THE SUN AND ITS OFFICE IN THE UNIVERSE.

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The sun, to us, is not only the largest apparent star in the universe, but also the most brilliant, and that which exercises over the earth the most dominant influences. It is from him that all the energies developed on the surface of the earth incessantly flow, and are continually and successfully carried on by the two hundred and thirty millionth part of the force radiated, which is all the earth is able to receive of the sun's rays. From him also, at epochs immensely distant from us, the planets have been thrown out successively, at first in the form of nebulous rings—agglomerations of matter which have in the end become condensed, and now form the planets of our system.

Compared with the mass of the earth, the mass of the sun is only about 355,000 times as great although its volume is 1,400,000 times larger, which indicates a less density. The matter of which the sun is composed is found to weigh but little more, volume for volume, than a quarter of that of which our own globe is formed. To express the weight of the sun in tons, by figures, would be useless—the number ranks among those which express nothing to the mind.

The light and heat received by our earth from the sun being taken as unity, the planet Mercury would be 6.673, and the planet Neptune, 0.001. Mercury is, therefore, lighted and heated nearly seven times as much as the earth; and the light and heat of the sun have an intensity 6673 times greater on the planet Mercury than at the surface of Neptune, where the apparent diameter of the solar disc is only 1min. 4sec. To compare and know correctly the calorific and luminous intensity of the sun at the surface of the different planets of our system, we must be acquainted with the nature of their atmospheres, and in what proportion the waves of light and heat are absorbed, in passing through those gaseous envelopes. Mercury, for instance, may have an atmosphere so dense that the soil does not receive more of the sun's influence than the soil of the earth.

It was in August, 1612, that Galileo wrote, in the second of his three celebrated letters, concerning the spots on the sun. "For the time to come," he says, "there will remain to physicists a field for speculations about the substance and manner of production of such vast masses as are the solar-spots, concerning which problem I would not venture to affirm anything." It is now more than two centuries and a half since Galileo discovered the solar-spots, and astronomers and physicists have speculated, and still speculate much to explain the phenomenon.

If the body of the sun be observed with a powerful telescope, the eye being properly protected, the enlarged image of the disc will usually appear more or less sprinkled with sun-spots —moveable belongings to the surface of the sun—which spots greatly help the study of the physical constitution of our luminary. The number of these spots follows a certain periodicity, which helps to establish a most interesting correlation between sun-spots and terrestrial magnetism.

When the sun-spots are observed with care during several consecutive days, they are found to vary both in form and position, amidst which variations there is one common and progressive movement in the same direction, from which has been deduced the rotation of the solar globe round an axis passing through its centre. This movement takes place from west to east, and fourteen days is the time during which a spot remains visible, and fourteen days is also the period which elapses between the diasppearance of a spot at the western border, and its re-appearance on the eastern. A point situated on the solar equator travels with a velocity of 4,560 miles an hour, or about $1\frac{1}{4}$ miles per second.

Sun-spots consist generally of one or more dark portions called *umbræ*, which appear black in comparison with the luminous parts of the sun's disc; around this dark portion is a grey tint, furrowed with dark striæ, this forms the penumbra. The spots are frequently composed of several umbra, inclosed in one penumbra, and sometimes the penumbra is not provided with umbræ. The penumbra frequently reproduces the principal contours of the umbra, and often presents a great variety of shades when examined with high powers.

The dimensions of the spots are variable, and are sometimes enormous; Schroter measured one which he found equivalent to sixteen times the surface embraced by a great circle of the earth, equal to four times the entire superficies of our globe, or more than 29,000 miles. Sir William Herschel, in 1779, measured a spot consisting of two parts, the diameter of which was not less than 50,000 miles. In August, 1839, Capt. Davies measured a sun-spot 186,000 miles in its greatest length.

According to Sir W. Herschel the surface of the sun is made up of "corrugations." Mr. Nasmyth describes the surface as having the appearance of "willow-leaves." Mr. Daws asserts that these interstices differ greatly in form and size—sometimes resembling an ill-shaped arrow-head, at others an irregular trapezium with rounded corners, and that they vary so much in these particulars as to defy every attempt to describe them.

To try and explain the phenomena, in such a manner that they can be connected with the sun's physical constitution, has been the employment of astronomers since the time of Alexander Wilson in 1774, and the results arrived at are such as to satisfy nearly all the conditions required:—

1st. There is a dark central mass.

2nd. There is a luminous stratum, or photosphere, enclosing the former.

3rd. There is a vaporous envelope in which the two are enshrouded, and which constitutes the real atmosphere of the sun.

4th. Is an outer chromosphere, lying on the surface of the luminous photosphere, enshrouding the whole, and through which the solar-spots, of various magnitudes, can all be seen during their formation.

Solar-spots are cavities, or openings of enormous size in the photosphere, and are caused by a down-rush or in-rush of outer vapour into the photosphere—or general plane of condensation for gaseous matter in the sun—which forms a cavity from 20,000 to 40,000 miles deep. On the 29th of August last I counted 42 of these spots, in three groups, on the surface of the sun while taking a transit, and about the same period there were brilliant displays of Aurora on three consecutive nights. On the 21st September I counted upwards of 70 sun-spots, the whole of which were immersed in the penumbra, and on the same evening appeared a strong Aurora. Sun-spots are now at a maximum, and Aurora displays frequent.

On the 26th of September, in company with Mr. Roblin, I counted 43 sun-spots and penumbra, and there were auroral displays on the 23rd, 24th, and 25th; the 26th was cloudy.

The truth of Galileo's opinion that the solar-spots have some relation to the planets has been verified, first by Schwabe of Dessau, and after by Lamont at Monaco, who individually found that the maximum and minimum of solar-spots, and of the variation of the magnetic needle had each a period of about ten years.

Contemporaneously with Lamont, General Sabine—who together with Hanstein investigated terrestrial magnetism—from observations made at two opposite parts of the globe (Toronto and Hobart Town), accomplished for the perturbation of the magnetic declination, what Lamont had done for the variations was intensity, and proved that a like period of about ten years was found for both inclination and intensity.

This period, observed in all the magnetic elements, precisely corresponded with that discovered by Schwabe for the number of solar-spots.

This isochronous periodicity has been further proved by M. Gautier, of Geneva, and M. Wolfs, of Zurich, each unacquainted with the other's researches, and ignorant of the observations of Sabine, Hanstein, &c.

Since these discoveries have been made, other relations of a different kind have been found to exist between the solar-spots and the position of other planets in the system ; not only the number or magnitude of the spots, but their position also is in part dependent on the places of the planets in space. The belief that the earth is a great magnet is of very ancient date, and the same power may be conceded to the other planets as being governed by the same laws. This was the opinion of Euler, Tobias Mayer, and Hanstein ; next came Gaus, whose system of terrestrial magnetism was what Newton's theory was to the solar system, as the law of magnetic force varies in inverse ratio of the square of the distance—just as is the case with universal attraction. The result of M. Gaus' investigations was a close agreement between theory and experiment.

There is, however, another phenomenon recognised in the Aurora, which is found to be produced by electro-magnetism, and is connected with the spots on the sun, their maxima and minima corresponding in every case.

It will be remembered by many members of the Society that on the 14th March, 1860, I had the honour to read, in connection with Colonel Broughton, R.E., a paper on "Atmospheric Electricity." At that time solar-spots were at a maximum, and there were some very beautiful displays of Aurora Australis. In the paper referred to I ventured on the following theory, viz., that the rapid rotation of the earth on its axis engendered a large amount of terrestrial magnetism at the poles, which becoming connected with atmospheric electricity, produced the beautiful corruscations which were then seen. My observations were sent home by Dr. Milligan, and forwarded to Professor Loomis, whose investigation of these and other records of the same nature enabled him to trace a period of about ten years for the maximum of sun-spots, of terrestrial magnetism, and of auroral displays.

Soon after that paper reached London I received a complimentary letter from a scientific meteorologist, who agreed with everything it contained except the theory of the production of the Aurora. Since that time, however, and only lately (December, 1869), Mr. Balfour Stewart, Director of Kew Observatory, read a paper before the Royal Astronomical

Society, on the auroral displays, between which and terrestrial magnetism he traced a connection.

This, as a theory, however, has been known since the time of Halley, who suggested that the phenomenon might be due to the passage of magnetism, from one magnetic pole to the other.

Although electro-magnetic power is so strongly developed in the universe, science has not as yet discovered the office it holds, or the part it plays in the movements so well known to be influenced by it. The dynamical theory, according to Faraday and Professor William Thompson, rests on no physical hypothesis whatever, but on the fact that *forces* emanate from the poles of magnets in certain directions, which are called *lines of force*, and occupy a magnetic field. If any body is plunged within this magnetic field, it disturbs or modifies these lines of force according to its nature. If magnetic it concentrates the lines, or draws them towards itself; if diamagnetic it causes them to diverge—thus originating attractive movements for magnetic bodies, and repulsive ones for those that are diamagnetic.

These two forces when applied to the sun, in the same way that we apply the term "gravity," are each capable of producing the same necessary consequences, both varying according to the inverse square of the distance, a property belonging to the law of nature, and which law is capable of being expressed by other terms better known to possess forces than the one in present use. The law of universal gravitation has this inestimable advantage—it may be reduced to calculation, and by a comparison of the results with observation, gives a certain method of verifying the existence of some such force.

To use the words of Laplace, and follow this motion from the departure of a planet on its perihelion passage, "the velocity is then at its maximum, and its tendency to recede from the sun surpassing its gravity towards it, the planet's radius vector augments and forms an obtuse angle with the direction of its motion. The force of gravity towards the sun, decomposed according to this direction, continually diminishes the velocity of the planet till it arrives at its aphelion. At this point its velocity is at a minimum, and its tendency to recede from the sun being less than its gravity towards it, the planet will approach it, describing the second part of its ellipse. In this part the gravity towards the sun increases its velocity in the same manner as it before decreased it, and the planet will arrive at its perihelion again with its primitive velocity and re-commence a new revolution as before. It is highly probable that this law extends from one planet to another, and to every distance from the sun."

To my mind this explanation of a planet's revolution round the sun requires the knowledge to be conveyed by some better term, without relying on the prestige of a name. From the various results obtained by analysis of the solar spectrum may be found the different forces produced by electro-magnetism, so abundantly provided for in the immense magnitude of, and power derived from, the sun.

Of late years a much closer relationship between the sun and the earth than was formerly supposed, has been proved by means of the Spectroscope; and we may consider that there is a still closer analogy between our own and other planets, so that as electric currents exist on the surface of the earth, similar currents exist on the surface of the other planets and of the sun. Venus, when in a crescent form, often appears to be covered with a phosphorescent light in the dark part, which indicates the presence of Auroras at the poles of that planet.

The sun is known to have a mean density equal to that of water, but not everywhere homogeneous or uniformly distributed. The radiation, therefore, to which the sun is subjected must greatly disturb the distribution of caloric, and develope a large amount of electricity, which is a perennial source of heat and light. "This heating force," says Professor Donatti, "which the sun produces through infinite space, when it comes to be confined in the bowels of the earth, is changed into that force which the magnet obeys; in this manner all motions are produced, whence arises heat, then electricity, magnetism, and light, which when combined form universal attraction, and eventually gravitation."

In solar chemistry, it is concluded with certainty, that in the sun's atmosphere, at a distance from us of 91,328,600 miles, the burning heat is produced by substances, the following of which have been found, viz.,—calcium, barium, magnesium, iron, chromium, nickel, copper, zinc, strontium, cadmium, cobalt, manganese, aluminium, titanium, and hydrogen. The lines of all these substances have their dark representatives in the sunlight, and are so characteristic and distinct as to leave no doubt of their presence. Many metals still remain undiscovered in the spectrum of the sun. There is exhibited in London a chromo-lithograph, which contains five hundred of Fraunhofer's dark solar lines, which, in all probability, have a representative in both the stellar and solar spectrum. In the former, especially in southern climes, where the atmosphere is clear, the stars are not all white; here and there may be seen, in beauteous contrast, richly coloured gems, red, orange, yellow, blue, green, purple, &c.; many of which are double stars exhibiting beautiful phenomena of complementary colours—yellow and purple, pale green and blue, orange and sea-green, yellow and sapphire blue, &c., &c. Coloured stars are also seen, with a good telescope, in small clusters invisible to the naked eye, such as ξ Crux, the area occupied by this object is about one-forty-eighth part of a square degree, and when viewed through an instrument of sufficient aperture, the object is extremely beautiful, giving the effect of a rich piece of fancy jewellery. Another such cluster in the same neighbourhood, about half a degree from η Argus, the constituent stars of which are equally brilliant and beautiful, is entered in the Cape observations as a neat cluster, but the colours are not named. These stars, either single, double, or in groups, are amongst the most beautiful objects to be seen with the telescope in either hemisphere, and when we consider that the colours of these stars are all produced by the same substances which we are so familiar with in the earth, we are taught that our knowledge of the universe does not depend only on the power of large telescopes, but that the human intellect may become familiar with things which the human eye cannot see.

It is known from various reasons that the stars are all suns, more or less chemically composed like our own sun; many of them are variable, some are known to have disappeared, and have not been seen since. Others, which before were invisible, have appeared, and remained visible since. About two years ago, there appeared a star of the ninth magnitude in the Northern Crown that all at once put on an unusual degree of brightness, and shone equal to a star of the second magnitude. The light of this star was examined by spectrum analysis, from which it was found to have been suddenly enveloped by flames of burning hydrogen. When the hydrogen was all consumed, the photosphere became less luminous, and the star returned to its former state.

The question which concerns us is, whether our sun is likely to undergo such a sudden change. The most recent observations show us that masses of hydrogen gas, in combustion, rise from the sun's photosphere many thousand miles in vertical height, and constitute the red prominences seen in total eclipses. If such should be the case with our sun—which the prolonged stability of our system does not justify us in believing—two opposite effects might naturally ensue. Either the cause which produces the gaseous evolution may gradually diminish so as to lessen the heat radiation; or this cause may augment and increase the power of the central fire: but in either case it is not certain that life would become extinct, although the altered conditions might gradually give rise to a new Fauna and Flora. We may then console ourselves without indulging in such flights of imagination as those so fitly pourtrayed by Lord Byron in his poem "Darkness":—

> "I had a dream, which was not all a dream.
> The bright sun was extinguished, and the stars
> Did wander darkling in eternal space,
> Rayless and pathless, and the icy earth
> Swung blind and blackening in the moonless air.
> Morn came and went—and came, and brought no day."

In concluding this brief paper I will mention a subject with which the Society is acquainted. Mr. Le Sueur, who had charge of the large Melbourne telescope, in his report to the Royal Society, London,—and contained in the President's address—makes the following statement relative to the star and Nebula η Argus:—"The Nebula around η Argus," says Mr. Le Sueur, "has changed largely in shape since Sir J. Herschel observed it; I believe the Nebula lies nearer to us than the fixed stars seen in the same field." Mr. Le Sueur also states his belief that the star η shines with the light of burning hydrogen, and thinks that the star has consumed the nebulous matter near it.

Without endorsing this opinion of Mr. Le Sueur, it is something to know that the fluctuations in the star η and its Nebula have another authority, notwithstanding there is pending a correspondence on several questions set forth on the altered features of η Argus with a view to obtain a solution, and a closer agreement between the drawings made at Hobart Town, and those made at the Cape of Good Hope, and in India; which, under the circumstances I believe to be impossible, as no two very dissimilar instruments will show nebulous matter alike—to detect small fluctuations will require patient watching over a length of time, with one and the same instrument (a standard) similar to the 18-inch reflector used at the Cape of Good Hope by Sir J. Herschel.