THE

ROYAL ASTRONOMICAL SOCIETY

OF

CANADA

SELECTED PAPERS AND PROCEEDINGS

1902 AND 1903

EDITED BY ARTHUR HARVEY, F.R.S.C.

TORONTO:
Z. M. COLLINS,
PUBLISHER TO THE SOCIETY.
1904.

The
Royal Astronomical Society
of Canada

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MEMBER OF THE ASTRONOMICAL SOCIETY OF FRANCE, HONORARY MEMBER OF THE ASTRONOMICL SOCIETY OF MEXICO, PRESIDENT OF THE TORONTO ASTRONOMICAL SOCIETY 1900 AND 1901.

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CANADA

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SUMMARY OF PROCEEDINGS

FOR

1902 AND 1903.

The first meeting of the Astronomical and Physical Society of Toronto, under its new constitution and by-laws, was held on the evening of the 25th of February, 1890."

These words preface the first annual publication of the Society, which had existed for five prior years as an unincorporated group of observers, united by a common love for the practical study of astronomy. It is a volume of 40 pages, and has been followed by eleven others, of which the last two bore the altered title of "The Toronto Astronomical Society." The most recent was therefore entitled "Transactions of The Toronto Astronomical Society for the year 1901, including the Twelfth Annual Report," and contained 164 pages.

It had been felt for some time that the name of the Society was too local for a body which had valued members in other cities and desired to bring together for their general good all Canadians who were interested in astronomical science, and its series of reports was the main ground of the Society's reliance that the distinguishing mark of Royal approval it humbly prayed for would be bestowed upon it. The official petition and the Royal sanction to its new title are as follows :—

TO HIS EXCELLENCY

THE GOVERNOR GENERAL OF THE DOMINION OF CANADA.

THE PETITION OF THE TORONTO ASTRONOMICAL SOCIETY HUMBLY SHEWETH,

1. THAT your Petitioner was founded and became THE ASTRONOMICAL AND PHYSICAL SOCIETY OF TORONTO for the purposes of (a) advancing and popularizing in Canada the study of astronomy and cosmical physics; (b) the diffusion of practical knowledge of these branches of science, and (c) the acquiring real and personal property mainly for these objects, including a library and instruments.

2. THAT in 1900 the name of your Petitioner was changed to that of THE TORONTO ASTRONOMICAL SOCIETY.

3. THAT your Petitioner encourages research and original work and regularly publishes Transactions for distribution to members and scientific bodies throughout the world.

4. THAT your Petitioner has promoted the formation in Canada of other societies with similar aims, of which several are working in affiliation with your Petitioner.

5. THAT your Petitioner has a steadily increasing library consisting of well selected standard works, maps, charts, globes, etc., and that its librarian is authorized within certain bounds to permit the general public to use it for the purpose of reference.

6. THAT your Petitioner has by purchase and donation acquired refracting and reflecting telescopes and other instrumental apparatus.

7. THAT the membership of your Petitioner is composed of Honorary Fellows, Corresponding Fellows, Life Fellows, Fellows and Associates; that the Honorary and Associate Fellowship is conferred only as a mark of recognition of the distinguished services of scientific men who have been invited to accept election; while Fellowship is conferred only on Associates who have in the opinion of the Council of the Society, entitled themselves to the election by reason of their merits as original workers, observers and otherwise. A list of the distinguished scientific men who have accepted Honorary and Corresponding Fellowship will be found in the volume of the Society's Transactions of 1901 presented herewith.

8. THAT, except in the months of July and August, your Petitioner holds fortnightly meetings, at which papers are read and discussed; that during July and August, as well as at other times throughout the year, your Petitioner holds open-air meetings for practical out-of-door work, to which the general public, educational and other bodies are invited, and that public

lectures are given under the auspices of the Society in various universities and schools and other institutions of learning.

9. THAT your Petitioner is in correspondence with more than one hundred societies and observatories in many countries, with which it exchanges its Reports, and is recognized in Canada and elsewhere as the representative Canadian Astronomical Society.

10. THAT your Petitioner having decided to change its name to that of The Astronomical Society of Canada has instructed its Council to solicit from His Majesty the King the privilege of prefixing to that new name the word "Royal"; for your Petitioner believes that such gracious permission would strongly stimulate its efforts in the promotion and diffusion of Astronomical Science and that its influence in this direction would be greatly extended thereby throughout His Majesty's Dominions,

YOUR PETITIONER THEREFORE PRAYS that Your Excellency may be pleased to lay at the foot of the Throne this its humble prayer for the privilege of prefixing the word "Royal" to its name, and your Petitioner as in duty bound will ever pray

R. F. STUPART, PRESIDENT.

J. R. COLLINS, SECRETARY. January 7th, 1903.

OTTAWA, 27th February, 1903.

Sir,

Referring to the recent petition of the Toronto Astronomical Society of Toronto to be allowed to use the prefix "Royal," I have now the honour to inform you that the Governor General has received a despatch from the Secretary of State for the Colonies acquainting His Excellency that His Majesty the King has been graciously pleased to grant permission to the Toronto Astronomical Society to adopt the title of the Royal Astronomical Society of Canada.

I have the honor to be, Sir,
Your obedient servant,
JOSEPH POPE,
UNDER-SECRETARY OF STATE.

R. F. STUPART, Esq., F.R.S.C.
President Toronto Astronomical Society.

Application was thereupon made to the Hon. the Chief Justice of the Common Pleas Division of the High Court of Justice for Ontario, to sanction the change of the title of the Society, and the following letter was received :—

ORDER

UNDER R.S.O., CHAP. 211, SECTION 20.

WHEREAS it has been made to appear to me that the Toronto Astronomical Society was incorporated under the provisions of The Act respecting Benevolent, Provident and other Societies, and that it is desirous of changing the corporate name under the provisions of the said Act to that of "The Royal Astronomical Society of Canada," and that such name is not desired for any improper purpose or is otherwise objectionable.

AND WHEREAS it has been further made to appear that His Majesty the King has been pleased to permit the Society to use in its new name the word "Royal."

NOW THEREFORE, I, the HONORABLE SIR WILLIAM RALPH MEREDITH, Chief Justice of the Common Pleas Division of the High Court of Justice of Ontario, BY VIRTUE of the authority in me vested by The Act respecting Benevolent, Provident and other Societies, DO HEREBY CHANGE the corporate name of the Toronto Astronomical Society to that of THE ROYAL ASTRONOMICAL SOCIETY OF CANADA.

W. R. MEREDITH,
CHIEF JUSTICE.

OSGOODE HALL. Toronto, March 3rd, 1903.

The Society felt, on receipt of His Majesty's gracious compliance with its prayer, that the honor it had obtained would but impose upon it new duties and greater responsibility to all those among us who are specially interested in the progress of astronomy, and it is their hope to receive the earnest co-operation of all the Canadian troop of Urania's votaries, as it will be their endeavour to deserve it.

Under the Council's order, this first Report under the new name has to embrace the Transactions of two years. From the list of papers it will be seen how abundant the material is. It has therefore been necessary to omit the business details heretofore annually given (which can, after all, be found in the Minute Book, and have usually the most ephemeral interest), also to issue, in many cases, rather a review of the subjects touched upon than the papers themselves in full, though often desired.

PAPERS.

1902

Jan. 7th—"Astronomical Notes of the Past Year." Mr. G. E. Lumsden, F.R.A.S.

Jan. 15th—"The Making of a Great Telescope." Dr. J. A. Brashear, F.R.A.S.

PROF. DE-LURY'S SPECIAL COURSE.

Jan. 21st—"The Cosmos as Understood by the Ancients."

Jan. 27th—"The Development of the Copernican Theory."

Feb. 4th—"The Newtonian Advance to Physical Astronomy."

Feb. 11th—"Special Consideration of the Solar System."

Feb. 18th—"La Place's Nebular Hypothesis and Stellar Evolution."

Feb. 25th—"The Planets," with lantern illustrations. Rev. Robert Atkinson.

Mar. 11th—"Phenomena of Polarized Light," with lantern illustrations. Mr. G. R. Anderson, M.A.

Mar. 25th—"The Spectroscope in Astronomical Research," with lantern illustrations. Mr. A. F. Miller.

April 8th—"The Pressure of Light in its Astronomical Aspect." Prof. G. F. Hull, Ph.D., Dartmouth College, N.H.

April 22nd—"The Apex of the Sun's Way." Mr. John A. Paterson, M.A.

May 6th—"The Transit Instrument and its Adjustments." Mr. F. L. Blake, D.L.S.

"Solar Radiation." Mr. Arthur Harvey, F.R.S.C.

May 20th—"Variable Stars." Mr. W. B. Musson.

June 3rd—"Lunar Ring-Plains." Mr. G. E. Lumsden, F.R.A.S.

June 17th—An Evening at the Observatory, with a short lecture on "The Constellations." Rev. R. Atkinson.

Sept. 9th—"Cause of the 25-day Period in the Magnetic Curve," Mr. A. Elvins, Past President.

Sept. 13th—Lawn Party held on the grounds of Mr. John Ellis, at Swansea, from 4 to 10 p.m. In the evening telescopes were provided for observation.

Sept. 23rd—"Astronomical Work for the Autumn." Mr. J.H. Weatherbe.

Oct. 7th—"The Application to the Stellar Universe of Kelvin's Theory of the Ether." Mr. J. R. Collins.

Oct. 21st—"Ancient Lunar Coast Lines." Mr. Lumsden, F.R.A.S.

Nov. 4th—"Astronomy in Canada." Prof. W. F. King.

Nov. 18th—"New Developments in Wireless Telegraphy." Mr. C. A. Chant, M.A., Ph.D.

Dec. 2nd—"Vagaries of the Mariner's Compass." Mr. A. Harvey, F.R.S.C.

Dec. 16th—"Stellar Motions." Mr. A. F. Miller.

1903.

Jan. 13th—Experiments with Physical Apparatus. Mr. A. F. Miller.

Jan. 20th—Address by R. F. Stupart, President.

Feb. 3rd—"Celestial Measurements." Prof. A. T. DeLury.

Feb. 17—"Stellar Motions." Mr. A.F. Miller.

March 17—"The Astronomy of Milton." Mr. John A. Paterson, M.A.

March 31st—"The Diatonic Scale." Mr. Geo. A. Anderson, M.A.

April 14th—"Is the Moon a Dead World?" Mr. J. E. Maybee, M.E.

April 28th—"Stellar Motions." Mr. A. F. Miller.

May 12th—A. R. Wallace's "Man's Place in the Universe," Discussion by Messrs. Lumsden and Collins.

May 26th..."The Adjustment of the Equatorial Telescope." Mr. F. L. Blake, D.L.S.

June 9th—"Rotation: a misleading term as applied to the Sun." Mr. Arthur Harvey, F.R.S.C.

June 23rd—"Helmholtz." Rev. R. Atkinson.

Sept. 15th—"An Evening with the Spectroscope." Mr. A. F. Miller.

Sept. 29th—"Pleasures of the Telescope." Dr. A. D. Watson.

Oct. 13th—"Stonehenge." Mr. J. C. Hamilton, LL.D.

Oct. 27th—"Radium and Astronomical Physics," Mr. J. R. Collins.

Nov. 10th—"Uranoliths (aerolites) with special reference to that which fell at Mazapil, Mexico. Arthur Harvey, F.R.S.C.

Nov. 24th—"The Nature of Ether Vibrations." C. A. Chant, M.A., Ph.D.

Dec. 8th—"Women's Work in Astronomy, Miss Elsie A. Dent.
"How I Built and Equipped my Observatory at Hamilton." Rev. D. B. Marsh, Ph.D., D.Sc.

Dec. 22nd—"Notes on a visit to Greenwich Observatory. John A. Paterson, M.A., K.C.

The committee appointed to take charge of the publication has done its work without the least clashing of opinion, and while each member is aware that improvement in the future is possible and requisite in the particular branch he is responsible for, all hope that under the peculiar circumstances their work will be satisfactory to the members.

The list of papers for the two years is remarkable, they think, for its variety, and in the selection they were forced to make, they were not guided by what they might think the superior merits of any of the essays or theses, but by the desire to choose subjects which had not been touched upon in recent issues. This method of selection should give an inkling of the most recent work and add the most interest to the series of Transactions taken as a whole.

Our last year was saddened by the loss of one of our members, who was of the original coterie above spoken of, was long our Corresponding Secretary, resigned that place to take, for the now customary term of two years, the President's chair, and all too soon thereafter was removed by a premature decease. Mr. G. E. Lumsden unfortunately left behind him no likeness which adequately represents his features with the habitual expression of *bonhomie* with which we were familiar. The best is a photograph taken by his daughter, which is reproduced. The Society offered, by an address, its sincere condolence to Mr. Lumsden's family, and in a note to these pages are given the remarks made by the seconder of that address,* which was appropriately moved by Mr. Andrew Elvins, who is looked up to as the father of the Society.

It only remains to record, here, the names of the officers for 1903; those for 1904 will be found on a previous page.

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REMARKS BY MR. J. C. HAMILTON, M.A., LL.B.

* It is difficult to realize that one has gone whom it seemed most desirable to retain as our mentor and guide, who was rightly esteemed for learning, and who wielded a beautiful influence not only in this Society but throughout the land.

Well developed thought and accuracy in result marked his course. His life of singular purity and almost austere simplicity was devoted to duty and science.

Among Mr. Lumsden's neighbors, of whom for some years I was one, no one was more esteemed, more willing to speak a pleasant word or do a kind act.

He was always ready to point out the great stars and constellations, and to aid the visitor in using the telescope on his premises. His gentle enthusiasm, as he dwelt on the beauty and magnificence of the firmament, induced many to pursue such charming studies. When weary after the day's labours, he found recreation in scientific pursuits, the change of mental occupation giving rest.

He delighted chiefly in regarding the wonderful surface of the moon, the rings of Saturn, and Jupiter with his belts and revolving satellites. Once, discussing such themes, he told me that his worthy father had the like inclinations, and that when, in his old age, a friend suggested that it seemed strange to find him still intent on nature's problems, the reverend man answered happily; 'I believe that in heaven we will continue the studies begun on earth, and I wish to know all I can before I depart."

As we consider his well rounded work and completed life, the words of Ovid come to us, expressive of our feelings,—

"Jamque opus exegi . . . .
Parte tamen meliore mei super alta perennis
Astra ferar."

"Completed is my work . . . .
My better part shall live for aye
Borne up beyond the stars."

THE

ROYAL ASTRONOMICAL SOCIETY

OF

CANADA

SELECTED PAPERS AND PROCEEDINGS

THE PRESIDENT'S ADDRESS.

The session of 1903 was opened on January 20th by an address from the President, R. F. Stupart, F. R. S. C., director of the Magnetic and Meteorological Observatory at Toronto, who chose as his subject in chief the history and a portion of the work of the institution under his charge. He said:—

At the beginning of another year you have again made me the recipient of your favour by re-electing me for another term. I hope the graceful compliment you have paid me indicates that I have not altogether fallen short of the mark aimed for, which is, to render some little assistance to the Society.

While unable to devote as much time as I should wish to astronomy, I can thoroughly appreciate the spirit which animated the framers of our Constitution,—to interest fellow citizens and countrymen in the marvels of the universe and to lead them thereby to have a more perfect respect for the wonders and grandeur of Creation. Such studies must enable us to appreciate more fully the privilege we possess in living; in being ourselves not improbably the greatest among the marvels of the universe. Man may probably never in life fathom the mysteries of time, yet surely a whole-hearted endeavour to acquire a better knowledge of Nature and her laws must tend to uplift our minds.

To the study of Astronomy, the Society joins the study of Cosmical Physics, and this it was that convinced me it would not be quite anomalous to have a Meteorologist as President. I am glad that during each session, papers and discussions on Solar Physics, Terrestrial Magnetism and Electricity have not been infrequent at the fortnightly meetings.

Meteorology, Trrestrial Magnetism, and perhaps I may add Seismology, are sciences especially marked out as fields of research at the Toronto Observatory, all of them akin to Astronomy, and hence a bond of fellowship should exist between its staff and the members of this society.

I purpose this evening to preface my remarks with a few words on the Toronto Observatory, my chief object in so doing being to show that in Toronto we possess most valuable records for the solution of problems in Terrestrial Magnetism and Meteorology-data which will always be available to those among us who wish to do something towards solving problems in these sciences. I may also, perhaps, remove some misapprehension as to why the Observatory was placed in Toronto, and further indicate the nature of the work laid out for its officers to perform.

A score or more of the centuries had rolled by since the Chinese had first travelled the plains of Tartary, guided by the lodestone. Three and a half centuries had elapsed since Columbus had discovered that the magnet does not point alike in all parts of the world. Fifty years had passed since La Perouse had perished with an expedition sent out by the French Government to investigate magnetic phenomena. Von Humboldt had chronicled facts derived from observations in various parts of the world which promised to throw light on many cosmic and terrestrial phenomena. British navy and army officers had taken scattered magnetic observations here and there, but nearly a third of the 19th century had gone by before Great Britain awoke to a sense of the claims of magnetic science on a nation, possessing extensive dominions in all parts of the globe.

It was in the third decade of the century that the British Association for the Advancement of Science had its birth, and from an early period of its history the interests of terrestrial magnetism received no inconsiderable share of the attention and exertions of its members; and I may quote here from Colonel Sabine's first report:

"In the year 1834 a magnetic survey of the British Islands was commenced and carried through by the joint labour of four of its members. In 1825 the Association called for a Report on the state and progress of researches regarding the geographical distribution of the magnetic forces on the surface of the globe; proposing to ground on this preliminary examination an application to Government to aid in the prosecution of the inquiry in remote parts of the earth unattainable by the means at the command of the Association itself, or of its individual members. This Report, presented in 1837, was taken into consideration at the meeting in Newcastle in 1838, and a memorial was addressed to the Government, which, being formally received by Her Majesty's Ministers, originated the naval expedition equipped in the following year for a magnetic survey of high southern latitudes. Deeming the opportunity a fitting one the British Association availed itself of the same occasion to solicit the attention of Her Majesty's Government to the expediency of extending the researches to be accomplished, by fixed observatories, at certain stations of prominent magnetic interest within British Dominions. The stations named were Canada and Van Diemen's Island, as approximate to the points of the greatest magnetic intensity in the northern and southern hemispheres. St. Helena, as approximate to the point of least intensity on the globe; and the Cape of Good Hope as a station where the secular changes of the magnetic elements presented features of peculiar interest. It was also suggested that the observatious at these stations should be metoerological as well as magnetic.

"Arrangements were made that the several observatories should be under the Ordnance Department of the army, and that observations should be taken by officers and non-coms of the Royal Artillery. Lieut. Charles B. Riddell was the officer chosen for duty in Canada, and he chose Toronto as the most suitable site for a magnetic observatory, and the University of King's College granted a site for the building. The first observatory building was of logs, roughcast on its outside and plastered inside."

The magnets were suspended in the observatory in September, 1840, and day by day, week after week, for more than half a century, faithful observers have watched and recorded the movements of the magnetic needle. Lieut. Riddell and his successors have seen it describe a fairly definite daily curve, reaching its greatest easterly elongation about 8 a.m., and westerly between 1 and 2 p.m.; they have watched the declination of this needle increase from less than 1° 14′ in 1840 to over 5° in 1900—and the dip decrease from 75° 15′ to 74° 30′. For months they have, day after day, watched the magnet follow almost the same daily path and then, perhaps suddenly, in an instant, move sharply aside, and perhaps for many days restlessly wander about, changing in a few moments more than it had before changed in as many weeks. Records of all this watching and registration are now available, on which to sound and test the validity of the several theories which have been propounded; the series being as long continued as any that exists, and therefore most valuable.

In 1892 there came a change. Modern applied science brought into existence the trolley car, and the Toronto Magnetic Observatory was, I think, the first to be ruined by the electric currents. Nearly all other magnetic observatories have since either wholly or partially succumbed. Washington, Potsdam, Paris, Greenwich, Kew, like ourselves, have had to look about for some spot where the workings of nature might be watched apart from the hurry and scurry of a modern city. Our Magnetic Observatory is now in the village of Agincourt, and although the tired watcher no longer awaits the stroke of the midnight bells before noting the position of the magnet by means of an eye-reading, yet noiselssly, persistently, a speck of light reflected from a small mirror attached to the magnet writes a faithful and continuous record of its every tremor.

The Toronto Magnetic Observatory has furnished observers for a partial survey over Canadian northern territories. In 1844 General Lefroy (then Captain), under whose direction the observatory then was, in charge of an expedition, observed as far north as Great Slave lake, while the writer of this paper took part in a magnetic survey along the coast of Labrador in 1884, and subsequently spent a winter at Cape Prince of Wales, in Hudson Strait. Observations of declination, dip and horizontal force were taken at Nain, Davis Inlet, and Nachvak on the Labrador, while for Hudson Strait we obtained a whole year of tri-hourly observations, and on two days of each month during the year readings of the declination were made each minute, as they also were during that same year at many points within the arctic circle.

With the great scientific awakening of the last century, students of science attacked, as was natural, the problem of atmospheric circulation, and among those who did the best work and achieved the first definite results was the astronomer Leverrier; he, in 1851, made a thorough investigation of the weather conditions in Europe just prior to and during a great storm which strewed the shores of the Mediterranean and Black seas with wrecks, and was able a little later to recommend to the French Emperor that a regular Meteorological Bureau be inaugurated in France, for the purpose of issuing forecasts by means of a synchronous weather map. Some years later Professor Kingston, the Director of the Toronto Magnetic Observatory, concluded that on him should devolve the privilege of inaugurating a Weather Service in Canada. Right nobly he rose to the occasion, and the autumn of 1876 saw the first weather forecasts issued from Toronto, based wholly on Canadian weather charts and the judgment of an official at the Toronto Observatory. The service has grown wonderfully since those days, and now the Canadian forecasts shew certainly as good a proportion of verification as any issued in the world. But how much remains to be done !

Meteorologists are working at the bottom of the atmospheric ocean, the currents and eddies of which it is important to know —but do not yet know why the corresponding seasons in different years differ. Some of our members have endeavored, with an uncertain quota of success, to trace a connection between sunspots and weather. We are as yet groping in the dark, but a ray of light here and there certainly illumines the field and encourages us to persist. A theory with a direct bearing on meteorological and magnetic changes, which is well worth while testing by observation and analysis, is based on the recent work of M. DesLandres, the Swedish chemist Arrhenius, and I may add the name of G. F. Hull, who, with Professor Nichols, has succeeded in demonstrating, by experiment, that which Clerk Maxwell had concluded some twenty years before, but was unable to prove experimentally, that light exerts pressure. A paper on this subject by Professor Hull was read before the Society last spring, and appears in our last published transactions. It has been proven further that when light pressure is exerted on particles of less than a certain diameter they will be blown away against the attraction of gravitation, and thus has been explained, what has long been an enigma, why comets' tails point away from the sun. Arrhenius thinks it not improbable that the zodiacal light, the gegenschein and the aurora are due to the extremely minute particles, negatively charged, which have been ejected from the sun, and his theory has been favourably commented on by Professor J. J. Thomson, of Cambridge, Eng.

In the "Popular Science Monthly" for January of last year, Professor John Cox gives a synopsis of the theory. In speaking of the aurora he says :

"Perhaps the most interesting application of Arrhenius' theory is his explanation of the aurora. In a well-known experiment the stream of negative particles forming kathode rays in a Crookes' tube are exposed to a magnetic field, when they are seen to describe helices round the lines of force. If the field is powerful enough, they may thus be bent into a complete circle inside a moderately large tube.

"Now, according to Arrhenius, the negative particles discharged from the sun arrive most thickly over the equatorial regions of the earth, which are most directly exposed to him. Long before they reach any atmosphere dense enough to excite luminescence, they are caught by the lines of force of the earth's magnetic field, which are horizontal over the equator, and have to follow them, winding round them in helices whose radii are so much less than their height above us that the effect on a beholder on the earth is as if they moved along the line of force. Over the equator there is little luminescence, for lack of atmosphere. But as the lines of force travel north and south, they dip downwards making for the magnetic poles, over which they stand vertical. Soon the particles find themselves in lower layers of the atmosphere, comparable in density with our highest artificial vacua, and begin to give out the darting and shifting lights of the kathode ray. But this can only be at the cost of absorption, and by the time the denser layers of air are reached, their energy is exhausted. Hence the dark circles round the magnetic poles from which, as from behind a curtain, the leaping pillars of the aurora rise. From this point of view it is significant that Dr. Adam Paulsen, who has made a special study of the northern lights, found so many points of correspondence between them and kathode rays that in 1894 he was led to regard the aurora as a special case of the latter, though unable to give any account of their origin in the upper atmosphere, such as is supplied by Arrhenius' theory.

"The most obvious test to which we can subject such a theory is to ask from it some explanation of the very remarkable periodic variations in the frequency of auroræ. If they are caused by streams of particles ejected from the sun, there should be some connection between the changes in the sun's activity, as indicated in the number of sun-spots, and the number of auroræ observed. Again, since a negative charge in motion is (*pace* M. Cremieux) equivalent to a negative current, the passage of electrified particles through the upper atmosphere should affect magnetic instruments on the earth. Sun-spots, auroræ and magnetic storms should therefore vary together. We know that sun-spots, auroræ and magnetic storms do go through a simultaneous increase and decrease in the well-known period of 11.1 years.

"Arrhenius then regards auroræ as kathode rays on a grand scale, and if so they must ionize the air, the negative ions will form centres for condensation, and, sinking to the earth by gravitation, will charge it negatively, leaving the layers at moderate heights positively charged. This agrees with the results of recent observations made from balloons up to heights of 3,000 meters.

"Since condensation will depend on the number of ions available for nuclei, we have at once an explanation of the curious fact that cloud-formation in the upper atmosphere is more copious in years of frequent auroræ than when they occurred rarely."

Now this appears to me as very important to the meteorologist. Here we have something to investigate. Are clouds and rainfall more prevalent in seasons when the aurora is frequent? It may be worth our while to test again whether the moon, after all, has not some effect on the weather, since a collection of statistics of auroræ has shown a maximum in the northern hemisphere when the moon is furthest south of the equator, and a minimum when she is further north.

That the problems to be solved are among the most intricate is fully recognized by Prof. Schuster, who at the last meeting of the British Association was president of the subsection on "Astronomy and Cosmical Physics." He explained that to the already established subsection of astronomy, other subjects had been added, such as meteorology, terrestrial magnetism, seismology, and, in fact, anything that the majority of physicists are only too glad to ignore. I cannot, however, quite agree with Professor Schuster as to the best means of arriving at results. He quotes Professor Turner, who, in addressing the Astronomical Department the year before, "had warned against the danger there is that the astronomer should allow himself to be swallowed up in routine work and mere drudgery The descent is easy," he says; "You begin by being a scientific man; you become an observer, then a machine, and finally—if all goes well—you design a new eye-piece." Professor Schuster adds:

"Most earnestly do I believe that the subjects of meteorology and terrestrial magnetism, and possibly also of atmospheric electricity, could be most quickly advanced at the present moment if all observations were stopped for five years and the energy of all observers and computers concentrated on the discussion of the results obtained and the preparation of an improved scheme of observation for the future. At the present we are disinclined to discontinue observations, though recognised as useless, for fear of causing a break. We make ourselves slaves to so-called 'continuity,' which is important, but, may be, and I believe is being too dearly purchased."

At the close of the address he says : "The great reform I have in view is this : before you advance make sure that your observations will be useful and will help to answer a definite question." Schuster is a high authority in physics ; but surely the course suggested is dangerous if taken literally. I personally feel with him that of the making of many observations, as of books there is no end, and that in some European countries fully equipped observing stations are perhaps needlessly close together, but assuredly were all the thousands of astronomical and meteorological observers to cease observing, there are but few in each thousand who, had they the inclination, could make any valuable use of the vast amount of material at their command. In Canada, we have, for meteorological work, but five fully equipped observing stations ; all others are for climatological purposes or for purposes of forecasting, and without reports from a certain number of these we certainly should be unable to issue forecasts such as we have them to-day, and which, without doubt, are the means of saving an incalculable amount of shipping and of perishable goods each year. Our present system is, perhaps, only provisional, but it is as yet the best we know of ; it is even now useful and we look forward to the time when research will enable us to do better.

I should like to call the attention of certain of our members to a research by Professor Osborne Reynolds, Professor of Engineering in Owens' College, Manchester, the substance of which was given by him in the Rede lecture at Cambridge last year. It is deemed remarkable by many eminent scientific men, as it provides an entirely new explanation of gravity and electricity. I will read a few paragraphs from a review of it which appears in the "Observatory" for December :

"Dr. Osborne Reynolds tells us that his new theory of the universe accounts for gravitation on Newton's original hypothesis that it is the effect of a state of stress in the medium surrounding all bodies. That medium, as Dr. Reynolds believes that he has discovered it, is not the homogeneous infinitely rare jelly which is understood by those who have hitherto spoken of the ether, but a definite granular structure, comparable to an illimitable heap of shot or sand piled in a regular fashion so that each grain is at the same mean distance from each of its twelve neighbours. By a method which is intelligible only to the trained mathematician, Dr. Reynolds has been able to work out from his experiments a complete series of measures for the grains of this primordial substance which he believes to fill all space. The result is one of the most amazing propositions ever laid down by a serious physicist. We are told that the size of these grains is inconceivably small, though it has been definitely measured by mathematical analysis as being the seven-hundred-thousand-millionth part of the wave-length of violet light, a unit which is itself roughly equal to the sixty-thousanth part of an inch. In a normal condition these grains are in motion with a mean relative velocity of about one and one-third feet per second, though the mean path of each grain is restricted by its neighbours to the four-hundred-thousandth-millionth part of its own diameter. From this it follows that the mean density of such a medium must be ten thousand times that of water, or four hundred and eighty times greater than that of the densest matter known on the earth; whilst it must be normally in a state of stress such that its mean pressure is seven hundred and fifty thousand tons on the square inch, or three thousand times greater than the strongest material known to us can bear. If, now, the reader will try to conceive the real meaning of Dr. Reynolds' assertion that the whole of space—which we call empty—is filled by this extraordinary medium —recalling Wordsworth's description of

> The heavy and the weary weight
> Of all this unintelligible world'

—he will have some idea of the epoch-making nature of this discovery."

To most persons such a theory will be quite unintelligible, but we must remember that only a few short years ago it would have been thought by the well-informed, as well as by the ignorant, to be impossible that disturbances could be created in the ether at any point on the earth's surface, which could be propagated across thousands of miles of land and sea, and we know not how far into what we call space; it is, perhaps, not inconceivable that the ether waves may beat on the shores of a neighboring planet.

Marconi's achievemts in wireless telegraphy have probably excelled all other results in applied science during the past year, but while he and many physicists have been experimenting with Hertzian waves, the Seismologist has been watching and measuring the shiverings and pulsations of the globe itself: every tremor, whether large or small, is now recorded somewhere. When a tremendous submarine landslide occurs along the steep slopes bordering the Tuscarora Deep, Japan trembles; a tremor in 16 minutes is felt at the antipodes, and in about 12 minutes feeble surface waves are recorded in Toronto. Earthquakes, whether occurring near the shores of Alaska or in Central America, produce earth billows which surge across the Continent, and every building in our cities and towns rises and falls as the long earth waves sweep by. We do not feel them, as the movement is small and the distance from crest to crest may be forty miles, but the movement occurs and chandeliers may begin to swing. On April 18th the warning note of trouble was sounded. Towns in Guatamala were wrecked by a quake which sent earth billows to the uttermost parts of the world. In Toronto we recorded one of the largest movements of the seismograph pendulum which has yet occurred, and this was probably the beginning of an intimately connected series of disturbances which culminated in the volcanic eruptions of Mont Pelee and La Souffriere. Nearly all volcanoes are near the ocean, and it has been long suspected that the explosive which causes the outburst is steam at high pressure. As readjustments of the earth's crust occur, whether through tremendous land-slips or cavings-in, such movements may themselves produce enormous heat, and cracks and crevices which allow the ocean to penetrate to the molten rock below, when, the steam generated blows off at the nearest safety valve or the point of least resistance. La Souffriere and Pele had for many days been threatening. Subterranean rumblings and showers of ashes disturbed the people of both St. Vincent and Martinique, but with a natural dislike of abandoning home, the inhabitants of St. Pierre waited, trying to lull themselves into a fancied security. What more pathetic than the story which comes from Fort de France—a story which shows the suddenness of the final catastrophe. A merchant there was talking over the telephone with a friend in St. Pierre, who was describing the volcanic phenomena which frightened him—"If," he added, these extraordinary outbursts continue I shall go to your town with all my family"—then all at once a frightful cry, then a second less strong, like a stifled gasp—then silence. It was finished. In that moment, while yet speaking, he and twenty thousand others were swept into eternity by a scorching, withering, poisonous blast, which was launched with more than hurricane velocity from Pelle's side. An interesting feature of the Martinique eruption is that a magnetic disturbance began on this continent almost co-incidently with the outburst.

While the Physicist has been unusually busy during the past year, the Astronomer has not been idle—indeed he has been just as busy as his brother in science. Many of the larger observatories have been steadily engaged, continuing the mapping of the heavens. No wonderful "Nova" has, however, flashed in sight during the past twelve months, and astronomers, while resting from the excitement of the previous year, have been quietly considering the meaning of the changing spectra and position of parts of the luminosity surrounding Nova Persei. No total eclipse of the sun has caused astronomers from all parts of the civilized world to congregate in spots along a narrow zone of the earth's surface, to view the sublimity of the corona, and wrest, by means of the spectroscope and camera, more of his secrets from the central body of our solar system. Comets, too, have not been numerous: in twenty years the annual average has been five, while in the year past but four have rewarded the diligent search of those enthusiasts who never let a night go by, when the weather admits of it, without sweeping the heavens with their comet-seekers. On April 15th, Brooks, that most successful discoverer of comets, noticed a small one which passed its perihelion on May 7th, when 25° south. Perrine discovered another, (1902 β) early in September, which most of us have seen; it was nearest the earth on October 8th, and passed the perihelion on November 24th. Another extremely faint comet was discovered on December 2nd. Astronomers, both professional and amateur, have been jealously observing Jupiter and his markings—a world perhaps now in the same state of development as was this planet of ours a hundred million years ago. The great red spot—what is it? Mr. Maunder is disposed to regard it as a partial solidification of the surface, a sort of continent in formation. Mr. Stanley Williams concludes that it is as an island in a river, offering resistance to the currents which surround it. Mr. Denning thinks it floats on the broad current of the southern band, and that it moves more slowly than the band, losing 58 secs or 370 miles each day. Mr. Comas Sala is of opinion that it is at a higher level than the current, and that it is a solid body, floating on the higher atmosphere of Jupiter, while the current passes underneath it.

And is the moon quite a dead world? Some astronomers are now fairly sure that it is not; certain it is, there is no field of astronomical research where the amateur may find better prospect of reward than in the careful persistent observation of the lunar surface.

We are beginning the year with a programme which assures us of many papers on interesting and instructive subjects. In our library we have almost every modern book on astronomy, and on our tables the principal periodicals which relate to astronomy and cosmical physics. May we not hope for increased membership; useful research by our members, and all that constitutes for us a prosperous year.

A CATALOGUE OF AEROLITES.

When I first thought of compiling a catalogue of Aerolites or Meteorites—bodies which fell to the earth in the solid form, but were not of recent terrestrial origin—in order to ascertain what evidence we had of the recurrence of showers, whether annual or periodical, I was little aware of the difficulties of the task. These difficulties I do not profess to have overcome. If my catalogue is more reliable than its predecessors (though perhaps less complete) I shall be satisfied. But I wish to note the principal difficulties as cautions for those who may take up the same task hereafter.

The first difficulty is that of distinguishing between lightning and aerolite falls. Lightning has sometimes fused or metamorphosed stones or sand in a way that causes them to be mistaken by the unskilled for aerolites. Lightning also often accompanies showers of hail, and there is a rare form of lightning known as globular lightning, which could easily be mistaken for the fall of an aerolite. I feel grave suspicions as to the reality of an aerolite-fall when it sets anything on fire. I doubt if there is any instance in which a genuine aerolite is known to have set anything on fire in its fall. How far a sulphurous smell is to be regarded in a similar light I am unable to give an opinion. But when trying to ascertain the laws (if any) by which aerolite falls are governed, all recorded instances which may be explained as effects of lightning should be discarded.

Again, the effects of volcanoes and earthquakes may easily be mistaken for aerolites. Volcanoes often eject stones which fall at a considerable distance, and earthquakes have sometimes a similar effect. Volcanoes frequently throw vast clouds of dust into the upper regions of the atmosphere, and this dust may be carried to the earth by rain—especially thunder-showers—at a considerable distance, and may be readily taken for meteoric dust. In fact, falls of meteoric dust should, I think, be excluded altogether; for, even when genuine, the meteors which produced them may have been dissipated high up in the atmosphere, and belonged to a different type from those which fall to the earth in the solid form. There are, however, mistakes on opposite sides as regards earthquakes. The shock caused by a detonating fireball seems to have been more than once mistaken for a slight earthquake.

The next difficulty arises from the deceptive appearances of falls, which frequently occur. Observers have often declared, in perfect good faith, that fireballs fell near them, when a computation of the path, from several observations, shows that nothing of the kind could have occurred. Not long since one man stated that a fireball fell near him in Scotland, while another declared that it fell near him in Wales. No doubt appearances of falling at sea are often deceptive also. Nor can we conclude because a detonation is heard—still less because we see a fireball break up into fragments—that any part of it has fallen to the earth in the solid form. Many of these fireballs seem to explode at considerable heights and are probably completely dissipated in the air. No doubt those which really fall are much more numerous than those which are seen to fall; but still it is but rarely that we can rely on a fall unless the stone is found. The aerolites which are preserved in our museums are the main *data* which we have to rely on in determining the laws by which aerolite falls are governed.

But to determine whether aerolites fall in showers and recur after certain periods as meteors do, we must know the date of each fall, at least approximately—for since meteor-showers seldom last for less than four or five days, a difference of that amount in the date of an aerolite-fall may be disregarded. Unfortunately, however, the exact date of an aerolite-fall was not until recently recorded with much care. The directors of museums chiefly concerned themselves with the mineralogical qualities of the stone and the peculiarities of structure and appearance which it presented; and from this carelessness as to dates even misprints have often come to be accepted either as an alternative date for the fall or as a second distinct fall. Differences of date also arise from the difference of Old Style and New Style, and from mere slips of the pen on the part of the compiler of the catalogue. That there was really but one fall in many instances is sufficiently obvious. The difference of date consists in writing April for August, June for July or perhaps January, March for May, etc., with the day of the month unaltered, or making an error of the same kind in the day of the month or in the year, such as 3 for 13, 1877 for 1677, or 1873 for 1773. But though the difference arises from mere carelessness, it is often difficult to ascertain which is right, and I have been content, for the most part, to follow the latest writer who appears to have given attention to the question of exact dates. I have tried to keep this catalogue clear of duplicates, which are peculiarly objectionable when we are trying to ascertain whether there is a clustering of aerolite falls about particular dates. In very few instances does the precise date of an early aerolite fall appear to have been accurately ascertained.

With regard to the clustering of aerolite falls about particular dates, it is not to be assumed that they all belong to the same shower. As regards meteors, there is not a single night in the year in which more than one shower is not active. This is very possibly true of aerolites also ; but a clustering of falls round a particular date indicates that there is at least one active shower about that date, to which probably a large proportion of the falls will be found to belong.

I have given, first, for each month, the aerolite falls represented at some museum (in which I have doubtless made some omissions), noting the cases in which the date of the fall is doubtful. I have then appended a supplemental list of other falls that appear to be fairly well ascertained. I have omitted all in which the date of the fall cannot be fixed within a few days with probability, if not with certainty. In compiling this supplementary list I have largely relied on the recent catalogue of Dr. Bornitz, using only those respecting whose actual fall he expresses no doubt. That a further scrutiny, however, would raise doubts in some instances seems certain. When we once abandon the safe ground of having found the stone and introduce fireballs that are alleged to have fallen, we not merely enter on an enormous field but we shall find it almost impossible to determine where to draw the line. I think it probable that all detonating fireballs belong to the same class as aerolites ; but the only safe course is, to deduce the laws which regulate aerolite falls from known aerolites alone, and then to try whether detonating meteors (of which a large number are observed every year) obey the same laws or not.

I have to return thanks for the valuable assistance given me by

Mr. Arthur Harvey, whose catalogue is known to most of my readers, and who has supplied me with much information not comprised in his catalogue. The recent catalogue of Dr. Berwerth, of Vienna, has also proved very useful, and I have sometimes followed his Alphabetical Catalogue in cases where he does not expressly state that the stone is in a museum.

I need only say in conclusion, that I am sure the Society will be happy to receive and publish any additions or emendations that may be sent to them, properly authenticated.

JANUARY.

Day.	Year.	Hour.	Place.
1	1869	12.30 p.m.	Hessle, Upsala, Sweden.
1	1887	6.00 p.m.	Bielokrynitschie, Volhynia, Russia.
3	1877	7.15 a.m.	Warrenton, Warren Co., Missouri, U.S.
8	1834	9.30 a.m.	Okniny, Volhynia, Russia. (Some give December 27 or 28, 1833).
15	1824	8.30 p.m.	Renazzo, Ferrara, Italy.
16	1796		Bjelaja, Kieff, Russia. (Some give January 4, 1796 or 1797).
19	1865		Supehee, Goruckpur, India.
19	1867	9.00 a.m.	Khetree, Rajpootana, India.
20	1869	5.00 a.m.	Angra dos Reis, Rio, Brazil.
21	1887	2.00 p.m.	De Cewsville, Haldimand Co., Ontario, Canada.
23	1852	4.30 p.m.	Yatoor, Nellore, Madras, India.
23	1870		Nedagolla, Madras, India. (Some give 26th December, 1869).
23	1877	4.00 p.m.	Cynthiana, Harrison Co., Kentucky, U.S.
25	1845	3.00 p.m.	LePressoir, Louans, Indre et Loire, France.
25	1899	8.00 a.m.	Zomba, British Central Africa.
27	1886		Nammianthal, Madras, India.
28	1883	2.45 p.m.	St. Caprais, Gironde, France.
29	1838	Evening.	Kaee, Oude, India.
30	1868	7.00 p.m.	Pultusk, Warsaw, Poland.
31	1835		Mascombes, Correze, France. (Date somewhat doubtful).
31	1879		La Becasse, Indre, France.

Supplementary Catalogue.

Day.	Year	Hour.	Place.
1	1862	1.00 a.m.	Breslau, Silesia, Germany.
2	1755-6	4.00 p.m.	Tuam, Ireland.
6	1894	8.00 p.m.	Rhuendorf, Lichtenfels, Germany.
9	1572	9.00 p.m.	Thorn, West Prussia, Germany.
9	1583		Castrovillari, Calabria, Italy.
10	1723	3.00 p.m.	Tregony, Cornwall, England.
12	1884	10,00 a.m.	In the Atlantic Ocean, 49° 30′N, 15° W.
13	1697	4 to 5 p.m.	Pentolina, near Siena, Tuscany.
15	1837		Mikolowa, Platten See, Hungary.
17	1883	8.00 p.m.	Glogovacs, Arad, Croatia, Austria.
21	1803	11-12 p.m.	Boganowo, Silesia, Germany.

FEBRUARY.

Day.	Year.	Hour.	Place.
2	1860	11.45 a.m.	Alessandria, Piedmont, Italy.
3	1882	4.00 p.m.	Mocs, Transylvania, Austro-Hungary.
3	1890	1.30 p.m.	Collescipoli, Terni, Italy.
9	1884	2.30 p.m.	Pirthalla, Punjaub, India.
10	1825	12 noon.	Nanjemoy, Charles Co., Maryland, U.S.
10	1853	1.00 p.m.	Girgenti, Sicily.
10	1896	9.30 a,m.	Madrid, Spain.
12	1875	10.15 p.m.	Homestead, Iowa County, Iowa, U.S.
12	1899	7.00 a,m.	Rio dos Antas, Santa Barbara, Brazil.
13	1839	3.30 p.m.	Little Piney, Pulaski Co., Missouri, U.S.
13	1893		Pricetown, Ohio, U.S. (Doubtful.).
15	1814	Noon.	Bachmut, Ekaterinoslav, Russia. (Other dates assigned).
15	1830	7.30 a.m.	Launton, Oxfordshire, England.
16	1827	3.00 p.m.	Mhow, India, N.W. (Some give 27th)
16	1876		Judesegeri, Mysore, India.
16	1883	3.00 p.m.	Alfianello, Cremona, Italy.
18	1815	Noon.	Durala, Punjaub, India.
18	1824		Tounkin, Irkutsk, Siberia.
18	1880	5.30 a.m.	Tajima, Japan.
19	1785	12.15 p.m.	Wittmess, Eichstadt, Bavaria.
19	1796		Tasquimha, Alemtejo, Portugal.
25	1847	2.45 a.m.	Marion, Linn County, Iowa, U.S.
28	1857	Noon.	Parnallee, Madras, India.
29	1868	11.00 a.m.	Motta di Conti, Casale, Piedmont, Italy.

SUPPLEMENTARY CATALOGUE.

DAY.	YEAR.	HOUR.	PLACE.
2	1212		Novgorod, Russia.
4–5	1886	Evening.	Thanax, Kalesi, Turkey in Asia.
10	1875	5.45 p.m.	Isle of Oleron, France.
15	1818	5.30 p.m.	Limoges, Haute Vienne, France.
18	1647	11-12 p.m.	Polau, Zwickau, Germany.
19	1899	7.45 p.m.	Friedeburg, Germany.
27	1671	Noon.	Near Oberkirch, Baden, Germany.
28	1850		Mainberg, Pyrmont, Germany.
29	1896	8.45 p.m.	Sochau, Greiz, Germany.

MARCH.

DAY.	YEAR.	HOUR.	PLACE.
4	1875		Sitithali, Central Prov., India.
6	1853	Noon.	Segowlee, Bengal, India.
6	1853		Duruma, Wanikaland, East Africa. (Day of month doubtful).
8–12	1798	6.00 p.m.	Salles, Villefranche, Rhone, France.
12	1811	11.00 a.m.	Kuleschowka, Poltava, Russia.
12	1899	10.30 p.m.	Bjurbole, Finland, Russia.
14	1881	3.30 p.m.	Pennyman's Siding, Middlesborough, England.
15	1806	5.00 p.m.	Alais, Gard, France.
16	1863	Afternoon.	Pulsora, Indore, India.
19	1882	1.00 p.m.	Fukutomi, Japan.
19	1884	4.15 a.m.	Djati, Penjilon, Java.
20	1868		Daniell's Kuill, Griqualand, S. Africa.
22	1841	3.30 p.m.	Gruneburg, Silesia, Germany.
25	1807	3.00 p.m.	Timochin, Smolensk, Russia.
25	1843		Bishopville, Sumter Co., S. Carolina, U.S.
25	1865	9.00 a.m.	Vernon Co., Wisconsin, U.S.
27	1886	3.00 p.m.	Cabin Creek, Johnson Co., Arkansas, U.S.
28	1859	4.00 p.m.	Harrison County, Indiana, U.S.
28	1860		Kheragur, N.W. India.
31	1875		Szadany, Temeswar, Hungary.

SUPPLEMENTARY CATALOGUE.

1	1564		Between Brussels and Mechlin, Belgium.
1	1596	5.30 p.m.	Crevalcore, Ferrara, Italy.
1	1895	2.00 a.m.	At sea. Lat. 43° 30′ N. Lg. 125° 40′ W.

DAY.	YEAR.	HOUR.	PLACE.
4	1888	11.00 a.m.	Schwachenwalde, Arenswalde, Germany.
5	1821		Greiswalder, Pomerania, Germany.
5	1895	5.30 a.m.	Virginia, Nevada, U.S.
8	1130		Mosul, on the Tigris, Asiatic Turkey.
8	1796	10.15 p.m.	Oberlausitz, near Storcha, Germany.
8	1813		Brunn, Moravia, Austria.
9	1875	8.00 p.m.	Orleans, France.
11	1886	6.15 p.m.	Astoedt, Bergen, Norway.
12	1859		Castilion, Gironde, France.
15	1826	8.00 p.m.	Lugano, Canton Tessino, Switzerland.
16	1636	6.00 a.m.	Between Sagan and Dubrow, Germany. (6th also given).
17	1901		Kerbriand, Brittany, France.
22	1491	8.00 p.m.	Crema, Lombardy, Italy.
23	1883	5.00 a.m.	Smidar, Bohemia, Austria.
24	1857	5.00 p.m.	Stavropol, Caucasus, Russia. (Some give April 5).

APRIL.

DAY.	YEAR.	HOUR.	PLACE.
1	1857	Night.	Heredia, San Jose, Costa Rica.
3	1889	8.30 p.m.	Lundsgard, Sweden.
3	1896		Ottawa, Franklin Co., Kansas U.S.*
5	·1804	Morning.	High Possil, Glasgow, Scotland.
6	1805	5.00 p.m.	Doroninsk, Siberia. (Date doubtful).
6	1885	7.45 p.m.	Chandpur, N.W. India.
7	1887	10.30 a.m.	Lalitpur, Nyagong, India.
7	1891		Indarch, Elisabetpol, Transcaucasia.
9	1894	4.00 p.m.	Fisher, Polk Co., Minnesota, U.S.
9	1896		Ottawa, Franklin Co., Kansas, U.S.
10	1812	1.30 p.m.	Toulouse, Haute Garonne, France.
10	1818		Zaborzika, Volhynia, Russia. (Date doubtful).
10	1890	3.30 p.m.	Baldohn, Courland, Russia.
11	1715	4.00 p.m.	Schellin, Prussia.
12	1864	4.45 a.m.	Nerft, Courland, Russia.
13	1896	7.30 p.m.	Lesves, Belgium. (Some say 1897).
15	1812	4.00 p.m.	Erxleben, Magdeburg, Prussia.
15	1857	10.30 p.m.	Kaba, Delreczin, Hungary.
17	1851	8.00 p.m.	Gutersloh, Westphalia, Germany.
18	1838		Akburpur, N.W. India.
19	1808	Noon.	Cusignano, Parma, Italy.

DAY.	YEAR.	HOUR.	PLACE.
19	1629	5.00 p.m.	Hatford, near Oxford, Berkshire, England. (9th by O. S.)
20	1876	3.45 p.m.	Rowton, Shropshire, England.
24	1875		Nageria, N.W. India.
26	1803	1.00 p.m.	L'Aigle, Normandy, France.
26	1842	3.00 p.m.	Milena, Croatia, Austria.
26	1895	3.00 p.m.	Bishunpur, N.W. India.
28	1893		Bherai, Bombay, India.
29	1844	3.30 p.m.	Killeter, Tyrone, Ireland.

SUPPLEMENTARY CATALOGUE.

11	1780	9.00 p.m.	Beeston, Notts, England.
14	1897	11.00 p.m.	Vierville, Caen, France.
22	1885		Fogelsta, East Gothland, Sweden.
26	1889		Southern Sweden.
30	1899		Aussig, Bohemia, Austria.

MAY.

DAY.	YEAR.	HOUR.	PLACE.
1	1860	12.45 p.m.	New Concord, Muskingum County, Ohio, U.S.
2	1890	5.15 p.m.	Forest City, Winnebago Co., Iowa, United States.
5	1869	6.30 p.m.	Krahenberg. Bavaria.
8	1829	3.30 p.m.	Forsyth, Monroe Co., Georgia, U.S.
8	1846	9.15 a.m.	Monte Milone, Ancona, Italy.
8	1872		Dyalpur, Oude, India.
9	1827	4.00 p.m.	Drake Creek, Sumner Co., Nashville, U.S.
9	1840	Noon.	Karakol, Ajagus, Russia.
9	1894	4.00 p.m.	Bori, Central Provinces, India.
9	1895		Nagy-Borove, Hungary.
10	1879	5.00 p.m.	Estherville, Emmet Co., Iowa, U.S.
11	1855	3.30 p.m.	Mœstel Pank, Oesel, Russia.
11	1874	11.45 p.m.	Sevrukovo, Kursk, Russia.
12	1861	Noon.	Butsura, Goruckpur, India.
13	1831		Vouille, Poitiers, Vienne, France. (Some give date July 18).
13	1855	5.00 p.m.	Bremervorde, Gnarrenburg, Hanover.
14	1861	1.00 p.m.	Canellas, near Barcelona, Spain.
14	1864	8.00 p.m.	Orgueil, Tarn et Garonne, France.
14	1874	2.30 p.m.	Castalia, Nash Co., N. Carolina, U.S.
15	1900	11.30 p.m.	Felix, Perry Co., Alabama, U.S.

Day.	Year.	Hour.	Place.
17	1830	Noon.	Perth, Scotland.
17	1851		Goetersloh, Westphalia, Germany.
17	1877	7.00 a.m.	Hungen, Hesse, Germany.
17	1879	4.00 p.m.	Gnadenfrei, Silesia, Germany.
19	1826		Paulograd, Ekaterinoslav, Russia. (Some give May 26, 1819).
19	1858	8.00 a.m.	Kakowa, Temesvar, Austro-Hungary.
19	1897	7.45 p.m.	Meuselbach, Schwartzburg- udolstat, Germany.
20	1848	4.15 a.m.	Castine, Hancock Co., Maine, U.S.
20	1874		Wirba, near Widdin, Bulgaria.
20	1884	8.30 p.m.	Tysnes Island, Bergen, Norway.
21	1871	8.15 a.m.	Searsmont, Waldo Co., Maine, U.S.
22	1808	6.00 a.m.	Stannern, Moravia, Austria.
22	1868	10.30 a.m.	Slavetic, Agram, Croatia, Aus tria.
22	1869	10.00 p.m.	Kernouve Cleguerec, Morbihan, France.
23	1865	6.00 p.m.	Gopalpur, Jessore, India.
24	1886	7.00 a.m.	Assisi, Perugia, Italy.
24	1892	5.00 a.m.	Cross-Roads, Wilson Co., North Carolina, U.S.
26	1751	6.00 p.m.	Hraschina, Agram, Croatia.
26	1893	3.30 p.m.	Beaver Creek, W. Kootenay, British Columbia, Canada.
27	1866		Pokra, Bustee, N.W. India.
27	1895		Ambapur, Nagla, N.W. India.
28	1886	2.30 p.m.	Barntrup, Lippe-Detmold, Germany.
30	1866	3.30 a.m.	St. Mesmin, Aube, France.

Supplementary Catalogue.

4	1543		Pforzheim, Bavaria, Germany.
11	1164		Meissen, Germany.
11	1649	3.00 p.m.	Munster, Alsace, Germany.
12	1825		Baydon, Hungerford, England
16	1646		Copenhagen, Denmark.
17	1561		Torgau, Saxony, Germany.
17	1806		Basingstoke, Hants, England.
18	1698	7.15 p.m.	Hinterschwendi, Berne, Switzerland.
18	1680		Near Gesham College, London, Eng.
18	1897	4.05 p.m.	Berlin, Germany.
19	1421		Novgorod, Russia.
22	1820		Oedenburg, Hungary.
26	1379		Minden, Hanover, Germany.
26	1892	Midday.	Berlin Schoeneberg, Germany.

DAY.	YEAR.	HOUR.	PLACE.
27	1580	2.00 p.m.	Near Goettingen, Germany.
28 (26)	1677	Evening.	Ermendorf, Dresden, Germany.
29	1868	11.30 p.m.	Cape Spartel, Morocco, Africa.

JUNE.

DAY.	YEAR.	HOUR.	PLACE.
1	1902		Marjalate, Viborg's Laen. Finland.
2	1843	8.00 p.m.	Utrecht, Holland.
2	1863	7.30 a.m.	Buschhof, Courland, Russia.
3	1822	8.30 p.m.	Angers, Maine et Loire, France.
3	1842		Aumieres, Lozere, France.
4	1828	8.30 a.m.	Richmond, Henrico Co., Virginia, U.S.
4	1890	8.00 a.m.	Kahangarai, Madras, Iadia.
6	1838	Noon.	Chandakapur, Nagpur, India.
6	1890		Nawapali, Central Prov., India.
7	1855	7.45 p.m.	St. Denis-Westrem, Ghent, Belgium.
9	1866	5.00 p.m.	Knyahinya, Austro-Hungary.
9	1867	10.30 p.m.	Tadjera, Algiers, Africa.
10	1901		Sindhri, Bombay, India.
11	1878	11.30 a.m.	La Charca, Guanajato, Mexico.
12	1834	8.00 a.m.	Charwallas, Delhi, India.
12	1840	10.30 p.m.	Uden, North Brabant, Holland.
12	1841	1.30 p.m.	Chateau Renard. Loiret, France.
13	1819	6.00 a.m.	Jonzac, Barbezieux, Charente, Inf., France.
13	1850		Kesen, Japan.
15	1821	3.30 p.m.	Juvinas, France.
15	1900		N'Goureyma, Soudan, Egypt.
16	1794	7.00 p.m.	Siena, Tuscany, Italy.
16	1860	5.00 a.m.	Kusiali, Kumaon, India.
17	1870	2.00 p.m.	Ibbenbuhren, Westphalia, Prussia.
17	1877	4.30 a.m.	Jodzie, Kovno, Russia.
18	1881	Morning.	Pacula, Hidalgo, Mexico.
19	1876		Vavilovka, Kherson, Russia.
20	1897		Lancon, Bouches du Rhone, France.
21	1668	1.15 a.m.	Vago, Verona, Italy.
21	1822		Clohars, Finisterre, France.
21	1889	8.30 a.m.	Mighei, Kherson, Russia. (Bornitz gives 18th).
22	1723		Ploschkowitz, Bohemia, Austria.
25	1890	12.55 p.m.	Farmington, Washington Co., Kansas, U.S.
26	1864	7.00 a.m.	Dolgowoli, Volhynia, Russia.
20–30	1868	3.00 p.m.	Pnompehn, Cochin-China.

DAY.	YEAR	HOUR.	PLACE.
28	1861	7.00 p.m.	Mikenskoi, Grosnaya, Caucasus, Russia.
28	1872	12 noon.	Tennasilm, Esthonia, Russia.
28	1876	11.30 a.m.	Staelldalen, Sweden.
29	1843		Manegaum, Deccan, India.

SUPPEMENTARY CATALOGUE.

2	1883		Near Constantinople.
3	1731		Lessay, Coutance, La Manche, France.
5	1722	3.30 p.m.	Schefftlar, Bavaria, Germany.
7	1706	2–3 p.m.	Larissa, Thessaly, Turkey in Europe.
7	1879		Lake Lugano, near Melidi, Switzerland.
15	1895	8.00 p.m.	Chimacum, Port Townsend, Washington, U.S.
18	1808		Seres, Macedonia, Turkey in Europe. (Some say 1818.)
22	1850	11.00 a.m.	Proava, Oviedo, Spain.
23	1530		Erfurt, Germany.
25	1876		Kansas City, Missouri, U.S. *(A)
28–29	1525		Milan, Italy.

JULY.

DAY.	YEAR.	HOUR.	PLACE.
1	1879	Evening.	Nagaya-Conception, Entre Rios, Argentina. (Some give June 30, 1880).
3	1753	8.00 p.m.	Tabor, Bohemia, Austria.
4	1842		Barea, Logrono, Stet, Spain.
4	1848		Marmande, Gironde, France.
8	1811	8.00 p.m.	Berlanguillas, Old Castile, Spain.
10	1899	8.00 a.m.	Allegan, Allegan Co., Michigan, U.S.
11	1868		Ornans, Doubs, France.
12	1820	5.30 p.m.	Lasdany, Lixna, Russia.
14	1845	3.00 p.m.	Le Telleul, La Vivonniere, de la Manche, France.
14	1847	3.45 a.m.	Braunau, Bohemia, Austria.
14	1860	2.15 p.m.	Dhurmsala, Punjaub, India.
14	1871	8.00 p.m.	Laborel, Drome, France.
15	1878	1.45 p.m.	Tieschitz, Moravia, Austria.
17	1840	7.30 a.m.	Cereseto, Casale, Piedmont, Italy.
17	1902		Mount Brown, New South Wales.

*(A) American Journal of Science, 1876, p. 316. But Prof. Farringtory of Chicago, does not believe it genuine.

Day.	Year.	Hour.	Place.
18	1889	6.00 p.m.	Ferguson, Haywood Co., N. Carolina, United States.
20	1892	10.30 a.m.	Guarena, Estremadura, Spain.
22	1838	Day.	Montlivault, Loire et Cher, France.
23	1872	5.30 p.m.	Lance, Orleans, France.
24	1790	9.00 p.m.	Barbotan, Lot et Garonne, France.
24	1837	11.30 a.m.	Gross Divina, Hungary.
25	1900		O'Feherto, Hungary.
27	1894	8.00 p.m.	Sawtschenskoje, Kherson, Russia.

Supplementary Catalogue.

3	1725		Mixbury, Bicester, Oxfordshire, Eng.
3	1887	11.00 a.m.	Nieder-Bartau, Courland, Russia.
5	1825	2.00 p.m.	Torrecillos del Campo, Castile, Spain.
5–6	1868	11.45 p.m.	Namur, Belgium.
7	1635		Calce, Vicenza, Italy.
8	1186		Hagenau, Belgium (June 30 also given).
8	1852	9.00 a.m.	Near Groningen, Holland.
8	1879		Louisville, Kentucky, U.S.
9	1862	11.00 a.m.	St. Louis, Missouri, U.S.*
10	1880		Wilcacowa, near Schroda, Germany.
10	1895	9.00 p.m.	Szakal, Temesvar, Hungary.
Middle.	1766	5.00 p.m.	Albareto, Modena, Italy.
19	1816		Starenburg, near Bonn, Germany.
19	1894		Surakina, Crete.
25	1498		Sweizenbach, Germany.
26	1249		Quedlinburg, Germany.
26	1581	1.30 p.m.	Buttstadt, Thuringia, Germany.
29	1854	11-12 p.m.	Gera, Germany.
31	1859	9.30 p.m.	Montpries, Styria, Austria.

AUGUST.

Day.	Year.	Hour.	Place.
1	1835	2.30 p.m.	Charlotte, Dickson Co., Tenn., U.S.
1	1897	10.30 a.m.	Zavid, Zvornik, Bosnia.
1	1898	9.00 p.m.	Quesa, Valentia, Spain.
2	1882	4.30 p.m.	Pawlowka, Saratov, Russia.
4	1835	4.30 p.m.	Aldworth, Cirencester, England.
4	1885	4.00 a.m.	Grazac, Haute Loire, France.
5	1812	2.00 a.m.	Chantonnay, Vendee, France.
5	1855	3.30 p.m.	Petersburg, Lincoln County, Tennessee, U.S.
5	1856	11.00 a.m.	Oviedo, Spain.

Day.	Year.	Hour.	Place.
5	1898	7.30 a.m.	Andover, Oxford Co., Maine, U.S.*
7	1822	Night.	Agra, India.
7	1823	4.30 p.m.	Nobleborough, Lincoln Co., Maine, U.S.
8	1863	12.30 p.m.	Pilitzfer, Livonia, Russia.
10	1818		Slobodka, Smolensk, Russia.
11	1859	7.20 a.m.	Bethlehem, Albany County, New York, U.S.
11	1863	Noon.	Shytal, Dacca, India.
11	1897		Hakata, Japan.
12	1865	7.00 p.m.	Dundrum, Tipperary, Ireland.
14	1829	11.30 p.m.	Deal, New Jersey, U.S.
14	1846	3.00 p.m.	Cape Girardeau, Missouri, U.S.
16	1875	12 noon.	Feid Chair, La Calle, Algeria.
16	1885	5.15 p.m.	Sabetmahet, Oude, India.
18	1870	6.15 a.m.	Cabeza de Mayo, Murcia, Spain.
22	1902		Caratash, Smyrna, Turkey in Asia.
25	1865	9.00 a.m.	Shergotty, Behar, India.
25	1865	11.00 a.m.	Aumale, Algeria.
29	1878	2.30 p.m.	Mern, Praestoe, Zeeland, Denmark.
29	1882		Pirgunje, Bengal, India.
29	1892	4.00 p.m.	Bath, Brown Co., S. Dakota, U.S.
30	1887	3.00 p.m.	Tabory, Perm, Russia.
31	1872	5.15 a.m.	Orvinio, Rome, Italy. (Also given as Oct. 31.)

Supplementary Catalogue.

1	1874	10.50 p.m.	Hexham, Northumberland, England.
3	1840		Tamaville, La Manche, France.
4	1642	4.30 p.m.	Woodbridge, Suffolk, England.
7	1843	1–2 a.m.	Reine, Westphalia, Germany.
9-10	1898	3.00 a.m.	Near Kiel, Schles-Holstein, Germany.
12	1890	11.15 p.m.	Plauen, Twickau, Silesia, Germany.
13	1580		Wiehe, Thuringia, Germany.
15	1732	Noon.	Springfield, Chelmsford, Essex, Eng.
18	1783	9.15 a.m.	Shetland Island, Scotland. (A)
20	1819	3.00 a.m.	Rottweil, Wurtemberg, Germany.
20	1902	10.15 p.m.	Lennep, Rhine Provinces, Germany.
21	1877	6.00 p.m.	Hanau, Hesse, Germany.
24	1900		Val, Jaen, Spain.
26	1834		Padua, Lombardy, Italy.

Note (A)—A splendid fire-ball in England was seen at about 9h. 15m. p.m. on this day, but, as it came from the north, it is not likely to have produced a stone-fall in Shetland. Hence I am very doubtful of this fall, even assuming 9h. 15m. a.m to be an error for 9h. 15m. p.m.

DAY.	YEAR.	HOUR.	PLACE.
28	1878	10.30 a.m.	Cologne, Germany.
29	1850	10.00 p.m.	Nauplia, Greece.
31	1891	3.00 p.m.	Renncher Muehle, Wurtemburg, Germany.

SEPTEMBER.

DAY.	YEAR.	HOUR.	PLACE.
3	1808	3.30 p.m.	Lissa, Bohemia.
4	1852	4.30 p.m.	Mezo-Madaresz, Transylvania.
5	1814	Noon.	Agen, Lot et Garonne, France.
5	1854		Linum, near Ferbellin, Prussia.
5	1878		Dandapur, Goruckpur, India.
5–6	1812	1.00 a.m.	Borodino, Russia. (Some give 1813).
6	1841		St. Christophe la Chartreuse, Vendee, France.
7	1753	1.00 p.m.	Luponnas, de l'Ain, France.
7	1868	2.30 a.m.	Sauguis, Pyrenees, France. (Also given as 6th and 8th).
About 8	1887		Orange River, South Africa. (Exact date uncertain).
9	1829	2.00 p.m.	Krasnoi-Ugal, Russia.
9	1831	3.30 p.m.	Wessely, Moravia, Austria.
10	1813	6.00 a.m.	Adare, Limerick, Ireland.
13	1768	4.30 p.m.	Luce, Sarthe, France.
13	1822	7.00 a.m.	La Baffe, Epinal, Vosges, France.
13	1902	10.30 a.m.	Crumlin, Antrim, Ireland.
14	1836	3.00 p.m.	Aubres, Drome, France.
14	1511		Territory of Crema, Italy. *(A)
14	1825	10.30 a.m.	Honolulu, Hawaii, Sandwich Islands.* (Some say 27th).
15	1897		Gambat, Khairpur, India.
16	1843	4.45 p.m.	Kleinwenden, Erfurt, Prussia.
17	1879		Fomatlan, Mexico.
19	1869	9.00 p.m.	Tjabe, Padangan. Java.
21	1865	7.00 a.m.	Muddon, Mysore, India.
22	1886	7.15 a.m.	Nowo-Urei, or Alatyr, Penza, Russia. (Other dates given).
22	1887		Phu-Hong, Cochin-China.
22	1893		Zabrodje, Wilna, Russia.
23	1873	5.00 a.m.	Khairpur, Moultan, India.
23	1899		Donga - Khorod, Bilaspur, Central India.

*(A) This fall is well authenticated at Sept. 4th, which is 14th, according to the new style.—Ed.

Day.	Year.	Hour.	Place.
26	1893	7.00 a.m.	Santa Barbara, Rio Grande do Sul, Brazil.

SUPPLEMENTARY CATALOGUE.

7	1514		Sugolie, Greuz, Hungary.
7	1900	11.00 p.m.	Calvi, Corsica.
14	1895	9.00 p.m.	Waldenburg, Silesia, Germany.
14	1901		Kaschau, Hungary.
15	1896		Tuttlingen, Germany.
18	1836	10.00 a.m.	Florence, Italy.
18	1897	Noon.	Engelsberg, Nordhausen, Germany.
19	1775	10.00 a.m.	Rodach, Coburg, Germany.
23	1899	11.00 a.m.	Gemeinde, near Namur, Belgium. (A)

OCTOBER.

Day.	Year.	Hour.	Place.
1	1857		Les Ormes, Yonne, France. (Some give 4th).
1	1862		Seville, Spain.
1	1868		Lodran, Moultan, India.
3	1815	8.00 a.m.	Chassigny, Haute Marne, France.
3	1883		Ngawe, Java.
5	1827	9.30 a.m.	Bialystock, Poland. (Other dates given).
5	1866		Jamkheir, Ahmednuggar, India.
6	1869	11.45 a.m.	Lumpkin, Stewart Co., Georgia, U.S.
7	1861	12.30 p.m.	Klein-Menow, Mecklenburg. (Other dates given).
8	1803	10.00 a.m.	Saurette, Apt, Vaucluse, France.
11	1857	12.15 a.m.	Ohaba, Transylvania Austro-Hungary. (Possibly 10th).
13	1787	3.00 p.m.	Jigalowka, Kharkov, Russia.
13	1819	8.00 a.m.	Politz-Gera, Reuss, Germany. (Some give 3rd).
13	1838	9.00 a.m.	Cold Bokkeveld, South Africa.
13	1852	3.00 p.m.	Borkut, Marmaros, Hungary.
13	1877	2.00 p.m.	Sokobanja, Servia. [Some give 3rd].
14	1824	8.00 a.m.	Zebrak, Bohemia, Austria.
21	1844	6.45 a.m.	Favars, Aveyron, France.
21	1901		Hoittis, Abo Laen Finland.
24	1899	7.00 a.m.	Peramiho, East Africa.

(A)—So many stone-falls are reported near Namur that I suspect some of them to be duplicates.

DAY.	YEAR.	HOUR.	PLACE.
31	1849	3.00 p.m.	Flows, Cabarras Co., N. Carolina, U.S.

SUPPLEMENTARY CATALOGUE.

1	1304		Friedland, near Halle, Germany. (A)
18	1738	4.50 p.m.	Carpentras, Avignon, France.
19	1876		Newbury Port, Massachusets, U.S.
20	1791		Monabilly, Launceston, Cornwall, Eng.
27	1634	8.00 a.m.	Charollois, Saone et Loire, France.

NOVEMBER.

DAY.	YEAR.	HOUR.	PLACE.
4	1879		Kalumbi, Bombay, India.
5	1814		Chail, Allahabad, India.
5	1851	5.30 p.m.	Nulles, Catalonia, Spain.
10	1886	3.00 p.m.	Maeme, Yeushigahara, Japan. (Some give October 26 or 29).
11	1836	5.00 a.m.	Rio Assu, Rio Grande do Norte Brazil.
12	1843		Werchne-Tschirskaja, Don, Russia. (Oct. 30 also given).
12	1856	4.00 p.m.	Trenzano, Lombardy, Italy.
15	1898	9.30 p.m.	Saline, Sheridan Co., Kansas, U.S. *
15	1902	6.45 p.m.	Bath Furnace, Bath Co., Kentucky, Unired States. *
16	1492	12.30 p.m.	Ensisheim, Alsace, Germany.
17	1773	Noon	Sena, Sigena, Arragon, Spain.
19	1877		Cronstadt, Orange River, S. Africa.
19	1881	6.30 a.m.	Grosliebenthal, Odessa, Russia.
20	1768	4.00 p.m.	Mauerkirchen, Bavaria, Germany.
20	1878		Rakowka, Tula, Russia.
23	1810	1.30 p.m.	Charsonville, La Touanne, Loiret, France.
24	1804		Hacienda de Bocas, San Luis Potosi, Mexico.
25	1833	6.30 p.m.	Blansko, Bruun, Moravia, Austria.
26	1874	10.30 a.m.	Kerilis, Cotes du Nord, France.
27	1868	5.00 a.m.	Danville, Alabama, U.S.
27	1877	6.00 p.m.	Bhagur, Khandeish, India. (Some give 1878).
227	1885	9.00 p.m.	Mazapil, Zacatecas, Mexico.

(A)—A fall reported on the 1st of October, 1304, or 1305, at Vandals, South Austria, is probably identical with this, but stones may have fallen in both places.

Day.	Year.	Hour.	Place.
8	1891	5.00 p.m.	Guca, Cacat, Servia. (Bornıtz gives October 10th).
30	1822	6.00 p.m.	Futtehpur, Allahabad, India.
30	1850	4.30 a.m.	Shalka, Bengal, India.

Supplementary Catalogue.

6	1548	2.00 a.m.	Near Mansfeld, Thuringia, Germany.
6	1869	8.30 p.m.	Tamley, near Southampton, England.
9	1892	11.45 p.m.	Altenburg, Saxony.
10–12	1761	4.45 a.m.	Chamblons, Cote d'Or, France.
14	1825		Leith, Scotland.
15	1860		Denisville, New Jersey, U.S.
27	1627	10.00 a.m.	Mont Vaisien, near Nice, France. (Given also as 1637).
29	1820	7.00 p.m.	Cosenza, Calabria, Italy.
29	1834		Szala, Gespan Salad, Hungary. (Also given as Nov. 13th).
29	1839	3–4 p.m.	Naples, Italy.

DECEMBER.

Day.	Year.	Hour.	Place.
1	1848	Evening	Fisherton near Salisbury England.
1	1889	2.30 p.m.	Kasak, Jelica Mountains, Servia.
2	1852		Bustee, India, N.W.
4	1864		Wairarapa, New Zealand.
5	1868	3.00 p.m.	Frankfort, Franklin Co., Alabama, U.S.
6	1866		Cangas de Onis, Oviedo, Spain.
7	1863	11.00 a.m.	Tourinne-la-Grosse Tirlemont, Belgium.
7	1894	Evening.	Ruschany, Grodno, Russia. (Doubtful).
9	1858	7.30 a.m.	Aussun, Montrejean, Haute Garonne, France.
10	1871	1.30 p.m.	Bandong, Java.
13	1795	3.30 p.m.	Wold Cottage, Thwing, Yorkshire, England.
13	1803	10.30 a.m.	St. Nicholas, Massing, Bavaria, Germany.
13	1813	Day.	Luotolaks, Wiborg, Finland.
14	1807	6.30 a.m.	Weston, Fairfield Co., Connecticut, US.
19	1798	8.00 p.m.	Krahut, Benares, India.
21	1876	8.45 p.m.	Rochester, Fulton Co., Indiana, U.S.
22	1863	9.00 a.m.	Mhamboom, Bengal, India.

DAY.	YEAR.	HOUR.	PLACE.
22	1868		Motecka-nugla, Burtpur, India.
24	1858		Molina, Murcia, Spain.
25	1846	2.45 p.m.	Schonenberg, Bavaria, Germany.
27	1848	Evening.	Ski, Akerhuus, Norway.
27	1857	2.30 a.m.	Queng Yonk, Pegu.

SUPPLEMENTARY CATALOGUE.

6	1885	10.25 p.m.	Naples, Italy.
8	1836	8.00 p.m.	Zuz, Graubusnden, Switzerland.
13	1889	6.30 p.m.	Near Kroepelin, Germany.
10–14	1863	Evening.	Jagli, near Trebizond, Turkey in Asia.
15	1834	Midnight.	Marsala, Sicily.
24	1706	5.00 a.m.	Barcelona, Spain.
26	1877	8.00 a.m.	Hohr, Nassau, Germany.
26	1896	8.00 p.m.	Agnesruh, near Bad-Elster, Germany.
30	1896	9.00 p.m.	Deggendorf, Bavaria, Germany. (A)

(A)—Possibly another version of the foregoing.

*Falls marked with an asterisk have been added by the Editor, from American sources.

There are in various small museums a number of American meteorites, not included in the above list. The records of several American and foreign meteorites besides the above have been examined, but they are too imperfect to add at present. Such are, e.g. meteorites that fell at Cerro Cosina, Guanajato, Mexico, 1844. Durango, Mexico, 1856. McKinney, Collin Co., Texas, 1870. Itapicura, Brazil, 1879. Fomatlan, Mexico, 1879. Bachmut and Scholakoff, Russia. (These Russian meteorites are so difficult to date properly, that one is inclined to strike them all out of a list designed to be reliable). Marengo, Iowa, U.S., 1894. Manzanares, Mexico, 1891. Atacama, Bolivia, 1883. Bueste, Pyrenees, France, 1859. Mont Galapien, Agen, France, 1898. Raphoe, Donegal, Ireland, 1860. A hundred other records have been examined to see if the accounts of them were true, and they have to be excluded by reason of uncertainty, sometimes even fraud. The Society will welcome all additional information, but it should be exact and complete. (Ed.)

SHOOTING STARS VS. URANOLITHS.

WITH SPECIAL REFERENCE TO THE MAZAPIL (MEXICO) METEORITE,

Our valued correspondent Mr. Monck, in the paper just read, refers to my assistance too generously. Indeed, I scarcely agree with his principle of exclusion, there are very many well authenticated falls quite as reliably dated as those of which specimens are preserved in museums. I have therefore only ventured to add slightly to the list, which it is his object to render accurate rather than exhaustive; I have merely added a few American meteorites, of which the dates of fall are well known. and, also in accordance with his desire, I re-introduce to the Society some branches of the deeply interesting subject, which he designedly excludes.

Mr. Monck wishes to provide a basis for examining a theory that aerolites travel in streams like shooting stars. Now in a paper "on the distribution of aerolites in space,"* I enquired "whether there is a periodicity among aerolites, and whether "they are connected with shooting stars and recognized comets." I gave instances of uranoliths which fell on the same day at places too far apart to be accounted for by the breaking up in our atmosphere of a single stone, and remarked that more complete tables would perhaps shew that "aerolites do not always fly in single file or in closely packed clusters, but that there are doubles and triples and double clusters too." Examples were cited of showers of stones which had fallen by hundreds and thousands over areas miles in extent. So I naturally welcome Mr. Monck's views as an extension of my own, and bespeak for them that careful criticism which is the best acknowledgement of their merit.

Shooting stars may be the discards of comets, for we shall presently compare the orbital elements of some swarms with those of comets known to be disintegrating, and observe their close agreement. Thus the inference that they once were parts of comets is as reasonable as to trace drops of water on a street to

*Trans. Royal Society of Canada, 1896.

a leaky water cart which has passed that way. But my opinion in 1896, was that the connection between aerolites and shooting stars was not so close as many writers believe, and that the former rather resembled dead comets than their living exhalations, and are rather a counterpart on a small scale of the dark stars in which we have lately been taught to believe. Prof. Bornitz is a leading exponent of the contrary idea, and thinks that shooting stars, bolides, fireballs and meteorites travel together as parts of the same swarms. His view has been brought before us in recent numbers of the "Astron. Mittheilungen," at the end of which the editor adds a review and verdict of "not proven." Mr. Monck does not declare himself as yet, but he writes to me (April 30th) that he too "rather concludes that the occasional coincidences (between shooting star swarms and aerolitic falls) are casual."

My table was compiled for the study of one problem in chief. Mr. Elvins had been advocating a theory which had a considerable vogue fifty years ago, that space was full of drifting matter, and that, as our system plunged through it, the sun and the planets encountered meteoric aggregations which were the cause of sun-spots, the fuel for his fires, and gave rise to the phenomena of Terrestrial Magnetism. My tables shewed that there was no great abundance of meteorites in one month more than another, while even the hours had each a fair average, after allowing for the obstacles to observation. The conclusion arrived at was that "aerolites are evenly distributed throughout space and move at various angles with the plane of the ecliptic." This answered in the negative the question whether there were clouds of drifting matter stratified in space, demolished the idea that inrushing meteors caused sun-spots, and confirmed the belief that internal Solar disturbances are the exciting cause of our magnetic perturbations.

Meteors, which had been heard and seen over a large extent of country were not excluded from my list, even though pieces of them had not been picked up. Mr. Monck does so exclude them, and confines to meteorites seen and immediately found and preserved, what we may call Class I. Fireballs seen and heard then fall into Class II, and a careful compiler could largely extend the existing list of such visitors, chiefly catalogued by

Germans. Bolides, which should for the purpose be defined as fireballs seen but not heard, could be placed in Class III, while the great majority of shooting stars which are not in any sense Fireballs can stay in Class IV. Prof. Bornitz would form a class of Comet-like meteors, but its limits are ill defined, and may include the long enduring trails of certain Fireballs, auroral clouds or even electrical phenomena.

The astronomical questions connected with shooting stars are interesting, important and obscure. They include a number of unsolved problems which, when understood, will teach valuable lessons in cosmogony. And observations are open to all, this being one of the few branches in which statistics are drawn as much from averages as from precise measurements. Conclusions too being quite unsettled, it may be given to any one to contribute an important suggestion which may illumine some of the difficulties.

Mr. W. A. Denning's great catalogue of shooting-star radiants mentions 4,408 of them, but by grouping those which are probably duplicates, the measurements being nearly identical, he reduces them to 278, named after the stars in the vicinity of radiant points. These thousands do not include more than a few hundred from the Southern hemisphere, where there are very likely as many as in the Northern, and until we have Southern observations with reasonable completeness, many of our deductions from partial premises are sure to be fallacious. As an instance, the proportionate numbers of radiants, active month by month, are given as follows (per mille) :

Jan., Feb., etc., to June, 54, 61, 56, 76, 55, 59=361
July, Aug., etc., to Dec., 109, 134, 124, 110, 86, 76=639

It will be seen that weather probably accounts for much of the difference. In November, December, January, February and March people are at their firesides, not in the open air observing meteors. The usual explanation given is that the Apex or point in the heavens towards which the motion of the Earth in its orbit is being from time to time directed, is nearer the Zenith in the last half of the year than in the first.

The direction of the earth's motion being at right angles to the line drawn from Earth to Sun, the Apex must always be on the ecliptic and 90° west of the sun. Therefore this " Meteoric

Sun" (Schiaparelli) attains its equinox June 21st, and is above the equator for the six months following. But Southern observations do not seem to give countenance to such a view, according to Neumayer's Melbourne record. I venture to prophesy that the number of radiants will be found nearly equal in every month and further prove both the even distribution of matter in space and the futility of reasoning without sufficient facts.

The swiftness of a meteor's approach to the earth varies with its direction. If it meets the earth full tilt the velocity would be 26 +18=44 miles a second, and if it has to meet in a stern chase the 18 miles, which is the earth's orbital speed, must be subtracted, giving 26–18=8 miles only. These are extreme cases. But they are the velocities on the confines of the atmosphere, which must rapidly diminish. The best calculations shew that shooting stars incandesce at a height of from 65 to 100 miles, sometimes even 120. They are burned out at a height of from 35 to 60 miles, averaging 50.

Perhaps Schiaparelli is entitled to the credit of originating the line of thought respecting the origin of shooting stars which at present prevails. He began by enquiring—"What would be the fate of a mass of diffused matter, hovering on the very confines of the Solar System", and his solution was that it would be drawn out into a sort of parabolic wisp, which might take hundreds of years to reach its perihelion. Starting from this point, we have had theories about the common origin of several comets, e. g. 1860 III., 1863 I., 1863 VI., which have nearly the same aphelia, and were together at aphelion in 1020; about the interferences of planets with comets, by which they were "captured" and their orbits changed into ellipses having aphelia near those planets' orbits; and finally the opinion that shooting stars are the discards of comets, due to a repellent force from the sun, now believed to be electrical. The earth's orbit must of course intersect the orbit of these scattered streams in order that they may be visible, Thus the point from which they seem to come is determined by the angle of meeting and relative swiftness of the earth and the stream, modified only by the influence of the earth's attraction. This is what is meant by the radiant. And if we meet and see so many, how many more must there be which we never do and never can meet or see! Here again we approach the infinities, as we always do in astronomical questions.

Schiaparelli, enquiring if any known comets had the same orbits as star-swarms, hit upon Tuttle's Comet, 1822, III., as having elements very like those of the Perseids of August 12th, which he had been calculating. Here are the figures :

	Perseids.	Tuttle's.
Longitude of perihelion, - - - - -	292° 54′	290° 13′.
" ascending node - - -	138° 16′	137° 27′.
Inclination, - - - - - - - - - -	115° 57′	113° 34′.
Perihelion distance, - - - - - -	0.964	0.963.
Time of revolution, - - - - - -	108 years.	121.5 years.

Schiaparelli and Le Verrier independently calculated the elements of the orbits of the Leonids of November 10th, and they were identified still more exactly with those of Tuttle's other comet of 1866, I., the time of revolution being 33.27 years. Next, Weiss found that the Lyrids had the same orbit as Thatcher's Comet, 1861, I., with a 95 year period, and the fourth case of identification was the Andromedids' orbit with that of Biela's Comet, 1861, I. These meteors are now frequently called Bielids, in consequence, though some astronomers differentiate the swarm into two. Its elements are :

	Bielid.	Biela's Comet.
Longitude of perihelion, - - - - -	108° 16′	108° 68′.
" of ascending node, - -	245° 57′	245° 53′.
Inclination, - - - - - - - - -	13° 8′	12° 34′.
Perihelion distance, - - - - - -	0.858	0.861.
Aphelion distance, - - - - - -	6.2	6.2.
Time of revolution, - - - - - -	6.6 years.	6.62 years.

This swarm suffers great perturbations, as may be supposed from its slight orbital inclination, and is intensely interesting because the comet, which was seen six times between 1772 and 1852, split in two in 1846, and has not been seen since 1852. Weiss, seeing that three revolutions of the comet made up 20 years, prophesied the return of the star shower in 1872, accelerated by a week , and there was a swarm on the 27th November, 1872, also on 27th November, 1885, when from 30,000 to 40,000 meteors were seen. In 1892, the Bielids came on the 23rd November, much less brilliantly. The influence of Jupiter must since have again disturbed the swarm, and will be the cause of an acceleration of several days more, when, in November, 1905, the display is again timed to take place. Among the multitudinous other swarms there have been found eight or ten whose elements closely agree with the orbits of known comets, but the argument for the connection of comets and shooting stars, however fortified by such buttresses, really rests on the four cases above mentioned.

Several cases of the dissipation of comets have been well ascertained. The fine comet of 1862, II., was seen to split up into five different nuclei, with very different times of revolution, due to different velocities of emission, and many nebulous masses left the main comet and vanished—one of them having been followed for three days. With the description of Brooke's Comet this Society is very familiar. (Trans. Astrom. Society of Toronto, 1896, page 136, etc.)

As to the numbers of shooting stars, it must be remembered that for one we see, there must be hundreds we cannot perceive. All of us have just glimpsed many very small ones, and some have been seen by telescopes which, unaided, could not be perceived.

If shooting stars are solid, it is difficult to understand how the bombardment of the earth can be so often furiously renewed without their reaching us in hurtful forms. They may be gaseous, with perhaps some very small solid particles as a nucleus. If they are the dispersed components of comets' tails, which are known to shew the spectrum of hydrocarbon, it is more likely they should have got together into gaseous agglomerations than that they should have combined into things solid and heavy. A low specific gravity would not impair their velocity, and their incandescence through friction and chemical action in aerial regions eighty or a hundred miles high is as intelligible on the supposition of their being considerable globes of hydrogen-compounds surrounding dust-like particles as on the theory that they are stony or metallic. A bituminous mass is reported by Bornitz as having fallen at Christiana, June 13th, 1822, 4 p.m. Stanislas Meunier, of the Paris Museum, says that a resinous substance found on the Prater at Vienna, 1898, is meteoric in origin. The same as to resinous matter found at Luchon, in the Pyrenees.

At Neuhaus, Bohemia, 1824, December 17th, a fireball and resinous matter came together. Nor is it easy to comprehend how, if they are small solids of an inch or two in diameter, they can be visible at such a distance, while if they are larger it is marvellous that they should not pierce the atmosphere, to our great discomfort. True, they fly at great distances from each other, not less than twenty miles during even the heaviest showers, and thousands of miles on ordinary days; true also, that if they did pierce the air but few would be found out of the number falling; yet among the daily seven or eight millions some would leave very serious traces. On the other hand, if they are constituted alike, the cause which would destroy one would destroy all, unless in cases of exceptional size. Whichever be the correct theory, it is clear that the ordinary shooting stars are the dwarfs of the race, and that bolides are merely those of larger proportions which become brighter every moment of their approach until sometimes an inaudible explosion occurs, and they are seen to break into several pieces which, with a somewhat changed direction, go but a little further. To account for the visibility of shooting stars, some have assumed that they make the very air incandesce.

Fireballs, however, rush across the sky, and in their passage illumine the whole landscape. They make a peculiar hissing or buzzing sound, and burst with a loud report often scattering a a shower of stars. The whizz precedes or follows the report, as the observer is in front of or behind the fireball. Their visibility is not strictly confined to the night time, like the two previous classes; for the incandescence of fireballs causes them to be occasionally seen and their explosions can sometimes be distinguished by day. Yet pieces of them are not to be found. This Society has traced two of these magnificent meteors across hundreds of miles of country—(Trans. Toronto Astronomical Society, 1898 and 1901)—but has sought in vain for tangible evidences of their nature. Possibly they are meteorites which enter the atmosphere at such an angle that they either escape total destruction by winging their way into space again, or have to traverse so much of it that they too are consumed.

I may mention that Delauney, Lieut.-Colonel Marine Artillery, Rochefort, France, considers that our solar system commenced with two nebulæ—one forming the interior planets and Mars, the other the bodies exterior to Mars. The shooting stars. he thinks, may be the left-overs of the Jovian and Saturnian system, the uranoliths of the more solid masses of the Venus order. Coming lastly to what the Latin peoples call uranoliths, a more definite term than meteorites or aerolites, I take up Prof. Bornitz' papers. He has very patiently and thoroughly collected records of meteorites and the fireballs. He gives 498 as the number of falls in Europe and Mediterranean coasts of Asia and Africa, of which the dates, to the day, are known, and he classifies them by months, as under:

In January - -	39,	May - -	60,	September -	45.
" February -	29,	June - -	52,	October - -	31.
" March - -	43,	July - -	47,	November -	38.
" April - - -	34,	August -	49,	December -	31.

Classification by days shews that several falls occurred at the following dates:

January . . .	1st, 5; 2nd, 4; 9th, 4, 31st, 3.
February . .	10th, 3; 15th, 3; 19th, 3.
March . . .	1st, 3; 8th, 4; 12th, 4; 15th, 2; 22nd, 3.
April . . .	10th, 4; 26th, 3.
May	4th, 3; 11th, 4; 14th, 3; 17th, 6; 18th, 3; 19th, 5; 22nd, 4; 26th, 5.
June	3rd, 4; 7th, 4; 9th, 4; 13th, 3; 17th, 3; 28th, 4.
July	4th, 5; 8th, 3; 19th, 3.
August . . .	1st, 3; 5th, 3; 10th, 5.
September . .	5th, 3; 7th, 5; 9th, 4; 13th, 4; 14th, 5.
October . . .	1st, 4; 13th, 4; 30th, 3.
November . .	12th, 3; 13th, 4; 20th, 3; 29th, 3.
December . .	6th, 4; 11th, 5; 24th, 3.

He also classifies the falls by centuries, including thirty-five before the Christian era, and gives the hours of fall in a number of cases, thus:

A.M., midnight to 1 hour, and so to noon—5, 4, 4, 8, 3, 7, 6, 13, 8, 7, 15, 29=109.

P.M., noon to 1 and so on to midnight—11, 14, 16, 32, 28, 18, 18, 17, 27, 19, 18, 18=236. In all 345

Mr. Denning has given us an estimate of the numbers of shooting stars observed each month, and if we compare them with Prof. Bornitz' numbers of uranoliths, reducing each to the standard of one thousand, we get the following comparative table :

Shooting stars, monthly proportion, per mille—

Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
34	22	21	68	26	29	121	381	51	85	113	49

Uranoliths, monthly proportion, per mille—

Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
78	58	86	69	121	104	94	100	90	62	76	62

The differences are evident, and since the uranoliths are not most frequent in the months when shooting stars are most numerous, viz., August and November, it seems to follow that there are great diversities in the origin and routes of travel of these two classes of bodies. The shooting star numbers need correction, to allow for the difficulties of observation in winter weather, and some correction should, perhaps for the same reason, be applied even to the uranoliths, though they compel attention rather than their silent relatives. But no such errors would account for the remarkable discrepancies.*

Prof. Bornitz, however, does not appear to have noticed this difference, and bases his argument chiefly on the frequency of meteor falls during star showers. He exhibits this as under :

Heis and Denning -	Quadrantids,	Jan. 1 & 2,	9 met. falls.
Greg - - - - -	Periodic swarm,	Feb. 15 to 19,	7 " "
Greg and Newton -	" "	Mar. 1 to 4,	7 " "
Forwald Kohl - -	" "	Mar. 12 to 14,	6 " "
Littrow - - - -	Lyrids (from β)	Apl. 12 to 13,	3 " "
" - - - -	" (from α)	" 19 to 23,	5 " "
Greg - - - - -	Periodic swarm,	" 28 to 30,	4 " "
Bogulawsky - -	" "	May 16 to 20,	16 " "
Von Niessl - - -	" "	June 3 to 7,	7 " "

* Similar difficulties cause similar discrepancies in other observations. For instance the number of solar prominences recorded by the contributors to the Memorie of the Italian Spectroscopists are much fewer in winter weather than in summer, even allowing for the shorter daylight.

Julius Schmidt - -	" "	July 3 to 5,	9 "	"
Littrow - - - -	Aquarids & Cygnids,	" 26 to 29,	5 "	"
" - - - -	Perseids	Aug. 8 to 13,	11 "	"
Julius Schmidt -	Periodic swarms,	Sep. 13 to 14,	9 "	"
Heis and Denning	Orionids,	Oct. 13 to 21,	11 "	"
" "	Leonids,	Nov. 12 to 16,	8 "	"
Greg - - - - -	Many swarms,	" 19 to 21.	6 "	"
" - - - - -	Bielids and (or) Andromedids,	" 27 to 29,	5 "	"
Kirkwood and Denning,	Geminids,	Dec. 6 to 13,	15 "	"

He thereupon remarks "That out of 498 meteor falls taken into consideration, 143 came on days of star swarms," and as the average is 4.36 per day, there should have been only 94 on the 69 days enumerated. But what may be called unconsciously preferential selection may account for the excessive ratio. If the argument is valid, one would expect a large quantity of uranoliths to fall during the fusilade of Leonids—for which five days are allowed, according to Prof. B.'s list. At 1.36 per diem, that means seven falls, and the enumeration gives but eight, viz. :

1492 - -	November	16—Ensisheim, Alsace, France.
1761 - -	"	12—Chamblon, France.
1820 - -	"	12—Chotmischsk, Russia.
1825 - -	"	13—Belmont, France.
1841 - -	"	13—Pas de Calais, France.
1843 - -	"	12—Werchine, Tchirskaya, Russia.
1849 - -	"	13—Tripoli, Africa.
1872 - -	"	13—Scilly Islands, England.

And No. 5 is a fireball, said to have fallen into the Channel, while Nos. 2 and 4 caused conflagrations and may have been electric fireballs, something very different. So the Leonids are not associated with a uranolithic surplus.

Nor do the Perseids, August 8th to 13th, confirm Prof. Bornitz' argument. Here we are in a summer month, the average of daily falls in summer being 1.57 per day, or 9.42 falls for the time. There are eleven catalogued, viz. :

1580	- -	August 13—Wiche, Thuringia.
1785	- -	" 13—Frankfort on Main, Germany.
1810	- -	" 10—Mooresfort, Ireland.
1818	- -	" 10—Slobodka, Smolensk, Russia.
1841	- -	" 10—Iwan, Oedenburg, Hungary.
1846	- -	" 10—County Down, Ireland.
1863	- -	" 8—Pillistfer, Livonia, Russia.
1865	- -	" 12—Dundrum, Tipperary, Ireland.
1885	- -	" 10—Grazac, Tarn, France.
1890	- -	" 12—Plauen, Silesia, Germany.
1898	- -	" 9—Kirk, Schl-Holstein, Germany.

Of these No. 2 was accompanied by the burning of two houses and was probably electrical, and No. 9 is a carbonaceous substance very doubtfully meteoritic. The excess is in any case too slight to serve as the basis of argument. It will, of course, be understood that these meteors did not fall at places where any special display of Perseids was being viewed, so the probability is that stars and meteorites came from different radiants, and belonged to different swarms.

There is but one uranolith known to have fallen while a star-shower was in progress. In the paper first referred to I mentioned it as a stone that fell at Mazapil, Mexico, during a shower of Bielids. In an article on Chili Meteorites sent by M. Stanislas Meunier, of the Paris Musée d'Histoire Naturelle, to the Scientific Society of Chili, he considers this a coincidence, and as a valued friend had thrown doubt on all the circumstances published respecting it, it seemed proper to investigate the occurrence, and I lately wrote to Don Manuel E. Pastrana, the director of the Central Meteorological and Magnetic Observatory, Mexico, who has been so kind as to send a verification of the facts, and has had the further goodness to present me with a cast of the meteorite obtained from his friend, Don José A. Y. Bonilla, which was made in New York, where the original is. This cast I respectfully offer to the Society in Don Pastrana's name.

Don Jose A. Y. Bonilla was and still is the director of the Observatory at Zacatecas, and naturally made special preparations for observing the meteors from Bielas' Comet, announced for November 27th, 1885. He also asked persons living in various towns of the State of Zacatecas to observe them with the greatest care.

"The sun," he says, "was to set at 5^h 20^m, local time. At 5h. 47m. the three principal stars in Andromeda were visible. At 6^h 20^m the first shooting-star was seen and the number increased gradually, until midnight, the phenomenon attaining its greatest intensity when γ Andromeda was passing the meridian, at which time Don y Bonilla counted 240 meteors in thirty minutes."

He exposed several photographic plates, without obtaining anything distinct, but he was more fortunate with his 6 in. equatorial, furnished with a Secchi spectroscope, with which the spectra of the shooting stars showed the characteristic lines of sodium, carbon, iron, nickel and magnesium. He never saw the atmospheric lines in the blue so well marked as in these spectra, unless when observing the sun near the horizon, and he entertained no doubt that this was to be accounted for by the extreme heat acquired by the air in contact with the meteors.

There were 2720 falling stars observed by the assisting party between 6^h 20^m in the evening and 3^h in the morning, when mist put an end to the observations.

On the 2nd of December following, Don y Bonilla received from Senor Eulogio Mijares, who was living at the farm called Concepcion, seven miles east of Mazapil, a stone which he had himself seen fall from the sky at 9 o'clock, during that night of the 27th of November. From his letter the following particulars are extracted.

"My attention was suddenly drawn to a hissing rush (*ruido extridente*) exactly as if a piece of red hot iron were suddenly plunged into cold water, also by a phosphorescent light which I perceived in the air, accompanied by sparks. I had scarcely recovered from my surprise when everything became dark with the exception of one place on the ground which seemed to be burning (*arder.*) All the people left their houses and ran to help me quiet my horses, which were much excited. Everybody thought the occurrence would be followed by a fire, but in a few moments we saw the light disappear little by little, and having fetched lanterns to examine the place we found a hole, in which a luminous projectile (*bola*) was lying, when everybody drew back, expecting an explosion. The sky was very clear and a great number of stars were falling, but without noise (*ruido.*) When the ball was no longer glowing (*se apago*) we tried to take it out of its hole, but as it was still burning-hot we had to wait. We finally succeded in extracting it and perceived that the aerolite had the appearance of a small mass of iron. All that night the stars kept on showering down, but none reached the earth; they were all quenched before penetrating the high regions of the air."

"Such is the simple tale," continues Don y Bonilla, "of one of our observers. I at once went to the place, 130 miles from Zacatecas, and on carefully examining the ground in the neighborhood of the cavity where the meteor had been stopped, I found a few pieces of iron which without doubt had split off the meteorite. The hole was eleven inches in depth."

"The aerolite weighed 3950 grammes.* I have had a few pieces taken off for analysis, and it now weighs 3854 grammes. It shews the characteristic von Widmanstatten lines, and is thus composed:—

Iron	91·25
Nickel	7·845
Cobalt	0·653
Phosphorus	0·30
	100.048

"Should we conclude that the fall of the aerolite at Mazapil is a chance coincidence? We must in any case acknowledge that it is an extraordinary one, to thus bring it into connection with the shower of Bielids, even though it be not a piece derived from the breaking up of Biela's Comet."

Now Mr. William East Hidden, in the Transactions of the Academy of Sciences, N. Y., gives several instances of fire-balls seen during that Bielid shower, viz.:—Liege, Belgium: a cloud of smoke, on explosion, lasted 15 minutes.—Suez, Egypt: a meteor trail persisted for 8 minutes.—Manhattan, Kansas, U. S.: a meteor was seen below the clouds which completely covered

* 8 lbs 11 oz avoirdupois.

the sky, at 12^h, 50^m: also 13 others during the next few hours. This extraordinary observation is credited to Prof. Cowgill.—Lyons, Drome, France: a bolide bursting emitted a cloud which lasted 12 minutes.—Palermo, Sicily: a bolide was seen, much brighter than Venus, which left a trail, first straight, then curving as if floating in a breeze; and lasted 20 minutes. Prof. Bornitz mentions other trails seen on that night, with their duration thus:—Westphalia 10 min.; England 10 min.; Scotland, two cases, 10 min. each; South Atlantic 16 min.; Prague, Bohemia, 2 min.; Rote Erde, Germany, 20 to 30 min.; Upsala, Sweden, 6 min. He instances a few on the same day in previous years. But when it comes to meteorites, he has but three others, viz.:—1637, Mont Vaisien, France; 1868, Danville, Alabama; 1878, Dhulia, India. He also lists as remarkable fire-balls:—1829, La Rochelle and Rochefort, France, detonating fire-ball; an earth tremor.—1862, Angermanland, Sweden, detonating fire-ball, seen to break into bits.—1878, Ebersdorf, Germany, in cloudy weather in the daytime, an explosion; earth tremor ; houses shaken by an invisible meteor. But the old dates should be dropped, for the star shower is being interfered with, as above stated, and if shifted forward by Jupiter every 20 years, as it has been during our time, the proper date for its occurrence in 1829, 1755 and 1637, would have been in December. Even without omitting them, the record of falls is too meagre to be convincing that uranoliths are travelling with the shooting stars radiating in Andromeda.

The duration of fire-ball trails and of the smoke which is sometimes visible from their explosions, is interesting. The snake-like forms which trails often take are clearly caused by storm-waves in the upper air; but the length of time they persist is less certainly explained. Cases are on record where, as at Taranaki in 1864, the smoke of an explosion remained visible for two hours. How matter can remain suspended, so long, in such a tenuous atmosphere as there is where fire-balls explode, passes my comprehension: the lightest dust we see in sunbeams would be heavier than lead in comparison. Possibly, too, Schmidt's and von Neissl's views should be considered by all who study this part of the subject—that meteors coming from the Anti-apex (spring equinox) move slowly through the air, do not attain such a degree of heat, penetrate the atmosphere more deeply, and leave longer and more lasting trails and smoke-clouds. Prof. Bornitz thinks the figures justify the conclusion. In the case of the whole of the swarms of the first half of our year, as compared with all those of the last half, the numbers given * are:—

	Total Seen.	Exploded.	Fallen.	Trails.
1st Jan'y to 30th June	698	99	73	166
1st July to 31st Dec.	1628	149	74	641
Percentages { First half		14	10·05	24
Percentages { Second Half		9	4·5	37
Taking the swarms nearest to the equinoxes, we have				
Spring equinox	203	30	30	40
Autumn "	1126	98	42	450
Percentages { Spring		15	15	20
Percentages { Fall		9	4	40

These tables, which I have rearranged, using his figures, do shew that in the fall more fire-balls burn up before reaching a place where they can be heard from than they do in the Spring, while less of them can reach the earth in solid form. Also that far more of them have visible trails. But the reasoning proceeds on the assumption that the weather has not affected the run of observations.† And the Mazapil meteorite, you will notice, rushed in upon us near the time when on the Apex theory, its motion should be most rapid. It rose (or fell) superior to all the Schmidt and Neissl difficulties.

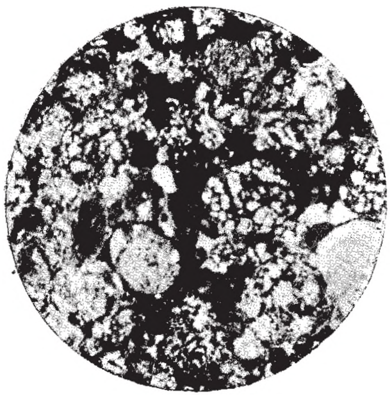
Uranoliths are most easily classed (as to their composition) according to the quantity of ferro-nickel they contain, into holosiderites, mesosiderites and asiderites; this Mazapil example being a pure siderite.

* Gaea—1904: part 6

† It is curious to note how the number of meteors observed decreases as people go to bed, while yet Prof. Bornitz and others base arguments on these relative numbers! His records shew:—

	Number Seen		Number Seen
8 to 9 p.m.	27	Midn. 1	5
9–10	19	1–2	4
10–11	18	2–3	4
11–12	18	3–4	8
		4–5	3
		5–6	7
		6–7	6
		7–8	13

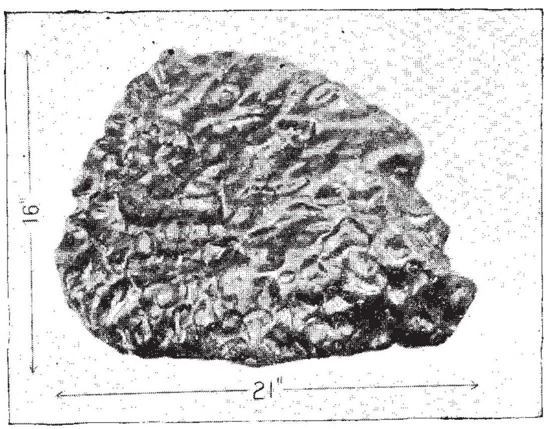
In the specimens, photographs and engravings you may see the chondritic structure which almost all but pure siderites have. *Chondros* is Greek for a grain—of barley, oats, grass, or anything you like—and you can see how grains of non-metallic substances are held together by a magma or cement of ferro-nickel. Nearly half the elements present in this world enter into the composition of meteorites; but there is a curious lack of free quartz, which I think shews there was no water on whatever world they came from. There are silicates, such as olivine, enstatite, bronsite, augite, etc.; and several compounds of sulphur ; e. g. sulphur with iron–Troilite: sulphur with iron and chromium–Daubreelite. The



Micro-structure of Aerolite, showing Chondritic Structure, from Simbirsk, Partsch, Russia. Magnified 9 diameters.

several nickel compounds are, I believe, never found on our planet in a state of nature. When siderites or meso-siderites, which enclose nodules of ferro-nickel, are cut, polished and treated with dilute acid, planes of crystallization are shewn which are supposed to be formed in cooling from a molten state—and these are the von Widmanstatten lines alluded to by Don Jose A. y Bonilla. You can see the Kamacite plates with Tænite films between them in this piece of siderite (shewn), and in the beautiful plates of the Catalogue of the Field Columbian Museum, Chicago, kindly forwarded by Dr. Oliver C. Farrington, Curator, Dept. of Geology.

The pittings on meteorites, sometimes called thumb-marks, are characteristic too. They may be places where some of the chondrules, under tension due to the varying degree of temperature caused by atmospheric friction, split off and form the trails so often alluded to, in the way, perhaps, that a stone in a coal fire will often detonate repeatedly. You can see them in the cast of the Mazapil meteorite, on the large aerolite in Victoria College here, and on every other I have seen. As against this theory is the enormous size of some of them, both in large and small meteorites, especially the former. Another peculiarity is the crust. This is supposed to come from the fusing of the surface of the uranolith as it incandesces, the fused part being blown away as soon as



Meteorite in Victoria College, Toronto.
Once an object of veneration by the Indians of the N. Saskatchewan.
Weight 386 lbs ; 91.33 iron ; 8.83 nickel ; 0.49 cobalt. (Coleman)

formed owing to the furious rapidity of the passage through the air which is doubtless condensed before it, like a cushion ; but a film is left which is the crust spoken of. Sometimes the "flow" is thought to be visible. As the direction changes each moment, some new point of the stone being directed to the front, owing to the changed position of the centre of gravity, by pieces splitting off irregularly, the flow is not invariably to be recognized. The crust may be only a hundredth of an inch in thickness. It varies in colour from grey through brown to black, and is occasionally lustrous.

Uranoliths are usually hard, but sometimes, within the crust, the materials are friable. Fractures may frequently be seen, like veins in our rocks, but I have never seen the least vestiges of stratification. Several observers have remarked that the chondrules often present a barred and fan-like structure, and Dr. Otto Hahn has shown us forms, by means of light transmitted through thinly sliced specimens, which so much resemble organic structures that it is hard to hold fast to a different view when looking at them through the microscope. Dr. Hahn believes that these forms are verily uranolithic fossils, resembling our sponges and corals. He also thinks there are meteorites not mineral but gelatinous.

On lofty mountains and in passes above the snow line, dust is sometimes found (which has even been described to me) by one of the party in charge of building the Railway through the White Pass to the Yukon, as black, like soot. It has been thought by some to be meteoric, but perhaps too readily: it may be volcanic or even of organic origin. So too the sporules brought up in deep-sea dredging are to me as yet doubtfully meteoric.

Reckoning from the numbers of uranoliths whose actual fall is from time to time recorded, considering that three-fourths of the globe is covered with water, and that not more than one in fifty that fall is found, even in well settled districts, and still less in the vast unsettled regions of all the continents, I arrive at a rough estimate that one aerolith a day falls somewhere on the earth. This estimate takes account of a multiple fall as one only, but uranoliths not unfrequently fly in swarms. The investigation by Biot, which led to their recognition as cosmical bodies, was called for by a swarm at L'Aigle, about 80 miles west of Paris, where from two to three thousand stones fell, a little before one o'clock in the daytime, April 26th, 1803. Seven or eight hundred at least were recovered from a fall in Winnebago County, Iowa, near Minnesota, 1890. A hundred thousand fell at Pultusk, Poland, 1868. These numerous bodies are said to be picked up in elliptical areas, but this is not an absolute proof that they travel in a spherical agglomeration: it may result, if true, from the breaking up of a mass in our atmosphere. Many of those found in comparatively close proximity when turning up the soil in the newer States of the adjacent Union—meteorites which have lain there for hundreds of years or more (for the nickel-iron of the siderite suffers little from rust, especially when encased in an air-proof covering) are so similar in composition that they are thought to have fallen at one time. Thus, five, found in an area 35x117 miles around Ness City, Arkansas, have the same composition, while four others from the same locality differ. Six masses found in a straight N. and S. line near the Tombigbee River, Alabama, are alike as to analysis, and it is curious to note that the smallest is at one end of the line, and that there is a regular progression until the largest is reached at the other.

It is not to be wondered at that the largest uranoliths are now to be found in America, for those which have fallen in the Eastern Hemisphere have been turned to some uses, often fantastic, centuries ago. They have been forged into weapons, with magical attributes, set up as idols, pounded for medicine, or worn as amulets. The bit I habitually carry is not to be a "mascot" for its owner, but serves now and then to puzzle and confound some of the so-called mineralogists who assume to assign names and values to any kind of "specimen." The heaviest, according to Prof. Henry A. Ward, * are in Mexico, the ten largest weighing 95·5 tons, of which one alone is responsible for 50. The largest found in the United States weighs 8⅓ cwt. There is an enormous mass in Brazil, but it is not certainly meteoric ; the Field Columbian Museum thinks it is a terrestrial iron.

How these meteorites conglomerate is as curious a question as the many others on which we have only had time to touch. It seems impossible to believe that such a huge mass as the Bacubirito meteorite, or the others which weigh tons, can have been broken up in passage through the air. If they were little planetoids, why were they not round ; if broken up, how does the great difference between their compositions arise ? How could a gas get together into a small mass and possess attraction enough to solidify ? How could heat enough be generated to fuse the irons and get them into a state to crystallize on cooling ? Was it heat or a chemical crystallization, and how, and when and where did the concourse and the sorting out of elements begin, the formation and aggregation of the chondrules ? I will not go into the question of occluded gases, said to be often found in meteors, in such quantity as to argue that they had their birth where the pressures

* Proceedings of the Rochester Academy of Science. June 24th, 1902

are greater than on the earth. The idea that they came from lunar or solar volcanoes I cannot discuss; lunar volcanoes there were and are, but tbe velocity of emission of fragments not to fall down again would be an impossible quantity. Solar volcanoes, to be like ours, would require a solid crust to the sun, in which I am a convinced unbeliever.

The fall of uranoliths, even when they come single, is a terrifying phenomenon, second only to the earthquake. The whiz, the roar, the loud explosion, the mass of fire coming with fearful speed, all of these features in a few seconds, are an experience which is trying to the nerves of the most stolid. During recent falls in Europe, people have been known to go down on their knees, shut their eyes, and pray, and not a few in Canada might do the same thing; but an astronomer or student of nature in any form should keep his eyes open and his wits at work, to note with meticulous particularity every incidental feature of the rare occurrence. If an aerolite were to strike any one, there would be scant time for repenting of one's sins. They have been known to do damage, to go through roofs of houses, to cut off branches of trees, even to kill cattle and men—a curious instance having occurred this year near Ellis, Edwards County, Texas, so the journals say. Ramon Cruz, a Mexican sheep-herder, was sitting on a large boulder, August 14th, when a meteorite fell on the boulder and was shattered. One piece hit the herder on the temple and caused instant death.

Other singular occurrences of this nature are recorded by Prof. Bornitz as follows:—1896, Sept. 23rd, a stone weighing 12·5 kilos fell near Namur, Belgium, and broke to pieces a rake which a farmer was using in a field of oats, throwing him to the ground.—1361, near Zweth, Germany, ten oxen were killed, —1552, May 29th, an aerolite fell near Schleusingen, Thuringia. Germany, and wounded the favorite horse of Prince George Ernest.—1511, Sept. 4th, 8 p.m., at Crema, Italy, meteorites fell during an eclipse of the sun, killing a monk and some poultry and sheep. Rafaelle painted a picture commemorating the event.—1668, June 29th, shortly after midnight, at Vago, near Caldiero, Verona, Italy, an aerolite fell in the monastery Santa Maria della Pace, and killed a Franciscan monk.—1881, Nov. 19th, 6,30 a.m., a stone which fell at Grossliebenthal, near Odessa, Russia, hit and wounded a postillion. Other instances of injury to life and limb could be collected, while many have fallen on houses and several upon ships, but this is of no astronomical interest.

In the matter of fires being caused by uranoliths, I am not so incredulous as Mr. Monck. 1885, Aug. 10th, 4 a. m., twenty stones were picked up at Grassac, Tarn, France, and one of the lot set fire to a stack of corn.—1897, April 14th, 11 p.m., at Vierville, Caen, France, a stone fell into a water trough, so hot that it made the water steam. Twenty or thirty cases are mentioned in Bornitz' list, of fires said to be caused by aerolites or detonating fire-balls, and surely they are not all errors. But there are many instances of stones, glowing hot, having been seen to fall; of one of which we have just heard in detail from a careful observer, and such stones could easily set fire to stacks, stables, barnyards and even wooden buildings.

In one of my papers* I treated of "aerolites and religion," and to that I must now refer those who wish to learn something of the curious ways in which uranoliths have been made an object of superstitious worship. The paper is rather suggestive than exhaustive, and is by no means complete. One of the omissions I will beg leave to repair now. It is in connection with the Homeric account of the "scene" between Jupiter and his wife, when the latter, taking advantage of the slumbers of the god, has had the Greeks driven to their trenches before Troy. Jupiter, in wrath, reminds her of the time when he suspended her from heaven, fastening anvils to her limbs by golden chains, and dared the other gods to loose them. Then (just after vs, 30, B'k xv) two lines have been excised by critics, because they were thought spurious. With these lines I have lately become acquainted and they are:—

> "Then only, loosing thy feet, towards Troy I tossed the great masses
> That, by long generations to come, the deed should be ever remembered"

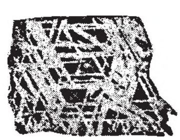
and Eustathius of Thessalonica, archbishop and Homeric commentator, says that both the anvils which gave rise to the lines were preserved to his time, A. D. 1198, and were believed to have fallen from the skies—which was probably true enough—quite in the same way that Prof. Garner, the student of monkey-language, told me he found in an African village treasure house two stones

* Transactons Royal Society of Canada, 1896

about the size of hens' eggs, which they said had been shot out from heaven and had killed the devil (or spirit which does harm) so they built a house for them and guarded them.

Many attempts to form masses resembling uranoliths have been made, but they have been failures ; except that Daubree has fused together iron, nickel and phosphides of iron and nickel, and the resulting mass shows lines like those discovered by von Widmanstatten. I have succeeded fairly well in producing a crust like that of meteorites by fusing the surface of a well mineralized bit of vein-matter, containing a quantity of iron pyrites in one case and a great deal of sulphide of silver and white silver in another. I used a water-surface for one pole of the electric arc and the fusion took place instantaneously, with crackling noise and coloration of the light produced, not unlike that of fire-balls. A beautiful experiment is said to be, to place a meso-siderite in boiling nitric acid, which will dissolve out the non-metallic parts and leave the ferro-nickel in its interwoven planes.

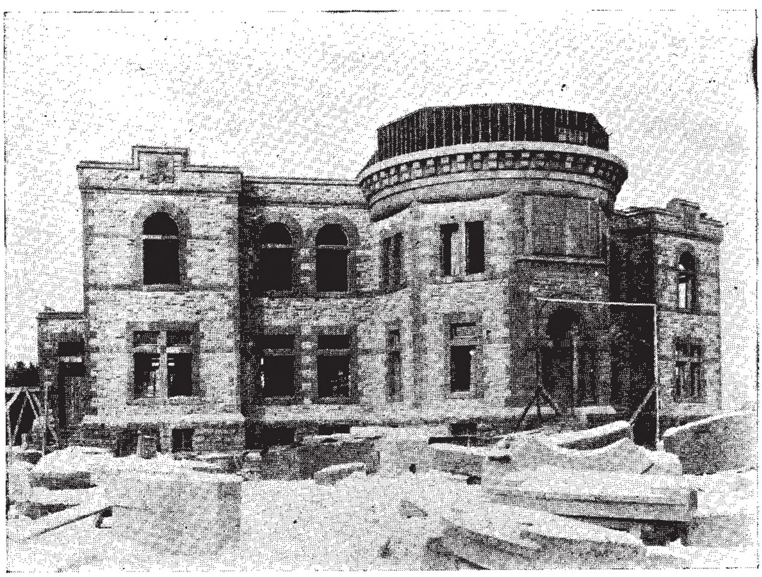
The illustrations shewn include the 50 ton meteorite of Bacubirito, Mexico, from Henry A. Ward's paper to the Rochester Academy of Sciences and the uranolith in Victoria College Museum, here, which I hope some day will be restored to the locality where it fell. "Pe-wah-bisk Kah-ah-pit (the iron where it lay)" as it had been there from time immemorial, It was a cruel thing to remove it, as the Indians believed that ills would follow—and they did. The collection of meteorites in small aggregations is a craze : they are really useful in large museums only.



WIDMANSTÄTTEN LINES

THE ASTRONOMICAL EQUIPMENT OF CANADA.

It seems fitting that at this stage of the history of our Society, when we are under a changed name beginning a new series of Transactions, we should survey the means for astronomical observation in the Dominion. They are as yet slender, and Prof. W. F. King, of Ottawa, on whose paper we in part rely, very suggestively remarked that "he did not wish to speak at



GOVERNMENT OBSERVATORY BUILDING, OTTAWA.

length of the history of astronomy in this country, nor even to attempt any account of what is doing now, but rather to speak of what ought to be done." It seems on the other hand that a record should be made of our condition at this starting point, so that we may from time to time measure the progress which will surely be hereafter made. Nor need the utterance put us to shame, however truthful its sarcasm may be, if we interpret into it so bitter an ingredient, for all the world knows that we have had to "clear" our land with hard and patient toil, to build our homes, to make our roads, canals and railways, and that so far as Ontario is concerned, that has fully occupied the first century of its existence as a Province. Quebec had the lead of the other Provinces in settlement, but constant war and struggle retarded its progress until about the same period. It is really only now that Canada has the time and means to give attention to studies like astronomy, which has the distinction of combining the highest science with the smallest pecuniary reward. Mr. King's words are apposite:—

"Up to the present time, the chief line of practice in astronomy here has been with reference to its direct practical applications, in surveying especially, the determination of the meridian line, of latitudes and longitudes, and of time. The course of study in our colleges has also been largely confined to the same lines; if further instruction in theory is given, it is devoid of the illustration by practical application and use of instruments, etc., which is needed to make it really effectual. The following of astronomy in its scientific aspect has been left to private effort almost altogether."

Prof. King argues that one reason for the greater attention paid abroad to the subject is that other countries are richer than Canada, and greater numbers of students have the leisure and the facilities for cultivating forms of science which are not directly productive. But it is a question whether we should admit the validity of the reasoning, in view of the observatories maintained in Costa Rica, at Cordoba in the Argentine Republic, and in Peru. The reason is rather to be sought in the fact that most students, in a country of vast resources, where so much has to be done, where people are ambitious and energetic enough to do much of it themselves; the applications of physical science, ever multiplying, whether in electricity, heat, or chemistry, suggest unlimited possibilities of success in the struggle for fortune as well as fame. Yet astronomy, Prof. King thinks, "is making good progress, assisted indeed, and stimulated, by these other branches of science." What is chiefly needed, he said, is "the providing of the facilities, that is, observatories and instruments. With these at hand, I think Canada could provide the men."

Mr. J. H. Pope, C.M.G., of Ottawa, has sent to the Society a photograph of the as yet uncompleted government observatory building there. It is reproduced at the head of this article. The equipment is in a rather more sdvanced stage of readiness, and in about a year we may expect to see this fine establishment in working order.

The heavy works, such as the moving gear for the dome, and the mounting for the equatorial telescope, also the filar micrometer and the attachment to the tube, for supporting and rotating the large spectroscope, are from Messrs. Warner and Swasey's establishment; the purely optical parts of the installation are by John A. Brashear & Co., of Alleghany. The difficulty of procuring or making optical glass is considerable, and the flint glass disc for the 15 inch objective for the Ottawa instrument gave the firm a great deal of trouble. In the first disc ground, there was a part about three inches in diameter which had a different density from the rest. That difference was indeed very slight, and it would yield to local correction, so that at a normal temperature the image of a star would be exactly and sharply defined. But at a temperature higher or lower than the normal, the stellar image was impaired, which Prof. Brashear tells us he could not tolerate, so a new disc was ordered, a new set of computations made for its figuring, so that a new set of curves was required for the crown glass disc also. Dr. Brashear says the new lens has proved all that could be asked for. He adds "now we know what the objective will do, and that is a satisfaction not to be bought with money."

The great objective is supplemented by positive and negative eye-pieces, a diagonal prism eye-piece, a wide-angle eye-piece for comets, nebulæ, etc., and a polarizing helioscope. To the tube are attached two finders with a 4 inch and a 2½ inch objective respectively.

The spectroscope is a three prism instrument with a fine grating for solar work. The definition is fine, which is a difficult condition to attain in prisms of any size, and there is to be a special correcting lens to flatten the color curve of the 15 inch objective, and enable work to be done on stars in the line of sight. Prof. King is completing the *data*, when this piece of work can be finished.

There is an 8 inch doublet and camera for stellar photography, after the type of two 16 inch cameras made by Messrs. Brashear & Co. for Dr. Max Wolf, of Heidelberg, Germany, with which his later asteroid discoveries have been made. Dr. Wolf also found on one plate, exposed in one of these cameras, a hundred and thirteen nebulæ!

There is also a new stellar photometer. With the wedge photometer as heretofore made, the observer had to use a light to see the scale and note the reading, the pupillary aperture would of course change, when from 3 to 5 minutes were required for the eye to come to its normal state again. With the instrument to be used at Ottawa, the records for 40 stars can be made without stopping to read the scale. The drum can then be detached, a new sheet put in in two minutes and another list of 40 stars taken. The instrument is complete in itself, weighs 6 or 7 lbs, requires no counterpoise in so large a telescope as that at Ottawa; it is simply inserted in the draw tube when the ordinary eye-piece is removed, and then any power eye-piece can be used, low powers being preferable.

Prof. King's paper deals somewhat with the question "What material value are we to look for in return for the expenditure" on such an institution, and he says he has heard the objection raised "that astronomical observatories are too expensive for a country like Canada; that it is unlikely discoveries of value will be made with the comparatively small instruments we can afford to purchase; and that it would be the part of wisdom to leave the cultivation of the science to wealthier nations, with the comfortable assurance that we shall ultimately benefit by their work." Having been entrusted with the organization of the National Observatory, he naturally feels sensitive to such remarks. He admits that "the paying public may reasonably say 'shew us something for our private or our corporate money,' and that the man who puts the question '*cui bono?*' is within his rights." And he does not dismiss the subject with the answer "it is for the benefit of science" which he thinks would be foolishly contemptuous. It has been from the first determined that the observatory shall be open to the public one evening in the week, to look through the large telescope, and oftener if possible, to see the instruments in actual operation; but he frankly states that but few will benefit from this, which we all know to be a fact, and he is far from basing upon such a consideration his justification for the building aud furnishing of the establishment. Mr. King's argument shall be given in his own weighty words :—

"The essential thing which entitles any pursuit of knowledge to the name of science is, that it shall be rightly directed, so as to tend towards the practical end of increasing the sum of human happiness and capabilities. Aimless investigations, collections of unclassified facts or observations are not, in this sense, true science : there must be such method in the collecting of data as to ensure the increase of available human knowledge.

"What is often considered the only useful end of any pursuit, the making of money, dollar for dollar, cannot indeed be the aim of the scientific man, and is generally altogether at variance with the true spirit of investigation—though ultimate practical utility is a proper and stimulating aim. . . . Even studies in the abstruse realm of the higher mathematics have their plsce in broadening the scope of the subject and leading, indirectly, to additions to the sum of useful knowledge.

"Something must also be allowed for what we may call the ornamenting of the mind. Who does not admire the beauties of architecture, without which our massive buildings would be dreary heaps of bricks and mortar? We must not say that the additional expense is wasted. Now-a-days the practical value of beauty is recognized.

"It is to be observed that no branch of science is altogether independant of the others, so that it can, without disadvantage, or even safely, be neglected. All form, or are, especially in recent years, tending to form parts of one harmonious whole. The advance of one branch means the advance of the rest, and, with the general advance, go the multiplication of useful applications, which frequently arise out of the general stock of knowledge and do not pertain directly to the particular branch of science upon which they are based. For example may be cited the applications to the healing art of discoveries in chemistry and physics--the Rontgen rays in surgery, for instance, being an application of a discovery made during investigation of the behavior of gases illuminated by the electric spark. Probably nothing was further from the mind of the discoverer than such a practical use.

"So, out of the labours of the theoretical investigator, arise the comforts and potentialities of our civilization.

"The Principal of an old-fashioned college, objecting to the establishment of a chair of physics, said physical science consisted too much of theory. 'Wait' he urged, 'until the scientific men have finished making discoveries.' An argument of this nature assumes that the field is limited, and in astronomy that field is not likely to be soon exhausted. There is enough work for all, and it is the duty of every country to do its share in increasing the general stock of knowledge. Important discoveries also are not always made with the largest instruments : in this matter, as in others, it is the 'man behind the gun' that counts.*

* In this connection Dr. Brashear, referring to the 8 inch camera, observes:—"I do hope Dr. King will have a good man at the end of it, for it has great possibilities."

"Besides, it is scarcely possible to cut off one branch from the tree without impairing the healthy growth of all or to tie down the development of thought to particular lines. Every country has its own problems, even in astronomy, and there are many allied branches, geodesy for instance, which are closely tied up with it. The presence in a country of a strong staff of scientific men is an important national benefit, a national asset which it is worth some sacrifice to acquire."

Prof. King proceeds to state as a further plea for the special endowment of astronomy with public money, that it stands at a disadvantage, compared with most other sciences, in that it requires expensive instruments and special buildings, besides a corps of observers to carry on the long and often tedious series of observations, without which little result may be expected. He hopes that before long "some of our wealthy men may emulate the example so many in the United States have set, of building observatories for the study of this branch of science. There should be not one public observatory in Canada, but many. Much is heard just now of public libraries ; may not the cities of Canada extend their ambition still further?"

OTHER PUBLIC OBSERVATORIES.

The other observatories where instruments are provided at public expense are that at Toronto, in charge of the magnetic and meteorological service, and that at Montreal, in charge of the McGill University.

The Toronto instrument is a beautiful equatorially mounted telescope, by Cooke, of York. Its objective is six inches in diameter and of fine quality. The instrument, with attachments, cost £400 in England. It was set up in 1881, to aid in observations of the transit of Venus. It can use powers up to 500 when the seeing is good. It is now used only for the observation of sun-spots, of which a sufficient record is kept to collate them with the phenomena of terrestrial magnetism and auroræ. The Director has always been ready to give the use of the tube to members of this Society and other astronomical students, under necessary restrictions only. There is a transit instrument, for time reckoning, with all the needful appliances, very carefully attended to. The severe cold of winter interferes with the movement of the telescope, and this has been particularly noticeable during the past season. The contraction of the metals of the equatorial mounting makes it too stiff for the clock to drive. Even solar observations have had to be made when the sun is on the meridian. This difficulty may be surmounted, but it is mentioned here in order that it may be considered by the makers of instruments for use in northern climates.

The Montreal instrument is called "The Blackman telescope," and has a 6¼ inch objective. In this case also, no regular astronomical work is done, except with the transit, for determining standard time, which is regularly exchanged with the Toronto station. There is, however, a 4½ inch photo-heliograph. The installation is for educational purposes and is occasionally made use of for viewing eclipses and occultations.

There used to be a reflecting telescope, of considerable power, at Quebec, and it is now in charge of the meteorological department, but it is useless until the mirror is reground.

The Woodstock, (Ont.), College has a regular observatory building, built of brick and containing three rooms. This installation has a proper dome and an equatorially mounted tube with an 8¼ inch object glass: the eye-pieces include a micrometer. Mr. C. L. Brown is in charge of this department and hopes before long to obtain a photographic attachment for the eleven foot telescope. Powers can be used up to 600.

Victoria College, Toronto, has a telescope, not now used. There is one also at the Ladies' College, Whitby.

PRIVATE OBSERVATORIES.

We now come to the private observatories, of which those of Rev. D. B. Marsh in Hamilton, of Dr. J. J. Wadsworth of Simcoe and Mr. A. F. Miller here, are the only ones we know that have equatorial mounts and driving clocks. All these are in Ontario.

Dr. Wadsworth's observatory is ten-sided, the floor 15 feet across, its walls 7 feet high, wooden, with an iron track for the dome, made of stout canvas. Its equipment is as follows:—

A silver-on-glass Newtonian Reflector with 12½ inch aperture, 105 inches in focus, having powers 105, 210, 315, varied by using a Barlow lens. The telescope was constructed by its owner about ten years ago, the speculum being ground and polished by him on the principles laid down by Foucault, Draper, and Wassell. Brashear's method is used for resilvering. The instrument rests on a metal equatorial stand of massive construction. The pillar stands on a solid base of masonry. The polar axis, three inches in diameter, and the declination axis, 2 inches, are both solid steel. The graduated circles, 13 inches in diameter, are the only parts not made in Simcoe. Cameras are attached, and clock motion applied when wanted.

Dr. Marsh has an unusually complete establishment, in a favorable position, under the shelter of the Hamilton "mountain," and probably does more astronomical observing than any other amateur. His observatory is of wood, circular, with an easily revolving dome carefully fitted. Transit room attached. Foundations for telescope—mason work and cement, on which is an iron pillar, to carry the equatorial mounting and clock. The chief instrument may be thus described :—Objective, 5 inch clear aperture, by J. A. Brashear & Co.; tube by the same ; all fittings made on the premises. The objective has the crown-glass turned towards the eye, the flint glass outside, Dr. Brashear believing that the flint glass used is less susceptible to moisture than the other. Powers from 50 to 550. The latter can be used satisfactorily when the seeing is good. A Brashear micrometer, star prism and Herschel prism (for solar work). A photographic attachment, a specially constructed camera with metallic shutter. Solar spectroscope also by Brashear, rotary grating, two eye-pieces, 150 to 200, sufficient for solar prominence and some chromosphere observations. The hour and declination circles are graduated to read minutes and seconds ; the former being double.

Dr. Marsh has equalled Dr. Wadsworth in the matter of construction, for though he did not grind his lens, he made the graduated circles on his own premises, and beautiful pieces of work they are.

Mr. Miller's observatory has a revolving dome. Is equipped with a 4 inch Wray objective telescope equatorially mounted, with circles and clockwork. It is provided with spectroscopes and other accessories. The defining power is excellent. High powers can be used under favorable weather conditions.

There are over a score of telescopes in various parts of the Dominion, owned by private individuals, chiefly with 3 inch object glasses, but a few of greater power. There is however little work of value or of very high interest to be done without equatorial mountings and driving clocks, and the description of the small observatories, with pictures, is given here for the purpose of shewing what is really a useful size, not too expensive for an amateur and yet most enjoyable when one knows how to make use of the instruments they contain.

THE SOCIETY'S INSTRUMENTS.

The Society itself possesses the following instruments, which it hopes to be able at some future time to instal in a home of its own. Meanwhile they are used as occasion offers, being usually in the temporary custody of members who have lawns and sufficient accommodation, and they are thus made available to its members as far as possible. All but the Cooke telescope were given to the Society by the members after whom they are called :—

(1) The Sir Adam Wilson Telescope.—6 inch reflector and stand, with finder and one eye-piece.

(2) The Larratt Smith Telescope.—3 inch refractor, an alt-azimuth on tripod ; 3 astronomical eye-pieces, 1 erecting eye-piece with two powers, 2 solar screens.

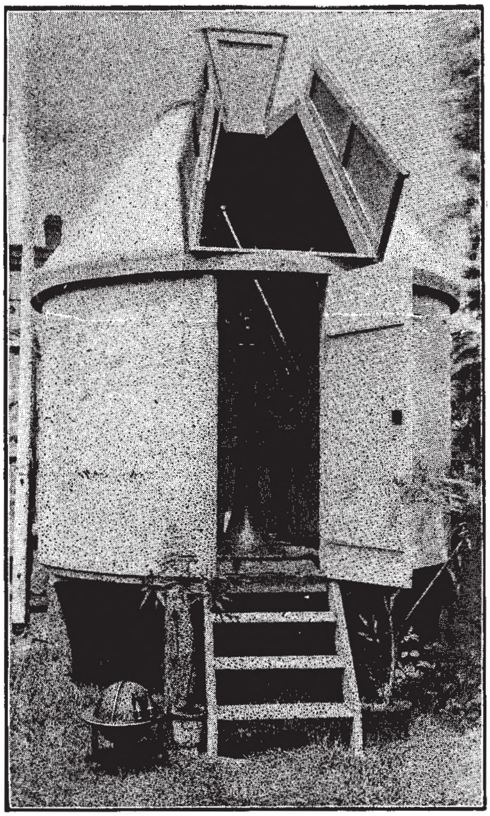
(3) The Andrew Elvins Telescope.—3 inch refractor with tripod and two eye-pieces.

(4) The Todhunter Telescope, a small 2½ inch refractor for the use of junior members.

(5) A Cooke Refractor Telescope.—a 4 inch objective complete with tripod ; 3 eye-pieces, 3 solar screens.

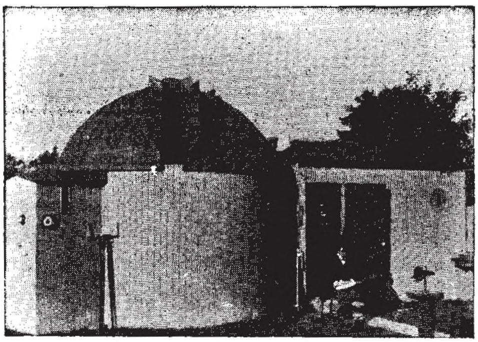
The following instruments once belonging to the late Mr. Charles Carpmael, for many years president of the Toronto Astronomical Society, were by his representatives presented to the Society :—1 direct vision spectroscope and prism of comparison, by Browning.—1 Browning student's table spectroscope with divided circle and prism of comparison.—1 App's induction coil, with condenser in case.—1 Browning spark condenser with electrodes for metals and solutions.—1 case of seven Flucher tubes, and one special tube made by Lockyer, containing iron electrodes in hydrogen vacuum.

In addition to the above the Society owns a diffraction grating —presented by Dr. Brashear. Also a Colt automatic electric arc lantern, complete with numerous slides.

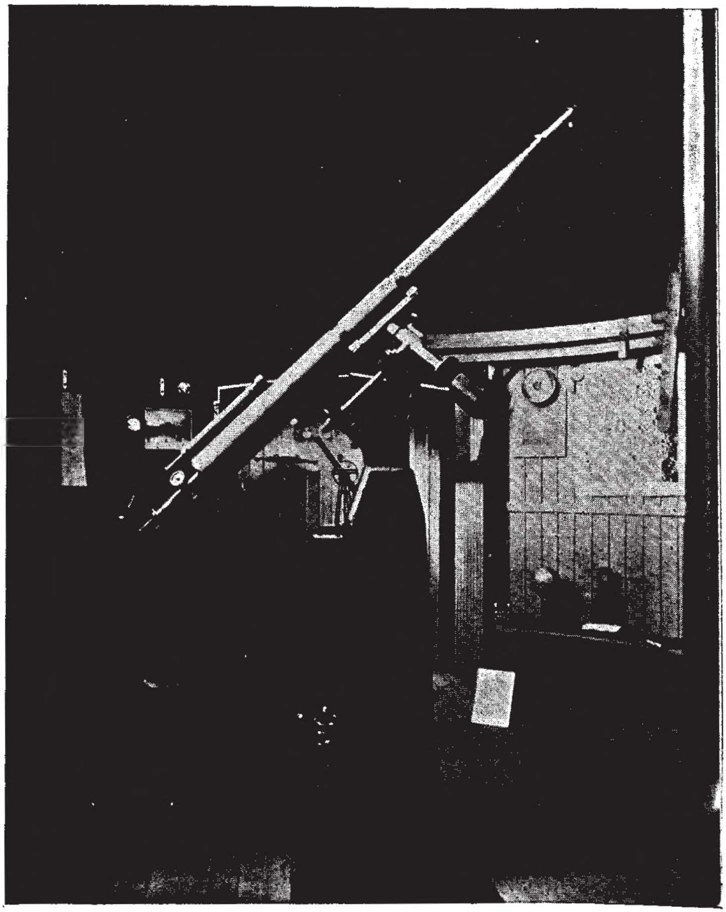


MR. A. F. MILLER'S OBSERVATORY,

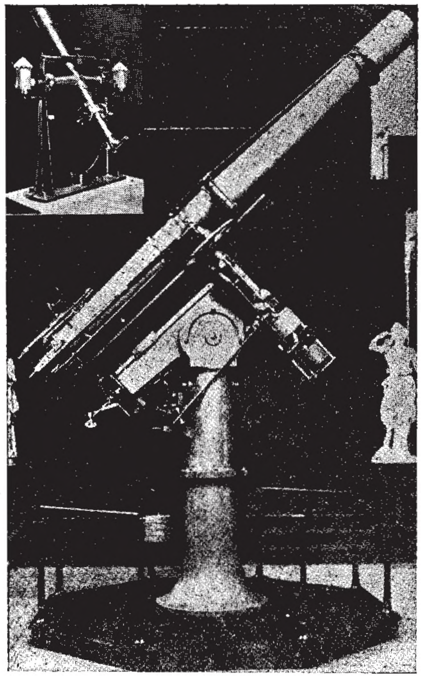
TORONTO.



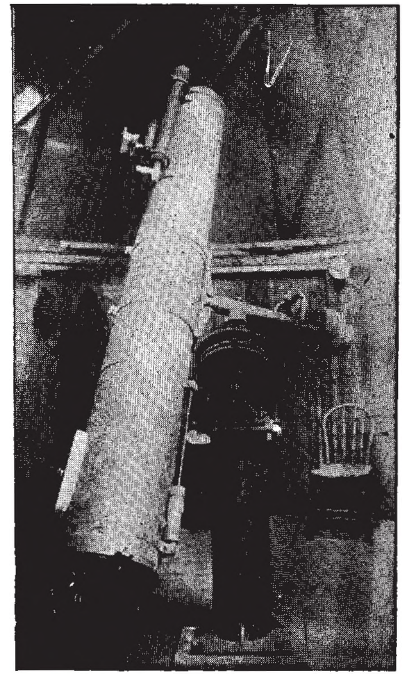
REV. DR. MARSH'S OBSERVATORY,
HAMILTON.



INTERIOR VIEW OF
DR. MARSH'S OBSERVATORY
SHOWING BRASHEAR 5-INCH TELESCOPE.



TORONTO OBSERVATORY TELESCOPE
AND TRANSIT INSTRUMENT.



DR. WADSWORTH'S 12½ IN. REFLECTOR
SIMCOE, ONT.

GREENWICH OBSERVATORY.

"Look here upon this picture and on this" may well be remarked when, after reading the summary of our Canadian equipment, we turn to the account given by one of our past presidents, Mr. John A. Paterson, of his recent visit to Greenwich, England, to view the most famous observatory in the British Empire, founded in 1675 by the Royal warrant of Charles II. A gateway of the Tower, said Mr. Paterson, was demolished and supplied the wood, while the iron, the lead and the bricks came from Tilbury Fort, where Queen Elizabeth had cheered her soldiers and sailors when the Spanish Armada hove in sight, and £520 realized from the sale of spoiled gunpowder supplied the wherewithal to build it. "Thus swords were beaten into ploughshares and spears into pruning hooks, because from materials that bore close relation to oppression, crime and war, arose Greenwich Observatory, to bear a proud sway in the advancement of science and in the establishment of principles that bore enduring triumphs in the art of navigation. This helped to make England mistress of the sea and established for her naval supremacy among the nations of the world." Mr. Paterson happily remarked that "Bellona, the maid of war, had laid her ragged garments at the feet of Science, who had woven them into a glorious robe for Urania, the muse of astronomy." There had been eight famous Astronomers Royal—Flamsteed, Halley, Bradley, Bliss, Maskelyne, Pond, Airy and Christie.

Mr. Paterson, who was graciously received by the officials, described the room, where "two massive pillars carry between them the fundamental instrument of the observatory—the transit circle," the optical axis of the telescope marking longitude 0°. He said :—

> "I stood there, looking south, in the optical axis produced, with my right foot in longitude west and my left foot in longitude east, and from this centre the whole world has measured and reckoned its time and the places where its navies rode or its armies marched, for more than two hundred years."

This transit room is the fourth which has been built, and on its walls are pictures of the transits of Halley, Bradley and Trough-ton, forming an interesting study in evolution.

Mr. Paterson said the observatory was founded for strictly practical purposes; especially the improvement of the art of navigation. Its *raison d'etre* was to observe the motions of the sun, moon and planets and to issue accurate star catalogues. It was to be, so to speak, a kitchen observatory, a hewer of wood and drawer of water—scientifically. Other observatories had taken up show work, and were, we might say, drawing-room and picture-gallery establishments. Big things had their uses; big theories, big telescopes, etc., but Greenwich was built for big results, with very small and ordinary instruments. A very great enlargement had been made during the period of the present Astronomer Royal, W. H. M. Christie, the eighth of the dynasty—nearly three-fourths of the present observatory having been added, together with the chief parts of the present instrumental equipment.

Some epochs in the history of the observatory were alluded to (additional to those to be found in the papers of the late Mr. Thomas Lindsay, in the Transactions of the Toronto Astronomical Society). As, for example, the offering of £20,000 for a clock that would keep time correct to two seconds in a voyage across the Atlantic, which brought about the chronometer, made by Harrison, the son of a Yorkshire carpenter, who received his reward in 1735. The care and rating of chronometers for the Royal Navy is now one of the most important duties of the observatory; they are put in different positions and subjected, among other trials, to a heat test, being kept for eight weeks in a close stove, at 85° or 90° temperature. Mr. Paterson said a dozen Blue-Jackets paraded, and "each man was given a chronometer, which had been carefully corrected, to carry away, which they handled as tenderly as a young mother her first baby." The most indefatigable of the Astronomers Royal was said to be Neville Maskelyne, who, with one assistant, made 9,000 observations between 1776 and 1811, which fill four large volumes. He observed the transit of Venus in 1769, and in 1774 deduced the density of the earth from the deviation of a plumb line from the vertical, caused by the attraction of the mountain Schiehallion. He reckoned this mean density to be four and a half times that of water. But the greatest of the Astronomers Royal was said to be George Biddell Airy, who in 1840 established the magnetic and meteorological department, carefully observed the transit of Venus in 1874, and took a distinguished part in delimiting the boundary between Canada and Maine, also the Oregon boundary. The present holder of the office had procured the building of the great new observatory, the new library, the transit pavilion, and the magnetic building. He had also put up the 28 inch refractor, the astrographic twin telescope, the new altazimuth, the 30 inch reflector and the 26 inch and 9 inch Thompson photographic refractors. The schedule shews, in addition to these and other stationary instruments, 16 telescopes at Greenwich, 10 loaned to the Cape observatory, Paris, Hong Kong, South Kensington and other places. The number of astronomical observations, from 11th May 1902 to 10th May 1903, was :—transits 11·734 ; circle observations 9·923 ; besides hundreds of others determining collimation errors, level errors, nadir point, etc. There were 4119 altazimuth observations. The personal establishment of the observatory now consists of 59, reckoning chief assistants, assistants, second class assistants, clerical assistants, established and supernumerary computers, covering all the branches–astronomical, chronometer, astrographic, Thompson equatorial, heliographic, magnetic and meteorological. with the mechanics, laborers and messengers. Compare this, said Mr. Paterson, with Flamsteed and his one drudge at ten shillings per week !

"The work of determining geographical longitude has been an important part of the work at Greenwich. Many distinguished astronomers from the leading observatories of the Continent have visited Greenwich and taken observations, and the positions where they stood are marked by flat stones on the ground. Now, however, a permanent pier has been erected and the Transit Pavilion built over it. The reason of the various observers coming to Greenwich, instead of exchanging clock signals, is, of course, the necessity of eliminating the personal equation.

"The heliographic department became most interesting when it was found that there was a close relation between earth magnetism and solar changes, and thus the Magnetic Observatory at Greenwich was supplemented by one devoted to the direct study of solar surface. By photography the magnets recorded their own movement, so that the sun registered his own changes, which gives us at once, as Maunder happily says, "both his portrait and his autograph." This department was established in 1873 by Airy. Two of these photographs are taken every fine day at Greenwich, but fine days are 1 in 3 even in summer and therefore Christie has arranged that photos should be taken in India and Mauritius, and these are sent to Greenwich to fill up the gaps in the Greenwich series. Why not also in Canada where our Lady of the sunshine holds her court? In the new dome, where the spectroscopic work is carried on, we find three telescopes rigidly connected with each other on one side of a pier,—(1) the great Thompson photographic telescope, (2) the 12¾ guide telescope to the Thompson refractor, (3) the photographic telescope of 9 inches for sun work and eclipse expeditions. The counter-poise for all these is not a mass of lead, but the 30 inch reflector, to which is attached the spectroscope.

"Greenwich was one of the eighteen observatories which took part in the great charting of the firmament. They charted in all forty millions of stars and produced a catalogue of two or three millions. It has a double star department, where the twenty-eight inch equatorial is used.

"We leave Greenwich Observatory with feelings of renewed interest. There we see the outward and tangible embodiment of the work of great men, who have for two and a quarter centuries questioned the silent shining Sybils of the sky, and have received to their questions sometimes clear answers, sometimes faint mutterings of uncertainty, and often, too often, dark silence. But the astronomers on the watch-towers, not only here at Greenwich, but round the world, and in the silent watches of the night, still address the firmament and continue to extract answers more and more clear as time moves on."

TO BE AN ASTRONOMER.

The late Dr. E. A. Meredith, one of the presidents of the Toronto Astronomical Society, said that Sir William Rowan Hamilton, Astronomer Royal of Ireland, when asked, at a time when Saturn was favorably placed, if he had been observing that planet, replied "No, he left that for others—the mathematics of astronomy were enough for him." So even Sir Isaac Newton had Flamsteed make the lunar observations on which he depended for the verification of his theory of gravitation. One may be an astronomer without using the telescope. But, if one desires to be an observational astronomer, he must, according to Dr. D. B. Marsh, of Hamilton, (one of our council) possess :—

1. A sound physical frame.

2. Enthusiasm such that the cold of winter or the heat of summer, or even the feeling of weary bones by night or by day, will not prevent observation and making records therof.

3. He must use faithfully what equipment he has and remove the word "can't" from his vocabulary.

4. Undertake work that seems to him difficult and stay with it until he has mastered it; then take up another problem and persevere with that likewise.

THE SUN, AND SOLAR RADIATIONS.

The revival of solar activity, which began about five years ago has again drawn general attention to the great central body of our system, and several papers on special solar features have been presented to the Society.

"The Apex of the Sun's Way" was the subject chosen by Mr. John A. Paterson, who said:—

THE APEX OF THE SUN'S WAY.

"An uninstructed and unphilosophical mind will assume that rest is the natural condition of a body in nature, but that is not so There is no rest in nature, unless in death, and even then there is an active disintegration of elements working constantly through chemical and physical changes ; our hearts beat all our lives, our lungs expand and contract from the cradle to the grave unceasingly. Movement, restless constant movement, is the law of nature, from the molecule that has existence and no magnitude, running to and fro in its little sphere, to the giant nebula that flames and heaves in the immensity of space, whole universes of world systems distant from us.

"Camille Flammarion enumerates twelve motions to which the earth is subject, and one of these, of which we now speak, is the drift of the earth with its sister planets, the whole Solar family, in fact, through the limitless fields of azure space. When this thought was first presented in any clear and definite form by Sir William Herschel in 1873, the scientists of the day looked dubious, and Burchardt and Bessel undertook to disprove his theory.

"Our system is encircled by other sun systems. It is one of a vast cluster, and the Universe is filled with clusters. The sun attracts the earth, and the earth the feather from the linnet's wing as it floats earthward, and it would be strange indeed that the great orbs throughout space, distant though they may be, were not to attract our Sun and its planet retinue, and equally strange if our Sun did not exercise some attraction over other systems. Gravitation reaches out her puissant arm universally, and with

NOTE.—1st line, read, which began about three years her unrelenting hand grasps everyting everywhere, and plants her throne of empire throughout the Infinite, until time shall be no more.

"There would be one chance in many millions that the attraction of orbits around us would counter-balance and hold the Sun and its planet family in equilibrium. So exquisite a balancing might be possible for an instant, but the attracting forces from other orbs would soon change their situation, and the system in rest would soon be set in motion, and once in motion never stop, and so we are guided through space with the swiftness of an angel's wing, and unerringly steer our way through black depths with beacon lights in front, guiding us onward and lights behind to show us whence we have come, through the remote æons of time not counted save in the chronology of Heaven. Gravitations innumerable tie together the most distant stars. Light is a magnificent and everlasting witness at all hours of the day and night of the relations of bodies. It is the universal language among the Solar families, and the spectroscope is the page on which the light writes its message, and Fraunhofer's lines are the letters that there are blazoned.

"There are no fixed stars. The name "fixed" is an archaism; it is unphilosophic ; it is untrue. There is nothing fixed in the universe. No conservatism finds place in its mechanism,—it is ever progressive. No blue mould marks its architecture; no stains of time blemish its columns.

"Our Solar system moves eighteen miles every second of time. Many stars move much faster. Groombridge, 1830, "the runaway star," moves 200 miles a second. It is a million times further away than the Sun from us, and it would take 250 years to traverse an arc of sky the diameter of the Moon.

"We can only with our telescope take cognizance of that part of the Sun's movement which is perpendicular to the line of sight. If a star comes directly to us or departs directly from us, then the spectroscope must solve the problem of its motion and of its rate of motion. Any direct observation we may make of the Sun itself cannot avail, for we move with him. Our fortunes for better or worse are fixedly linked with his. In the language of a well known ancient poem, we may say of the Sun, and each member of his royal retinue may say to the other—

"Whither thou goest, I will go,
And where thou lodgest, I will lodge.
And where thou diest, I will die,
And there will I be buried,
Naught but death shall part thee and me."

"If we could remove ourselves from the Solar system and watch the Sun with a meridian circle, we could make accurate observations, but situated as we are, the points of reference can only be provided by the stars, and here is a fundamental difficulty. Sitting in a railway train, we can measure its rate by observing the telegraphic poles as they move backwards past us, but suppose the posts themselves move; what then? If there were only a few stars the solution of the problem would be almost impossible, but there are thousands of stars, and only by the principle of averages do we reach a conclusion. If they were all equal in velocity and parallel in direction, then observations would be useless; or if they tended to move one way, then results would be erroneous, but by a combination of averages, stars moving in one way and stars moving in the other way, we reach results.

"We may set aside as beyond the reach of discovery, the deduction of the form of orbit in which the sun possibly revolves. Doubtless if our observations had extended over millions of years, we might be able to discover something more or less accurately with regard to movements so stupendous. We have discovered only actually rectilinear motion at the present. The Sun no doubt moves in a curve of some sort, but we can only find the direction of the tangent to the curve. The problem is to find the point to which the stars behind seem generally to converge, and to find the point from which stars in front seem to diverge. Almost all the great discoveries of astronomy have resulted from consideration of the great principle of residual phenomena of a numerical kind, that is to say, of such portions of the numerical results of observations as remain outstanding and unaccounted for after allowing for all that would result from known cases. From this principle the precession of the equinoxes, the aberration of light and nutation were discovered.' Sir William Herschel was the pioneer of the solution of this problem, and to him is due the expression "Apex of the Sun's way." In 1783 he made observations of the proper motions of such stars as could be tolerably ascertained, and from these he fixed the apex as near Hercules, R. A. 260°, 24′ and D. 26°, 3′. Argelander in 1838, Otto Struve in 1841 and Galloway in 1790, reached results not differing in right ascension, but somewhat different in declination. The most recent determinations are those of Newcomb, Kapteyn and Campbell, varying in right ascension from 274° to 277°, and declination from 20° to 35°. This gives us a general direction, variously placed; in Lyra, between Cygnus and Hercules, and the last result is about midway between Vega and Beta Lyræ. Great Hercules is yearly becoming huger and brawnier,—his club, and especially his bow, growing every year more formidable. This Solar flotilla sails away through space towards Hercules in an orbit so vast that the part that has been described from the day of the earliest accurate observations does not differ sensibly from a straight line. Shall we double the wondrous cape of some great ellipse, and as we return in millions of years hence, will the Dove begin to expand and plume her heavenly wings, while champion Hercules will dwarf behind us?

"Sir John Herschel pronounced the theory of a common movement round Alcyone as utterly improbable. Out of the plane of the galaxy, he says it is almost inconceivable that any general circulation can take place. We must abandon the idea of a great Pleiad central orbit, but we have the bed-rock of evidence for the theory of the rectilinear movement of the Sun through our cluster. We are then on our way to 61 Cygni, at a rate of 154 millions of miles a year, and we will arrive at that station in 123,000 years, roughly. The future earth inhabitants will be seeing a new heavens a few thousand years hence. The firmament will sparkle with new glories, and the constellations opposite Vega will have paled and dwindled away. 12,000 years hence Vega will be our Pole Star, and we will be driving head onwards towards the North Pole. The life of our Solar system is thus spent in a glorious panorama of a changing firmament, and while individually our lives are spent as a tale that is told, and we see only a small portion of the universe, still, through the distant ages yet to be, Apollo will drive his Sun Chariot through our celestial scenery, where stars now invisible will wander with golden feet. Near Vega, the great Harp Star, is our apex. Its name is Arabic. It means the "Falling Eagle." Its sapphire hue dazzles us. It is the arc light of the sky, hung near the zenith, and will our remote posterity get a nearer view of the celebrated quadruple star? And will the great ring Nebula in Lyra unfold its dim nebulous haze and let its secret be read by the astronomers of a far distant age? And will the great Hercules cluster, that little patch of sky, which is a glorious company of glowing Suns, draw near? And will our earth in the far-away future become neighbor to those 4000 Suns that are packed together like the boss of a blazing shield? Speculation runs rife with us, and we may give rein to our conjectures, and that is legitimate enough, so long as we do not discard or trifle with scientific truth."

DISCUSSION OF PAPER.

In discussing Mr. Paterson's paper it was noted that the apparent immobility of the stars (notwithstanding the fact that if the earth travelled round the sun, it changed its place by the mere fact of that revolution nearly two hundred millions of miles) was one of the obstacles to the early acceptance of the Copernican theory. The share of Halley in the discovery that there were such movements was also touched upon, for he informed the Royal Society nearly two hundred years ago that the great stars Aldebaran, Arcturus, Betelgeux, and Sirius were all South of the positions assigned to them by Hipparchus, just two thousand years since. Cassini's and Mayer's results, the latter using some observations of Romer's, were also alluded to, and the figure used by Mayer was recalled, who said the movement observable among the stars must be like the way in which trees in a forest open up in front and close behind as a traveller passes through. Herschel had made use of Maskelyne's observations; the proper motions of seven stars having been established in 1783 and of five times as many in 1805. The results being discordant, led to scepticism, which lasted through the times of Bessel to that of Argelander, who, by examining Bradley's work of 1755, in the year 1830, had a much longer period than Herschel to work upon, and settled the controversy by obtaining a result very close to that of Herschel's first estimate. Since that time many astronomers have studied the question; some taking the smaller stars exclusively, some the larger ones alone, and the results are not identical, possibly because the larger stars may be the nearer ones also, and have some motion in common with the Sun. The recent photographic survey of the heavens will afford a better basis, in a generation or two, for the determination of this among other important problems. Meanwhile the spectroscope, which by a method pointed out by Sir William Huggins shews for us the rate of motion in the line of sight (i. e., of approach or recession) gives another basis of calculation, and determines far more accurately than the older method, the rate at which the Sun is moving. By ascertaining, at Lick Observatory, the motions of about three hundred stars, Prof. Campbell finds that the element common to them, which must be due to the Sun's motion, is something less than 13 miles a second, at which rate we are all being carried towards Vega. We can therefore use this measure as a scale for proving the distances of other stars, whose motions we shall soon thoroughly know, and for learning much about the extent of the stellar universe.

SOLAR PHENOMENA AND TERRESTRIAL EFFECTS.

The relation of the numbers and areas of sun- spots to manifestations of terrestrial magnetism, earth-currents and auroræ has always been a favorite subject with the Society, and the long series of records at the Toronto Observatory gives opportunities for original work in connection therewith.

It was at the request of Prof. A. Wolfer, of Zurich, that Mr. Arthur Harvey prepared from these records (by the permission of Director R. F. Stupart) a table of the differences between the highest and lowest monthly mean readings of the declinometer here, from 1843 to 1903. The curve deduced therefrom shewed the same correspondence with that of relative sun-spot numbers which is establishedthrough the Greenwich observations by Prof. William Ellis and through the Parc St. Maur observations by M. Camille Flammarion.

The considerations suggested by the table led Mr. Arthur Harvey to offer the Society a paper on The Vagaries of the Mariner's Compass.

Mr. Harvey recalled that at the date of the great oceanic discoveries which revealed to the world the East and West Indies, the magnetic meridian passing through the Mediterranean

Sea very nearly coincided with the geographical meridian, whence came the idea that the needle pointed to the north, but that as Columbus sailed into the west, he gradually drew away from the places where that condition prevailed, and when it was found the compass no longer pointed to that quarter, a new terror was added to his voyage. In Tennyson's verse

> "The compass, like an old friend, false at last
> In our most need, appall'd them."

Shortly afterwards it was noticed that the angle between astronomical and magnetic North, called declination, varied according to locality ; it was also found to change from year to year. For a long time such a displacement of the magnetic pole was thought interesting to mariners and land-surveyors only, but it gradually dawned upon the world that the exciting cause of terrestrial magnetism is solar, and that its phenomena have cosmical relations, which immensely widened its sphere of importance, ennobled magnetology, and brought it into close connection with astronomy. Portions of the paper, relating to the effects of compass disturbances on navigation and surveying, were at the request of the Ontario Land Surveyors' Association read at a meeting of that body. and have been summarised in their Proceedings for 1903, where the need is shewn for a magnetic survey of the coasts of the Gulf of St. Lawrence, of Nova Scotia, Newfoundland and Labrador; a subject which the principal shipowners of Canada are now bringing to the notice of the Government of the Dominion.

The needle pointed due north, at London, in 1657: its direction moved westward until 1878, when it was 24° 30′ W., since which time it has been returning. This secular variation is still westward here. Any who suppose it to be a grand uniform movement are mistaken : it is a vacillating march. In 1856 it was 4′ 84″ ; in 1857 3′ 77″ ; in 1887 it was 3′ 10″ ; in 1888 3′ 24″ , nor is there any uniformity from month to month, as may be seen from the following figures for the two last mentioned years in which give the movement in declination of the magnetic needle at Toronto, in minutes of arc :

	1887	1888
January	East 0'.06	West 0'.46
February	" .06	" .11
March	West .17	" .21
April	" .40	" .53
May	" .31	East .08
June	" .03	" .23
July	East .04	West .31
August	West .53	" .45
September	" .61	" .42
October	" .36	" .27
November	" .40	" .41
December	" .45	" .38
	West 3'.10	West 3'.24

The rate of secular change is not directly related to sun-activity, for the curves of spot numbers and of the westward compass deflections are not at all alike. There is however a relation between this magnetic movement and the curves of temperature. At Toronto, the two agree in general, but until much more time has elapsed and a long series of temperature observations collected to give the mean annual temperature of the North American Continent, a close agreement, year by year, is not to be expected. In Europe, the same relation obtains. The curves for Brussels agree very closely indeed; they have been obtained from Prof. M. Dehaley, of the Observatory at Liege, Belgium. In a few years the general law governing this relation will be accurately laid down. The two diagrams, for about thirty years in each place, are reproduced.

Mr. Harvey considered the sequence of sun-spot and allied phenomena to be as follows:

(1.) Internal Solar action, whose cause is yet unknown, as well as its precise nature; possibly a chemical change connected with convection currents from the intensely hot interior towards the cooling surface of the wholly gaseous solar sphere.

(2.) Emission from that active region of an unusual quantity of cathodic or other radiations, with particles carrying electrons, or of electrons alone—their velocity being of the order of that of light. Their path resembles that of a beam from an electric search light, because those rays which start at a considerable angle from the line perpendicular to the solar surface must traverse a great thickness of the solar atmosphere and be absorbed thereby.

(3.) The magnetic effect upon the earth is therefore not continuous during the solar disturbance, but recurs at about the interval of a solar synodical relation, and may so recur with greater or less force for several such intervals. Some solar regions are continuously active for years together.

(4.) The first visible sign of internal solar action is the development of faculae, disturbances in the upper region of the solar atmosphere.

(5.) Among these faculæ (if they are in the spot-belt region, which is usual) and often after they have been prevalent for many days, spots break out, and there is a recrudescence of cathodic emissions—felt, as before, when the active region is near the central meridian.

(6.) Auroræ are associated with the distribution in streams of these electrons.

(7.) When solar cathodic rays are directed upon the earth they ionize our atmosphere, cause condensation of moisture therein, a local rise in temperature, an expansion of the air, which gives rise to the well known features of wind and thunder storms. Barometric "lows," once formed under such influence, travel according to terrestrial laws.

(8.) After the solar commotion dies away, the spot disappears, and faculæ which have not been dispersed subside.

(9.) Protuberances or prominences on the sun do not affect the magnetic condition of the earth. A great outburst of prominence-activity may be seen on the east limb, without exciting the magnets during its passage. Neither is there any connection between the ordinary hydrogen prominences and sun-spots or faculae (though metallic promînces are often seen where spots are to appear). Rather is the opposite true, that where faculae develop, prominences become rare.

These views have been repeatedly expressed to the society. The last item is still under discussion; several illustrious men are looking to prominences as closely connected with terrestrial phenomena, and Mr. Harvey therefore referred with some relief, to the weighty opinion of the Rev. A. L. Cortie, of Stoneyhurst Observatory, that "Solar prominences have no connection with magnetic storms." If that be so, they can have no influence on our climate.*

A series of maps of the sun was submitted, plotted on a system of rectangular projection, for convenience of showing latitude and longitude and of exhibiting on one plan the whole circumference. While sun-spots are practically confined to a zone of 30° on each side of the equator, and thus form two belts, there are four chief belts or prominences, two on each side, the most important being about in 50° of latitude. The diagrams shewed the position and relative sizes of the sun-spots seen in six months, near a maximum, and of those seen in the southern spot-belt during seven years. Also the position and numbers of the protuberances catalogued during 50 rotations, from a maximum through a minimum, to another maximum. This shewed how the chief prominences are distributed in belts, not unlike those of Jupiter and Saturn; also that at maximum they tend to be farther from the equator than at minimum.

The composite diagram of the spots seen in southern latitudes during the seven years appears to indicate three chief areas of disturbance. The limitation in latitude to a zone of about 30° and the absence of equatorial spots is also made evident. It would also appear from the other diagram that a disturbed area on one side of the equator is roughly related to one in the other hemisphere, in similar longitude.

The spot and prominence diagrams were on the same scale, which in the reproduction they are not, but it may be noticed in these diagrams, which are given to shew the belts in which such

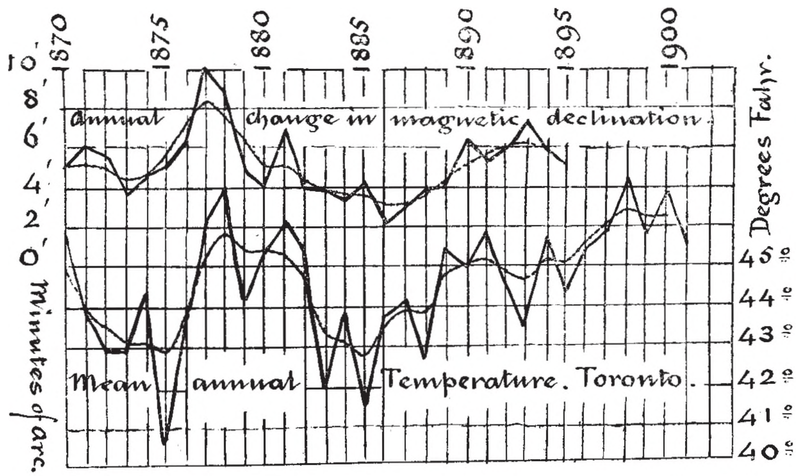
* Mascari shews (Bull. Belgian Astron. Society, February, 1904) that no excess of prominences accompanied the magnetic disturbance of October 13th, 1903, and the huge spot which was then central. But there was great prominence activity when the smaller spot, central at the time of the magnetic storm of October 31st, was passing off the disc, and presumably also during its centrality. He recognizes that the size of spots is not a measure of the intensity of the contemporaneous magnetic disturbances. This confirms the author's contention that the sun-spot area is not a perfect measure of solar activity.

phenomena occur, that a sort of repulsive influence is exercised towards prominences by faculæ, and especially by spots. At a maximum of spots there are more prominences than at a minimum, but the belts of prominences seem driven away from the spot zones. Commenting on the extreme rarity of the evidences of disturbance on the solar equator, Mr. Harvey said there were some indications of a constant and rapid current there, of about five degrees in breadth, in the direction of the sun's rotation, which might mechanically prevent the formation of spots and faculæ, and even hinder, to some extent, the development of prominences. He was led to think this was the cause of the apparent indraught of recurrent spots towards the equator, and the preliminary tabulations made indicated a velocity for such a current of something less than 200 miles an hour.

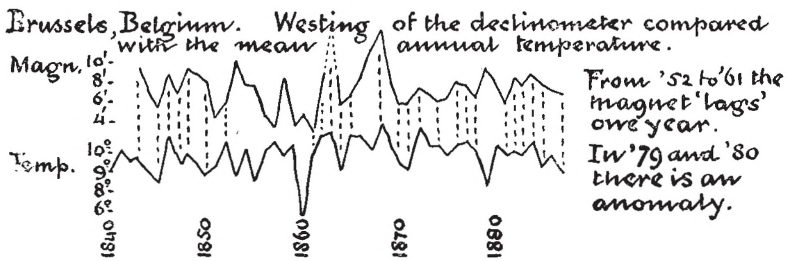
The general correspondence between solar and magnetic activity is now so generally admitted that it was not lengthily discussed, but the identification of particular magnetic disturbances with special solar phenomena was dwelt upon. With respect to the sun-spots and magnetic tremors of 1902 the following conclusions were arrived at :—

1. In at least 13 out of 16 cases in which such disturbances were contemporaneous with spots, the maximum development of spottiness closely corresponded with the magnetic disturbance, the latter occurring generally a day or two later than the apex of the spot curve.*

* In the "Monthly Notices" R. A. S., January, 1904, Mr. E. Walter Maunder thus states his conclusions :—(1) There is a real connection between large sun-spots and great magnetic storms. (2) Also a real but only rough connection between the size of the spot and the intensity of the storm. (3) The area of the sun-spot is not an exact index of the degree of the magnetic disturbance. (4) The great storms he has investigated began during a period of 34 hours before the spot reached the central meridian and 86 hours after; the mean being 26 hours after. These are the conclusions often alluded to in this Society's transactions (e. g., 1901, pp. 26-27). The calculation of the mean "lag" is new, we have not yet attempted it; we identify with particular spot areas so many more magnetic disturbances than Prof. Maunder deals with. In a second paper the same author refers coronal rays to magnetic disturbance; we think them connected rather with prominence phenomena, which do not appear to us directly related either to magnetic effects or particular spots. Mrs. Walter Maunder, in an interesting paper, endeavors to



(See page 73)



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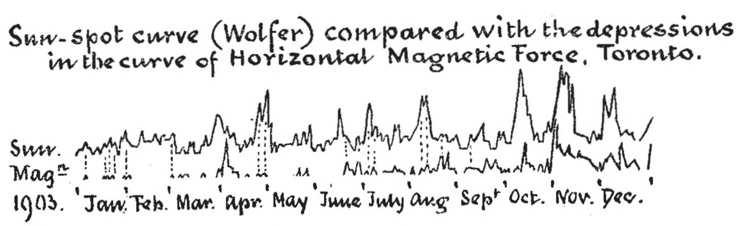

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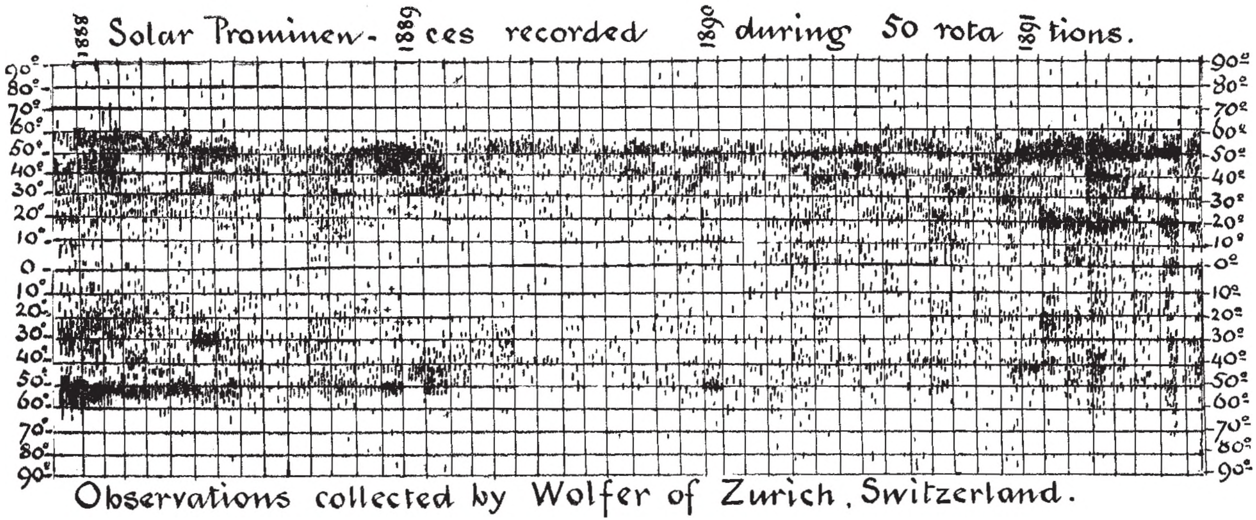
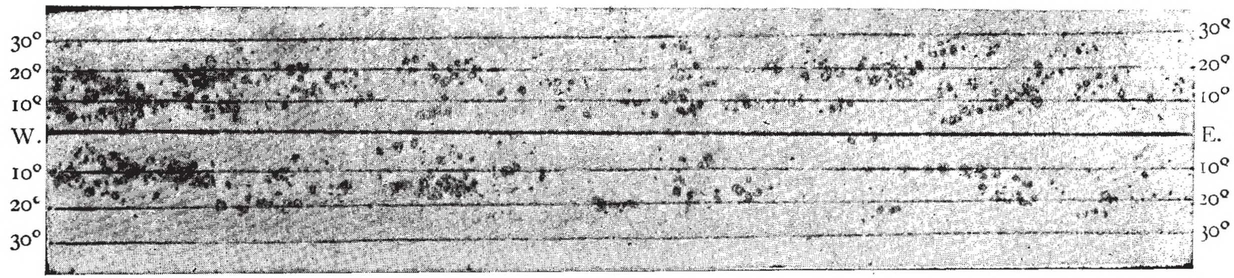

1888
Solar Prominen- 1889 ces recorded 1890 during 50 rota 1891 tions.
90°
80°
70°
60°
50°
40°
30°
20°
10°
0
10°
20°
30°
40°
50°
60°
70°
80°
90°
Observations collected by Wolfer of Zurich, Switzerland.

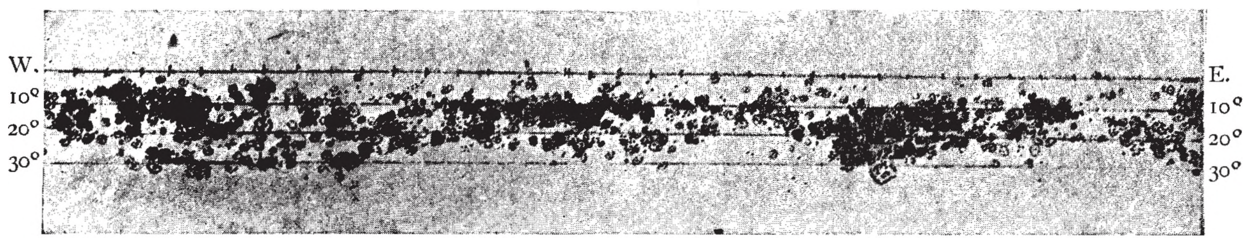
(See page 75)

SUN-SPOTS SEEN DURING SIX MONTHS (7 ROTATIONS) NEAR MAXIMUM



(See page 75)

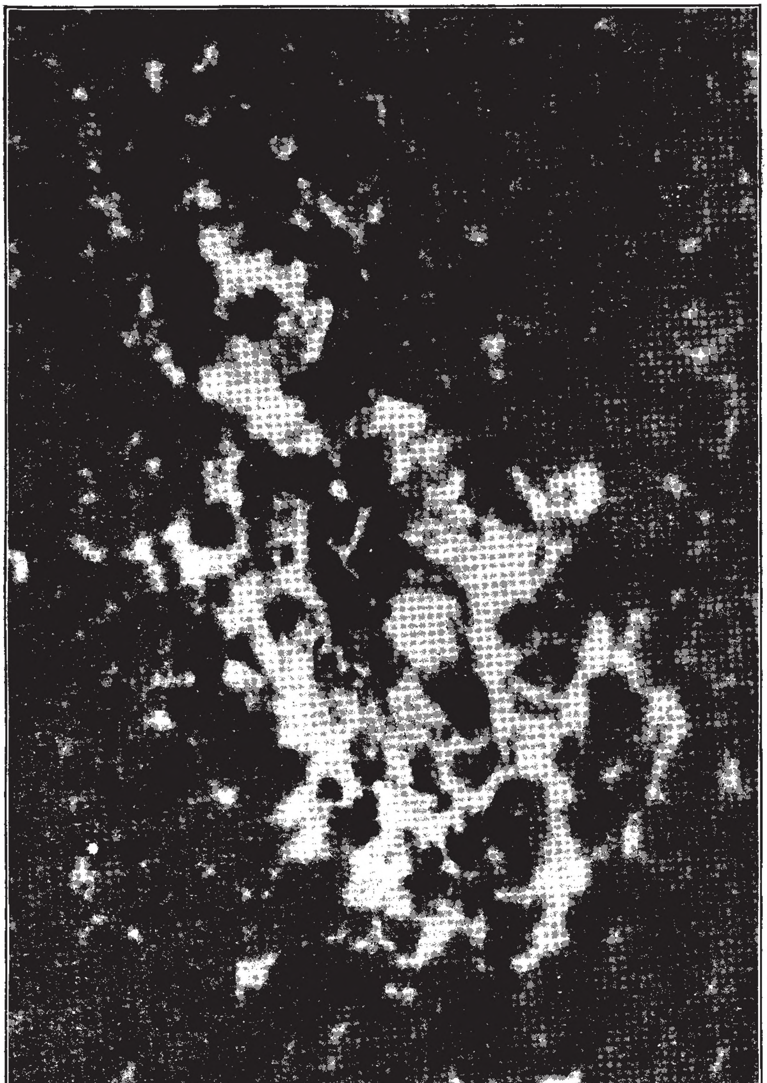
SUN-SPOTS OF SIX YEARS (80 ROTATIONS)—SOUTHERN HEMISPHERE



OCT. 9, 3^h 42^m. CALCIUM FLOCCULI, LOW H_1 LEVEL
Slit at λ3962

THE GREAT SUN-SPOT OF OCTOBER, 1903
Scale: Sun's Diameter—0.550 Meter

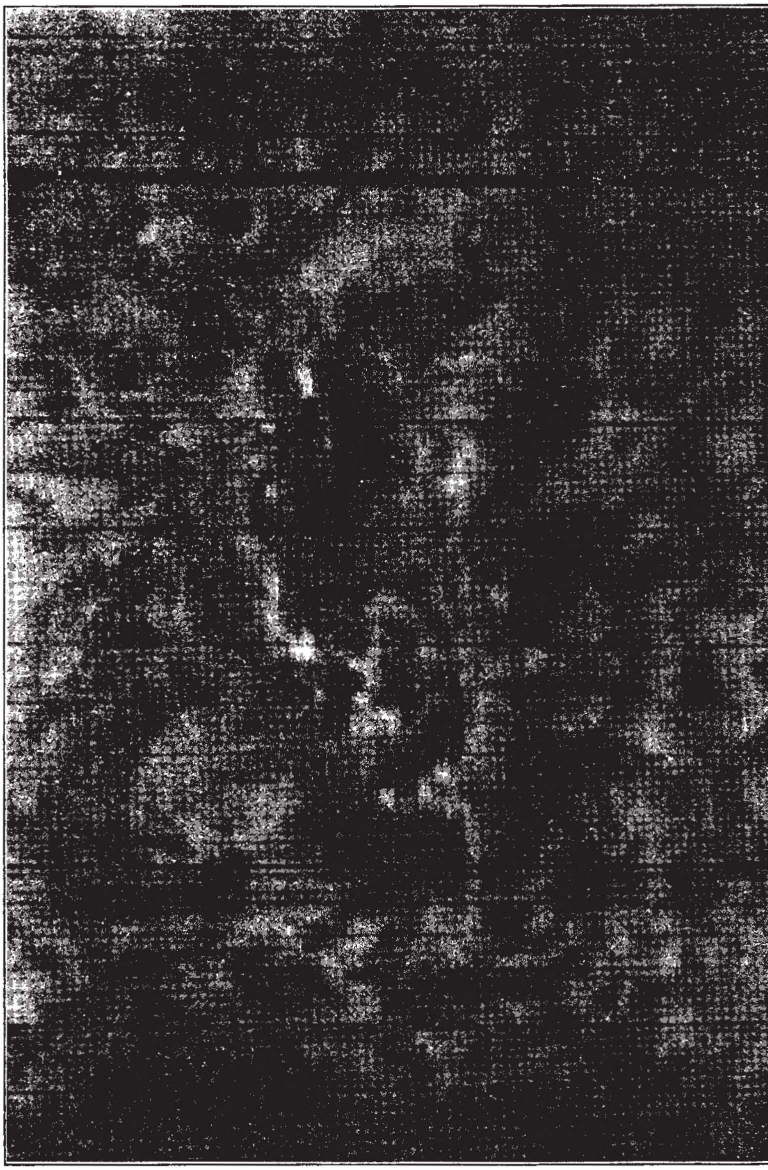
PHOTOGRAPHED AT YERKES OBSERVATORY (See page 81)



Oct. 9. 3^h 30^m. Calcium Flocculi, H2 Level
Slit at λ3968.6

THE GREAT SUN-SPOT OF OCTOBER, 1903
Scale : Sun's Diameter—0.550 Meter

PHOTOGRAPHED AT YERKES OBSERVATORY (See page 81)



Oct. 9, $1^h\ 04^m$. Hydrogen Flocculi
Slit Set on $H\beta$

THE GREAT SUN-SPOT OF OCTOBER, 1903
Scale: Sun's Diameter—0.550 Meter

PHOTOGRAPHED AT YERKES OBSERVATORY (See page 81)

2. In 4 other cases the magnetic development corresponded with that of faculae.

3. In 10 cases the disturbances were repetitions of that of January 10th, at the usual rotational interval, while in only 5 cases did spots occur with the like periodicity, which was thought to prove that the interior solar disturbance is more steadily persistent than its spot effect.

4. The dates when important faculous areas passed across the central meridian corresponded with magnetic effects without the "lag" mentioned in the first of these conclusions.

(The observations relied upon were those of Prof. Wolfer, of Zurich, for spots, and Prof. Mascari, of Catania, for faculae.

The diagram was subsequently published in the "Canadian Engineer," for May 1903, and shewed that the magnetic disturbance of May 8th, coincident with the Mont Pelé eruption, was but a repetiton of that of April 10th.)

The diagram for 1903 is appended, shewing a continuously

connect the secular changes in terrestrial magnetism with sun-spot phenomena, which we have so far failed to do, but Mrs. Maunder goes beyond the eleven year cycle and thinks the needles may sympathize with a possible greater solar cycle. Her paper should be considered along with Prof. Wm. Ellis' contribution which follows it, on the aurora and magnetic disturbance, in which he refers to the Tromholt auroral catalogue for Norway. The auroral curve made therefrom has here been compared with the Wolfer sun-spot curve, and the subject was discussed before the Canadian Institute, last year. The Wolfer spot curve used here does not quite agree with Mrs. Maunder's for the score of years following 1855, yet we use figures sent us by Prof. Wolfer himself. The auroral curve shews a "lag" of at least a year behind the spot curve, and we look to Prof. Ellis and to Mr. and Mrs. Maunder for an explanation of it. Prof. Ellis' conclusion seems almost like a summing up of our papers of years past. He says "Our earth is found not to be an isolated body, simply receiving light and heat from the sun, but one subject to other external influences. . . . that *may* pervade the whole solar system." It has been our satisfaction to show that they *do*, and that (again to quote Prof. Ellis) they "involve in one common field of action all the bodies thereof." Is it a mere coincidence that in these same "Monthly Notices" we see that contemporaneously with the increased sun-activity of 1903 "extensive disturbance is observed on Saturn," (Denning, p. 123), and "the greater conspicuousness of the red spot on Jupiter" is indicated? (Phillips, p. 252). Nor does the "field of action" mean the field of a spherical magnet, for Prof. Ellis at last suggests the idea of the direction of the solar radiations, which has been for years contended for here.

increasing sun-spottiness, also that with almost every spot there was a magnetic development which generally had a relation as to intensity with the spotted area, the principal exception being at the beginning of May. Mr. Harvey prefers the horizontal component of the magnetic force to declination, as a measure of sun-activity, though the latter is used in Europe because there are many long records of it, as against few and short series of horizontal force observations. When the instruments for observing vertical force are brought under better control as regards temperature changes, that will have to be considered too.

The magnetic disturbances and the great aurora of August 24 were synchronous with the central passage of a comparatively small spot, but the solar area in which it appeared was exceedingly active, as evidenced by the great spot development at the next rotation period, September 17th, and the still greater ones of the following periods, October 15th, November 10th and December 7th. The August entrance of this spot was among a moderate sized group of brilliant faculae, and were it not for subsequent events one might have doubted its connection with the magnetic storm which occurred at its centrality and the magnificent aurorae attendant thereupon. They do not seem to have been much remarked in Europe, but here they were seen from the Atlantic to the Pacific. A very fine display was described, seen by Mr. W. G. C. Lanskail in the mountains of Washington, where the needle points 23½° east of north. The aurora was in the form of a great continuous bar, from 2° to 6° in width passing slowly overhead, forming an arch. By the next rotation in September, the faculae in that region had much increased in extent, and a solar observer must have been reminded of the way clouds gather upon earth, seeming to be drawn from all around to some storm centre and to form as it were out of nothing. The two small spots were still to be noticed among these bright solar patches, while the recurrent magnetic development was strongly in evidence on the 19th, two days later than the centrality of the principal spot area. In October the faculae had taken on a still more important phase; they covered more than 40° of solar longitude and a magnificent spot-group appeared among them, active and constantly changing as to the position and shape of its parts. Mr. Harvey described it and sketched it, showing great streaks of light, superimposed, it seemed, over the penumbrae, and in the case of the two middle component sub-groups separating even the umbrae and bringing their dark shades into relief. The spot was easily visible to the natural eye, through smoked glass, and from the prominences seen when it was coming around the limb, there were evidently many small ones spouting up even among the attendant faculae. The magnetic disturbance was very pronounced, and there were fine aurorae on the 13th. The great spot was central about the 12th, but one of its active companions was timed to the 14th. By the following rotation, in November, the great cloud of faculae remained as extensive as before, and the spot was still large, but it was in ruins, and no prominences were visible either as it came into view on the eastern limb or as it disappeared on the western. The forces of activity seemed to be breaking up into two parts. The total spotted area was larger during the November rotation, but that was not all due to this spot, though the maximum was on the 6th, the day for its centrality. Again, on Dec. 3 was the last central passage for the calendar year of a phenomenon of almost unexcelled magnitude and interest. The two peaks of the sun curve for November and December correspond with the two divisions of this area.

The most marvellous observations of this magnificent spot at its highest development in October are those made by Prof. Geo. E. Hale, of the Yerkes Observatory, with the great Rumford Spectroheliograph, an instrument similar to one which has been in use for some years by M. Deslandres, of Paris, France, but as we have not seen any of his results, the work of Prof. Hale comes to us as a revelation, the opening of a new realm to Science.

The spectroheliograph had for its original purpose, when invented by Mr. Evershed, in England, the photography of the chromosphere and the prominences of the sun, but it has found a wider application. "Imagine", writes Prof. Hale, " a direct vision Spectroscope in which the eye piece ordinarily employed is replaced by a (second) slit. If an image of the sun is formed on the first slit of this spectroscope, the second will permit the passage of only a narrow region of the spectrum. If the slit is now moved until it coincides with the H β line, for example, only hydrogen light will pass through. If then a photographic plate is placed behind the second slit and the spectroscope is moved at right angles to its optical axis, an image of the sun, in monochromatic hydrogen light, will be built up on the plate. . . . The second slit serves to isolate any desired line in the spectrum." Now, when a considerable quantity of calcium vapour is introduced into the electric arc, broad bands appear at the position of the H and K lines of the spectrum, and the width of these bands may be taken as an approximate measure of the density of the vapour. Assuming that similar conditions prevail on the sun, lines proceeding from layers of different densities can be selected, and hence *photographs can be obtained of different levels in the sun's atmosphere.* For the denser the vapour, the lower its level must be. As a working hypothesis, the accuracy of Mr. Evershed's and Prof. Langley's judgement as to what they have seen on the sun is assumed. They seem to agree that the upper part of the solar photosphere consists of filaments, floating as it were in a vertical position, and very close together. Their extremities, which alone we usually see, are what appear to us as granules. The chromosphere looks like "a structure of small filaments, like blades of grass, covering the entire surface." It is, perhaps, "a region of innumerable small eruptions of the same nature as the jets of highly luminous gas which are constantly to be seen with the spectroscope in all regions of the sun's limb." The supposition is that from the summits of the photospheric filaments which appear, it has been said, as "grains," columns of vapour of calcium arise, which, on attaining their extreme height, expand and appear on a photographic plate as bright spots and small patches of light, which cannot be well perceived by the natural retina of the eye. Prof. Hale suggests for them a name which is admirably descriptive, *flocculi*, (little tufts, as of wool), but they must not be confounded with the faculae, which we can see without the spectroscope and the photographic plate. The flocculi are largest and most numerous in the vicinity of faculae and spots, but are general over all the solar surface. When photographs are taken of a solar spot-region by light of different wave lengths, as above explained, that is, of different sections or planes, above the spot but within the solar atmosphere, the view of the upper plane will show that the vapour columns have expanded, so as to invade and partly cover the spot. Prof. Hale, one of those who have graced the Society by accepting Honorary Fellowship, has sent us the fine publication by the Yerkes Observatory in which many of these wondrous photographs are reproduced, and, at his suggestion, we have procured by the favor of the University of Chicago three of the beautiful plates, being representatives of the great sun spot, taken on October 9th, with the slit at $\lambda 3962$, $\lambda 3968.6$, and on the H β line respectively. The two former show, therefore, calcium flocculi at levels respectively near the base of the chromosphere and near its surface ; the latter hydrogen flocculi. The spot is almost covered up in the last two views by the overspreading vapours.

Prof. Hale now suggests that a united attack be made on solar problems; by all the numerous methods of research now available, spectroheliography being re-inforced by spectroscopic observations of motions in the line of sight and of the widened lines in sun-spots ; by direct photographic views of the photosphere and of spots, and by bolometric methods (for the examination of differences of heat emitted). The essential point is that the attack should be simultaneous, and it is to be hoped that, by the time it is organized, the Observatory at Ottawa may be sufficiently advanced to take an honorable part in the assault.

Though this huge spot-group of Oct. 4–27th, the finest of recent years, 125,000 miles in length, was so striking an object, especially at moments of perfect "seeing," when, besides the divisions of its large components, the very numerous minor ones could be perceived, with very numerous variations in the shading of the penumbrae, and though dozens of views have been attempted by photographic means and eye-drawings, none have given any idea of its mobility. Possibly photographs of a great spot taken at observatories all around the world might be arranged as a moving picture to the advantage of science and the enlightenment of the general public, but at the present time fitting ideas on the subject are confined to those who constantly use their telescopes. It does not appear that as a usual thing, a high power, or anything beyond a 3 inch or 4 inch object glass is needed, though the writer once had the privilege of hearing Prof. Barnard, now of the Yerkes Observatory, describe a rare view he one day obtained of a large spot with a great objective, which will allow of a high power on a perfect day, if proper means are taken to control the heat, which as well as light is thereby concentrated. Prof. Barnard, who had been inclined to consider Prof. Langley's well known typical sun-spot drawing mythical as to some details, said he then saw how truthful it was, the great filaments curling in to fill up an awful cavern. But with all that, Mr. Harvey said he had never been able to realize any impression of violence as connected with these great movements, and the very extent of surface they cover should, he thought, dissipate the idea of great volcanic effects, which seems to dominate most minds. In the tenuous atmosphere which alone we saw, a movement of extreme rapidity would not necessarily imply great explosive power at any given point, for which a solid crust was required, such as did not exist in the sun. Rapidity can produce no dynamic effect without resistance.

A singular feature of the sun-activity of October was that in addition to this huge spot, another of considerable size developed about 250° eastward of it, whose history was similar, but whereas the huge spot, central about Oct. 12th, was accompanied by a magnetic storm of which the effects were not abnormal, this smaller one, which was central on the 31st, was accompanied by a remarkably violent magnetic disturbance, and by the most extended aurorae seen for many years. The weather at Toronto was unfavorable for observation, bnt they appeared both east and west of us. In Europe too both auroral and magnetic phenomena were extreme in character. M. Camille Flammarion gives a fairly complete account of them in the Bulletin of the Astron. Society of France. Paris was shut off from communication by telegraph with the greater part of her sister cities, as well as from England, Spain, Italy, Tunis and all beyond. Even the Submarine cables were influenced. The interruption lasted from 9 a.m. to 4.40 p.m., and there was a short renewal at 5.30. From Spain we learn that the cable to the Canaries was violently interrupted, also that from Africa to Brazil. In England, the storm was the heaviest since February 13th, 1892, of which it is a repetition, from the same solar region, if the synodical rotation formerly calculated by the writer from magnetic effects is correctly given at 27.24575 days, the interval of 4278 days being 157 solar rotations of that length. The varying rate of rotation of the several visible parts of the solar envelope has led him lately to place less stress than formerly on his estimate, but that this time is so exact a measure of the interval of more than eleven years is a remarkable coincidence, if nothing more. It may be worth noting too that in examining the curves of the past, for Toronto, the outbreak, which in its course seems most to resemble this, happened on October 23rd, 1847, just 751 rotations of the above length.

The French government detailed one of their experts in telegraphy to attend the meeting of the Astronomical Society at which the subject was discussed, one M. Bordelongue, who said that the Brest-Cape Cod cable remained available, though all the other French and the English cables were out of business for the time, and the old cable from Brest to St. Pierre, laid in 1879, which had developed a fault in 1884, near Newfoundland, at a depth of 16,000 feet, had the fault so much increased by the earth currents that it ceased working for good. At 3.30 a.m., on the 31st, they heard by the Cape-Cod cable that a fiery cloud had appeared in the skies there and all over America. He thought that the neighborhood of Newfoundland was particularly subject to magnetic influences ; there were probably great bodies of iron ore below water there. Curious facts were observed, as, for instance, when buoys were placed to mark the spots where cables were being spliced, you might go back the next day and fail to find them, though placed with the greatest care. Even in normal times, there were disturbances of the mariners' compass near Newfoundland, to which such events were due. This strengthens Mr. Harvey's belief, that a hitherto unsuspected danger to navigation exists around the Newfoundland and Nova Scotia capes, due to their basaltic nature and the frequent derangement of ships' compasses in consequence.

The aurora is not synchronous to the hour at all places. Mr. Harvey thinks the hygrometric condition of the atmosphere has an effect upon its colors and mode of appearance. In one place rapidly moving streamers, in another almost stationary clouds appear: the aurora will be rose, orange and green here, but white or at most a pale yellow there. Still, in all parts of both hemispheres, the distribution of the excess of electricity received from the sun during the whole course of a magnetic storm is proceeding.

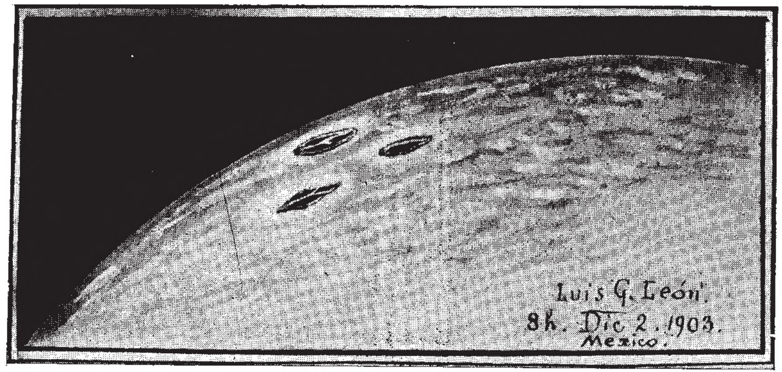
The distribution of the electrical activity must occur in the upper regions of the atmosphere, because air, in the state of condensation in which we breathe it, is a non-conductor, and at the surface there must be great resistance to the transmission of electric influence. This is further proved by M. Marchand, the director of the observatory on the Pic du Midi, France, 9380 feet above sea level, who compares the figures given there with those obtained at Bagnieres, at the foot of the Pic, 1800 feet only above the sea. The total range of the declination magnet on the Pic, Oct. 31st, was 1° 27′ as against 1° 15′ in the town. Similar differences have been noticed ever since the foundation of the mountain observatory in 1895. M. Marchand calculates that if the currents of disturbing influence produce an effect inversely proportional to distance, those passing from N. to S. on Oct. 31st were 19 kilometers over the mountain, and those going from S. to N. were 14 kilometers high, or 10 and 8 miles respectively.

The auroral frequency and brilliancy for October centres about the 12th and 13th and the 30th and 31st. In Canada the weather service returns give some idea of brilliancy, the U. S. returns go by numbers only. The following shews roughly the relative importance of the two series of displays :—

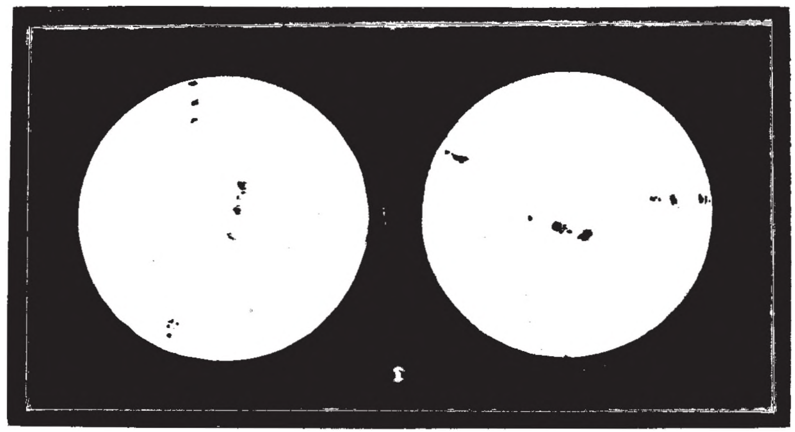
	Oct. 12th.	Oct 13th.	Oct. 30th.	Oct. 31st.
Canada	118	85	46	126
United States	42	45	19	139
	160	130 = 290	65	265 = 330

SUN-SPOT DRAWINGS FROM MEXICO.

Some beautiful drawings of the sun-spots of last Autumn have been received from our Honorary Member, Prof. Louis G. Leon, of Mexico City, one of which is reproduced herewith because it gives an idea of the great extent of the faculæ attending last year's grand outbursts. Prof. Leon remarks that on January 6th, 1904, faculæ extended from two new spots near the Eastern limb to one spot which was nearing the Western limb. He adds, as to his methods, "I projected the surface of the sun on a white card-



SUN SPOTS AND FACULAE
DRAWN BY
LOUIS G. LEON, MEXICO.



at 8.30. a.m. THE SUN, Nov^{r} 4th 1903. at 4. p.m

board and in a dark room : the aspect was beautiful and splendid."

APPARENT MOTIONS OF SUN-SPOTS.

Mr. J. H. Weatherbe has been continuing his studies of apparent motions and has this year been giving the Society his observations on the apparent motion of sun-spots. The subject interests amateurs who, like Mr. Weatherbe, have telescopes of moderate power, not mounted on a polar axis. By way of illustration, Mr. Weatherbe gives the accompanying diagrams of the sun, one as seen in the morning, the other in the afternoon of the same day, through a telescope fixed to a common tripod. The inclination of the sun's equator to the visible horizon has materially changed, and if the sun had been drawn every half hour and the images compared, the spots would seem to have moved in circular paths, half around the disc, considered as stationary. When a student endeavours to draw these curves, on a circle representing the sun, he will find how intricate the apparent motions are. Beginning even with one spot, and eliminating the position angle of the solar axis, and the inclination of the plane of the ecliptic to that of the sun's equator, he will find the task difficult enough. There is the orthographic projection of the sphere to be made, the rate of spot-progress near the edges and the centre respectively to be considered, and the lines drawn along which the spot appears to move day by day. Were one to begin without a knowledge of the rotation of the sun and of the earth and of the angle between the ecliptic to the equatorial planes, these motions would seem as puzzling as the apparent motions of the sun, moon and stars did to Ptolemaists ; "with cycles and epicycles plastered o'er." Mr. Weatherbe indeed thinks that were there no bodies except the sun and the earth to be seen and no other observations available but those of sun-spots, the main facts of the Copernican theory could be deduced therefrom—the circling of the earth around the sun, its rotation around its axis, and the globular form of both the sun and the earth. A clear statement of the reasons why a spot which is on the apparent right of the sun's disc at night appears to be on the left the next morning, must involve, he says, a recognition of the cardinal truths of astronomical science. Mr. Weatherbe interested himself in discovering by actual observation how much slower, in the system of spiraloid curves, a spot appeared to travel from 10 a.m. to 2 p.m., compared with its motion in the four hours before or after, and shewed that this variation depended principally on the latitude of the observer, and to a smaller extent on the seasons. The discussion of apparent motions leads us to be thankful that Copernicus lived and rediscovered the Pythagorean analysis thereof, but Mr. Weatherbe's treatment of them proved of advantage to many of the Society's members, and will be so to any who may be enabled by this review to trace for themselves the spiral, with a loop in the centre, which represents the motion of a spot which would be seen if we could look at it continually through a transparent earth, or the oscillatory semi-spirals which we actually can see a spot follow—the result, in Prof. Chant's words, of the "combination of the earth's circular motion and the motion of the spot across the sun's face."

Sun observations are by no means the simple matters casual and spasmodic lookers at the sun may fancy. Whether taken photographically or by hand, a variety of reductions have to be made. In some cases the photographic method is preferable, in others hand-drawing, because the sun is often too much obscured by drifting clouds and mists to give a good photographic image, while his disc can be caught sight of several times almost every day, sufficiently to draw the spots with accuracy. This is usually done by projection. A frame is fitted to the eye-piece of the telescope, which carries a small plane table on which to place the paper for the drawing, at right angles to the axis of the tube. The image thrown on the paper must be kept uniform in size, for as the earth's distance from the sun varies, owing to the elliptcity of its orbit, so the size of the sun's disc varies, unless adjustments are made. The drawing is usually made in pencil, carefully outlining all the spots and faculæ visible. The micrometer must be so fixed to the eye piece that its declination thread indicates the true parallel, which must be noted. The position-angle for the day is then taken from the tables, the axis of the sun drawn in, and the time of observation noted. Next comes the calculation of the true latitude and longitude of each feature, that is, its heliographic co-ordinates, and allowances made therein for refraction in the solar atmosphere according to the situation of the spot, for the inclination of the ecliptic and the apparent curvature by projection of the sun's equator and all parallels thereto. The precession of the equinoxes has to be allowed for, also the fact that the synodical rotation angle is not the same when the earth is in perihelion as when it is at aphelion. Published tables aid the modern observer with many of these detatls, and he further has the opportunity of making a transparent graduated plate with a circle of the size of the projected disc, which by superposition over the drawing will be of much assistance in determining solar latitude and longitude with rapidity, by mere inspection. Solar latitude depends on fixed lines, but solar longitude is really conventional. A given meridian is taken to start from, that which at noon on a certain day is central on the disc, and the period taken for the rotation of the sun determines the time between each solar degree. The statement therefore that we are considering the five hundredth rotation of the sun means that it is the five hundredth noted at a given place, with its special assumptions. The rotation period adopted in England is not the same as that in use on the Continent of Europe, but, so long as the differences are known, observations can be compared.

THE MOON.

IS THE MOON A DEAD WORLD.

Owing to the illness and untimely death of Mr. Lumsden and the advancing infirmities of Mr. Elvins, two of our chief lunarians, the telescopic observation of our twin sister has somewhat languished. We have had shewn to us some beautiful photographs of the moon, by Dr. D. B. Marsh, who has been equipping his neat private observatory with the requisite apparatus, and we may hope that he will worthily take the place of one of those whose work is finished.

However, Mr. J. Edward Maybee has not suffered interest in the moon to lag, for he has brought to the Society's attention the subject of life upon the moon, dealing with it in an original way under three heads—Is there animal life on the moon, or vegetable life, or what he defines as physical life.

The requirements of animal life, said Mr. Maybee, are air, moisture, a suitable temperature, light and food. (1). As to air, man requires an average lung capacity of 20 cubic inches, to supply the necessary oxygen, but if he ascends about 16000 feet above sea-level he finds it very difficult to get enough air into his lungs to keep himself warm and carry on the vital processes. Now if, as Prof. S. C. Comstock, of the observatory of the University of Wisconsin, states, the moon's atmosphere is at most only the ten-thousandth part of ours in density, and if the composition of the lunar air isthe same as ours, a man would need a lung capacity of 200,000 cubic inches, while if it were all oxygen instead of one-fifth, he would still need 40,000 cubic inches, or 23 cubic feet. "Fancy," said Mr. Maybee, "a 6 foot man needing a chest from 2,000 to 10,000 times greater in capacity than he now owns, to pick up enough oxygen to keep the blood red in the remainder of his somewhat over-shadowed body. Even for cold-blooded animals such an atmosphere would not suffice. And the moon's atmosphere is most likely composed of carbon dioxide and water vapour." (2). As to moisture, that must be unattainable even

NEW MOON

PHOTOGRAPHED BY REV. DR. MARSH
WITH HIS 5 IN. BRASHEAR TELESCOPE, WITH SCREEN,
1904.

if by some change in structure an animal could exist in such an atmosphere. Protoplasm, the ultimate constituent of all living organisms, contains 80 to 85 *per cent.* of water and 15 to 20 *per cent.* of solids, the water being necessary for the metabolic processes of life. Now water, at ordinary atmospheric pressures of about 30″ or 760 mm. of mercury can exist in either solid, liquid or gaseous conditions, but if the pressure is reduced below 4·6 mm. the liquid condition is impossible, and, according to the temperature there will be either ice or vapour. Now the pressure of the moon's atmosphere being only ·076 mm. no water can exist there as liquid; one's blood must therefore be either ice or steam, a state of affairs which Mr. Maybee suggests is hardly conducive to health. (3). As to a suitable temperature, while Prof. Huxley placed the limits for animal existence at between + 60° and –60° centigrade, and while some algæ find a temperature within a few degrees of ordinary boiling point quite congenial, the superior limit does not much concern us, for, according to Profs. S. P. Langley and F. W. Very, the temperatnre on the moon does not rise above 0° C., and probably falls as low as –200° C. Dr. Macfadyen and Mr. Rowland shewed at the last meeting of the British Association that certain primitive organisms such as *Bacillus anthracis* can withstand a temperature of –252° C. for as much as ten hours, and some were kept in liquid air (–190° C.) for six months without impairing their vitality. They say "the ordinary manifestations of life cease at zero, but at –190° C. we have every reason to suppose that intracellular metabolism must also cease, as a result of the withdrawal of two of its cardinal conditions, . . . It is difficult to form a conception of living matter under this new condition, which is neither life nor death." Thus, argued Mr. Maybee, "while very low organisms may sustain a temperature comparable with the lower limit assigned to the moon by Prof. Langley, and for a period much longer than the length of night upon the moon, I think I am safe in saying that such temperatures would be fatal to highly organized life." To the objector who argues that we cannot say that life must everywhere exist under the conditions which obtain on earth Mr. Maybee replies that life here is always manifested as a function of protoplasm, a peculiar combination of carbon, nitrogen, oxygen and hydrogen, and as in all our experience we do not know any chemical element or combination which possesses identical powers with any other, it seems improbable that, as things are constituted, any other combination of elements is possible which can possess the property of life. That justifies, he thinks, the conclusion that "life, wherever existent, will be found dependent on protoplasm and therefore on heat, moisture and other conditions which obtain on earth, and highly organized animal life must be absent from the moon."

Passing to the next division of his subject, can vegetable life exist on the moon, the same reasons are adverse to the presence there of the higher forms. Trees rarely reach to our own Arctic circle: they mostly cease when the mean average temperature for January is –30° F. and for July 50° F. Plants do indeed grow very far to the north and south, but the number of species is wofully diminished, showing that the limit is nearly reached, and that where the mean temperature is about –37° F. for the winter months and +33° F. for the summer. Compare these with the lunar temperatures (–328° F. and +32° F.)!

While in low latitudes on earth phanerogams (seed bearing plants) rarely predominate over cryptogams, in the Arctic regions the latter take the lead in the preportion of 1687 to 762, shewing that the lowest forms of plant life stand cold the best. Among cryptogams lichens are included, and are the hardiest of all. According to Rev. J. M. Crombie, the proportion of lichens to phanerogams increases in a regular ratio from the equator to the pole, and from the base to the summit of mountains, while in Arctic and alt-alpine tracts they constitute almost or altogether the sole vegetation. If then plant life does exist in the moon it is probable it resembles lichens rather than any other terrestrial species. If a lichen were capable of absorbing water in the solid or gaseous form and of holding it in its cells under pressure, so that it might assume the liquid form, and, further, could stand a temperature of –200 C., then, of such lichens the vegetation of the moon might consist.

Many observers expect to see bright green patches on the moon, and, in effect, Prof. Klein, of Cologne, notes as remarkable the "intensely green color of the whole surface which is surrounded by the great rill near Herodotus." Of this region Gruithuisen wrote in 1824:—

NOTE.—2nd line in 2nd paragraph, read, largely, instead of rarely.

"In the East and North East of Aristarchus is a mingling of all kinds of colors, in small spots which give an indistinct impression of plantations. With us vineyards, meadows, summer and winter grainfields and woodlands, all mingled, would have this appearance, were one to view them from the moon."

But we shall never, Mr. Maybee thinks, find vegetation on the moon by seeking for such appearances as our terrestrial forests or fields present from a balloon. Now lichens are usually yellow, orange, red-brown, gray, gray-green, olive or black in tint, and never vividly green. Their growth is extremely slow. One specimen, observed by Mr. Crombie, had not attained its maturity in its 45 years. They are perennials, in the widest sense of the term, and many defy the ravages of time for many hundred years. Indeed " the life of lichens bears in itself no cause of death and is only to be ended by external injuries." Hence the assumption that such species as *Lecidea Geographica*, growing on the summits of lofty mountains, date from more than fabulous epochs and outrival in longevity the ages assigned to the oldest trees. Mr. Maybee thinks that vegetation on the moon must be akin to lichens, for it cannot grow to maturity and again fade in the short space of 14¾ days, because such progress is inconceivable when the the thermometer does not rise above freezing point. The variable spots found by Pickering and by him ascribed to vegetation were between 55° N. lat. and 60° S. lat. The phenomena are "a rapid darkening, followed by an equally rapid fading towards sunset . . . At their maximum some of these spots are intensely black, some are a dark gray, others a light gray." These changes, Mr. Maybee thought, could not be due to organic growth, but perhaps were due to real changes of the surface or to shifting shadows.

Mr. Maybee next passed to the evidence of what he called physical life on the moon's surface, meaning changes due to internal or external heat, volcanic or seismic action, the formation of snow, or the disintegration of lofty peaks. And here Mr. Maybee's words should be given in full :—

"On the moon, heat cannot produce the grand phenomena we are here accustomed to. No raging cataracts pour down its rocky heights; no mountain streams brawl to the plains beneath; no placid rivers roll through fertile plains to join the heaving sea; no furrowed waters lash the shores of its wide spread ocean; no clouds obscure the heavens or trail grateful shadows over the lunar plains; no blinding snow-storms can ever sweep the land or gentle rain revive the parched soil. On the moon all is barren rock or arid dust. Here a volcano may be puffing up ashes and vapors, but no winds will scatter them abroad. In the most active volcanic regions no hot springs will bubble up from Plutonian realms. Dry water vapor, or pieces of hot ice at most, would be the lunar equivalent for a Terrestrial geyser. Perhaps a seismograph might indicate tremors shaking the rocky frame of our satellite and every now and then toppling down some crag or opening up new cracks in her crust. Perhaps too a Pele sometimes explodes harmlessly over uninhabited wastes and remakes itself for the benefit of prying human eyes. What evidence have we of changes such as these? Linne is the classic example, of which W. H. Pickering speaks thus:—

> "Early in the last century Lohrman described Linne as being very deep, and as over four miles in diameter. Maedler observed it seven times and described it as very distinct under the oblique illumination of the sun, when the contrast of shadow was strongest and as measuring six miles in diameter. Schmidt drew it eight times, and represented it as being seven miles in diameter and one thousand feet deep. Schmidt, in 1843, was the last astronomer, apparently, to see it with any such dimensions, and in 1866 he announced that it had disappeared. A few months later, however, he found in its place a small craterlet about a quarter of a mile in diameter, which, in the course of a couple of years, gradually increased to a mile and a half. Although still visible, its diameter had shrunk to three quarters of a mile. It is only fair to say that although the change previous to 1896 is now generally admitted, Dr. Klein strongly queries any changes since that date."

Imagine, he adds, a crater six or seven miles in diameter and a thousand feet deep being wiped out of existence and replaced by a mere pimple! So too with rills and clefts. Sometimes a rill has been seen with ease, but on similar occasions under the same illumination it has seemed to have utterly vanished—as rolling mists might hide a river from the sight of an aeronaut. Sometimes a new cleft has been found in a much studied formation, when earlier observers had noted much more difficult details. The delicate cleft joining the Ariadæus and Hyginus rills, just north of Agrippa, is an example of an elusive feature, and a fine cleft on the floor of Mersenius was discovered by Elger in 1883 though more minute details had been described by earlier selenographers, without mentioning this. Dr. Klein had studied the region of Hyginus for 12 years, yet on May 27th, 1877, he first discovered a dark depression a few miles north west of it, which now is not a difficult object and its present existence is undoubted, whatever may be thought of its recent birth, which appears to depend on the evidence of but one observer. Mr. Maybee then passed to Prof. W. H. Pickering's contributions to the new selenography; the result of his observations at Arequipa, Peru, and in Jamaica. Here again, Mr. Maybee must be quoted verbatim as to the alleged discovery of snow and hoar-frost on the moon.

"If we agree that volcanic action on the moon has not yet ceased, it is evident that gaseous pressure of some kind must exist to produce it. On earth, water vapor or steam is responsible for the explosive energy and possibly is so on the moon. This steam rising into the moon's atmosphere becomes cooled and is deposited as hoar frost.

"Surrounding some craters, notably Abulfeda, Censorinus and Linne, are white patches or halos, which are largest at sunrise and gradually diminish towards sunset, only to reappear of their original size at the next sunrise. Again, some of the lunar peaks, e. g., the Appennines, exhibit a dazzling brightness as though crowned with eternal snows, while equally illuminated surfaces are darker. The lunar poles too exhibit an unusual whiteness, which also distinguishes a large area surrounding Tycho, while many lunar craterlets are lined with some substance which is dazzlingly bright under suitable illumination. Polar brightness may of course be due to snow caps, the white linings of craters may be caused by congealed vapors from their vents, while the mountain caps may have stolen something from the scanty moisture of the lunar atmosphere. But to me the evidence is not conclusive.

"It does not seem to be asserted that the polar whiteness waxes and wanes in size, as one would expect if it represented caps of snow or ice.

"The well known bright rays are attributed to snow by Prof. Pickering without any convincing proof. All these appearances might just as well be explained by other hypotheses, except the waxing and waning of the bright spots already referred to about Linne, Censorinus and Abulfeda. Perhaps there, if we could transport ourselves on etherial waves, we might behold dazzling fields of snow, unless closer scrutiny showed the illusion to have been caused by peculiarities of illumination of the rough uneven surface.

"Plato has also been carefully scrutinized by Pickering who finds that the relative prominence of the numerous little craters on its central plain is very variable, which he explains by supposing that vapors are emitted by these craterlets which occasionally obscure or even entirely hide some of them.

"Certain bright streaks also appear which Pickering believes to exhibit a change of form, but which Dr. Klein thinks are due only to a varying illumination. Again, near the north east side of Herodotus, similar changes were noted of visibility among some seven or eight small craters, and similar variable light streaks and spots.

Mr. Maybee, notwithstanding his belief that the causes of these changes are yet not certainly known, and his suggestion that as the changes seen by Prof. Pickering were only observed on rough floored craters, where under side illumination the surface might seem light, but under direct illumination dark, considers it reasonable to think that the moon is not physically dead, but is still able, faintly and spasmodically, to breathe out vapor of water or other gases. He thinks, however, that without favorably situated telescopes of high power, no increase of knowledge can be reached by instrumental means. Even Pickering admitted that formations less than 200 yards in diameter were beyond his ken, notwithstanding his fine objectives and his magnificent 'seeing,' therefore a whole Vesuvius might disappear and observers with small instruments know nothing of it. But at least one series of changes is within the range of a 4 inch glass—that which takes place in the twin craters Messier and Messier A., not at present intelligible unless caused by hoar frost in fogs.

In conclusion Mr. Maybee outlined the argument from the unity and continuity of life and being, as follows:—

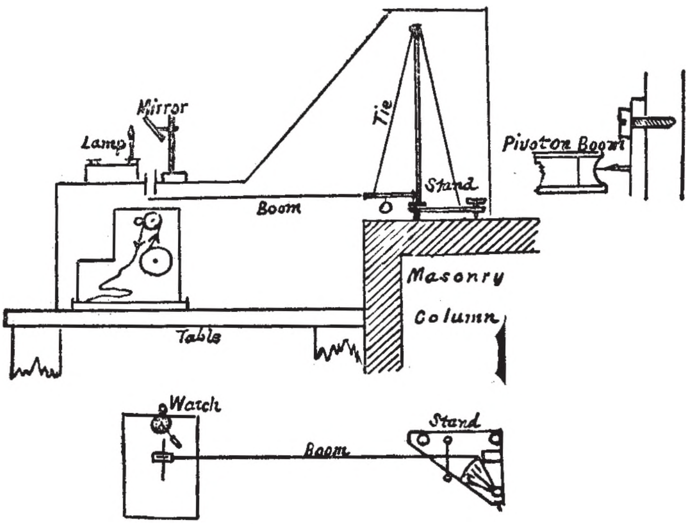
"We know that, having formulated a plan, the Creator never departs from it. Is there any necessity that vertebrate animals should all be built on variations of the one plan, except that the Creator has apparently aimed to work along the simplest lines possible, and with the greatest possible economy of fundamental ideas. ? We find too that a given effect is always the result of the same cause ; mind is always a function of brain matter ; a tree always takes its life from some other tree of the same species ; water is always formed by the union of hydrogen and oxygen and never otherwise.

"Are we not justified then in supposing the same changelessness, the same economy, will be exhibited in the rest of the Universe of which we are a part?

"Newton believed that the law of gravity on earth held good in the heavens. He proved it as far as the moon, as far as the planets, and with faith we believe it to the uttermost ends of the Universe. The laws of light in space are the laws of light on the earth ; the laws of God revealed here we believe to be universal."

THE EARTH AS A PLANET.

The cosmic phenomena to be noticed on the earth properly belong to the domain of astronomy, though it is not easy to define sharply where the astronomer should leave the field to the geographer, who marks on our planet such lines of seas and continents as we are attempting to chart upon Mars and Venus—or to the meteorologist who studies here the aerial currents and clouds which we observe upon Jupiter, Saturn and the Sun—or to the geologist who treats of world-building as if it were not our particular study. Our Society has always considered Geophysics as one of the subjects it should feel interested in, and has discussed with attention the seismological records which Mr. R. F. Stupart has from time to time exhibited.



THE GRAY-MILNE SEISMOGRAPH.

We have no active volcano in Canada and few warm springs. Our coasts shelve so gradually into the ocean deeps that no earthquakes now orginate here, so that the tremors we feel are but the vibration of convulsions centered elsewhere. The following is the complete list of the disturbances noticed at the Toronto and Victoria Observatories in 1903, and is furnished by the courtesy of the Director, Mr. R. F. Stupart.

EARTHQUAKE RECORD BY GRAY-MILNE SEISMOGRAPH, TORONTO.

P.T. = PRELIMINARY TREMORS ; L.W. = LARGE WAVES ; 1 MM. = 0″.37. † ABOUT ; ‡ OVER ; ‖ GRADUAL.

No.	Date 1903	P.T. Commence	L.W. Commence	Max. H.M.S.	End H.M.S.	Max. Amplitude	Remarks.
438	Jan. 4	5.30.7			† 6.52.0	0.3	Small and prolonged
439	" 14	1.54.4	2.1.3	2.11.2	4.28.6	‡ 18.0	Very large and important
440	" 17	16.16.4		16.24.2	† 17.37.0	2.0	Small and well defined
441	" 21	23.53.8		24.19.0	† 1 a.m 22nd ?	0.3	Small but well marked
442	" 23	19.39.4			19.42.5	0.1	Thickening
443	" 24	5.40.8	5.45.0	5.48.1	6.41.5	2.0	Medium and well marked
444	" 24	15.49.8			† 20.30 ?	0.3	Small, continuing for a long period ; suspicion of air currents.
445	Feb. 1	10.9.2	10.27.8	10.36.0	† 11.31.0	1.1	Medium. P.T's, long time before L.W.
446	" 2	No. Pt's.	10.6.0	10.8.5	† 10.34.0	1.1	Medium. No P.T's, sharp commencement. Tremors soon died away.
447	" 5	† 19.5.0		19.44.0	† 15.0.0 ?	0.4	Mixed up with air currents. Very small.
448	" 6	8.28.0			† 8.36.5	0.1	Marked thickenings.
449	" 10	3.22.0			† 3.25.0	0.05	Mere thickening.
450	" 12	22.26.2			22.29.5	0.1	Very small.
451	" 24			18.49.0 ?		0.05	Mere thickenings, too undefined to measure accurately.
452	" 27	1.28.0		2.28.2	† 3.10.5	0.7	Small and well defined. P.T's preceded L.W. by long interval.
453	" 28	9.54.6		10.5.2	10.23.5	0.2	Very small but well defined.
454	Mar. 1	16.18.4 ?		16.55.5	17.11.0 ?	0.1	Thickenings
455	" 15	14.25.6	14.32.5	14.34.9	15.50.0	3.0	Medium and well defined.
456	" 29	16.49.0			† 17.0.0	0.1	Very small but well marked

457	Apr. 3	† 9.51.0	9.56.9	9.57.1	† 10.33.0
458	" 12	3.17.0	3.22.8	3.24.1	† 4.30.0
459	" 12	17.31.9			† 17.40.0
460	" 21	9.47.7			9.57.7
461	" 29	0.25.8		0.33.0	0.36
462	" 29	4.40.0	5.16.0	5.24.0	6.18.5
463	May13	7.2.0 ?		7.37.0	8.26.5
464	" 15	12.22.0 ?			12.56.0 ?
465	June 2	13.26.3	13.36.4	13.44.8	‖ 15.30
466	" 7	10.12.2			† 10.24.2
467	" 10	attend'g inst.			† 18.34
468	" 11	13.33.0			† 13.35.0
469	" 16	0.30.2	0.31.2	0.32.2	0.36.5
	" 22	switching of boom 12 to 20 GmT.			
	July 21	Nothing			
470	" 27	0.39.0			0.44.0
471	" 27	10.46.0	10.49.0	10.52.8	11.34.0
472	" 27	12.42.0		12.45.8	12.52.0
473	" 28	4.1.2			4.5.8
474	" 31	14.10.4			†14.11.4
475	Aug. 3	7.7.2			7.17.0
476	" 9	17.2.5			17.8.0
477	" 11	4.53.5			5.25.0
478	" 13	16.44.2			16.48.0
479	" 16	13.50.0	13.54.0	13.55.0	14.24.0
480	Sept. 7	7.41.0		8.28.0	9.4.0
481	" 10	11.10.8			11.18.0
482	" 10	14.9.5			14.15.5
483	" 13	15.46.0			15.52.5

1.1	Small and decided.
1.1	Small and decided.
0.15	Very small
0.05	Mere thickenings.
0.3	Small and well defined.
1.0	Medium and marked. Long interval between
0.15	Prolonged thickening. [P.T's and L.W.
0.05	Mere prolonged thickening.
6.5	Large, well defined double max.
0.05	Thickening.
0.05	Minute thickenings.
0.05	Mere thickening.
0.3	Small.
0.05	Minute thickening.
1.1	Medium.
0.5	Small, lasting a short time.
0.1	Mere thickening.
0.05	Mere thickening.
0.1	Very small.
0.1	Small.
0.2	Very small and extended.
0.05	Mere thickening.
1.2	Medium,
0.3	Small and extended, long interval between
0.05	Small, lasting but a short time. [P.T's and L.W.
0.2	Marked thickening.
0.1	Minute tremors.

No.	Date 1903		P.T. Commence	L.W. Commence	Max. H.M.S.	End H.M.S.
484	Oct.	17	18.8.4			18.22.0
485	"	21	10.40.5			11.34.0
486	"	29	15.25.2 ?		16.0.0	16.28.0
487	"	30	4.41.0 ?		5.13.0	6.10.0
488	Nov.	10	18.13.0		18.34.0	18.49.0
489	"	10	22.1.0			22.16.0
490	"	26	12.14.0		12.44.0	13.5.0
491	"	29	18.55.0			18.58.2
492	Dec.	1	7.4.5		7.27.0	7.56.0
493	"	5	5.25.8	5.29.5	5.34.0	6.10.0
494	"	7	15.5.00		15.8.0	
495	"	23	1.27.0			† 2.39.0
					VICTORIA, B.	
442	Jan.	4	5.19.0	5.28.6	5.35.2	† 7.6.0
			Sudden Start			
443	"	14	1.55.6		2.18.5	4.32.0
444	"	17	16.11.5	16.32.0	16.34.3	† 18.1.0
445	"	21	23.47.1		24.3.1	24.46.1
446	"	23	19.54.0			20.5.0
447	"	24	5.33.4	5.37.6	5.41.5	6.45.0
448	"	24	15.45.7		16.17.6	† 17.0.0
	Feb.	1—Nothing.				
449	"	1	9.57.0	10.20.0	10.25.0	† 11.31.0
450	"	2	10.0.0			10.2.5 ?
451	"	2	10.10.0		10.11.0	10.48.0
452	"	5	19.8.3	19.12.5	19.04.2	† 20.18.0

Max. Amplitude	Remarks.
0.1	Very small, no P.T's.
0.1	Extended thickenings.
0.5	Very small and well marked.
0.5	Very small and well marked.
0.3	Small and well marked.
0.5	Minute thickenings.
0.2	Marked thickenings.
0.1	Marked thickening.
0.3	Very small but well marked.
1.5	Medium.
	Very small.
0.10	Very small but extended.

C., RECORDS. (*Vib. 15 seconds = 0''.76*).

1.1	Small, well defined and extended.
6.7	Large and continued.
5.5	Large. Sudden cessation of large vibrations [after max.
0.5	Medium and well marked.
0.1	Thickening.
6.1	Large.
0.5	Small and extended.
2.1	Medium marked switching of boom after P. T's.
0.1	Marked thickenings.
0.3	Small quake.
0.8	Small but well marked.

453	"	6	8.18.0		8.24.5	†8.42.0
454	"	10	3.16.0		3.18.4	3.26.8
455	"	12	22.10.0			22.20.0
456	"	24	18.20.0		18.30.0	†18.58.0
457	"	27	1.8.7		2.9.2	3.29.0
458	"	28	10.10.7 ?		10.18.8	10.32.0
459	Mar.	1	17.3.0			17.17.5
460	"	15	No P.T's	14.14.4	14.16.7	16.1.6
461	"	29	16.51.8			16.55.5
462	"	29	17.15.3			17.47.5
463	Apr.	1	8.19.0			8.25.5
464	"	3	9.40.6		9.46.8	†10.3.0
465	"	12	3.17.1	3.21.1	3.29.0	†4.7.0
466	"	12	17.38.9	17.41.1	17.43.0	17.51.0
467	"	21	9.27.8		9.41.9	†10.0.0
	"	28—Boom partly anchored.				
468	"	29	4.32.0	Boom partly stuck.		5.1.0
469	May	13	6.51.2		7.51.3	†8.25.0
470	"	15	12.7.2		12.9.3	†13.7.0
471	June	2	Sudden. 13.21.8	13.22.1	13.31.7	15.6.1
472	"	10	17.0.0			†18.11.0
473	"	11	13.18.1		13.20.6	13.27.0
474	"	16	0.25.3			0.33.2
475	"	25	22.56.3			23.00.3
476	July	12	5.42.8		6.34.0	7.5.0
477	"	21	17.16.1			17.18.1
478	"	27	0.24.0			0.31.0
479	"	27	11.6.5		11.21.0	11.44.5

0.4	Small, lasting a short time.
0.4	Very small.
0.2	Marked thickening.
0.1	Thickenings.
0.8	Small prolonged P.T's, long time ahead of L.W.
0.2	Very small.
0.1	Thickenings.
5.1	Medium.
0.1	Thickening.
0.2	Thickening.
0.2	Small but well marked.
1.0	Medium and well marked.
3.0	Moderate, gradually smaller after max.
0.5	Small and well defined.
0.2	Three distinct thickenings.
0.1	Mere thickening.
0.3	Small but extended.
0.3	Small, then minute vibrations continuing some time.
6.0	Large two marked max's. Disturbance began suddenly.
0.15	Extended thickenings.
0.2	Small and well defined.
0.2	Marked thickening.
0.05	Mere thickening.
0.5	Prolonged thickenings decidedly marked.
0.1	Minute thickening brief period.
0.1	Marked thickenings.
0.3	Very small.

No.	Date 1903	P.T. Commence	L.W. Commence	Max. H.M.S.	End H.M.S.	Max. Amplitude	Remarks.
480	July 28	4.08.0	4.11.0	4.12.0	4.21.0	0.4	Small.
481	" 31	14.32.0				0.05	Minute thickening.
482	Aug. 3	6.55.2		7.1.0	7.6.5	0.4	Small and well marked.
483	" 9	17.18.0			17.36.0	0.1	Thickening.
484	" 11	4.56.0			5.44.0	0.2	Very small and extended,
485	" 13	16.28.2				0.05	Brief thickening.
486	" 16	14.6.2	14.10.0	14.14.0	14.25.0	0.3	Small.
487	Sept. 7	7.36.2			8.50.0	0.2	Small but prolonged.
488	" 10	11.4.0		11.13.0	11.23.0	0.3	Small, lasting only a short time.
489	" 10	13.54.5		13.57.5	14.11.5	1.1	Moderate and well marked,
490	" 11	23.44.3				0.05	Mere thickening.
491	" 13	15.56.0			16.5.0	0.05	Thickenings.
	Oct. 17—Nothing.						
492	" 21	10.42.0			12.9.0	0.15	Marked and extended thickenings.
493	" 29	14.43.5		15.41.0	16.54.0	0.2	Very small, continuing for a long time.
494	" 30	4.21.5		5.8.0	6.1.0	0.2	Marked thickenings.
495	Nov. 6	15.4.2			15.16.0	0.15	Marked thickenings.
496	" 10	17.44.8		18.33.5	18.44.0 ?	0.05	Slight thickening.
497	" 26	12.27.5		12.31.8	12.45.5	0.3	Small.
498	" 29	18.54.0			19.0.0	0.2	Marked thickening.
499	Dec. 1	6.57.4		7.20.0	8.3.8	0.5	Small, prolonged, well marked.
500	" 7	15.8.0			16.6.0	0.3	Very small, gradual beginning, a quiet interval, then marked disturbance.
501	" 23	1.25.0		1.25.5	2.20.0	0.4	Small and well marked. No P. T's.
502	" 30	15.17.0	Grad'l Commencement		15.24.0	0.2	Small and well marked, lasting but a short time.

Earthquake which was recorded at Toronto on the 5th Dec. was missed at Victoria. Boom being off the paper,

CAUSE OF VOLCANIC ACTION.

Earthquakes are now attributed to the dislodgement from the submerged slopes of continents, where their grades are steep, of enormous masses of sediment, accumulated in the course of thousands of years—great submarine land slides, set in motion possibly by barometric disturbances. That the crust of the earth is adjusting itself to suit altering conditions is evident, parts rising (as e. g. the Swedish coast) parts sinking (as e. g. the coast of New Jersey). Mountains exist near lines of pressure due to folding and stratigraphic fracture. In the oscillations which occur in such regions, some of the rocks are driven nearer to the central heat of the interior, and the heating of their materials is now, by many enquirers, thought to be the cause of volcanic eruptions. This subject was brought into discussion through an article by M. Armand Gautier, in the *Comptes Rendus* (Nov. 1st, 1903) and one by M. Stanislas Meunier, of Paris, in La Nature (May, 1902). The latter said that the heating of hydrated rocks by deeper strata, pushed up above them, was an important feature in Telluric Physiology ; the former vave detailed analyses and remarkable measurements to show whence came the water vapour and deadly gases discharged from Mont Pele and other volcanoes, which, he said, had no connection with the infiltration of water from the ocean.

Mr. Moissan, by a careful analysis of the gases from the fumarolles of Mont Pele, found them to be composed of Carbonic acid 44·2 ; nitrogen 10·2 ; argon 2·0 ; carbonic oxide 4·6 ; methane 15·7 ; hydrogen 13·3. The other ten parts were vapour of water and air (calculated by the proportion of oxygen). Mr. Gautier, by heating specimens of primitive rocks, obtained from them a notable proportion of water and from 6 to 16 times their volume of gas, composed of :

	GRANITE	PORPHYRY	OPHITE
Carbonic Acid	14·80	59·25	35·71
Nitrogen (rich in Argon)	·83	2·10	0·68
Oxide of Carbon	4·93	4·20	4·85
Methane	2·24	2·53	1·99
Hydrogen	77·30	31·09	56·29

Porphyritic granite, dried at 250°, (centigrade) still contains 7 or 8 grammes of water per Kilo. which it loses when raised to 500° or 600°. That water, set free by the heating of subterranean rocks, acts on ferrous silicates, forming ferric silicates, produces and liberates hydrogen in abundance; it also sets free carbonic acid and carbonic oxide, even before reaching red heat.

Now a cubic kilometer of granite weighing 2664 kg. per cubic metre, subsiding to a hotter level, or by the intrusion of molten matter into cracks heated to 500° or 600°, would give 26,640,000 tons of water, and $6{\cdot}7 \times 10^9$ cubic metres of gas, at 15° temperature, which at red heat has three times that volume—almost all combustible gas. As the gas from granite contains 79 *per cent.* of hydrogen, the 5293 millions of cubic metres of hydrogen, burning in the air, would give 4,266,000 tons of water. The enormous pressures can be conceived, and the violence of volcanic eruptions understood when one considers such a result as the consequence merely of the moderate heating of one fifth of a cubic mile of granite rock

ANOMALIES OF GRAVITY.

When a mountain range is uplifted, along with its plateaux, it seems to be relieved of the strain theretofore put upon it, while the strata which underlie the deeps of the sea, still bear the pressure of the folding. This affects their gravity, and Prof. A. de Lapparent says that near coast lines where there are great variations in depth, the crust has been so much compressed, under the seas, as to more than compensate for the deficiency in mass due to the volume of water above it.

Prof. A. Venturi and A. Ricco have been examining the anomalies of gravity in Southern Italy and Sicily, and find that while all the anomalies are positive, the least is that at the observatory on Ætna, 2943 metres above sea-level; the greatest at Augusta, on the Coast, 14 miles S. E. of it, while it greatly increases a few miles out at sea, where the Mediterranean is as deep as the mountain is high. This, notwithstanding the density of the rocks is about 2·5 (water being 1.) The rocks under the water must be compressed to a considerable degree to make up for the difference. If, say these eminent contributors to the *memorie* of the Italian spectroscopists, the contraction of the cooling earth begins with the nucleus, the crust cannot accomodate itself thereto without dislocation, when up must come some parts, in the way astronomers can see some portions of the moon's surface to have been raised, and where the rocks are relieved from the lateral pressure, *i. e.*, in the raised portions, they are the lightest, coming to a mean near the coasts, while they are heaviest in the ocean troughs. The forces which cause earthquakes and volcanic eruptions are all endogenous. In the earliest geological epochs they produced on a grand scale the extrusion of granite formations, then basalts, afterwards lavas—all in decreasing proportions. The thickening of the crust by cooling and the deposition of sedimentary rocks closed the way more and more to their display, until now there are but 560 active volcanoes, which are decreasing and giving out, while it is very rarely a new one is formed. No force seems able to do more than shake the crust, it is seldom fissured to the surface, there are no more great outpourings of fluid matter, The earth is tending towards a condition of greater stability but less vitality; it will finish with a great general calm, not with a gigantic and universal cataclysm, as its people seem to prefer believing.

THE NEW CONTINENT.

The Antarctic expeditions sent out by England, Germany, Scotland, and Sweden have added much to our knowledge of the regions about the South Pole. We have from Dr. Otto Nordenskjold and Dr. Gunnar Audersson, of the Swedish expedition, some preliminary accounts which shew that Antarctica, as a continent, does really exist, and is probably larger than Europe. The barrier ice, which Ross thought the edge of an ice pack, is recognized as a glacier or rather an ice field, like that of Greenland, and Arctowski actually sends us a proposal to explore it by means of specially constructed automobiles! There have been discovered well-preserved fossils of cycads, conifers and ferns, a mesozoic flora and some remains of vertebrates, so that at a not very remote period the climate was mild enough for these lands to be covered with vegetation and inhabited by animals.

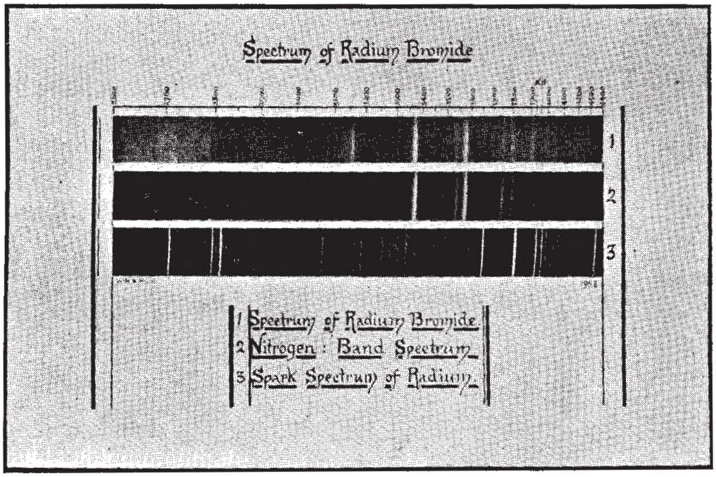
RADIUM

AND ITS BEARING ON ASTRONOMICAL PHYSICS.

Mr. J. R. Collins, the Secretary of the Society, commenced his paper on Radium by stating that the spectroscope proved the elements met with upon the earth to be existent throughout space, so that terrestrial chemistry and physics, applied to the problems of the skies, became the astrophysics of the astronomer. The atomic theory had been first outlined by Democritus, who thought the universe was a fortuitious concourse of bodies of very small dimensions, in rapid motion in all directions, which formed combinations among themselves and broke up again to form something else. He and all other Greek speculative philosophers gloried in having no direct evidence in support of their views, which were founded on a metaphysical basis. Not until recent times had a theory been formed which was founded on an observed order in nature, and Dalton had been the leader of modern thought on this subject.

By his atomic theory all material substances were held to consist of a number of unchangeable elements, which combined in definite proportions; all elements having uniform atoms, but different for each, so that if hydrogen, for instance, was lighter than oxygen, it was because its atoms were lighter. Each atom was thought to have different selective properties which governed its various combinations into compounds, and the smallest possible particle of any of such combination was called a molecule. This had for a hundred years remained the working hypothesis of chemistry, which had enabled chemists to wrest from Nature many of her secrets and turn to practical account a great variety of the properties of matter. Atoms were at first assumed to be spherical, but formulæ had lately been employed which abandoned all idea of fixity of shape and made it possible to consider them as centres of force (Boscovitch) or vortex rings (Kelvin).

The kinetic theory of matter supposed molecules in gases to be in rapid motion in right lines among themselves, and their collisions and rebounds to cause agitation in the surrounding



COPY OF SPECTRUM PLATE
SENT BY SIR WILLIAM AND LADY HUGGINS.

RECENT PHOTOGRAPH OF THE GREAT NEBULA IN ANDROMEDA,
BY G. W. RITCHEY OF THE YERKES OBSERVATORY.
COPIED BY J. W. PARKIN, OF TORONTO, ON ORDINARY BROMIDE PAPER,
USING RADIUM AS A SOURCE OF LIGHT.
R. A. 240: EXPOSURE 12 HORURS.
RADIUM SUPPLIED BY J. R. COLLINS.

ether—the vibratory motions radiating outwards in waves of light, heat and other forms of energy. In liquids the molecules were thought to be closer together and to move with less velocity; attractive forces coming into play and bending the course of the particles as the path of a comet is swerved when it comes within the influence of the gravity of the sun or a planet. In solids the paths of the particles, no longer free, were thought to be very short, so that the molecules merely rotated around each other, with enormous speed, as do planets about the sun, or double stars around each other. These various motions differed as to the molecules of each substance, but in any of the three states the particles on a free surface would tend to move away from it, and to be recalled by gravity, unless their velocity was such as to carry them beyond its influence.

The mean velocity of the molecules of many gases had been determined. That of hydrogen was placed at 5.571 feet *per* second; helium, 2,600 feet; nitrogen, 1,488 feet; oxygen 1,397 feet and carbon dioxide 1.189 feet *per* second. The critical velocity that would carry a body away from the earth would be 36.000 feet, or a little over 6 miles *per* second. The moon would not have gravitative pull enough to retain any of the gases composing the earth's atmosphere, and Dr. Johnstone Stoney doubted whether even Mars could retain any except carbon dioxide. The critical velocity of vibration must apply to the internal structure of the molecule, and it had lately been believed that the same law applied even to the atom. Lenard, Hittorf, J. J. Thomson, Hertz, Rontgen, Lodge, Crookes, Becquerel and others had shewn that certain substances give off emanations when stimulated by an electrical discharge and some even without an artificial stimulus at all.

Many physicists and chemists had long suspected that the "ultimate atom," which was regarded as a hard, indestructible particle, was in itself but a bundle of still smaller particles cemented by some cohesive force, and that indeed all such atoms might be formed from the same protyle or common stock of very minute particles, which, grouped in different numbers, formed the chemical elements. Prout suggested that hydrogen might be the substratum, but some elements were shewn to have an atomic weight inconsistent with any given proportion of hydrogen, so

Mendelejeff, amongst others, contended that the protyle must come from particles much smaller than the hydrogen atom, and worked out what is called a periodic scale, in which all the elements fell into regular steps like those of a ladder, and, where any rungs were wanting, he predicted that the gaps would be filled by the discovery of new elements. This had actually happened, and radium fitted into one of the vacant spaces. In developing his subject * Mr. Collins acknowledged the receipt of publications from Sir William and Lady Huggins "On the Spectrum of the Spontaneous Luminous Radiation of Radium at Ordinary Temperatures": from Sir William Crookes "On the Radio-activity of Uranium," "The Stratifications of Hydrogen," "Radio-activity and the Electron Theory" and "Modern Views on Matter, the Realization of a Dream": from Sir Oliver Lodge his Romanes lecture "Modern Views on Matter."† Also some interesting correspondence had been received from Mr. Stephen T. Lockwood of Buffalo. The Society desires to add the thanks of all its members to those Mr. Collins expressed to them. Mr. Soddy, a co-laborer with Prof. Rutherford, had also been good enough to write, and Prof. J. C. McLennan, and Mr. Burton, of the University of Toronto, had favored him with their paper on the radio-activity of metals generally.

As long ago as 1879 (Mr. Collins continued) Prof. Crookes had shewn that when an electric discharge was forced through a tube containing a rarefied gas, streams resembling particles in a fog were driven from the cathode or negative pole with great velocity, and as he had reasons for concluding that the molecules and atoms of the gas were broken up into particles neither gaseous, liquid nor solid, he termed them "the fourth state of matter." That the change must be significant could be understood when it was considered that the length of the free path of the molecules of, *e. g.*, nitrogen gas was 39 ten millionths of an inch, the

* Specimens were exhibited of pitch-blende and of carnotite, also of radium-barium-chloride, r. a. 240, of radium-barium-oxide, r. a. 10, and several radiographs made by Mr. Collins by the use of radium tubes.

† Also an article from W. J. Hammer, of New York, on "Radium and Other Radioactive Substances," and letters from Eimer & Amend, New York, distributing agents for Curie's Paris labarotory; also some papers of Sir W. Ramsay and Hon, R. A. Strutt.

number of collisions a molecule undergoes is 4.760 millions in a second, with the velocity of 1.488 feet per second, and the average distance between them is from the one twelfth to one sixteenth of a hundred millionth of an inch. These were the reasonably certain deductions of the physicists. Taking nitrogen at ordinary pressure and temperature, and expanding the cubic inch of nitrogen to a cube sixteen miles square, the "particles" would be from an eighth to a quarter of an inch apart. It might be added that it would take 1400 million million million particles (14×10^{11}) to weigh a grain, the four hundred and eightieth part of an ounce.

Leonard and Hertz detected such particles after being driven through sheets of aluminium and other metals, inserted as windows in the "Crookes tubes." Rontgen found that the shocks caused by the impact of the particles against the tubes and among themselves caused the apparent *ether disturbance* known as X-rays. Prof. Henri Becquerel, who had also been active in the investigation of such phenomena noted that the emanations from uranium behaved like those in the cathode streams, penetrating objects opaque to light so as to affect a photographic plate, discharging an electroscope, and being deflected by a magnet. Then M. and Madame Curie came on the scene. They were working, with small resources, in Paris, on uranium residues known as pitch-blende, when they noticed a trace of a material which, they inferred, must give off these Becquerel rays more intensely than uranium, and in pursuing the investigation they discovered radium.

Prof. Rutherford of McGill University, Montreal, and Mr. Fredrick Soddy, have been the closest Canadian investigators into the nature of this still mysterious substance, and the following are some of their conclusions :—

Radium emits three kinds of rays, which they call α, β and γ. The α-rays are easily absorbed by solids and carry a positive electric charge. The mass of the particles is enormous, they are but slightly deflected by a magnet, and that in an opposite direction to negative electrons. Rutherford shews that they are ions, with a thousand times the energy of β-rays, and moving with a velocity of the order of light. The β-rays are classed as free electrons or atoms of electricity projected into space apart from gross matter, identical with Crookes' "matter in the fourth state," with Kelvin's "satellites," Thomson's "corpuscles," and Lodge's "disembodied ionic charges" retaining individuality. Sir William Crookes thinks them neither ether waves nor a form of energy but substances possessing inertia. Liberated electrons are exceedingly penetrating, they will discharge an electroscope at ten feet distance, affect a photographic plate through 6 mm. of lead, or several inches of wood or aluminium. They are not readily filtered out by cotton wool, do not behave like a gas, but more like a mist carried about by air currents, to which they impart temporary conducting powers. They cling to positively electrified bodies and, if left quiet, to the walls of the containing vessel. They are shot off from radium with a velocity about a tenth of that of light, but gradually slow down on account of collisions with air atoms; they can turn corners, be concentrated by mica cones into bundles, and produce phosphorescence. The γ-rays are intensely penetrating too, but they carry no electron charge. They are identical with x-rays, and are produced by the sudden arrests by collisions of the α and β rays, which give a quiver to the ether and cause Stokesian pulses or explosive waves which are shot off into space.*

Sir Oliver Lodge (continued Mr. Collins) illustrated the comparative size of the atom and the electron by likening the former to a church and the latter to about 700 grains of sand dashing about inside, or, as Lord Kelvin says, rotating about with inconceivable velocity. The chief defect in the electrical theory of matter to which all these researches lead is, in Sir Oliver's words:—

"The positive electron, if it exists, has never yet been isolated from the rest of an atom of matter. It has never been found detached from a mass less than the hydrogen atom; whereas the negative electron is constantly and freely encountered flying about alone, its mass being little more than the thousandth part of an atom of hydrogen. Until a positive electron can be similarly isolated, the hypothesis that an atom is really composed solely of electricity, that is to say of equal quantities of positive and negative electricity associated together in a certain grouping of little bodies, each of which is nothing more than a concentrated charge of electricity of known amount, must remain a hypothesis. . . . The process of radio-activity may be likened

* Besides the α β and γ rays a gas or emanation had been noticed by Rutherford and Soddy and had been successfully liquified by the latter and Sir W. Ramsey.

in some respects to the condensation or contraction of a nebula. The particles constituting a whirling nebula fall together until the centrifugal force of the peripheral portions exceeds the gravitative pull of the central mass, and then they are shrunk off and left behind,, afterwards agglomerating into a planet; while the residue goes on shrinking and evolving fresh bodies and generating heat. A nebula is not hot, but it has an immense store of potential energy, some of which it can turn into heat, and so form a hot central nucleus or sun. A radium atom is not hot, but it too has a great store of potential energy, immense in proportion to its mass, for it is controlled by electrical, not by gravitational forces; and just as the falling together of the solar materials generates heat, so that the shrinkage of a few yards per century can account for all its tremendous emission, so it has been calculated that the collapsing of the electrical constituents of a radium atom, by so little as one per cent. of their distance apart, can supply the whole of the energy of the observed radiation—large though that is—for something like 30,000 years."

Radium, said Mr. Collins, was a metal of the calcium, strontium and barium group; atomic weight, according to Rutherford, 225, and it has a characteristic spectrum, (reproduced from Sir Wm. Huggins' photograph.) One of the most extraordinary properties of radium was its power of pouring forth torrents of emanations, which Sir William Ramsay and Mr. Soddy had been able to collect, and, after keeping them for some time, they shewed, instead of the spectrum of radium that of helium, and all the characteristic properties of that substance.* Mr. Soddy's letter to Mr. Collins (Oct. 31st) contained the following explanatory paragraph :—

"We consider the emanation a new element, withal a very unstable one, lasting but a few weeks,, and continuously generated in the break-up of the radium—belonging to the argon family and being probably the heaviest member. When it breaks up, it gives helium and it is possible the α rays are particles of this latter gas, projected at the moment of disintegration. The β rays are electrons, 2000 times lighter than helium and are perhaps the splinters."

This led to a consideration of the views of Sir Wm. Crookes' "dream realized." Sir Humphrey Davy, in 1809, had said "if particles of gases were made to move in free space with an almost

* Huggins has lately concluded that the "glow" spectrum of radium is essentially that of nitrogen, hence that the luminosity is due to the violent inter-atomic or inter-molecular agitation of nitrogen in the air in contact with it, which receives the fierce bombardment from the disintegrating radium. (Proc. Roy, Soc., Vol. LXXII, p. 409.)

infinitely great velocity—*i. e.*, to become radiant matter—they might produce the different species of rays.'' Again, in the same year and in 1811, he spoke of the possibility of resolving the chemical elements into simpler forms. In 1816 Faraday said ''To decompose the metals, to reform them, and to realize the once absurd notions of transmutation, are the problems now given to the chemist for solution.'' And so the matter remained seething in men's minds, Sir William Crookes declaring that ''the atoms of the chemical elements were not eternal in existence but shared with the rest of Creation the attributes of decay and death.'' Clerke Maxwell, Helmholtz, Zeeman, Dewar, in addition to those others above mentioned, contributing something to the general stock of ideas. Now, the formation of helium from radium emanations leads to the belief that the theories of the old alchemists may be translated into facts. Radio-activity is not confined to radium, and perhaps not to uranium salts alone. Prof. McLennan finds radio-activity in the earth, in rain, in snow, in ordinary air, in the water of deep wells, it is in freshly pumped petroleum, while it seems that at the surface of all metals ''an excess of positively charged corpuscles is being continually emitted.'' Deslandres has detected it in the sun.

Mr. Collins briefly referred to the effect of radio-active substances on photographic plates and on organic and living tissues. He exhibited specimens of radiography, and submitted a letter from Dr. Jas. MacKenzie Davidson, of the Charing Cross Hospital, London, Oct. 15th, 1903, as follows :—

"I have not yet tried the 'emanations' of radium in the cure of any disease.

"I have applied glass tubes with 5 milligrammes of radium bromide directly to rodent cancers and epithelioma for half an hour at a time—sometimes longer, sometimes shorter, according to reaction. The stronger the radium salt the better the glass cuts off the α rays, so we only get the β and γ rays. The results are most encouraging and far exceed the rapidity and convenience of application than the X-rays or the ultra-violet rays (Finsen treatment). I hope soon to publish full notes of my cases."

Mr. Collins explained that the action of uranium was taken as the standard for radio-active (r. a.) effects, so that if we had a sample of radium marked r. a. 10, it meant that it had an effect ten times more active than uranium to discharge an electroscope and produce other measurable effects. Pure radium had not yet been produced, it was estimated that its r. a. would be a million, or more. The highest potency thus far separated was r. a. 500.000. A specimen of r. a. 100.000 would in an hour produce on the skin, if brought near it, a severe burn, not easy to heal. A high r. a. would destroy in a short time the germinating power of seeds: insects and small animals suffer death or partial paralysis, and the bodies struck by the rays often become radio-active themselves. Prof. Curie states that he cannot approach his instruments for hours after he has been in the vicinity of radium because of the r. a. of his clothes. A r. a. of less than 10.000 is of little value in therapeutics.

The principal source of pitch-blende is in Bohemia, but the Austrian Government having forbidden the export of the residues from its treatment the price of it has become excessive. It was always expensive, because 5000 tons of residues had to be worked over at a cost of $20.000 a ton to produce 2 lbs of radium. It becomes important then to find other sources of the metal, and Mr. Collins had an interesting letter from Mr. Stephen T. Lockwood, of 202 Main St., Buffalo, which we print in full:—

Sec'y Royal Astronomical Society of Canada,
Toronto, Canada.

Dear Sir:—

Your favor of the 6th inst. is at hand, in which you make inquiry as to the present conditions for the manufacture of high power radium-barium preparations and ask us to give some information which may be embodied in a paper you are about to read before the Society.

The writer is connected with the above concern, which is the company which is about to engage in the business of the reduction of uranium ores by a process in which the radium contents will be saved as a by-product, and subsequently purified. These ores are obtained from the mines of this company located on the north-western slope of the La Sal Mountains in south-eastern Utah and on the Grand River. These ores are mineralized with the well known American uranium mineral called carnotite, (a sample of which, pulverized, I send to you herewith), and carry on the average from three to five per cent. uranium oxide contents, although the sample sent to you is very much richer and contains about 25 per cent. uranium oxide. These ores also contain from 50.000 to 500,000 gram units of activity, due to radium present, per metric ton: that is to say 2½% ore will have ½ a decigram of radium compound of 1,000,000 units activity present per metric ton weight and a 25% ore will have ½ a gram (500 mgs.) of this compound present for a like weight of ore.

The presence of radium was first demonstrated by the action of the portion of the ore insoluble in sulphuric acid on a photographic plate. . . .

Next a 25 lb. sample of ore which was sent to Professors Phillips and Magie of Princeton University, and Prof. Phillips obtained from the same over a gram of radium-barium compound, having an activity of about 1000 units. The lower activity fraction of a further fractionation of this sample, which consisted of 417 mgs., was sent by us to Columbia University where it was found to test 365 units. The higher fraction is still in the hands of the Professors at Princeton, and, of course, tests much higher in activity.

We have not thus far, attempted to purify any of the radium-barium by-products obtained from the reduction of our ores, and no high power products will be offered for sale for perhaps a year yet. We are now getting out our first carload of ore, which will be forwarded to this city and reduced for its uranium and radium contents. This carload, consisting of 15 tons, is estimated to contain 750,000 gram units of activity due to radium, 750 mgs. of compound having an activity of 1,000,000 units, It will not, however, be purified to more than 100,000 units activity. The product is all pledged to our friends.

The current prices for pure radium-bromide crystals vary exceedingly. One London house offers 5 mg. tubes for 55/ or $13.38 each, while another concern in Philadelphia quotes 10 milligrams for $85,00. In the absence of proper testing apparatus it would be difficult to determine which proposal offers the most for the money.

Yours very truly,
Stephen T. Lockwood,
Manager the Welsh-Lofftus Uranium and Rare Metals Co.

Mr. Collins concluded by referring to the enormous energy which a small quantity of radium could exert. Electrons were, after all, believed to be ponderable, and Max Abraham had calculated (Drudes' Annalen, vol. VII, p. 8) that a number of them, sufficient to weigh a gram, had associated with them 40 million million foot pounds of energy. A hot gas, radiating five watts per gram, would then have electronic energy associated with each atom sufficient to last for a hundred million million million of oscillations before exhaustion occurred. The breaking up of an atom might be due, it had been suggested, to something akin to an explosion, fragments being most violently expelled, or it might be produced by the velocity of atomic rotations pushed beyond the critical point. Whatever its cause, it was constantly in progress. As Sir William Crookes said :—

"This fatal quality of atomic dissociation appears to be universal, and operates whenever we brush a piece of glass with silk, it works in the sunshine and rain-drops, and in the lightnings and flame; it prevails in the waterfall and the stormy sea."

Are all the elements going to pieces? Mr. Collins said the evidence seemed to indicate it, though the span of atomic life was thought to be immense, compared with any estimates of time with which we are familiar, since, according to Rutherford, the life of a small bundle of free radium atoms would be about 1000 years, whilst this measure of time would be but a multiple of the staying power of the more stable elements.* And, again, as Prof. Crookes wrote :—

"Although the whole range of human experience is all too short to afford a parallax whereby the date of the extinction of matter can be calculated; Protyle, the 'formless mist,' once again may reign supreme, and the hour hand of eternity will have completed one revolution."

† Hæc quoque non perstant, quæ nos elementa vocamus.—Ovid, Metam. xv, 237. [Note by the Ed.]

SPECTRUM
OF LIGHT REFLECTED FROM SALTS OF URANIUM.

Mr. A. F. Miller mentioned that while examining a number of salts in the medical laboratory at Stimson Hall, Cornell University, he remarked a singular fact as regards the spectrum of light reflected from the surface of a crystallized salt of uranium, (uranium acetate). This salt, like other uranous salts, is of a vivid yellow-green color, and when sunlight or light from the sky is reflected from the surface of the crystals the spectroscope shows that it consists almost entirely of a series of bright bands which are sharpest toward their more refrangible edges. The brightest band (α) is situated in the green, more refrangible than E, ; the second brightest (β) near "little b," a third (γ) in the blue green, a fourth (δ) in the yellow. These bands he denotes by the Greek letters in order of their visual brightness as is customary in such studies, and he has approximately determined their wave-lengths in $\mu\mu$, which provisional positions, however, he wishes to revise before putting them on record. He is of opinion that besides the four bright bands above mentioned there are at least two others in the blue region, where certainly some strong absorption bands exist. In this regard, as well as the more exact determinations of the positions of the particularly bright bands, he is continuing the investigation. He has examined in a similar manner a considerable number of colored crystals and strongly colored substances, but finds the behavior of the uranium salts quite unique as regards spectroscopic peculiarity. He does not obtain the bright-band spectrum by reflected artificial light unless the source of the light is very brilliant. On the other hand, very feeble daylight from a dull cloudy sky readily shows the characteristic phenomenon of the spectrum. He offers as yet no theory in explanation of the phenomena observed.

THE CONSTITUTION OF MATTER.

Mr. Andrew Elvins, again advocating the views as to the nature of matter and the constitution of the universe which he has held for many years, referred to his paper on "moving matter," in the Transactions of the Society for 1890. He believed that a definite number of moving atoms existed in the universe, and that the sum of their motions was a constant quantity. Force was the result of matter in motion, and was the product of the number of atoms in any given mass and the rate of their motions. Every atom occupied space; no two could occupy the same space simultaneously; they were solid and impenetrable. They were in perpetual motion, and their collisions and rebounds caused what is known as heat, which must therefore have a mechanical equivalent, and *vice versa*. Lengthening the free path of the atoms must increase the size of a mass composed of them, without affecting its weight.

Until lately, Mr. Elvins said he had been constrained to base such views on assumptions. He had long held that the true atom or ultimate particle was far smaller than the chemical atom, or chemic. But, now that the hydrogen atom is shewn to consist of about 700 particles, he thought assumptions were replaced by acknowledged facts. These particles, he said, should really be called atoms.

Ever since Sir William Crookes introduced his vacuum tubes, Mr. Elvins had thought the name "radiant matter" properly applied. He believed there was a real breaking up of the terminals of the metallic wires.

Moving atoms filled all unoccupied space, passing through the interstices of masses, and this rendered the Hertzian, Rontgen and Becquerel rays possible and intelligible.

The particles formed chemical atoms in space, and these should be regarded as of celestial rather than of terrestrial origin, but, large or small, they must be subject to gravitation. Then "chemics" must move in orbits as do planets and comets, and, when colliding and their projectile force destroyed, they would fall on the body in whose sphere of influence they happened to be. If near the earth, they must increase its mass, while the impact or the arrest of motion would raise its temperature. Thus the earth's heat was conserved and that of the sun maintained. The law of Avogadro was a necessary result of such a constitution of matter, and this theory would explain the aggregation and dispersion of worlds, as well as the cause of gravity.

SEEING A STORM THROUGH A TELESCOPE.

The 28th of February last was a delightful day in Hamilton, cold but sunny, and the writer was visiting Dr. Marsh's observatory there. Dr. Marsh projected the sun's image, but the "seeing" was imperfect. The spot blinked at us, with a regular pulsation—now it was distinct, now almost invisible, nothing but a blur. The writer said "That is a heavy storm, coming from Texas. It will be here soon—one or two days at most, now." The storm did indeed come—a sudden thaw on the 29th and one of the worst snow-blizzards ever known, that evening and Monday, the 1st of March.

The phenomenon is not infrequent but it is only since the installation of the aero-hydro-barometer, at the Toronto Observatory, by Mr. G. Napier Denison, that its cause has been certainly known. When South Western storms develop, they send out great and regular air-waves, which travel over the surface wind-layer, at a height of ten or more miles. They are chronographed by that instrument, and some calculations can be made of their size. It is their interference with the steadiness of atmospheric refraction which causes the irregular "seeing." They begin to disturb things here while they are 500 miles away. They correspond with the *seiches* on lakes and bays.

VARIABILITY OF THE LIGHT OF STARS.

A paper on the light curves of various stars was brought before the Society in 1902 by Mr. W. B. Musson, who had promised himself to make a careful examination and classification of all the curves so far determined, ready for this publication. The astronomical amateur may however long most ardently for time and opportunity, while the imperative calls of the affairs he has in charge enforce delay. That this has occurred in the case of Mr. Musson, the editor extremely regrets, but hopes that the pressure of business will not be so severe during 1904 as to prevent his carrying out his plans for bringing to a focus the observations on this important subject.

Mr. Musson's remarks on the variability of Algol, standing as they do, apart from the general subject of light-curves are appended as follows.

VARIABILITY OF ALGOL.

"It was suspected some years ago that a change was taking place in the light curve of Algol, and in 1888 Prof. Chandler undertook a discussion based upon a comparison of some 700 of the star's observed minima, which he published in the Astronomical Journal of that year. His conclusion was, that the irregularity comprised two inequalities. The first having a period of about 140 years, and the second of something over 37 years.

"The question of the irregularity was discussed somewhat fully in a paper which I had the honor of reading to the Society in 1897, and from which I take the following sentences:—

"When making observations to determine alterations in terrestrial latitude, Prof. Chandler, among other stars made use of Algol. During the course of these investigations the suspicion was aroused that this star was subject to a change in position not to be accounted for by any variation in latitude on the Earth, and a closer examination convinced him that, not only was this suspicion correct, but that Algol's change of place among the stars was closely related to its period of variation in brightness. He was further led to the conclusion that Algol and its companion revolved about a third body in an orbit nearly equal to that of Uranus.

"According to Chandler,s explanation a maximum of acceleration should take place when Algol reaches the point of its orbit nearest the Earth, which is expected to be about the year 1900; after this the intervals between the eclipses should begin to lengthen until 1934. It will therefore be seen that observations made at the present time, and for the next few years, will be of especial interest.

"Since writing the foregoing I had been unable to ascertain whether or not this prediction had been fulfilled until the appearance of the Astronomical Journal of Oct. 15, 1901, which contained an article from the pen of Prof. Chandler on "The Period of Algol." In this paper Prof. Chandler summarizes an exhaustive series of recent observations in the following words :—

"It will be seen that the actual course of observation has satisfactorily verified the prediction that the protracted interval of general decrease which began about 1830 and had continued up to the time of the publication of that paper (the one before referred to—1888) would soon be followed by a long interval of increase. The beginning of this increase indeed set in immediately after rather than earlier than the elements indicated.

"It is manifest that the length of the principal inequality, which was there assumed as 18.000 periods is considerably less than that. The new value now adopted, 15.000 periods, or 116 years, cannot be very far from the truth."

"It will thus be seen when we come to study carefully Algol variables, that we are in reality dealing with true binary systems."

Many of the variable stars are known to be doubles, and when the plane of their orbit with respect to the sun and earth is such that one of the companions interferes at times with our view of the other, there must be a change in the light received. The spectroscope has helped us in such cases to determine the velocities of the components; also to discover spectroscopic binaries—that is, stars so close that our telescopes do not enable us to separate them visually.

Others are thought to be of the nature of our sun, which is a slightly variable star, with a simple period of a little over eleven years, the increased area of spots appearing to cause a diminution of light, from internal action. It may also have a longer period, embracing several of the shorter ones, though the Lockyer period does not yet commend itself to all students.

Some of the smaller bodies of the solar system are known to be variable too ; Jupiter's moons and some of the asteroids. We shall not speculate on the supposed causes—irregularity in shape or different reflecting materials on different parts of their surfaces.

We have pleasure however in publishing what is believed to be a new observation respecting an important star in Orion, from one of our own members, G. Miller Barr, of St. Catharines.

The great nebula in Orion is with reasonable certainty thought to be in a state of change ; this writer has made a number of drawings of it, and brought to the Society's attention a few years ago a supposed change which had taken place in fifty years, near the Trapezium. It seems to be established that while there may have been few if any real changes in its form, the brightness of its several parts has varied. Whether the nebula is connected with the constellation as a whole is not yet ascertained ; it may be that some even of the large Orion stars are only visual neighbors, and that parts of the extensive nebula may be independent of these stars. Still, others are in what we may call the same part of the universe, and subject to similar and peculiar laws. It is therefore not surprising to learn of slow changes there and we are sure Mr. Barr's paper will be read with much interest.

THE VARIABLE STAR BELLATRIX (γ ORIONIS).

"The writer has lately been collecting evidence which tends to show that the well-known star Bellatrix has increased in brightness by about one-third of a magnitude during the last quarter-century. This evidence rests largely on a comparison of the earlier and later Harvard results for the photometric magnitude of Bellatrix. The indicated change is strongly confirmed by the careful estimates of Herschel, Argelander, and Gould, and by my own recent observations (by Argelander's method) of γ, ε and ζ Orionis.

"The Harvard photometric observations point clearly to an increase in the light of this important star. It is rated as 1·86 mag. in the *Harvard Photometry* (1879-82), 1·64 mag. in the *H.C.O. Annals*, vol. XXIV., and 1·59 mag. in the *H. P. Revision* (1891-94).* The earlier result is based on sixteen obser-

* In the Harvard Photometric Durchmusterung (1901) the magnitude of Bellatrix is given as 1.62 ; but this is simply the mean of the results given in vols. XXIV and XLIV of the Annals, as cited above.

vations, the least and greatest values of the magnitude being 1·73 and 2·13.* The probable error of the more recent determination, as derived from the 11 residuals given in the *H. P. Revision*, is ±0·04 mag. It will be seen that the difference (0·27 mag.) between the earlier and the later results is nearly seven times as great as the probable error of the later determination, while the latter is smaller than the least of the sixteen separate values obtained in 1879-82.

In the *H. P. Revision* ζ Orionis is rated as 1·89 mag.—just 0·3 mag. fainter than γ. A somewhat larger difference is indicated by my own recent observations, which make γ about 6 grades (⅓ to 0·4 mag.) brighter than ζ. There is apparently no reason to suspect variation in the light of ζ, the estimates of Gould, P. Herschel and Argelander, and the Harvard photometric measures of this star agreeing as closely as could be expected.

On the other hand, γ was only 0·03 mag. brighter than ζ in 1879-82, according to the Harvard observations. Moreover, Sir John Herschel's carefully-observed "sequences" (1836-38) make ζ brighter than γ by just 0·3 mag., according to Doberck.†

"The only other estimates of magnitude available to the writer, for purposes of comparison, are those of Gould (*Uranometria Argentina*) and Argelander (*Uran. Nova* and *Durchmusterung*):‡

	U.N.	B.D.	U.A.
γ Orionis	2	2.0	1.7
ζ "	2	2.0	1.8

These data, taken in conjunction with Sir John Herschel's and the early Harvard observations, render it practically certain that γ was in former years nearly equal in brightness (or mean brightness) to ζ Orionis. It is important to add that in the *Uranometria*

* These data are taken from a paper in the MONTHLY NOTICES R.A.O., vol. XLV, p. 411. I have been unable to procure a copy of the original Harvard Photometry, which is now out of print.

† ASTROPHYSICAL JOURNAL, April 1900, pp. 196, 203, and May 1900, p. 274. Herschel recorded 11 observations of γ and 12 each of ε and ζ Orionis.

‡ I hope, later on, to consult the URAN. NOVA OXONIENSIS, the Potsdam PHOTOMETRIC DURCHMUSTERUNG, and other important catalogues.

Argentina (1879) the query "var. ?" is appended to the estimated magnitude of γ Orionis*; but this suspicion of change seems to have been overlooked in recent years. The later observations, as cited above, afford convincing evidence that Bellatrix has sensibly increased in brightness since 1882. It appears probable that the star's light is subject to more or less gradual changes of an irregular nature. This view is confirmed by Herschel's observations (as reduced in detail by Doberck), which point to a considerable increase, and subsequent decrease, in the star's light within the year 1836. My own observations—made during the past four months—point in the same direction, as I have thought the star brighter on some occasions than on others. On Feb. 22, 1904—the date of my latest recorded observation—γ appeared conspicuously brighter than ζ Orionis, and was rated as 2½ grades above ϵ—the brightest of the "belt" stars.

"It is hoped that members of the Royal Astronomical Society of Canada may give some attention to this interesting star, as the multiplication of observations is here very desirable.

"An examination of the Harvard photographs of the Orion region would probably yield further light on the subject. The only photograph available to me is a glass negative reproduced from a plate taken at Harvard College Observatory on Jan. 4, 1902. On this plate—which is No. 25 in the Harvard Photographic Map of the Heavens—γ Orionis appears distinctly larger than ϵ or ζ.

"From an astrophysical standpoint, Bellatrix is one of the most important stars in the sky. It is a member of the great helium group in Orion; and is probably several, if not many, thousand times brighter than our sun, intrinsically. An increase of one-third of a magnitude (about 36 *per cent.*) in the light of such an orb must, from any point of view, appear highly suggestive. The star should be observed, photometrically, at frequent intervals, and its spectrum should also be photographed from time to time, with a view to the detection of possible changes, synchronous with its light-variations."

* Cited in DRAPER CATALOGUE p. 291.

WOMEN'S WORK IN ASTRONOMY.

BY MISS ELSIE A. DENT.

I fancy I hear someone say that a very few moments will suffice to dispose of the subject of what women have contributed to the science of Astronomy. It must be confessed that we have no Newton, no Herschel, no Laplace; and yet, while no really great original discovery in astronomical science can be attributed to a woman's genius, I feel very strongly that I have no cause to be ashamed of my subject, for in the face of serious opposition until very lately, women have contributed materially to the general sum of astronomical knowledge. One of the obstacles with which women have had to contend in the pursuit of a scientific life is their lack of preparation and equipment for such work, owing to the omission from the general education of girls of studies in any way cultivating scientific tastes. Another, of course, is the prejudice which has always existed in the popular mind towards "learned ladies," as they have been termed. Blue-stockings have never been considered quite becoming or quite "feminine." While women have, no doubt, to a certain extent justly earned some of this prejudice, it must be remembered that it was the fight for what they believed to be their "Rights", that has developed in many a good woman an unfeminine aggressiveness that is most effectual in arousing antagonism in her masculine opponents. On the other hand, I think it will be found that, notwithstanding the complaints we hear occasionally about the opposition of masculine rivals, in the cases where a woman has achieved real distinction in any scientific pursuit, her scientific brethren have been the first to pay her, and most generously, true honour and appreciative recognition. Both Caroline Herschel and Mrs. Somerville have borne witness to the absence of anything approaching professional jealousy in their contemporaries. These women met with encouragement only from men. And this is as it should be; it is an old saying that there is no royal road to learning, and the successful student, man or woman, must travel that stony path, but owing to lack of educational advantages, women have in the past been but ill shod for the journey.

It is idle to open the question now why girls have not been educated in scientific directions, but it will be acknowledged, I think, that for centuries the tendency has been towards the cultivation of their emotional rather than their reasoning faculties. This alone would account for the small proportion of women who have had scientific gifts, But there is another reason of much greater weight than those of popular prejudice and lack of education, and that is the eternal feminine in herself. I mean a woman's natural love of and pride in her domestic concerns. her husband, her children and her home, and her instinctive defence of them from any intruding outside interest which might conflict with their comfort and happiness. Science and learning are not enough for a woman, nor even honors, if she earns them, and when a woman with scientific talents and ambitions finds that her domestic happiness is imperilled by those talents and ambitions, it is very seldom that she will persist in them ; only when circumstances allow of the pursuit of learning and entire domestic happiness going hand in hand and in perfect harmony can a womanly woman follow such a career. Mary Somerville could have done very little scientific work, in spite of her great scientific gifts, if her first husband had lived. With such limitations, then, the wonder is not that women have done so little in science generally and in Astronomy in particular, but that they have done so much.

Apart from any original astronomical service which has been rendered by women, however, their indirect influence has been enormous, merely by the force of encouragement and sympathy with those dear to them. From Hevelius to Sir William Huggins it is an often repeated tale, "His wife was his companion and shared his scientific work." The inspiration that comes from the touch of the talisman Sympathy is immeasurable ; few can do original work without it. Many a man's faith in himself and his powers has been shaken, almost shattered, by adversity, but, from discouragement and sickness of heart, he has been able to face the world again with courage, and in the strength born of that courage achieve wonders, simply because some one—sometimes a sister, oftener his wife—had unwavering confidence in his genius and his ideals. When to sympathy is added mental ability to share in his labours, the result is the happiest possible for all concerned. The principle enunciated in Tennyson's Princess that the interests of men and women are neither diverse nor antagonistic, and that they rise and fall together, met with much good-natured ridicule and criticism when it was first published. It was held "impracticable," "a poet's dream," and so forth. Fifty years have passed since the "poet's dream" was given to the world, not a very long space of time, but already popular opinion seems to be inclining towards the idea that Tennyson's is so far the most rational solution of the perplexing "woman problem" that has been attempted. At any rate, it is indisputable that the man and wife who can work together can do more and better work than if they were working separately.

There was published some years ago by a French writer, Rebiere, a work on the women who have contributed to the scientific knowledge of the world.* This work mentions in all some six hundred women, of whom one hundred or more have been identified particularly with the science of astronomy. Many of these, most of them, in fact, are quite unknown now, and perhaps their labour was of no great value, but such a compilation indicates that from the earliest times and under the most adverse conditions there have been women who were attracted to the study of the heavens. I intend to refer very briefly to only a few who have given something to astronomy that it had not before.

The record begins far back in ancient history, where there are about a dozen women whose names have lived because they were more or less associated with astronomical learning. The most celebrated of these was Hypatia, now best known as the heroine of Kingsley's novel. Another was the German St. Hildegarde, who was born before the close of the century which brought the Normans to England, and is regarded as the patron saint of physicians. Her astronomical work was a book which, if tradition is to be believed, contained some remarkable statements : (1) that the sun is in the midst of the firmament, retaining by his force the stars which move around him ; (2) that when it is cold in the northern hemisphere it is warm in

* "Les Femmes dans la Science."

the southern ; (3) that the stars not only shine with unequal brilliancy, but are themselves really unequal in magnitude, and (4) that as blood moves in the veins and makes them pulsate, so do the stars move and send forth pulsations of light. This is almost too good to be true. Copernicus, Galileo and Harvey were not born for many centuries afterwards.

Hevelius, the celebrated astronomer who lived and worked at Dantzig, in the 17th century. had endless trouble with his assistants. Three of them were so unfeeling as to die within a few years ; the various household servants were impressed into the service, but things went very badly indeed in the observatory until Madame took pity on her distracted and discouraged lord, and she is said to have been a most competent assistant. Little is known of her personally, for her individuality seems to have merged itself in that of her husband, but we are told on the very good authority of her husband, that she was beautiful, good and clever. The catalogues constructed by the pair contain the places of nearly 2,000 stars, all of which had been observed without the aid of the then newly invented telescope.*

Marie Marguerite Kirsch was the wife of the astronomer Kirsch at Berlin, and became his companion in his work. After her husband's death she continued her studies, and in 1712 she wrote a book in anticipation of a conjunction of Jupiter and Saturn. Her work was important, not on account of the conjunction, which of course amounted to nothing, but because, at a time when astronomical knowledge was clogged with astrological impedimenta, her work was purely scientific. Her son, Christfried Kirsch, helped his mother in her work, and in time became Director of Berlin Observatory. Her daughters, when their mother was gone, carried on her work, and made the calculations for the Ephemeris and Almanack published by the Academy of Sciences in Berlin.

In the 18th century, when Lalande was Director of the Paris

* Suor Maria Celeste, Galileo's eldest daughter, should not be forgotten in this connection. Her sole joy was in doing her father service ; she copied his letters, attended to his affairs in his absence, attended to his nourishment herself, and even consoled herself for his penance by reciting in his stead his weekly tole of Psalms. When she died, under the stress of her father's most sorrowful year, it seemed to him impossible he should long survive her. [Ed.]

Observatory, there were three women of whose scientific attainments he spoke very highly, but of whom I shall only mention one, Madame Lapante. With the astronomer Clairaut she worked for eighteen months for the purpose of predicting for the first time in history the return of a perturbed comet. Their prediction was verified by the return of the comet at the time when it was expected. This was regarded as a wonderful computation. Such predictions are common enough now, but it is the first time and the first test that is the difficult one.

Maria Agnesi was a woman remarkable not only for her scientific attainments but for piety and benevolence. She was born in Italy in 1818, and her precocity in science and languages early earned for her the title of "the oracle in seven tongues." I must confess that in her childhood and early girlhood she seems to have belonged to that very disagreeable class the "Infant Prodigy Order." She had an adoring and indulgent father, however, which may be some excuse for her. At nineteen, against many learned men who attended her celebrated and fashionable *salon*, she had maintained the marvellous record of nearly 200 theses on philosophical subjects. During her father's illness she filled his place as a Professor at the University of Bologna. Her manner in lecturing was very attractive, modest and refined, and she was possessed of considerable beauty. After her father's death Pope Benedict nominated her for the chair of mathematics, but she refused the professorship, for, with the inspiration of her father's encouragement withdrawn, she had no heart in the work, so she took the veil and entered a religious sisterhood. The rest of her life was devoted to good works, first educating her little brothers, and then working among the sick and needy in Milan, the city of her birth, where there is a statue in her honour. Her principal scientific work was an exposition of Newtonian doctrines which has been very highly regarded, and which has been translated into French and English. It appeared in England in 1804, and for curiosity's sake I looked to see whether the lash of the Edinburgh Reviewer had fallen upon it. Instead, a very favorable review closes by saying : "We cannot leave a work that does so much honour to female genius without earnestly recommending the perusal of it to those who believe that the great talents are bestowed by nature exclusively upon men. . . Let those who hold these opinions endeavor to follow the author of 'Analytical Institutions' through the long series of demonstrations which she has contrived with so much skill and explained with such elegance and perspicuity; if they are able to do so they will probably retract their former opinions and acknowledge that, in one instance at least, intellectual powers of the highest order have been lodged in the breast of a woman."

Caroline Herschel was a German girl with a German girl's education ; that is, she could read and write and she was a good housekeeper. Her brother William, the elder Herschel, took her to England to manage his house, and gradually trained her to become his assistant in his astronomical work. The poor girl seems to have had literally no natural talent for scientific labors, but she had what probably answered as well or better, an adoring self-forgetting love for her brother, great perseverance and conscientiousness, and so, although her task was sometimes cruelly hard, she accomplished it with a cheerful devotion and joy in serving her brilliant brother that is marvellous to read of. Though her work, in calculating stars and nebulæ, was enormous, no computational error has ever been attributed to her. Besides the compilation of immense catalogues of these objects she discovered no less than eight comets. The last twenty-five years of her life were dreary and lonely, for her brother was gone, and she lived among comparative strangers, uncongenial, unsympathetic ; but she could comfort herself by making for her nephew, Sir John Herschel, the great catalogue of 2,500 nebulæ, for which the Royal Astronomical Society conferred its medal upon her, an honour never before or since conferred upon a woman.

Women are proud of Caroline Herschel as an astronomer, but her most valuable work was not her fine catalogues and her discoveries of many comets. Expert mathematicians could have made the catalogues, and astronomers might have found the comets. But she was more than an astronomer. It took a great and noble soul to give the patient and accurate service which she laid at the feet of her illustrious brother, service upon which he was able to rely absolutely, and which left him free to devote himself to advanced work, which her affectionate sympathy and understanding must have made as sweet to him as it has proved valuable to the world. She shared his labours and she should share his immortal fame.

One of the most brilliant and original women who have rendered astronomical service was the Marquise du Chatelet. The philosopher Voltaire visited England in 1726 and returned full of enthusiasm for English science, and with ambition to make Newton's theories dethrone Descartes at the Academy. Mme. du Chatelet, who had a genius for mathematics, and who had written a book on "The Institutions of Physics," and other works, was the one chosen by him for the translation of the "Principia," a work which she performed admirably, accompanying it with algebraic elucidations. It is no small feather in our caps that it was a woman who gave Newton to the French and a woman who gave Laplace to the English. This reference it will at once be seen is to Mary Somerville, who was distinguished alike for scientific knowledge and feminine virtues. People who went to see her, expecting to see a female prodigy, were disappointed, for they saw only a sweet and motherly little woman, the capable mistress of a household. She concealed her learning with the graceful and artistic accomplishments in which she excelled. The record of her private life is commonplace, a tale which might be written about a million other women; there were babies to nurse, children to clothe and educate, preserves to be made, and social duties to perform; and with all this she was in the front rank of the scientific writers of the world.

She was born in 1780, being the child of a distinguished naval officer, afterwards Admiral Sir William Fairfax. The family was too poor to afford a governess, and it was thought to be more "respectable" that she should run wild, learning nothing, than that she, a gentleman's daughter, should be sent to associate with the children who attended the school in a little Fifeshire village. Her mother taught her to read, and only desired that her daughter should write a good hand and be able to keep accounts. When her father came home from one of his voyages, however, he was dissatisfied that his little girl should be growing up so, and his brilliant inspiration for reaching a higher standard of education was to have the poor little soul read a "Spectator" essay aloud every day after breakfast. As may be guessed, the result of this course was rebellion, and that Mary was not a lover of the classic Addison when the time came for her to choose her own literature. Her father after a time became aware that his plan had not the enlightening effect that he intended, and she was sent to a girls' school for one year. Here she learned writing, the rudiments of English and French grammar, and actually, page by page, much of Johnson's Dictionary ! Her real book-learning began at home when she found a copy of Shakespeare, and this opened a new and wonderful world to her. She lived then in the garden of romance, and read and re-read the delightful and enthralling plays, to the utter dismay of her family, who considered that her tastes were most unladylike, and that she would be better employed in sewing on her sampler. As an antidote she was sent to the village school to learn plain sewing, in which she all her life excelled, and the village dominie taught her the use of the globes. Little by little, as occasion offered, she picked up odds and ends of knowledge. She tells how a girl friend showed her an illustrated fashion magazine. "At the end of the page," she says, "there was what appeared to be simply an arithmetical question, but on turning the page I was surprised to see strange looking lines mixed with letters, chiefly x's and y's." Her curiosity was at once aroused. Her friend knew no more than that it was called algebra. "I thought I would look if any of our books could tell me what was meant by algebra. In Robertson's Navigation I flattered myself that I had got precisely what I wanted, but soon found I was mistaken. I perceived, however, that astronomy did not consist in star-gazing, and as I persevered in studying the book I certainly got a dim view of several subjects which were useful to me afterwards. Unfortunately not any of our relations and acquaintances knew anything of science ; nor had they done so would I have had courage to ask any of them a question, for I should have been laughed at."

Another educational spurt was made when her mother sent her to a pastry-cook's to learn to cook, and, as she grew up, lessons followed, in music, dancing, drawing and painting, of all of which she was very fond. She made all her own dresses too, and must have been an exceedingly winsome girl, for she was called "the Rose of Jedburgh."

This, for a start in life for an ordinary girl was very well, but for a young woman with a great scientific career before her such a miscellaneous stock of accomplishments does not seem an elaborate or very promising preparatory training.

Mary was twice married ; the first time to Samuel Greig, who was the Russian Consul in London. "After my marriage," she says, "I was alone the whole of the day, so I continued my mathematical and other pursuits, but under great disadvantages ; for, although my husband did not prevent me from studying, I met with no sympathy whatever from him, as he had a very low opinion of the capacity of my sex, and had neither knowledge of nor interest in science of any kind." Mr. Greig dying after three years of married life, she returned to her father's house, a widow with two little sons. Having now more leisure, she resumed her studies in earnest. Trigonometry, conic sections and astronomy formed her fancy work, and from them she went on to Newton's "Principia," Having worked on these for some time she asked the advice of Professor Wallace of Edinburgh University as to the books she should read to take a thorough course in mathematical and astronomical science, and at so low an ebb was mathematical science in Great Britain, in the list of fifteen books which he gave her, there was not one English author's name.

Then came her marriage with Dr. William Somerville, a physician in the navy, which brought her into companionship, perhaps I should say comradeship, with one who entirely sympathized with and understood her. She took up the systematic study of botany, while nursing her little baby, and then followed studies of mineralogy, geology and other subjects, in which her husband was her fellow student.

Her first real contribution to science was in the form of a paper to the Royal Society on Experiments on the Magnetic Properties of the Violet Rays in the Solar Spectrum, which was published in the Philosophical Transactions of 1826. The result of this was that Lord Brougham asked her to popularize Laplace's "Mecanique Celeste" and Newton's "Principia." She was, as she says, surprised beyond expression, but at her husband's entreaty, she consented to attempt the work upon the "Mecanique Celeste." Upon its completion, in 1830, it was sent to Sir John Herschel, who reviewed it in the "Quarterly," in the highest terms. Although her "Celestial Mechanics" is founded on Laplace's work, it was not a mere translation ; she without hesitation expressed her own views of the value of his propositions, and accepted or rejected them as she saw fit. The publication of the book made her a famous woman. She was at once elected an Honorary Member of the Royal Astronomical Society and Honorary Membership in the Royal Academy of Dublin soon followed. The Fellows of the Royal Astronomical Society subscribed to have the bust made by Chantry, which now adorns their library. Whewell, afterwards Master of Trinity, looked upon the book as "one of the most remarkable works which our age has produced," and his gallantry broke out "When Mrs. Somerville shows herself in the field in which we mathematicians have been labouring all our lives and puts us to shame, she ought not to be surprised if we move off to other ground and betake ourselves to poetry," and to the poetic muse he actually did betake himself, and the poetry was not so bad either for a mathematician; moreover it expressed every generous and chivalrous impulse towards her both as a woman and as a scientific colleague.

"Celestial Mechanics" was followed in 1834 by "The Connection of the Physical Sciences," which has passed through many English editions, besides several pirated ones in America, and has been translated into other languages. Long after its publication, when the Somervilles were at a Christmas dinner party at Collingwood, Sir John Herschel's home, where Mr. Adams and M. Leverrier, of the orbit of Neptune fame, were also guests, Mr. Adams told Dr. Somerville that a sentence in "The Connection of the Physical Sciences" first suggested to him the idea of calculating the orbit of Neptune. The sentence is: "If after the lapse of years the tables formed from a combination of numerous observations should be still inadequate to represent the motions of Uranus, the discrepancies may reveal the existence, nay, even the mass and orbit of a body placed forever beyond the sphere of vision." This prediction was fulfilled in 1846 by the discovery of Neptune; its mass, size and position in space, and its periodic time having been determined before the planet itself had been seen.

The "Physical Geography" is probably Mrs. Somerville's best known work, but others followed, viz.:—"Treatises on the Tides of the Ocean and the Atmosphere," "On Curves and Surfaces of the Higher Orders," "The Form and Rotation of the Earth," and "Analytical Attraction of the Spheroids."

Though her mind was essentially mathematical she was broad in her literary tastes. Scott, Brougham, Melbourne, the Herschels, Whewell and the geologist Lyell were members of her intellectual circle, and Humboldt, Arago and Laplace were among her correspondents. The Society for the Prevention of Cruelty to Animals found a warm friend in her; she was interested in music and art, and generally in the ordinary every-day things of life.

After the death of her husband in 1860, followed by that of her favorite son, she felt the need of systematic employment, and in her ninetieth year, with the energy and courage of youth, started on her work "Molecular and Microscopic Science," prefacing it with the motto from St. Augustine, "*Deus magnus in magnis, maximus in minimis;*" ("God, great in great things, greatest in the least"). She says very frankly of this book: "In writing this I made a great mistake and I repent it. Mathematics are the natural bent of my mind. If I had devoted myself exclusively to that study I might possibly have written something useful." She was her own severest critic.

She never grew actually old. To the end of her life she kept up with the new theories in all branches of science. In her early days geologists had shocked the orthodox world by proving that the formation of the earth had extended through enormous periods of time; but to her the theories of modern science were welcome. Hers was a deeply religious nature, and her prayer was for light and truth and knowledge, knowledge in the sense in which Tennyson uses the term—

> "Let knowledge grow from more to more,
> But more of reverence in us dwell."

The spirit which moved Newton to kneel in prayer when he reached the close of his exposition of the theory of gravitation, was the spirit in which her work was approached. Times have now so changed that it seems a shocking thing that Mary Somerville was preached against by name in York Cathedral, after the publication of the "Physical Geography." As a matter of fact it has been since said that she did more to christianize the sciences than any other scientific writer. She could face life and death and the revealings of the fiercest search-lights of science with firm and unclouded faith that nothing could be discovered regarding the great universe and the laws by which it was governed that would not redound to the glory of its Creator.

Not long before her death the old sailor's daughter wrote:—

"The Blue Peter has long been flying at my foremast, and now that I am in my ninety-second year I must soon expect the signal for sailing. It is a solemn voyage but it does not disturb my tranquillity. Deeply sensible of my utter unworthiness and profoundly grateful for the innumerable blessings I have received, I trust in the infinite mercy of my Creator. I have every reason to be thankful that my intellect is still unimpaired, and although my strength is weakness, my daughters support my tottering steps and by incessant care and help make the infirmities of old age so light to me that I am perfectly happy."

With such a tide, as moving seemed asleep, the brave old ship put out to sea, so quietly, so tranquilly, that those about her hardly knew when it had again turned home. All that is mortal of this altogether lovely woman lies in the English Campo Santo at Naples, where she died.

And now, as quickly as I can, I shall mention a few of the more modern scientific women.

Agnes Mary Clerk is a Corresponding Fellow of this Society, and one of whom the Society has every reason to be proud. She was born in Ireland in 1842, and taught herself elementary mathematics. I took the liberty of asking her whether her education had been such as to fit her for scientific work. She says :—

"The truth is bare and bold enough in sound, that in the scientific sense, I had no education, but just picked up what came my way. I had a childish passion for natural knowledge and read the books accessible to me in my father's library, taught myself with the minimum of assistance some elementary mathematics, and that was all. I was also very delicate growing up and never went to school . . . but I had admirable instruction from private professors in languages and music. I had from time to time tried writing stories and poetry, with indifferent success; but in Italy I undertook more serious work and contributed on various topics to the Edinburgh Review, from 1877. An article on "The Chemistry of the Stars" made a turning-point. The studies for it revived my astronomical tendencies; Messrs. Black accepted my proposal to write for them a history of recent astronomy, and so I went on."

Her "Popular History of Astronomy during the Nineteenth Century," published in 1885, won for her the attention of scientific workers all over the world, and has been translated into

German. In 1888 she spent some months working in the Observatory at the Cape, observing the southern heavens, the result of which was the publication of "The System of the Stars." Other works of hers are: "Familiar Studies in Homer," 1892; "The Herschels and Modern Astronomy," 1895. Her latest work "Problems in Astrophysics," published last year, has received very high praise. Two sections of "Astronomy" in the "Concise Knowledge Series" are also hers, and she has contributed about one hundred lives of men of science to the Dictionary of National Biography. In the Encyclopedia Britannica the articles on Galileo, Kepler, Laplace, and many others are hers. Her literary style is attractive, filling the demand for works which are both popular and scientific, expressed in terse and musical English.

The name of Lady Huggins is honoured wherever that of her famous husband is known. Sir William has devoted himself to the development of spectroscopic astronomy; spectroscopic photography originated with him, and as a matter of fact the modern science of astrophysics is practically his. The work of Lady Huggins in collaboration with that of her husband is acknowledged by their coupled names on the title pages of all their later publications.

The greatest living woman astronomer is Dorothea Klumpke. Dr. Klumpke is a member of the staff of Paris Observatory, being chief of the Bureau for the measurement of the photographic star-charts. Her chief accomplishment is the completion of an exhaustive work on the rings of Saturn, which was begun by Madame Kovalesky, the brilliant but unfortunate Polish girl who became the first woman professor of modern times in a European university. She met an early death, leaving undone the work which Dr. Klumpke has carried to a conclusion. When the International Astronomical Congress undertook to catalogue all the stars as far as the fourteenth magnitude, a new department for the accomplishment of the French share of the work was created at Paris Observatory, and Dr. Klumpke was placed at its head with four assistants, all women. In most observatories, the photographs taken by astronomers with the great telescopes are given to photographers to develop. At Paris Observatory the astronomers, who take the photographs, develop, tone and treat every print; often keeping as perfect only one out of a hundred, and it is upon this class of work that Dr. Klumpke and her staff are engaged. The Directors also gave her charge of a telescope with which she has made observations which won her an appointment as an officer of the French Academy. Dr. Klumpke is the only woman member of the Astronomical Society of France, and the only woman upon whom the degree of Doctor of Philosophy has been conferred by the University of Paris. She is a San Francisco lady, one of a remarkable family of four clever girls, who seem to be endowed with both genius and ambition, which do not always bear one another company, and who have made themselves famous in the work which they have individually taken up. The story goes that Dorothea's ambition was first aroused by living in apartments overlooking the old observatory at Paris. The gloomy buildings seemed to fascinate her, and she became possessed of the idea that she would make herself an astronomer. Her application to the Observatory was a surprise to the authorities. There was no precedent for the admission of a woman. However, while the institution had hitherto been sacred to men, the Salic law had not penetrated there in statute form, and they were impressed with her ability. So they examined her, but made her prove her fitness for the work beyond a doubt, by making the examination as difficult as possible. Her answers were brilliant, she passed with honours, and in 1887 entered the Observatory. Dr. Klumpke is a thoroughly up-to-date astronomer, and is said to be personally idolized by the staff at the Observatory. One of her remarkable achievements is the ascent in a balloon to view the Leonid shooting stars from above the clouds.

At the Paris Observatory there is another woman who in a quiet way exercises some influence on matters astronomical, for Madame Flammarion is said to act as her husband's secretary and to be the author of popular astronomical articles.

Among Englishwomen, Miss Elisa Brown was Director of the Solar Observation Section of the British Association, and her memory is still alive among those in Toronto who met her here and corresponded with her afterwards. In 1887 the Association sent her to Russia to observe the total solar eclipse of that year.

Mrs. Maunder was, for several years before her marriage to the well known astronomer, on the staff of computers at Greenwich Observatory, and also editor of the Journal of the British Astronomical Association.

As for American women who are interested in astronomy, and who have contributed something towards the science, especially the popularizing of the study, their name is legion. It would be impossible to even mention all their names, but those of Rose O'Halloran, Anne Sewell Young and Mary Whitney appear constantly in the scientific journals. One of the first and probably the most widely known among American women astronomers was Maria Mitchell, who first won distinction as the discoverer of a comet, though her most valuable work was probably as a teacher. From her earliest childhood her father directed her attention to the heavens, this being one of the few instances I have found of the twig having been bent as the tree was afterwards inclined. She for nineteen years computed the tables of Venus for the Nautical Almanac, and became Professor of Astronomy and Director of the Observatory at Vassar.

Professor Asaph Hall says that the discovery of the satellites of Mars is as much due to Mrs. Hall as to himself, her persevering energy having urged him on and encouraged him when he was on the point of abandoning the search. The lot of a professional astronomer is proverbially not a particularly happy one so far as the accumulation of this world's goods is concerned. When Professor Hall took his young wife to Cambridge he was earning the not very luxurious salary of $3 a week, but they struggled together against poverty and discouragement, and would rather be poor than give up scientific work. Through the dark days, and afterwards when prosperity came, his cheerful helper in his scientific work was his wife. Who would say that astronomical science owes nothing to her?

Mary Proctor, the daughter of Richard Proctor, has done good work in popularizing astronomy. Though an Englishwoman, she now lives in New York and contributes principally to American journals.

Mrs. Fleming, who is in charge of the department at Harvard Observatory for the examination of photographic plates taken with the Draper telescope, is of Scottish birth. She has discovered about one hundred variable stars and is at the head of a large staff of women employed on astrophotographic work.

The work of professional women is being so quietly prosecuted that only one who watches the scientific magazines and Observatory Reports can realize how many women there are who are engaged in astronomical duties. I have two interesting letters, one from Professor Hale, of the Yerkes Observatory, who says there are three women employed there on astronomical work, and that "in all cases the work of the women employed at the Yerkes Observatory has been entirely satisfactory." Dr. Brashear says that there is at Alleghany Observatory a very clever girl, Miss Alice E. Davis, who will, when the observatory equipment is complete, be put on original research work, and of whose qualifications he speaks very highly. But his closing paragraphs I shall read :

> "Some little time ago I had a most charming evening with Belopolsky, the great Russian Astrophysicist. Our little scientific club entertained him at dinner—our custom when such 'big' fellows come among us. One of the things he told us was that a number of young women are employed at the observatory at Pulkova, as well as young men, mostly as computers, and that the young women were paid the highest wages. We asked him how this came about, as it seemed passing strange, coming from a Russian. His reply was—'They are more accurate and make fewer mistakes than the young men.' "

Then there are the women who have given of their wealth to astronomy.

Annie Sheepshanks founded an astronomical scholarship at Trinity College, Cambridge giving £10,000 for the purpose. There are several prizes at the Academy of Sciences and the Paris Observatory, the gifts of women, including one of $20,000 (lying unclaimed for the person who first finds a way of communicating with a star or planet and receives an answer from it. Dudley Observatory at Albany is the gift of a woman ; Morrison Observatory at Cincinnati was founded by a woman; Alleghany Observatory was benefitted largely by a woman's generosity ; Harvard has received valuable instruments and large sums of money from Mrs. Henry Draper ; the American National Academy of Sciences has received $20.000 from Miss Alice Gould, and Miss Catharine Bruce has given sums of money large and small to an enormous amount, for astronomical purposes. One of her gifts is the photographic telescope, the largest in the world, with which Dr. Wolf of Heidelberg finds his asteroids.

Before closing this paper may I digress to say that in the reading I have done to prepare it I have been especially interested in the personal side of these women and the effect of their scientific work on their characters as women ? More particularly have I kept a watchful eye for what the Americans used to call "the strong-minded female," a type with which we are all familiar in fiction, and I have come to doubt very much whether as a matter of cold fact this type ever existed—such as Dickens, for example, presented it in Miss Toppit (Martin Chuzzlewit). "Mind and matter," said the lady in the wig, "glide swift into the vortex of immensity." If there is any ground for the tradition that learning has the effect of making a woman an obstreperous nuisance, and unfitting her for her natural sphere in the world, the lives of the women I have mentioned ought to bear out that theory, but, though I have kept diligent watch for a representative of that type, I have not found her. I think the "mind and matter" lady was a myth pure and simple, a creation of the fancy of the great novelist, but she has served during the last half century as ammunition for the scoffer at the attempts of women to educate themselves. If the type ever existed, it was the result, not of an overdose of the elixir of learning but of a mild infusion, on an ill-balanced mind. The point which I wish to emphasize is that, with possibly one exception, these scientific women have all been fine womanly women, endowed with an uncommon share of common sense ; hopelessly feminine in their tastes, good wives and wise mothers, most of them, and some, actually, in utter defiance of popular tradition, beautiful. My deduction is that scientific work is not unwomanly, nor (what some people consider almost worse) unladylike. We are beginning to realize the fact that the woman who has wits enough to acquire a high intellectual standard has also wits enough, should marriage come to her, to fit herself to her surroundings, and to make just as good a wife and mother as though she knew nothing outside the four walls of her home. Flammarion says "The present is an open door through which the future is hurried into the past." It may be that the future is bringing us a higher type of both men and women and that Tennyson's theory, the "poet's dream," will be the medium for raising the standard of life.

[At Miss Dent's request, the editor appends the following letter from Madame Manora, which speaks so clearly for itself that no remarks need be added, except to hope that the sun of worldly prosperity may soon again shine upon its writer.]

MANORA OBSERVATORY.

Lussinpiccolo (Austria-Hungary), Jan'y 5th, 1904.

Respected Sir :—

As, in addition to my Slavonic mother-tongue, I can only express myself in Italian and German, and as the latter is probably better known in Canada, will you forgive me if I answer in German your esteemed favor of the 18th Dec.?

In accordance with your desire I inform you that in my childhood, in the Slovak country (Upper-Hungary) I was taught by our minister some of the wonders of astronomy, and afterwards felt an active interest therein, without having an opportunity to occupy myself further with the science. That happened to me first in 1892, in Cilli, Steiermark, when I bought a 3 in. refractor, in the purchase of which for me Leo Brenner interested himself. At his initiative I next ordered a seven-inch equatorial, which happily turned out so wonderfully that it could compare with the largest existing telescopes, and I installed it at Lussin, where in the meantime, Brenner had found that the atmospheric conditions were exceptionally fine. Building began the 18th Sept. 1903 ; the cupola was set up the 2nd of Jan'y 1894, and the observatory was opened the 23rd of Feb., 1894. Since that time Brenner and I myself have made observations, as often as we could, though, as for me, I could give but little time, on account of my house-keeping duties. As a rule, Brenner called me to the instrument only when there was something to be confirmed as to which he was in doubt, or when there was something very highly interesting to be seen. He has in his papers—scattered among various astronomical publications, but for the past five years collected in the "Astronomische Rundschau," published by us—repeatedly referred to my co-operation ; among other things to the division of the crape-ring of Saturn from Ring B., which I first discovered and is named after me the Manora division. In 1900 I observed the Eclipse of the sun in Algiers ; in 1898 I was observing in the Vienna observatory and in 1899 in that at Catania. I have repeatedly made drawings of Venus, which have usually agreed well with those of Brenner's. So also our separate sketches of Mars usually show the same canals and other objects, which, in view of recent doubts as to the existence of these channels, may be of interest. Our drawings of Jupiter agree also fairly well, and I have been the first to observe some craters on the moon which have subsequently received Brenner's confirmation.

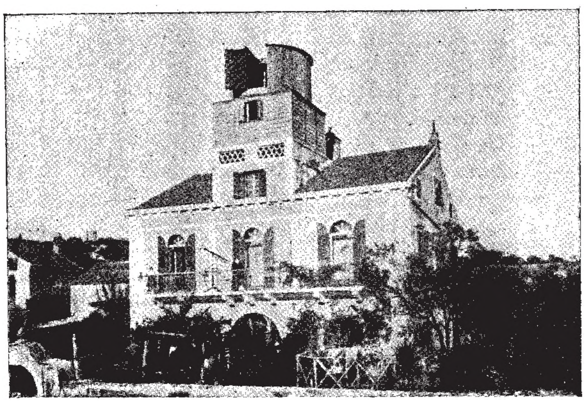
As for our instruments, they are at present :—The seven inch equatorial; a 4 1-4 in. refractor ; a 5 1-5 in. comet seeker; an excellent micrometer, a prize pendulum-clock, a chronometer, a helioscope, a spectroscope, a 2 1-8 in.

telescope, a large Trieder opera-glass, a transit instrument, and some minor accessories.

For financial reasons, the activity of the observatory had to be restrained, from 1897, and therefore less has of late been done. For similar reasons I have resolved, with a heavy heart, to sell the observatory, with its library of 2,000 volumes, to the first comer who is ready to pay $6,000 for it. Then I would leave Lussin, settle elsewhere, and use a smaller instrument in my leisure hours for observations interesting at the moment.

I enclose a view of the Observatory, and remain,

Yours very sincerely,
FANNY MANORA GOPSEVIC.



THE MANORA OBSERVATORY,
LUSSINPICCOLO, (ISTRIA), AUSTRIA-HUNGARY.

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