UNIVERSITY LECTURES.

ASTRONOMY.

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LECTURE VI.

Spots on the Sun's Surface.—Their changeable character.—Rapidity of their Expansions and Contractions.—Their Motions towards the Solar Poles. — Their Forms.—Where these Spots are the most numerous. — Arrangement in Belts or Zones.—Apparent changes arising from the Solar Rotation.—Opaque Mass of the Sun. — Enveloped in two Atmospheres.—The Interior one Transparent, with Clouds.—The Exterior one Self-Luminous.— Their Depth. — Theoretical Causes of the Spots.—Luminous Waves or Ridges.—Where seen. — Their Magnitude. — Vast Columns or Sheets of Flame, resembling our Northern Lights. —The immense Solar Forces in Constant Operation.—The Lecturer's Conjectures as to their Origin.—Supposition of some that the Sun is a Glorified World.—Amount of Heat radiated from the Sun in one Second.—Radiant Heat and Light is Motion, transmitted in the form of Ethereal Waves.—Heat of the Stars Measured.—Stellar Temperature of our Regions. — Immense Mountains of Solar Flame.—Spectroscopic Observations of the Sun and Stars, revealing their Elementary Constitutions, their Absolute Motions, Velocities and Directions.

ALTHOUGH the sun is by far the largest body of our system, yet we are comparatively ignorant of the nature of this vast luminary. Some have supposed it to be a vast globe of fire. But when viewed through a telescope, as we have already observed, large dark spots are seen upon the sun's disc. These spots are of different magnitudes; some are over 40,000 miles in diameter, while others are barely visible, being not over 500 miles in diameter. The spots appear to be perfectly dark, surrounded with a border or penumbra of a fainter shade. This penumbra is often of the same shape as the central dark spot, and frequently embraces several thousand miles of area or space; the shade of the penumbra wears a uniform aspect throughout its whole extent. Sometimes several dark spots of different sizes are embraced within the limits of the same penumbra. The number of spots is continually varying, sometimes there are none to be seen; sometimes only two or three; and at other times several hundreds. During the last century and a half, more or less spots have been seen every year; but they are far more numerous some years than in others.

These spots are continually changing their aspects. This arises from two causes, one of which is real—the other only apparent. The real changes may be described as follows:

First, they are observed to expand or contract in their dimensions. When they first make their appearance, the dark nucleus and the penumbra surrounding it are so small, as to be barely visible; these gradually expand from day to day, some with much greater velocity than others until they attain to various degrees of magnitude, from a thousand to forty or fifty thousand miles in diameter. Again, they are observed to contract—the sides gradually approaching, until from their smallness, they are rendered invisible. That these changes are not the effects of perspective, occasioned by the relative positions of the spots on the surface of the rotating globe of the sun, is demonstrated from the fact that in the same regions some spots are seen in the act of enlarging while others are diminishing; this could not happen from a change of their relative positions, for in such cases the relative positions remain the same; therefore the changes must be real. The time occupied in the expansions and contractions of these spots, follows no regular law—some have been seen to arise and vanish in less than one day—others continue for six weeks, but it seldom happens that they continue longer than this; though in some rare instances they have been known to continue for several months.

Second, it is also observed, as a general thing, that when the expansions are gradual, the contractions are also gradual—and when they enlarge suddenly, they diminish suddenly. These spots sometimes break in pieces, and the fragments recede from each other with very great velocity. The movements exhibited by the expansions contractions, and the receding of the fragments, in case the spots become broken, are carried on upon the grandest scale. A single second of angular measure upon the sun's disc as seen from the earth, would include an extent of 461 miles. A circular spot, therefore, of this diameter, would embrace an area, of about 167,000 square miles, which is the least space that is distinctly visible on that distant orb. But spots have been observed, embracing an area of about 2,000,000,000 of miles, whose diameters were over 50,000, miles.

Now such spots have been observed to close up and disappear in the short space of two or three weeks; the borders, therefore, of such spots must approach each other with a velocity of between one and two thousand miles per day. Sometimes very large spots have closed up within the short period of one day; their velocity, therefore, must have been equal to five hundred or a thousand miles per hour.

Third, besides the changes, observed in the dimensions of the spots themselves, it is also observed that they are not stationary on the sun's disc, but travel from one region to another with prodigious velocity, as we have already remarked in regard to the fragments of broken spots receding from each other in every variety of direction. But unbroken spots, instead of moving indiscriminately in all directions, seem to follow a more regular law in their movements; those on each side of the sun's equator, in most instances, gradually move towards the nearest pole with a velocity of four or five thousand miles per day.

Fourth, these spots are subject to numerous changes of form as well as of magnitude; these forms are constantly changing, sometimes being nearly circular; sometimes of an oval shape; at other times, presenting a variety of irregular figures. The exterior boundary of the penumbra always presents a curvilineal appearance, instead of sharp angles and straight lines, while the borders of the dark nucleus assume every variety of shape. When the penumbra is in the act of encroaching upon the nucleus, it sometimes divides the nucleus into two or more parts, and when the nucleus disappears, the penumbra remains visible for a short period, and then vanishes.

These spots do not appear on all parts of the globe of the sun, but are limited, generally speaking, to a zone extending from 30deg. to 40 deg. each side of his equator; spots are rarely seen beyond these limits; in the polar regions they are never seen. The equatorial belt or zone is less frequently visited by these spots than the adjacent zones, situated a few degrees to the north and south of the equator. The zone in the northern hemisphere, comprized between the 10th and 20th degrees is the most fertile in the production of spots—their numbers and magnitudes being greater than in the southern hemisphere.

Another circumstance worthy of remark is the arrangement of these spots. It is observed, that when the spots are numerous, they frequently arrange themselves in belts or zones parallel to the sun's equator.

We will next explain the apparent changes which these spots exhibit, arising from the rotation of the sun. If a large, well defined spot be observed throughout its passage across the sun's disc, it will exhibit the following phases:

First, when it is in the centre of the disc or in the middle of its path, the whole encircling penumbra, and the central dark nucleus will be distinctly visible.

Second, as the spot approaches the western limb, the penumbra on the side nearest to the eye of the observer will gradually become more and more narrow in the direction of the line of vision, while the penumbra on the opposite side of the nucleus from the eye, will apparently grow broader and broader; at length, as the spot arrives near the western limb, the eastern part of the penumbra, as well as the dark spot entirely disappears, while the western or more distant portion of the penumbra still remains visible until near the time of its passing the edge of the limb.

Third, after the spot is carried round on the opposite and invisible hemisphere by the sun's rotation, it will reappear near the edge of the eastern limb; in this position, the eastern portion of the penumbra will be seen first, then the dark nucleus, then the narrow portion of the western or nearest side of the penumbra which, as the spot approaches the middle of its path, will widen out, and at length, when it has gained about the same relative position it had at the commencement of the observation, it will again exhibit nearly the same appearance. These are not real changes, but apparent, arising wholly from the effects of perspective. Every spot which crosses the sun's disc is observed to present the same aspects, so that the law is ascertained to be universal. These apparent changes can, perhaps, be more clearly perceived, if we picture to ourselves an artificial globe suspended over our heads with holes or pits in its surface, with shelving sides and black bottoms; as the globe is made to rotate, so that the upper surface shall move from west to east, it is evident that the under surface will move from east to west. When one of these pits is directly on the underside, the shelving sides, surrounding the pit will represent the penumbra, and the dark bottom of the hole will represent the black nucleus. As this artificial globe slowly rotates, the hole and shelving sides as they are brought near the western side, will exhibit the same aspects as the solar spots already described; the shelving side next the eye will be lost sight of first, then the bottom of the hole, and then the most distant shelving side. Similar, but opposite phenomena would happen as the spot reappears on the eastern limb.

From a careful and attentive consideration of all the observed phenomena, relating to the sun's spots—to their forms, magnitudes, and motions, both apparent and real, we are almost irresistibly led to the conclusion that the great body of the sun mainly consists of a dark mass of a similar nature to that of the earth and other planetary bodies—that this opaque mass is surrounded by two atmospheres several thousand miles in depth—that the lower one next to the opaque globe of the sun, is transparent—within the upper stratum of which float innumerable clouds—the thickness of the cloudy stratum being greater or less in proportion to the various degrees of density existing in the layers of which it is composed—that the loftier or exterior atmosphere consists of a self-luminous phosphorescent gas, radiating light and heat to the surrounding worlds.

On this theory the dark mass of the sun is protected from the destructive influence of the heating power of its upper atmosphere by the intervention of the cloudy stratum, which serves as a kind of shield or veil. But what are these dark spots? And what are the encircling penumbra which surround them? According to this theory, the dark spots are portions of the surface of the dark globe beneath, seen through the openings occasionally formed in the luminous and cloudy strata. The penumbra are the dark clouds which lay beneath the shining fluid or nearer the body of the sun; the luminous fluid being driven aside, the clouds below reflect a portion of the light which they receive from the shining fluid above. These openings are formed from some unknown force below. The depth of these atmospheric openings have been approximately ascertained by taking the angular measurements of the sides when near the eastern or western limb, at which time the most distant portions of the penumbra appear broader in consequence of their planes being nearly at right angles to the line of vision; this, therefore, is the most favorable position for taking their angular measurements. The depth is thus ascertained to be from 2,000 to 4,000 miles.

Besides these openings in the luminous and cloudy strata, there are other spots which have a brighter aspect than the surrounding medium; these apparently exist in the form of immense waves or ridges in the luminous regions of the exterior atmosphere. These ridges are more distinctly seen towards the eastern or western margin of the sun; when they are brought by the sun's rotation across the central portions of the disc, they uniformly disappear and remain invisible for four or five days. This is what would naturally take place, admitting that they are waves or ridges; for such elevations would, from their position relative to the line of vision, be seen when near the edges of the disc; but when near the middle of their path, or in front, they would be foreshortened, and consequently disappear.

These immense ridges are principally confined, like the dark spots, to a zone extending about forty deg. each side of the sun's equator; they are seldom seen at a greater distance. Some of those immense waves extend over a space equal to 75,000 miles; others are smaller; they are frequently changing their form and also their position.

It has also been observed that those parts of the sun's disc, where no spots exist, do not exhibit a uniform brightness, but present to the eye a surface finely dotted with minute black pores which are in a constant state of change, as if the luminous medium were intermixed or floating within the transparent non-luminous atmosphere in vast sheets or columns of flame, resembling the sheets or columns of our northern lights. It is evident that such columns, streaming forth in lines perpendicular to the surface, would present the appearance of a finely mottled surface of darkness and brightness—the spaces intervening between the vast columns of light would evidently appear dark; and as these great sheets of flame are constantly darting up in new places and vacating their former positions, such a condition of things would exhibit a constant change in the position of the dark dots or pores. If an observer could be placed a few thousand miles above the surface of the earth in our northern regions, and look down upon the northern lights, darting upwards from the earth's surface through the atmosphere, they would, probably, behold in miniature a faint resemblance of some of the grand phenomena displayed upon the sun's surface.

The spots—the immense ridges—the variegated or mottled appearance of the general surface—the vast changes to which they are all subject in form, in magnitude, and in position—the occasional breaking to pieces of large spots and the prodigious velocity of the fragments. as they recede from each other—the proper and more regular motions of the spots themselves, as they move upon the surface towards their respective nearest poles—all indicate the operation of sudden and tremendous forces either originated by the solid body of the sun itself, or generated within his atmospheres. How inconceivably powerful must be those forces which can burst asunder the great ocean of clouds and light, surrounding that vast orb, which can roll aside the billowy deep, and expose the immense foundations on which it rests; extending over an area of 2,000,000,000 of square miles! How tremendous must be the force which can roll up the surface of that luminous ocean to the height of several hundred miles above its mean level, forming an immense wave of light, extending seventy or eighty thousand miles in length! How grand and magnificent must be the scenery, to behold the dashing, surging, whirling movements of these immense elevations as they roll in awful majesty around the circumference of that shining. globular ocean of light!

Whatever these forces may be, it is evident that they are connected in some way with the rotation of the sun upon its axis; this is indicated by the tendency which the spots have to arrange themselves in zones parallel to the equator.

But what are these forces? We are not aware that any philosopher has ever attempted to answer this question. We will venture to offer a few conjectures or speculations upon this subject, not, however, without diffidence, knowing how liable we are to be mistaken, when we venture beyond the limits of demonstration. It is known that heat, light and electricity are evolved, in a greater or less degree, by chemical operations. Now these agents, doubtless, do exist in a latent state in greater or less quantities in connection with all the materials of which the great globe of the sun consists. Reasoning from analogy, we can, with propriety, suppose that there are great chemical operations taking place among the sun's materials, as well as among the materials of our globe. If so, heat, light, and electricity would necessarily be set free. Now let us suppose that the materials in the sun's equatorial regions are more favorably situated for great chemical changes than elsewhere, it is evident that those regions would be raised to a higher temperature and the atmosphere immediately in contact with the surface would partake of this temperature, and becoming specifically lighter would arise; this upper or ascending current would have a velocity proportional to its relative temperature, and the rushing in of colder currents from the polar regions of the solar orb would have the same proportional velocity; the exterior atmosphere being much lighter than the interior would exhibit far greater changes and displacements. All these currents would be modified more or less by the sun's rotation, producing phenomena very similar to those of our trade winds. The upper currents of the dense transparent atmosphere would necessarily be inclined towards the solar poles; and in their progression thither they would be subject to many fluctuations which no doubt would frequently burst asunder the clouds and luminous atmosphere above, through which we could gaze upon the dark body of the sun beneath; as the immense wave rushes towards the poles successive portions of the luminous fluid above is flung aside, which will account for the progressive movement of the spots towards the nearest poles, and which will also account for the vast ridges or elevations and depressions observed. Moreover, the electric fluid, set free by chemical operations, would be conveyed or conducted to the higher regions, where it would stream forth in sheets of flame or columns with greater or less intensity, constantly varying their positions, producing all the phenomena already described, and accounting for the lack of uniform brightness on the sun's surface.

These conjectures are merely thrown out before this audience, though by no means matured. Hypotheses are frequently useful, when made stepping stones to truth, but never should be received as truth, only when supported by a vast collection of facts.

Some, perhaps, may be inclined to suppose the sun in a much higher state of progression than the earth. They may suppose it sanctified and glorified, and that it now occupies a place among the celestial order of worlds, and that the robe of light which it now wears is nothing more nor less than a cloud of celestial light and glory from the presence of the Lord. Be this as it may, it does not invalidate the theory of its being still governed by laws of heat, light, and electricity. A glorified celestial body is still under the dominion of laws, though such laws, in some respects, may differ from the laws governing worlds of a lower order. If we were certain that the sun was a redeemed glorified world, this should not prevent us from endeavoring to search out, as far as possible, every law connected with his physical constitution, or with the various phenomena observed. Indeed, such knowledge, instead of being an obstacle in our way, should inspire us with a still more ardent desire to search out the more glorious works of that Almighty Being who governs and controls all of His creations, by laws of His own prescription.

The actual amount of heat radiated from the sun's surface, may be estimated approximately, by exposing given surfaces of material bodies to the vertical action of the sun's rays. The intensity of heat varies inversely as the square of the distance. And by making the calculations founded upon this law, we find that the heat at the sun's surface must be about 46,000 times greater than at the distance of the earth. Now by observing, with a thermometer, the sun's heating power in a given time, say for instance one second, on surfaces exposed vertically to his rays, and multiply this by 46,000, the product will be the intensity of heat at the sun's surface. Again by multiplying the superficial area of the sun's surface into its temperature, the product will be equal to the total amount of heat radiated from that body in one second; this is found to be sufficient to