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# PROCEEDINGS

OF

# THE CANADIAN INSTITUTE

## NEW SERIES

No. 11. JULY, 1902. VOL. II. PART 5.

CONTENTS.



TORONTO:
MURRAY PRINTING COMPANY,
11-13 JORDAN STREET.

## RECENT VIEWS RESPECTING THE CONSTITUTION OF THE SUN. BY ARTHUR HARVEY, ESQ., F.R.S.C.

*(Read 30th November, 1901.)*

AT the base of a mountain the view is usually limited and obscured, but the horizon widens and the prospect gains in clearness on the upward climb. Still, when the Alp is scaled, peaks beyond peaks become visible. So in science, and especially in astronomy, some new fact or theory is daily added to the general store, but it is only thereby made evident that there is far more beyond our ken than within it, and we are compelled to think of the last words of Laplace:—"Ce que nous savons est peu de choses; ce que nous ignorons c'est immense!"

The sun is the orb of which, in comparison with its importance, we know least, and its various phenomena are almost all, as yet, mere riddles. What was thought fifty years ago to be assured knowledge has not held firm, while even modern views as to his constitution are uncertain and indefinite, notwithstanding the array of new facts of which we have become the masters through the aid of the huge telescopes, the perfected spectroscopes and the photographic instruments lately brought into use.

Changed views as to the sun have been forced upon us by the alteration of our ideas about the earth, in which, too, there has been a revolution within a life time.

No longer are we told that the height of our air is forty miles. Auroræ can now with reasonable certainty be numbered among atmospheric phenomena and I have proved one remarkable auroral arch to have been over 150 miles above the ground.* We now know that falling stars light up by friction in the air, and in tracing the path of a remarkable bolide seen in Toronto, I learned that it became luminous at the height of 80 or 100 miles.† The trail of that meteor became snake-like before it vanished, the sinuosities having a breadth of half the apparent diameter of the moon. If these were caused by air-waves, such as Mr. Napier Denison has told us of,‡ these waves had a breadth of at the least 2,000 feet. Laplace, a hundred years ago, said the atmosphere was bounded by a lenticular shaped surface of revolution whose volume is about 155 times that of the solid earth and should reach out to a distance of about 26,000 miles at the equator and 17,000 at the poles. Professor Woodward, lately President of the Mathematical Society of America, appears to agree with him.§ New gases have been discovered in the air, and its constitution is even thought to change as we ascend in it. Carbon dioxide decreases, hydrogen increases and it is thought by some that on the aerial outskirts there is hydrogen alone or with the smallest admixture of the

* Transactions Astronomical Society of Toronto, 1895, p. 78.

† Transactions Astronomical Society of Toronto, 1898, p. 118.

‡ Transactions Canadian Institute, February 6th, 1897.

§ Science January 12th, 1900.

oxygen and nitrogen which so largely predominate on the surface.* We now know that the higher the clouds are the faster they move and *Ciel et Terre* says that the motion of cirrhus clouds is on the average 60 feet a second in latitudes like our own and 45 feet within the tropics, while there are thus currents in the upper air to the violence of which nothing indicates the limits. The word violence I understand implies chiefly velocity and amplitude, for in highly rarefied air, the force of such currents must not be likened to what we should experience if there were at our level a constant gale of from 30 to 45 miles an hour. From mountains and balloons those who frequent high altitudes have often seen below them the upper surface of a layer of clouds, the existence of which surface depends upon a delicate adjustment of heat and gravity. They have described how huge billows will rise from the placid and shining cloud-layer and sometimes subside as quickly as they arose. *Ballons sondes* and high-flying kites have carried instruments which show that there are frequent horizontal strata in our atmosphere, and that the low barometer in one is seldom vertical to the low in another, so that the lowest reading at a height of ten thousand feet may be hundreds of miles distant from the lowest reading at the surface. And the characteristics of these layers are very different. Thus; the outer one, which we never shall reach, must shade off in temperature to the cold of space, dust and moisture never reach it and its inferior surface is the upper limit to the lightest possible cloud. Then comes the air of which the lower limit determines the snow-line on our mountains. Lastly we may place the shell in which we live, within which alone lightning flashes and rains fall, and there is enough moisture to interpose a blessed screen against the terrible cold of a very few miles above. We will not consider the terrestrial hydrosphere and lithosphere because there can be nothing analogous to them in the solar orb, to which we will now turn.

The first scientific conception I can find as to the physical nature of the sun is that of Anaxagoras, who is reported to have said it was a red-hot stone, as large as the Peloponnesus. A hundred years ago it was defined as a glowing solid mass, stationary in the heavens. Even Sir John Herschell in the early edition of his astronomy which I used when a school boy said "it is hardly possible to avoid associating our conceptions of an object of definite globular shape and of such enormous dimensions with some corresponding attribute of massiveness and material solidity." A theory that it was liquid fire prevailed for a time. But it seems to be regarded now as composed of incandescent gas, and I too believe that the sun is a great globe of such vapours or gases, of which the visible outer envelope is as tenuous as the smoke of a cigar.

No sooner had Galileo turned his *perspicillum* on the sun than he perceived its frequent spots, and it was his treatise *Delle macchie solari* which was the ostensible cause of his disfavour with the papacy. Milton, who as a youth visited him, has a half punning allusion to them :—

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

Their nature was mysterious then, and the question as to their cause and nature is not yet surely answered. One plausible theory, which still holds a certain sway, is Wilson's, who thought they were depressions in the luminous solar envelope, through which the dark interior body of the sun became visible. But out of hundreds of drawings, made with the utmost care and minutely examined, less than one in three gives any countenance whatever to this view. Were it true there should be a regular shading off from the circumference of spots to their centre, whereas there are only two well marked distinctions, viz., the black looking umbra near the middle and the more lightly shaded penumbra irregularly surrounding it. The way spots are usually drawn in astronomical journals has become conventionalized; radiations from the centre towards the circumference or *vice versa* are rarely to be seen. Moreover, this hypothesis assumes the interior layers to be less luminous than the exterior, which, as they cannot well be cooler, is improbable. Another theory was that the spots are scum or slag, floating on the surface of molten matter, but if the visible surface be

* M. G. Heinrichs, Comptes Rendus de l' Academie, August 20th, 1900.

not liquid, it must be abandoned. I have seen a large dark spot which seemed to show on the western limb as an indentation, but the effect might be produced by a dark mass covering a considerable surface or by the obscuration of that surface otherwise, and I incline to the belief that some emission from the interior spreads over the surface of the photosphere in the form of vapour, some matter which impedes the transmission of radiations giving light and perhaps heat as their effects, but does not so impede or absorb the radiations which carry electrical charges.

Whatever may be the cause of spots, they were seized upon as affording means for determining the time of solar rotation, and Sir John Herschell, in his Astronomy, edition 1842, thus summed up this branch of the subject :—

"Our telescopes show us dark spots upon its (the sun's) surface, which slowly change their places and forms, and by attending to whose situation at different times astronomers have ascertained that the sun revolves about an axis, inclined at a constant angle, of 82° 40′ to the plane of the ecliptic, performing one rotation in a period of 25 days, and in the same direction with the diurnal rotation of the earth."

Some further elements of supposed precision having been introduced by Mr. Carrington, the Greenwich Observatory adopted and keeps to a rotation period of 25.38 days, sidereal.

I found, however, as a very casual observer may easily do, that this period did not suit the spots I examined, with a view to discover if there were not permanently active regions on the sun, answering to volcanic districts upon the earth. The changes in spots seemed anything but slow, they drifted in irregular ways, both in latitude and longitude, and when after disappearance they again emerged at about the same region, the time was not sufficiently exact for identification. So, as the attitude of a student towards all science should be one of scepticism, following the advice of St. Paul to the Thessalonians, πάντα δὲ δοκιμάζετε, judge for yourselves about all things, I began to see if I could not ascertain the exact period of solar rotation for myself, by less difficult and more certain means than the observation of spots. I sought for and thought I had found it in the periodicity of outbreaks of terrestrial magnetism. My theory was that the internal convection-currents bringing intensely heated matter from the sun's interior towards his surface would cause solar disturbance which in some way would be radiated in pencils, like beams from search lights, from the sun to the earth, that such convection-currents would follow established lines, and that whenever the particular solar locality was turned towards the earth, there might be a magnetic effect here, and surely would be, if at the time that solar volcanic vent were active. I found from the whole series of Toronto observations, which began in 1844, that one magnetic storm repeated, intermittently, but continuously enough for a preliminary identification, in 27.24575 days synodical or 25.35447 days sidereal.*

Two new announcements bearing on the subject were made about that time. One was that cathode rays, which exist in abundance in solar radiations, carried with them charges of negative electricity. Mr. H. Deslandres communicated to the French Academy in 1898 his discovery to that effect, and shortly afterwards it was added that Lenard and Becquerel rays, emitted by radio-active substances, have the same property. This solved the perplexing question, how could electricity be radiated across space, in which there is no permanent conducting medium. The other was that the spectroscopists, who have now perfected their instruments so that they can tell the rate at which a luminous body is moving towards or away from them, announced their agreement with the astronomers who had been doubting the uniform rotation of solar spots. The sun being two and a half millions of miles around, and rotating in 25 days, the velocity of its rotatory movement at the equator is a mile and a quarter per second. Thus a point at the equator is approaching us at that rate when it comes into view, and receding as it vanishes. The rates of approach and recession vary with the distance from the equator of the locality under observation, but are quite sufficient even near the poles to noticeably shift the dark lines of the solar spectrum nearer to the blue end in the one case and to the red in the other. The

* Transactions, Astronomical Society of Toronto, 1897.

most painstaking observations are perhaps those of Crew and of Duner, which have been worked out by three different formulæ and give as results :—

Rotation period at the equator................days 25.53 ; 25.71 ; 25.50
Rotation period near the poles.................days 37.66 ; 49.45 ; 45.98

Bringing such periods to the measure of velocity we have the materials for a table in which $\varphi$. is the latitude, $v$. the velocity, while $v$. sec. $\varphi$. is the velocity at the equator corresponding to that observed at the various latitudes.

| $\varphi$. | v. *per* Second in Miles. | v. Sec. $\varphi$.; Miles. |
|---|---|---|
| 0°.4 | 1.23 | 1.23 |
| 15 | 1.15 | 1.19 |
| 30 | 0.98 | 1.13 |
| 45 | 0.74 | 1.04 |
| 60 | 0.46 | 0.92 |
| 74.8 | 0.21 | 0.81 |

It is evident that if the sun rotated as a solid, all the values of $v$. sec. $\varphi$. should work out the same, that is, to 1.23 miles per second. But the table shows that the region in latitude 74° 8′ rotates one-third less swiftly than it would on that supposition. Something analogous is found in connection with Jupiter's rotation, for his cloud-belts differ in their rate of movement, though not nearly in the same proportion.

The consequences of this discovery have not all been reasoned out, and, as Crew does not completely agree with Duner, further observations are necessary, but the view that the gases at the visible surface of the sun are extremely tenuous is much strengthened. A rotation of a solid sun in sections is unthinkable; there can be nothing approaching to solidity where there are such varying rotatory rates. Yet at a depth not far below the surface there must be density enough to make the great gas-ball more coherent, and as the density increases the substance must tend more and more to act as a viscous if not as a solid body. The sun therefore appears to rotate more slowly in depth than at the surface. Again, since the more rapid the rate of rotation the greater the centrifugal force, the convection-currents from within the sun must be directed towards his equatorial belt, they must acquire additional force in proportion as they are so deflected, which is not an improbable reason for the excess of solar energy manifested near his equator.

To treat of the Corona which envelops the sun, and has up to the present time only been seen during total eclipses, would be foreign to the purpose of this paper. It may, however, be remarked that attempts have been made to determine whether it rotates too, and at what rate. I have only heard of one successful observation, made by Deslandres in 1900, who thought it rotated faster than the sun, so far at least as its west side was concerned.

Already, however, we can picture to ourselves the sun as a star surrounded by a nebula of which the greatest extension is about its equator and revolves with something like planetary velocity. It does indeed seem that the materials of which the solar system is composed have not yet been completely absorbed into the sun and his planets, but that a remanet still girdles him and is seen in the Corona and especially in the zodiacal light.

What is it then that causes so sharp a distinction between the visible disc of the sun and the nebula outside it? Seen through powerful telescopes it is as definite as it appears to the unaided vision. it does not shade off by degrees like comets' tails or nebular wisps. I have thought that the cold of space prescribed the limit, that there is a line beyond which solar vapours cannot incandesce, like that which limits the height of clouds upon the earth, alluded to at the outset. Therefore, as I do not learn that any variability has been observed in the sun's diameter, I have not been an enthusiastic supporter of those who think the sun's condition gives hot or cold seasons to the earth. If from any cause the sun did emit more heat one year than another, the first effect, it seems, would be the expansion of his own visible disc. Nor does the answer given by Schmidt, of Stuttgart, make this objection less weighty, whose work of 1891 has been recalled and further explained by Otto Knopf, of Jena, in 1893. They do not think that the light reaches us from the solar surface; in a word, they deny that there is a definite surface to the sun. They say his light originates within a globe of superheated gases and that, owing to the refractive index of these gases being reduced through diminished density as the external strata are reached, the rays from within the sphere necessarily appear to be limited by a circle. They think the spots are not upon what looks to be a photospheric surface, but below it, and even suggest that they may be optical phenomena due to disturbances of the refracting properties of the superior layers. Their theory of the spectrum is necessarily unusual too. The solar spectrum was long supposed, following Kirchoff, to originate on the photosphere, which he considered liquid, and covered by an atmosphere which by absorption caused the well-known dark lines. Schmidt and Knopf think the violet and blue rays originate in a smaller concentric shell than the red rays, under greater pressure, and that having to pass through a denser medium throws them farther along the spectrum. The visible circumference of the sun being unreal, the absorption lines may have their origin at a considerable depth within the solar atmosphere, which they think is so rare in the shells outside the incandescent strata as to have very little absorptive effect.

That the sun does emit more heat at certain periods than at others, varying according to the extent of spots upon his surface, seems to be the opinion of the day, though our own Canadian records do not indicate the slightest periodicity, excepting in so far as rain-fall is concerned (where there is a certain periodicity which may be due to heat elsewhere). But there is no doubt there is a somewhat ill-defined term of more or less spottiness, called the sun-spot period. If we cannot as yet certainly connect it with radiations of additional heat or of light, we can certainly trace its concordance with the varying intensities of the earth-currents of electrical force. In my paper for our semi-centennial memorial volume,* I brought down to that date my own studies on the subject, and to avoid repetition, I refer thereto, especially as that was the first publication of my discovery that the solar disturbances which cause sun-spots and our magnetic storms and auroræ also cause simultaneous excitation in the tails of comets and in the condition of other planets. There has been no doubt since the publication of Professor Loomis' papers in the American Journal of Science, many years ago, that the curve of magnetic excitement followed very closely that of sun-spottiness, and the curves which prove their similarity have been brought down to the present date by Mr. W. Ellis, F.R.A.S., attached to the Greenwich observatory. Shortly after the date of my paper just referred to I made a curve from the differences between the observed brightness of Encke's comet at its many apparitions and the brightness it should have attained if distance from the earth and sun had been the only factors to be considered. That investigation, published in a Presidential address to the Toronto Astronomical Society, showed that the excitation of that comet has always corresponded in a most remarkable way to the magnetic excitation of the earth, and therefore to the condition of the sun.†

We have, however, been passing through a period of minimum solar excitation, and I have on that account been giving less attention to phenomena expected at active periods than to those which can be studied within walls and ceilings, and I have nothing new to say on that subject.‡ I find, however, that I have not yet communicated to the Institute my demonstration that antarctic auroræ are synchronous with auroræ boreales. This I was able to prove from the observations of that painstaking and thorough meteorologist Henryk Arctowski, now of Liege, who was with Commander de Gerlache on the *Belgica* during her antarctic sojourn. His table of auroræ seen in *Belgica* Straits, far to the south of Cape Horn, answers precisely to the table made from Canadian and Washington

* Transactions, Canadian Institute, 1898, 1899, p. 345.

† Transactions, Astronomical Society of Toronto, 1898.

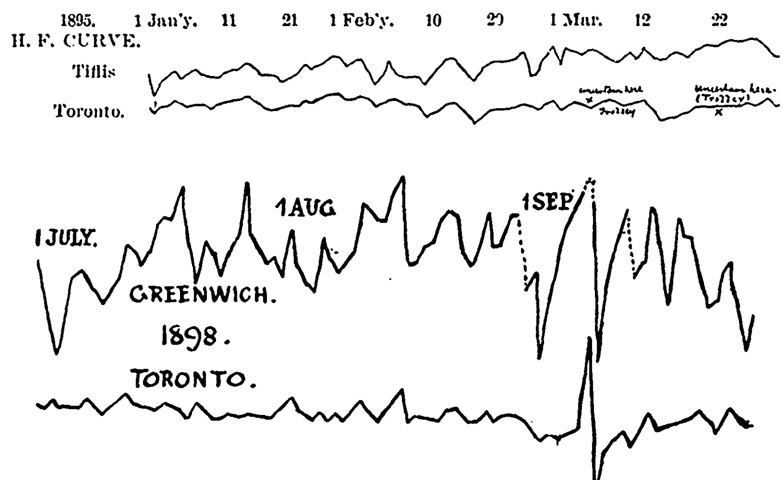
‡ Since the reading of this paper, the author has found reasons for believing that the zodiacal light also brightens during magnetic disturbances.

observations. Mr. Arctowski, in an address to the Royal Geographical Society, published in its *Journal*, called on northern meteorologists to see if there were any correspondences between these Auroræ, Australes and Boreales, and it is, I think, extraordinary that the *Journal*, with which we exchange, should have lain on our table for a month before I saw it, and that even then I should have been the first to answer the appeal. But as our President remarked, there is a sort of justice about this affair, for it was to trace out magnetic similarities and differences in the two hemispheres that the Toronto observatory was established, sixty years ago, and it is to its admirable continuous work and the courtesy of its director that this concordance of Arctic and Antarctic auroræ has now been determined by a Toronto amateur. I need scarcely add that magnetic disturbances have also synchronised with Arctowski's most brilliant auroræ. That synchronism as regards our northern lights is treated of on page 352 of the memorial volume above quoted from. We have thus additional proof of the cosmical bearing of auroral phenomena and can mentally see the spectacle of earth, receiving electrical discharges by means of cathode rays thrown off during solar disturbances, and lighted up around both poles with the lovely coruscations accompanying the distribution of this electrical surplus.

Is it permissible to enliven the course of a scientific discussion with the spice of romance? In the papers by Arctowski I noticed one dated at Liege, where a daughter of mine was studying at the Conservatory of Music. I wrote, enquiring if Liege were Mr. Arctowski's permanent residence, and received an answer that she had the pleasure of knowing him, and she was going that evening to Madame Arctowski's house. Did I know he had been lately married, and how it came about? Supposing I did not, she would tell me the story. When the ship was in the ice pack, the four chiefs of departments were in their little dark cabin, with just light enough to see by, and they were amusing themselves by turning over for the twentieth time the pages of year-old magazines. Subject for discussion—which was the best looking girl of all whose portraits were figured there? Each made his choice and gave his reasons, and Arctowski, cutting out the picture of an American then in Paris, put it in his pocketbook and vowed that if he lived to get back to Europe, he would find that fair woman out and marry her. And so he did. May the pair enjoy to the full the wedded bliss which had so strange an origin!

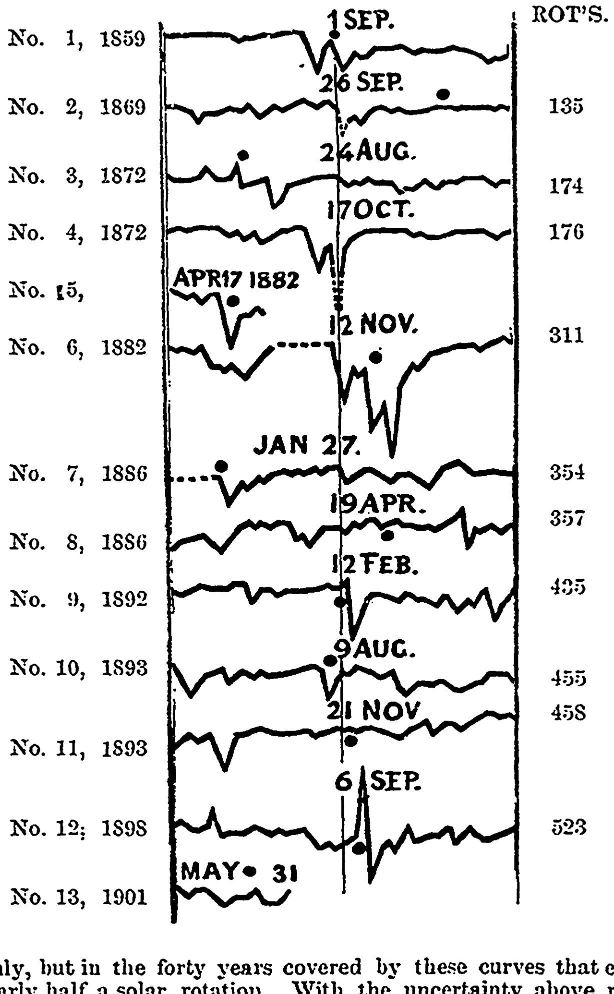
Mr. Arctowski's letters were insistent on a further point. Were the characteristics of the auroræ seen here at given dates similar to those which he observed at corresponding dates in the southern hemisphere? He thought Toronto was more homologous than any other station as to position with respect to the northern magnetic pole to that which the *Belgica* had occupied with respect to the southern. Observations of the auroræ here were unfortunately not in sufficient detail to give an answer to the question, but I was able to obtain fifteen or sixteen reports from the United States Weather Bureau which were of service in establishing a presumption that it must be negative. At the date of an aurora which Arctowski would describe as waving curtains of yellow light, the aurora here would as often as not be seen as almost stationary auroral clouds. More puzzling still, the aurora was not seen in equal brilliancy, of corresponding colour, or of similar rapidity of motion in the different stations here from which it was reported. In two of the instances given by Mr. Arctowski, there was a clear sky in our latitude from the Atlantic to the Pacific. But the local distribution of the auroræ observed was singular—in one case they were reported all over the north-eastern States and our Maritime Provinces but were not seen west of Toronto until the region was reached which in both the United States and Canada adjoins the Rocky Mountains. In the other case the display was not seen east of Toronto or far west of Minneapolis. I wrote a paper on this subject for the Royal Society of Canada, as complete and as brief as possible, but that Society is very dilatory with its publications and appears to care more for literature than science. The fact is probable that atmospheric conditions, other than clouds, interfere with the visibility of auroræ, and hence the erroneous opinion that because magnetic storms are not everywhere accompanied by auroræ, the connection is not fully established. It is, however, possible that longitude has something to do with the location of auroræ, and that Arctowski's "homologous" positions will have to be reckoned with. It may be that a broad tongue of electrical influence shoots from the north towards the equator, and that another issues from the south to meet it at the rendezvous. A study of the few auroral observations made by Borschgrevink when he was in the Antarctic on the "Southern Cross," which have been tardily issued, favours this inference. His station was on the other side of the globe; we had here the magnetic depression to accompany, but not in all cases the auroræ, which may have illuminated the northern Pacific ocean more brightly than this western region.

I have searched available records for further proof of the statement respecting the connection between sun spots and magnetic storms made at pages 351 *et seq* of our Memorial Volume, and present a diagram which shows the magnetic disturbances associated with the most noteworthy sun spots of recent years. I begin with the magnetic disturbance of the end of August and beginning of September, 1859, because it is somewhat celebrated in astronomical history, and has given rise to a fabulous legend. Most popular works on the subject of sun-spots report that while Messrs. Carrington and Hodgson were examining the sun they saw a spot appear and there was a simultaneous disturbance of the magnets. The original statement of Mr. R. Hodgson, F.R.A.S. was made to the British Association as follows:—"While observing a group of sun-spots on September 1st, 1859, I was suddenly surprised at the appearance of a very brilliant star of light, much brighter than the sun's surface, most dazzling to the unprotected eye, illuminating with its light the upper edges of the adjacent spots . . . It lasted five minutes and disappeared instantaneously. From a photograph taken of them at Kew the previous day the size (length) of the entire group appears to have been about 2′ 8″, or say 60,000 miles. The magnetic instruments at Kew and at Greenwich were simultaneously disturbed at the same instant to a considerable extent." I assume that the sun spot group was central at that date, and the magnetic curve is taken from the Bombay register as we do not possess the 1859 Greenwich records. The whole world, however, feels these magnetic disturbances with wonderful simultaneity. Here are two examples of the curves




CURVES OF HOR. MAGNETIC FORCE. DAILY MEANS.

for three months' daily mean readings of horizontal magnetic force; one pair Toronto and Tiflis, the other Toronto and Greenwich. Allowing for differences in scale, you will see that the ups and downs exactly correspond. Even the principal tremors are to be seen on the photographic curves now made at quite distant places, such as Paris and Perpignan, Berlin and Vienna, Manila and Zi-ka-wei, and so exactly to the instant that the difference in longitude can be checked by this strange wireless telegraphy. The beginnings of magnetic storms are often noted by a jerk in the regularity of the trace, and this appears to be observable at every station. Returning from this aside, I will ask you to examine the magnetic tracing for the year 1859. You will see that Carrington and Hodgson's disturbance was fairly severe on April 21st, May 19th and June 16th, strong on July 11th, slight on August 8th, and very severe on September 2nd. These various dates are separated by about the interval of a solar rotation, and I have arranged the other curves so that the same solar meridian which faced the earth on that September 1st, also faced it at the dates placed underneath it in all, adopting my own rate of solar rotation. It differs from the one adopted at Greenwich by 3/100




of a day only, but in the forty years covered by these curves that equals twelve days or nearly half a solar rotation. With the uncertainty above referred to as prevailing in reference to this exact period I need scarcely say that we should not yet be too positive of correctness. The concordances apparently established by my diagram and table may be accidental. The diagram is made to show that great spots are associated with magnetic storms, and each of the curves gives some noteworthy proof of this fact; their being placed under each other has an independent bearing upon the other fact as well. I have taken all the great spots of which I have found an account in the volumes accessible to me.

In an old "London Almanack" I find there was about central on October 13th, 1869, a huge spot, 672,000,000 of miles in area. I therefore had to plot the magnetic curve, No. 2, and it seems to show that the disturbance repeats after 135 rotations, but the spot has no relation to this storm; it may, however, be the outcome of the solar disturbance which caused the depression of September 14th, a rotation before. The next curve, No. 3, is plotted to show at August 25th, 1872, the beginning of a storm which culminates on October 17th—176 rotations. It also shows the association of a spot and a disturbance in the beginning of August, both of which are on another disturbed meridian which shows magnetic effects in all the subsequent tracings and has spots associated with it in Nos. 5, 7 and 13. The two curves Nos. 5 and 6 are given because of a paper in the "monthly notices" of the Royal Astronomical Society "On the great sun-spots of 1882, April, also November 12th–15th." The day of centrality in April is not given, but on the 17th there was a magnetic storm so violent that it could not be completely registered. It can be traced back to September 12th and October 9th of the previous year. The November sun-spot is in the middle of a long and pronounced disturbance of the needles, the beginning of which is 311 rotations subsequent to the storm of September 1st, 1859. In the "monthly notices" there is a paper "on a remarkable sun-spot of 1886, April 24th." This is an instructive occurrence because there was no remarkable disturbance of the magnets along with it (see curve No. 8), but there was a disturbance on January 8th and 9th, with an accompanying spot; there was another on March 31st, which apparently gave rise to the spot which appeared the month after. In these curves, especially in No. 7, the commotion with which it began may be seen to continue. Curve No. 9 shows the depression figured in detail by the late Professor Carpmael in the frontispiece of the Transactions of the Astronomical Society for 1892, which produced the celebrated rose-auroræ of February 13th, and what the Royal Astronomical Society's notices say was an exceedingly large composite spot, the largest up to that time ever recorded. I observed this spot with care and submitted a series of drawings of it to our Astronomical Society. The spot had appeared during the previous rotation, January 8–12, and the magnetic disturbance, which can be traced back to September 25th, 1891, continued as regularly as could be expected, considering the immense solar area involved, well into 1893. You may see that it kept on causing spots, shown in curves Nos. 10 and 11. The Toronto Astronomical Society records in 1898, September 2nd–15th, a spot 65,000 miles long and 75,000 miles broad, belonging to a disturbed area 150,000 miles across, and curve No. 12 shows the great magnetic depression which immediately followed it. Lastly I give the location of the spot of May of the year 1901, which is rather celebrated, though not a very large one. The Abbè Moreux, of Bourges, first saw it on May 20th, when it was so active that he thought the solar spot-minimum had suddenly passed away. His vivid description of its rapid changes of form and division into two main parts startled the world, who expected a scorching summer in consequence, a fear which I attempted to allay by showing its small comparative importance and the absence of great magnetic disturbances connected with it. Its activity may, however, yet be important to science, as it was just on the edge of the sun at the time of a total eclipse, and we may hear of moderate coronal disturbances near the latitude it occupied.

Physicists and astronomers are indeed now beginning to admit, with apparent and unaccountable reluctance, the intimate connection between the two effects of a common cause, sun-spots and magnetic storms. Mr. Wm. Ellis, F.R.S., says: "the general effect observable is that in our latitude there may be at one time a large solar spot with great magnetic disturbance . . . at another time a considerable solar spot may appear without accompaniment of unusual magnetic movement; and again, magnetic disturbances may occur without any noteworthy spot." The "general effect" is not quite fairly stated, even by this most cautious and painstaking official; there seldom if ever is a great spot without a magnetic storm with which it can be connected, usually while it is visible, occasionally a rotation before. Mr. Ellis does not seem to have quite freed himself from the old idea that spots cause storms, or fully to recognize either the cosmical nature of magnetic phenomena or their effect all over the earth, else why does he allude to "our latitude?" The converse, as he puts it, that there are magnetic storms not accompanied by spots, proves little—the cause of the storm may have been in a solar region where spots do not appear, or, for reasons we cannot think of, may not have given rise to spot phenomena.

Several astronomers still cling to the idea that to prove the connection a spot must be absolutely central at the time of a magnetic storm. The diagram just explained shows that the spot often lags a day or two behind its related storm. It also indicates that there are three active meridians on the sun. I am not yet prepared to speak of the latitude of active spot regions, but I have checked the prominences for several years, and while they too are apparently more numerous on three meridians, they are strangely distributed in belts, like those of Jupiter and Saturn, while there seem to be extensive regions of comparative quietude. I find that Professor Wolfer, of Zurich, has been doing similar work, and his results, which I have seen in the *Memorie* of the Society of Italian Spectroscopists, are apparently the same as my own.* As I have worked out each year separately, the question of the exact rate of rotation is not seriously involved. I do not at present attach a high value to this work, but it is interesting as showing changes in the latitude of prominence belts. Some years this activity extends to near the poles, and we have a belt of prominences in latitude 80°. The next year it may be five degrees or even more nearer to the equator. Sometimes prominences are numerous in the northern solar hemisphere, and again the southern hemisphere may exhibit more activity. Prominences often occur in the neighborhood of spots, but frequently where none are visible, and the range of prominences is much greater than that of spots, for they have been seen at the very pole. I have not been able to discover that they affect the needle in any way, though they are more frequent and larger when sun-spots are many and magnetic disturbance great.

I must not conclude without a notice of the labours of Dan Carlos Honore, director of the International Solar Institute of Montevideo. Like myself he found it needful to arrive at a true period of solar rotation but he pursued the meteorological method. Professor Frank H. Bigelow, of Washington, D.C., had already shown similarities between magnetic curves and North American temperature waves, and by making a time allowance for the movement of pulses of heat and cold from the Rocky Mountains towards the Atlantic Coast, he brought them into tolerable harmony. Mr. Honore does not attack this concordance; he takes as a guide the normal temperature of each day, attributing the surplus or defect of heat to radiations from the sun. The days of surplus heat are shown in his figures on one side of a circle and the days of excess of cold on the other, he then finds a marked periodicity, and declares the synodical solar rotation to be 27,241,326 days. I understand he thinks the solar shell from which we get the most effective heat rotates in that time, and if the shell which causes electrical manifestations rotates a little more slowly, according to my reckoning, there is nothing contradictory in that difference. Mr. Honore has so much confidence in his theory that some parts of the sun are hypothermic, and cause an excess of heat when turned towards the earth, that he has prepared tables of solar rotation covering hundreds of years. On dividing the year into two, and superimposing the curves, he found an inequality, and concluded that there is an interior sun, with an axis slightly inclined to that of the photosphere, and a rotation slower by 0.00867 of a day, which leaves 363.33 days for the heliothermic year and 27.25 days exactly for the synodical rotation of the interior sun. With these data Mr. Honore thinks he can define the latitude as well as the longitude of the solar regions on this interior sun which send us heat, and even by those whose radiations he believes cause earthquakes. He has sent me diagrams of solar thermic centres, calculated by his tables, also other diagrams which localise the solar seismic centre, which he thinks controls the Mexican volcanic field in a seismic circle of 15 heliothermic years, or 200 synodical rotations of the interior sun. With this cycle he identifies every one of the long list of Mexican earthquakes published by the Antonio Alzate Society. I have the calculations, not yet carefully examined.

I think the sun's condition does influence the earth in the matter of cold and hot days, but the number and area of sun spots has but a slight connection with

* Vol. XXIX, dispensa 7a.

that particular irregularity. In Toronto there is evidently no settled relation between annual temperatures and sun-spot frequency. Many times sought for, any correspondence whatever has eluded the researches of others besides myself. But this is the worst of places in which to look for periodicities in weather, the areas of low barometric pressure coming from the Rocky Mountain districts may go a hundred miles north or south of us, and thus introduce a disturbing element which baffles investigation. Even a slant of wind off the lakes may cool the shores, or its absence heat them, and thus disturb the temperature of any given day. It is in Tropical regions and in places where storms of wind and rain with thunder and lightning are rare, that we may probably discover a periodicity corresponding with that of solar rotation, and perhaps even find a temperature curve agreeing with the sun spot cycle; but such changes must be very slight, on the general average, and it is the height of absurdity to hold the sun responsible for a great excess of heat or cold lasting for a whole season. The excess or defect of mean temperature at Toronto above or below the average is seldom a degree, and has never been known to be four; very hot seasons here are probably balanced by cool ones in other parts.* We are therefore working on very small margins. This is natural, since the sun and the earth are not in their youth. Lord Kelvin has reduced his estimate of the time the earth has lasted since the first crust covered its surface from a hundred million years to forty, but though I side with the geologists who think a hundred millions are too few, yet in this connection I can be content with the smaller number as an estimate. For, before its crust formed, there were long aeons during which the earth was an agglomeration of mere vapours. Nor is Terra the first born, but, with Venus, is a daughter of the sun's old age, while Mercury is his Benjamin. Mars, Jupiter, Saturn, Uranus, Neptune, and probably another, are his elder sons. The sun then has had time to become fairly steady. Being a ball of gas, convection-currents are probably doing their work quietly; the solar disturbances cannot be of the nature of a terrestrial eruption in which the violence seems to be determined by the resistance to interior forces of an exterior crust. The spots float up from the places which these convection-currents disturb, and as stated at the beginning of this paper they are probably nothing more than large quantities of vapours much attenuated on reaching the surface, possibly absorbent of light vibrations, certainly so constituted as to interfere with them. But though these produce the primary effects of solar disturbance but slight secondary effects here, there is something irresistibly attractive in observing them and endeavoring to account for their origin and nature.

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* The average in Toronto since 1840 has been 44°. In 1875, the average was 40°.07, and in 1880 it was 47°.02.

## SUN-SPOTS AND WEATHER CYCLES. BY A. ELVINS.

*(Read 15th February, 1902.)*

We all feel interested in the *weather*, our personal comfort and the prosperity of our country depend very much on it. Some seasons are *early*, some *late*; some *wet*, some *dry*; our *farms* and *gardens* are productive or the reverse, as the weather is favourable or unfavourable; the opening or closing of navigation, whether it is early or late, depends on the weather, and this is important to our sailors, and to trade and commerce generally. If we could foretell the *general character* of a coming season we could act, so far as possible, to meet coming conditions.

Nations have seen the importance of knowing the climate of the different parts of the earth's surface and have erected and maintained observatories where observations are made and preserved. From these records the *mean* meteorological conditions existing at such localities are known.

But the *extremes*, rather than the mean conditions, are what is needful to be known. Every one knows that we sometimes get a *wet* spring, and on other years a dry one. Our pastures are some years green in summer, at others dry and parched. In 1843 and again in 1878 we had above *48* inches of rain at Toronto, and less than *18* in 1874 and 1887. *What can be the cause of these changes?*

We know that our summer results from the northern hemisphere of the earth being then turned sunward, and our winter from the same hemisphere being turned from the sun, and we naturally turn to the sun and try to find an answer to our question *from it.*

Ever since the invention of the telescope the sun has been an object of great interest to astronomical observers; sometimes it is a spotless globe of light, and at others, one or more spots are seen on its surface. They break out unexpectedly, exist for a short time, occasionally two or three months, and gradually disappear. Some of those spots are of great magnitude. I have seen some more than 100,000 miles in length, or rather the group has been that long. In and around these spots the sun's surface seems very much disturbed, and with the aid of the spectroscope great uprushes of gases can be seen rising to an enormous height; and we are led to ask if those great solar outbursts, sun-spots, etc., are not the cause of our weather changes.

I shall have to return to those sun-spots, but here I shall diverge a little to refer to another fact. When a magnet is suspended so as to move freely on a pivot as in surveying instruments, and properly protected from local disturbances, it points in a definite northerly direction and is as a rule stationary. But it is not always without motion; sometimes it vibrates from side to side of the main line, and this continues for a time, and then disappears. This is known as a magnetic storm.

Such magnetic storms are found to be more frequent when the sun is much spotted than at other times, and it has been thought that these *storms* are *caused* by the disturbance on the sun, which disturbs the ether of space, and the magnetism of the solar system; that is, that magnetic storms are the result of the outbreak of sun-spots, or as Mr. Harvey thinks, of the disturbance to which the spots themselves are due.

There is also another phenomenon which must not be overlooked, that is, auroral displays. We at Toronto have had good opportunities of studying these, for we have been well situated for their observation during the past century, and the displays have been frequent and very grand. Like the disturbance of the magnetic needle, the auroral displays are more frequent and brilliant when the sun is most spotted, and when we plot the number of occurrences in a curve for many years we find the sun-spot curve, the curve of magnetic disturbance, and the auroral curve, to be so nearly alike that one curve differs very little indeed from the other.

It seems almost certain that the disturbed condition of the sun must produce magnetic and auroral disturbances, or that some common cause produces *all three.*

Careful observations have established the fact that there is a periodicity, somewhat irregular it is true, but still a periodicity, from one maximum of those phenomena to the next following, the period being eleven years and a little over, and the curves of all three phenomena are so nearly alike that the coincidence is unmistakable.

These coincidences require to be examined with care, and we should find which is the cause of the different phenomena, or if some cosmic condition may, or may not, produce all of them.

Are there any facts which show if the magnetic storm is caused by the outbreak of spots, or whether they are both the effect of some common cause?

There are two important facts which seem to me to help us to answer this question.

(1) Many *magnetic storms* have occurred when no spots have existed on the sun.

(2) Large spots have broken out and run their course, and no magnetic storm has been observed.

It seems from these two facts that the many synchronisms which undoubtedly exist, must be chance coincidences, and not that the sun-spot caused the *magnetic storm.*

Let us now look at the *auroræ* which are also numerous at the time of sun-spot maximum. *First:* We frequently get magnetic storms when fine auroræ are visible, and we sometimes get magnetic storms when no aurora is visible here, but we *never* get a fine aurora without a magnetic storm coincident with it.

This seems to show that the *aurora may cause the magnetic storm*, but that the *magnetic storm cannot* cause the aurora.

And even the magnetic storm which sometimes exists when no aurora is visible here, may be the result of the descent of auroral matter somewhere near. Mr. Stupart speaks of a distinct auroral display observed by him when returning from the North-West, and though we had no aurora here, the chronograph showed a disturbance of the needle at the same time.

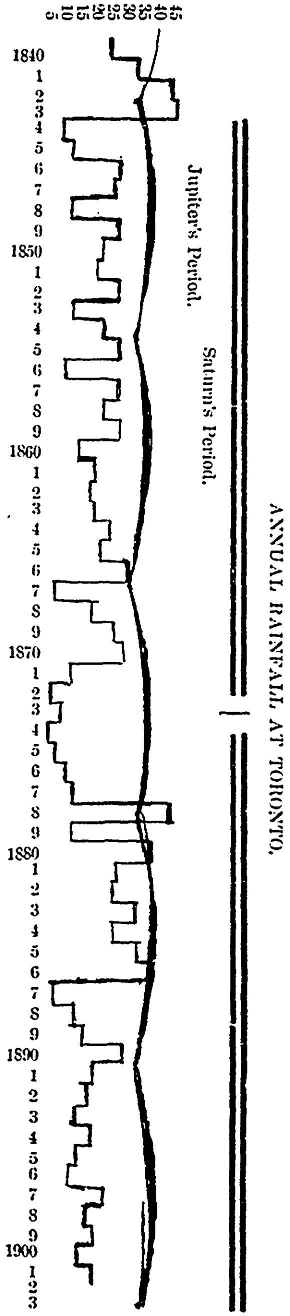
For the cause which produces the three phenomena we must look into the space in which the solar system exists, and the space through which it moves. Is it possible to find what the disturbing cause is?

I do not think that we can say with certainty; but there are reasons which lead me to think the disturbing element is to be found in the cosmic or meteoric matter existing in space, and which must be revolving in orbits around the sun, and possibly in a far less degree around the planets also.

Proctor in his "Other Worlds," Chapter ix., proves clearly enough that the solar system, especially near its centre, is crowded with meteors of all sizes, from almost invisible particles to masses of many tons weight. (Page 191., 4th edition) he says: "we recognize how erroneous that opinion is which an eminent astronomer recently expressed, who asserted that the united weight of all the bodies other than the planets in the solar system must be estimated rather by pounds than by tons." His reasons are convincing, and lead justly to the conclusion "that the aggregate weight of the various meteoric systems circulating around the sun must be estimated by billions of tons rather than by ordinary units."

Can we not go a step further? I have long thought that the atoms of the chemical elements may and do exist in space; if so, such would be as obedient to the laws of motion as larger masses are. In fact, all aggregations of *physical particles* (which in my papers on "Moving Matter" I have called *atoms*) will be subject to the same laws as large masses or worlds.

And perhaps we need not stop here. I have long thought that the chemical atoms are themselves aggregations of smaller particles, and these again of particles smaller still—the ultimate particles, or primitive atoms—those being the units of which all masses are built up; and that the chemical atoms are formed in space and should be regarded as of celestial, rather than of terrestrial origin.




All such cosmic matter within the sphere of the sun's influence will be gathered into the solar system. Let us try to follow their course when they pass toward the sun.

Masses coming into the system move rapidly around the sun and as a rule pass off into space; they may sometimes collide with other masses moving in opposite directions, and as this would destroy their projectile force and shatter the masses, some of the fragments will in such cases fall on the sun. The planets as well as the sun will receive cosmical matter, and I think the meteoric showers which fall on the earth are but a small fraction of the matter which is constantly being added to its mass. The ultimate particles existing in space must be aggregating and forming chemical atoms; these enter our atmosphere and form part of it.

I have frequently observed the beautiful auroræ with which we in Canada are so often favoured, and I could not repress the conviction that some attenuated form of matter was descending through the atmosphere from a radiating point above us, when the arches passed roughly from east to west, with waves of light near the zenith passing westward, and especially when a corona has formed at the zenith. Streamers radiating from that point reminded me so very forcibly of the meteoric shower of 1868 that I could not doubt but those radiating beams of light were the result of matter of some kind falling on the earth, as the star showers are known to be.

This view of the aurora finds support from the fact that bright meteors have been seen to fall passing parallel to the direction of auroral streamers, and the fact that the magnets in the Observatory of Itataya were violently disturbed during the fall of a meteorite which fell or rather passed very near it. (See note, page 119.)

We thus find a reason why magnetic storms, auroræ, and sun-spots are most numerous at the same time, namely, that a larger quantity of cosmic matter is in the central part of the solar system than at other times, which falling on the earth produces auroræ. The auroræ cause the magnetic storms, and large masses fall into the sun, producing sun-spots.

It is now time for us to ask if this affects the weather? To answer this question we must ask why more cosmic matter exists near the earth sometimes than at others.

If no planets existed moving around the sun in the same plane, our weather would be less varied. It is the action of the outer planets on the incoming cosmic matter which condenses it in some parts, causing it to move in streams at

The above diagram shows the rainfall in each year since 1840 The arcs of a circle represent the periods of Jupiter of which there are five. It will be noticed that each period ends with a heavier rainfall than the average, and this is followed by a dry year. If this is a law we should have a *wet* year in 1902 and a dry one in 1903. But as the more distant planets Saturn, Uranus, and Neptune will be disturbing factors a year plus or minus may be possible.

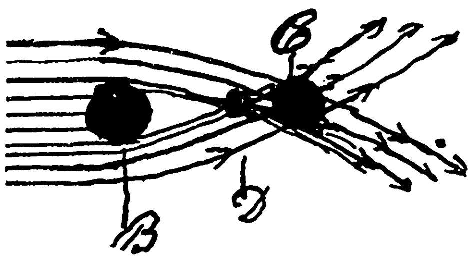
The late investigations of J. J. Thompson and of Arrhenius, on fractional portions of the chemical atom, seem to me to be in harmony with the views expressed in this paper.

some points, and scattering it in others, which projects incoming matter in paths sometimes wide off the orbits they would have followed but for planetary action.

The sun has a sphere of attraction beyond which its influence is practically nil; but the dimensions must be enormous. From the remotest parts of this sphere cosmic matter moves sunward, very slowly at first, but increasing its rate of motion as it draws nearer and nearer to the solar system. The distance from our system will be so vast that off in space the lines of their motion must be practically parallel.

And here it should be understood, that no matter whether my speculations as to the origin of the chemical elements are correct or incorrect, the fact remains that cosmic matter, solid and gaseous, really exists in space, and moves in orbits around the sun, and so far as the weather is concerned it does not matter how they originated.

Matter coming from beyond the orbit of Neptune, will, when moving in the medial plane of the planetary orbits pass near the orbits of Neptune, Uranus, Saturn, Jupiter and Mars before it reaches the *Earth*, and will have its path changed more or less by any and every planet which it may pass near to; and as those atoms and masses are passing sunward in vast numbers, and at greater or less distances from the planet, their paths will intersect and cross each other at a distance, as shown in the figure.



It is not possible to represent sizes and distances correctly in a figure, but it is easy to see if cosmic particles came into the system in the direction of the parallel lines and passed on each side of the planet B, they would cross and fall on an inner planet at C in greater numbers than at other points. If we suppose B to represent Jupiter and C the Earth, the earth would receive more meteoric matter when it was passing through this focus than before it reached it, or after it had passed through it. All the outer planets would act in the same manner on incoming matter, and this matter comes from all directions. Some will move *direct* and others *retrograde;* large numbers moving in opposite directions will collide, destroy each others' motion of translation, and fall on the planet within whose sphere of influence they may be at that time.

The great mass of the planets Jupiter and Saturn will probably cause them to be the disturbers of incoming matter, and we may consider them to be so situated as to act most powerfully to produce changes. They will shift their position in relation to each other constantly, and as Jupiter's period is 12 years and Saturn's 30, they will not be in the same position in relation to each other, and their position in the zodiac, for two revolutions of Saturn and five of Jupiter or 60 years, $12 \times 5 = 60$. So we have two cycles, one produced by Jupiter of 12 years, the other by Saturn of 30; and a cycle of 60 when both will act together. These may be causes of weather. Can we trace or find such cycles in our meteorological record?

Here is the rainfall record at the Toronto Observatory.

Sixty years ago Saturn and Jupiter occupied nearly the same position which they do this year (1902); we had a sun spot minimum in 1843 and a great rainfall, 43.55, and our average is only about 26.

Starting from 1843 as our zero year, we find a 12 year cycle fairly marked by rainfall, and this cycle ends in 1903. 60+1843=1903 which (if the theory is correct) should give us a plus from the Jupiter cycle. And again, two revolutions of Saturn starting at the same time also, end in 1903; so from this theory we should get 43 inches of rain next year. But all the other planets must have an influence of like kind; and to follow all the changes is beyond my power, and I give it up; but I still think that it will be done by some future meteorologists, and I wish our Mr. Stupart and other workers ultimate success.

NOTE TO PAGE 117.—This was observed by Dr. Massena at Itataya, Brazil, Aug. 7th, 1868. See Sci. Am., Oct. 28th, 1868.

## THE PLEIADES IN LEGENDS, GREEK DRAMA AND ORIENTATION. BY J. C. HAMILTON, M.A., LL.B.

(*Read 5th April, 1902.*)

Mr. Hamilton showed that the Seven Stars, by their gentle rays, impressed their image on the scroll of humanity in all ages. They were the clock stars of old astronomers, the guides of the mariner in his voyaging, and the husbandman in his seasons. The cluster was a familiar object in early British days. "Ye Old Seven Stars" is an inn in Manchester, whose license dates back to the reign of Edward III., in 1356, and the time of Chaucer. Guy Fawkes was here a visitor. Clubs of literary and social character took their names from the Pleiades.

The Seven Wise Men of Greece included Solon and Thales, the astronomer. Ptolemy Philadelphus had a Pleiad of Tragic Poets. Charlemagne formed a similar literary party, himself being one. Henry III. of France had his Great Pleiade, and Louis XIII. followed the example. In New England, there was a Pleiad of Yale poets, including Timothy Dwight and other ante-revolutionary men of learning. All poets have found them fit subjects for their muse. In "Locksley Hall," their rising is beautifully described. Wordsworth speaks of them, in his poem "Peter Bell:"

"The Pleiads that appear to kiss
Each other in the vast abyss,
With joy, I sail among them."

The cluster was affectionately regarded in Germany, Servia and Spain.

In the famous adventures of Don Quixote, that knight and Sancho Panza were made to pass the place where the "Little Nanny Goats," as they were called, were kept, and Sancho describes them inimitably. Thus the Spanish peasantry style these far-away, twinkling orbs.

Allusion was made to the customs in India, in reference to the measure of time and observing of feasts in honour of these stars. So, also, in China, where they are the Seven Sisters of Industry.

American legends as to them were discussed at length. They were also prominent in the religious ritual of the Aztecs and their successors in Mexico. In Peru, they were the gods of rain, and the year was counted, not by the sun but by them. The legends were very marked among the Blackfeet, Hydahs, Crees, Ojibways and Cherokees, of which interesting examples were given. While these are generally rudely drawn tales, inherited often from Asiastic ancestry, they have features in common; the persons represented are always seven, of whom one is lost or otherwise disappears.

The Blackfeet have a zodiac of 29 constellations.

Mr. Hamilton then discussed the beautiful references to these stars in the Agamemnon of Æschylus, and the Iphigenia and other dramas of Euripides.

In the building of temples and other public structures, reference was, by the Egyptians, Greeks and other ancient people, made to a particular star at its rising or setting. Such star was used as a clock, its light being made to fall into the temple an hour before sunrise, that time being fixed for the morning sacrifice. Among temples oriented to Alcyone, chief star of the Pleiades, were that of Minerva, at Athens, 1530 B.C.; the temple built in 1150 B.C., on the site afterwards occupied by the Parthenon; that of Bacchus, at Athens, and several others. The Jews avoided this custom as heathenish. The Temple of Solomon and the Tabernacle were so designed as to cause the worshippers to face west.

Ezekiel VIII., 16, refers, with abhorrence, to a place where worshippers faced the east and worshipped the sun. This was 500 years B.C.

The description of the Great Pyramid, as given by the late Professor Piazzi Smith in his book, "Our Inheritance in the Great Pyramid," edition of 1880, was referred to, who declares that the Pleiades were there, as also in old Mexican temples, specially honoured; but it was shown that later writers, such as Gerald Massey, dispute much of this theory.

Mr. Massey, so, also, comes into conflict with the theories expressed by Ernest de Bunsen and R. G. Haliburton, and limits the cult of the Pleiades very much to Greece and Rome and the races sprung from them.

The late work of Sir N. Lockyer and Dr. Penrose, F.R.S., in orienting Stonehenge on Salisbury Plain was lastly discussed.

They show that there was here a great Temple of Apollo, after the Grecian or Egyptian model, oriented to the Sun, and declare that it was erected about 1680 B.C., or 500 years before the fall of Troy, by people who were not ignorant of astronomy, and whose priests knew more of the arts than they are generally credited with.

Stonehenge was assumed to be the place referred to in Diodorus Siculus II., 47, as a sacred enclosure dedicated to the Sun-God, and by Caesar, de Bello Gal. VI., where he stated that its Druid priests taught of the movements of the stars, the size of the world, the nature of things and the power of the immortal gods.

Mr. Hamilton referred to certain legends connecting Stonehenge with the Pleiades.