TRANSACTIONS

OF THE

ASTRONOMICAL AND PHYSICAL SOCIETY OF TORONTO,

FOR THE YEAR 1899

INCLUDING TENTH ANNUAL REPORT.

PRICE ONE DOLLAR

TORONTO:
THE CARSWELL COMPANY, LIMITED,
PRINTERS TO THE SOCIETY.
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*Mr. D. J. Howell's paper on "Colour Photography," read before the Society on February 21st, 1900, was subsequently presented to and published by the Canadian Institute.

[Authors are alone responsible for views expressed in papers or abstracts of papers published in the *Transactions.*]

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TRANSACTIONS

OF

The Astronomical and Physical Society

OF TORONTO,

DURING THE YEAR 1899.

FIRST MEETING.

January 25th ; the Honourary President, Hon. G. W. Ross, LL.D., etc., occupied the chair.

This was an open meeting held in the theatre of the Normal School, and to which the public had been invited.

The President, Mr. Arthur Harvey, F.R.S.C., delivered the annual address on "Recent developments in the by-ways of Astronomy and Physics," the full text of which appears in the Appendix to the *Transactions* of the Society for 1898.

SECOND MEETING.

February 7th ; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

This was the first business meeting since the death of the Vice-President, E. A. Meredith, LL.D. The Secretary stated that immediately on learning of this sad event a meeting of the Council had been held and instructions had been given to send to the family residence a floral token, expressing the affection which the members of the Society had always felt for the deceased. This duty had been performed and a letter of acknowledgment from Mrs. Meredith was read. It was then moved that a committee be appointed to draw up a resolution expressing the sympathy of the Society with the family of the late Vice-President.

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Mr. John A. Paterson and Mr. G. E. Lumsden would form this committee.

The Corresponding Secretary stated that on December 24th last, he had written to several of the honourary members of the Society resident abroad. In each of the letters to British members of the Society, it was intimated that it was one of the first to be mailed on Christmas Day, the day upon which came into effect the new Imperial Penny Stamp, Canadian edition, "which would appear to mark a step nearer, in the approach towards each other of England and her colonies."

The following were among some of the replies received :—

From Sir Robert Ball, F.R.S., etc., Astronomer Royal of Ireland :

OBSERVATORY, CAMBRIDGE, 6th January, 1899.

I greatly appreciate your consideration in posting to me one of the earliest letters under the new arrangements, and I heartily reciprocate your wishes for the closer union of England and Canada.

I remain, yours truly,

ROBERT S. BALL.

From W. H. M. Christie, C.B., F.R.S., Astronomer Royal of England:

ROYAL OBSERVATORY, GREENWICH, LONDON, S.E., 6th January, 1899.

Accept my best thanks for your kind wishes on behalf of The Astronomical and Physical Society of Toronto, of which I am proud to be a member, and, at the same time, I wish to congratulate you on the introduction of Imperial Penny Postage, through the efforts of Canada. With best wishes for the New Year to The Astronomical and Physical Society of Toronto, believe me,

Yours very truly,

W. H. M. CHRISTIE.

From Miss Agnes M. Clerke, the eminent writer of standard astronomical works and magazine articles of the highest class :

64 REDCLIFFE SQUARE, LONDON, S.W., 6th January, 1899.

You have sent me an original and delightful New Year's greeting, for which I must thank you at once, and cordially.

Among the "streams of tendency" visibly flowing from the nineteenth into the twentieth century, few are more promising for the future of our race than the growing loyalty of the colonies to the mother country. She needs it and appreciates it profoundly ; and they find in it the realization of a great world-thought, which elevates and intensifies their national existence.

So that I welcome the first Canadian penny stamp as truly symbolical of progress towards a grand ideal.

With very sincere good wishes to you, and every member of the Society you represent, I am

Faithfully yours,

AGNES M. CLERKE.

From Sir William Huggins, K.C.B., F.R.S.:

90 UPPER TULSE HILL, S.W., 7th January, 1899.

I beg to thank you very much for your kind and historic letter of the 24th ult., being one of the first letters to inaugurate the great Imperial enterprise, in which Canada has played the leading part, of closer union through a penny postage. Your letter and the new Canadian stamp, at once charming and suggestive, mark, I doubt not, the beginning of an era of greater Imperial prosperity, through closer postal union.

I thank you, too, as representing The Astronomical and Physical Society of Toronto, for your expressions of good-will. I beg to offer you, in return, personally, and as the representative of the Society, all good wishes, that you and the Society may have many years of increasing prosperity.

I remain, yours very truly,

WILLIAM HUGGINS.

From Prof. J. E. Keeler, D.Sc., Director of Lick Observatory:

Thank you very much for your New Year's greeting, for which I send you my own, with all good wishes. With regards to my friends in Toronto, I am,

Very cordially yours,

J. E. KEELER.

THIRD MEETING.

February 21st; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

Dr. E. E. Barnard, M.A., F.R.A.S., of the Yerkes Observatory was duly elected a corresponding member of the Society.

The committee appointed to draw up a resolution expressing the sympathy of the Society with the family of the late Dr. E. A. Meredith, presented the following

RESOLUTION OF SYMPATHY.

Resolved, that this Society places on record its sincere sorrow at the death of Dr. Edmund A. Meredith, its gifted Vice-President. The loss we suffer is that of one, who, while he endeared himself to all our members by his native gentleness and amiability of character, commanded admiration by his accurate and far-reaching scholarship, and knit himself to us with those bonds of brotherhood that come from a generous and sympathetic devotion to astronomical and physical science. Humanly speaking, his work here was far done and was well done, and so the Father opened for him the palaces of eternity for better and higher effort. Like a watch-worn and weary sentinel he has put off his armour and rests, we are assured, in the presence of the King. With hesitancy we venture to stand on the threshold of the sacred temple of his widow's grief and offer her and the family our tenderest sympathies in their bereavement; may she see through her tears the rainbow glories of that certain hope to which our esteemed Vice-President and friend has attained.

On motion the Secretary was instructed to inscribe the resolution on the minutes of the Society and to forward a copy of the same to Mrs. Meredith.

In discussing recent observations, Mr. G. G. Pursey stated there had been no spots on the Sun for nine days in succession. Mr. G. E. Lumsden had forwarded the following memoranda from his note books:—

OBSERVATIONS.

February 11th, 1899; aurora from 9 p.m. to dawn, faint at first, grew more and more pronounced until 2 a.m. Began as a mere glow, gradually deepened until it presented a compact arch with dense black segment; no streamers were noticed at any time and no activity except once, when, at a point a little west of north, a momentarily brighter spot occurred.

February 12th, 1899, Sunday; no sun-spots.

Faint aurora from 9 to 9.30 p.m., a few weak streamers, but everything faint and nothing pronounced.

Observed, off and on, from 7 p.m. to 11 p.m.; sky clear but definition with high powers unsatisfactory; good with low powers. Examined many objects in Orion, Canis Major, Gemini, Canis Minor, etc. Mars very small in telescope and nothing sharp. Great nebula in Orion magnificent; could not see more than four stars in the trapezium. During observations the temperature fell from zero to 5° below; cold very penetrating; happily no wind.

February 13th, 1899, 8.30 a.m.; examined Venus in sunshine, found her a half-moon, terminator rough, markings or shadings indistinct, planet bright, necessitating use of Venus glass; could not make out the dark globe of planet against the sky, though I used various powers; bitterly cold, 6° below zero and some wind.

Mr. D. J. Howell then read a paper on "Colour Photography." (See Appendix I.)

FOURTH MEETING.

March 7th; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

Mr. C. A. Chant, B.A., Lecturer in Physics, Toronto University, was duly elected to fill the office of Vice-President rendered vacant by the death of Dr. E. A. Meredith.

Mr. W. B. Musson gave notice that he would bring forward a motion embodying new rules for the regulation of the Society's library. Mr. Musson also reported having found several old volumes of British Association Reports, the purchase of which was recommended. The hope was expressed that a complete set of these valuable publications might yet be procured.

Reporting solar observations, Mr. G. G. Pursey stated that the Sun's surface had been quiescent for nearly a whole rotation, a remarkable feature in his experience.

Mr. R. Wallace reported a series of observations of Mars, and had noted the little loop it formed while passing from direct motion to retrograde and again to direct. Situated between Castor and Pollux the planet was particularly conspicuous and well placed for observation.

Mr. A. Elvins then read a paper on

WORLD FORMATION AND DISPERSION.

I. *The Building of the Chemical Molecule.*

Our senses satisfy us of the existence of *matter.* No amount of reasoning will satisfy the average mind that matter does not exist. We see masses of rock, trees, animals; they have form and colour. We feel them; they are more or less solid to the touch; we can divide a mass, and feel so well satisfied with the evidence of our senses, that any logic which leads us to deny the existence of matter must be *wrong somewhere.* We say with Byron:

"When Bishop Berkley said there was *no matter*, and proved it, *'twas no matter what he said.*"

Matter Exists.—Space is that in which matter does, or can exist. Where nothing exists in any part of space, that space must be a perfect vacuum. Matter occupies *space*, and differs from space in the fact that it has dimensions; length, breadth, and thickness. We examine masses of matter, and find that it exists in different states, solid, liquid, and gas; and the distance between particles composing masses, determines the state in which it exists.

It is difficult to be certain that the molecule of a chemical element is not the ultimate condition, or smallest particle into which a mass can divide; but there are weighty reasons which lead us to think that each chemical molecule is itself composed of a definite number of *physical* atoms, smaller than the molecules of any chemical element; and that the number of atoms in a molecule determines the atomic weight of that element; and the rate of motion of a molecule in a gas, diminishes as the number of atoms in the molecule increases.

Beside matter in its ordinary states, there exists in space, *something* which conveys *energy* from one body to another, and which penetrates all *masses.* A glass vessel may have the gas (or air) extracted, as in a Crookes' tube, but light will pass through the glass, and it will render objects on the inside visible. Radiant heat acts in the same manner, and may be thrown through the walls of the glass and be focussed inside. The medium which conveys the radiant energy whatever it may be, we call ether.

We naturally want to know the nature of this ether. This requires much enquiry, much thought; but before we proceed to attempt an answer to this question, we must refer to the laws of motion by which ordinary dead matter is governed. These laws are three, and are known as Newton's laws of motion, and may be expressed thus:

(1) Matter in motion has a tendency to move at an equable rate, and in a straight line. (2) When acted on from without, it may be accelerated, or retarded, and if the force be at any angle to the line of its motion, it will move in a diagonal of the two forces. (3) Action and reaction are equal and opposite. If we have a clear conception of these laws, we may proceed to enquire into the nature of the ether.

Division of Matter.—If we take a piece of common salt and strike it with a hammer, it will divide, we strike one of the fragments and it divides again, and we may repeat such divisions until we reduce it to a powder; we take a very small quantity of this, and with a pestle and mortar divide these so fine that we can no longer see their form, but we place a few particles beneath the microscope, and we see it as cubes, as distinctly as we did previous to breaking; some of this fine powder is placed in a drop of water on a glass slide, and warmed a few moments over a lamp, and it is so finely divided that no microscope can render it visible; we taste the water, and find that we can detect the salt, and by evaporating the water we restore it to its primitive condition. But the chemist will take a portion and divide it still further; he breaks up the molecules of salt, and they become two elements, sodium and chlorine; *they are salt no longer*. The molecules of those elements fly apart and move in free paths, colliding with each other, and rebounding according to the third law of moving matter. Such at any rate is the kinetic theory of gases; I do not feel *sure* that the theory is correct, though it gives a satisfactory reason for nearly all the phenomena of gases, and it is just the thing to help me to make my conception of the *ether* intelligible.

Ultimate Atoms.—That the chemical molecules are not the ultimate parts of which matter is formed is highly probable. Each molecule may be composed of a number of smaller parts which nature finds means to divide; and it is supposed by Wood, Gore, and others, that these *ultimate particles,* perfectly *rigid* and moving in free paths with enormous speed, colliding with each other and rebounding, as the kinetic theory of gases requires the gaseous molecules to do, are really the ether which fills space, and is the medium by, and through which radiant energy is conveyed from one part of the universe to another.

For many years the conviction that Nature is building up masses from the ether, and separating masses into their ultimate parts, thus again restoring them to the ether, has been a growing conviction in my mind. I shall try to follow the processes by which ether may form masses, and the manner in which it must act on them when formed. The rigid ether atoms dart with tremendous velocity through space in straight lines until they collide with other atoms, when the direction of the motion will be changed, action and reaction are equal and *opposite.* No motion can be lost, and vibration must be conserved; but the motion will change from translation to rotation of the atoms frequently. When a collision occurs at an angle from the centre, the colliding atoms will turn on an axis and *rotate.* This motion of rotation must diminish the rate of *translation* to that amount, or by the amount of its own motion of rotation. After many collisions, the translation of a number will be so diminished, that, aided by accidental impacts they form a small mass, a chemical molecule. This molecule being composed of several atoms, would be less translated by a single collision than one, or a single atom would be with a similar collision, and as impacts would now take place all around equally, it would remain a stationary object. If this small mass or molecule had been in a perfect vacuum, the only object existing in the universe, it would remain perfectly stationary, and the same will be the case if it is acted on by forces equal all around. This will be the case when a molecule exists in the *ether*. The atoms in the molecule will be in close contact with each other, and of necessity the mass of the molecule must be greater than the atom of which it is composed (and it is probable that the number of atoms in the molecule determines the element and the atomic weight).

Gravity.—But we have been considering the case of a single molecule and we see such must be motionless, blows, or pressure, being equal on every side. Let us see what will happen when a second molecule is formed near it. The first molecule can no longer be struck equally all around, for some of the ether atoms on one side will be stopped by the second molecule; the force of some moving atoms will act on the outside of both molecules, leaving a minus between the molecules; and this force will act to press them together. This is the cause of chemical affinity and gravitation. The assumption that two molecules if existing in a perfect vacuum would have any tendency to approach each other, is both inconceivable and unnecessary. There is no gravitating tendency in the ether atoms, and gravitation is only possible when two molecules or masses exist.

Heat.—The same law is probably true in relation to *heat*, molecules have their atoms in contact, and will act as a unit. Heat is a vibration of the *molecules* colliding with, and rebounding from each other; more than one molecule must form a mass before it is possible for *such* to vibrate by collisions; when the molecules of a mass are vibrating, that vibration is what we call *heat*, so heat is impossible before the molecules are formed into, and exist as a mass. The vibrating particles of a mass communicate their motion to the ether particles in which the mass exists; every collision of two particles sends out a wave through the ether, as a blow from a hammer or an anvil sends out a sound wave through the air. The waves will follow each other as fast and no faster than blows are struck, or as collisions of the particles of the mass occur; and as the impulses or waves move through the ether at the same rate, whether the blows fall fast or slow, the rate at which the impulses follow each other is what we call wave length.*

* I regard rotation of molecules in a mass as latent heat or potential energy.—A. E.

Size of Molecules.—I think it likely that the size of particles in a mass may determine the rate of vibration, blows of ether atoms would move small particles more rapidly than large ones, and hence the rate of collisions in the one case would be more rapid than in another. This may be the cause of the different wave lengths of light and energy in general. I have frequently tried to form a conception of how the chemical elements give lines of different wave lengths at the same time, sodium, one or two lines; iron and zinc, many; possibly particles of different sizes may form a chemical element; in that case there must be a difference of wave length of light, or energy, coming from the element. Whatever the cause of wave motion may be, *such waves exist*, and these radiations set the molecules of masses in motion when they strike matter which may lie in their path. We become acquainted with the effects of radiant energy by different means; in all cases it imparts molecular motion, that is, heat; this expands masses by increasing the free path of the molecules, and on our muscles and nerves we feel it as heat. On the eye, within given wave lengths, they enable us to see objects, and distinguish colour; they produce chemical changes which is the foundation of photography; and indeed almost everything is more or less affected by radiant energy.

Without dwelling further on the nature of the ether and supposing all masses to be aggregations of ether atoms, at one time diffused through space, let us try to follow it during the process of aggregation, which has resulted in the formation of suns and worlds.

The first step towards the formation of a mass from the ether, must be the collision of two or more of its atoms. If two atoms were moving directly toward each other, as they are rigid, and as motion cannot be lost, they must rebound (action and reaction are equal, third law); in such a case the motion after collision will be on the same line in which the atoms moved when they approached each other; the path of translation will remain unchanged. Collisions in which the centres of the atoms lie on the line of their motion will be few; they will more frequently strike at some angle from the line of motion; and in such a case both would be deflected from the line of their former motion, the change in direction being greater or less according to the angle from the centre of figure (of the atoms) of the points of collision.

Rotation Generated.—But this will not be the only result of the collision; both atoms would be caused to rotate around their own centres, and this rotative motion brought into existence by the collision would be the exact amount of motion which has been lost to translation by the collision.

So far as the atom as a whole is concerned, it has received an additional form of motion by the collision, for it has both rotation and translation now; but we must remember that the exact amount of motion which exists now as rotation, has been taken from, and been lost to translation; the mode of motion only has been changed, none gained, none lost. But the motion of translation has decreased, and by future collisions it may be diminished still further, and there is a possibility, and by the millions of collisions, a probability, that some will become relatively stationary near each other; they will still rotate, but their translation as atoms has ceased.

Let us suppose the translation of a number of *ether* atoms to have been changed to rotation, and they now form a small mass, say a hydrogen molecule; millions of such will form hydrogen gas. Eight times the number of atoms forming a hydrogen molecule, when existing in a group, would be an oxygen molecule, and myriads of such would be oxygen gas. Carbonic acid (CO_2), would have twenty-two times as many physical atoms as hydrogen (H.). Compared with hydrogen, their motion must be slow, their free path short, and probably the rotation of each molecule *very rapid.*

It thus seems that an increase of physical atoms to any chemical molecule increases its specific gravity, and shortens the length of free path. The density then of a mass whether gaseous or solid depends on the number of physical atoms contained in a given volume; and the same rule applies to specific gravity.

This leads us to the interesting conclusion that the free path of a chemical molecule is shortened by every addition of atoms, so that a gas under the same conditions of pressure and temperature will contain the same number of molecules in the same volume *for any gas.*

Thus the law of Avogadro becomes a necessity *from the nature of matter*, and might have been expected to have been a fact in nature, though Avogadro had never propounded his *great chemical law.*

FIFTH MEETING.

March 21st; the President, Mr. Arthur Harvey occupied the chair.

Copies of the Society's *Transactions* for 1898 were distributed to the members.

A communication was received from Mrs. Meredith acknowledging in grateful terms the receipt of the Society's resolution of sympathy.

Mr. J. R. Connon, of Elora, wrote describing a strange noise heard in that vicinity on the afternoon of March 6th. The only explanation offered by those who had heard it, was that it might have been the sound of a meteor exploding in daylight and unseen.

The President communicated the following extract relating to early observations of the Andromedes:—

In the *Transactions* of the French Academy of Sciences, Mr. D. Eginitis discusses the display of shooting stars mentioned by Nicephorus, Patriarch of Constantinople, who wrote the history of the reign of the Emperor Constantine Copronymus. He says, "All the stars seemed to detach themselves from the heavens and to fall to Earth." He further relates that the exhibition began in the evening towards the end of twilight and lasted all night. Unfortunately, however, Nicephorus gives no precise date, day, or month, or even year. Mr. Eginitis, however, shews that it must have been in the autumn of 752, for it was after the capture of Melitenum and before the death of the Patriarch Anastasius.

From the hour of the commencement of the phenomenon, Mr. Eginitis thinks the stars cannot have been the Leonids, whose radiant does not rise above the horizon until after midnight, and he excludes the Lyrids, Perseids and Orionids for the same reason. He believes them to have been Andromedes, which, having a supposed derivation from Biela's Comet, are sometimes called Bielids. These were seen in 1852, 1872, and 1892, at intervals of 20 years, and that interval, carried back for 55 periods further, would bring us to 752. The exact period of the comet is now 6.69 years, so that the densest part of the meteor track is met with at every third passage of the Earth through it. A great comet was seen seven years before the taking of Melitenum, *i.e.*, in 745, and it is conjectured that this was Biela's, which has not hitherto been traced farther back than 1772.

Mr. Thos. Lindsay then read a continuation of the

HISTORICAL SKETCH OF THE GREENWICH NAUTICAL ALMANAC.

IX. *Star Catalogues.*

Having completed our description of the early *Nautical Almanac* in so far as the phenomena of the Sun, Moon and planets are concerned, it remains to devote a chapter to the sidereal heavens, and learn what Dr. Maskelyne presented to the astronomer anxious to extend his knowledge beyond our little solar system. Although in actual practice the navigator manages very well with data concerning only a few of the brighter stars, he would still be disappointed with the almanac office if that institution did not present him with a pretty long star list. Moreover, the ephemeris is not and never was solely intended for navigators; astronomers have always been considered; so we may reasonably expect to find that the early issues contained information regarding stars other than the properly called, lunar distance stars.

Remembering the verdict of Flamstead regarding the impossibility of closely determining the longitude at sea, we feel justified in saying that credit for the first construction of star catalogues, as we understand the term, belongs to English astronomers. Prior to King Charles' decree and the establishment of Greenwich Observatory, there did not exist any catalogue based upon observations with telescopes. At the same time we must not fail to give due credit to those students of astronomy who strove to marshall the hosts of heaven by the eye alone. A record of their work is readily accessible.

It appears that Hipparchus constructed a catalogue of about 1,000 stars. This is not now extant, but we have only to remember that this really great man among the ancients discovered the motion of the pole among the fixed stars, and the consequent displacement of the latter, and we have good evidence that he did compile a star list. It has been presumed that the list given by Ptolemy in the second century of our era was practically that of Hipparchus; this contained 1,028 stars among the original, for that is the word here, 48 constellations. Throughout the thousand years and more of darkness this was the list known to the very few for the sake of whom science did not altogether desert this world. "I will not destroy it for ten's sake."

Then the new era dawned and the spirit of research fell upon—whom? You will remember our ex-President in one of the annual addresses quoting Carlyle in his denunciation of Tamerlane and such as he. But there seems nothing wholly bad in this world, for out of the house of Tamerlane came his grandson Ulugh Beigh, devoted to astronomy and determined to construct a new star catalogue. This he did for the epoch of 1437 A.D. The star list compiled by this prince under the serene skies of Persia found its way westward, and was rendered into an English form in 1665 by Thos. Hyde, an eminent divine and professor of oriental languages at Oxford. Now we are drawing nearer home and the opening of the seventeenth century finds a list by Tycho Brahé, soon to be revised and published by Kepler. About the same time Bayer of Augsburg constructed a chart (not a catalogue) of the stars of the northern hemisphere, and denoted the stars by the Greek letters of the alphabet. It reflects no small credit upon this astronomer to say that his method is still in use, and although many stars have been added to the list which he compiled, thousands of them known only by their numbers in the observation lists of the great observatories, whenever we meet a Greek letter we know the star was observed by Bayer.

But all this from eye observations. Tycho Brahé was immensely in advance of his predecessors as an observer, but yet far behind the next great astronomer who imposed upon himself the task of constructing a catalogue. This was our own Edmund Halley. It was not, however, at Greenwich but at St. Helena that the "optick tube" was first used for the purpose of accurately determining the places of a large number of stars; this in 1676-7-8. I have not seen Halley's catalogue, but am able to show the chart of the southern skies which was constructed upon his observations. This is loaned to us by Dr. Tyrrell of this city, in whose library it has been for some time. It is in excellent condition although over 200 years old, has been in careful hands evidently, from first to last. It is dedicated to King Charles II., very naturally, for he it was, you will remember, who decreed that an observatory should be built at Greenwich for the proper study of the celestial bodies. We have here also, from the Doctor's library, two other charts, one of a still earlier date, and one evidently prepared shortly after the opening of the eighteenth century, giving tables of the solar system as known then, and the orbits of all the notable comets that had been observed.

In the meantime work was progressing at Greenwich and what is known as the Flamstead catalogue was being prepared; this was published in 1725. Then we are among the moderns and have a little later, the work of the three great contemporaries, Bradley, Lacaille, and Mayer.

I am sure there are many members of this Society who will perfectly understand me when I say it was with feelings of genuine pleasure that I opened an old volume of Dr. Vince's Astronomy, picked up in Mr. Britnell's shop, and found therein the catalogues of these illustrious astronomers. Here they are. Lacaille constructed three catalogues, the earliest published in 1757, in the *Fundamenta Astronomiae*, for the epoch 1750. Grant says that this was the first star list which can be compared in point of accuracy with 19th century catalogues. It contained, as published, 398 stars. Lacaille had spent two years at the Cape of Good Hope amassing observations, and we find in this catalogue several stars in far south declination. The list became rare, but was revised by Francis Bailey and taken care of by the Royal Astronomical Society. The catalogue given by Dr. Vince was evidently not that of the *Fundamenta*, entry for entry, as there are only 307 stars named. The Doctor says the list was taken from the *Ephemerides des Mouvemens Célestes* from 1765 to 1775. It was probably a selected catalogue. The remarks at the end would bear this out. It is said: "The right ascensions were settled with a transit instrument by comparison with the stars in the *Fundamenta Astronomiae*. But the right ascensions of the stars in the *Fundamenta* having been settled by equal altitudes, the right ascensions of the stars compared with them must be subject to the same inaccuracy." I am quoting from the edition of 1799, at which time Dr. Vince would certainly point out, as indeed he does, that the equal altitude method was not so reliable as direct observation with a transit instrument. Lacaille's second catalogue was of northern stars; nearly 10,000 had been observed and of these the places of 1,942 were reduced by the author; the list being published at Paris in 1763, after his death. It is an evidence that science has no nationality, to learn that the British Association undertook the reduction of the whole number in 1838. What is now specially shown as Lacaille's catalogue of 9,766 stars was printed at the expense of the British nation in 1845. Still another star list was prepared by this arduous worker, a catalogue of 515 zodiacal stars for the epoch of 1760, published after his death. And here it is also, embodied in Dr. Vince's work, and this time complete. Regarding the construction of this, Dr. Vince says: "The right ascensions were determined by taking equal altitudes with a quadrant of three feet radius; but this method of determining the right ascensions is less exact than that by the transit instrument. The declinations were deduced from the meridian zenith distances observed with a quadrant of six feet radius."

So much for the illustrious Frenchman, and now we turn to the German's work.

Grant says that Tobias Mayer catalogued 998 zodiacal stars, published in a volume of posthumous works, Gottingen, 1775. Further, that the list was published in England in 1826 by the Board of Longitude. But the catalogue must have been known before that time for here it is in Dr. Vince. The number of entries is 992, and a few stars are not zodiacal. The epoch here is 1790. I take it, however, to be the same catalogue, and am very glad to possess it. Dr. Vince describes Mayer's method. He, like Lacaille, used his large quadrant, but of course took extreme care to determine instrumental errors.

It will be noted now that when Dr. Maskelyne began the preparation of the *Nautical Almanac*, he had access to the work of Lacaille certainly, and probably to that of Mayer; but there was one other catalogue, home made, which was known to English astronomers of the inner circle. This was the work of a predecessor, not less illustrious than his contemporaries, Dr James Bradley. You will remember that there was some difficulty about the publication of Bradley's observations; his heirs refused to give up the manuscript to the Government simply because the Government would not say "please," and so publicity was long delayed. But a catalogue of stars was specially prepared by Charles Mason who was given full access to the records, and this list became known to the astronomical world as Bradley's catalogue. It contained 389 stars and was first given to the world in the *Nautical Almanac* for 1773. It appeared again when Bradley's observations were published at Oxford under the direction of Dr. Hornsby, who, you will remember, was one of the Admiralty Board, signing the first warrant for the *Almanac*.

This catalogue we have also here in Dr. Vince's work, and we may review it at leisure.

The epoch of the list is January 1, 1760. Two-thirds of the stars are in the zodiacal constellations. The remainder is about equally divided among circumpolar, southern and northern constellations. There is no star in the list farther south than Alpha in the Southern Fish. A few of the brightest are denoted by their distinctive names, long since given them, and the others chiefly by Bayer's letters. As in Lacaille's catalogue of 307, every star had a designation, and had, therefore, been observed before. In Mayer's list many of the stars are denoted only by his number. This is the case also with Lacaille's zodiacal list. The columns gave name, magnitude, R. A., Dec., and annual precession; the last being given for the epochs 1760 and 1800.

Here we may stop to compare the three catalogues and see how they agree.

In Bradley for 1760 R. A., *α* Arietis ..	28° 25′ 26″·6	
Deduct precession for 10 years........	8′ 18″·4	
Bradley would have given for 1750....		28° 17′ 08″·2
Lacaille gives for 1750		28° 17′ 05″
Mayer gives for 1790	28° 50′ 21″	
Deduct his precession for 40 years	33′ 28″	28° 16′ 53″

The agreement certainly is very close. Bradley's work was done with the transit instrument constructed by John Bird, and according to the notes given in the ephemeris for 1773, there had been many observations of each star before its position was finally set down.

The tables in the ephemeris gave the longitudes and latitudes of the stars; these columns are omitted in Dr. Vince.

One peculiarity in all these catalogues we notice readily; there is no particular exactness attempted with the magnitudes. There are no fractions in this column and generally the stars are of higher magnitude than is given them now.

But while the preparation of Bradley's catalogue was going on, Maskelyne himself was not idle. Day by day he was amassing observations, with the final result that his own star list was freely acknowledged to be an immense advance on all preceding. He constructed a fundamental catalogue of 36 stars, from which the positions of others were to be measured. Grant says, "This was by far the most accurate production of the kind that had yet been given to the world."

You know the difficulty I have had in procuring early volumes of the ephemeris, so far away from home; though I am not complaining and will not complain since Dr. Downing has been kind enough to send across the Atlantic a rare copy for my inspection; and you will not expect me to show you a copy of the *Almanac* containing Dr. Maskelyne's first list of fundamental stars. Yet we are not lost, for Dr. Vince again comes to our aid, and here we have the 36 stars for the observation of which Maskelyne received so much credit. Fernando de Zach, a contemporary of Dr. Vince, prepared a catalogue of 381 stars for the epoch of 1800, in which were marked Maskelyne's fundamental stars. In the columns before us these are printed in italic type. Dr. Vince says "* * by a comparison with which, M. de Zach found the R. A. of the other stars by a transit instrument 8 feet long by Mr. Ramsden."

In discussing the positions of a planet in the heavens it is very necessary to name the time of any observation; and exact astronomy requires that we be no less particular when dealing with observations of the fixed stars. The catalogues we have been considering were constructed for stated epochs; to say that Bradley's catalogue was compiled for epoch, 1760, simply means that the positions given were correct for the beginning of that year, and not for any other time. But astronomers could hardly be expected to give new catalogues every year, and so a very important column to which we have already referred was given in the tables, precession in R. A. and Dec. It is a matter of common knowledge that the cause of precession remained a mystery during the eighteen centuries between Hipparchus and Newton. But the slow motion of the pole among the stars is regular within very narrow limits indeed, so that the astronomers before Newton's time probably gave the corrections to a star's place very approximately correct. Further, it was not until this present century that the theory of precession was elaborated, and all the causes of irregularity taken into account. I hope in the near future to illustrate the phenomenon generally, but in the meantime will rely upon plain diagrams for a rough representation.

[The usual diagrams of the text book were here drawn and briefly discussed.]

A word in conclusion suggested by the history of star catalogues. We have no difficulty in understanding that it is necessary to study the planets and a reasonable number of the brighter stars for the purpose of determining the figure of the Earth, and the positions of points upon its surface; but the use for a catalogue of 10,000 stars such as Lacaille compiled, is not just so apparent. Nay, what did Ptolemy want with a thousand stars; or Tamerlane's grandson, born, reared and destined to die amidst a horde of savages, however splendid in their trappings? There is not and there never was, any real, practical use for the great volumes of star catalogues that weigh down the shelves of our libraries.

The navigator and explorer need never see them at all. Why then were these pages compiled? Why have astronomers from Hipparchus' time to the present spent their lives in the weary routine work of observing the places of tiny points in the stellar depths? Does it not seem that there is something in the mind of man that impels him to seek after knowledge—truth—for its own sake? Something heaven born, heaven nurtured, God-given, something that was not—evolved? I will not enter into any quarrel with the school of evolution; with the theory that a process of selection has *turned out* our self-sacrificing searchers after knowledge; I simply beg to be allowed to stand without the school and to plead invincible ignorance, as being utterly unable to see what nearly everybody else sees so easily. That there is something in man common to him and his Creator, and therefore eternal, may not be according to the theory of natural selection, but it is in beautiful accord with the plain statement that "God made man in his own image." And while the love of knowledge for its own sake has an abiding place on this Earth, it will be useless to present to me, steeped in the densest ignorance, any so called evidences of the *evolution* of man.

SIXTH MEETING.

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

A cordial letter was read from the Secretary of the American Association for the Advancement of Science, stating that the Society had been placed on the exchange list for the publications of the Association.

The President laid before the Society a letter from Prof. H. Kreutz, the Director of the Central Astronomical Bureau, Kiel, Germany, referring to Mr. Harvey's discovery that disturbances in comets' tails are often synchronous with magnetic storms on the Earth, which goes to prove that both phenomena have their origin in solar outbursts, and extends the influence of solar magnetism to comets. Mr. Kreutz says the observation is new, so far as he is aware, and while advising further examination, supplies three instances of sudden illumination observed in comets and enquires what the magnetic conditions were on these particular days. One of these is Comet I., 1888, which on the 20th and 21st of May suddenly became brilliant. Mr. Harvey stated that on May 20th the greatest magnetic depression of the season occurred, and showed a diagram of the curve of horizontal force in proof of the statement. He promised investigation of the other two cases at a future time.

The announcement was made that the Royal Society of Canada would meet in Ottawa on May 23rd. The Secretary was instructed to prepare a condensed report of the Society's work during the past year, to be read at the Ottawa meeting.

The Librarian reported having obtained a copy of the two-volume edition of Galileo's works, published at Bologna in 1656. The books were shown to the members and occasioned an interesting discussion. The wood-cut reproductions of Galileo's observations of sun-spots, and of his map of the lunar surface were of particular interest. The President was specially requested to favour the Society with a description, in some detail, of these volumes, and kindly acceded to the request.

A discussion was entered into regarding Dr. See's theory of stellar temperature and also on the recent experiments in the production of liquid air.

Mr. Lindsay read some notes on the "Planets and the Weather," reviewing the theory that terrestrial meteorology is bound up with the configurations of the planets. He was unreservedly opposed to the theory, and held that it was as easy to prove one thing as another from the positions of the planets. For every case in which a certain configuration had preceded a certain meteorological condition there would be an instance exactly of the opposite character. It was thought strange too, that weather prophets only troubled themselves about changeable climates. In parts of the world where the meteorological conditions were practically always the same, or where changes occurred with great regularity, there would be no use for planetary interference.

SEVENTH MEETING.

April 18th ; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

The matter of appointing a delegate to the meeting of the Royal Society was discussed, and the President was unanimously elected to represent the Society at Ottawa.

Several communications were received from corresponding members and others. Mr. David Brown, of Port Elgin, forwarded the following notes :—

"PORT ELGIN, April 1st, 1899.—A fine parhelion was observed here on February 11th, in the morning. The Sun was surrounded by a ring with two mock suns, one on either side, and nearly a half-circle, very like a rainbow, above the circle near the zenith. At 11 a.m. there was a streak of light radiating outwards from each of the mock suns. Another of these phenomena was seen here a week ago, quite different. The Sun shone brightly with a ring fainter, but very bright, at the north and south parts. A half circle of faint light radiated from the north part, down to a few degrees away from either side, and a mock sun was seen on the bottom of the western streak. I do not remember having seen the rainbow-like circle so bright as the parts mentioned."

Mr. Lumsden stated that he had learned of Dr. Brashear's approaching visit to Muskoka, and was requested to write the Doctor and ascertain whether he could favour the Society by being present at one of the meetings, and possibly to address the members.

The subject of drawing up rules for the regulation of the Society's library was discussed at some length. The opinion was freely expressed that as a result of the untiring efforts of Mr. W. B. Musson, the library was now in a most excellent condition, and with a view to making it as convenient as possible, with due regard to the safety of the books, the following were adopted as the

REGULATIONS PERTAINING TO THE LIBRARY.

1. The library is divided into two branches—
   A. Works for reference.
   B. Works for circulation.

2. All the *Transactions* of other Societies, publications of observatories, and such other books, charts, etc., as the Librarian may classify

in this branch, shall belong to the Reference Library, and shall not be removed from the room.

3. All periodicals and books that can be purchased from booksellers in the ordinary course of trade shall belong to the circulating branch.

4. Access to the library can be had whenever the Canadian Institute is open. Any member can obtain a key from the Librarian on payment of cost thereof.

5. No member shall at any time remove from the room any book, magazine, chart, or other publication, unless same has been obtained from the Librarian or his assistant, and a receipt given therefor.

6. No book or periodical shall be taken out on such receipt until it has been on the shelves or tables for one month.

7. Members taking any works shall return them in good order within two weeks, and shall replace the same in the event of loss or damage.

8. Members leaving the room are requested to lock the door to prevent the intrusion of strangers, but are at liberty to introduce friends under the following conditions :—(*a*) Residents of the city, whom they accompany, and with whom they remain while in the building. (*b*) Non-residents, whose names they must enter in the visitors' book.

Reports of observations were received from several members. Mr. R. Wallace presented several diagrams illustrating his observations of Jupiter, with a four-inch telescope. Mr. G. G. Pursey reported his solar observations and was requested to bring these forward in a form of a paper for discussion.

Mr. Elvins and Mr. Lumsden joined in a discussion regarding depressions in the lunar surface near Theophilus, which Mr. Lumsden had recently made the object of a series of observations.

EIGHTH MEETING.

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

Communications were received from Mr. T. S. H. Shearmen, of Brantford; Rev. D. J. Caswell, Ph.D., Meaford; and from the vice-director of the Vatican Observatory, on the subject of solar magnetic disturbances, to which the special attention of the observatory had been called by Mr. Harvey.

The Society learned with deep regret of the sudden decease of Miss Elizabeth Brown, the director of the Solar Section of the British Astronomical Association, announced in the *Journal* of that body, Vol. IX., No. 5. The President said he had enjoyed the pleasure of correspondence with her, and exceedingly regretted her untimely death. She was very clever at drawing solar spots, which she preferred to do by projection, and the writer of the memoir in the *Journal* correctly says that "her trained hand and eye made her own contributions to the illustrations of the *Annual Memoir* a noticeable feature, their uncommon beauty and delicacy being an almost perfect transcript of the spots themselves."

Miss Brown had visited Canada, and was always ready to extend a helping hand to Canadian enquirers into solar phenomena, which the President desired to have the Society acknowledge, by sending a letter to the British Astronomical Association expressing regret at her death and sympathy with her surviving sister.

Observations of the Sun and Jupiter were reported by Mr. Pursey and Mr. Wallace. A brief discussion ensued on the possibility of detecting variation in the brightness of Jupiter's satellites in moderate telescopes.

Mrs. Savigny described an aurora observed on April 21st, at 9h. 30m. p.m.

The President then introduced Dr. J. A. Brashear, remarking that the Doctor really needed no introduction to this Society, and announced that the evening would be at his disposal.

Dr. Brashear then addressed the Society on the subject of "Diffraction Gratings," dealing with all the processes in the construction of the instrument, from the casting of the mould for a metal grating, to the construction of the screw regulating the motion of the dividing engine. The Doctor's remarks relating to the diamond point itself, which does the ruling, were particularly interesting. It was said that all parts of the dividing engine are a fair field for science to work upon, but there is no science about the diamond. For instance, a gem may be selected which, under the microscope, has just the point required; it is tried and found useless; again, the diamond may not, by such tests as can be applied, appear to have its plane of cleavage just right, and yet it may work beautifully. Dr. Brashear, without offering any theory at all, stated that it seemed to him that there is just one crystal, poised upon another, which does the marking; but this may drop off by wear, and although another crystal is there, the evenness of the spaces is destroyed in that moment for that plate. An interesting circumstance was related in connection with the work of the late Prof. Rogers, of Maine. It appears that Dr. Rogers had accustomed himself to the sound made by the diamond point, feeble as it was, when cutting the lines, and he was able to tell when the machine was working properly, and could detect the very moment when the unfortunate changing of a crystal might occur. The truth of Dr. Brashear's remarks were clearly perceived when he stated that the commercial value of a first-class diffraction grating is never remotely an equivalent of the time and labour and worry expended upon its construction. Small gratings, however, may be made, the commercial value of which does more nearly approach the real value as measured by the energy expended upon them. The Doctor's characteristic words were, "when a man has ruled a perfect grating, there is no more conceit left in him."

After having inspected several gratings which had been brought in illustration of the lecture, the members of the Society were most agreeably surprised when Dr. Brashear presented to them one of the very finest, ruled by Prof. Rowland's engine, with 14,000 lines to the inch. The cordial thanks of the meeting were voted to the Doctor, and appreciative remarks made by the President and others. The opinion was freely expressed that Dr. Brashear had conferred a very great favour on the Society by coming to Toronto to address a meeting.

NINTH MEETING.

May 16th; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

The Secretary announced that the Society had received from Larratt W. Smith, Q.C., several volumes of astronomical publications, some of which were now rare and could not be procured by purchase at all. The sincere thanks of the Society were due to Dr. Smith for his valuable gift.

A communication was received from the "Eclipse Committee," of which Prof. Newcomb was Chairman, asking for information regarding plans which the Society might adopt in the observation of the total eclipse of the Sun in May, 1900. Mr. Lindsay was requested to bring this forward at a future meeting, with a recommendation for action.

Mr. Pursey, in reporting his solar observations, stated that no spots had been seen on the solar disc since May 4th.

The following notes were read by the President on

AN AUREOLE ABOUT MERCURY.

In his annual address to this Society, at the close of 1896, Mr. J. A. Paterson mentioned as one of the most interesting observations of the year, that Herr Leo Bremner, of the Manola Observatory, Lussinpiccolo, had seen Mercury, in April of that year, encircled by an aureole, its disc, therefore, standing out dark against the sky. I thought, at the time of the delivery of that address, of investigating the magnetic conditions of the Earth at the time; but it passed from my mind until during the past week, when I sought for the authorities on which Mr. Paterson had made the statement. I found them, through Mr. Lindsay's assistance, in the *Journal* of the British Astronomical Society, and in referring to my magnetic charts I was delighted to find that on April 18th, the day when the phenomena was seen, there was in progress the most severe magnetic storm, not only of the month, but of the half year.

Mr. Ex-President's report did not at all exaggerate the beauty or the importance of the observation. Mr. Leo Bremner had taken all precautions against optical deception, and called Madame Manola to view the wonderful sight. She said that the aureole and the disc, the latter darker than the sky, was a conspicuous object, which reminded her of the appearance of Venus in 1895.

There can be no reasonable doubt whatever, after the discovery of the severe magnetic storm then raging, that the phenomena was of the nature of an aurora. This confirmed the theory I have had the pleasure to announce to this Society, that disturbances on the Sun, which are felt here in magnetic depressions of the curve of horizontal force, and shown in the curves which I have made, are also felt by other bodies revolving around the Sun.

If there was ever a discovery due to the discussions and observations of a Society, not to those of an individual member only, this is the one. In my claim to have shown that the sudden brightening of comets is synchronous with magnetic depressions in the curve of horizontal force, I wish to acknowledge my obligations in the first place to Mr. Pursey, whose diagrams of solar spots induced me to commence magnetic investigations, also to Mr. Elvins.

I claim to have been the first to discover that the Sun's influence extends not only to the Earth but to comets, and I adduce in proof thereof the coincidence of the brightening and even the disintegration of comets during magnetic storms here. This coincidence has so far only been noticed by Berberich, and that in one case, that of Encke's comet. He failed to generalize or, indeed, to realize the importance of his statement. I find that in seven cases, so far, of which in my annual presidential address I mentioned only four, there is a precise synchronism between magnetic storms on the Earth and remarkable changes in comets. I now discover that the excitation noticed in Mercury is also referable to a magnetic storm, which perturbed the needles on the Earth, and produced fine auroras here. Therefore it is evident that when a magnetic impulse is developed on the Sun, the whole solar system feels the thrill, and all the comets and planets show at the same hour the influence thereof.

The fact might have been easily foreseen, but it was not noticed. Therefore, the honour of observing it belongs to this Society, to whom, and in consequence of our discussions of the subject, the announcement was first made in my annual address, and through whom it was first published to the astronomical world.

We can now form a new outside view of the solar system, note the electrical disturbances which permeate it, and see the comets and planets encircled by electrical influences which proceed from the Sun. It may be regarded as proved, that all the bodies in the system are most luminous at times when the Sun is active.

Mr. A. Elvins then read a description of a simple and inexpensive method of constructing a polariscope showing the phenomena of polarization by reflection. A bundle of glass plates was laid upon a board covered with a black cloth, and the apparatus tilted to receive the light at the polarizing angle. The light was received through another pile of plates held in the hand, and a piece of mica being interposed, the chromatics of polarization could be easily studied. The members were much interested in the simple apparatus, and took the opportunity to prove its effectiveness by observation.

TENTH MEETING.

May 30th ; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

A communication was received from Rev. T. E. Espin, who had forwarded a list of stars with remarkable spectra observed at Tow Law.

Captain C. H. Davis, Superintendent of the U.S. Naval Observatory, had kindly forwarded a copy of the official circular conveying information regarding the eclipse of May, 1900. It was arranged to devote one evening to a thorough discussion of the best plan to pursue in the matter of organizing an expedition from Toronto.

An interesting letter was read from Mr. David E. Hadden, of Alta, Iowa, who was enthusiastic in regard to observing the eclipse. Speaking of solar activity, Mr. Hadden noted that there had been few auroræ during the past year or two. In 1892 and 1893 (the maximum of sun-spots) auroræ were frequent and some displays were magnificent. On the 1st of May, 1899, a slight aurora was seen at Alta, and also on May 3rd, which latter took the form of a comet-like beam of light, extending upwards from the horizon, fifteen degrees or more, in the N. W. sky. It reminded Mr. Hadden of the photographs of Comet b, 1893, or Brook's, 1893, comet. On the dates named there were no solar disturbances either at the east limb or on the central meridian of the Sun. It was thought that there would be an opportunity to test the various theories regarding auroral displays and sun-spots, during the next few years.

Mr. Lumsden reported an observation made by Dr. Brashear in Muskoka on May 3rd. The Doctor had observed a beautiful aurora accompanied by phenomena which seemed to prove the existence of "dark auroræ." Mr. Lumsden also reported his own observations of the minor planet Ceres, seen as a yellowish star.

The President reported his visit to Ottawa to take part in the proceedings of the Royal Society of Canada. He was pleased to be able to state that Prof. Alfred Baker, M.A., of Toronto University, had been elected a Fellow; thus strengthening the position in the Royal Society, of the science of astronomy. Mr. Harvey also read a brief summary of his paper presented to the Royal Society on "The synchronism of terrestrial magnetic disturbances with excitation in the trails of comets."

Mr. John A. Paterson then read a paper on "Oceanic Tides." (See Appendix II.)

ELEVENTH MEETING.

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

Communications were received from Rev. T. E. R. Phillips, F.R.A.S., of Yeovil, England, who kindly forwarded a copy of his drawing of Mars; and from Mr. J. Munro, of Croydon, England, on the subject of "dark auroræ," which he had observed in 1894.

Mr. T. Lindsay reported having recently paid a visit to Meaford, Ont., where he found the Astronomical Society in a very flourishing condition indeed. At an open meeting presided over by the President, Rev. D. J. Caswell, Ph.D., the lantern slides of the Society had been shown to a large and appreciative audience.

Mr. G. G. Pursey, had recently paid a visit to Markham, Ont., and was much impressed with the beauty of the evening skies in that locality. There was a vast difference between the best of the atmosphere around Toronto and what is enjoyed in the country.

Mr. G. E. Lumsden presented the following

NOTES OF OBSERVATIONS.

June 10th, 1899; after a good deal of sweeping, finally with an opera-glass, picked up in Hercules, Comet a, 1899 (Swift). The object visible to the unaided eye a month ago, was faint and nebulous in appearance, resembling somewhat but not closely, the great nebula in Andromeda. Its ramifications seemed to quite fill a low-power eye-piece and with a higher power to present a central condensation, not stellar, but nebulous in character, with ill-defined branchings in several directions. By vibrating, or jostling the telescope, the brighter and darker areas became more easily discernible. On the following night again examined the comet, which presented no change in appearance though it had shifted its position among the stars, moving southerly; easy object in an opera-glass, but only as a nebulous patch on the sky.

Jupiter was a magnificent object. The belts and the markings of various shapes and tints upon them, were distinct and extremely interesting. I saw Saturn for the first time this year; seeing good and object steady; several moons visible. The rings, the shadow of the ball upon them, the belt in the northern hemisphere, all came out well. The planet seemed to present Herschel's square-shouldered form. The ball was of a much paler yellow than the rings.

June 11th, noon; interesting group of sun-spots just passing off western limb of the Sun; small double spot in central part of disc, and two extremely bright faculæ immediately within the eastern limb. At night observed Jupiter with advantage, having succeeded in picking up the planet in bright daylight. After night-fall the Jovian belts and other details came out, at instants of steady air, beautifully. At 10.30 the planet was visible with his moons grouped around, one on the right and three close together on the left.

The following paper, contributed by Mr. W. H. S. Monck, F.R.A.S., was then read by the Secretary :—

STATIONARY METEOR RADIANTS.

The attention of astronomers has been again called to the subject of stationary meteor-radiants—radiants from which meteors come to us for perhaps months in succession—by the papers read before the Royal Astronomical Society by Profs. Turner and Herschel. But neither of these writers, nor the Society itself, seems to me to recognize the generality (if not the universality) of the phenomenon; and if it is not a special and exceptional case, all attempts to explain it as such postulate their own failure.

I think it may be safely laid down at the outset that shifting radiants are not the rule. If they occur at all they do so very rarely. Mr. Denning in his well-known paper in the *Monthly Notices of the Royal Astronomical Society* for May, 1890, only asserts this shifting of the Perseids of July and August and the Lyrids of April, while in a more recent paper he expresses his doubts as to the shifting of the latter. Almost all other showers are in one sense stationary—that is to say, the meteors come from the same point in the sky for more than two nights in succession. Mr. Denning traced the Leonid shower during eight successive nights without any change in the radiant, while in the case of the October Orionids the radiant remained without change for three weeks. Neither of these is a stationary radiant in the ordinary sense—a radiant from which meteors come to us for months in succession. But both last quite long enough to render a shifting of the radiant perceptible if it existed, and the failure to detect any such shifting presents the same difficulty as if the showers were of longer duration. Mr. Denning, moreover, was not the first to signalize the fact that showers usually come for a considerable time from the same unaltered radiant. A remarkable paper on the subject by Mr. R. P. Greg will be found in the *Monthly Notices* for April, 1878. The *average* duration of the showers mentioned in the various catalogues which he had examined he sets down as three weeks, during which time, as a rule, there was no perceptible change in the radiant. Thus the general rule appears to be that meteor showers last for several nights in succession, and that the radiant does not shift during the continuance of the shower. It is to this general rule that any satisfactory explanation of the facts must be adapted. Exceptional circumstances cannot be resorted to in order to explain the ordinary features of the phenomena.*

Mr. Denning has proved that many of these showers continue longer than Mr. Greg and his compeers supposed. Where the shower was of great tenuity, it might be supposed to have ceased although really still active and a similar result might follow if the radiant was during part

* This paper was written before the publication of Mr. Denning's General Catalogue of Meteor Radiants in the *Memoirs of the Royal Astronomical Society.* This Catalogue generally bears out my conclusions. I have altered a few passages in relation to it.

of the year in an unfavourable position for observation. Mr. Denning has, by noticing this, succeeded in tracing some showers throughout the year, and others during several months. But are these cases exceptional? Do we require anything more than additional observations, or observations made under more favourable circumstances, in order to trace many other showers throughout the whole year also? I doubt it. Mr. Denning's observations and those of others since Mr. Greg's time have led me to think that his average of three weeks to a shower should be considerably increased. Take Mr. Denning's catalogue in the *Monthly Notices* for May, 1890, and arrange the radiants in order of R. A. or Declination instead of date, and we cannot fail to be struck by the manner in which they group themselves round particular points in the sky almost irrespective of date. Instead of the forty-five stationary radiants given by him in the paper already referred to, he might, I believe, have given three times the number. Indeed, he has recently published a much longer list. I shall give a specimen of this grouping before the conclusion of the present paper.

Reverting to the question of shifting, the Lyrid radiant (whose shifting Mr. Denning now thinks open to doubt) has been feeble for several years past, and considering that the radiants observed on the same day have differed by 6° in R. A., the evidence of shifting cannot be regarded as very satisfactory. As regards the Perseids there is undoubted evidence of shifting, but it is strangely mixed with evidence of a contrary character, and it is evident that we are dealing with a very complicated state of facts. To attempt to simplify this state of things by rejecting certain meteors as not "true Perseids," is really to beg the question. The exact date when the shower begins and ends, and the precise amount of shifting have not been ascertained; but it is certain that about the end of July, when a fine shower has sometimes been observed from about 32° + 53°, another though feebler shower has also been observed coming almost from the exact radiant of the main shower on August 10th. Mr. Denning observed this latter shower on the 31st of July, 1878, and fixed the radiant at 43° + 58°, and he gives as "other nights of observation," July 27, 28, 29, so that this shower would seem to come for five successive nights in July without change from the main August radiant. The shower has, moreover, been observed by Father Denza and others, as well as Mr. Denning; while recently Mr. Blakeley deduced a radiant at 45° + 51° from nine meteors between July 17th and July

22nd. That meteors come in small numbers from what I may call the principal Perseid radiant during the earlier part of August must, I think, be admitted ; so that if we regard Mr. Blakeley's observation as sufficiently approximate, we have meteors constantly coming from this principal radiant for three weeks before the maximum on August the 10th, while at the same time the shifting radiant is continually approaching it. And this state of things naturally suggests the inquiry whether the principal Perseid radiant, situated at about 44° + 56°, is not a permanent or stationary radiant. Looking at Mr. Denning's catalogue I find the following :

June 23 (14, 19, 25)	40° + 56°
Aug. 21 (20)	40° + 59°
Sept. 14	50° + 54°
Oct. 8 (6, 12, 16)	42° + 55°
Oct. 14 (8)	43° + 58°
Oct. 14	48° + 60°
Nov. 5 (7)	45° + 60°
Nov. 29	44° + 56°
Dec. 1 (9, 10)	44° + 56°

NOTE—"Other nights of observation" are placed in parentheses.

I also find that Mr. Denning deduced from Italian observations,

Aug. 24–Sept. 14	45° + 57°
" "	47° + 57°
Oct. 29–Nov. 13	47° + 56°
Nov. 25–Dec. 31	46° + 57°
Jan. 1–Jan. 15	49° + 61°

The coincidences in the first table are not very accurate, but I think they can hardly be regarded as the result of chance, while the element of chance seems almost excluded by the second table. Mr. Denning indeed has himself noticed the coincidence, especially in his latest catalogue in *The Memoirs*, where some other observations are added.

Now, let me notice another circumstance. On the theory of the shifting radiant, the finest display previous to that on the 9th to 11th of August is that from 32° + 53° on the 30th of July, which radiant Mr. Denning determined from no less than 53 meteors on one occasion. This radiant does not quite accord with the theoretical position on the theory of shifting, and it is almost certainly of the stationary type, for I find it again active from the 14th to 23rd of August, about the 20th of September, and on the 8th of October, according to Mr. Denning's catalogue, while other observations would extend its duration still further. There are thus undoubtedly stationary radiants mixed up with this Perseid shower, and to disentangle the shifting part from the stationary part will be no easy task.

Another famous shower is that of the Andromedes connected with Biela's comet. That there is a stationary radiant almost coincident with the radiant of this shower seems clear. Thus I find in Mr. Denning's catalogue,

Aug. 4 (10)	26° + 42°
Aug. 16 (12)	22° + 46°
Aug. 19 (21)	25° + 42°
Aug. 23 (21, 22, 25)	24° + 42°
Sept. 4 (15, 16)	28° + 45°
Oct. 15 (14)	25° + 44°
Nov. 4 (7)	25° + 46°

Of course it is possible that the coincidence of the radiant of the Bielids with this stationary radiant is due to mere chance, but when the same thing is found to hold good of the Perseid radiant this becomes improbable. Mr. Denning in his last catalogue shows that the principle is still more general.

The theory which ascribes the apparently stationary character of these radiants to the enormous velocity of the component meteors is eminently unsatisfactory. In no instance in which the path of a meteor has been ascertained with an approach to accuracy has any such velocity been computed. Nor could such an enormous difference in the velocity of meteors escape the notice of a skilled observer. One of the best ascertained stationary radiants is situated at about 47° + 44° within a few degrees of the Perseid radiant, both showers being active at the same time. Is it possible that one set of meteors should be travelling with a velocity of four hundred miles per second and the other with a velocity of forty miles without the attention of every observer being attracted by the contrast? But Mr. Denning has noticed that the effect on the Earth's motion on the meteors which come from stationary radiants is plainly discernible. In the case of the radiant to which I have just referred, the meteors which are very swift in July gradually become slower until they are rated as "very slow" in December. The Earth's motion could not produce such a change as this in the speed of the meteors if their original velocity had been as much as one hundred miles per second. But this varying velocity is a very common characteristic of showers from stationary radiants. And some of them appear to send slow meteors throughout. Here, for example, is one from Mr. Denning's catalogue of 1890 :

May 30	290° + 60°	slow, yellow.
July 13 (8, 9)	290° + 60°	slowish.
Aug. 21, 22, 23 (25)	291° + 60°	slow, bright trains.
Aug. 24 (21)	289° + 60°	very slow.

There cannot, I think, be much doubt of the stationary character of this radiant, especially as Schmidt has noticed it in September at 290° + 58°.* Moreover, the meteors from the famous radiant at 262° + 63° which seems active throughout the entire year are usually noted as slow. A radiant which according to Mr. Denning continues active from June to December is situated at 346° + 0°. Among the large meteors from this radiant he noticed one which was visible for six seconds and another for three and a-half seconds. If these meteors were travelling at the rate of one hundred miles per second, how could an observer at a single station keep them in view for this length of time? In another case a meteor coming from a well-known stationary radiant was kept in view for sixteen seconds. In short, I think it may be safely stated that the great velocities supposed by Mr. Proctor's theory do not really exist.

Prof. A. S. Herschel points out that this change of velocity of meteors as the direction of the Earth's motion changes is a serious objection to the theory of Prof. Turner. The change seems to occur in almost all cases. As to the actual velocity of meteors the professor admits that our results are open to some uncertainty.† But I wish to point out that when a meteor has been so highly heated by the resistance of the atmosphere as to become luminous, its velocity must be considerably reduced by this resistance, and that this reduction of velocity will vary with the size and shape of the meteor. Indeed I am disposed to think that the defects of the current theory arise in great part from the assumption that the changes in the direction and velocity of the meteor caused by its passage through the atmosphere are insignificant. Yet some meteors have exhibited a decided zig-zag motion while others have been apparently checked in their course, and then moved forward again with increased speed. If irregularities in the atmosphere produce such

* It is recognized by Mr. Denning in *The Memoirs.*

† There are good reasons to hope that we shall soon be in possession of more reliable determination of the actual velocity of meteors.

changes, can we suppose that the effects of the normal condition of the atmosphere are imperceptible as regards its velocity, though they may raise its temperature to the heat of total vaporisation? The speed of the meteor will, I apprehend, be gradually reduced from the instant that it enters the atmosphere, and will be least just before it disappears. The train of a large meteor usually seems to consist of detached fragments which travel more slowly than the principal mass because the retarding effect of the atmosphere is greater in the case of small bodies than of larger ones. However, according to Prof. Herschel and others, meteors are often travelling with *more* than parabolic velocity. As the resistance of the air would lessen their speed this would indicate that the original motion was hyperbolic, and if so, how is it that the shower continues for several years in succession? Further observation may show that showers of fast-moving meteors die out soon, and that for a long continuance of the shower the orbit must be elliptic, but I know of no evidence to this effect at present available. It should be noticed, however, that an agreement between computed cometary radiants and observed meteor-radiants is of very rare occurrence. The fact that it has been found to hold good in the case of two or three conspicuous showers has naturally called the attention of astronomers to it, but it may be doubted whether its importance has not been exaggerated because the fainter showers were neglected.

In conclusion, I desire to present a portion of Mr. Denning's catalogue of 1890 rearranged so as to place the radiants in order of R. A. I selected those whose declinations lie between 70° and 80° N., because these can be pretty well observed throughout the year. The grouping of radiants will be apparent at the first glance, and further examination would explain some of the apparent exceptions:

	POSITION.	DATE.	VELOCITY.
1.	12° + 70°	July 31	Swift.
2.	25° + 71°	Sept. 15	Swift.
3.	25° + 71°	Sept. 30	Swift.
4.	25° + 71°	Oct. 6	Slowish.
5.	26° + 70°	Aug. 25	Rather swift.
6.	26° + 72°	Aug. 23	Swift, short.
7.	26° + 72°	Oct. 29	Slow.
8.	27° + 71°	Nov. 29	Slow, short.
9.	27° + 71°	Nov. 30	Slow.
10.	28° + 70°	Dec. 9	Slow, bright trains.
11.	28° + 72°	Sept. 18	Slowish, short.

	POSITION.	DATE.	VELOCITY.
12.	29° + 72°	Oct. 11	Small, short.
13	32° + 70°	Oct. 13	Slow, faint.
14.	40° + 72°	Sept. 4	Swift.
15	40° + 77°	Oct. 31	Not swift, faint.
16.	50° + 75°	July 21	Swift, short.
17.	53° + 71°	Nov. 17	Rather swift.
18	54° + 71°	Aug. 21	Very swift, streaks.
19.	54° + 71°	Oct. 6	Slow.
20.	54° + 71°	Oct. 21	Swift.
21.	55° + 71°	Sept. 17	Swift, streaks.
22.	69° + 70°	Sept. 19	Swift, streaks.
23.	82° + 75°	Sept. 14	Not very swift, streaks.
24.	84° + 74°	Jan. 9	Swift, short.
25.	85° + 72°	Sept. 22	Swift.
26.	96° + 72°	July 31	Slow.
27.	99° + 70°	Dec. 9	Swift.
28.	100° + 72°	Nov. 29	Swift.
29.	100° + 73°	Oct. 2	Very swift.
30.	102° + 73°	Nov. 7	Very, very swift.
31.	104° + 79°	Aug. 13	Very swift, very short.
32.	105° + 73°	Sept. 25	Not swift.
33.	109° + 77°	Oct. 15	Small, swift, short.
34.	133° + 70°	Nov. 13	Swift.
35.	133° + 79°	Oct. 4	Swift, streaks.
36.	134° + 78°	July 30	Slow.
37.	135° + 78°	Aug. 24	Swift.
38.	136° + 77°	Nov. 30	Swift.
39.	157° + 74°	Nov. 16	Slow, faint.
40.	158° + 72°	Dec. 9	Rather swift.
41.	160° + 78°	Aug. 31	Swift.
42.	167° + 75°	Oct. 3	Swift, streaks.
43.	169° + 74°	Nov. 23	Slow.
44.	185° + 71°	Nov. 29	Swift, streaks.
45.	186° + 71°	Oct. 4	Slowish.
46.	190° + 79°	Nov. 30	Swift.
47.	192° + 79°	Sept. 20	Very, very slow.
48.	208° + 71°	Dec. 8	Swift, white.
49.	213° + 75°	Oct. 27	Slow.
50.	213° + 79°	Oct. 15	Not very swift.
51.	215° + 76°	Aug. 12	Slow, bright.
52.	219° + 72°	July 1	Swift.
53.	220° + 78°	Sept. 6	Swift.
54.	248° + 70°	Dec. 24	Swift, faint.
55.	248° + 73°	Jan. 11	Very slow, yellow trains.

	POSITION.	DATE.	VELOCITY.
56.	265° + 77°	May 3	Slow.
57.	277° + 73°	Dec. 19	Slowish.
58.	290° + 70°	Oct. 4	Rather slow
59.	291° + 70°	Aug. 1	Swift, short.
60.	292° + 70°	Aug. 29	Swift, streaks.
61.	292° + 71°	Sept. 22	Slowish, streaks.
62.	293° + 70°	Dec. 29	Slow.
63.	310° + 77°	Oct. 4	Slowish.
64.	310° + 79°	July 12	Swift, small, short.
65.	312° + 77°	Oct. 17	Swift.
66.	316° + 76°	Mar. 18	Slow, bright,
67.	330° + 70°	Aug. 12	Swift, short.
68.	330° + 70°	July 19	Swift, short.
69.	331° + 71°	Aug. 22	Swift.
70.	335° + 71°	Sept. 9	Slow, bright.

This table undoubtedly presents some anomalies and suggests that in a few instances there has been a mere casual coincidence. Thus, if we compare Nos. 42 and 43 with Nos. 44 and 45, the opposite changes in velocity, bearing in mind that both pairs are situated in the same region of the sky, can hardly be explained on the assumption of a physical connexion between *both* pairs, and I would be disposed to think that the coincidence in the radiants of the former pair was casual. But when three or more radiants cluster together, I think it will be found that anomalies of this kind disappear; and the impartial reader will come to the conclusion that fifty of these seventy radiants belong to the stationary type. I should be disposed to say sixty.

I have rather sought to state the problem than to solve it. A full solution would require more mathematical knowledge and more time than I can command. But besides the effect of the atmosphere on all meteors which become visible to us, I wish to call attention to the change in the radiant which would necessarily take place if the Earth ran through a meteoric ring near the perihelion. The paths of the different meteors when we encountered them would not be parallel as they would practically be in most instances where the perihelion was distant. A shifting of the radiant might thus be established, but only in exceptional cases; and as far as I can judge it is only in exceptional cases that it occurs. While I can find no trace of *continuous* shifting in the foregoing table, it will be noted that several radiants seem to possess what may be called outliers—radiants near enough to suggest physical connexion, yet not so close as such a connexion would lead us to expect. But similar outlying radiants – sometimes called sub-radiants — have been observed on the same night as the principal radiants. Indeed the sub-radiant has sometimes been so active as to give an apparent duplicity to the principal radiant itself. Thus on the 10th of August, 1878, Mr. Denning deduced from 106 meteors a double radiant at $42\frac{1}{2}° + 54°$ and $44° + 59°$. Many persons would regard such a difference as this, if occurring on different nights, as fatal to the theory of a stationary radiant; yet it occurred with the same shower on the same night. But in most instances we need not call these outliers to our aid. Thus Nos. 2 to 12 in the foregoing table clearly establish a stationary radiant, whether Nos. 13 and 14 belong to the same series or not. The problem, therefore, which the mathematical astronomer has to solve—and to solve as a matter of every-day occurrence — is what kind of physical connexion between the showers Nos. 2 to 12 would lead to the remarkable coincidence in the position of their radiants. The explanation by chance is no explanation at all.

While the velocity of meteors is plainly affected by Earth's motion it does not seem to be affected by Sun's motion in space. Hence, they probably belong to the solar system.

TWELFTH MEETING.

June 27th; this was an open meeting held in the Toronto Observatory, at the invitation of the Director, Mr. R. F. Stupart.

Mr. A. Elvins occupied the chair.

Before engaging in observational work some letters were read from members who were absent from the city.

Mr. Lumsden wrote from Muskoka:

June 25th; spent five or six hours in close examination of the sun-spot which came over the limb on 21st; used 2-in. telescope with eye-piece darkened by dense green disc to protect the eye. In Toronto this dark glass always give more or less of a greenish tint to the solar image, but here the image is almost a pure white. Definition excellent; at times everything clear and very distinct; sun-spot pear-shaped; umbra intensely black; penumbra rather less dark than usual in my experience, and so much foreshortened at preceding end as to be quite imperceptible, suggesting deep depression; spot followed by a large area of very bright faculæ. During the day small spots broke out and were added to the two seen in the early morning; the upper one of the two, as seen in an inverting eye-piece, becoming double. In fact, with the play of light in and about the faculæ and with the changes apparently going on in and around the spot, there seemed to be real evidence of considerable activity within the disturbed region.

The President had also written, from Fort Francis, Ont., describing a lunar rainbow.

The meeting then adjourned and a pleasant hour was spent in observation with the large telescope of the observatory, and with smaller instruments brought by members and placed on the lawn.

THIRTEENTH MEETING.

July 11th; Mr. John A. Paterson, M.A., occupied the chair.

The President, who was spending some time at Saw Bill, Ontario, had forwarded the following notes of observation, in a letter to the Secretary, July 8th, 1899 :—

On the nights of the 6th and 7th inst., there were fine auroræ here; both of the second class. You might telephone Mr. Stupart and see if the magnets were perturbed; of course there was some sort of a dip in horizontal force, for the aurora, lasting two nights, cannot well have been purely local. In this region there is very little local variation in the compass, I wonder if auroræ are more frequent where there is little variation, and if parts of the Earth where this local variation is noticeable carry off in some way the electrical (?) influences which make auroræ visible.

The arch from which the yellowish white glow expanded was particularly well marked. On the 6th the streamers were distinctly seen above it; on the 7th the arch was even brighter, but the streamers fewer and less noticeable. On neither night were they brighter than the Milky Way, but the arch was. On the 7th I looked attentively, to see if it was what Mr. Lumsden calls a dark aurora. You will remember that I have given you an account of one I saw from near the Manitoulins, which looked so black we thought it was a storm approaching. This aurora of the 7th seemed at first to be darker, under the arch of light, than the rest of the sky, but I think it may have been an optical illusion, caused by the contrast. The edge of it changed its regular form from time to time, not at all departing from continuity. The arch was about stationary for an hour. It was quite a flat-arch; base about 90° or 100° of the horizon, height 8° or 10° only—above which was the light.

Several members reported having observed the beautiful auroral belt of June 28th, a great white arch had spanned the sky from south-east to north-west on that evening, and had evoked wide spread interest. Mr. Elvins had observed the spectrum, and stated that the characteristic green line of the auroral spectrum had been easily distinguished. Commenting on this Mr. Elvins said that it had been thought that the spectrum of the belt did not give the "auroral line," as the streamers did; his observation, however, proved that the phenomena were the same.

The Librarian reported having received as a donation from Mr. J. Britnell the manuscript of a series of lectures on navigation, which had been delivered before the United States Naval Academy in 1854, by Prof. Coffin. Mr. Lindsay had examined the work and found it of very great interest. The handwriting was not that of the author. A supplementary note established this, and recorded that Prof. Coffin had received a large sum of money from the naval authorities of the United States for his solution of the lunar distance problem and his tables to be used in simplifying the calculations.

Mr. John A. Paterson, M.A., presented several valuable books to the library, for which the thanks of the Society were cordially tendered.

Mr. A. Elvins read a short paper on "Meteorology," dealing mainly with the effect of atmospheric tides and taking into account the actual form of the atmospheric envelope as perturbed by the Sun and Moon. A possible cause for weather changes, and particularly for the path of cyclones, was thought to be referable to these phenomena.

FOURTEENTH MEETING.

July 25th; Mr. A. Elvins, occupied the chair.

The Corresponding Secretary read a letter received from Mrs. Elger, widow of the late T. Gwyn Elger, F.R.A.S. Several lunar sketches made by the distinguished observer had been found among his papers, and these had been kindly forwarded. The thanks of the Society were directed to be conveyed to Mrs. Elger for this gift, which is to be retained as a souvenir of a departed corresponding member, who had taken a kindly interest in the Society and encouraged several of its members devoted to observations of the Moon.

The Librarian read a cordial letter received from the American Philosophical Society, on the subject of exchange of publications.

An interesting discussion was entered into on the subject of determining the height of the aurora. Some extracts were read from current publications, in which the theory was held that the aurora is a phenomenon similar to a rainbow, and therefore has no parallax—each observer seeing his own aurora, as each sees his own rainbow.

Mr. G. G. Pursey reported his solar observations, stating that the surface of the Sun had been quiescent for a week past.

A series of sketches of the Sun's surface during the last week in June were presented and a brief description given of the changes noted from day to day. One observation gave the impression that where a spot was divided into two by a bright patch of the surface, this latter was really only covering up a part of the spot, the black umbra passing underneath.

FIFTEENTH MEETING.

August 8th; Mr. John A. Paterson, M.A., occupied the chair.

A letter was read from Dr. J. A. Brashear, reporting observations of auroræ made in Muskoka during the previous week.

The Chairman reported having addressed a meeting of the Boys Brigade at Port Dalhousie, on July 25th, on the subject of astronomy. It had been intended to hold the meeting outdoors, but the weather was not favourable. The result was very gratifying in proving that a wide spread interest is being taken in natural science among the younger members of the community.

The Librarian reported the receipt of the "Report of the India Eclipse, January, 1898," from the British Astronomical Association.

The evening was then devoted to the reading of Prof. See's paper on "A new theory of world formation," and Prof. Young's paper on "Lane's law of temperature." An interesting discussion ensued, in which all the members took part.

SIXTEENTH MEETING.

August 22nd; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

A cordial letter was read from Mr. H. P. Hollis, F.R.A.S., editor of *The Observatory;* also a number of letters from various sources, addressed to the President and bearing on observations of the brightening of comets coincident with solar magnetic storms. The last recorded brightening was that of Comet (1) 1899, Swift, on June 4th.

Observations of the Sun were reported by Mr. G. G. Pursey; he had found the solar disc quiescent since July 30th, the longest interval in his experience. Further observations of auroræ were reported by the President, as seen at Saw Bill. There seemed to be decided evidence that the dark auroræ to which the attention of the Society had been frequently called, have a real existence, whatever may be the explanation of the phenomena.

A short paper was read by Mr. T. Lindsay descriptive of a recent visit to Yale Observatory. Mr. Lindsay had met Dr. Elkin, Dr. Chase, and Mr. Robert Brown, Secretary of the observatory, and was indebted to these gentlemen for much information regarding the equipment and maintenance of the institution. He was particularly struck with the public spirit of wealthy American gentlemen. Funds for various lines of research have been bequeathed to the scientific institutions of the country so fully that the want of money seems never to be felt at all. One notable example is that of Prof. Elias Loomis, the well-known mathematician, who died in 1889, leaving practically the whole of his fortune, upwards of $300,000, to Yale. The great man's heart was in the university and its surroundings. An oil painting of Prof. Loomis hangs in the computing room of the observatory—the picture of a man severely honest, of fixed and resolute purpose, and of the highest culture. Mr. Lindsay's visit had been altogether a delightful one and he acknowledged the unvarying courtesy with which he had been treated, and which was quite in keeping with that experienced by other members who had visited the centres of astronomical science in the United States.

SEVENTEENTH MEETING.

September 5th; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

In reporting observations, Mr. G. G. Pursey called special attention to the disappearance of a small sun-spot on August 26th. This had been seen on the previous day and when under examination on the morning of August 26th had disappeared almost under the observer's eyes. This was the nearest approach to an observation of spot formation or destruction which Mr. Pursey had made, and a special note was made of the occurrence.

The President reported meteors seen on September 2nd, which he thought may have been Delphids.

A discussion arose on the merits of the new form of opera-glass by Prof. Zeiss, in which the ray after passing through the object glass is allowed to undergo reflection twice before reaching the eye. The length of the instrument is thus shortened while the objective might have considerable focal length. Mr. R. S. Muir of Belleville, who was present, took part in the discussion and gave a brief sketch of the attempts to improve the common form of opera or field glass.

Part of the evening was spent in the Library, which, now in excellent order, was intended to be a place for informal meetings of the members. Mr. Musson showed all the latest acquisitions to the Society's treasures.

EIGHTEENTH MEETING.

September 19th; Mr. G. G. Pursey occupied the chair.

A communication was read, received from the British Astronomical Association, conveying information in regard to the proposed expedition to Spain to view the solar eclipse of May 28th, 1900.

Mr. E. W. Maunder, F.R.A.S., had written the Corresponding Secretary, and by kind permission of the Astronomer-Royal, had forwarded copies of photos of the Sun taken at Greenwich. These were made at the time when Mr. Lumsden was observing in Muskoka.

Prof. Wood of Haversham, R.I., had written a most interesting letter on the subject of lightning photographs. Some time was agreeably spent in discussing Prof. Woods' views regarding what are known as the "dark streaks." The article on the subject appearing in the current number of *Science* was read.

Reports of meteors observed by Dr. J. A. Brashear, August 11th and 19t were read and discussed.

Dr. J. J. Wadsworth, of Simcoe, had forwarded some notes on the interest taken in astronomy in his locality. The Doctor wrote :—

"I think you will be pleased to learn that much interest has been taken in the oldest of the sciences in this town this summer. I often have from four to six looking through my telescope when the skies are clear. Two nights ago I had *thirteen* visitors, a few being ladies. Two men drove nine miles and back to see the Moon and Saturn, and think of setting up a telescope in their town. I kept them at work with the telescope till after midnight, as they had come so far.

"They worked most indefatigably at the fine points in Saturn, Cassini division, crape ring, shadow on ring, belt on globe, and satellites. Then I set them to find "straight wall" in Luna. It was no easy task for beginners, as the terminator was running through Gassendi. But after an hour's search they were victorious, and greatly delighted. Then I used the circles and showed nebulæ and clusters in Hercules and Sagittarius, and the grandeur of the universe began to dawn on them as it seldom does for most men."

Dr. Wadsworth's report was thought to be very gratifying indeed. In the course of a discussion on the best method of making popular a taste for astronomical studies the subject of the coming solar eclipse was taken up. It was decided to set apart the next meeting for special papers on the subject, Mr. Lumsden being requested to prepare a paper for distribution among such as might wish to take advantage of the favourable circumstances; while Mr. Lindsay would prepare some notes on the exact path of the shadow, and the times of visibility of the total phase.

NINETEENTH MEETING.

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

Correspondence was read from Mr. F. W. Salmon, of Windsor, Ont., on the subject of the aims and objects of the Society. Mr. Salmon was duly elected an Associate Member.

Mr. G. G. Pursey, in reporting his solar observations, stated that the few spots seen on the Sun's disc had been near the equator. This was thought to be an evidence that the minimum had not yet passed. It had been observed that after the minimum the spots were seen at a considerable distance from the equator.

It had been arranged that this meeting would be devoted to a discussion of the proposed expedition to the Southern States in May, 1900, on the occasion of the total solar eclipse. To the end that public interest might, in some measure, be aroused two papers were presented, one by Mr. G. E. Lumsden, who endeavoured to treat the subject of eclipses in general, and of the eclipse of next May in a somewhat popular style; the second by Mr. Thomas Lindsay, who explained the method by which the instant of first contact for Toronto had been calculated. Mr. Lumsden's paper was as follows :—

TOTAL ECLIPSE OF THE SUN OF MAY 28TH, 1900.

"Ladies, I pray you, do come in! M. Cassini, the director, is one of my best friends, and I know he will have real pleasure in recommencing the eclipse for us."

The story is told by Arago, who uses it to sketch, in rapid outline, a picture something like this: a dandy, a marquis, as it happens, stands, hat in hand, entreating several women, dressed in the height of fashion, to make haste and descend from their chariot, which has just drawn up at the door of the Paris Observatory: entreaties being met by indignant words and disdainful glances, the ladies having learned from an attendant that, after all their trouble to get ready, their escort has managed, or rather mismanaged, to bring them one-half minute too late to see anything of the eclipse of the Sun which for weeks has been the talk of the Town. Anxious to retrieve his fast-falling credit, the poor marquis undertakes that his friend the director shall repeat the eclipse if the ladies will only alight and enter the observatory

In handing down this, to us, merry incident, the famous French astronomer may have intended, by a single master-stroke as it were, to portray some idea of the kind of information which, in the reign of Louis XV. passed current among the *beau monde* for scientific knowledge. No doubt many of the prevailing conceptions as to matters of astronomical moment were whimsical and absurd, but in the day of the marquis there had been general and substantial progress towards the truth, for time was, and not long before either, when, among even the learned, still more whimsical and absurd notions were held in high repute. Flammarion says that the public announcement of the near approach of the solar eclipse of the 21st of August, 1560, created a panic in France. The impression that direful effects attended upon eclipses was so firmly fixed in the popular mind that, upon the express injunctions of the doctors, a multitude of frightened people shut themselves up in very close cellars, well heated and perfumed, in order to be sheltered from the contagions that infected the air after the passage of the Moon's shadow. And, on the authority of Pêtit, the same astronomer declares that as the moment of the complete obscuration of the Sun was impending, and public consternation was greatest, a country parson, being no longer able to administer consolation to his terror-stricken parishioners, as they came to him one by one, was obliged to tell them that on account of the wealth of the penitents, the eclipse had been postponed for a fortnight.

In those days, as had been the case for ages, much that happened in public and private life was still ascribed to the Moon, planets and stars. All manner of theories, usually incorrect, were entertained. For instance, it was taught that the Moon was a damp body, subject to varying temperaments, due to the fierce radiation of solar heat. To the baleful influence of the Moon when in conjunction with certain planets, were attributed ailments such as apoplexy, paralysis, epilepsy, jaundice, inflammations and colds. Children born during the dark of the Moon and while Saturn was in the ascendant, were doomed to be weak, mentally and physically. When cupping was a panacea, some surgeons advised that the various temperaments of the Moon should be taken into account, as well as the dispositions of patients. Sanguine persons should be blooded during the first, choleric individuals during the second, phlegmatics during the third, and melancholics during the fourth quarters, the Moon, in these respective quarters, being, first, warm and moist; next, warm and dry; third, cold and moist, and, last, cold and dry. Theories now known to be utterly nonsensical were cherished. And to this day may be found in many countries people, otherwise intelligent, who firmly believe that the Moon steadily exerts influences, for the most part pernicious, over men, animals, plants and minerals.

Like comets and other signs and wonders in the heavens, eclipses were misunderstood by the masses. The ignorant and superstitious regarded them as sinister precursors of offended deity sent to men, as individuals or nations, to warn them of punishments about to come upon them in the form of rebellion, assassination, conflagration, war, pestilence, famine, deluge, or other special or general disaster. The I Told You So's were, therefore, always able to perceive the hand of God in any and every significant event that followed closely upon an eclipse. The wisest of men have been confounded by these simple phenomena. Their power over the superstitious is now inconceivable. By them the courses of human events have been changed into other and new channels. As inauspicious auguries, they have led to the wrecking of military expeditions and to the overthrow of states; they have, at moments of supreme peril, endangered the success of the plans of kings, rulers and generals; they have stopped pitched-battles and have brought long wars to an end. Sometimes they have been used for the benefit of the crafty. A total eclipse of the Moon was visible in Jamaica on the 1st of March, 1504. Advantage of his prior knowledge of the event was taken by Columbus to compel the unwilling natives to supply food to his forces. Early in the day he threatened to deprive them of the light of the Moon as she rose in the evening, and when they saw that he was apparently able to carry out his threat, they hastened to comply with his demands and avert the impending calamity. Such, indeed, has been the credulity of mankind that a phenomenon so innocent of direful consequences as the rapidly increasing brilliancy from night to night of the fiery red planet Mars, due to approaching the Earth, has carried consternation round the world.

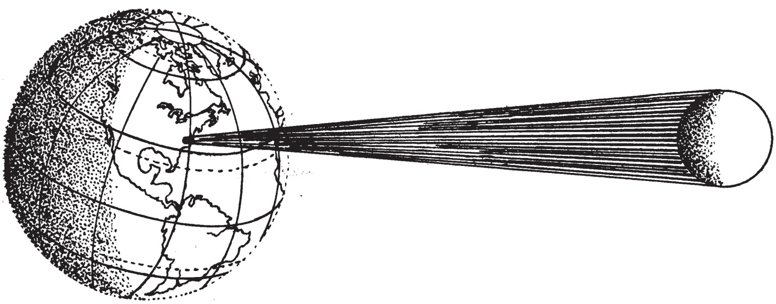
Were it possible for us to see shadows against the sky, and to take up out in space a suitable position for the purpose, we should perceive that both the Earth and the Moon ever cast behind them vast black cones pointed away from the Sun, the common source of illumination. Could we measure these cones, we should find that the shadow of the Earth is

850,000 miles, and that the shadow of the Moon is 238,000 miles in average length. The Moon's path is far from being exactly circular. It is elliptical, or egg-shaped, so that while the distance which separates the Earth and Moon from each other averages 240,000 miles, there are days when she is only 222,000 miles away, and other days when she is as far off as 252,000 miles, a difference of 30,000 miles. And this is the reason that, to the naked eye, our satellite at times appears to be larger, or smaller, than at other times. Any one who follows her through a sufficient number of lunations will detect not only these but other interesting differences, and will notice that she never "fulls" twice in precisely the same part of the sky, because she is constantly changing her position by rising or falling from night to night, thus passing, as it were, every month, through many degrees of north and south declination. And it will be further observed that, in obedience to some law, the Moon in our summers becomes full at or near her lowest point as she hangs over the southern horizon, and in our winters at her highest point over our heads, thus providentially affording light to that pole, for the time being, most in need of it. An eclipse of the Sun visible to us can occur only when the Moon is new, that is, when she passes exactly between us and the Sun, just as one might pass his clenched hand from right to left between his face and a lighted lamp. Now, if an eclipse happen when she is at her least distance, 222,000 miles from us, and, therefore, apparently greatest in diameter, the apex or point of her shadow-cone will come into contact with the surface of the Earth, and be broken off to the extent of some thousands of miles If, however, one happen when the Moon is at her greatest distance, 252,000 miles from us, and, therefore, apparently least in diameter, the apex of the shadow will pass over our heads at a distance of some thousands of miles, and somewhat after the fashion of a balloon floating by at a considerable height. In the first instance, the eclipse will be total along the path, more or less curved, over which the broken shadow travels, because the Moon will be large enough to hide the Sun. In the second, the eclipse will be annular, because the Moon will have been, by her distance, apparently diminished to that degree that at no instant while she is crossing the solar disc can she completely obscure it, for around her coal-black body will blaze a ring of the white-hot Sun.

Little did the ancients dream, far less know, that when the full Moon, seemingly without cause, turned into blood, she was passing behind the

Earth and through the Earth's shadow, or that the Moon was only passing between them and the Sun when they saw, or thought they saw, a black monster, demon or fish, come out upon the sky and devour the God of Day. After all, what phenomena occur during total eclipses of the Sun with which we, at present, are concerned? Except as to magnitude and intensified effect, nothing more than the phenomena which attend upon a compact, rounded cloud drifting eastward across the sky, followed by a dense shadow, still more swiftly drifting across hill and dale bathed in sunshine. Who is not charmed by the animated play of light and shade as cloud-shadows go skimming and flitting over gracefully waving fields of golden grain! Who, from the top of a hill or mountain has not marvelled over the beauty of scattered cloud-shadows flying across the landscape: sweeping in out of space, as it were, upon the scene, darting down steep declivities, scurrying through gorges and valleys, dashing up opposite ascents, and sweeping out again into space! They come and go, and that is all. Even on these magnitudes cloud-cast shadow-apparitions are imposing. On the stupendous scale of total solar eclipses, Moon-cast shadow-apparitions are impressive and awful to the last degree: they are phenomena, never forgotten by those who see them. Than Professor Langley, there is no better authority, he having observed three. No wonder he declares that repetition does not dull the interest, and that a total eclipse of the Sun is worth a journey round the world to behold.

For the purpose of observing these phenomena, scientific men and women do not hesitate, literally, to go to the ends of the Earth. Especially promising eclipses have found enthusiastic observers on the steppes of Russia, the wastes of Asia, the inhospitable shores of Africa, the peaks of the Andes and lonely rocks in mid-Pacific. The total phase is the only portion of a solar eclipse of the slightest value to astronomers or solar physicists, or, indeed, of real interest to the mere sightseer, and this phase, under the best possible conditions, cannot at any one place last so long as eight minutes; commonly, the duration does not exceed three minutes. Notwithstanding this and the chance of complete failure, owing to the presence of clouds, costly expeditions are from year to year fitted out by governments, observatories, societies and private munificence, and the arduous duties devolving upon them are ungrudgingly assumed by men eager to glean from the sky every vestige of information obtainable by telescope, spectroscope and camera during the few precious moments that the obscuration of the Sun is sufficiently complete to allow critical examination to be made of the solar appendages visible to man only when daylight has been thus temporarily turned into night. Amateurs will, therefore, readily appreciate the keen interest with which scientific men and women on this continent are looking forward to the next total eclipse, which, most fortunately for them, will, on the 28th of May, 1900, be visible in Mississippi, Alabama, Georgia, South Carolina, North Carolina, and Virginia, or, in other words, throughout a broad belt extending from New Orleans to Cape Henry.



This paper is not, in any sense, intended to be technical or scientific. Its object is to awaken and arouse public interest in a phenomenon at once splendid and rare. Happily, there are at hand everywhere excellent works which treat of all the phases of eclipses. Some of these are but recently published, and several, to their credit, have been charmingly written and illustrated by women. To these, the readers of this paper are deferentially referred.

The shadow-path of the approaching solar eclipse will cross the American continent and, within the United States, will cover a belt fifteen hundred miles long by about forty miles wide at New Orleans and sixty miles wide at Cape Henry. Observers should, if possible, take up positions on the central line of the path, as the shadow will there be densest and the phenomena best seen. Along this central line, and within the north and south limits of the path, there will be thousands of excellent stations. From every city, town, village, hamlet and farm throughout the belt, observations may be made to great advantage. The best positions will be found in the Moon's path from the Appalachian Highlands on to the Atlantic coast. Some of these have already been selected by professional astronomers, who have chosen localities likely to be most free from cloud. These ladies and gentlemen will take care to be on the ground several days in advance so as to arrange their instruments and drill their staffs to the last degree of thoroughness and precision. No doubt, the unprofessional men and women who will be present on eclipse day will number many thousands. Well equipped parties will go south and east from all parts of the continent. At least one official party will come out from England, while other parties from that and other countries will go to places in Europe and Africa. The eclipse will be total along a path extending, like an arc, from a point near the southern end of Lower California, across Mexico, the United States, the Atlantic (twice cutting the path of ocean travel) Portugal, Spain, Algiers and Egypt. Outside of this path the eclipse will, some time during the day, be more or less partial to observers from the North Pole to the River Amazon and from the central Pacific Ocean to the Red Sea.

On the 28th of May next, sometime after local sunrise, the round shadow-cone of the Moon, like a great arm, will sweep in out of space, coming into contact with the Earth near the Revilla Gigedo Islands, in the Pacific Ocean, about five hundred miles south and west of California. With the tremendous initial velocity of about one hundred miles a minute, the shadow-cone will rush towards the mainland and enter Mexico near Cape Corrientes. In eight minutes it shall have crossed the Rocky Mountains, where, flying from peak to peak, and from valley to valley, the spectacle must be sublime, though lasting but thirty seconds. By 7.30, Central Standard Time (or 8.30, Eastern Standard Time), it shall have crossed the Gulf near the mouth of the Rio Grande, and plunged New Orleans into sepulchral gloom.

Let us imagine ourselves to be a group of enthusiastic men and women, not necessarily scientific or practised observers, but anxious to see everything possible, for which purpose we are present on the eclipse track. We should be posted upon the highest suitable eminence, so as not to miss the tremendous impressions due to the sudden rushing upon us of the stupendous shadow. We ought to be in the centre of the ground over which the shadow will pass. If this position be near New Orleans, we shall have totality for seventy-seven seconds. If we are at Union Point, Greene County, Georgia, the centre of the path in the United States, we shall have darkness for ninety-two seconds. If we are near the Atlantic coast, not far south of the city of Norfolk, we shall have one hundred and five seconds for observation. Let us assume that we have brought with us opera and field-glasses, telescopes, spectroscopes, barometers, thermometers and well-regulated time-pieces set to Washington, Greenwich, and local times. Of course we have note-books, drawing-paper, cardboard, white and black, upon which have been laid down black and white discs, on or around which our artistic members, by rapid sketching, with coloured chalks, may draw the phenomena we shall see. We have candles and lanterns, the latter for use if wind arise. Of course we have cameras and plates of various speeds and densities of coating, for we have seen the beautiful photographs taken on the 22nd of January, 1898, in India, by Mrs. E. W. Maunder, with a small camera, having a one and a-half inch lens, nine inches in focus—photographs due entirely to her own conception of what might be accomplished with such a camera, and which have proved to be of scientific value. The images were small, but from them excellent drawings have been made. We have everything in readiness. Instruments are mounted or suspended. Cameras have been focussed, the most distant objects being used for the purpose. Thermometers have been placed so that we shall be able to take the temperature of the air and soil ; we have been told off by our director, who has given each of us some special duty to perform, and who is sufficiently well informed to tell us what to look for, and to explain the various phenomena as they come under our notice. Time-pieces and thermometers must be read ; information as to exposing plates must be given ; the moments of contact announced, and the seconds during totality called off in a loud voice. And though we are all assisting, we shall be able to see everything. Professional astronomers will not be so fortunate. They must be in constant attendance upon their instruments, and will probably work behind screens shutting them off from the world, so that their attention shall not be distracted. From our calculations, we know when the various contacts will occur. The Sun is about three hours high and the sky clear. We are told that the edge of the lunar disc is all but touching the edge of the Sun, but we cannot detect the presence of our satellite. It has been explained to us that the Moon is really moving towards the east and at the rate of about half a mile per second, that the surface of the Earth is carrying us towards the east at the speed of about fifteen miles a minute, and that the shadow is approaching us from the west at the velocity of nearly one mile a second. During the hour and twelve minutes which must elapse between the first detected cutting by the Moon into the Sun's limb and totality, we shall have ample opportunity to observe and draw sun spots and faculæ, if any; to note down our impressions; to estimate the effect the gradual extinction of the direct solar rays is having upon objects around us, and the falling of the mercury in the thermometers. As totality approaches, we should look on the ground for the beautiful crescented images of the Sun which will be found under every low-branching tree through whose leaves the sunlight passes; and if there be no trees, this effect can be produced by allowing the sunlight to pass through a small hole in one card held above another. Then we should be on the alert for the shadow-bands which are usually present in bewildering variety a few moments before the face of the Sun is hidden, pulsating, it is said, in a manner to suggest the throes of Nature as if in dissolution and conscious of impending disaster. Nor should we forget to notice the effects of increasing twilight upon animals, birds, insects and flowers. On such occasions, domestic fowls go to roost, birds return to their nests, butterflies act "as if drunk," deer run about in alarm, and flowers, such as crocuses, tulips, anemones, gentians, hepaticas, pimpernels, wood sorrel, and wild geraniums, close, and a peculiar hush falls upon everything. At this moment attention must be given to the Sun, or what is left of it, for we must see the splendid phenomena known as Baily's Beads, visible for an instant or two as the Moon's advancing edge closes in upon the eastern edge of the Sun, but visible again when the western edge of the Moon moves forward just enough to allow the solar rays to glint round at us through the valleys among the lunar mountains.

But when warned by our director, every eye must be turned to the west, for, whatever else we succeed in doing, we must not fail to see the lunar shadow as it approaches. We may not live long enough to witness another eclipse under such auspices. Let us make the most of this. Forbes who observed, at Turin, the total eclipse of 1842, said that he was so confounded by the awful velocity of the shadow, which swept towards him from the Alps, that he felt as if the great building on which he was standing swayed beneath him, and began to fall over in the direction of the coming gloom. The rapidity of its motion and its black intensity produced the sensation that something material was flying over the Earth at a speed "perfectly frightful," and he involuntarily listened for the rushing noise of a mighty wind. Airy describes as "very awful" a shadow retreating away amongst the hills of Northern Spain. Other writers are no less dramatic in their accounts of these phenomena and the tremendous impressions they create. But when the shadow has come, and after we have recovered to some degree from the effects of shock and of the sudden darkness into which we have been plunged, we must rivet our attention upon the Sun, or rather upon the Moon, around whose black disc by this time will have appeared the splendid phenomena associated with a total solar eclipse seen in all its majesty. Striking, indeed, is the almost instantaneous substitution, as in a dissolving lantern, of one picture for another, the one showing the sky with the blackened Sun like a blot upon it, the other showing the sky suddenly draped in the mantle of Night, upon whose sable bosom glow planet, star and coronal halo, and also roseate jets of incandescent gaseous matter leaping upwards from and falling back upon the Sun. Now we photograph, sketch and colour most assiduously, not losing a single second. We lay down the positions of planets, comets, if any, and of bright stars. The eclipse is taking place in the constellation of Taurus, between the fine red star Aldebaran and the Pleiades. We look to see whether Aldebaran is able to make its presence known by shining through the gauzy structure of the corona, and how many of the bright stars in Orion and other constellations can be detected. We glance about the horizon and note the rich colour-tones, ranging from black, in the zenith, through browns, purples, crimsons and reds, to yellow lying along the rough sky-line thirty miles away, where the Sun is still shining, though with a partially hidden disc. We notice the ashy tints around us, reflected in our own faces. But a sudden glow along the western edge of the Moon warns us that totality has gone like a flash, and that we have time only for a quickly exposed photographic plate or two, and for watching another lovely dissolving view,—the fading out of Night before the returning glow of all-conquering Day. Almost instantly the landscape brightens and becomes familiar. Not until now, as we feel the warmth of the solar rays, did we suspect a passing chill. New life throbs everywhere. The black lunar shadow has swept majestically by us and is already out on the Atlantic, rushing towards Europe. Its vast track behind us is sprinkled with thousands of people, spellbound by the wondrous vision vouchsafed them by Nature, who, for a moment, as it were, has drawn aside a corner of her curtain and allowed them to gaze upon glories, the impressions of which will never fade fron memory.

The total solar eclipse of 1900, with its splendid phenomena, has come and gone, and is historic !

Mr. T. Lindsay then read the following particulars of

THE PATH OF THE SHADOW.

It has been noted that the eclipse of next May is a very favourable one for observers in Canada. Remembering through what out of the way places the shadow usually passes, and glancing at a map of the continent, it will be seen that we are indeed fortunate on this occasion. We cannot regard New Orleans as very far away, when our object is to stand in view of the indescribable beauty of the Sun's corona ; but we need not go even so far. Starting from New Orleans, we have the path of the shadow as follows :

The city will be completely in the shadow at 7h. 30m. on the morning of May 28th, by Central Standard Time, which is in use there. The Sun will then be 30 degrees above the horizon of the observer. Now glance at the other end of the path, Cape Henry ; this point will be in total darkness at 8h. 52m. by Eastern Standard Time. Reducing to absolute time, we see that the shadow sweeps from New Orleans to Cape Henry, a distance of nearly 1,000 miles, in the short space of 22 minutes. Leaving New Orleans the shadow travels east-north-east, its centre passing over the mouth of the little Pearl River in Mississippi, while the edge of the cone is outside the coast line. Mobile lies just within the path ; totality here will last only a few seconds ; but north of Mobile, on the Alabama, are three small places, Blakeley, Stockton, Claiborne, which stretch across the path. Continuing eastward are Starlington, Greenville and Troy, the first named exactly on the central line. Montgomery, a large railroad centre, is just outside, north of the path, lying between the edge and a bend of the Alabama River. Then we are into Georgia and have Columbus, another railway centre, almost on the central line. Mason and Covington are, respectively, south and north on the edge of the path. Milledgeville is a little within ; then a little further east is Union Point, at about the centre of the central line between New Orleans and Cape Henry. A glance at the map now will show that if we start from Toronto bound for Georgia, we must go by way of Detroit and Toledo, as the nearest route. And we must remember that Prof. Bigelow, of the Weather Service, prefers points in Georgia to places further east. Totality at Union Point begins at 7h. 40m., when the Sun has attained an altitude of 39 degrees. The duration of the total phase will be 92 seconds. Leaving Union Point, we cross the Savannah and are into the Carolinas. Right on the central line, as it passes on to the ocean, are, Newberry, Lancaster, Wadesboro, Pocket, Raleigh, Nashville, Gatesville, Cape Henry. The Cape itself is perhaps too near the mists of the ocean, though if the weather should prove favourable there will be the best opportunity for studying the corona, for totality lasts here for 1m. 45 sec. If we choose points in Carolina, Raleigh will be a good place as a "base of supplies;" or perhaps Charlotte, N.C. The latter is a large railway centre, but is itself outside the shadow track. It is about 13 hours rail from Washington.

It will be seen then that for us the path of totality is not very far away, and it is much to be desired that as many of us as can, will take advantage of the circumstances.

APPENDIX.

For those who remain at home the eclipse will be far from devoid of interest. The partial obscuration will be much greater than at the time of the eclipse of 1893, when the last really successful observations were made. The following computations determine the moment of first contact at Toronto; the usual notation is adopted, and the method of attacking the problem is substantially that of Bessel, "the incomparable," who first gave real exactness to calculations of this character.

For Toronto Observatory, we have the constants—

Geocentric latitude, $\phi' = 43° \ 27' \ 56''{\cdot}3$

log radius of the Earth, $\rho = 9{\cdot}9993010$

$\rho \cos \phi' = 9{\cdot}8601102$; $\rho \sin \phi' = 9{\cdot}8368366$.

From an inspection of the eclipse charts given in the ephemeris, and by a first method of approximation which has been fully discussed in former papers, we obtain as the assumed time of first contact of the limbs of Sun and Moon,

Greenwich mean time, May 28th, 0h. 51m. 30sec.

The longitude of Toronto, $\lambda = + \ 79° \ 23' \ 39''$.

At the assumed time the hour angle of that point of the star-sphere towards which the shadow is projected, is, at Greenwich, $13° \ 37' \ 12''$.

The hour-angle at Toronto, $h = 65° \ 46' \ 27''$.

Then we have $\log \sin h = 9{\cdot}9599640$; $\log \cos h = 9{\cdot}6131379$.

Referring again to the ephemeris for the declination of that point towards which the axis of the shadow is projected, we have

$$\log \sin \delta = 9{\cdot}5629100; \ \log \cos \delta = 9{\cdot}9688600.$$

We require now to know the position of Toronto on the flat disc of the Earth, as seen from the Sun's centre. For the co-ordinate along the axis-major of the ellipse into which the latitude circle of Toronto would appear projected, we have

$$\begin{aligned} \rho \cos \phi' &= 9{\cdot}8601102 \\ \sin h &= 9{\cdot}9599640 \\ \hline & 9{\cdot}8200742 = {\cdot}66080 = \xi \end{aligned}$$

expressed in terms of radius unity of the disc or "fundamental plane."

For the co-ordinate along the meridian we have

$$\begin{aligned} \rho \sin \phi' &= 9{\cdot}8368366 \\ \cos \delta &= 9{\cdot}9688600 \\ \hline & 9{\cdot}8056966 = {\cdot}63929 \end{aligned}$$

= distance on the disc from its centre to centre of ellipse, along the meridian.

$$\begin{aligned} \rho \cos \phi' &= 9{\cdot}8601102 \\ \sin \delta &= 9\ 5629100 \\ \cos h &= 9{\cdot}6131379 \\ \hline & 9{\cdot}0361581 = 10868. \end{aligned}$$

= co-ordinate along axis-minor.

$${\cdot}63929 - {\cdot}10868 = {\cdot}53061 = \eta$$

= co-ordinate along the meridian of the disc.

We now take from the ephemeris the co-ordinates of the axis of the shadow on the fundamental plane.

For the co-ordinate along the equator of the disc

$$\begin{aligned} \text{we have at 0h. 50m. } x &= 1{\cdot}17059 \\ \text{variation in 1m. 30sec.} \quad &- {\cdot}01382 \\ \hline & 1.15677 = x \text{ at assumed time.} \end{aligned}$$

$$\begin{aligned} \text{We have also at 0h. 50m. } y &= 0{\cdot}31100 \\ \text{variation in 1m. 30sec.} \quad &+ {\cdot}00099 \\ \hline & {\cdot}31199 = y \text{ at assumed time.} \end{aligned}$$

We have thus on the fundamental plane a right angled triangle, of which the hypothenuse is the distance between Toronto and the axis of the shadow. To compute this we have x and ξ, both negative, for to the imaginary observer at the Sun both axis and place are moving towards the meridian, not yet upon it; and y and η, both positive, being north of the centre, with η the greater.

$$\text{Then } x - \xi = \cdot 49597$$
$$\eta - y = \cdot 21862.$$

Call the hypothenuse m, and the angle at the axis M; then we have

$$m \sin M = 9 \cdot 6954554$$
$$m \cos M = 9 \cdot 3396899$$

$$\tan M = 0 \cdot 3557655$$
$$M = 66^{\circ}\ 12'\ 44''$$
$$\sin M = 9 \cdot 9614429$$
$$\log m = 9 \cdot 7340125 = \cdot 54202$$

This is the distance, in terms of radius unity, between Toronto and the axis of the shadow. If the distance m were just equal to the radius of the penumbral cone, which has its vertex between the Sun and Moon, then, at the observing station, the two limbs would be seen to be in contact. We require then to know what the radius of this cone is.

The semi-angle of the penumbral cone is very small; the log. of its tangent is computed in the ephemeris, $\tan f = 7 \cdot 6639200$. The radius of the shadow when it touches the fundamental plane is also computed, $l = \cdot 54349$. We put ζ equal to the actual distance of Toronto from the fundamental plane at the assumed time and we have $l - \zeta \tan f = L$ = radius of penumbral cone at Toronto.

To compute ζ we have

$$\rho \sin \phi' \sin \delta = \cdot 25104$$
$$\rho \cos \phi' \cos \delta \cos h = \cdot 27676$$

$$\zeta = \cdot 52780$$

$$\zeta \tan f = \cdot 00243\ ;\ l - \zeta \tan f = \cdot 54106 = L.$$

Comparing, we find that m exceeds L by $\cdot 00096$; that is to say contact has not quite occurred at the assumed time 0h. 51m. 30sec. But our problem is to determine the exact moment when the variations of all the quantities involved will bring $m = L$, that is bring Toronto just upon the surface of the penumbral cone. We consider these small variations.

The variation of ξ is expressed by

$$[7 \cdot 63992]\ \rho \cos \phi' \cos h = \cdot 0012976 = \xi'$$

The variation of η is expressed by

$$[7 \cdot 63992]\ \rho \cos \phi' \sin \delta \sin h = - \cdot 00010541 = - \eta'$$

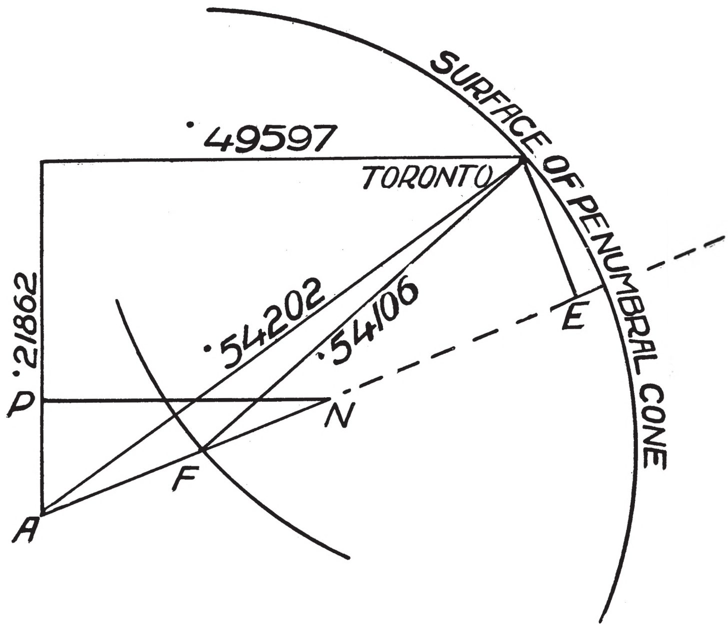
(The quantity in brackets is the logarithm of that part of the radius equal to one mean solar minute.)

The variations of x and y are computed in the ephemeris $x' = +$ $\cdot009214$; $y' = + \cdot000666$.

We note here that x' and y' are both positive, for the penumbral cone is moving eastward and northward over the disc. Again, ξ' is positive, for the observing station is moving eastward ; but η' is negative for Toronto is on that part of its latitude ellipse which curves southward from the edge of the disc to the meridian.

Then we have $x' - \xi' = \cdot007917$; $y' - \eta' = + \cdot001720$.

A simple diagram will now make the position clear ; the figure however is necessarily exaggerated and out of proportion.



T is Toronto as seen near the edge of the disc of the Earth ; A is the point where the axis of the cone touches the fundamental plane, or the plane extended. $TA = m = \cdot54202$. We have determined the *relative* motion of the axis in one minute, the observing station remaining stationary. Take $AP = \cdot001720$; $PN = \cdot007917$. Join AN, which is the relative path of the axis in one minute. From T let fall a perpendicular to AN produced, meeting it in E. With radius, L = ·54106 from centre T, describe an arc cutting AN in F. Then F is the position of the axis of the cone at the moment of first contact of the limbs. The line AF expressed in time as compared with AN which equals 60 seconds will give the correction to the assumed time.

$$\chi' - \xi' = n \sin N = 7{\cdot}8985606$$
$$y' - \eta' = n \cos N = 7{\cdot}2355284$$

$$\tan N = 0{\cdot}6630322$$
$$N = 77^\circ\, 44'\, 33''$$
$$\sin N = 9{\cdot}9899849$$
$$\log n = 7{\cdot}9085757$$
$$n = {\cdot}00810$$

The angle $(M - N) = TAN = 11^\circ\, 31'\, 49''$; $TFN = \psi$

$$\text{Then } \sin \psi = \frac{TE}{L}\ ;\ \sin (M - N) = \frac{TE}{m}$$

$$TE = m \sin (M - N)\ ;\ \sin \psi = \frac{m}{L} \sin (M - N)$$

$$\sin (M - N) = 9{\cdot}3007817$$
$$\log m = 9{\cdot}7340125$$
$$\text{colog } L = 0{\cdot}2667546$$

$$\sin \psi = 9{\cdot}3015488$$
$$\psi = 11^\circ\, 33'\, 3''$$

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

$$\log \frac{m}{n} = 1{\cdot}8254368$$
$$\cos (M - N) = 9{\cdot}9911460$$

$$1{\cdot}8165828 = 65.55 \text{ min.}$$

If now we deduct FE expressed in time we have the final connection to the assumed time

$$\frac{FE}{L} = \cos \psi\ ;\ FE = L \cos \psi, \text{ or in time} = \frac{L}{m} \cos \psi$$

$$\log L = 9{\cdot}7332454$$
$$\cos \psi = 9{\cdot}9911154$$
$$\text{colog } n = 2{\cdot}0914243$$

$$1{\cdot}8157848 = 65{\cdot}43$$

The difference ·12 min. is the line *AF* expressed in time and in this case to be added to the assumed time. The result is 0h. 51m. 37·2sec. as the moment of first contact, at Toronto, in Greenwich mean time. In standard time this is May 28th, 7h. 51min. 37·2 sec. a.m.

TWENTIETH MEETING.

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

A letter was read from Dr. B. Walter, of Hamburg, asking for a copy of Mr. Lefroy's photograph of the lightning flash, which it was resolved to forward.

Prof. E. C. Pickering, of Harvard, had kindly forwarded, for the use of the members, copies of the region of the heavens around the radiant point of the Leonid meteors.

A discussion followed regarding the work which might be done in Toronto, all the members present agreeing to make systematic observations, on the nights when the meteors might be expected.

Mr. W. B. Musson introduced the subject of lantern-slide exhibitions, and in the course of the discussion which followed it was suggested that public lectures might be given by members of the Society, if the City Council would give the free use of certain public buildings. The Secretary was instructed to address the Mayor and Council in this matter.

Mr. A. Elvins then read by request a paper on "Invisible Light," from a current periodical. This referred to the work of M. Le Bon and explained how light had been proved to have the property of penetrating bodies we call opaque, without the aid of Crookes' tubes or the electric current. Mr. Elvins stated that he would at an early date endeavour to repeat the experiments of M. Le Bon.

TWENTY-FIRST MEETING.

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

Letters were read from Mr. F. W. Salmon, of Windsor, Ont., and from Mr. J. A. Corbett, of Thornton, Ont. The latter wished to join the circle of observers of Leonids, with a view to working up a report for Harvard Observatory.

Several members had been in correspondence with Mr. E. McLennan, of Brooklyn, Iowa, on the subjects treated in "Cosmical Evolution," some copies of which Mr. McLennan had donated to the Society's library. A discussion was entered into on the merits of the views expressed by the author. The chief difficulty in the way of agreeing with the results brought out was that the phenomena of Nature were not explained in any more simple manner than they already are. Indeed, some of the members thought that greater difficulties had been brought in by Mr. McLennan's persistent refusal to recognize the Newtonian theory of gravitation. It was due, however, to the author, to say that he most decidedly had the courage of his own convictions.

TWENTY-SECOND MEETING.

November 14th; this was an open meeting, held in the Physical Room of the Toronto University, Mr. Arthur Harvey, F.R.S.C., in the chair.

It had been announced that Mr. C. A. Chant, B.A., Lecturer in Physics, would deliver a lecture on "The diffraction of light"; invitations had been issued to all friends of the Society, and a large audience was present.

Mr. Chant's paper was illustrated by a very elaborate series of lantern slides, and was thoroughly appreciated. The special thanks of the Society were voted to the lecturer for the pains taken to make the subject easily understood.

TWENTY-THIRD MEETING.

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

A letter was read from Mr. J. W. Ney, of Bracebridge, Ont., describing a very brilliant meteor seen by him on the evening of November 12th. The President stated that this had also been seen in Toronto.

The report of the Corresponding Executive Committee of the British Association was received and found to contain an excellent account of the work done in Toronto during the past year.

Reports of observations of the Leonids being asked for, it was found that none of the members had met with sucess. The Secretary stated that he had received a report from Miss McBain, of Port Dover, relating to observations in 1898, when a large number of Leonids had been seen at her station.

Mr. A. Elvins then read the follwing note on

THE TIDES.

We have been accustomed to think and speak of the tides as sweeping around the Earth. I question if this conception is the correct one, and I think a truer conception of what is really taking place could be formed in the following manner :—

Think of a mass of yielding matter possessing cohesion enough to form a sphere. Now let this mass be revolved around a centre outside of itself, and held in its orbit by gravitation. The attraction of the central body would act more strongly on its nearer than on its further side, and the tangential force would be strongest at the most distant point. This would elongate the sphere, lengthen it in the direction of the radius-vector, and in form it would become a prolate spheroid.

When formed, let us conceive a solid globe to be placed in its centre, and let *this globe* rotate on an axis nearly at right angles to the plane in which the whole mass revolved, but making about 28 rotations whilst the prolate mass, in common with itself, made one revolution around the central body.

Under such conditions a point on the equator of the solid *globe* would pass twice through the longer axis of the eclipse of the fluid mass, viz., when it was nearest to, and when it was farthest from the centre around which the body *revolved*. This is just what happens in the case of the tides, the mobile waters (and, I think, air) take the prolate form as a result of the motion of the Earth around the Sun and Moon, and it would be better to conceive the elongated waters as the fixture, and the Earth turning round in it every 24 hours, whilst the waters rotated (or rather revolved) once in a lunar month.

But for the projecting land, the water of the ocean would retain its prolate figure, and the longer axis would point moonward, and so any point of land would pass under a high tide twice each day.

As the Moon passes over about one twenty-eighth part of its orbit every 24 hours, the tide will be somewhat less than one hour later each day.

The friction of the waters on the solid Earth becomes quite apparent in this way of viewing tides, and the retardation pointed out by Prof. Darwin, is seen to be a necessity unless it is counteracted by some other force.

TWENTY-FOURTH MEETING.

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

Mr. J. W. Ney, of Bracebridge, had written describing an interesting meteor seen on December 9th. In this case there was a double explosion; Mr. Ney thought that after the first explosion one piece went on and again exploded, while the other piece fell to the Earth.

Mr. Benjamin S. Mayhew, of Clive, Manitoba, had forwarded the following notes of observations of meteors :—

Observation on November 13th, from 11 p.m. till 2 a.m.: No meteors seen, sky became overcast from 2 a.m.

Observation on November 14th, from 11 p.m. till 2.30 a.m.: No meteors seen; sky became overcast from 2.30 a.m.

Observation November 15th, from 11 till after midnight, when clouds came: no meteors seen.

November 16th: Cloudy.

November 24th: Observation from 11 p.m. for several hours. Meteors fell from all parts of the heavens, in all directions, about eight every five minutes, most of them small, occasionally one brilliant. For an hour before dawn they fell at about the same rate, and of similar appearance.

The meteors seen on the 24th were thought to have been Andromedes, as these would be seen in the manner described by Mr. Mayhew.

The Librarian reported having received from the directors of the Paris Observatory the first set of photographs published by the International Congress for the Photographic Survey of the heavens.

The thanks of the Society were ordered to be conveyed to the donors for this most valuable addition to the library.

Mr. J. G. Ridout reported having observed a minimum of Algol on December 6th. It was noted that there would be a minimum on the night of the next meeting of the Society.

The President then called upon Mr. C. A. Chant, B.A., to continue the subject of "Diffraction of Light."

Mr. Chant explained thoroughly how the diffraction grating may be used for the purpose of making measurements of the wave lengths of light, and proceeded to the experiment, which was successfully conducted and proved of the greatest interest to all present.

TWENTY-FIFTH MEETING.

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

Before proceeding to business, the members adjourned to make an observation of Algol, which was then declining in brilliancy.

On resuming business, Rev. R. Atkinson was duly elected an active member of the Society.

The nomination of officers for the ensuing year was then proceeded with and resulted as follows, the nominations in all cases being unanimous: President, Mr. Geo. E. Lumsden, F.R.A.S.; Vice-Presidents, Mr. R. F. Stupart and Mr. C. A. Chant, B.A.; Corresponding Secretary, Mr. W. B. Musson; Treasurer, Mr. Chas. P. Sparling; Recording Secretary and Editor, Mr. Thos. Lindsay; Librarian, Mr. Z. M. Collins; Director of Photography, Mr. D. J. Howell; Members of Council, Mr. A. T. DeLury, B.A., Mr. J. R. Collins, Mr. G. G. Pursey, Mr. J. Phillips, Mr. J. G. Ridout.

Several reports were received ot observations of the partial eclipse of the Moon which had occurred on December 16th. Mr. Howell and Mr. Collins noted that the peculiarity of colour had not been so pronounced as in the case of a total eclipse. Some of the members present confessed to having overlooked the phenomenon entirely. Among these was Mr. Lindsay, who stated that he had no apology to offer, for like many others he had been too much absorbed in watching the record of events transpiring in South Africa, to take much interest in the path of the Moon. He had been glad to learn that the temporary darkness had aided the gallant defender of Ladysmith in his flashlight signalling operations.

Mrs. A. G. Savigny then read a brief but concise review of the work done at Flagstaff, Arizona, by Mr. Percival Lowell and his staff. The planet Mars was specially dealt with, Mr. Lowell having added so much to the existing knowledge of that body. The contention of the observers at Flagstaff, that the seeing there is distinctly better than at other stations, was referred to and occasioned some discussion. Conditions similar to those at Flagstaff had been said to exist in our own Muskoka district, and had been frequently the subject of remark. Some of the members present had met Mr. Lowell on the occasion of his visit to Toronto in 1897, and were specially pleased with Mrs. Savigny's review of the work of one whose charming personality it would be hard to forget.

ANNUAL MEETING.

January 9th, 1900; the President, Mr. Arthur Harvey, F.R.S.C., occupied the chair.

The officers nominated at the previous meeting were declared elected for the year 1900.

The unfinished business of the previous meeting was then taken up; this related to the election of the Honourary President of the Society.

It was moved by Mr. Geo. E. Lumsden, seconded by Mr. Chas. P. Sparling, and

Resolved, That on the occasion of becoming Prime Minister of the Province of Ontario, and retiring from his position as Minister of Education for the

Province, this Society wishes to place on record its appreciation of the countenance given to it by the Honourable G. W. Ross, LL.D., who, by reason of being such Minister of Education, was invited and gladly consented to become the Honourary President of this Society, an office which he has graced and which he has filled to the satisfaction of the Society; and that a copy of this resolution be forwarded to Dr. Ross.

It was then moved by Mr. W. B. Musson, seconded by Mr. G. G. Pursey, and

Resolved, That the Honourable Richard Harcourt, M.A., Q.C., Minister of Education of the Province of Ontario, be asked to accept the position of Honourary President of this Society, in the room and stead of the Honourable G. W. Ross, LL.D., who, having become Prime Minister of Ontario, has resigned the said office of Minister of Education, and relinquished the said office of Honourary President, which he occupied and held as such Minister.

The question of appointing an Assistant Librarian was then discussed. Mr. Elvins stated that he would be glad to give Mr. Collins any assistance he might require. This being most acceptable to the Society, Mr. Elvins was appointed Assistant Librarian.

Mr. Elvins called attention to the announcement of the death of Mr. Green, an old contributor to the *Astronomical Register*, at a time when Mr. Elvins was a contributor and correspondent. Mr. Green would be missed very much in the astronomical world.

The report of the Treasurer was read and adopted. The financial position of the Society was about the same as at the close of the preceding year.

Mr. W. B. Musson read his report of progress made in regard to the Library. Several additions had been made to the exchange list, and a large number of sets of publications had been bound. It was the intention soon to issue a complete catalogue of books, monographs, etc., in the Library.

Mr. D. J. Howell reported progress madè in his department, and stated that he had made a complete set of negatives of the plates of the Lunar Atlas as far as they had been received from Paris. These would soon be ready for lantern projection.

After a general discussion on various matters of interest the meeting adjourned, closing the tenth year of the Society's existence.

ASTRONOMY, IN INFANCY, YOUTH AND MATURITY.

[*Address delivered before the Astronomical and Physical Society of Toronto in the Lecture Hall of the Canadian Institute, January 23rd, 1900, by the retiring President, Mr. Arthur Harvey, F.R.S.C.*]

The President, Mr. Geo. E: Lumsden, F.R.A.S., occupied the chair

I have found it as difficult to choose a title for my farewell address as to condense it into reasonable compass. I wish to treat, first, of the earliest stage of the development of our science; next, of the time and manner in which it threw off its swaddling clothes; and lastly, of some of its latest achievements. Mr. Lindsay, our editor, suggested as a caption, "The Growth of Astronomy," which will do very well, but I do not intend to attempt a consecutive history.

To be orderly, this paper should begin with the enquiry how old our civilization is.

Plato makes his Kritias tell a curious tale. He brings him to our notice as an old man, who, when a boy, heard from his grandfather the story Solon brought from Egypt. A priest at Sais told the Athenian student that the present Greeks were children, ignorant of their own history; they had really occupied Hellas 8,000 years before,* and had waged successful war with the Atlantides, who, coming from a great island just outside the Pillars of Hercules, had subjugated Europe and Africa, as far as the Tyrrhenian sea on the north, and Egypt on the south shore of the Mediterranean. Suddenly, however, great earthquakes and floods occurred, as indeed in the history of the human race they often had before: the island of Atlantis was submerged, and the Greek hosts were also swallowed up. In these floods the cities suffered destruction, and none but the hill folk escaped, so that Hellenic civilization had to recommence. Egypt, however, had always been free from earthquakes and torrential rain, having only the usual regulated flood of the Nile, wherefore it had preserved the records which traced back its history to the foundation of the kingdom—9,000 years before. The description given of the Atlantic island is minute, and it has ever

* In the Timæus the figures are thus given, in the Kritias a thousand more years are added.

been a debated question whether Plato's account is altogether mythical or not. I incline, with Grote, and against Jowett, to think it had a foundation in some recorded facts, though there is little to favour the contention of an American writer that the ancients had a regular communication with Mexico and Peru by galleys which rendezvoused near Ceylon and proceeded to the west coast of both North and South America.

Saint Augustine, in his great work *De Civitate Dei*,* refers to a letter written by Alexander the Great to his mother Olympias. After the conquest of Persia, Alexander turned his arms to Egypt, which had for a short time been most unwillingly subject to the Shah. He was received rather as a protector and liberator than as an enemy, and as he professed respect for their great past, for their monuments and their religion, he was favoured by the priests, who were the depositories of historical and scientific lore. One of these supplied him with information from the sacred books to the effect that even the Assyrian kingdom was 5,000 years old, though the Greek histories, which began it with the same king, Belus, assigned to it only 3,500 years. He gave as the duration of the Persian and the Macedonian empires more than 8,000 years, though the Greeks allowed but 580 for the growth of Macedon, and but 233 for the Persian rule. Yet, said he, these high numbers must be trebly multiplied to reach the antiquity of Egypt! St. Augustine died in A.D. 430, when authentic copies of Alexander's letter may have been still extant. In an endeavour to minimize the length of time, he says the Egyptian year had been one of four months only, but Diodorus expressly states that it consisted of three hundred and sixty-five days six hours, and he gives to Egypt an antiquity of more than 20,000 years. Callisthenes, who was in Alexander's retinue, informed Aristotle that the Babylonians reckoned their city to be at least 1,903 years old when Alexander entered it. And Manetho, who was keeper of the Egyptian archives under Ptolemy Philadelphus, gave 5,300 years as the recorded length of the Egyptian dynasties.

We now have evidence from papyri, monuments and tablets to check these figures, for we have learned to read Egyptian and Assyrian almost as well as our own language, and have spaded up whole libraries of information. The Prisse d'Avennes papyrus is claimed to be the oldest writing in the world, and of the third dynasty 5,318 B.C. It is in a bold, clear, firmly set handwriting, which tells of a civilization old

* Book XII. chap. 10.

even then. Mr. J. C. Conder * says the Babylonians of the sixth century B.C. believed the first Chaldæan empire was established more than 3,200 years before their time, and it was certainly founded by men of Mongol race, whose language, called Akkadian, is found on the oldest records. Scholars have not yet come into thorough accord ; one Dr. Hilprecht assigns 3,000 B.C. as the date of an inscription in cuneiform writing, which displaced Hittite hieroglyphics when Semitic races became powerful around Babylon, while a Dr. Oppert thinks it a thousand years later. However, the earliest Assyrian and Egyptian records come fairly close together, and there seems no prospect of tracing either further back than six or seven thousand years.†

The origin of astronomical studies is coëval with reason and observation, and a singular record of them appears to be found in the pyramids of Egypt. They seem to have had openings from which a passage led to the interior, so built that on a certain day the Sun or a given star could be seen from the recesses of the monument, as if shining down a tube To such stars these pyramids are said to be "oriented." The most recent investigation of this interesting subject is to be found in the *Proceedings* of the Royal Society for last November, where Dr. E. A. Wallis Budge discourses on the Pyramid fields of the Soudan, which are especially important because while in northern Egypt the pyramids are oriented east and west, in southern Egypt and the Soudan, star worship is indicated. These tombs had on the south-east side a shrine or chapel, "into the innermost part of which the light from the celestial body to which it was oriented could enter. * * They consisted of two and sometimes three chambers with narrow doorways which served, like the various sights and sections of a telescope, to direct the rays of light from the celestial body to a given spot—that spot in the case of a pyramid being the centre of the shrine, where a figure of the deceased was placed." Now in these Soudan cemeteries, the star chiefly used as a "warning star" is Alpha Centauri, and it was so used from the XIIth dynasty, about 2,700 before Christ. As, owing to the precession of the equinoxes, the place of a star must change, the later tombs would have an orientation

* Scottish Review, October, 1899.

† The Chinese records do not much differ, for they state that the first Emperor Fohi reigned 2,952 years before Christ, and he, too, composed astronomical tables. The first King of the Indies is said to have lived 3,553 years before our era, and the astronomical epoch of the Brahmins is supposed to begin in 3,101 B.C.

somewhat different from the earlier ones, and Dr. Budge says the theory is strengthened by the fact that "archæological considerations indicate that the pyramids which have different orientations belong to different periods."

Prof. C. Piazzi Smyth, as you probably all know, wrote a book on "Our Inheritance in the Great Pyramid," in which he insisted that it was a measure of the polar diameter of the Earth, and was intended as a standard of weights and measures. It seems, however, thoroughly established that it is so oriented that the passage points due north, at an angle which Col. Howard Vyse measured as 26° 41′. Sir John Herschel calculated that in 2,121 B.C. the star α Draconis was the Pole star, and that its lower culmination was then 26° 15′ 45″. As the annual precession in north polar distance in that part of the sky is 18″, the date of the orientation, supposing Col. Vyse's measure to be exact, was 83 years before, or 2,204 B.C.

According to Dr. F. C. Penrose, Greek temples were similarly oriented, and in the same number of the *Proceedings* of the Royal Society he gives several new instances. Three of the temples he has thus surveyed are oriented to α Arietis, rising; two to Spica rising; one each to α Pegasi setting and α Leonis rising. To illustrate the method of investigation I transcribe one :—

Name of Temple.	Orientation Angle.		Stellar Elements.	Solar Elements.	Name of Star.
The new Erechtheum.	265° 9′	A. Amplitude of star or Sun.	+ 6° 30′ E	+ 7° 20′ E	α Arietis rising.
		B. Corresponding altitude..	4° 0′	3° 25′	
		C. Declination	+ 10° 35′	+ 7° 34′	
		D. Hour angles	6h. 13m.	7h. 26m.	
		E. Depression of Sun when star heliacal	......	12°	
		F. R. A..................	23h. 58m.	1h. 11m.	
		G. Approximate date	445 B.C.	April 9	

In the case of temples the star would shine through some opening in the wall into the adytum at the date of the festival with which the temple was connected.

The Greeks took lessons in astronomy from the Egyptians, and perhaps from the Assyrians, and in due course became the teachers of the

Roman world. Lucretius. the poet of science, gives them that credit in some noble verses,* which suffer grievously in my translation :—

> Of old, when Human life lay crushed to earth
> By onerous creeds, each claiming heavenly birth,
> Which showed their horrid forms in dreadful guise,
> The Greeks first dared to lift their questioning eyes.
> No tales about the gods, no lightning dire,
> No growling thunder, threatening heaven's ire,
> Cowed their free minds or stopped their opening wide
> The gates of nature, theretofore untried.
> And thus the living forces of the soul
> Began to contemplate one glorious whole,
> Outreached the luminous boundaries of Earth,
> Made the great universe a field of worth
> For mental culture, and correctly taught
> The lawful bounds of profitable thought.

In his "Republic,"† Plato considers of the sciences to be studied. First, he mentions arithmetic, and then geometry, "which draws the soul towards truth and creates the spirit of philosophy." Next, he names astronomy, "For every one, as I think, must feel that astronomy compels the soul to look upwards and leads us from this world to another." "The spangled heavens," he urges, "should be used as a pattern, and with a view to that higher knowledge." And he insists that they should be studied with love "since knowledge acquired under compulsion has no hold upon the mind."

These old philosophers had some fair conceptions of the mechanism of the heavens. A paper by Mr. W. B. Musson, in our *Transactions* for last year, gives an excellent account of the theories of motion held by various Greeks, and Vince's "Complete system of astronomy," which we possess, gives a good summary of the history of the science among eastern nations. It seems clear to me that Plato spoke of the Earth as "revolving" around its pole, though the word used may have another meaning. Nor could Anaxagoras have explained the way in which the Moon is illuminated unless he had understood its motion with reference to both Earth and Sun. He was imprisoned for so doing ; the world often maltreats its benefactors. The Aristotelians reasoned out the necessary rotundity of celestial bodies, and the Pythagoreans seem to have held a proper theory of the revolution of the wandering stars. One can see in

* De naturâ rerum, Lib. I., vv. 63-67. † Book VII.

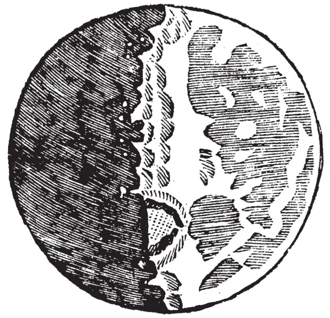
the Atlantean myth that the ancients appreciated the effect upon our globe of seismic forces and of heavy storms. But though they prepared the way for such men as Tycho Brahé and Copernicus, we must honour Galileo Galilei as the man who launched the barque of astronomical science upon its great modern career. All before him I call the childhood of astronomy. With him its vigorous youth began.

Our Librarian has placed us in possession of a copy of Galileo's works, printed at Bologna in 1655, only thirteen years after his death. It seems to me that we get nearer to the great men of past centuries through the perusal of these old editions, and he must be dull indeed who does not feel a thrill of unusual interest when he sees the *Syderius Nuncius* in something like its original dress.

After the dedication to Cosmo, of the Medici, dated in March, 1610, and the license to print, declaring that the work contains nothing contrary to the Holy Catholic Faith, the State, or approved custom, the second and fuller title of this celebrated tract appears, "*The Astronomical Messenger*, being an account of recent observations with the new Perspicillum on the surface of the Moon, the Milky Way and the nebulous stars; also of the innumerable fixed stars and of four planets named the stars of Cosmo, never before seen." (In the dedication they are called "Medicean stars.")

"About ten months ago," says Galileo, "there came a rumour to our ears that a certain Belgian had made a lens by the aid of which visible objects, though far from the eye, could be distinctly seen, as if they were near, * * which some believed and others not. A few days afterwards the fact was confirmed in a letter I had from Paris, which caused me to turn my thoughts to the reason for the effect, and to preparing an instrument that should produce the same result. I studied the subject of refraction, and, having made myself a leaden tube, I fixed glass lenses in the ends of it, plane on one side and spherical on the other—one convex and the other concave. On placing my eye to the concave glass, I looked at some objects of fair size and at a short distance, which I found three times as close and nine times as large as when looked at with natural sight. I then made another instrument which magnified sixty times. Finally, sparing neither time nor money, I made one so excellent that things seen by it were almost a thousand times enlarged, and appeared more than thirty times as close as when viewed by unaided vision."

The revolutionary and epoch-making narrative of two months' observations follows.



First as to the Moon. "It is of consequence," he says, "to know that the surface is not smooth and highly polished, as formerly supposed, and of exact spherical shape, as the great cohort of philosophers have thought it and other celestial bodies to be, but, on the contrary, accidented and rough, covered with swellings and cavities, and furrowed like the Earth with mountain ridges and deep valleys." He likens the spots to the eyes on a peacock's tail and to the marks on the surface of chilled glass. He applauds the Pythagoreans, who said the Moon was like another Earth, and thinks the Earth, seen from afar would resemble her, especially in mountainous parts like Bohemia. Alluding to the features we call *maria*, as well as to the more frequent but smaller craters, and the differing phenomena of sunrise and sunset thereon, he opines that lunar hills are much loftier than ours.

As to the fixed stars, he thinks it strange they do not appear so much increased in brilliancy as the power of the telescope would seem to call for, since with a magnifying power of a hundred, stars of the fifth and sixth magnitude show no brighter than those of the first do to the naked eye. While the planets look like spheres or little moons, no disc can be noticed to the fixed stars, which are surrounded with rays, like lightnings, but in addition to the stars of the fifth and sixth magnitude the lens reveals an incredible number of smaller ones. His pamphlet gives several engravings of the Moon, and diagrams of the belt and sword of Orion, also of the Pleiades, in which he shows 36 stars instead of the six which are usually visible to the naked eye. He proceeds to rejoice in setting the world free from the disputes, which for so many centuries had engaged philosophers, as to the essence or material of the Milky Way, which is seen in his telescope to be merely a collection of innumerable stars, and, passing to nebulæ, he gives an engraving of one in the head of Orion; also of the Prasepe. In the former he figures 21 stars, and the latter, so far from being a single object, is an assemblage of more than 50. Lastly, and with more interest still, he describes the four secondary planets he has discovered, circling around Jupiter. On the seventh of the preceding January (1610), in the second hour of the night, he was looking at the stars with his newest telescope, when Jupiter became visible, and he saw three small but bright stars near the planet, which he supposed to be fixed, but admired because they were in a straight line, parallel to the ecliptic. Two were to the east of Jupiter, one to the west. Eight days thereafter, by a chance he cannot explain, he looked again, and saw quite a different situation; all three were west of the great planet. His work gives 65 diagrams of their positions, with an occasional fixed star as a point of comparison, and explains that the four satellites revolve around Jupiter as the Moon does around the Earth.

The whole of these announcements—title, dedication, figures and all—are contained in a pamphlet of 41 pages, and, at the end, the "candid reader" is told he may expect more soon, a promise which was fulfilled in the *Continuation of the Sidereal Messenger*, issued in 1611.

Galileo having found in his survey of the heavens something he did not wish to publish at the time, announced it to Kepler in the following jumble of 37 letters:—

Smaismrmilmepoetaleumibvnenvgttaviras.

Kepler tried to put this "pie" into intelligible words, but failed, so on November 13th, 1610, Galileo wrote to him from Florence, whither he had moved from Padua, and gave him the answer to the enigma:—

altissimum planetam tergeminum observavi.

(I have seen the farthest planet divided into three, or, consisting of three parts.)

Another such jumble concealed until 1st January, 1610, the discovery of the phases of Venus. The *Continuation* announced also, though with some uncertainty, the gibbosity of Mars. No wonder Kepler said that Galileo used his lens like a ladder, with which to scale the furthest and loftiest ramparts of the world!

But all was not done yet. Our volume contains the long and famous treatise *Delle macchie Solari* (on sun-spots), the equally famous *Saggiatore*, and the four dialogues in which Salviate, Sagredo and Simplicio, discuss the causes of coherence and the method of finding centres of gravity. An appendix gives an account of the new discovery that projectiles have a parabolic course, and of one of Galileo's first observations, that the pendulum swings in equal times whatever be the arc it describes—a discovery which was fatal to all previous time-keeping appliances, orientations of public monuments, sun-dials, clepsydras, and hour-glasses.

Those who feel that they have added something to the sum of human knowledge can understand the sentiment of Horace, "*Non omnis moriar.*" It was not mere vanity that inspired Archimedes, as, leaping from his bath, he cried "Eureka!" when the principle of specific gravity flashed upon him. It was not an ignoble impulse that animated Bacon, who said, "We build the foundation of the sciences deeper and more securely and begin investigation earlier than man has done before," nor should we irreverently listen to his prayer "that the Father who gave visible light as the first fruits of creation, and at the completion of His work inspired the countenance of man with the light of understanding, would vouchsafe to endow the human race through his hands with gifts of knowledge." When Newton discovered the law of gravitation he was so ecstatic that he had perforce to employ hired service to complete his calculations about meaner subjects. Franklin's chief honours were given him because with his key and kite string he first drew lightning from the clouds. *Fulmen eripuit cœlo* is a juster title to honour than the *Sceptrumque tyrannis* which completes the inscription on his celebrated medal, and none can have felt more justly sure of the so-called immortality of fame than Galileo, when he opened a glorious new vista in the sky. He accomplished for the heavens what Columbus had recently been doing for the Earth. He loosened the clasps of a new volume of nature's records and spread open many of the most beautifully illuminated pages of a missal which, before his time, had been all but closed. From Prometheus to Darwin there is hardly a nobler name. Yet in his lifetime he was not happy, and even now there are some who grudge him his posthumous glories.

It was, of course, time for his discoveries. Leonardo da Vinci made drawings of a combination of lenses for seeing distant things enlarged, long before the Belgian Lippershey produced his telescope, and had not the inspiration come to Galileo to point the magic tube towards the heavenly spheres, it would soon have been done by others, for the

May-time of the modern world was drawing forth the long slumbering energies of mankind. But Lecnardo did not put to use the telescope he designed. He locked up in all but undecypherable notes his proofs that the Sun is central and the Earth revolves around it. He was of a procrastinating disposition, and, though divinely gifted in Art, has left all too few exemplars to an admiring world. Therefore Copernicus can justly claim the honour of unlocking the riddle of planetary motions, and Galileo that of bringing the heavens closer to the Earth. There are often more discoverers than one of important facts, quite independent in their work, but the world recognizes him who first makes known his claim and carries on a successful fight for its establishment.

The *Saggiatore* is in this light an instructive document. The title is singular. It means "the assay scales," most delicate of balances, and is in great part a reply to the *Libra Astronomica* of Lotario Sarsi. It leads off with a complaint that the author's desire to serve the world by publishing his discoveries was met with enmity, detraction and fraud. Galileo was angered by the self-sufficient folks who cheapened the value of his work. "Why," he cries, "what a field for admirable speculation was afforded by my letter about solar spots, yet many disbelieved or thought little of it, doubted the correctness of my observations and theories, or imputed to me ridiculous or impossible opinions. One person has even claimed priority in the discovery." He was especially irritated because one Simon Marius, who had in earlier years stolen the idea of his geometrical compass, now claimed to have seen the satellites of Jupiter before him, and published a book, the *Mondo Gioviale*, to say so. The *Saggiatore* was printed in 1623. Later, in 1638, in dedicating his dialogues to the Count de Noailles, Galileo says he had been so confused and stupefied by the bad success of his other works that he once resolved not to print again, but to leave his manuscripts in some public places. His troubles with the Inquisition had, moreover, been followed by partial deafness and total blindness, and it was when thus afflicted that our Milton visited him.* *Paradise Lost* seems to bear evidences of the meeting. In it he dreams of—

—"A spot, like which, perhaps,
Astronomer in the Sun's lucent orb
Through his glazed optic tube yet never saw."

* "There it was that I found and visited the famous Galileo, grown old, a prisoner to the Inquisition, for thinking in astronomy otherwise than the Franciscan and Dominican licencers thought."—Milton's *Areopagitica*.

And, with the poetic instinct, always prophetic, he speaks of the lordly Sun's

> —"Magnetic beam, that gently warms
> The universe, and to each inward part
> With gentle penetration, though unseen,
> Shoots invisible virtue, even to the deep."

Milton, himself sightless, remembered Galileo when he cried :

> "Seasons return, but not to me returns
> Day, or the sweet approach of even or morn,
> Or sight of vernal bloom, or summer's rose,
> Or flocks or herds, or human face divine—
> But cloud instead, and ever-during dark
> Surrounds me."

Even in his blindness, however, the great Italian must have found some consolation, as Milton did, in knowing that he had done much to enlighten the world, and posterity has done him justice. The whole Earth has made the assay, and weighed the button of gold correctly, and found Galileo's work entitled to the hall-mark. One would like, did time permit, to dilate on the almost parallel experience of Columbus. But it will be enough to say that when one had found the way across the Atlantic and the other had bridged the sky, they had hosts of followers who enlarged their discoveries. For each in his chosen way stood at the dividing line between the childhood and the youth of knowledge. Each in his sphere broke the leading strings with which the world had been guided, for the time for guidance at the hands of antiquity had passed, new methods and new instruments were needed, new aims animated a re-born world; but while we recognize the fact, and so far from regretting it, are endeavouring as our chief object in this Society to help the progress of the new sciences, we must not forget the respect due to the ancients, who nourished them in infancy.

Let us now issue a new *Sidereal Messenger* and take up the subjects treated in the old tract. We have in our library the first plates of the great Lunar Atlas, the work of Messrs. Loewy and Puiseux, at the Meudon Observatory near Paris. The Society is having them photographed and adapted to lantern slides, believing that in this way we can here extend the liberality of the French Government. Galileo would stand long in wonder if he could see them ! He would have to be told of the achromatic telescopes we now can make, with equatorial mounting, moved by clock work, so perfected as to follow the complex apparent motions of the Moon to the smallest fraction of a second in both latitude and longitude. He would have to hear the story of the photographic plate, undreamed of in his time. When he had mastered the elements of the new science of geology, he would perceive he could no longer agree with the Pythagoreans who thought the Moon was like the Earth. For, however carefully we scan these grand lunar maps, we can see no trace of any Neptunian action, no effect that can be referred to the influence of air or water, nothing that resembles the terrestrial layers of limestones, slates or clays. The Moon looks like an aggregation of primitive rocks, and if there have been inundations, they have been those of lava, stiffening quickly in the intense cold of space. The authors of these maps think they see evidence of five successive lava-flows. The lunar mountains, higher in proportion yet not quite so elevated as those of Earth, have been measured as well as mapped, and we are watching with the greatest care for some little change in the stony face, which we think will be noticed, if at all, in connection with the small secondary craters of which there are so many, and will be traceable by comparing later photographs with these, for without air or water there can be no smoke or other of the phenomena usual in terrestrial convulsions. The *maria*, which Galileo thought were places covered by stationary clouds, are now known to be low-lying plains, without mists of any kind, though why they are darker than the hilly regions we do not yet know. How he would enjoy looking at our twin planet with the various forms of telescope invented since his day, though he would find none of them fitted with the combination he employed, which has been relegated to the opera glass alone. It would be news to him to hear of the discovery of planets beyond Saturn, but not surprising to learn that there are moons for all the large planets outside the Earth, for he thought it likely. He knew nothing of the hundreds of Asteroids.

Would it not be delightful for Galileo to discourse with us of light? He devotes a page in his first dialogue to a suggestion for measuring its velocity. He wished to have a lamp put on a distant hill in charge of a confederate, and to place a similar one beside himself. This he intended to suddenly cover up, and when its extinction was noticed afar off, the other observer was to cover his. He tried this method, but only at the distance of a short mile, and he was "unable to decide whether light expanded instantaneously or not, but if not, it was extremely rapid." He says he thought light somewhat resembled sound in its way of moving, but added that he saw difficulties in the way of its traversing a vacuum across the infinite, across the indivisible, across instantaneous motions, and there were other matters to be reasoned out in this connection. Here was the infinite so bounded by numbers as to become unity; from the indivisible must be born infinite divisibility, a vacuum must become a plenum, and finally the circumference of a circle must be considered as an infinitely long straight line. How gratified he would feel to learn that his own Medicean stars gave the first measure of the velocity of light by the difference of time in the occurrence of their eclipses, when Jupiter was in opposition and conjunction. It is not a little singular that Foucault's experiment, which first measured the velocity of light across terrestrial distances, was really based on his suggested method. Astronomical and physical science has certainly progressed far when we can correctly measure the wave-lengths of variously coloured light with a two foot rule, as our Mr. Chant did in our presence, at a recent meeting of this Society. Now that we have the spectroscope, to combine with the telescope and the photographic film, the science seems to have reached maturity, and is in the plenitude of its powers. Perhaps we may carry on the simile and say that Newton, who first produced the sunlight spectrum in a scientific way, and discovered in gravity the bond which holds all worlds together, married astronomy to physics, so that Urania no longer sits on a solitary eminence. The union has been fruitful, and while some of the intimates of the pair prefer one, and some the other as a friend, all respect them both, and even we, in the very name of our Society, profess to be admirers of the happy conjunction.

Our new *Sidereal Messenger* cannot indeed say that the stars have a perceptible disc, but we know the distances of many of them, we know that they are in rapid motion, that they are of many kinds, in various stages of growth or decay, that they are not all luminous, that some are revolving around each other. We know several of the substances present in their glowing atmospheres and we are engaged in measuring not only the light they emit but the heat we receive from them, and such is the perfection of our instruments, that at the Yerkes Observatory, Mr. Nichols has a radiometer so sensitive that the heat of a candle, 28 kilometres or 17½ miles away, will make it deviate a millimetre. Arcturus gives us no more heat than a common candle 8 or 9 kilometres or 5 miles distant. Yet we can measure it! What would

Galileo think of the photographic examination of Omega Centauri, in the southern hemisphere, where over 7,000 stars are seen in a luminous patch resembling a faint cloud, and smaller than the Moon, of which we know that 120 are variable?

Galileo was fortunately wrong in thinking he had settled all questions about the Milky Way; it is the subject of more lively interest now than ever. It seems to be the rim of the stellar aggregation of which our Sun forms part, and may be likened to the equator on the globe. Most stars of the first magnitude appear to be disposed in another great belt in a way resembling the ecliptic. The stars of different constitutions seem to be sorted out in layers or streaks, insomuch that a great difference is noted between the actinic and visual light of stars of different galactic latitudes. The most earnest attention of astronomers is now being given to stellar spectroscopy, the precise work being three-fold—the classification of stars according to the type of spectrum they show, the measurement of the wave-lengths of their bright and dark spectral lines, to identify the substances in their atmospheres, and the measurement of the displacement of such spectral lines from the normal, by which the velocity of the stellar motion in the line of sight can be determined. For this, the giant telescopes are used, also for the measurement of close double stars, the spectroscopic and photographic examination of nebulæ and the discovery of new planetary satellites. They are not employed in the work formerly done by smaller instruments, but in that which until their advent could not be done at all, so that the smaller observatories still have their hands full, and there is room even for the ordinary instrument of the amateur. To place this question on its lowest plane, 'tis clear there is no telescope so small that its use will not give a better conception than the unaided eye of the features of the Sun, Moon and stars, and enable its possessor to read with increased interest the works of astronomical writers.

One of the most interesting discussions of the present day is as to the age of our system, and especially of our own planet, which is distinct from the question of the time when man first developed upon it, and equally natural and appropriate at the close of a century. Between the physicists and the students of the natural sciences, the battle rages hotly. At the head of the former stands the illustrious Lord Kelvin, who announced his opinion in 1862, when he was Prof. William Thompson.* From the rate of increase of heat as the miner goes down-

* *Transactions* Royal Society Edinburgh, vol. xxiii.

ward, he reasoned out the rate of secular cooling, and declared that our Earth must be more than twenty but less than four hundred millions of years old. This argument has been reinforced by one depending on the retardation of the Earth's rotation by tidal friction, and another on the limitation of the age of the Sun. Lord Kelvin has, therefore, reduced his maximum to "not much more than twenty millions." The contest is by no means new. In the Atlantean myth are clear traces that the geologists of pre-Christian days required great lapses of time between deluge and deluge. That great geologist Hugh Miller, though a cataclysmist, a believer in the sudden destruction of whole races of living beings by terrestrial catastrophes, in beautiful and forcible English almost unequalled in our literature, proved the existence of life during incalculable æons. It is, therefore, historically right that the geologists of to-day, under the banner of Sir Archibald Geikie, should have taken up the gage of battle against Lord Kelvin, for themselves as well as the biologists. Nor is the subject unimportant, for if the sciences are true, they must be concordant, and it is needful, in the warfare of true knowledge against superstition, which is surviving ignorance, that divergences should be removed, as removed they cannot fail to be. The whole of Sir Archibald's address to the British Association, 1899, ought to be read by all interested in the subject; but I will quote a few sentences now.

"Even in the most ancient of the sedimentary registers of the Earth's history, not only is there no evidence of colossal floods, tides and denudation, but there is incontrovertible proof of continuous orderly deposition, such as may be witnessed to-day in any quarter of the globe. * * The conclusions drawn from the nature and arrangement of the sediments are corroborated and much extended by the structure and manner of entombment of the enclosed organic remains. * * Undoubtedly, most impressive of all the palæontological data is the testimony borne by the grand succession of organic remains among the stratified rocks as to the vast duration of time required for their evolution. * * So far as I have been able to form an opinion, one hundred millions of years would suffice for that portion of the history which is registered in the stratified rocks of the crust. But if the palæontologists find such a period too narrow for their requirements, I can see no reason on the geological side why they should not be at liberty to enlarge it as far as they may find needful for the evolution of organized existence on the globe."

Sir Archibald proceeds to regret the absence of numerical data, to form a satisfactory basis to compute the rate of denudation, and asks for the aid of all who can furnish any, as to the wearing away of coasts, the decay of buildings, and even of tombstones. I feel called upon to respond to his request with a new rule for measurement.

Our West Algoma is a severely glaciated region, in which none but archæan rocks remain, and many gold-bearing reefs have been exposed. Since the ice-cap left, the surface has been decaying, and the greater part of the aluminous and siliceous constituents of the rocks has been removed by water and wind. But the particles of gold, which are not destructible and are of too high a specific gravity to be blown away or carried off by trickling rain, have, in favourable places, been left, and I had a number of assays made last summer from one such spot. The gold contents of the reef, when "the solid" was reached, were about $3.50 to the ton, but. the thin surface soil assayed $100, and, for several inches down, the fine particles of the precious metal had "crawled" into the crevices, enriching this surface rock to about $12. Averaging the gold contents of half a foot in depth at $25 to the ton, there must have been an erosion of nearly eight feet, to yield the values. Now, in 1875, I raised a large gneiss boulder to the surface of my grounds in Toronto, since which there has been a noticeable decay, but it cannot exceed the twentieth part of an inch. If the Algoma rocks have been disintegrated at this rate, it would have taken 6,000 years to wear away a foot, and nearly 50,000 years to erode the eight feet in question. I once measured the amount of detritus carried away by the creek which ran below the plateau where I live, by taking given quantities of its turbid water in times of freshet and measuring the sediment. Assuming continuity of conditions, I found it must have taken 70,000 years to excavate the valley of that Rosedale brook, and I argued that if the geological theory were true and the removal of a glacier-dam at the foot of Lake Ontario had caused the fall of its water-level, this was the time that had elapsed since the ice age here. As the ice must have left this latitude and elevation before it left Algoma, the calculations tally fairly, which may indeed be fortuitous, but it is only by averaging reasonable calculations that a safe estimate can be reached. I do not think the time given for the decay of a foot of granite should cause incredulity. I have seen the Pont du Gard, in France, built about 1,700 years ago, and the great stones there have not decayed three inches. The climate there is perhaps the less severe, but I think the material is limestone, which can scarcely be so durable as granite. But do rocks, covered lightly by the product of their own decay and by vegetation, take longer to wear away than those uncovered, and does much interior decay proceed along with exterior weathering? An affirmative answer to both these questions would perhaps not much change the result obtained; but, until they and many others can be answered, much doubt will envelop the subject, and the limits of possible error will have an enormous superior range.

But as no marked biological changes have been noted in that portion of the quaternary period which is subsequent to the ice age here, the disappearance of the ice-cap must be geologically very recent. A hundred times as much would be all too short for the evolution of present forms of life from its first beginnings in early stratified rocks, below which we have tens of thousands of feet more of strata in which no traces of life are visible. I myself measured 30,000 feet of the early Cambrian black slates exposed on the north-west of Lake Superior, and searched for many weeks for traces of life therein, without finding any. Only after these do we come to the archæan formations, of unknown thickness! It does seem, fain though I am to take sides with the physicists, that there is some error in their computations, of omission or assumption, and that this world is almost from everlasting, while almost to everlasting it must go on, as indeed they themselves prove.

Lord Kelvin's argument, however, like everything emanating from him, is beautifully simple. He adopts Fourier's analysis of the following problem:—Given, an infinite plane dividing an infinitely large solid mass, with different constant temperatures on each side of the plane (at the beginning of an epoch). What will be the rate of variation from point to point, and the actual temperature at any point? He shows that in the case of a globe 8,000 miles through, the surface may be considered as such a plane, and the depth infinite, without sensible error for more than a thousand millions of years. We thus have an equation into which there enter as elements the initial temperatures, the time, the distance of any point from the given plane and the temperature of that point at the time, also the conductivity of the solid. A tyro in differentials can follow the "mathematical poem" throughout. Assuming time to be a hundred million years, the conductivity, in relation to specific heat, the same as that of Edinburgh rocks; and the temperature 7,000° hotter than the present surface, the rate of increase works out one fifty-first part of a degree per foot for the first hundred thousand feet or so, such rate then rapidly decreasing. The chief variation allowable is in the function of the conductivity, and this, diminished by half or increased by one-half, gives the superior and inferior limits first alluded to by Sir Arch. Geikie. What new fact has induced Lord Kelvin to reduce his estimate I do not yet know. The effective temperature of the Sun is stated in the *Astrophysical* Journal for August, 1899, as 11,300° Centigrade, which equals 20,340° Fahr., and if the Earth had at the first a heat approaching this, and the cooled surface did not sink, as Lord Kelvin assumes it did, until by convection the temperature was so much reduced that the Earth became practically a solid—if, moreover, the protection given by its atmosphere of many miles introduces a neglected element into the Fourier problem—it may be that even Lord Kelvin's estimate will be again revised and meet biological requirements. The extension of our thermometrical range by Dewar's apparatus in London, and Moissan's electric furnace in Paris, has made it possible to study the behaviour of substances under conditions of cold and heat respectively, which could not be produced until now. In our immediate neighbourhood are great factories of carbides of calcium and silicon. It is possible that much of our world's original carbon is in the shape of carbides down below. Some of their known qualities may determine the position of active volcanoes which are all near oceans, and otherwise influence miners' experiences as to increasing heat.

Some progress has been made in the enquiry into the synchronism between magnetic storms on the Earth and changes in the luminosity of comets, and this being a discovery of my own, first announced to this Society, I venture to descant upon it here.

If a magnetised bar be suspended at right angles to the magnetic meridian, one force with which it strains towards its normal position, parallel with that meridian, is called the Horizontal Force, while if it be so pivoted as to oscillate up and down, the strain with which it dips towards the magnetic pole is called the Vertical Force. The third element, Declination, involving the angle between the geographical and magnetic meridians, is possibly of little importance in this connection. These forces vary, like the wind, from hour to hour, and when the variation is rapid and continuous and considerable, we have what is called a magnetic storm. Some years the magnets are stolidly quiescent, in others they show frequent and striking signs of great agitation. and it has been found that the measure of annual disturbance in the Sun, obtained from records of the areas of its spots, corresponds with the measure of the disturbance of our magnets. This was first noted by Sir Edward Sabine, when, in 1851, he was discussing the magnetic observations at Toronto and Hobarton from 1843 to 1848, and found in both a progressive increase of disturbance. Schwabe had just then published his tables of sun-spot frequency, which showed an increase of spot areas during those very years. Mr. Ellis has published diagrams in the *Proceedings* of the Royal Society which establish this concordance to the present date.

The delusion that sun-spots are the causes of magnetic disturbance must be dispelled. Many of our magnetic storms can be traced on the records as in process of preparation for months before the appearance of a sun-spot, appearing as slighter but very evident disturbances at previous periods, measured by the length of the Sun's synodical rotation. Thus the sun-spots can only be an effect of some cause which also makes the magnets tremble. The frequently coincident appearance of great sun-spots and magnetic disturbances shows indeed that there is a bond of relationship between them, but no rule obtains as to the position of the spot on the solar disc. At the crisis of the storm, the spot may or may not have reached or passed centrality.

Other phenomena are associated with these disturbances. The auroral curve is intimately connected with those of Magnetic Forces. The number of thunder-storms is said to be influenced by them too. In the *Comptes Rendus* of June 26th, is a table of the number of earthquakes in Greece, from 1893 to 1898, which follow fairly well the descending curve of sun-spots, for that period. In the *Monthly Weather Review* for April, the eruptions of Mauna Loa are reported to coincide approximately with sun-spot minima, and the same thing has been said about the eruptions of Ætna, though further statistics are needed in both cases. I do not find any agreement in the case of the Philipine islands' volcanoes. Mr. C. Parkinson, writing in a recent *Cornhill* of phosphorescence in the ocean, says that "on certain nights the entire marine fauna pulsates with a mysterious incandescent force suggestive of some connection with the magnetic currents of the universe."

If now we can sustain the assertion that comets feel this influence at the same time that Sun and Earth do, we locate the origin of the disturbances in the Sun—not in the region of cosmic space through which the system is passing.

In Prof. Barnard's account of the breaking up of Brooke's comet of 1893, October 22nd and following days, he says it seemed as if the body was passing through some resisting medium in space. On turning to the magnetic records I found a great disturbance from the 23rd to the 25th, and that was the most disturbed period of a year of great disturbances, just before a sun-spot maximum, and I thought solar influence might be found to explain the change in the comet more plausibly than floating cosmic matter. Additional researches gave colour to this view, and in our *Transactions* for last year, page 136, are some confirmatory notes, especially respecting Eucke's comet in 1871, just after a solar spot-maximum, and Donati's in 1858, when a maximum was close at hand. Mr. Elvins subsequently drew my attention to Swift's comet, 1892, I; as described by him in the Canadian Magazine. April 6th, the comet seemed very bright and on the 7th the tail was torn up. There was a magnetic disturbance from the 5th to the 7th, not very severe, but the sun-spot maximum was close at hand. I then wrote to Prof. H. Kreutz, the Director of the Astronomical Central Record Office at Kiel, who had the kind civility to reply at length, stating that the idea was new, but referring me to a paper of Prof. Berberich's in the *Astronomische Nachrichten* for 1888, in which that distinguished astronomer had treated of a relation between the brilliancy of Encke's comet at its successive visits and the number of sun-spots existing at these times. He had the further goodness to send me three recorded instances of sudden changes in comets, and enquired how they fitted in with the theory advanced. They were comet Pons-Brooks, 1884, I, which showed a sudden change in brightness on September 21st, 23rd, 1883; comet 1888, I, which changed its appearance suddenly, May 20th-21st; and comet 1892, III, Holmes, in which "from a simple mass of nebulous matter without a nucleus, there suddenly developed on January 16th, 1893, a bright nucleus surrounded by nebulous matter, which after some time disappeared." I find with respect to the Pons-Brooks comet that the observations, of which we have a full account in the pamphlets of our late Honorary member, Father Terby, of Louvain, were very imperfect, owing to continuous bad weather. The comet seems to have been very variable, and the magnetic weather was most variable too. There was a very great storm from the 15th to the 27th September, the greatest violence being however, before and after the date given for the cometic change. Comet

1888, I, gives a much more distinct confirmation of my views, for on the 20th May, the day mentioned by Prof. Kreutz, the greatest depression of the year occurred in the curve of Horizontal Force, and one of the most remarkable magnetic storms known was accompanied by one of the most brilliant auroræ all over the world. Though it was at a sun-spot minimum, there was a large regular spot on the Sun followed by many others in an irregular stream, the whole in a state of constant change. The spotted areas for May and the two months preceding and following, were:—

1888	March	April	May	June	July
Umbræ.... .	5	4	37	5	3
Whole spots..	34	26	206	36	25

The principal spot, first seen on May 11th and last observed on the 23rd, was 37° past the central solar meridian by noon on the 20th, Greenwich civil time.

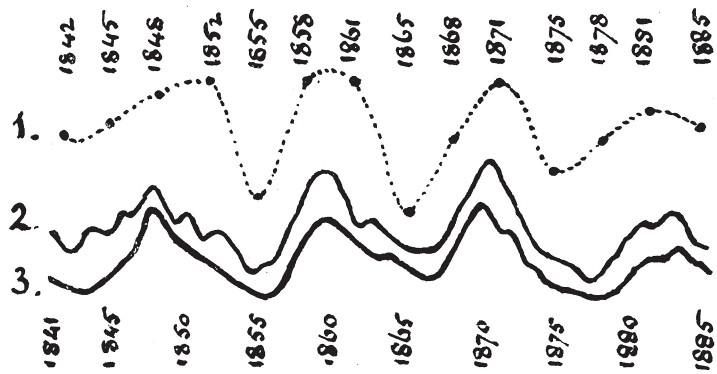
It only needs a few more of such striking coincidences to establish my theory beyond a shadow of doubt.

It must be admitted that no marked depression occurred on January 16th, 1893, the date given for a change in the comet Holmes;* there was indeed an increase of Horizontal Force on the previous day. But a great variability in the comet is recorded, as well as a much disturbed magnetic curve in November and December, 1892, the S. S. maximum then fast approaching. As meteoric stones are known to vary in composition, so comets perhaps vary too, and all may not be equally susceptible to the particular solar influence which produces the brightening or dispersion of their appendages.

As showing the effect of this influence on another body than the Earth, I must refer to Leo Brenner's observation of Mercury on May 18th, 1896, when he was astonished to see the dark side of the planet surrounded by a beautiful aureole. To make sure it was not an illusion, he called Madame Manola to the telescope. That day was the crisis of a magnetic storm upon the Earth. He has promised to send me a list of the days when he has seen aureoles around the dark side of Venus, a much more frequent phenomenon, that I may see if they are coincident with magnetic disturbances.

* In the *Transactions Royal Society* for March, 1893, page 332, the accounts given of this comet for January and February do not agree with those of the *Nachrichten*. The only sign of a tail alluded to is on January 27th and February 4th, when there were depressions in the Horizontal Force curve.

Berberich's paper on Encke's comet gives data as to its brightness from 1786 to 1885. The intensity it ought to show is given by the formula $I = \frac{1}{r^2 D^2}$ where r is the distance of the comet from the Sun and D its distance from the Earth. After carefully reading the accounts he gives of its observed brightness, I have assigned to them numerical values from 1 to 10, placing a concordance with the average between 5 and 6, and have constructed a curve therefrom, which agrees remarkably with the Ellis curves of magnetic Horizontal Force and of sun-spot areas. Berberich thinks a higher power of r should be used to bring calculated intensity into accord with what we see when the comet is bright. I suggest adding instead another factor, connected with magnetic stresses, and I hope to find what it should be. I do not doubt that other periodical comets are most luminous at times of great magnetic disturbance, or that more comets can be observed in such seasons. That is, however, a different phenomenon from what I have noted, viz., the immediate effect upon some comets of particular magnetic storms.



No. 1 is the curve for brillancy of Encke's Comet.
No. 2 is the curve of Hor. Magnetic Force.
No. 3 is the curve of sun-spot areas.

The second and third from Mr. Ellis paper; the first prepared from Berberich's descriptions by the author.

Last year was not an *annus mirabilis* for observational astronomy. The Sun was almost clear of spots. The planets were not in very favourable positions. No large new stars blazed out. Comets were few and small. Even the November meteors were disappointing. Here it was generally cloudy and I saw through the drifting clouds but one, which was not a Leonid, as it came from Cancer and crossed the barely visible sickle in Leo. It is a beautiful sight to see a large shooting star through a haze or mist. Dr. Larratt Smith observed one such, in January last, which shot upwards from a radiant below the horizon, and Mr. Gordon Mowat reports seeing one through a cloud which shut other stars from view. The observatory at Meudon collected Leonid notes from Delhi in India to San Francisco, and observers all reported a paucity of meteors. The calculation of Leverrier was thus verified, that after the fine display of 1866, the Leonid ring would pass near enough to Jupiter and Saturn to have its orbit changed, and no confocal stream supplied its place, which seems to prove that the meteor-roadway of the ortho-Leonids is comparatively narrow. It is thought the star-shower will be more brilliant in November next. Remarkable observations were, however, made from balloons, two of which were sent up from Paris and three from other places to see the Leonids from above the clouds. Miss Klumpke, an *attachée* of Meudon, was one of the aeronauts. Balloon observations afford several advantages. The stars shine brighter when seen from above the mists of Earth. Notwithstanding the light of the nearly full Moon, all the stars in Leo Minor could be well seen, and the colours of the meteors were far better marked. Only minutes were noted, as no chronometer was taken up, but in future ascents, when the omission will be made good, comparisons both as to colour and brilliancy can be made with observations from *terra firma*. The course of such balloons, ascertained by compass, can be checked by dropping weighted cards. The Perseid stream, of August, as important in its bearing on meteoric astronomy as the Leonid ring, was well observed in Europe, the average number of meteors during five days being about 100 an hour; and from a simple calculation we can obtain a very fair idea of the celestial spaces involved in the display. The Earth is 8,000 miles through, and rushes across the meteor-stream with a front we may estimate as equal to a plane of fifty million of miles in area. Supposing an observer can see 35 miles in every direction, he covers about 5,000 square miles, so that ten thousand stations would be needed to see all the meteors that fell. Now a hundred an hour, at ten thousand stations, for five days, means a hundred and twenty million meteorites. Again, the orbit traversed by the Earth in a year is about six hundred millions of miles long, so that in five days, the Earth would have crossed eight millions of miles, which is the breadth of the thickly starred part of the Perseid stream—the only necessary allowance being for the angle at which the orbits of the Earth and of the meteors intersect. Further, the Earth travels its own diameter-length in about seven minutes, so that the plane of fifty million miles with its ten thousand stations met within the space traversed in that time 120,000 meteors, and each one must have been flying along over thirty miles, on the average, from its neighbours.

Though experienced star-gazers may remember more splendid transitory sights than those of last year, observers who are young, either from years or from newly kindled interest (and of such there is a fresh crop every season) have had enough to stimulate them. They have enjoyed what some of us have long since lost ; the exquisite luxury of vivid first impressions. The bright diamonds which attend on Jupiter can be seen every year with quite small telescopes ; so, too, can the wonderful Saturnian microcosm. Double stars and nebulæ are always with us, I was about to say unchanged, but that is not the case ; companion stars circle about each other, while changes in the form and relative brightness of parts of some nebulæ are thought to be noticeable also. The Moon is only inconstant in a Shakespearean sense, she is an object of transcendent loveliness of which old astronomers never tire ; I know not whether she is more beautiful when the lace-like edge of the cresent shows like a fringe between the glare of her sunrise and the darkness of her half-month-long night—when she shines full upon us, a silvery, shadowless sphere—or when, the veil of eclipse thrown over her, she is coloured with the lovely bronze and blue tints of diffracted light.

Though passing shows have been few, there has been no pause in the progress of our science. Wonderful news reaches us from the mountain tops, where the clearest seeing is. The observatories there are in an astronomical fairy land, where the visible stars are brighter than below, and doubles shine with colours like "combinations of garnets and sapphires, topazes and rubies."

Schaeberle, at the Lick telescope, has seen, of a dull purple, the massive companion to Procyon, previously only known to exist by inference, like many other so-called dark stars. The companion to

Sirius is calculated to be of great size and weight, and it is very obscure. It was first seen by Alvan G. Clark in 1862, and has lately been almost in line with its principal, but now emerges. Its orbit is described in 52·20 years. The chief companion to Algol goes round in less than three days.*

Prof. See suggests that dark stars seem to be so because they shine with vibrations our optic nerves cannot respond to—say of the ultra-violet type. They may in such case be hereafter caught on a well focussed photographic plate, which is sensitive to vibrations the eye cannot perceive. Phœbe, the new ninth satellite of Saturn, was so found, and has not yet been distinguished by direct vision. It is the most distant of his family, just within the limit of permanent attraction, and quite small, showing only as a 15·5 magnitude starlet.

More asteroids have been "located." The first, Ceres, was discovered on the first of January, 1801, by Piazzi, at Palermo. The eccentric Eros, first known as D. Q. (No. 433), was introduced to his elders in 1898, and now we have E.W., which means that thirty have been found since then. The family group is now so large that when new members are caught, they are turned loose again, unless their orbits present some noticeable peculiarity.

Spectroscopists have scored another triumph in the discovery of a layer of carbon in the Sun. Prof. G. E. Hale and Mr. F. Ellerman, of the Yerkes Observatory, announce that they have found it at the base of the chromosphere, a very thin envelope, but unmistakeable. Only instruments of the highest power have revealed its existence. Non-telescopic spectroscopists rejoice in the discovery of vanadium in almost all stony meteorites, while it is absent from siderites, which they consider proves diversity in their origin.

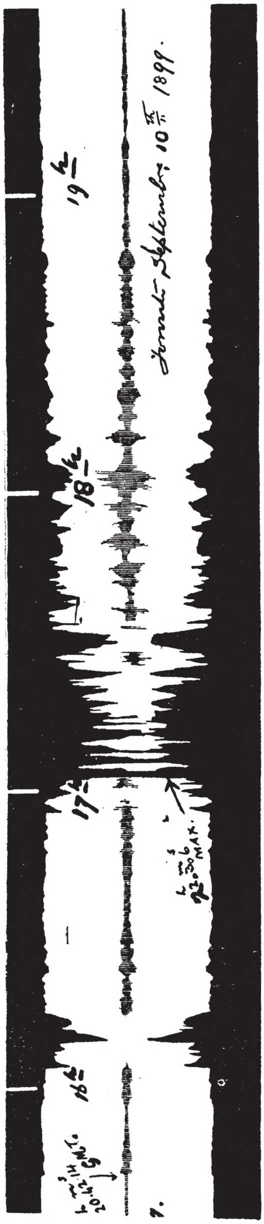
Physicists are to the fore with an explanation of transparency, based, if I understand Mr. Sarzac aright, on the arrangement of the particles in the medium and on its elasticity. Light-waves, striking the surface of glass, water, or the like, force back its particles and communicate successive vibrations, which, if the thickness be not sufficient to absorb

*It is interesting to compare these periods with those of bodies such as one of the components of the double-double ϵ Lyræ, which takes 900 years to revolve, or the comet of 1811 which is calculated to have an elliptical orbit with a period of nearly 2,000 years.

the impulses, are transmitted by the second surface to the ether on the other side. Transparency, and the index of refraction, depend on the arrangement of the particles in such a method as to propagate wave motion harmoniously. The communication has recently been made to the French Academy.

In Radiography we now speak of Russel rays and Becquerel rays in addition to those of Roentgen. It is suspected indeed that all matter, including the human body, emits influences which will affect a sensitized plate, if kept in darkness for a sufficient time. Until last year uranium was thought to be the substance whose emanations most rapidly affected the film ; it was displaced by radium, but Madame Curie's discovery of polonium gives us a metal which has four hundred times as much energy, and that without apparent exciting cause or perceptible diminution. Radium is even more energetic, with this remarkable difference, that its influence is affected by an electro-magnetic field, whereas the radiations of polonium seem not to be deflected thereby. This new science has already many applications, the latest being a proposal of Dr. Kolle's, in the *Electrical Engineer*, to supersede some of the processes of typography.

I do not know under what head to class the announcement by Mr. Chas. Honoré, of Montevideo, that the body of the sun, interior to the photosphere, rotates somewhat more rapidly than the visible exterior, and on an axis inclined to that we see evidence of. He promised proof, and thinks that periodicites in the phenomena of temperature and earthquake can be referred to this helio-thermic year.



We have had some very interesting records from the Toronto seismograph. The instrument is of the Milne type, only intended to show the time at which shocks occur, to aid in studying the rapidity of the transmission of tremors, and thus learning something more about the effective rigidity of the Earth. It is not meant to show the character of the oscillations, but it does to some extent show their violence. In 1898 it gave us notes of 28 earthquakes, and in 1899 of 37, the excess being probably due to its improved setting. Of these no less than 29 were in September last. It seems by the tracings that for several days the Earth was constantly shivering until on September 10th at 17h. 11′ 56″ Greenwich mean time a great throe began. The record from Victoria, B.C., miscarried in the mails, so we lack the most interesting comparison, but at Kew the first tremor was 3 minutes 7 seconds later. The maximum was noted here at 20h. 42′ 14″ Greenwich mean time, and at Kew 24 minutes 42 seconds later. Another great shake began at 20h. 42′ 14″ Greenwich mean time, with a maximum at 22h. 3′ 6″. Mr. Stupart, the director of our observatory, has kindly given me the tracings, and I show you that of the last great shock. The whole disturbance lasted for nine hours, though it was some days before absolute quiet reigned. The centre of disturbance was near Mount St. Elias, in North-western Canada, but as the Americans own the Pacific coast-line there, we shall hereafter read of it as the great Alaska earthquake. The local effects were terrifying and the region affected by the shocks was 4,000 miles or more in diameter. The contour of the coast-line was permanently changed, parts of islands being swallowed up and well-known land-marks having disappeared. Tidal waves rushed in from the ocean, the waters on submerged reefs were violently agitated and shaken into foam, the waters of inland lakes were let loose, and the sparse Indian inhabitants of the region were greatly frightened. The Rev. S. Jackson, Superintendent of Education of Alaska, was at Yakutat Bay, to which some panic-stricken people fled, and we may expect the full details next summer. Dawson City was badly shaken too. The most extraordinary effect seems to have been the changing of the face of every glacier on the coast, the Muir glacier with the rest, the ice having been fractured for a mile or more from the sea and having slid or been cast into it.

In the immediate future we are looking forward to the sun-eclipse of May 28th next. Expeditions are being organized on the other side of the Atlantic for its thorough observation, especially in Algiers, while on this side, observers will favour Georgia and Alabama, where at that time the least interference from clouds is to be expected, and the chance of a clear sky is seven or eight to one. The corona will not be widely extended, the carmine prominences will probably be small and few, but both, as well as other usual phenomena of total eclipses, will be as interesting as they are rare, including the onrush of the Moon's shadow over the Earth, the mysterious grandeur of which is alone worth going South to see.

I must not close without alluding to the progress of time reform, in which this Society has always taken a deep interest. "One of the great reforms of the last twenty years," says the *Weather Review* of Washington, "has been silently advancing. * * This amounts really to an internatioual agreement that longitude and time shall be as far as practicable referred to the Greenwich meridian. * * Thus, in the Atlantic States, we use seventy-fifth meridian time, but in the Mississippi river water-shed, ninetieth meridian time, except, perhaps, in the western portion, where the one hundred and fifth is adopted," as it is on the Pacific. The same is the case in Canada, and the system is spreading on the other hemisphere. We have not yet succeeded in having the twenty-four hour notation commonly used, or in having astronomical and civil time brought together, the former still beginning its day at noon. The French *Annuaire du Bureau des Longitudes* has, however, this year adopted mean civil time, from 0h. to 24h., and astronomers there will have to fall into line. But a still more important change is perhaps being accomplished, as I speak, viz., the adoption in Russia of the Gregorian reform of the calendar, which dates from 1582. Ten days were omitted from the year when first the reform was instituted at Rome, eleven when England adopted it, in 1752, and the Russians will now have to omit thirteen. Reports being as yet contradictory, we are not yet sure. Some say the difficulties in connection with regula-lating church festivals are insuperable. It seems curious that time reckoning, which is strictly a matter of astronomy, should be made a matter of religion. It is however proposed that on January 1st, 1901 all Christendom shall date its letters on the same day and month. Then, on to Cosmic time, when every clock will be set to the same hour and minute! The greatest feature of the past century has been the general acknowledgment that one law, one common nature, one evolutionary system pervades not only this world but all others, and surely one law as to weights and measures, especially that of time, ought to be observed among men.

And now, in the last year of the century, in the last year of the Society's first decade, with my last words as your President, I think I ought to express the satisfaction we must feel in looking back over our own particular little day. From being peripatetic wanderers, we have become a settled institution, having comfortable quarters under the roof of the Canadian Institute. Our special room is decently furnished. Our library is fast growing into value, our volumes are properly bound, well arranged and catalogued, and I do hope the Society will continue the assiduous care of this department, for though the heavens are our chief books, written in pandemic language, and their suzerainty is ever preferable to that of the printed page, we need many others as commentaries upon them. Our *Transactions* have been regularly issued and have been well received at home and abroad. We are free from debt. Our organization has worked smoothly, our officers have been earnest and faithful, and our future seems as bright as we can reasonably wish. I received my trust from a model President, I surrender it to a capable and respected member. In the hands of Mr. G. E. Lumsden, F.R.A.S., the dignity of the position will not be impaired, and he will repay you for the honour conferred upon him with no less loving service than his predecessors.

APPENDIX II.

OCEANIC TIDES AND TIDAL PHENOMENA AS REVEALED IN THE GENESIS OF WORLDS.

BY JOHN A. PATERSON, M.A.

We are all in some sense familiar with the phenomena of the tides as commonly understood to be the rising and falling of the waters of the ocean caused by the attractions of the Sun and Moon. There come to us many school-day memories when the diagrams in our geography-book or those drawn on the blackboard by some long ago preceptor exhibiting circles with elongated wings illustrated to us those diurnal heavings of the bosom of the sea. We may, too, have stood beside the shore and have seen—

> " The Ocean at the bidding of the Moon
> Forever changing with his restless tide."

And we may have watched the rising of the little waves smoothing down the ruffled sand with their soft white hands, and then the ebbing away following that mysterious pull from Sun and Moon which has been working from remote æons of ages. Twice every day, like every God-fearing man in the morning and evening, the ocean, being God-created, lifts itself to heaven and worships, and twice every day after its orison and matin it sinks back to its level and pursues its round of daily service or nightly rest. Those who see this every day phenomenon never think that wrapt up in this are those eternal principles on which the vast problems involving the origin and history not only of our solar system but of other celestial systems depend.

These attractions of Sun and Moon are most easily exhibited in their effects on the water that wraps the Earth, and though the Earth is comparatively solid, yet it is not perfectly rigid, and therefore it is that its shape is even now thus affected, although from their minuteness they may be incapable of registration. But that was not so before "the beginning," when the Earth was in her molten or plastic condition, and then it was that the strong hands of her parent Sun, and even those gentle touches from her child, the Moon, helped to mould and carve our Mother Earth, and prepare her for the habitation of sentient and thinking beings. And thus the word "tide" is not merely a rising and falling of the Earth's waters, but has a wider sweep and has a vaster sky line, it must include alternating deformations of a solid and elastic or of a molten and plastic globe. In fact the theory of tides properly investigated and given its proper place in scientific research is a chapter in the unfolding of the vast problem of Evolution, that multiform and brilliant philosophy of the universe which has taken so deep hold of the science and literature of our time. The tide-problem fully studied is another minaret in that glorious temple, the foundation stone of which was laid by Charles Darwin; it is another chord in that great rhythm that proclaims the universality of intelligent law, dethrones blind chance and exalts the Creator working through eternity not by revolutionary dramatic fiats, but by invincible evolutionary purpose and unceasing Providence. And we shall see, too, how where more fully studied this problem deals not only with the question of our past origin but with our future goal, not only with our "whence?" but with our "whither?" and gives rise to many curious and far reaching astronomical speculations.

From the pen of George Howard Darwin, the Plumian Professor in the University of Cambridge, only last year came a book on "The Tides." It is verily a discussion of that problem down to date—a classic, presenting in a popular form the mathematical argument as organized common sense, and smoothing out the intricacies of this most interesting subject. It is a book of nearly 400 pages, illustrated by 43 diagrams, many of them intricate and demanding close attention. A short account of the principles and theory of the book will, it is trusted, encourage my hearers to read more fully and accurately for themselves. Some account of the knowledge the ancients had as to the theory of tides may be interesting. Aristotle and Pytheas of Marseilles, pointed out the connection between the phases of the Moon and the tides. Julius Cæsar while fighting the yellow-haired Gauls took occasion to notice the connection between the Moon and spring tides. He says:—"*Eadem nocte accidit, ut esset luna plena, qui dies maritimos æstus maximos in Oceano efficere consuevit.*" And he tells us how in consequence his ships broke from their moorings because "*nostris id erat incognitum*"—his legionaries being accustomed to the navigation of the Mediterranean where the tides are hardly noticeable. While Pliny says, "*verum causa in sole lunâque*"—Seleucus, the Babylonian living near the Red Sea, noticed that when the Moon was in the equinoctial the tides followed each other regularly, but when she is not there, but in the solstices, the height and succession of the tides were irregular, and that this irregularity depended upon her distance from the equator. Modern astronomers would express that by stating that the diurnal inequality vanishes when the Moon is on the equator, and is at its maximum when the declination is greatest. Seleucus must have watched the Atlantic tides where this diurnal inequality is almost evanescent, and he must have observed the tides of the Indian Ocean, especially about Aden, where the diurnal inequality is very great. Kepler indicated that the Sun and Moon moved the water, but his suggestion of gravitation was the merest surmise, and Galileo criticised Kepler in not exhibiting his usual acuteness while he referred the phenomena to the rotation of the Earth.

The true theory of tide generating force was not expounded until Newton, in his Principia in 1687, by his genius established the foundation on which the whole philosophy of tides rests. If I may be permitted to rest and turn aside from the path of serious and honest inquiry, and to drift into Mohammedan romance, I may quote from the prophet "on whom be the blessings of God and His peace," when he says, "Verily the angel who is set over the seas places his foot in the sea and thence comes the flow, then he raises it and thence comes the ebb."

We are all more or less familiar with the ordinary theory of the tides.

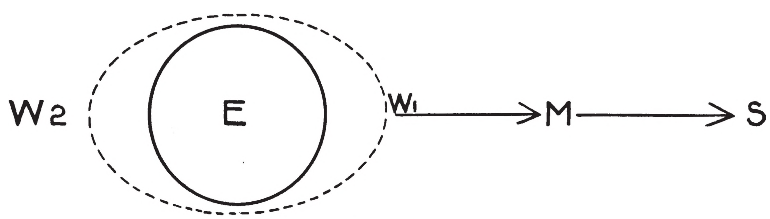


Fig. 1.

When the Moon (M.) and the Sun (S.) are in conjunction as in Fig. 1, their combined attractions lift the volume of water W_1 from the solid Earth E and thus a high or spring tide is generated. Furthermore, the same effect is produced at the other side of the Earth, inasmuch as the combined attraction of M. and S. pulls the Earth away from the water *W*2 and so leaves the water heaped up there, and thus here also a spring tide is generated. This is the position at new Moon on both sides of the Earth.

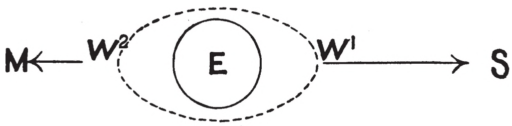


Fig. 2.

When the Moon (M.) and the Sun (S.) are in opposition as in Fig. 2, their attractions are opposed but still spring tides are produced as before. This is so because the Sun pulls the water W_1 from the solid mass of the Earth and also the Earth away from the water *W*2, and so leaving *W*2 heaped up. The Moon has similar effects on *W*2 and *W*1. This is the position at full Moon on both sides of the Earth—the solar and lunar tides combine just as in Fig. 1.

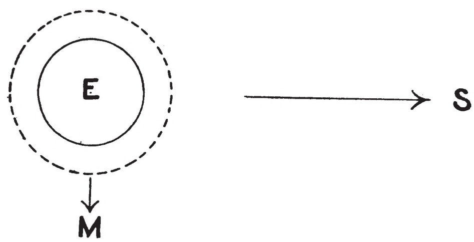


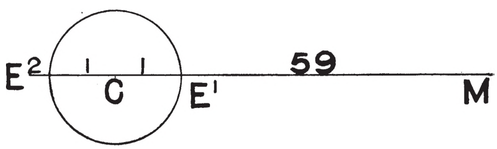
Fig. 3.

When the Moon and Sun are in quadrature or 90° apart as in Fig. 3, then the water is more or less equally distributed over the Earth for reasons evident upon an examination of the different attractions of M. and S. as explained with respect to Figs. 1 and 2. In this position the Sun and Moon attract separately and not in conjunction, and it is the same whether the Moon is 90° east or 90° west of the Sun, and so at each of the two half-moons in the month, that is, at the first and third quarters, the neap tides which are the lowest, occur.

Furthermore, the lunar tide is the highest, for although the mass of the Sun far transcends that of the Moon, yet the Moon is so much nearer that its effect is greater. It must be also remembered that the tidal effect is produced not by the attraction of the Sun or Moon only but by the difference of the attractions exercised by each of these bodies upon the nearer and further sides of the Earth and the water envelope. And as the proportion of the Earth's diameter to the lunar distance is much greater than the proportion of the Earth's diameter to the solar distance the lunar tide is the stronger. These fractions roughly are:—

$$\frac{8000}{240{,}000} \text{ and } \frac{8000}{92{,}000{,}000}$$

As this is an important matter let us get at this proportion more closely. As the tides are occasioned by the attraction of gravitation it is easy to premise that for equal distances the tidal effect must vary as the mass of the attracting body. And if the problem of the tides was simply a question, what is the attractive force exerted by a heavenly body upon another heavenly body as the Earth? The question would be answered by the statement that the effect on the ocean would vary directly as the mass of the attracting body and inversely as the square of the distance of the attracting body. But as has been already said the tide depends not on this but on the differentiation between the attraction on one side of the Earth and the attraction on the other side of the Earth. This is more complicated. Let me proceed to demonstrate the true law without having recourse to anything but ordinary school arithmetic.



Let CM represent the distance from the centre of the Earth to the Moon, which is 60 times the semi-diameter of the Earth which we will take as a unit of measurement

$$E_2C = CE_1 = 1 \text{ and } E_1M = 59.$$

Now the attraction at E_1 exceeds the average

by $$\frac{1}{59^2} - \frac{1}{60^2} \text{ which} = \cdot 000{,}009{,}49\,;$$

but $$\frac{2}{60^3} = \cdot 000{,}009{,}26\,;$$

$$\therefore \text{ the difference nearly} = \frac{2}{60^3}$$

Again, the attraction at $E2$ exceeds the average

by $$\frac{1}{60^2} - \frac{1}{61^2} = 000{,}009{,}03\,;$$

$$\text{which nearly} = \frac{2}{60^3}.$$

These two over balances are therefore nearly equal and vary inversely as the cube of the distance of the Moon from the Earth. The law therefore is that the tide generating force varies directly as the mass and inversely as the cube of the distance of the mass

or $$F \propto \frac{M}{D^3}$$

To compare the tide-generating forces due to Sun and Moon

Mass of the Sun $= 331{,}000$ Earth mass
Mass of the Moon $= \frac{1}{81}$ Earth mass
Sun's distance $= 390$ Moon's distance

$$\frac{\text{Solar tide-force}}{\text{Lunar tide-force}} = \frac{\dfrac{331{,}000}{390^3}}{\dfrac{1}{81}}$$

$$= \frac{331{,}000}{39^3 \times 1000} \times \frac{81}{1} = \frac{331}{3^3 \times 13^3} \times \frac{3^4}{1}$$

$$= \frac{3 \times 331}{13^3} = \frac{993}{2197} \text{ nearly} = \frac{990}{2190}$$

$$= \frac{33}{73} \text{ nearly} = \frac{30}{70} = \frac{3}{7}$$

If lunar tide be 1.
Then lunar tide + solar tide = spring tide

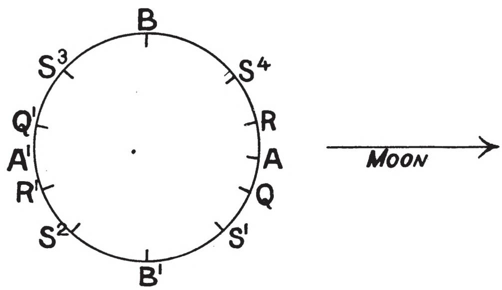
$$= 1 + \frac{3}{7} = \frac{10}{7},$$

and lunar tide — solar tide = neap tide

$$= 1 - \frac{3}{7} = \frac{4}{7}$$

Proportion of spring tide to neap tide is as 10 to 4.

A short explanation of what is meant by the priming and lagging of the tides should now be made :



Between new Moon and first quarter, the Sun is over a point S_1 behind A. Here the Moon tends to draw the water towards A, A', and the Sun tends to draw the water towards S_1 and the antipodal point S_3. Therefore the combined action tends to draw the water towards two points Q, Q' between A and S_1 and between A and S_3 respectively, whose longitudes are rather less than those of A and A' respectively. The resulting position of high water is therefore displaced to the west, and the high water occurs *earlier* than it would if due to the Moon's influence alone. The tides are then said to *prime.*

Between first quarter and full Moon the Sun is over a point S_2 between B' and A', and the combined action of the Sun and Moon tends to draw the water towards two points R, R', whose longitudes are slightly greater than those of A, A'. The resulting high tides are therefore displaced eastwards, and occur *later* than they would if the Sun were absent. The tides are then said to *lag.*

Between full Moon and last quarter the Sun is over some point S_3 between B and A', but the antipodal point S_1 is between A and B'; hence the tide *primes.*

Between last quarter and new Moon, when the Sun is at a point S_4 between B and A, it is evident in like manner that the tide *lags.*

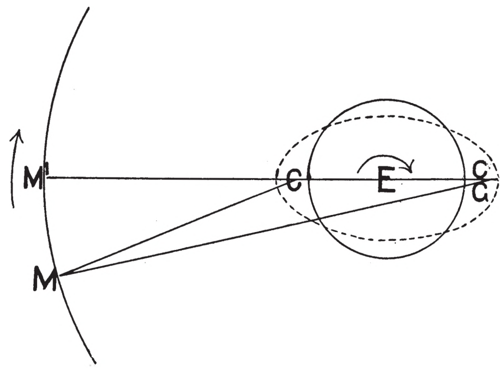
Hence spring tides *occur at the* Syzygies (conjunction and opposition). Neap tides occur at the quadratures.

From Syzygy to Quadrature the tide primes.

From Quadrature to Syzygy the tide lags.

All mathematicians know the difficulty of working out the problem of the three bodies. So complicated is it that it defies the instruments of analysis. The problem of two bodies is capable of exact demonstration. This is somewhat analogous to the difficulty of predicting tides by calculation. If the globe were covered with water to a uniform depth and the friction of continents and configuration of land and the complications occasioned by estuaries and bays and inlets and varying depth of ocean were eliminated then the tidal problem would be an exact one, but that would be a condition of matters where the solution of this problem would be useless as the Earth's inhabitants would be aquatic creatures whose calm content would not be disturbed by any perplexing inquiries from the "crossgrained muses of the cube and square." Or if the ocean ran in parallel canals belting the Earth and were of uniform depth then the theory of tides and calculations as to tides would be of the most charming simplicity and the happy peoples who would then inhabit the dividing banks could delight themselves with the most gentle exercise. But we must take things as they are and we find most irregular distributions of land and water and varying depths of ocean and hence the prediction of tides by calculation is one of the most complicated problems of practical astronomy. Theoretically at new and full Moon high water would be exactly at noon and at midnight, but roughly speaking the tides follow the Moon's course so that high water always occurs about the same time after the Moon is on the meridian. And as the Sun crosses the meridian with the Moon at new or full Moon the hour of the clock at which high water occurs at such periods is in effect a statement of the number of hours which elapse between the Moon's meridional passage and high water. This is called the "establishment of the port" and is constant for any particular place. Thus the establishment of the port at London Bridge is 1h. 58′, so that lunar high water occurs 1h. 58′ after the Moon's transit—and the same with the solar high tide. The actual high tide being due to Earth and Moon conjointly is earlier or later than the lunar tide by the priming or lagging. By adding a correction for this to the "establishment of the port" the time of high water may be found for any phase of the Moon.

Knowing, as we do, the effect of gravitation, and knowing, too, that the Earth and Moon and planets are nearly spherical in shape, we conclude that these bodies were once molten and plastic. A swiftly moving fly wheel will continue to revolve for a long time after the moving force has ceased to operate. Its inertia will carry it on, but the friction upon its bearings, the Earth's attraction and the resistance of the air will at length reduce it to rest. The Earth has no bearings, but yet the tidal friction applied as it is to its surface acts as a brake, and must thus retard the Earth's rotation, and as by Newton's Third Law of Motion, action and reaction are equal and in opposite directions it must follow that as the Earth is retarded the Moon is accelerated. This proposition, however, demands a more careful investigation.



Let the circle represent the normal shape of the Earth rotating in the direction of the curved arrow. Suppose the water envelope or the plastic mass of the Earth to be devoid of friction and to take the shape represented by the ellipse, and at this moment let the Moon be at M_1. But in fact there is friction and the crest of the wave or the protuberances of the ellipse is belated and, therefore, carried onward by the Earth in her rotation beyond the proper position. To put the figure right and to avoid confusion, let the Moon be set back to M which is the proper relative position when the effect of friction and rotation are taken into account. What now is the effect of the Moon upon the egg-shaped Earth? Suppose the tidal protuberances to be centralized in and represented by two masses at C and C_1 respectively. Now it is evident that the attraction of M on C tends to retard the Earth and the attraction of M on C_1 tends to accelerate it. And as C is nearer to M than C_1 it must follow that the retarding pull is stronger than the accelerating pull. Therefore, it is clear that the first effect of fluid friction is to throw the tidal protuberances forward, and the second effect is to retard the Earth's rotation. Action and reaction are equal and in opposite directions, and as the Moon pulls the tidal protuberances they in turn pull on the Moon and therefore the Moon is carried forward in the direction of the arrow. This increasing force will force the Moon out to move in a spiral curve at ever increasing distances and thus the time of the Moon's revolution is increased. And not only so, but the effect of this accelerating force is actually to retard the velocity. Thus for both reasons the length of the month (the time of the Moon's revolution round the Earth) is increased. The same result has been shown as to the length of the day (time of Earth's revolution round her axis). This result may be presented in another form. The attraction of the tidal protuberance increases the Moon's areal velocity. Now in a circle the areal velocity $V \propto \sqrt{R}$. Therefore as V is increased the Moon's distance R is gradually increased, and hence also her periodic time or month is increased. This is true theoretically, but the investigation of astronomical records since observations have been made does not offer much or any corroboration to the rigid mathematical proof—the changes for centuries past have been so slow. But it does not follow that this has always been so. When the Moon and Earth were gifted with more iuvenility in the remote ages relative changes were far more rapid. Let us remember that the tide-generating force varies as the inverse cube of the distance between the Moon and the Earth, so that if the Moon's distances is reduced to $\frac{1}{3}$, $\frac{1}{4}$ or $\frac{1}{5}$ of its present distance then the force and the tide generated would be 27, 64, 125 times as great. This is, however, only half the truth. We must not forget that while tide is being augmented the Moon's attraction is also increasing. These two coalesce and each is increased as the cube of the distance decreases, so that the cube power must be squared or made the sixth power. The tidal retardation of the Earth's rotation therefore varies inversely as the sixth power of the Moon's distance. For example, when the Moon's distance was reduced to $\frac{1}{10}$ of the present distance then the tidal action was 10^6 or 1,000,000 times as great as at present. The action at present may be slow enough but when the Moon was nearer us it went on with immense rapidity. Looking forward in point of time we will reach an era when the Earth will take about 1,400 hours to turn on her axis, and the Moon will take the same time to make a revolution round the Earth. The result will be that the Earth and the Moon will go round their common centre of gravity as if united by a solid bar and locked together in about 55 of our present days with the day and the month identical in length. Lunar tides will then cease and any retardation of the

Earth due to the Moon can then no longer exist. Solar tides will however continue to exist so long as water is left on the Earth. The solar tide will thus retard the Earth's rotation and so further lengthen the day; this will retard the Moon's motion and diminish her areal velocity. The Moon will therefore approach the Earth and will ultimately fall into the Earth in a long ever-contracting sweep. The Earth will thus finally turn the same face to the Sun, and so remain locked with perpetual day over one hemisphere, and perpetual night over the other. As the system can be traced forwards to the 55 day period, so it can be traced back until we find the Moon revolving round the Earth and almost touching the Earth in a period of between three and five of our present hours. And thus beauteous Luna had her birth from the fiery Earth æons ago, when in the throes of a world's parturition she was thrown off to go seek her fortunes in the universe and work out her destiny as our satellite, once doubtless a flower-spangled world, with refreshing streams and heaving oceans and gentle breezes, now a derelict, a ruined world. In the ages yet to come whose number can alone be reckoned in the arithmetic of heaven, this fair daughter born of her Earth-mother will in a long circling spiral come back again and gently like a fallen blossom from one of Earth's flowers fall back on the bosom of her parent not with the crash of colliding spheres and the heat of riven globes, but softly make her grave where her cradle was in the long ago past.

The effect, therefore, of solar tidal friction is to retard the revolution of the Earth while the revolution of the Moon in her orbit will increase. Until recently no case of a satellite having a less period than its planet's rotation appeared to exist, and it was therefore argued that the theory was unsound, as not being borne out anywhere in visible nature. But in 1877, Professor Asaph Hall discovered two satellites of our near neighbour Mars, which he named Phobos and Deimos—Fear and Panic, the dogs of war. The period of Deimos is about thirty hours and that of Phobos something less than eight hours, while the Martian day is nearly twenty-four hours. Here then is an illustration of the future condition of our Earth-Moon system for the solar tidal friction having such an effect upon Mars which is so much nearer the Sun than our Earth has slowed him down so that Fear circles round him nearly three times every day, which would surely be enough to drive all the warlike spirit out of him. The ultimate fate of this satellite will therefore be absorption into his planet. The Mars-Phobos system is therefore further advanced and it will remain for astronomers in coming centuries to discern any approach of Phobos to his parent Mars.

If Darwin's theory be true we would naturally turn to Mercury and Venus and see what effect solar tidal friction has had on their rotation-periods. As the solar-tide raising force varies inversely as the cube of the distance of the planets, these solar tides are far greater on Mercury and Venus than on our Mother Earth. Although younger in point of years than Terra, as indeed would become the Queen of Beauty and the swift-footed messenger of the gods, yet as Sun-planet systems they are older because their gradations are farther advanced. It would therefore be reasonable according to the theory that we are investigating that the immense solar tides must have so diminished their periods of rotation that they are united as at the end of a bar with the Sun as obtains in our Earth-Moon system and so like loyal courtiers they keep their faces always turned to the Sovereign Sun. The keen-eyed Schiaparelli of Milan, has announced such to be their relative condition as the result of his observations, and these have been corroborated by Percival Lowell and T. J. See, working at the Lowell Observeratory at Arizona, under the very best atmospheric conditions.

The theory of tidal action has an important place in the evolution of celestial systems. The nebular hypothesis as suggested by Kant and developed by Laplace and modified by G. H. Darwin and Poincaré is the most reasonable theory of evolution yet presented. Time forbids more than a passing reference to it. Apart from any hypothesis based on the dynamics of a rotating nebula, and the evolution therefrom accompanied with the attendant phenomenon of tidal friction it is interesting to note that very recent investigations of the great nebula in Andromeda seem to indicate the lenticular shape with its central condensation, the annulation of the outer portions and even the condensation in the rings which are destined to form planets. The Scriptures of the sky, therefore, appear to reveal to us Nature in parturition, and a celestial system being evolved before our very eyes in the great nebula of Andromeda. By the theory of tidal friction our Moon took her origin very near to the present surface of the Earth. To account for the orbits of the satellites of Mars, Jupiter, Saturn and Neptune, we must have recourse to the nebular hypothesis. The Earth-Moon system is unique. The Earth is only 80 times the weight of the Moon, while Saturn weighs about 4,600 times as much as its satellite Titan, which is the giant satellite of the solar system. All other satellites in other systems but ours are infinitesimally small in comparison with their primaries. As a reason explanatory of this peculiarity of the Earth-Moon system it should be remembered that the Earth is nearer to the Sun than any other planet attended by a satellite. By the nebular hypothesis rings are, so to speak, shed from the central nucleus when the nebula has contracted sufficiently to create a proper degree of increase of rotation. If from any external cause this rotation is retarded then the genesis of the ring is retarded or indeed may be entirely prevented. The friction of the solar tides furnishes this external cause. We therefore find that Mercury and Venus have no satellites, the Earth has one, Mars two, Jupiter five, and all the exterior planets have each a retinue of satellites. In the Earth system the genesis of the Moon was retarded by the solar tidal friction but not absolutely prevented.

The phenomenon of double stars present a special study in the investigation of tidal phenomena. It is impossible that so many systems of double stars should have attained their relative positions by an accidental approach from the infinite depths of space. Tidal action tends to increase the eccentricity of the orbit in which the bodies revolve about one another and the results are much increased when the two bodies are not very unequal in mass. It is remarkable that spectroscopic observations show that the orbits of the majority of the known "doubles" are very eccentric. Tidal friction causes, too, a repulsion between the bodies and so as in the Earth-Moon system, the two members of a binary system must once have been close to each other. The next step is the rupture of the parent nebula in the form of an hour-glass into two detached masses, as witness the great dumb-bell nebula (27 Messier Vulpeculæ). Dr. T. J. See's observations and ingenious theories have done much to develop this philosophy of Dr. Darwin's; let us remember that conjecture is the parent of discovery and often the grandparent of truth. Future researches with the photographic plate, the spectroscope, and the telescope and their results interpreted by skilful astronomers, will open to us yet marvellous vistas of observation; like the Queen of Sheba we may yet have occasion to be startled with many sparkling gems of discovery and exclaim that the half was not even dreamed of.

Tidal action has been in the mighty hands of the great Sculptor the instrument by which He has hewed out the outlines of our globe, working out new beauties, softening down harsh lines, and rendering her more and more fit for the habitation of man. Mother Earth sent forth her daughter Moon ages ago, and since then, obedient to Earth's impulses, and never leaving her, she has with strong but gentle hands, moulded Earth's plastic form into shapes and curves, and worked out with its wondrous friction coupled with Earth's internal forces these configurations of ocean and continent that now are with us. And since Earth became in a sense solidified the Moon has kept the oceans moving and heaving and health-giving, deftly shaping and rounding the fulness of her beauty. Many times Earth's face has changed and it is changing yet; lands have been swept away and seas wash in the palaces of former kings.

> There rolls the deep where grew the tree,
> O Earth what changes hast thou seen !
> There where the loud street roars, hath been
> The stillness of the central sea ;
> The hills are shadows, and they flow
> From form to form, and nothing stands,
> Like mists they melt, the solid lands,
> Like clouds they shape themselves and go.

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(INSTITUTED 1893.)

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The Meaford Astronomical Society.

Transactions of 1899.

The one hundred and eighth meeting of our Society, and the first for the new year, was held at the residence of Mr. S. Huff, Science Master of Meaford High School, on January 19th. After routine matters of business and reports of observations, the President read an article from a Toronto newspaper giving a description of the new Magnetic Observatory at Agincourt, near Toronto. Miss Paul read an article on "Liquified Air."

The next regular meeting was held at the Society's rooms on February 2nd. Observers reported a "sun dog" on the 31st January. "A Learned Lecture in Parson's Town" was read by Mrs. Manley, and also an article on "The Destiny of the Sun." Several paragraphs were read and discussed on the subject of "Lunar Craters," the Society's text book throwing much light upon the subject.

The one hundred and tenth meeting was at the residence of Mr. H. Manley, on February 16th, a large number of members being present. The report of observations showed that many were on the alert for phenomena, and could give the details of the time, place, etc., with accuracy. The President called attention to the favorable position of certain planets for observation, and showed also a neat little planisphere, which any one might copy, and have at hand a ready guide to locate any of the planets in their relation to our earth, the sun and the constellations of the zodiac.

The next meeting was called to be held at the residence of Mr. S. Huff, March 9th, for a special reason, as will be shown from the proceedings of the evening. Besides a large attendance of members, there were present a number of visitors, among others Dr. Hamill, Mayor of the town. The President reported that several scientific instruments had been received by him from the Observatory of Toronto for the purpose of establishing a Meteorological Station at Meaford. The chief subject of the evening was an address by Mr. Huff on "Acetylene Gas," during which he not only fully described the method of preparing and showed its advantages for illuminating purposes, but also showed a generator and explained the various parts and processes of manufacture, and had the room in which we met brilliantly illuminated by it. A hearty vote of thanks was tendered to the lecturer.

At the next meeting, held at the residence of Mr. H. Manley, on March 23rd, a communication was read from Mr. Mackenzie, of Owen Sound, regarding the weather for the month of February, and showing the total snowfall for the winter so far to be about 16 feet, more than has ever been known in this country, and also that the cold has been more intense. Dr. Caswell gave a description of some meteorological instruments and the method of registering observations. A portion of the text book was read and discussed on the subject of sun-spots.

The one hundred and fourteenth meeting was held at the residence of Mr. J. G. Sing, April 20th. The President reported having observed two pairs of sun-spots on April 12th. An article on "The Pleiades" was read, and a drawing illustrating the subject was exhibited by Dr. Danard.

The question of when the twentieth century begins was brought up, and after discussion, Mr. J. S. Wilson consented to prepare a paper on the subject for another meeting. Dr. Caswell also read Mr. T. Lindsay's article from *Popular Astronomy* on "Astronomical Myths."

At the one hundred and sixteenth meeting, May 10th, at the Society's rooms, the President reported a visit to Toronto, and having made arrangements with Mr. Lindsay to be present at our Annual Public Meeting on June 2nd. He also described a visit to the Canadian Institute, and an evening spent with Mr. Stupart at the Meteorological Observatory. Mr. J. S. Wilson, M.A., then read his paper on "The Close of the Present Century," which was very clear and satisfactory to all present, showing the end of the century to be December 31, 1900, and by resolution Mr. Wilson was requested to have the paper published in one of the local newspapers.

The next was a public open meeting, held in the Foresters' Hall on June 2nd. The Rev. Dr. Caswell, President of the Society, in the absence of Dr. Hamill, Mayor, took the chair, and introduced Miss

Stephens, of Owen Sound, who gave a piano solo. A very interesting and appropriate reading was given by Miss Howson, B.A., teacher in High School, and this was followed by a song by Mrs. H. W. Revell. Mr. Thomas Lindsay, of Toronto, was then introduced, and delivered the lecture of the evening. His subject was "The New Astronomy," and was cleverly handled, to the interest of the large audience present, who followed the lecturer closely. The subject was illustrated by lantern views, presented by Mr. S. Huff, and illuminated by acetylene gas light. A hearty vote of thanks was proposed to all who took part in the evening's programme, and especially to Mr. Lindsay for his kindness in coming up from the city to give his lecture. This was moved by the Rev. S. H. Eastman, B.A., and seconded by W. Moore, Esq., Sr., and unanimously carried, and the meeting closed by the singing of "God Save the Queen."

The next meeting was held at the residence of W. Moore, Esq., Jr., on June 15th. After routine business the Corresponding Secretary handed in some splendid photographic views of the moon, presented by Mr. G. E. Lumsden, of Toronto, and taken at the Lick Observatory. Some discussion took place regarding heavy thunderstorms happening of late, but the chief subject of the evening was that of "Eclipses," and several pages of the text book were read and discussed in reference to this question and some practical illustrations shown.

The one hundred and nineteenth meeting was held on June 30th, at the residence of Miss Layton. A communication was read from Dr. Keeler, Director of the Lick Observatory, in reference to some recent publications. Among the observations the phenomenon of a belt of auroral light near the zenith had taken the attention of members, and led to many questions and searching of text books for explanation. A resolution of sympathy and condolence to the relatives of the late Mrs. D. S. White, who was a member of our Society for some years, was passed, and the Secretary requested to send a copy to the members of the family. As the evening was fine and the sky clear, the members adjourned to the lawn and spent some time in the study of constellations in sight.

The next meeting was held at the Rectory, on July 13th. A communication from Dr. Danard, of Rocklyn, was read, in which he called attention to several observations of sun-spots and other phenomena which he had recently made, and regretting his inability to be present at our meetings. The President read an article of interest from *Popular Astronomy* on the "Parallax of the Gegenschein," and the rest of the evening was spent out of doors studying the constellations and taking observations of double stars with the telescope.

At the residence of J. S. Wilson, Esq., M.A., on the evening of 27th July, a large number of members assembled. A communication from the British Astronomical Association was received stating that they were sending four volumes of *Memoirs* and six volumes of their *Journal*, and these the Corresponding Secretary also laid upon the table. A resolution was passed thanking the British Association for the contribution of such publications towards our small library. Dr. Caswell gave an account of a recent visit to Ottawa, and of steps which are being taking towards the erection of a National Observatory at the Capital. Several pages of the text book were read and discussed in reference to the planet Mercury.

The next regular meeting was held at the residence of Mr. H. Manley, on September 14th. From the observations reported was seen that all members had been watching for phenomena and had been rewarded. The principal subject discussed was that of the planet Venus, illustrated by readings from the text book and other sources, giving us an evening of considerable interest.

The one hundred and twenty-third meeting of the Society was held on October 2nd, at the Rectory. Mrs. Kirton of Buffalo, and formerly an active member of our Society was present as a visitor, and expressed her regret at not finding in the city where she resided anything of such interest in the line of Astronomy or Physical Science, as she formerly enjoyed when in Meaford. The President explained the method of recording meteorological observations, and showed the Register in which all records are kept, and also the curious signs used in such markings and how they are easily understood.

Mr. G. G. Albery described a visit to Toronto Observatory, where he had enjoyed the courtesy of Mr. Blake in the explanation of the different apparatus, and particularly that belonging to photography as used at that institution. Attention was called to the expected shower of meteors and the necessity of reading up on the subject for the next meeting.

On October 12th, the Society met at the residence of Mr. H. Manley, and a large number of members answered the roll call, and a few visitors also were among those present. After routine business Miss Paul handed in a description of a new telescope now being constructed by Professor Pickering. An article on meteors was read by Mrs. Manley. Dr. Caswell read from a scrap book an extract from a Toronto newspaper, giving a description of the shower of meteors as seen from the tower of Toronto Observatory in November, 1867. Dr. Caswell himself having been one of the students who kept watch that night, and recalling some reminiscences of the evening at the Observatory, gave living interest to the subject. The annual election of officers was then proceeded with, and resulted as shown on a preceding page.

The one hundred and twenty-fifth meeting of this Society was held at their rooms on October 26th. A circular was read from Professor Edward C. Pickering, in reference to making proper records of the coming meteoric shower. Miss Paul read an article on the "October Heavens," and Mrs. Manley an article on "Meteoric Astronomy."

On Nov. 9th, the Society met at their rooms; Mrs. Paul had the various sectional views of the moon all nicely framed and ready for hanging up, and received a hearty vote of thanks for the care and trouble which she had taken. The subject chosen for the evening was that of meteoric showers, and arrangements were made for meeting at the Rectory on the evening of Nov. 15th. Mrs. Manley read an article on meteors. The paper of the evening had been prepared by the President giving the supposed origin, and the result of many observed facts and interesting data in connection with meteorites. By a resolution, it was requested that this paper should appear in printed form.

According to arrangement, many mumbers met at the Rectory Nov. 15th, to watch together for the expected shower of meteors. The following is taken from the *Meaford Mirror*, and gives an account of the "watch night."

A NIGHT OF IT.

On Wednesday evening of last week, Nov. 15th, a number of the more ardent star gazers assembled near the Rectory at midnight to await the expected fall of meteors. At 10 o'clock, the sky had been clear and lovely, but at midnight it was completely covered by clouds and the outlook discouraging. Some twenty-five or thirty persons must have assembled at 12.30, but the most of them became discouraged, as the sky was overcast and a pretty strong east wind blowing. Seven or eight, however, decided to await developments and adjourned to the Rectory and enjoyed a cup of coffee and spent the next three hours very pleasantly, some one going out occasionally to report the prospects. About 3 o'clock word came that the sky was clearing and accordingly all repaired to the trysting place to watch. The Constellation Leo was now gradually rising toward the meridian, and the watchers were rewarded by getting a glimpse of some of the flying meteorites though nothing like a shower was seen. The following will show what were actually counted :—

3 to 4 a.m.	7
4 to 5 a.m.	16
5 to 5.30 a.m.	1
Making a total of ..	24

No doubt the bright moonlight militated against a better showing. Three of those observed were sporadic, but the others came, as judged by the observers from the same point in Leo which has been regarded as the radiating point. From reports since received, no general showers of meteors rewarded the watchers in Europe and America, though in a few places several hundreds were counted. The probability now is that the shower may be looked for at the same date in 1900.

The next regular meeting was held at residence of Mr. H. Manley, on Nov. 23rd.

After routine business, the members reported their experiences in watching for meteors.

An article was read by Miss Paul, describing a view of the meteors from a balloon.

Mrs. Manley was requested to read the verses which it was stated that she had written concerning the night of watching for meteors. These verses were then read, and by resolution Mrs. Manley was requested to permit them to appear in local newspaper.

On December 7th, the Society met at their rooms, and among the predictions of phenomena the President called attention to an expected eclipse of the Moon on the evening of the 16th December. Mrs. Manley read an article entitled the "Fiasco of the November Meteors." Dr. Caswell exhibited a chart or drawing, showing what is called a "Cyclone Prognostic," and giving the regular course of a storm passing over any given locality. This was found very interesting to many aud elicited much questioning and discussion.

The one hundred and twenty-ninth meeting of the Society and the last for 1899, was called to meet at the residence of Mr. H. Manley on December 28th. Our subscription to *Popular Astronomy* was renewed, and the British Astronomical Association *Journal* was laid on the table.

The President reported having received to-day a letter from Montevidio, South America, in reference to the establishment of an Observatory and the publication of astronomical and other scientific observations. He would translate the letter and bring it to the next meeting.

Under the head of observations made, all the members reported their having watched the late eclipse of the moon. Dr. Caswell had made drawings of the eclipse at its various stages and noted the time of each from the entrance of the moon into the umbra until its exit. These were exhibited, and also a method of illustrating the eclipse by means of a diagram. An article entitled "Looking into the New Century" was read and discussed, and the meeting adjourned after appointing their next assembly to be held at their rooms on January 11th, 1900.