening being unsuitable for observations, Dr. Larratt Smith read a short paper affording an interesting description of the sidereal heavens in regard to the probable distribution of the stars, and forming a chapter from "The Scenery of the Heavens," by Mr. J. Ellard Gore, F.R.A.S.

SIXTEENTH MEETING.

September 6th. Mr. J. A. Paterson, M.A., Vice-President, in the Chair. There was a large attendance.

The Honourable Mr. Justice Osler, and Messrs. J. P. Clougher and T. R. Clougher, of Toronto, were elected Active Members of the Society. It was announced that seven candidates for Active Membership had been put in nomination; that the growth of the Society had been almost phenomenal, and that the interest it had aroused in the subjects of astronomy and observation throughout the Province had been very gratifying.

The correspondence included letters from Miss Agnes M. Clerke, London, and Mr. W. F. Denning, F.R.A.S. Bristol, England. The following announcement from the Rev. T. E. Espin, F.R.A.S., and director of the Observatory at Tow Law, England, was listened to with attention :—"Mr. H. Corder, having informed me that Nova Aurigæ has increased; it was examined here August 21st, and proved to be of magnitude 9.2 ; spectrum monochromatic, one intense line (500 ?)." It had been reported from numerous observing stations that the Nova was practically invisible, having decreased to about the 17th magnitude.

Commenting upon this, Mr. A. F. Miller stated that the spectrum then to be seen, indicated that the star had become nebulous, certainly a very remarkable change, and one difficult to explain in view of former theories which obtained. Its apparent increasing brightness might render it necessary to materially modify some of the theories advanced to account for its former brilliancy. The intense line referred to by Mr. Espin, was believed to be identical with the chief nebular line. Its existence in the Nova, if proven, would lead to very startling conclusions.

Considerable additions to the Library of the Society were reported by Mr. G. G. Pursey. These included volumes and publications from the United States Naval Observatory, and from British Societies. It was stated that the plan of the Society of devoting a portion of its meetings to practical work had been commended, and its adoption urged upon some of the leading Astronomical bodies in Europe.

The observations reported, included the occultation of Mars by the moon on the morning of September 4th. This was widely observed; reports from members, including three resident outside of the city, were read. Mr. John Goldie, of Galt, took the time of the total disappearance of the planet as 1h. 19m. 1sec. Dr. J. C. Donaldson, of Fergus, observed the first contact at 1h. 15m. 45secs., and the total immersion 45 seconds later. References were made to Jupiter; to occultations of stars, and to auroral displays; reports were received from Toronto, Grimsby, Fergus, and several places in Muskoka where members were either living or staying.

Mr. Robert Dewar, read the following analysis made by himself of the meteoric stone in the possession of the Society, the gift of Mr. Joseph Townsend:—Iron, 83·7%; Phosphide of Iron, 10%; Phosphide of Nickel, a trace, Ni., 4%; P., 2%; Mn., trace; Co., trace; S. trace, total 99·7%. Mr. Dewar was satisfied that the analysis proved the meteoric origin of the stone.

Mr. Miller, presented a photograph of a portion of the solar spectrum, which showed some of the lines very clearly. This was taken with the same modest appliances used to photograph the stars in Aquila on a former occasion. In reply to a question, Mr. Miller explained his method of working, and expressed the opinion that much might be done by amateurs in that direction.

Predictions of phenomena, as usual, were announced, but, on this occasion, they included the partial eclipse of the sun to be visible in Canada on the 20th of October. The necessary particulars having been given, it was stated that the Society would be glad to receive reports from any part of the Dominion.

The paper of the evening, entitled

NOTES ON METEORIC OBSERVATIONS,

was contributed by Mr. W. F. Denning, F.R.A.S., of Bristol, England, a Corresponding Member of the Society, and was as follows:

"The systematic observation of meteors forms a very interesting branch of practical Astronomy and it is one in which amateurs may suitably engage with the certain prospect of success. Expensive instruments are not needful; in fact, a man has only to use his eyes and exercise his patience and in time he will be able to accumulate a mass of useful materials.

"Meteoric observation consists in attentively watching the sky and recording the apparent paths of such falling stars as appear; in estimating the durations of their individual flights and in determining their radiant-points. The work is entirely one of eye-estimation, and, therefore, its accuracy mainly depends upon the skill and judgment of the observer. These desirable qualities are only to be acquired by practice; indeed, this particular research imposes upon the student a considerable amount of preparation. The more experience he gains, the greater the confidence that can be reposed in his records. And there is no doubt that the longer he investigates this subject, the more deeply interesting will it become to him. But, at first, the discursive flights of meteors will be sure to create confusion and doubt, and he will find it difficult to reduce such materials to an orderly arrangement. Complications will arise which his lack of knowledge will prevent him from unravelling. Oft renewed vigils will, however, soon enable him to gain a clearer insight into the details and requirements of the work and he will proceed with more confidence.

"A celestial globe of about eighteen inches diameter is very convenient on which to mark the meteor-tracks as observed. The Right Ascension and Declination of the beginning and end-points of each track should then be read off and catalogued, together with the time of appearance, apparent star-magnitude and length. The register should also state whether the meteors were accompanied with phosphorescent streaks, or trains of sparks, and a column should be given for estimates of the duration. It is necessary to include these details as to the visible appearance of the objects, as their radiants may then be more correctly assigned and the meteors associated with others bearing a physical resemblance. When a number of paths have been projected upon the globe, the radiants may be determined by carrying these paths backwards in the same directions, or lines of flight, and finding the places where several of them intersect. A considerable number of meteor showers are visible on every night of the year so that a collection of tracks on a globe will give evidence of many different showers.

"A very attractive sphere of labour is for two observers, at stations from 50 to 100 miles apart, to arrange to watch simultaneously for meteors. In such cases both observers are pretty certain to notice several of the same objects, and, from a comparison of the data obtained, the real paths of all such meteors in our atmosphere may be readily computed.

"There is a pressing need for much further observation in this field, where hitherto the labourers have been few, though a rich harvest has been waiting to be gathered. Some questionable features of meteor streams still require definite settlement. There are many obvious distinctions to be found amongst them, and the phenomena exhibited by radiant points are often extremely dissimilar. Some displays are regularly visible every year, like the fine shower of August Perseids. Others are more fugitive in their recurrences, like the Andromedes of November 27th. Certain displays are of great richness, furnishing many thousands of meteors in an hour ; others are so attenuated as to scarcely supply one meteor in ten hours. These remarks apply to the extent of sky commanded by a single observer. In duration also we find marked differences ; some showers apparently endure for a few hours only, while others continue actively in play for several months. The radiant points, also, show various peculiarities. Those of the Perseides and Lyrids are proved to have a rapid easterly motion amongst the stars, while many others present a stationary position during long intervals. A large number of new and trustworthy materials would greatly aid the further investigation of these features and place our knowledge on a better basis.

"Though meteoric astronomy is comparatively recent in many of its most important developments, there is no doubt that it constitutes a branch very wide in its operations and significant in its teachings. Its range is apparently illimitable, for space is probably teeming with meteorites and what these bodies lack in size they compensate for in numbers.

"Observation in this field affords a most useful experience for amateurs. During meteor-watches, the configurations of the stars become familiarly impressed on the mind, and the student learns patience as well as how to be methodical in his work."

Bristol, 1892, August 10.

After a short discussion of the paper, and after some subjects of general interest had been mentioned, the meeting adjourned to the lawn of the Normal School, Ontario Education Department grounds, where telescopes had been mounted. The moon and Jupiter and Mars were shown to those present, including some ladies and visitors. The Sir Adam Wilson telescope was officially used for the first time and gave satisfaction.

SEVENTEENTH MEETING.

September 26th; Mr. James Todhunter in the chair.

Miss Jessie Semple, Miss Alice A. Gray, and Mr. W. A. Munro, of Toronto, were elected Active Members, and Mr. R. J. McLellan, of Dundas, an Associate Member of the Society.

The letters read included one from the editor of the Montreal *Star*, seeking information about the Society, and one from Mr. McLellan, of Dundas, speaking favourably of the table of Predictions appended to the last issue of the Society's Transactions.

Among the publications reported by the Librarian was the receipt from Mr. J. Ellard Gore, F.R.A.S., of a copy of his work entitled "Southern Stellar Objects."

Mr. Mungo Turnbull, of Toronto, a manufacturer of telescopes and celestial globes, presented a circular explanatory of the use of the new celestial globe, recently donated by Lady Wilson. Mr. Turnbull announced that he was preparing an exhibit of globes for the World's Fair.

Difficulty having arisen in identifying upon maps, etc., markings upon the planet Mars, owing to the existence of several official lists of names of continents, seas, etc., differing each from the other, the Corresponding Secretary was instructed to communicate with the Reverend T. E. Espin, F.R.A.S., the editor of the new edition of Webb, in the hope that he would cause to be arranged for observers a table of names that would be satisfactory.

It was reported that Dr. Sandford Fleming, C.M.G., having returned from Europe, had been notified of his appointment to be Chairman of the Committee on Astronomical Time Notation, and that he had been requested to prepare, for general circulation, a list of questions, drawn up and intended to elicit the views of astronomers the world over on the subject of reckoning the Astronomical Day from Mean Midnight instead of from Mean Noon.

Mr. A. F. Miller made a verbal report upon the excellence of the Sir Adam Wilson Telescope and of the telescope loaned to the Society by Dr. Larratt Smith.

Under the head of Observations, Mr. Miller referred, with some detail, to the groups of sunspots observed during the previous few weeks.

Mr. A. Elvins and others described very richly tinted after-glows, which appeared after sunset on the 17th and 18th of September. An aurora was observed on the 17th. Many references were made to Mars, then gibbous in form, some observers thinking that definition was better than it was when the brilliancy of the planet was very great in ordinary telescopes of small aperature.

The announcement of the evening was the reported discovery, on the 11th of September, by Professor E. E. Barnard, of the Lick Observatory, of a fifth satellite to Jupiter. Mr. Elvins deeply regretted that the intimation of the discovery consisted of an item in the telegraphic news, which had not been confirmed. He had written to Professor G. E. Hale for information, as the intimation had apparently been made by wire by Mr. Barnard to Mr. S. W. Burnham at Chicago. If this discovery were true, he, from his very heart, congratulated Professor Barnard, who had already placed himself in the front rank of observers, and who had now acquired imperishable fame.

Assuming the announcement to be well founded, Mr. G. G. Pursey, in justice to his old friend, reminded the Society that so long ago as March 10th, 1891, in the course of a paper on the Great Red Spot on Jupiter, Mr. Elvins alluded to its appearance as a conspicuous object ten years before, and laid on the table drawings made by him at that time; that he pointed out that the swift movement of the spot across the disc of the planet showed strikingly the rapid rate of the planet's rotation; that the dark belt between the spot and the equator seemed to be driven from the spot by some repelling force; that observations showed that while spots on the belts cross the disc in somewhat less time than the red spot does, the same is true of the belts themselves; that Mr. Elvins suspected that the matter composing the red spot was above the atmosphere of Jupiter, and detached from it; that, if so, it would come under the operation of Kepler's laws and revolve more slowly than the planet rotates; that he suggested the possibility of this being the first state of the existence of a satellite, as yet, but slightly condensed, a new satellite, in fact, in which case it would pass outside the planet's disc; but evidence of this he had not been able to perceive, and that he thought the spot should be carefully observed for the purpose of ascertaining whether it could be detected beyond the disc and of catching its shadow.

Mr. Elvins said that he was naturally much interested in the reputed discovery, but like others, he awaited the confirmation of the report before accepting it as authentic.

The Secretary read a letter from a gentleman stating that the late Mr. Jackson, of Eglinton, near Toronto, "maintained that Jupiter had five moons." The writer went on to say that he himself had seen six moons, and he submitted nine diagrams, made on as many evenings in August, 1892. It was, however, clear that the writer had included two stars in the constellation in which Jupiter was placed.

Mr. Lumsden read a paper consisting of a statement of the reputed discoveries upon Mars announced up to date. A portion was based upon two papers on the planet, which had been contributed to *Astronomy and Astro-Physics* by Professor W. H. Pickering, Director of the Harvard Observatory Annex, at Arequipa, Peru.

Professor Pickering's discoveries were enumerated, and instructive extracts respecting the Martian seasons, and the colours and changing tints due thereto, were read.

EIGHTEENTH MEETING

October 4th; Mr. John A. Paterson, M. A., Vice-President, in the chair.

A considerable portion of the evening was devoted to discussing the future of the Society. The pressing necessity for a permanent place of assemblage and for the deposit of the Society's books and apparatus received especial attention. All the speakers regretted the loss of the pleasurable features connected with the fortnightly re-unions at the dwellings of members that would ensue, but most of them felt that if a hall were secured, the membership would still more largely increase, and that other advantages would result. Remarks were made by Dr. Larratt W. Smith, Q. C., and by Messrs. A. Harvey, D. G. Ross, R. B. Ellis, G. G. Pursey, A. Elvins and others. The subject, with several others, was referred to the Council for report. The Council was also requested to make arrangements for the due observation of the Leonids, the showers of meteors which fall during the 13th and 14th of November.

The predictions of phenomena having been announced, observations were called for. Reports were received from Mr. John Hollingworth, of

Beatrice, Muskoka, respecting auroræ in September; from Dr. Larratt W. Smith, who described a splendid meteor, apparently larger and brighter than Jupiter, observed by him about eleven o'clock on the night of September 30th, as it passed overhead in a North-easterly direction; from Dr. J. C. Donaldson, of Fergus, on double-star work, and experiments on different evenings and under different conditions to ascertain the smallest possible aperture with which the companion to the Pole-star can be seen; from Mr. A. F. Miller, who drew attention to an aurora on September 28th and to the solar disturbances of September 28th and 29th, on which days striking enlargements of several groups in both hemispheres were noted and the fact once more recorded that the activity simultaneously affected Northern and Southern groups having the same longitude,—on October 3rd, however, though important changes were observed in a Northern group of spots, the corresponding Southern region was unaffected; from Mr. J. R. Connon, of Elora, who sent in some photographs of the Sun, remarking that he had noticed of late that the atmosphere appeared to be darkened by particles of dust, or other substance; and from Mr. J. G. Ridout, who referred to his observation of the recent occultation of Mars, made while in quarantine on his return from Europe. Mr. Ridout also described his visit to observatories in England, and said that a letter of introduction from the Society had secured for him and party the privilege of being shown over Greenwich Observatory.

Mr. A. Elvins alluded to Professor Barnard's famous discovery of a fifth satellite to Jupiter, and read the following letter from Professor G. E. Hale, of the Kenwood Astro-Physical Observatory, Chicago:—"I have heard from Mr. Barnard himself in regard to his discovery, and there can be no doubt about its validity. The new satellite is about the 13th magnitude, with a period of 11h. 59m. It can probably be seen with only the largest instruments." Mr. Elvins added that, in a letter of congratulation, he had told Mr. Barnard that his discovery of the new moon and Professor Keeler's discovery of the motion of nebulæ in the line of sight, were discoveries so important that the erection of the Lick Observatory had been more than justified, even if nothing more were ever accomplished.

NEW JOVIAN SATELLITES.

Mr. Elvins then made the following statement:—"In the Transactions of this Society for the year 1891 there was published an abstract of a paper of mine upon the Great Red Spot on Jupiter. In the course of that paper, I expressed the opinion that that planet is continually throwing off matter, which, by mutual attraction, forms solid masses, and I suggested that the Red Spot might be a mass of gaseous and solid matter thus thrown off, and that it might be the first stage of the development of a satellite. Some correspondence with observers followed this paper, and, among others, I called the attention of Professor Barnard to my theory, my hope being that he would, in the course of his observations, look for such satellites. I received from the Professor a reply, dated the 2nd of January, 1892. On the 11th September, as we all know, Professor Barnard discovered a fifth moon to Jupiter. I am sorry the Professor has not made some reference to my letter to him, for, though the Red Spot is not the satellite found by him, I have reason for supposing that my letter induced him to institute a more careful search than otherwise might have been made for Jovian satellites, which, I have no doubt, exist. I now wish to indicate the position of the next satellite, which, as I anticipate, will yet be found. The position of this moon will be about 166,000 miles from the centre of Jupiter, and will have a period of about twenty-one hours. My reasons for this supposition are as follows:—There appears to be a law in the case of Jupiter's system not the same as, but somewhat akin to, Bode's Law of Planetary Distances. Passing outward from Jupiter, we find that the period of each satellite is about twice that of the satellite next between it and the planet. For instance, **I** has a period of about forty-two and one-half hours; **II** has one of about eighty-five and one-quarter hours; **III**, one of one-hundred and seventy-five and one-quarter-hours, and **IV**, of about four hundred hours. Now, if we take half of the period of the inner satellite (**I**), it will be found to be about twenty-one and one-quarter hours, which would require a satellite at a distance of 166,000 miles from the centre of the planet. No satellite at that distance has been discovered; but if we halve this period, the period of the one next nearest the planet should be very close to the position of Prof. Barnard's moon, whose period is between eleven and twelve hours. Like the break in Bode's Law, between Mars and Jupiter, which has been bridged by the Asteroid Group, the break in the system of Jupiter will, doubtless, be filled by the discovery of one or more small satellites between **V** and **I**. This, however, is a work in reserve for the great telescopes of the future, and if Professor W. H. Pickering can be furnished, at Arequipa, with the instrument his work on Mars and Jupiter deserves, I anticipate that Satellite **VI** will be found."

Dr. Larratt Smith read from *The Eclectic Magazine* an interesting and instructive paper on the planet Mars, written by Sir Robert S. Ball, formerly Astronomer Royal for Ireland, and now the successor at Cambridge of the late Professor J. C. Adams. The paper was listened to with much attention, and caused considerable discussion, participated in by Messrs. Harvey, Miller, Elvins and others.

NINETEENTH MEETING.

October 18th; Mr. Larratt W. Smith, Q.C., D.C.L., Vice-President, in the Chair. Mr. A. Elvins called attention to the announced fact that the doubling of some of the lines on Mars, known as Schiaparelli's Canals, had been observed at the Lick and Arequipa Observatories during the favourable opposition of the planet in August.

Professor A. C. McKay, B.A., of McMaster University, Mr. J. A. Copland, and Mr. F. A. Saunders were elected Active Members of the Society.

The communications read, included a letter from Dr. Sandford Fleming, C.M.G., relative to the adoption of a new Astronomical Time Notation, and asked for a list of Astronomers to whom the proposed circular by the Society might be sent. Mr. A. F. Miller thought that the information desired by Dr. Fleming could be obtained from a report recently prepared by Lieutenant Winterhalter, of the United States Naval Observatory, on the observatories of Europe.

The report of Council dealing with a permanent place of meeting and other matters was read and adopted.

The Corresponding Secretary was requested to write a letter introducing Dr. C. B. Langford, of Blenheim, to Professor Swift, Director of the Warner Observatory, Rochester, N. Y.

On behalf of Mr. Charles P. Sparling, Mr. Elvins presented to the Society a large and handsomely bound album, suitably inscribed and intended to receive the Astronomical drawings, plates and views belonging to the Society. Mr. Elvins said he had inserted various plates and original sketches, and would be glad to receive from members others to be thus preserved. Mr. Sparling was heartily thanked for his timely and valuable gift.

Mr. Aronsberg presented to the Society a copy of the October Number of *Astronomy and Astro-Physics* received by him for that purpose from Mr. E. W. Gardner, with an intimation that it was his intention to send in the succeeding numbers, as they were issued. Mr. G. G. Pursey, and Mr. D. J. Howell, for the Committee having in hand the purchase of Astronomical slides for the Society's lantern, reported progress.

Under the head of observations, Mr. Elvins described the difficulty he now meets with in seeing the Great Red Spot on Jupiter, an object easily seen and drawn a few years ago. Mr. Miller referred to solar phenomena, and Dr. J. C. Donaldson, of Fergus, to further double-star work.

Dr. Larratt Smith read two selected papers, entitled, "The Fuel of the Sun," and "Inter-Astral Communication," the latter by M. Camille Flammarion. The papers were of a popular character, and proved to be interesting and instructive. M. Flammarion's was in a happy vein, and seemed to prove conclusively that while it may be possible, under certain circumstances, to communicate with the inhabitants of the moon, if there be any, communication with those of Mars, or any other planetary body, is quite beyond the possibility of achievement. Both papers were followed by discussion.

TWENTIETH MEETING.

November 1st; Mr. Larratt W. Smith, Q.C., D.C.L., Vice-President, in the chair.

Miss Jeane Pursey, Messrs. E. N. Williams, J. Y. Reid, Jr., R. E. Chapman, S. R. G. Penson, and John Henderson were elected Active Members of the Society.

After the communications (including one from Mr. S. R. Peal, of India), had been read, Mr. A. Elvins called attention to the obligation under which the Society had been placed by Mr. J. R. Connon, of

Elora, who had forwarded a series of excellent photographs of the solar eclipse of October 20th.

Miss S. L. Taylor was appointed Assistant-Recording Secretary; Miss A. A. Gray, Assistant-Treasurer, and Miss Jeane Pursey, Assistant-Librarian. Mr. James Todhunter was chosen to fill a vacancy on the Council.

The partial solar eclipse of the 20th of October, having been well seen at Toronto, formed the chief observational feature of the evening. Mr. Elvins and Mr. G. E. Lumsden agreed as to the time of first contact, 11h., 53m., 30sec.; this being also the time predicted for Toronto by the President of the Society.

Mr. Arthur Harvey presented a short paper on his own observations of the phenomenon, and drew particular attention to the difference between the edge of the sun proper and the edge cut into by the moon; the outside edge seeming to be defined against a blue background, while the inside edge was absolute black; the inference drawn was, that there was evidence in this of some illuminated atmosphere or other envelope outside the fiery mass.

Some discussion arose as to the possibility of seeing inequalities on the limb of the moon when projected on the sun, a member who observed with a $10\frac{1}{4}$ inch reflector, having mentioned that the roughened lunar limb was very apparent.

Mr. J. Warren, P. L. S., of Kincardine, reported observations made at that place.

Mr. D. E. Hadden, of Alta, Iowa, sent in a report of observations made at his station, the times agreeing very closely with the computed times.

Among other observations, Dr. Larratt Smith reported that he had observed the close approach of Mars to the star δ Capricorni.

Mr. Elvins read an extract from a private letter announcing that the fifth satellite of Jupiter had been seen by Professor Young in the 23-inch telescope of Princeton College.

Mr. Elvins read a short paper continuing his series on Moving Matter. The subject was "Some Thoughts on Radiant Matter," and the question of the cause of refraction and diffraction of light was discussed. A theory was announced in explanation of the path of a ray of light through a prism. Some discussion arose at the close of the paper bearing upon molecular physics, Mr. Harvey and Mr. Robert Dewar taking part.

TWENTY-FIRST MEETING.

November 15th; Dr. Larratt W. Smith, Q. C., Vice-President, in the chair.

By letter, Mr. Thomas Lindsay stated that owing to his removal from the city, he was obliged to resign his position of Recording Secretary. Dr. Smith and Mr. G. E. Lumsden were appointed to be a Committee to prepare a resolution that would suitably express the Society's sense of obligation to Mr. Lindsay for the efficient services rendered during the last two years, partly as an officer and partly as a private member of the Society.

In addition to the regular publications, Mr. G. G. Pursey, the Librarian, reported the receipt of the American Ephemeris and Nautical Almanac for 1893 and copies of a pamphlet on Sunspots, by Mr. G. W. Tinsley, of Columbus, Indiana.

Some discussion was caused by the reading of Mr. Tinsley's theory. That writer contends that sunspots are cool caps that form at either pole of the sun, and are perpetually drawn from their place of formation by the conjunction of Sirius, Jupiter and the Earth, or (as in their last considerable appearance this year) of Sirius, Jupiter and Venus. The circular set out Mr. Tinsley's reasons for his theory, and was illustrated by several diagrams. The criticism which followed was generally adverse to the contention of the author.

The paper of the evening, by Mr. John Phillips, was a continuation of a series of papers entitled "How Our Satellite May Have Found Her Orbit," read last year. It dealt with the moons of Mars, especially Phobos, the inner one. Mr. Phillips claimed that his theory of projection accounts for the rapid revolution of Phobos, whose period is only about one-third of the time of Martian rotation. The author contended that the theory applied equally well to all the satellites in the solar system having direct motions in their orbits. As a result of the animated discussion which followed his paper, Mr. Phillips, in answer to the objections of Mr. J. G. Ridout and others, announced that he would read a further one showing the bearing of his theory on the retrograde motions of the moons of Uranus.

TWENTY-SECOND MEETING.

November 29th; Mr. John A. Paterson, M.A., Vice-President, in the chair.

The subject of appointing a successor to Mr. Thomas Lindsay as Recording Secretary having been brought up, Miss S. L. Taylor was nominated, she having acted at the last meeting. Miss Taylor, however, declined, and Mr. G. H. Meldrum was elected by acclamation.

Among the publications reported by the Librarian were *The Monthly Notices* of the Royal Astronomical Society, *Journal* of the British Astronomical Association for September, and Proceedings of the Royal Society, volumes 51 and 52, Mitteilüngen for September and October, *Journal and Proceedings* of The Hamilton Association, 1891-2.

General regret was expressed that owing to continuously cloudy weather, no observations of any kind had been made between the 24th and the 29th of November. This was especially disappointing owing to the fact that several remarkable meteoric displays had been anticipated and that no one had been able to observe Holmes' comet, with respect to which some very alarming predictions had been communicated to the newspaper press. Fortunately for those interested, the earlier part of the 23rd of November was clear, and was made the most of by some of the members of the Society. Among the individual observers who made reports were Miss Anna A. Gray and Miss Sarah L. Taylor, and Messrs. A. Elvins, A. F. Miller, A. T. Gilbert and J. A. Copland. During thirty-five minutes, Miss Gray counted one hundred and twenty-six meteors, some of which were very bright. Mr. Elvins counted twenty-three in a few minutes about 8 o'clock; Mr. Copland twenty-five in six minutes, ending at 8.01 o'clock, and Mr. Gilbert, who observed for an hour, saw no less than three hundred worthy of note. On the morning of the 23rd, at 4.30 o'clock, Mr. Copland saw two Leonids, which appeared to travel in the same path, the second immediately behind the first, which was the smaller one and of a bright bluish-white colour. The larger meteor was yellow in colour and was seen to explode in the direction of ψ Ursæ Majoris; though listened for intently, no detonation was heard. The radiant points indicated that most of the shooting stars were Andromedes, though there were undoubtedly Taurids and Leonids. The yellow, or orange, meteors far outnumbered the bluish-white ones.

During the ensuing discussion, authorities were cited in proof of the statement that millions of meteoric stones daily fall into the upper strata of the earth's atmosphere, but that only an occasional one is composed of material hard enough to escape destruction in its passage through the air. As a rule, these stones are sufficiently friable to be dissipated into dust while in mid-air, the heat due to friction causing them to fly into minute particles, which appear to us as the sparks which make their paths luminous. Owing to steadily overcast skies, which had prevailed for weeks, no solar or planetary observations were reported.

The paper for the evening was contributed by Mr. Thomas Lindsay, on the subject of

WORK FOR AMATEURS.

In the course of the paper, Mr. Lindsay said that of those who are interested in Astronomy, some there are who apply the work of their whole lives to the study of the sublime science; these are astronomers by profession, to whom the whole world is indebted; while, following, is the great army of amateurs, taking up the study as recreative science while engaged in various pursuits in the regular business of life, keeping well informed as to the work done by the great minority, and hoping, always hoping, to be of some little service in the field. One must not be discouraged at the very outset and despair of being ever of any service simply, perhaps, because first-class instruments are not at hand, or because the study of the higher branches of mathematics has been neglected. It is a great mistake to suppose that no discoveries can be made outside of well-equipped observatories; or that nothing can be added to the work of those who fill page after page with algebraic formulæ, as easily as one can write "one, two, three," or, that all the theories enunciated by the great masters are laws. On the contrary, many important discoveries are made outside of observatories as well as in them; very many little points in the mathematics of Astronomy have been overlooked by adepts; and a theory is not by any means a law, but is open to the attack and kindly criticism of the whole world.

Let us consider the first line of work for amateurs, that is, observation. Those who possess small telescopes will take a great deal of pleasure in becoming acquainted with the use of the instrument, and with a few of the objects within its reach. This is preparatory and, strictly speaking, is not work, but the possessor of an instrument very soon wants to call in his friends; to show them what he has; to point out what little he can, and, gradually, to interest some one else in the study of Astronomy. There his work begins, and, let it even end where it begins, a great work has been done. "He who makes two blades of grass grow where but one grew before, is a public benefactor." One who brings a young mind, or an old one for that matter, into the circle of observers does something for Astronomy.

If only in this regard, the result of this Society's work, as a whole, is very apparent. Reports of our progress are courteously received by the press, eagerly read, and have given a push to the study of Astronomy in Canada such as no well equipped observatory could have done; it is not, indeed, the province of professional astronomers to do this.

Now, to consider what the amateur may do for the advancement of science in particular lines of observation: In the sidereal heavens we have all the unexplored regions we desire. If every square degree of the celestial sphere were photographed there would still be work for amateurs. Photographs would not give us all the coloured, physically double, variable and new stars that are to be seen in the heavens. It has been shown that a constant observation of a particular part of the heavens by one observer is a very important work, and if it were undertaken with instruments rather better than the ordinary two or three-inch telescope of the amateur, some knowledge would surely be added to the stock. The great problems of the sun's motion in space and the distribution of the stars, are to be solved, if ever solved, by some such systematic work as this, undertaken by a number of observers, and they may be amateurs.

Then there are comets to be seen. Discovery of new ones is as likely to be made by amateur observers as by skilled workers in observatories; once discovered and watched awhile, the mapping out of their paths is not a matter of very great difficulty, this branch of mathematics having been very well explained and illustrated by popular writers who have studied out methods requiring little more than very careful drawing.

The sun is pre-eminently a field of observation for amateurs. The observations of no two days will be alike, and the records of the appearance of the solar surface, telescopic and spectroscopic, by amateurs, is as likely to be of very great value as are those sent out from the great centres. This was very well illustrated recently by one of our own members, where an observation quite new to him, either as an observer or a reader, was made by him alone, and communicated to a well-known observatory where it had not been made. The class of work, however, which is of decided value as adding to our knowledge of the sun, requires more than the ordinary small telescope, though not more than will be found in the enthusiastic amateur's outfit.

The moon is the one object that is always interesting, no matter how often we see it, and if it is celebrated for anything in particular it is this, that it is the starting point for all possessors of telescopes—about the first object the beginner looks at. Advancing from the moon and sun to the planets and the fixed stars, the field becomes so gloriously wide that whole volumes are written upon the beauties revealed; and although it is only in the largest telescopes that the canals of Mars are to be seen, and although new satellites to the planets are hardly likely to be first discovered in small telescopes, yet there are many features in planetary observations which are quite likely to be first noted by amateurs, and, whether noted first or not, they may certainly be followed up with advantage. And again, in the line of mathematical astronomy we are accustomed to take everything for granted that is given to us by the great masters of the science and, at the same time, are too ready to admit that there is nothing we may discover for ourselves. To give one instance showing that this is wrong, I may mention that some short time ago a number of letters appeared in *The English Mechanic* on the subject of the finding of the time of Easter for any period. This led to an investigation of the moon's period, and some writers certainly gave, for tracing her path down through the ages, easy rules that were not to be found in text books.

For the amateur who wishes to obtain some knowledge of mathematical astronomy in a practical way, the best book is the Nautical Almanac, or several of them. To begin with, he may assume that everything in that book is correct within very narrow limits, indeed; if he doubts, he may easily verify a great deal of the matter contained therein. But suppose he accepts it. Then by following page after page of, say, a planet's places in the heavens, he will note the regularity of the motion and, if he endeavour to name a planet's place by the use of the period of revolution, which he would have no trouble in getting, he will find he strikes it very accurately, having the Almanac to prove the work; then he will surely be convinced that it is quite within his even limited knowledge to name a planet's place for a thousand years hence. So that what seems a stupendous problem is really very simple within certain not very wide limits of error.

I do not suppose there is much interest taken in finding a planet's place for a thousand years hence or back. I merely wish to show that an amateur need not speak of the problem as being one that belongs entirely to the domain of the professional astronomer. For instance, Mars was in opposition to the sun on August 3rd, 1892, about midnight, at Greenwich; he is in this position every 779·9 days. Multiply this by 500 and we arrive at A.D. 2,960, and we shall probably be able to verify in another world what we may predict now, that there will be an opposition in the latter part of that year. If there are some other little matters to look into in these problems, they only keep up the interest in them.

Tables in the text-books are so complete and starting-points are given in the almanacs with such rigorous accuracy, that the errors in many of these problems are questions merely of hours, not days, and in the matter of new moons, eclipses, etc., we know how the ancients managed and we may take a lesson from them by providing ourselves with a succession of almanacs for nineteen years and go on naming the moon's phases till the brain would reel, and one hour would be the largest error we would ever make.

The advantage of this kind of work to the amateur consists in this, to state the writer's own experience: It gives him a delightful idea of the regularity of the motions of the heavenly bodies, and generates a desire to attain nearer and nearer to the accuracy of the masters of the science, while it certainly shews where the line is drawn between accurate and approximate results. All this is work for amateurs and opens up a wide field.

I have not said anything of the work of amateurs in the domain of those departments of Physics that are allied to Astronomy. Perhaps the physicist would rather have it that Astronomy is one of the departments of Physics, but it is all the same. This is the experimental field and absolutely limitless. Here the amateur may revel amid the wonders of Nature, and strange, indeed, if he does not some time ask Nature a question never asked before, and get an answer.

Then, finally, let the amateur consider how many theories are still only theories; how many strange phenomena need explanation, and he has work for a lifetime.

The moon's surface; is it rock or ice? Is it absolutely still, or are there, even now, upheavals of its interior? Was it once a part of the earth, or did it come from without?

And the sun;—what is it, anyway?

Just run over a few of the theories regarding the sun's constitution and see if there is not room for an amateur's speculations. And the source of the sun's heat, nay, the theory of light itself, is it absolutely established? Firm as it may appear, it is not unassailable.

TWENTY-THIRD MEETING.

December 13th; Dr. Larratt W. Smith, Q. C., Vice-President, in the Chair.

Mr. C. A. Chant, B.A., Lecturer in Physics in University College, Toronto, was elected an Active Member.

As the skies had been almost steadily overcast by clouds, no observations were reported, with the exception of a description by Dr. J. C. Donaldson, of Fergus, of the appearance of the satellites of Jupiter as seen by him on the evening of the 1st of December. That observer also called attention to the fact that during the year the solar disc had never been entirely free from spots, which, at times, had been numerous and interesting. Mr. Elvins stated that on the 11th of December, during a brief interval of clear weather, he observed seven spots and two promising groups on the sun.

The letters read included one from Professor Daniel Kirkwood, LL.D., of Riverside, Cal., who transmitted a copy of his paper "Groups of Asteroids."

After the transaction of routine business, the nomination of candidates and the election of members, the evening was, according to appointment at the preceding one, devoted to the consideration of comets and meteors, their composition, their periodic returns, their orbits and the history of certain well-known comets and meteoric streams.

The Chairman and Mr. J. A. Paterson, in turn, read selected passages from the writings of astronomers treating upon these matters. Among the authorities quoted, was Mr. J. Ellard Gore, F.R.A.S., a Corresponding Member of the Society. Dr. Smith read Mr. Gore's chapter on Fireballs, Meteors, etc., from his "Scenery of the Heavens," an advance copy of the second edition of that book having just reached one of the members. Mr. Paterson read extracts from the writings of Mr. George Coakley, Professor of Astronomy in the University of New York; an interesting paper, by that writer, on "The Probable Origin of Meteorites," having appeared in the November number of *Astronomy and Astro-Physics.*

In the discussion that followed, Mr. A. Harvey referred to Proctor's theory that comets were the means of keeping up communication between one solar or stellar system and another, and of carrying the seeds of life throughout the universe by means of the meteors which follow in their train and reach the surface of the various bodies within whose attractive power they come. He stated that Dr. Otto Hahn, of Toronto, had made a study of meteorites by the petralogical method, which went to show that these bodies contained evidences of fossil life similar to what is seen in an examination of some of the rocks of the earth.

Mr. A. Elvins stated that the views assigned to Proctor, were really those of Sir Wm. Thomson, and that the latter had abandoned the theory.

The discussion was participated in by Messrs. J. G. Ridout, A. F. Miller, J. Phillips, J. A. Paterson, the Chairman, and others. It was decided to take up at a future meeting the special subject of Meteorites and their composition.

Mr. Paterson read extracts from *Astronomy and Astro-Physics,* respecting a judgment given, in Iowa, by a Court in a law-suit over the possession of a meteorite.

TWENTY-FOURTH MEETING.

December 27th. Professor Charles Carpmael, M.A., F.R.A.S., etc., President, in the Chair.

The letters read included communications from Mr. E. W. Maunder, F.R.A.S., of Greenwich Observatory, who, among other things, spoke of M. Flammarion's recent book on Mars as "a most complete and exhaustive monograph," and applied to Professor Carpmael for tracings at the Toronto Observatory of the magnetic curves for certain great storms; from M. L. Niesten, of the Royal Observatory of Belgium, with respect to the globes of the Planet Mars made by him, and from Dr. M. A.

Veeder, of Lyons, N. Y., who drew attention to an interesting point which had arisen in connection with his investigations. The following are extracts from Dr. Veeder's letter :—" Noting in the tables of auroral frequency that the extent of the displays and the severity of the accompanying magnetic storms are greater when the moon is nearest the sun, although the orbital motion had increased the inductive effect, as is the rule with moving bodies in a magnetic field, I was led to surmise that it might, perhaps, be worth while to look for something having the character of an aurora in the vicinity of the moon itself, that is, attached to and moving with it. I have not been so fortunate as to secure such an observation myself, but in hunting through such records as have come to hand, I have found several instances in which the appearance of something resembling an auroral streamer has been observed independently by different observers. One of these records was made so long ago as 1742, by a very careful observer, R. P. Jacquier, who was watching the occultation of a star by the moon, and saw at the time a streamer, of a breadth equal to half the diameter of the moon, and and four times as long, which he at first thought to be a cloud, but which remained attached to the moon until its setting. Such an appearance is very liable to be overlooked or regarded as being a cloud, or halo, so that observations concerning it are necessarily rare. I have, however, called the attention of a number of very competent observers to the point, and it is to be hoped that during the present increase of auroræ, opportunity may be afforded for seeing whether anything of the sort really exists. You will see at once the importance of the observation when the fact that the moon has no atmosphere is taken into account. A lunar aurora could only result from the play of electrical discharges upon cosmical dust or meteoric *debris*, and not upon ice particles or air particles as has been supposed to be the case with terrestrial auroræ. The play of such discharges upon such particles suspended *in vacuo* in interplanetary space might reasonably be expected to exhibit peculiarities in the resulting spectrum. Also, if this is the source and location of auroral luminosity, it is evident that it is impossible to determine the depth of the atmosphere from the height of the auroræ, even if the latter should be known."

Miss A. Sanderson was elected an Active Member of the Society.

Mr. G. E. Lumsden gave notice that he would move "That the Constitution of the Society be so amended as to create an Associate

Membership, to which may be appointed ladies and gentlemen, not residents of the City of Toronto, whose qualifications shall not, in the opinion of the Society, entitle them to be elected as Corresponding Members, an honourary rank to be reserved for Astronomers and Physicists especially deserving of recognition."

This being the last meeting of the Society for 1892, the nominations of candidates for the various offices in the gift of the Society for the ensuing year were made.

Mr. G. G. Pursey stated the substance of an interview he had had with Dr. Sandford Fleming, C.M.G., regarding the adoption of Cosmic Time, and also reported the receipt of the following, in addition to other, publications :—" Some Results and Conclusions Derived from a Photographic Study of the Sun"; "The Ultra-Violet Spectrum of the Solar Prominences" and "The Yerkes Observatory of the University of Chicago," by Professor G. E. Hale; "The Lick Astronomical Department of the University of California," by Miss Millicent W. S. Linn, and *Astronomy and Astro-Physics* for December.

At the request of the Treasurer, Mr. D. J. Howell, Messrs. Todhunter and Ellis were appointed to examine and audit his accounts for the year 1892.

Observations were reported by Mr. John A. Copland, of Toronto, who had succeeded in timing accurately the passage of a number of Leonids on the morning of December 4th; and by Dr. J. C. Donaldson, of Fergus, who had been testing the excellence of his telescope (a three and a-half inch Cooke) by ascertaining the smallest aperture with which he can see certain well-known double-stars. On the night of October 9th he was able to see the companion to Polaris with his glass stopped down to an aperture of 1·8 inches. With the same aperture, on the 12th of December, he saw the companion to Rigel and the four stars of θ Orionis, and, with two inches, the six stars in the multiple-star σ Orionis.

The paper of the evening was entitled

BEFORE THE BEGINNING,

and was read by Mr. John A. Paterson, M.A., who, after a defence of the value of investigation based upon the inductive method, and of speculation and hypothesis within the bounds of probability and reason, sketched the nebular theory of Laplace and Herschell, and proceeded to review the theory of stellar evolution as stated by Dr. Croll, of Edinburgh.

So far as we know, the manner in which the works of the Deity are performed is not by any sudden creative act, but by slow process of evolution. The nebular hypothesis seeks to explain the origin of the solar system from matter which, in some way or other, came into being and under the operation of forces which exist yet and have existed for œons of time. But let us go behind the nebula and ask from whence came it ?

In 1868, the hypothesis was predicated that the gaseous nebula from which our solar system was formed was produced from the colliding of two dark masses, and, as the sun is nothing but a star, the stars in all probability had a like origin. In a word, we have the impact theory of Stellar Evolution.

By the known laws of motion a body set in motion, if not disturbed by any other force, will move for an infinite time in a straight line with uniform velocity, and, if two dark stellar masses, created we know not when, moving with velocities we know not how immense, and coming from we know not whence, were to collide, the dynamical result would be that, by the well known principle of the parallelogram of velocities the component body would proceed with a velocity and in a direction represented by a diagonal of the parallelogram whose sides are proportional to the component velocities. The physical result would be that the dark cold masses, if striking together with sufficient force and at a favourable angle, would develop a gaseous nebula of most intense heat, while a multitude of fragments, shattered to pieces towards the outer circumference of the nebulous mass, would pass outwards into space with a velocity which would carry them far beyond the gravitation of the present nebula —meteorites would then be the offspring of sidereal masses. Evolution would then commence at the moment of collision. Were these dark masses to move through the wilderness of space and never collide, then there would be no beginning—we speak of "Before the Beginning"—no development.

But do these dark cold masses strike with forces due only to their mutual attraction, or have they initial velocities independent of attraction, and do they therefore smite each other with these mighty velocities ?

Sir William Thomson in 1887 adopted the first of these theories, but the second has more than one able physicist to uphold it. According to the first, these forces will in time inevitably collide, and the universe would be a scene of repeated wrecks. According to the second, these bodies will generally miss. When a collision occurred, it would be productive of mighty results—otherwise, many would occur and produce imperfect suns—half formed systems—like Gloster, hurried "into this breathing world deformed, unfinished, scarce half made up, curtailed of fair proportions."

There are stars which have a far greater velocity than can be due to gravitation only; for example, the star 1830 Groombridge which moves 200 miles a second. Professor Newcomb says:—"Groombridge is a runaway star flying in a boundless course through infinite space with such momentum that the attraction of all the bodies of the universe can never stop it." The probability is that this star derived its motion where it derived its light and heat, viz., from the collision of two masses. Other stars, such as 61 Cygni, μ Cassiopeia and Arcturus possess motion which cannot be derived from gravity.

Our own solar system is progressing through space. This problem was investigated by the most distinguished Prussian Astronomer, Argelander, of Bonn; and Struvè, of Pulcowa, determined the yearly motion of our system as seen from the more distant stars of the first magnitude. Peters converted this into miles, fixing his calculation upon the absolute mean distance of the first magnitude stars, and it is now predicated that our system is sweeping in a straight line through space towards a star marked π in the constellation Hercules with a velocity of 33,350,000 miles a year. The resultant of the motions of the dark stellar masses that before the beginning of their collision engendered the solar nebula, is in a line towards π Hercules. The stars in Hercules are gradually widening their relative apponent distances. Every century Hercules' mighty arm grows brawnier and the girth of his club will so increase that ages hence it will fall from his grasp.

The theory of impact offers a rational explanation of all the peculiarities of nebulæ—such as the immense space occupied by them; their varied shapes; their gaseous condition; their feeble light. The theory accounts, too, for various systems which would be produced by two bodies coming into what Dr. Croll calls "grazing collision."

The phenomenon of sudden outbursts of stars can be accounted for on the supposition that the stars had been struck by one of these dark bodies. Star clusters would result from a widely spread nebula breaking up into separate *nuclei.*

Variable and temporary stars present a peculiar charm to the astronomer. The well known Algol, or the "Demon Star" is one of the most remarkable of the *variables.* Its regularly recurring diminution of light may probably be caused by the interposition of a dark body revolving round the star. Here is an instance of a dark, cold, stellar mass which escaped impact but was caught by the strong gravitation arms of Algol and compelled to sweep around their common centre of gravity.

The theory of impact must, however, stand or fall by a scrutiny into the age of the sun's heat. Now, the best authorities put the age of the sun's heat, if due to gravitation alone, at 12,000,000 years. This is Sir Wm. Thomson's result, and is based on thermal and dynamical principles, ascribing the solar heat solely to the influence of condensation produced by gravitation. Helmholz the originator of the condensation theory of solar heat, puts the period at 20,237,500 years. But when we come to the story of the rocks and read "Sermons in Stones," the geologist tells us that there are records on this earth of heat having been radiated for more than 70,000,000 years. Whence, then, comes this source of heat? By the impact theory we are not limited; the momentum of the impact, depending as it must on the mass and kinetic energy of the dark stellar masses, will produce any conceivable, or, perhaps it should be said, inconceivable, quantity of heat which would put the period of world rock life back about any period of time.

Now, what does geology teach us on this mighty problem? The best authorities after most laborious methods and years of observation, tell us that the present rate of sub-ærial denudation is one foot off the surface of the land area in 6,000 years. Now, taking land and water area together, there is four times as much as the land area alone; it would therefore need $4 \times 6{,}000 = 24{,}000$ years to spread one foot of denudation over the whole globe. Most geologists put the total quantity of stratified rock on the globe, if spread out in an even layer, at 1,000 feet. It would require $1{,}000 \times 24{,}000 = 24{,}000{,}000$ years to deposit such a stratification. But the greater mass of sedimentary rocks have been formed out of old sedimentary rocks, and these again out of others still older. It would not be too far to predicate that there have been at least three cycles of rock life: that at least three times were the cliffs levelled and three times the dust of new continents was sown, and this would bring up the period of the solar heat to 72,000,000 years, for which period it is most difficult, and, if the methods are correct, it is impossible to account on the gravitation theory of solar energy.

Evolution is a process, and this process commenced, according to this theory, when the dark solid masses collided. If there had been no impact there would have been no energy evolved; no change; no work performed, and therefore no evolution. Evolution, therefore, is not eternal—it had its beginning. And before that beginning—those dark masses, hurled by the hand of the Creator, speeding through space illimitable. Whence they emanated? When they were aggregated? When they became dowered with that mighty energy? These and other tremendous problems rear themselves dark and vast before the human intellect. To these the Creator, enthroned in the circle of the heavens, has thus far closed the door: the fiat "Thus far shalt thou come and no further" has been written across the threshold, and the eagle intellect of man has bravely struggled to reach the summit, but, baffled and weary, has fallen back upon itself.

But yet, when all is said, and when the topmost height of human reason has been climbed, and we struggle for truth, sometimes successfully, but ofttimes vainly, do we not find in the words of the dead Laureate—

> "Our little systems have their day,
> They have their day and cease to be:
> They are but broken lights of Thee,
> And Thou, oh Lord, art more than they."

The reading of the paper was followed by a lively discussion, in which the President and Messrs. Elvins, Harvey, Phillips, Dewar, and others took part.

ANNUAL MEETING.

January 10th, 1893; Mr. John A. Paterson, M.A., Vice-President, in the chair.

The chairman, on behalf of the deputation appointed by the Council to wait on Mr. Hart A. Massey, reported that as the designs for the proposed Massey Memorial Hall, a gift to the citizens of Toronto, were near completion, and as the work was to be begun at once, Mr. Massey could not give any distinct promise that he could erect an observatory in some part of the building for public use. When finished, the Society might have a room in which to hold meetings. Mr. Massey was sorry the matter had not been mentioned at an earlier day as he was willing to do what he could to advance the study of Astronomy, a subject in which he took a deep interest. Mr. Elvins intimated that if anything was to be done in the future by the Society in regard to constructing a popular observatory, no doubt Mr. Massey would assist substantially.

Among the letters read was an interesting one from Professor W. H. Pickering, Director of the Harvard College Observatory, established at Arequipa, Peru. Owing to a want of uniformity in the Martian names employed in England, Europe, and the United States, difficulty had been experienced in appreciating everything contained in Professor Pickering's telegraphic reports to the press. His attention having been called to this, the Professor thus wrote to the Society :—

> The nomenclature upon Mars is certainly in very bad shape, and I should be glad to join in any movement to improve it. I feel the more interest in the matter as I hope to publish a map of the planet, shewing a number of features not previously located. Personally, I find Professor Schiaparelli's names often very long and very hard to remember. The English nomenclature, in that respect, seems to me much superior. On the other hand, if that is retained, it seems to me the same difficulty will arise in the future that now exists in the case of the moon—very inconspicuous and uninteresting peaks commemorate great names like Herschell, Le Verrier, and Encke, while much more important summits are named after mediocre men who lived long before them. Moreover, it seems to me a little presumptuous to foist any man's name upon a grand natural object. I am quite prepared in my work to adopt any plan of nomenclature that meets with general acceptance.

The following officers of the Society for 1893, were declared to have been duly elected by acclamation, Miss A. A. Gray, who had been nominated for the office of Treasurer, having been permitted to withdraw :—Honourary President, the Honourable George W. Ross, LL.D., Minister of Education; President, Charles Carpmael, M.A., F.R.A.S., F.R.S.C., etc., Director of the Toronto Observatory and Superintendent of the Dominion of Canada Meteorological Service; Vice-Presidents, Larratt W. Smith, Q.C., D.C.L., and John A. Paterson, M.A.; Treasurer, James Todhunter; Corresponding Secretary, G. E. Lumsden; Recording Secretary, Garnet H. Meldrum; Librarian, G. G. Pursey; who, with the following gentlemen, compose the Council of the Society for 1893 :—Messrs. A. Elvins, A. F. Miller, E. A. Meredith, LL.D., Arthur Harvey and D. J. Howell.

The paper for the evening was entitled

METEORITES,

and was, by request, read by the author, Dr. Otto Hahn, of Toronto, who has given the subject a great deal of attention.

The paper was an elaborate one, and the interest aroused by it was enhanced by the exhibition of a large number of micro-photographs and specimens. Having referred to the superstitions respecting meteorites during the period when they were objects of worship, and to the use by the ancients of meteoric iron weapons at a time when the smelting of iron was unknown, Dr. Hahn dealt in a critical manner with the chemical and physical nature of meteorites, the different kinds: iron, half-iron and stone (chondrites, enkrites, and cool meteorites), their constituents and the chemical combinations contained in them, the former being the same as on the earth, the latter nearly all the same. The doctor then took up the question of the origin of meteorites, concerning which he has published a book, in which are detailed the organisms found by him to occur in the chondrites. On this point he laid stress on the constitution of the chondrites, their structure as rocks, the structures of the enclosures (χονδροι), which have not the appearance of fossils embedded in rock, nor of a glassy mass, but of particles of the rock itself. Next, he explained the structures of the enclosures or substances found in the meteorites, and their relation to the structure of organisms, such as corals (favosites), sponges, and crinoids, all fossils occurring in the earliest schists of the earth. Dr. Hahn contended that meteorites are not broken planets; that most of them have fallen in the same shape and are of the same constitution; and that "as they are born, each is the germ of a planet if it could find material enough for growing." The doctor exhibited a large collection of meteorites (iron and stone) and of thin slices of meteor stones with substances which were claimed to be corresponding fossils of the silurian age; many of the specimens were polished so as to show the beautiful forms within them. His collection of micro-photographs seemed to be very complete, and challenged the admiration of the members of the Society, the doctor having, with great patience and skill, prepared his own microscopic slides. The examination of the slides by means of seven or eight powerful microscopes, which brought out perfectly the exquisite detail of the specimens, was by no means the least interesting portion of the evening's work.

Mr. Arthur Harvey, in moving a cordial vote of thanks by the Society to Dr. Hahn, first, for his paper; second, for his exhibition of specimens; and third, for his gift to the Society of a meteoric stone and a series of photographs, expressed the hope that a work containing the doctor's views on the forms of life which he has found in the chondrites, would soon be given to the world.

The motion was seconded by Mr. J. M. Clark, M.A., and carried with applause.

Mr. Lumsden's motion respecting Associate Members, notice of which was given at a previous meeting, was carried; it was decided that the fee for such members should be one dollar per annum.

The duty of re-arranging the list of Corresponding and Associate Members in accordance with the resolution was referred to the Council.

Dr. Harrison, of Keene, was elected an Associate Member, and Mr. G. Hahn, of Toronto, an Active Member of the Society.

Mr. Charles P. Sparling was appointed to be Recording Secretary, vice Mr. Garnet H. Meldrum, whose resignation was accepted with regret, owing to his inability, by reason of other duties, to retain the office. As the work in connection with the Society was increasing, the following assistants were elected:—Miss Annie A. Gray, to be Assistant Recording Secretary; Miss Sarah L. Taylor, to be Assistant Treasurer; and Miss Jeane Pursey, to be Assistant Librarian.

The best thanks of the Society were directed to be conveyed to the editors of the morning papers in Toronto for their unvarying courtesy in publishing the reports of the meetings held from time to time, and for otherwise advancing the Society's interests.

Mr. D. J. Howell, the retiring Treasurer, read a Statement which showed that the Society was in a very prosperous condition; that its membership was steadily increasing, and that a valuation exceeding $1,000 had been placed upon its books and apparatus, which include many volumes, which could not now be duplicated, and the Sir Adam Wilson telescope and celestial globe and other instruments, lantern-slides, etc. Mr. Howell was accorded a vote of thanks for his services, extending over several years.

The communications read included one from a gentleman in Assiniboia, thanking the Society for a slight service rendered; one, from a distant member, asking that a copy of the annual reports of the Society be sent to the editor of *The Arena*; one from Mr. J. Ellard Gore, F.R.A.S., respecting a work of his recently published; one from Dr. Joseph Morrison, Ph.D., F.R.A.S., of the American Nautical Almanac Office, Washington, congratulating the Society upon its progress, and offering a paper on the general and special methods of computing planetary perturbations, written so as to simplify the demonstrations of the various *formulæ* and to give most persons a pretty clear idea as to the manner in which the subject is handled; and one from Dr. M. A. Veeder, of Lyons, N.Y., containing a special announcement with respect to auroræ:—"I am still considering the question of the local distribution of the auroræ, a subject on which I corresponded with you last year, and now intimate that it is possible to report progress to the extent, at least, of saying that whatever it may be that attracts the auroræ in certain localities as compared with others in the same latitude, it is in some way associated with sharp bendings and displacements locally of the lines of equal magnetic declination; that there are three localities thus far identified which exhibit the peculiarities, viz., Northern Maine, the Adirondack region of Northern New York, and the region near the mouth of the Ohio river, and that I have not secured any clear evidence that the copper deposits in the vicinity of Lake Superior have any special attractions for the auroræ."

The Rev. T. E. Espin, F.R.A.S., of Tow Law, England, sent a list of new *comites* to well-known double-stars detected by him during the autumn, while measuring stars for the new edition of Webb's Celestial Objects, which he is editing. In his letter, Mr. Espin was good enough to say that the suggestions of the Society, invited by him some months before, respecting the plan of the new edition, had been helpful, and that he hoped to be able to adopt most of them.

The publications laid on the table by Mr. G. G. Pursey, the Librarian, included the latest issues of The Royal Astronomical Society, The British Astronomical Association, and The Astronomical Society of the Pacific, as well as some pamphlets from Observatories and Societies in France and Germany. A copy of Miss Ellen M. Clerke's recent book, "Jupiter and His System," was shown to the members. Observations on the sun, planets, meteors, and Comet Holmes were made, or read, by Messrs. Pursey, Harvey, Miller, Elvins, Copland, Lumsden, and others.

Mr. Lumsden laid on the table, a copy of M. Camille Flammarion's new work on Mars. The book which is beautifully illustrated by nearly six hundred designs, was carefully examined and was highly commended.

NEW COMPANIONS TO DOUBLE-STARS IN WEBB.

The appended paper, referred to above and contributed by Mr. Espin, was read :

The following new companions have been discovered during a revision of some stars for the new edition of Webb's Celestial Objects. The telescope used is the 17¼ inch reflector of the Wolsingham Observatory ; the micrometer was made by Troughton & Sims. The mean measures only are given. The stars are arranged in their order of constellations. The Right Ascension and Declination are for 1900. The magnitudes are on Struvès Scale. The work was done from September to December, 1892.

NO.	STAR.	R. A.	DECL.	P.	D.	N.	MAGS.		
		h. m.	° ′	° ′	″				
1	Σ 994	5 52.8	37 14	220.9	9.13	1	7.2	12.0	AC.
2	P III.97	3 34.5	59 39	96.2	18.68	1	6.0	13.8	AB.
...	....	....	.....	302.4	34.65	1	...	13.0	AC.
3	Dembowski	4 32.0	53 17	69.0	18.04	3	8.5	12.5	AC.
4	β Camelop.	4 54.5	60 18	167.4	14.81	2	7.0	11.5	BC.
5	Cassiop.	0 25.6	56 14	113.3	6.36	3	8.2	8.5	AB.
6	Anon.	0 29.4	56 3	158.5	8.66	3	8.	9.	Yellow : blue.
7	Anon.	0 49.7	57 15	116.3	4.86	2	9.6	9.8	AB.
8	Σ 18.	1 49.3	60 48	75.2	29. 9	2	7.0	13.5	AC.
9	Σ 306.	2 43.4	60 1	74.3	17.02	2	7.1	13.8	AC.
...	....	....	.....	112.0	19.21	2	..	13.5	AD.
...	....	....	.....	105.6	27.40	2	...	13.0	AE.
10	Anon.	23 56.7	59 26	289.3	10.13	...	8.	9.	Yellow : blue.
11	Webb.	19.46.8	44 54	327.9	31.54	5	8.0	9.0	AB.
...	....	....	.....	138·8	7.68	3	...	11.5	AC.
12	Anon.	20 45.2	32 51	245.6	9.61	3	8.7	9.0	AB., very red : blue.
...	....	....	.....	141.1	17.86	3	...	10.0	AC.
13	59 Cygni.	20 56.6	47 8	224.1	37.09	3	4.7	13.5	AD.
14	H. V. 66	7 21.7	22 21	23.9	11.31	1	7.0	13.5	
15	Σ 2916	22 27.0	40 42	118.0	16.56	3	8.0	13.8	BD.
16	8 Lacertae	22 31.4	39 6	200.±	9.95	3	8.0	13.8	Dd.
17	Σ446	3 41.9	52 21	42.7	11.69	1	7.	12.5	AC.

NOTE.—No. 3. Place of 2 Cameli. No. 9 Dembowski measured a more distant *comes :* there are three others still more distant. Where the stars are below 12.5, the measures have been made with great difficulty and show considerable differences both in distance and angle. The mirror has not been silvered for four years and so the faint stars are difficult objects with it.

T. E. ESPIN.

Tow Law, Darlington, England, 1893, January 6th.

As Mr. Espin's paper was considered to be of interest to observers and as the report of this Society would not, on this occasion, be issued for some months, the Secretary was requested to offer it to the editor of *Astronomy and Astro-Physics*, who published it in the March number of that periodical, with some observations by Mr. S. W. Burnham.

After some discussions on general topics, the Society brought the proceedings for the year 1892 to a close and adjourned.

THE
Astronomical and Physical Society of Toronto.

(INSTITUTED 1885: INCORPORATED 1890.)

Constitution and By-laws.

(ADOPTED 25TH FEBRUARY, 1890: AMENDED 2ND MAY, 1893.)

ARTICLE I.—NAME AND OBJECTS.

1. The name of this Society shall be THE ASTRONOMICAL AND PHYSICAL SOCIETY OF TORONTO.

2. The objects of this Society shall be:—(*a*) To encourage, advance and popularize the study of Astronomy and Physics, and to diffuse as widely as is practicable, information in those branches of Science. (*b*) To publish, from time to time, the results of the work of this Society in the form of Transactions, which shall contain such Notes and Papers as shall have been approved of for publication, and (*c*) To acquire and maintain a library and such apparatus and other property, both real and personal, as may be necessary and convenient for the due carrying out of the said objects of the Society, or any of them.

ARTICLE II.—MEMBERSHIP.

1. This Society shall be composed of Active, Associate, Life, Corresponding and Honourary Members.

2. Active Members shall be persons who shall have been elected to Active membership and shall have paid their dues. [The persons who made the Declaration for the incorporation of this Society under the provisions of the Revised Statute of Ontario, Chapter 172, were thereby declared to be Active Members, duly elected, and to become fully qualified as such upon payment of their dues.] An Active Member shall pay an annual fee of $2.

3. Associate Members shall be persons not resident in the city of Toronto, who shall have been elected as such. An Associate Member shall pay an annual fee of one dollar, and be entitled to all the privileges of the Society, when present at any of its meetings, and shall receive a copy of its Reports.

4. Life Members shall be persons who shall have been elected to Life Membership and shall have paid the sum of twenty dollars to the Treasurer of the Society. An Active Member of the Society may, at any time, commute his dues by the payment of twenty dollars, and, upon the vote of this Society, may become a Life Member thereof. The Society may, in its discretion, confer Life Membership upon any person.

5. Corresponding Members shall be persons, not residing in Toronto, who shall, by reason of their qualifications and eminence as Astronomers or Physicists, be, in the opinion of the Society, entitled to some special recognition of their claims as such, and shall have been elected to Corresponding Membership.

6. Honourary Members shall be persons highly distinguished for their attainments in Astronomy and Physics, who shall have been elected to Honourary Membership. The Honourary Members of this Society shall, however, not exceed fifteen in number.

7. No Active or Associate Member in arrears, shall be entitled to vote at any meeting of this Society.

8. Corresponding and Honourary Members shall pay no dues and shall have no votes.

9. A candidate for Active Membership in this Society may be proposed at any regular meeting by a mover and seconder, in good standing, and may be voted for at any subsequent regular meeting. The vote shall be by ballot, and an assenting majority of the members present shall be required for an election. The candidate shall, on his election, pay into the Treasury of this Society such sum as shall be due and in the following proportion for the year in which he is elected:—$2, if elected before the first day of September, and $1 if elected subsequently to that date; and no accepted candidate shall be deemed to be an Active Member of this Society until he shall have duly paid in such sum.

10. Any member desirous of resigning his membership in, or of withdrawing from, this Society shall give to the Recording Secretary due notice thereof in writing, and shall pay all arrears, if any, whereupon his membership shall cease.

11. If at any time the harmony, well-being, and best interests of this Society shall appear to require that any one or more of its members shall cease to be a member or members, the President, or other presiding officer, at a regular meeting of the Society, shall, upon a motion to that effect in writing, call a special meeting of the Society for the purpose of considering the matter, and shall cause due notice thereof to be given such member or members, and if, upon due examination, the charge or charges shall, in the opinion of a majority of the members present, appear to have been sustained, the officer presiding shall thereupon invite such member or members to resign forthwith, and, in default of such resignation being forthcoming, the Society shall expel such member or members.

12. Any member who shall resign, withdraw or be expelled from this Society shall, thereupon, forfeit all interest in or claim to the property and funds of the Society.

ARTICLE III.—OFFICERS.

1. The Executive Officers of this Society shall consist of an Honourary President, a President, two Vice-Presidents, a Treasurer, a Corresponding Secretary, a Recording Secretary, and a Librarian. These Officers, with five Active Members to be elected for the purpose, shall form the Council of this Society, to which shall be committed the general management of its affairs. Three members of the Council shall form a quorum.

2. The President, or, in his absence, either of the Vice-Presidents, or, in their absence, any member of the Society, appointed for the purpose, shall preside over its meetings. It shall be the duty of the presiding officer for the time being, to preserve order, regulate the proceedings of the meetings, and to exercise a general supervision over the interests of the Society.

3. The Treasurer shall receive and, from time to time, account for all the moneys and such papers of the Society as shall have been committed to his custody, and, if required, shall deposit all moneys in a chartered Bank and shall give such security as, to the Society, shall seem proper. Payments of amounts approved by the Society, or by the Council, as the case may be, shall be made by cheque or order, drawn by the Treasurer and countersigned by the President, or by one of the Vice-Presidents. The Treasurer's accounts shall be audited annually, or as often as shall be required by the Society.

4. The Corresponding Secretary shall conduct the official correspondence of the Society and shall keep copies of all letters written by him and shall preserve and index all communications received, and shall read such communications to the Society at the first regular meeting after receipt.

5. The Recording Secretary shall keep the Minutes of the Society and shall have the custody of its records generally. It shall be his duty to notifiy members of their election and of the times and places for holding the regular meetings of the Society and, when required by the presiding officer to do so, to call special meetings of the Society, or of the Council, as the case may be.

6. The Librarian shall have charge of and be responsible for the safe-keeping and proper condition of the books, publications and apparatus of the Society, and shall report to each regular meeting the names of such donations and publications as may have been received.

7. The Society may appoint such other officers as shall appear to be required and may specify their duties, and may vary the duties of the officers composing the Council.

8. The presiding officer of this Society, at any regular meeting, may appoint a Special Committee to report to the Society upon any subject upon which it desires information, or advice, not within the province of the Council to procure.

9. The officers of this Society shall be chosen at its annual meetings, which shall be held on the second Tuesday in the month of January in each year, at the hour of twenty o'clock, at a place of which due notice shall have been given. Nominations shall be made at the last meeting to be held in the month of December, and voting shall be by ballot. In the event of vacancies occurring during the year, the same may be filled at any regular meeting of the Society, nominations and voting to be in due form.

ARTICLE IV.—PAPERS.

1. The title of any Paper, Memoir, or other production by a member intended to be read at a meeting of this Society, shall be submitted, together with an abstract of its contents, to the Council, through the Recording Secretary, previous to the meeting at which it is to be read. The paper, if approved and read, shall be submitted to a committee, and, on report of said committee, may be recommended to the

Council for publication, either entire or in abstract, in the Transactions of the Society.

ARTICLE V.—LIABILITIES.

1. No liability or obligation whatever on the part of this Society shall be incurred, and no contract shall be entered into, or expenditure, in excess of the sum of $5, shall be made, unless and until such liability, obligation, contract, or expenditure has been recommended in writing by the Council and afterwards approved by the Society at a regular meeting held after reasonable notice shall have been given of the intention to submit at such meeting the subject of the approval of such liability, obligation, contract, or expenditure; this provision shall not apply, however, either to the incurring or to the payment of any petty incidental expenditure, not exceeding the sum of $5, which shall have been recommended by the Council. Every such expenditure shall, however, be reported to the Society at the ensuing regular meeting.

ARTICLE VI.—POWER OF REVISION.

1. The Constitution and By-laws of this Society may, upon the recommendation of the Council, be amended, if the amendment or amendments be agreed to by two-thirds of the members present at any regular meeting of which due notice shall have been given.

ORDER OF BUSINESS.

1. Chair to be taken at 20 o'clock.
2. Reading of Minutes.
3. Business arising out of the Minutes.
4. Communications.
5. Reports from the Council.
6. New Business.
7. Election of Members.
8. Nominations for Members.
9. Librarian's Report.
10. Reports of Committees.
11. Predictions of Phenomena.
12. Report of Observations.
13. Announcements, including next place of meeting, and paper to be read thereat.
14. Adjournment.

APPENDIX I.

OCCULTATIONS BY THE MOON, 1893.

The following Table of Occultations by the Moon has been reduced from the list of phenomena visible during 1893 at Washington. Eight minutes have been added for difference between Washington Mean Time and Eastern Standard Time, in which the predictions are given. The times must, therefore, be taken as roughly approximate. The letters "a" and "p," respectively, stand for "a.m." and "p.m."

DATE.	STAR.	MAG.	IMMERSION.	EMERSION.
New moon.				
May 4......	43 Ophiuchi	5·8....	1.41 a.	3.15 a.
" 19......	ω^1 Cancri	6	7.11 p.	8.14 p.
" 19.. ...	ω^2 Cancri	6·3....	7.56 p.	8.37 p.
" 24......	η Virginis	4	9.29 p.	10.28 p.
June 5......	38 Capricorni	6·9....	1.37 a.	2.51 a.
New moon.				
June 22......	h Virginis	5·8....	7.09 p.	8.35 p.
July 7......	*B.A.C.* 410	6	1.24 a.	2.25 a.
New moon.				
July 23......	Antares	1·4....	8.36 p.	9.27 p.
" 24......	43 Ophiuchi	5·8....	8.46 p.	10.15 p.
Aug. 3......	ϵ Piscium	5·5....	0.03 a.	0.52 a.
" 4......	*B.A.C.* 609	6	0.53 a.	1.52 a.
" 4......	π Arietis	5·7....	11.21 p.	12.06 a.
" 5......	ρ^2 Arietis	6	2.28 a.	3.28 a.
" 5......	ρ^3 Arietis	6	2.32 a.	3.13 a.
" 6......	*B.A.C.* 1189....	6	0.38 a.	2.24 a.
New moon.				
Aug. 16......	86 Virginis	5·9....	7.06 p.	8.20 p.
" 24......	ω Sagittarii	5·1....	1.47 a.	2.23 a.
" 25......	38 Capricorni	6·9....	8.48 p.	9.56 p.
" 25	37 Capricorni	6	8.50 p.	10.14 p.
" 26......	κ Capricorni	5	2.38 a.	3.43 a.
" 27......	ψ^1 Aquarii........	4·1....	10.09 p.	11.02 p.
" 28......	29 Piscium	5	8.48 p.	9.48 p.
" 28......	*B.A.C.* 8351....	8 ...	9.10 p.	10.13 p.
Sept. 1......	36 Arietis	6·5....	4.01 a.	5.13 a.
New moon.				

DATE.	STAR.	MAG.	IMMERSION.	EMERSION.
Sept. 23......	74 Aquarii........	6	7.47 p.	9.0 p.
" 25......	24 Piscium	6·1....	3.50 a.	4.39 a.
" 28......	δ Arietis	4	8.34 p.	9.27 p.
" 29......	τ^1 Arietis	5	1.40 a.	2.49 a.
Oct. 2......	49 Aurigæ........	5·7....	3.25 a.	4.34 a.
" 3......	ν Geminorum	4·3....	2.11 a.	2.47 a.
New moon.				
Oct. 17......	b Sagittarii	4·6....	5.14 p.	6.0 p.
" 20......	56 Aquarii........	6·3....	5.49 p.	7.08 p.
" 27......	36 Tauri.........	6	3.56 a.	4.59 a.
New moon.				
Nov. 14......	*B.A.C.* 7077....	6·4....	6.30 p.	7.04 p.
" 15......	33 Capricorni	5·7....	7.13 p.	8.27 p.
" 18......	24 Piscium	6·1....	11.45 p.	12.44 p.
" 22......	τ^2 Arietis	5·3....	9.09 p.	9.39 p.
" 25......	136 Tauri..........	5·3....	5.59 a.	6.38 a.
" 27......	ω^1 Cancri	6	2.00 a.	3.05 a.
New moon.				
Dec. 18......	ζ Piscium	4·8....	1.26 a.	2.12 a.
" 19......	40 Arietis	6·3....	6.40 p.	7.16 p.
" 21......	36 Tauri.........	6	2.20 a.	3.19 a.
" 23......	47 Geminorum	6	5.51 p.	6.39 p.
" 24......	λ Cancri	5·7....	6.51 p.	7.41 p.
" 31......	86 Virginis	5·9....	5.05 a.	6.07 a.

MERCURY.

The following table will enable the observer to find Mercury by reference to more conspicuous objects :—

ELONGATIONS.

July 11..........	8 a.m.......	Greatest Elongation	...... E	26°	30′
Aug. 25..........	9 p.m.......	" "	......W	18°	16′
Nov. 5..........	5 p.m.......	" "	...... E	23°	12′
Dec. 14..........	1 p.m.......	" "	.... .W	21°	23′

Configurations in R. A.

May 20...	2h. 6m. p.m..........	In Conjunction with	Jupiter
June 14..........	9h. 40m. p.m..........	" "	Venus
June 27	11h. 20m. a.m..........	" "	Mars
Nov. 10..........	9h. 11m. a.m..........	" "	Moon

VENUS.

Venus is morning star at the beginning of 1893, reaches the aphelion point of her orbit on March 5th, and is in superior conjunction May 1st. On July 9th, at 9 a.m., she will be in close conjunction with Mars. Both planets pass the meridian on that day at 1h. 23m. mean time, in declination 23° N. Venus continues evening star till the end of the year, reaching her greatest elongation East on December 6th. On October 12th she will be in close conjunction with the second magnitude star δ Scorpii.

MARS.

Mars begins the year 1893 as evening star. His declination North is gradually increasing until May, when his highest altitude is attained. Passing then southwards and nearer to the sun, he is in conjunction on September 3rd, after which he is morning star and less favourably situated for observation. Not being in opposition in 1893, the tiny moons will not be visible. Mars is in conjunction with Saturn on October 31st, and with Uranus on December 6th. On the morning of December 7th Mars, Uranus, and the 3rd magnitude star α^2 Libræ will be nearly in same field of the telescope.

JUPITER.

Jupiter was in conjunction with the sun on April 27th, and will be again visible in the twilight on mornings in June. He reaches opposition again on November 15th, being then in Declination 18° North and most favourably situated for observation. Several occultations of Jupiter occur in 1893, but none are visible in Ontario. The following table contains the phenomena of the satellites reduced to Eastern Standard Time, and limited to events visible before 2h. a.m. Abbreviations signify as follows :—*tr. in.*, transit ingress of satellite ; *tr. eg.*, transit egress ; *sh. in.*, shadow ingress : *sh. eg.*, shadow egress ; *ec. dis.*, disappearance of satellite behind planet ; *oc. dis.*, disappearance of satellite in planet's shadow.

SATELLITES OF JUPITER—PHENOMENA.

July.

D.	H.	M.	SAT.		
5	1	54	I.	*tr.*	*in.*
6	2	23	II.	*ec.*	*dis.*
12	2	17	III.	*oc.*	*re.*
15	1	38	II.	*sh.*	*eg.*
	1	41	II.	*tr.*	*in.*
19	1	32	III.	*ec.*	*re.*
20	1	51	I.	*ec.*	*dis.*
21	2	32	I.	*tr.*	*eg.*
22	1	51	II.	*sh.*	*in.*
24	1	46	II.	*oc.*	*re.*
28	2	19	I.	*tr.*	*in.*
29	1	40	I.	*oc.*	*re.*
31	1	47	II.	*ec.*	*re.*
	2	10	II.	*oc.*	*dis.*

August.

D.	H.	M.	SAT.		
5	11	36	I.	*sh.*	*eg.*
	11	55	III.	*sh.*	*eg.*
6	0	57	I.	*tr.*	*eg.*
7	2	09	II.	*ec.*	*dis.*
9	1	22	II.	*tr.*	*eg.*
12	2	00	I.	*ec.*	*dis.*
13	0	40	I.	*tr*	*in.*
13	1	30	I.	*sh.*	*eg.*
	2	12	III.	*sh.*	*in.*
16	1	14	II.	*sh.*	*eg.*
	1	41	II.	*tr.*	*in.*
20	1	12	I.	*sh.*	*in.*
	2	27	I.	*tr.*	*in.*
21	1	55	I.	*oc.*	*re.*
	11	15	I.	*tr.*	*eg.*
22	1	29	II.	*sh.*	*in.*
24	1	42	III.	*oc.*	*dis.*
24	10	53	II.	*ec.*	*re.*
	11	25	II.	*oc.*	*dis.*
25	1	42	II.	*oc.*	*re.*
28	0	17	I.	*ec.*	*dis.*
	10	57	I.	*tr.*	*in.*
	11	47	I.	*sh.*	*eg.*
29	1	08	I.	*tr.*	*eg.*
31	0	03	III.	*ec.*	*dis.*
	1	33	III.	*ec.*	*re.*
	11	15	II.	*ec.*	*dis.*

September.

D.	H.	M.	SAT.		
1	1	29	II.	*ec.*	*re.*
	1	58	II.	*oc.*	*dis.*
2	10	23	II.	*tr.*	*eg.*
4	2	10	I.	*ec.*	*dis.*
4	11	29	I.	*sh.*	*in.*
5	0	50	I.	*tr.*	*in.*
	1	41	I.	*sh.*	*eg.*
6	0	09	I.	*oc.*	*re.*
8	1	50	II.	*ec.*	*dis.*
9	10	18	II.	*sh.*	*eg.*
	10	37	II.	*tr.*	*in.*
10	0	53	II.	*tr.*	*eg.*
10	11	42	III.	*tr.*	*in.*
11	1	02	III.	*tr.*	*eg.*
12	1	22	I.	*sh.*	*in.*
	2	41	I.	*tr.*	*in.*
12	10	33	I.	*ec.*	*dis.*
13	2	00	I.	*oc.*	*re.*
	10	03	I.	*sh.*	*eg.*
	11	20	I.	*tr.*	*eg.*
16	10	33	II.	*sh.*	*in.*
17	0	54	II.	*sh.*	*eg.*
	1	06	II.	*tr.*	*in.*
	10	13	III.	*sh.*	*in.*
	11	56	III.	*sh.*	*eg.*
18	10	28	II.	*oc.*	*re.*
20	0	27	I.	*ec.*	*dis.*
	9	45	I.	*sh.*	*in.*
	10	58	I.	*tr.*	*in.*
	11	57	I.	*sh.*	*eg.*
21	1	09	I.	*tr.*	*eg.*
	10	17	I.	*oc.*	*re.*
24	1	09	II.	*sh.*	*in.*
25	2	13	III.	*sh.*	*in.*
	10	33	II.	*ec.*	*re.*
	10	38	II.	*oc.*	*dis.*
26	0	53	II.	*oc.*	*re.*
27	2	21	I.	*ec.*	*dis.*
	11	39	I.	*sh.*	*in.*
28	0	47	I.	*tr.*	*in.*
	1	51	I.	*sh.*	*eg.*
	2	58	I.	*tr.*	*eg.*
	10	00	III.	*oc.*	*re.*
29	0	06	I.	*oc.*	*re.*

October.

D.	H.	M.	SAT.		
2	10	55	II.	*ec.*	*dis.*
4	9	23	II.	*tr.*	*eg.*
5	1	33	I.	*sh.*	*in.*
	2	34	I.	*tr.*	*in.*
	9	36	III.	*ec.*	*re.*
	10	43	I.	*ec.*	*dis.*
6	0	19	III.	*oc.*	*dis.*
	1	32	III.	*oc.*	*re.*
	1	53	I.	*oc.*	*re.*
	9	01	I.	*tr.*	*in.*
	10	14	I.	*sh.*	*eg.*
	11	12	I.	*tr.*	*eg.*
10	1	30	II.	*ec.*	*dis.*
11	9	29	II.	*tr.*	*in.*
	10	00	II.	*sh.*	*eg.*
	11	44	II.	*tr.*	*eg.*
13	0	07	III.	*ec.*	*dis.*
	0	39	I.	*ec.*	*dis.*
	1	36	III.	*ec.*	*re.*
	9	55	I.	*sh.*	*in.*
	10	47	I.	*tr.*	*in.*
14	0	08	I.	*sh.*	*eg.*
	0	58	I.	*tr.*	*eg.*
14	10	08	I.	*oc.*	*re.*
18	10	17	II.	*sh.*	*in.*
	11	49	II.	*tr.*	*in.*
19	0	37	II.	*sh.*	*eg.*
	2	08	II.	*tr.*	*eg.*
20	2	32	I.	*ec.*	*dis.*
	9	02	II.	*oc.*	*re.*
	11	50	I.	*sh.*	*in.*
21	0	33	I.	*tr.*	*in.*
	2	02	I.	*sh.*	*eg.*
	2	42	I.	*tr.*	*eg.*
	9	00	I.	*ec.*	*dis.*
	11	52	I.	*oc.*	*re.*
22	8	30	I.	*sh.*	*eg.*
	9	10	I.	*tr.*	*eg.*
23	8	00	III.	*sh.*	*eg.*
	9	08	III.	*tr.*	*in.*
	10	20	III.	*tr.*	*eg.*
26	0	53	II.	*sh.*	*in.*
	2	06	II.	*tr.*	*in.*
27	11	18	II.	*oc.*	*re.*
28	1	44	I.	*sh.*	*in.*
	2	17	I.	*tr.*	*in.*
	10	56	I.	*ec.*	*dis.*
29	1	36	I.	*oc.*	*re.*
29	8	12	I.	*sh.*	*in.*
	8	42	I.	*tr.*	*in.*
	10	24	I.	*sh.*	*eg.*
	10	44	I.	*tr.*	*eg.*
30	8	02	I.	*oc.*	*re.*
	10	14	III.	*sh.*	*in.*
	11	59	III.	*sh.*	*eg.*
31	0	26	III.	*tr.*	*in.*
	1	39	III.	*tr.*	*eg.*

SATURN.

The ringed planet will be a most beautiful object in 1893. He was in opposition, March 29th. The elevation of the earth above the plane of the ring was 9° on January 1st; this decreases to 6° on June 9th, after which it increases until, at the end of the year, when the planet is again morning star, we shall have the magnificent spectacle of the northern surface of the ring at an elevation of 14°. Saturn is in the constellation Virgo throughout the year, and on April 8th was in close conjunction with the beautiful double γ Virginis.

APPENDIX II.

REPORT OF THE LIBRARIAN FOR 1892.

Books, donations, exchanges, periodicals, etc., added to the Library since last report:—

A Possible Cause of Lunar Vibrations. By S. E. Peal.
Astronomy with an Opera-glass. J. A. Serviss.
A Theory of Lunar Surfacing by Glaciation. By S. E. Peal.
The Zodical Light. By M. A. Veeder.
Solar and Magnetic Disturbance. By T. S. H. Sherman.
Solar Photography at Kenwood Astronomical Observatory. By G. E. Hale.
Remarkable Solar Disturbance. By G. E. Hale.
Spectroscopic Observations of the Great Sunspot, February, 1892. By G. E. Hale.
Ultra Violet Spectrum of the Solar Prominences. By G. E. Hale.
Spectroscopic Observations of Light Curve of Nova Aurigæ. By T. E. Espin.
Orbit of Binary Star Σ 1536.
On the Orbit of 7 Centauri and 7 Coronæ Australis. By J. E. Gore.
The Red Stars in the Great Perseus Clusters. By T. E. Espin.
Note on the Variability of Es.-Birm. 673 = D. M. +39° 4208. By T. E. Espin.
Elementary Principles Governing the Efficiency of Spectroscopes for Astronomical Pürposes. By. E. E. Keeler.
Star Spectroscope of Lick Observatory. By E. E. Keeler.
Recent Result in Solar Prominence Photography. By G. E. Hale.
Report of Magnetic Observations of Europe. By C. C. Marsh.
Reports of Observations of Total Eclipse of Sun, January 1st, 1889. Lick Observatory.
Greenwich Observations, 1889.
Proceedings and Transactions of Royal Society of Canada, 1891.

Journal of Proceedings of the Hamilton Association, 1891.
Monthly Review of Iowa Weather and Crop Service—August and September.
Report of United States Naval Observatory for years ending June, 1889, 1890, 1891.
Magnetic Observations of United States Naval Observatory, 1890, 1891.
Meteoric Observations and Results, United States Naval Observatory, 1888.
American Ephemeris and Nautical Almanac, 1893.
Report of Meteorological Service of Dominion of Canada, 1888.
Astronomy and Astro-Physics—constant supply.
Diagram of Sunspots; February, 1892.
Proceedings of Royal Society, 1892; fourteen numbers.
Exchange List of Royal Society.
Royal Astronomical Society; six numbers and supplement.
Astronomical Society of Pacific; five numbers.
Science Observer; ten numbers.
Mitteilüngen: six numbers.
Washington Observations 1887, Appendix I.; 1888. Appendix II.
Observations of Double-Stars. Hall.
Der Brorsen'sche Comet. Lamp.
Photographs of Solar Phenomena. G. E. Hale.
History of Physical Astronomy. Grant.
A Meteorite (fragment). Presented by Townsend.
Telescope and Celestial Globe. Presented by Lady Wilson.
Handsome Album for Preservation of Drawings, Photographs, etc. Presented by Chas. P. Sparling.
Meteorological and Magnetic Charts, Solar and Lunar Photographs.

APPENDIX III.

LANTERN SLIDES, THE PROPERTY OF THE SOCIETY.

1. Mechanical Slide. "The Solar System," showing the revolution of all the planets and their satellites around the sun. Donated by Mr. D. J. Howell.

2. "Sunspots," from negative made by Capt. Ashe, of Quebec, and in possession of Mr. A. Elvins.

3. Another portion of same.

4. (*a*) "Photograph of a portion of Lyra;" R. A. 29h. 19m.-N. D. 50° 0′, 18th June, 1887. Donated by MM. Henry Brothers, of the Observatory, Paris, France.

5. (*b*) "Photograph of a portion of Cygnus;" R. A. 20h. 4m.-N. D. 54° 30′, 28th July, 1886. Donated by Henry Brothers.

6. (*c*) "Photograph of a portion of Lyra;" R. A. 18h. 34m.-N. D. 59° 0′, 17th June, 1887. Donated by Henry Brothers.

7. (*d*) "Photograph of a portion of the Moon's surface."

8. (*e*) " " "

9. (*f*) " " "

From photographs presented to the Society by the Henry Brothers.

10–11. Two Lunar photographs reproduced in *Knowledge* from negatives by the Henry Brothers, of Paris.

12–13. "The Moon in three phases," from negatives made at the Lick Observatory (no date).

14. "Photograph of a portion of the Moon's Surface," from negative made at the Lick Observatory (no date).

15. "Photograph of the total eclipse of the Sun, January 1st, 1891,' from negative made at the Lick Observatory.

16. "Photograph of the Solar Disc, partially eclipsed by the Moon," from negative made at the Lick Observatory.

17. "Copy of engraving of Saturn."

18. "Photograph of Saturn," from negative made at the Lick Observatory.

19–20. "Two views of Mars," from engravings.

21. "Photograph of portion of plaster model of the Moon's surface," by Nasmyth; donated by Mr. A. Elvins.

22. "Copy of engraving of total eclipse of the Sun," showing the solar atmosphere, from "The New Astronomy," in *The Century Magazine.*

23-25. Copies of engravings from same article, showing the Sun's Surface and a series of spots.

26. "Shooting Stars;" copy of engraving in *The Century Magazine*: "Comets and Meteorites."

27. "Donati's Comet;" copy of engraving from *The Century Magazine*.

28-29. Photographs, from *Knowledge*, of portions of the Sun's Surface, showing the rice-grain and willow-leaved structure; also, two spots without penumbra

30. Copy of engraving of the Great Nebula in Andromeda, from photograph by Mr. Isaac Roberts, F.R.A.S.

31-39. Copies of plates in "The Stars of Winter," in *Astronomy with an Opera-Glass*; by J. A. Serviss.

40. "Diagram showing Maximum and Minimum of Sunspots in Fifteen"—Years;" 1874 to 1888 inclusive.

41. "Diagram by Elvins of Storm Periods and Solar Activity."

42. "Chart of Magnetic Variations and Solar Ativity for Sixteen Years"—from 1873 to 1888 inclusive.

43. "Diagram by Elvins of Solar Activity, Storms, Magnetic Variation, etc."

44. "Copy of engraving of the Planet Jupiter."

45-46. Two portraits of the late R. A. Proctor.

Besides the above slides, there are :—

(*a*) A fine 8-10 negative of the Moon; diameter of disc, five inches.

(*b*) One positive print on glass, "Transit of Mercury, May 9, 1891;" size, 6½ x 8½ inches; diameter of Sun's disc, 4⅝ inches.

(*c*) One positive print on glass, "The Transit of Venus, 1882," 6½ x 8½ inches; Sun's disc, 4½ inches.

(*d*) One positive print on glass of "A Portion of the Cluster in Perseus,' 8 x 10 inches, made November 3rd, 1890.

(*e*) One positive print on glass, 8 x 10 inches, of the Sun's Surface, showing Sunspot, February 11th, 1892, 10h. 35m. 48s., P. S. T.; Sun's disc, 4½ inches.

The above were presented to the Society by Prof. E. S. Holden, LL.D., Director of the Lick Observatory.

APPENDIX IV.

CIRCULAR-LETTER ADDRESSED TO ASTRONOMERS OF ALL NATIONS.

PROPOSED CHANGE IN RECKONING THE ASTRONOMICAL DAY.

TORONTO, CANADA, 21st April, 1893.

The Canadian Institute in co-operation with The Astronomical and Physical Society of Toronto, have had under consideration the subject of Astronomical Time Reckoning, and have, after much deliberation and consultation, appointed a Joint Committee to suggest the best means of ascertaining the views of astronomers throughout the world.

The Joint Committee have presented the accompanying Report, in which both Societies concur.

On behalf of the two Societies we have the honour to direct attention to the observations and recommendations of the Joint Committee, as well as to the appended extracts, expressing the views of the following gentlemen :—

1. Sir John Herschell.
2. M. Otto Struvè, Imperial Astronomer, Pulkowa.
3. Mr. W. H M. Christie, Astronomer Royal, Greenwich.
4. Prof. S. Newcomb, Nautical Almanac Office, Washington.
5. Commodore Franklin, United States Naval Obs., Washington.
6. Mr. C. Carpmael, President Astronomical Society, Toronto.
7. Mr. Arthur Harvey, President Canadian Institute, Toronto.

In order to obtain the views of as many astronomers as possible the Joint Committee recommend that answers be invited to the following question :—

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?

It is requested that early answers to this question be sent to the following address :—

JOINT COMMITTEE ASTRONOMICAL TIME,

CANADIAN INSTITUTE,

TORONTO, CANADA.

As it is intended to send copies of further papers on this subject to those replying, it is desirable that the full name, official designation, if any (professional or non-professional) and proper address be furnished with each reply.

ALAN MACDOUGALL,

G. E. LUMSDEN,

Joint Secretaries.

Report of the Joint Committee

Of The Canadian Institute and The Astronomical and Physical Society of Toronto.

SANDFORD FLEMING, C.E., C.M.G., LL.D., Etc., *Chairman.*

Canadian Institute.

Arthur Harvey, President.
Geo. Kennedy, M.A., LL.D.
Alan Macdougall, C.E., Secretary.

Astronomical Society.

Charles Carpmael, M.A., F.R.A.S., Etc., President.
John A. Paterson, M.A.
G. E. Lumsden, Corresponding Secretary.

Toronto April 20th, 1893.

Your Committee on the subject of Astronomical Time Reckoning, beg leave to report as follows :—

(*a*) That the Sixth Resolution of The Washington International Conference of 1884, which was carried unanimously by the representatives of the twenty-five nations there assembled, counting among them several astronomers of world-wide fame, reads as follows :—"The Conference expresses the hope that, as soon as may be practicable, the Astronomical and Nautical Days will be arranged everywhere to begin at Mean Midnight ;"

(*b*) If any action is to be taken on this Resolution, the most appropriate date for the new reckoning to take effect would be the first day of the new century ;

(*c*) As the Ephemerides are usually prepared four or five years in advance, it is obvious that if it be decided to make Astronomical Time accord with Civil Time at the date named, a common understanding should not be delayed beyond the year 1895 or 1896 ;

(*d*) To arrive at an agreement, it is considered essential to ascertain the views of those concerned ;

(*e*) The Canadian Institute and The Astronomical Society should, in the general interest, assume the duty of inviting opinions upon the subject, to be collated, tabulated and published in a special report ;

(*f*) If the weight of opinion expressed by those who respond to such invitation, be in favour of a change, further steps may be taken with the view of reaching an international understanding ;

(*g*) Your Committee suggest that the opinions which have already been expressed by some leading astronomers be published. To this end, extracts from the writings of Herschell, Struvè, Christie, Newcomb and Franklin, are hereto appended; also, remarks recently made by the President of the Astronomical and Physical Society of Toronto, and the President of the Canadian Institute;

(*h*) Your Committee recommend that replies be asked to the following question, and that it be widely circulated :—

QUESTION.

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?

(*i*) Your Committee further suggest that astronomers generally throughout the world be invited to send definite replies to the question as soon as convenient. Replies to be addressed, "*Joint Committee, Astronomical Time, Canadian Institute, Toronto, Canada.*"

Respectfully submitted,

SANDFORD FLEMING,
Chairman.

APPENDIX.

EXTRACTS FROM THE OPINIONS OF ASTRONOMERS AND OTHERS REFERRED TO BY THE JOINT COMMITTEE.

I. (935) Astronomical time reckons from noon of the current day; Civil, from the preceding midnight, so that the two dates co-incide only during the earlier half of the Astronomical and the later half of the Civil Day. This is an inconvenience which might be remedied by shifting the astronomical epoch to co-incidence with the civil. (147) . . . This usage has its advantages and disadvantages, but the latter seem to preponderate; and it would be well if, in consequence, it could be broken through and the Civil reckoning substituted. Uniformity in nomenclature and modes of reckoning in all matters relating to time, space, weight, measures, etc., is of such vast and paramount importance in every relation of life as to outweigh every consideration of technical convenience or custom. The only disadvantage to astronomers of using the Civil reckoning is this—that their observations being chiefly carried on during the night, the day of their date will, in this reckoning, always have to be changed at midnight, and the former and latter portions of every night's observations will belong to two differently numbered civil days of the month. There is no denying this to be an inconvenience. Habit, however, would alleviate it; and some inconveniences must be cheerfully submitted to by all who resolve to act on general principles. All other classes of men, whose occupations extend to the night as well as day, submit to it, and find their advantage in so doing.—*Sir John Herschell's Treatise on Astronomy—Third Edition.*

II. Much earnest reflection, on the other hand, must be given to the desire expressed at the meeting, that Astronomical Time Reckoning should be brought in accord with the commencement of the day in civil life. In this matter, astronomers have not simply to abandon a custom of long standing, and consequently to make conditional changes of practice established for many years, but, at the same time, astronomical chronology is disturbed, which is easily understood, must exercise a marked effect on the comprehension of all problems bearing upon matter. Without doubt, the astronomer must make a great sacrifice for the fulfilment of this desire; but, in reality, this sacrifice is not greater than that entailed on our forefathers when they passed from the Julian to the Gregorian Notation of Time, or when they altered the commencement of the year: a sacrifice of convenience by which we yet suffer when it becomes necessary to refer to phenomena of remote dates. At this period, we must the less stand in fear of a like sacrifice, when by such means an acknowledged existing non-accord between science and ordinary life can be set aside: a non-accord which, it is true in individual cases, does not press heavily on the astronomer, but which is a constant source of inconvenience for non-professional astronomers who are desirous of making use of astronomical information. And in such respect, this sacrifice ceases so to be considered and is transformed into an act of public utility with regard to all astronomical details which stand in clear relationship with the outer world in which almost daily conflicts come to the surface between the different designations of dates. Conflicts among others which are even injurious to astronomical labours in such observatories where observations are continually adjusted to the day. . . . While the Directors of the Pulkowa Observatory make their full acknowledgment to the Astronomer Royal for this precedent, which has been established, so are they ready to follow the example, and this fact leads us the more to expect that also this course will be adopted by the Washington Naval Observatory, as in the American Marine the Date Notation from midnight has been already accepted. It is only in the matter of the period when the Date Notation, according to Universal Time, should be introduced into the publications of the observatories, that we feel inclined to recommend that there should be delay until, in this respect, the most perfect possible understanding be attained by all astronomers, in order to avoid the much more critical disturbance in astronomical chronology which would arise if the transition to the new Date Notation was not equally followed on all sides. We are desirous, accordingly, of suggesting a suitable time-point for the commencement of the year for which the Nautical Almanac would inaugurate the changes corresponding to the requirements named. The latter, as has before been said, could come to pass in the year 1890. We would, however, ourselves prefer the change to take place, in the first instance, with the change of the century. Until that date it would probably be the simultaneous proceeding of all astronomers, with general consent, to look forward to this period of transition, and it would more easily stamp itself on the memory of all who hereafter would be busied in investigations in which exact chronology plays a part.—*Paper on the Washington Conference by Otto Struve, Director of the Imperial Astronomical Observatory, Pulkowa, Russia.*

III. The reasons for making the change, as affecting astronomers, are:—(1) The introduction of the Universal Day commencing at Greenwich Midnight, and reckoning from 0 to 24 hours makes it inexpedient to have another time reckoning of 0 to 24 hours starting from Greenwich Noon. There are already frequent mistakes of date arising from confusion between civil and astronomical reckoning, several practical observers using the former, which is also commonly employed in almanacs and occasionally in some astronomical periodicals. The use of *three* different systems of reckoning solar time would greatly increase the confusion. (2) The circumstances under which astronomical observations are made have completely changed in modern times since the application of powerful telescopes to meridian instruments and the development of Solar Physics. The change of date at noon in the middle of the day's work has thus, in many cases, become very inconvenient. (3) As regards meridian observations, the experience of the past year at Greenwich Observatory (where observations are carried on as continuously through the 24 hours as at any other observatory) shows that the whole of the astronomical day can be introduced very easily and with decided advantage on the whole. (4) In the case of extra-meridian observations, the observer usually finds it convenient to work in the earlier hours of the night, so that little or no inconvenience would result from a change of date at midnight. Discoverers of comets and observers of meteors, who observe in the early morning, often use civil reckoning, and mistakes of date have, on several occasions within my own knowledge, resulted from the existence of two different modes of counting time. (5) For spectroscopic and photographic observations of the sun, it is now recognized that the day should be reckoned from midnight, and the same reckoning would naturally be used by the observer when he takes spectroscopic and photographic observations at night, and also in determinations of the places of comets, stars, etc., which he may make in connection with his spectroscopic observations. It seems absurd to expect the same observer to change his system of reckoning mean solar time according to the class of observations he is making at the moment. (6) The proposal to include in the routine work of an observatory, photography of the stars, as well as of the sun, will further increase the difficulty of maintaining a distinction as regards time-reckoning between the various classes of astronomical observations. (7) At many observatories, magnetical and meteorological observations are carried on concurrently with astronomical observations, and it is admitted that for the two former classes the day commencing at midnight should be used. (8) For the distribution of the time to the public, a work which is undertaken by many observatories, the civil day would be used. (9) Thus civil reckoning commencing at midnight must be used for solar, magnetical, and meteorological observations, and also for the distribution of time to the public, so that the retention of astronomical reckoning would involve the use of two different systems of mean solar clocks, differing by 12 hours, in the same observatory—a circumstance likely to lead to intolerable confusion. (10.) As regards the supposed discontinuity which would arise from the change in the Nautical Almanac, the difference of time-reckoning is precisely similar to that which would have to be taken into account in the comparison of Greenwich observations with those made at any other observatory. The astronomical calculator is in the habit under the present system of allowing for the difference in time-reckoning between different observatories, and his task would be greatly simplified if he had only to deal with universal time.—*Report to the Trustees of Greenwich Observatory, by W. H. M. Christie, M.A., LL.D., Astronomer Royal of England.*

IV. The first of these recommendations proposes a change in the method of counting astronomical time which has come down to us from antiquity, and which is now universal among astronomers. The practice of taking noon as the moment from which the hours were to be counted originated with Ptolemy. This practice is not, as some distinguished members of the Conference seem to have supposed, based solely upon the inconvenience to the astronomer of changing his day at midnight, but was adopted because it was the most natural method of measuring solar time. At any one place solar time is measured by the motion of the sun, and is expressed by the sun's hour angle. By uniform custom, hour angles are reckoned from the meridian of the place, and thus by a natural process the solar day is counted from the moment at which the sun passes over the meridian of the place or over the standard meridian. . . . A change in the system of reckoning astronomical time is not merely a change of habit, such as a new method of counting time in civil life would be, but a change in the whole literature and teaching of the subject. The existing system permeates all the volumes of ephemerides and observations which fill the library of the astronomer. All his text-books, all his teachings, his tables, his formulæ, and his habits of calculation are based on this system. To change the system will involve a change in many of the precepts and methods laid down in his text books. . . . But this would only be the beginning of the confusion. Astronomical observations and ephemerides are made and printed not only for the present time, but for future generations and for future centuries. If the system is changed as proposed the astronomers of future generations who refer to these publications must bear the change in mind in order not to misinterpret the data before them. The case will be yet worse if the change is not made by all the ephemerides and astronomers at the same time epoch. It will then be necessary for the astronomers of the twentieth century, using ephemerides and observations of the present, to know, remember, and have constantly in mind a certain date different in each case at which the change was made. For example, if, as is officially announced, the Naval Observatory introduces the new system on January 1, 1885, then there will be for several years a lack of correspondence between the system of that establishment and the system of the American Ephemeris, which is prepared four years in advance. . . . I see no advantage in the change to compensate for this confusion. If astronomical ephemerides were in common use by those who are neither navigators nor astronomers the case would be different. But, as a matter of fact, no one uses these publications except those who are familiar with the method of reckoning time, and the change from astronomical to civil time is so simple as to cause no trouble whatever. The change will affect the navigator as well as the astronomer. Whether the navigator should commence his day at noon or midnight, it is certain that he must determine his latitude from the sun at noon. The present system of counting the day from noon enables him to do this in a simple manner, since he changes his own noon into the astronomical period by the simple addition or subtraction of his longitude. To introduce any change whatever into the habits of calculation of uneducated men is a slow and difficult process, and is the more difficult when a complex system is to be substituted for a simple one. I am decidedly of the opinion that any attempt to change the form of printing astronomical ephemerides for the use of our navigators would meet with objections so strong that they could not be practically overcome. . . . I respectfully submit that in view of these considerations no change should be made in the change of reckoning time employed in the publications of this office until, by some international arrangement, a common date shall be fixed by all nations for the change.—*Argument against changing the Astronomical Day, by Prof. S. Newcomb, LL.D., Etc., Superintendent of the Nautical Almanac Office, Washington, Dec. 6, 1884.*

V. Referring to the letter of Professor Newcomb, concerning the resolution of the late International Meridian Conference on the subject of the change of the astronomical date, so as to make the midnight of Greenwich 0 hours, instead of noon as at present, I have the honor to submit the following considerations. . . . The order referred to was not issued without a knowledge on my part of the views of such a distinguished astronomer as Professor Adams, of England, as well as of those of other members of the Conference. A reference to the proceedings of the Conference shows that its recommendation on this point was unanimous. It has been publicly announced in *Nature* that the Astronomer Royal of England proposes to make the change on the same date as that directed by me ; this has been confirmed by a telegram received from him by me. So far as the counting of astronomical time from antiquity is concerned, it is the argument of conservatism which desires no change in an existing order of affairs; yet, assenting to this argument, we might refer to a still remoter antiquity—to the time, not of Ptolemy, but of Hipparchus, the "Founder of Astronomy," who reckoned the twenty-four hours from midnight to midnight, just as the Conference has proposed. While it is unquestionably true that some confusion may occur, yet the liability to it will be almost entirely with the astronomer, who, through his superior education and training, could easily avoid it by careful attention to the ephemerides he was using. During the years of change, before the ephemerides are constructed in accordance with the new method, it will only be necessary to place at the head of each page of recorded observations the note that the time is reckoned from midnight, to call attention to the fact, and thus obviate the danger of error. It is an undeniable fact that the educated navigator finds the conversion of time a simple matter, yet experience has demonstrated that to the mariner who is not possessed of a mathematical education there is a decided liability to the confusion which is so greatly deprecated by all who are interested in this subject. I believe that to all navigators, at least to all English-speaking ones, the new method will prove itself decidedly advantageous. As is well-known, for many years navigators kept sea time, by which the day was considered to begin at noon, preceding the civil day by twelve and the astronomical day by twenty-four hours. The change to civil time now kept on board ship was effected readily and without friction, so that the recommendation of the Conference regarding the commencement of the nautical day has already been largely anticipated. The navigator is concerned not with his longitude but with his Greenwich time, having obtained which he can take from the Nautical Almanac the data he seeks, whether given for noon or midnight, and when the ephemerides shall have been made to conform to the new system there will be one time in common use by all the world. It seems to me eminently proper that the nation which called the Conference should be among the first to adopt its recommendations, and while it might possibly be better to wait until an entire agreement has been entered into by the astronomers of all nations, yet the fact that the first and most conservative observatory in the world has acceded to this proposal of the Conference would seem to be a sufficient reason why we should not wait for further developments. In deference, however, to the views so well advanced by Professor Newcomb, and in view of the fact that the President has recently transmitted the proceedings of the Conference to Congress, as well also of the desirability of securing uniformity among the astronomers of our own country at least, I have suspended the execution of the order for the present.—*Remarks by Commodore S. R. Franklin, Superintendent United States Naval Observatory, Washington, Dec. 11th, 1884.*

VI. The subject of reform in time-reckoning was brought before the Canadian Institute many years ago by Mr. Sandford Fleming. The reforms suggested were much needed, and were so ably advocated by Mr. Fleming that already several of them have been adopted not only on this continent, but in various countries all over the world. One important suggestion, however, although recommended by the Washington Conference, has not yet been acted upon, viz., the making of the astronomical and nautical day to accord with the civil day. It has been suggested that a body like this Society may render valuable assistance in this matter by collecting the opinions of astronomers on the subject. The Canadian Institute having been the first society to bring the whole subject prominently and successfully before the world, it would be well for us to ask their co-operation with us in this matter. As an illustration of some of the inconveniences which result from the present want of accord between the astronomical and nautical day and the civil day, I may refer to a case within my own experience. In 1873 a sudden and very violent storm caused great destruction along the south-eastern coast of Nova Scotia. I had occasion to investigate that storm, and, for the purpose, obtained the logs of vessels which were caught in it. I was assisted in this by the late Sir Henry Lefroy, then Governor of the Bermudas, who procured the logs, or copies of the logs, of the ships which put into the islands for repairs. The satisfactory examination of these logs was attended by great difficulty owing to a want of uniformity among the sea captains in making entries. For instance, many of the captains wrote up their logs at noon for the twenty-four hours. Some of them were accustomed to enter up the events occurring between, say, noon of the 20th of the month and noon of the 21st, under the date of the 20th ; that is, the astronomical and nautical day during which they happened, while others entered the same events under date of the 21st, or that upon which the entries were made, so that, in the absence of specific information, it was impossible to tell to which set of twenty-four hours any given event should be referred. Had the captains been in the habit of changing their dates at midnight, no such inconvenience would probably have resulted. For my part I am decidedly in favour of bringing Astronomical Time into harmony with civil reckoning at the change of the century. After considering all that can be said against any alteration in the present dual system, I am satisfied that any inconvenience which would result to individuals from the change would be limited in duration and would not be felt by a large number of persons. If it be determined once for all to abandon the double notation of dates at the beginning of the new century, ample time would be allowed for any necessary preparation for the change, and when the period of transition arrived any inconvenience which might temporarily be felt could not be compared with the advantages which would follow in all future years from uniformity of reckoning.—*Remarks to the Astronomical and Physical Society of Toronto, by Charles Carpmael, Esq., Superintendent of the Meteorological Service of Canada, February 11th, 1893.*

VII. The Canadian Institute, which took the initiative in bringing before the Scientific world, in 1879, the principle of Universal Time Reckoning, heartily co-operates with its sister society in the endeavor to bring the Astronomical day within the sphere of uniformity it has continuously advocated. The Council of the Institute approves of the terms of the Circular Letter prepared by the Joint Committee under the Chairmanship of Mr. Sandford Fleming, long identified with this subject, and an honourary member of both societies. It is not easy for me to conceive any reason for beginning the day at noon, other than the convenience of having all the hours of darkness brought within one astronomical day. Stellar observations for the purpose of practical astronomy no longer requiring darkness, this reason no longer exists, and I trust we are now warranted in expecting the abolition of a double notation of date as the result of our efforts.—*Arthur Harvey, Esq., President of the Canadian Institute, Toronto, April, 1893.*

While replies may be in any form, the following, if found convenient, may be filled up and returned by post.

To the Joint Committee on Astronomical Time,

Canadian Institute, Toronto, Canada.

In reference to the circular-letter addressed to Astronomers of all Nations, dated April 21st, 1893, and in reply to the question therein submitted, the undersigned is * in favour of the Astronomical Day being changed so as to begin at mean midnight on and after the close of the present century.

Signature..

If the person replying is officially attached to an Observatory, please give the name of the Observatory. } ....

Post Office Address..

* *The word* NOT *written in this blank will indicate that the person replying is opposed to a change.*