Observations on the Zodiacal Light, tending to show its Connection with the Sun's Motion in Space. By H. SKEY.

(With Illustrations.)

[*Read before the Otago Institute, 12th March,* 1872.]

THE remarkable illumination in the heavens, known as the Zodiacal Light, is visible just after sunset, when the air is very clear, during the months of March and April, and again, just before sunrise, during the opposite months of September and October, and follows in a general direction the course of the ecliptic, or, according to Sir John Herschel, that of the sun's equator. Its apparent angular extent from the sun at its base to the vertex of the cone of illumination varies from 40° to 50°, and sometimes even to 90°, with a breadth varying from 10° to 30°. It has been conjectured that it derives its form (that of a lenticularly formed envelope) by its rapid revolution with the sun on its axis, only the upward half of which we see at one time, the other half being below the horizon.

An insuperable objection, however, to this explanation must at once present itself. If we see the upward half of this figure just after sunset, in March, what is there to prevent the other half from being seen during the same month in the mornings, just before sunrise? Why have we to wait till the opposite season?

It follows, therefore, that whatever may be the cause of this illuminated cone, it exists on one side only of the solar orb; and the next step is to account for its visibility at one time of the year only in the evenings, and at the opposite season only in the mornings. Let the accompanying figure (Pl. XIV.) represent the earth's annual motion along the ecliptic, the small arrows indicating the direction of its diurnal rotation; then, as the Zodiacal Light during September is visible in the mornings, it follows that the direction of the cone must point towards some portion of the earth's orbit lying between September and March. For reasons hereafter adduced, let us assume it as constantly extending towards the earth's position early in December (as far as longitude is concerned), and examine the appearance it would present in March, when the earth has arrived at a diametrically opposite part of its orbit.

It will be seen on reference to the diagram that the Zodiacal Light can then only be visible in the evenings, just after sunset, when its extremely delicate illumination ceases to be overpowered by the direct solar light.

In accounting physically for the existence of matter, or of a medium susceptible of illumination, on the one side only of the sun, let us consider the direction of the sun's proper motion in space in connection with some inter-

stellar and resisting medium. From the investigations of astronomers and mathematicians, conducted in a variety of ways, there cannot remain a shadow of a doubt of the reality of solar motion, or as to its direction in space to a point near to Right Ascension, 261° 29′; and to North Polar Declination, 65° 16′, which are the results deduced by Mr. Airy. The point determined by M. Argelander is in R. A., 256° 25′, and N. P. D. 51° 23′, resulting from the examination of twenty-one stars having a proper motion exceeding one minute per annum in arc. The velocity of the sun's motion relatively among the stars, according to M. Otto Struve, is 422,000 miles, or nearly its own semi-diameter per diem.

With a velocity approaching to this, it is not difficult to conceive the effect it must have on the solar atmosphere, if the existence of a resisting medium can be demonstrated. Perhaps the best proof of such a medium is in the observation of comets. They are known to be bodies of extreme tenuity, and Encke's comet has a period of revolution round the sun which is continually diminishing, proving that it is gradually approaching that luminary. The solution proposed by Encke, and the one generally adopted, is that it is retarded by a very rare ethereal medium pervading the regions in which it moves.

In the diagram, the direction of the sun's motion, as projected on the plane of the ecliptic, is shown as Right Ascension 261° 29′, but the North Polar Declination of its motion being 65° 16′, its course will be obliquely upward on the north side of this plane. Here we must consider the difficulty of determining with exactness the direction of the solar motion. Sir John Herschel remarks, "The whole of the reasoning upon which the determination of the solar motion in space rests, is based upon the entire exclusion of any law either derived from observation or assumed in theory, affecting the amount and direction of real motions both of the sun and stars. It supposes the non-recognition in those motions of any general directive cause, such as, for example, a common circulation of all about a common centre."

I might thus illustrate the case. During a calm at sea the smoke from an ocean steamer would give the exact direction of its motion, both when the water was motionless, and also if it was influenced by an ocean current. A ship might be steaming in a northerly direction, and a current might be moving westerly; if both velocities were the same, then the true motion of the vessel would be north-west, as also manifested from the line of smoke; and a person in the ship taking observations on other ships also moving in the same current, but otherwise stationary, would conclude that his ship was moving due north, but in reality the line of smoke would give the resultant of all the compounded motions affecting the vessel. Similarly we may be unable

to determine the sun's true direction in space by the apparent proper motions of the stars, for we may suppose a general movement of the stars in the sun's neighbourhood as drifting in a line parallel to the sun's equator (the most reasonable direction by analogy), then the direction of the Zodiacal Light would be brought nearer still to its observed direction.

From modern researches in solar chemistry we are certain of the existence of the vapours of many metals, and also hydrogen, in the sun's atmosphere. Substances, therefore, of extreme tenuity exist in the vast laboratory of the solar orb. Portions of these substances, under the influence of heat repulsion, must exist at a considerable elevation above the surface, and when subjected to such commotions as have been actually observed (120 miles per second) would be transported to such a distance from the sun as to preclude their revolving around the sun in the same time; moreover, on account of their sudden translation from near the sun's surface to such an increased distance from the centre of diurnal rotation of the sun, some time must elapse before they acquire the additional velocity required. Such masses therefore lag somewhat behind in their daily rotation, and in consequence of the sun's proper motion accumulate in rear thereof. Other portions doubtless might become detached from time to time, forming comets with greatly elongated orbits, having their perihelion passages very close to, and in advance of, the sun's motion until perturbed by the planets.

It becomes interesting to enquire whether the earth ever comes in contact with any portion of this matter, and if so in what part of its orbit?

The illuminated medium known as Zodiacal Light has sometimes been observed reaching our zenith, proving that it extends at times to a distance from the sun fully equal to that of the earth; therefore, if its direction from the sun were truly on the plane of the ecliptic, then the earth must pass very near, if not actually through, its cone, and this at a certain fixed time aunually.

In the diagram the cone is drawn on the ecliptic in Right Ascension 261° 29′. If the general direction of this cone extending from the sun were stationary, then the earth would pass very near, if not actually through, it early in December; but it must be borne in mind that the constant attraction of the earth for months too before it reaches this part of its orbit must hasten the time of contact. The November meteors appear to furnish convincing proof of such collision. They were observed in the year 472 (the sky appeared to be on fire over the city of Constantinople, with coruscations of flying meteors); next by the Moravian missionaries in Greenland, and by Humboldt in South America, in which the whole sky was filled with fiery particles, thick as hail, for four hours. Mr. Ellicot also observed these near the West India islands, when the whole heavens appeared as if illuminated

with sky rockets, moving in all directions, excepting from the earth, to which they all seemed inclined more or less, some of them descending perpendicularly over the vessel he was in. They were again seen in the autumn of 1818, when in the language of one of the observers, the surrounding atmosphere seemed enveloped in one expansive ocean of flame. The next exhibition on the grand scale was in November, 1831. This was followed by another in 1832, at the same time. The most splendid display was in November, 1833, when the whole sky is said to have been lit up with these meteors and immense fire-balls. One was observed nearly stationary in the zenith for some time, emitting streams of light. Luminous trains marked the path of these meteors, which remained in view for some minutes. This remarkable fact was established, that they all moved in lines which, when traced backwards, converged to the same point in the heavens. The position of this radiant point among the stars was near Leo, which point remained stationary among the stars during the whole exhibition. They were again observed, but on a smaller scale, in Europe and America, in November, 1834, tending, moreover, from the same radiant point. No less than twelve displays have been noticed. They are also found to be more frequent every thirty-three and a quarter years. Accordingly they were anxiously looked for in 1866, at which time they also made their appearance, and their radiant point fixed in reference to the ecliptic in long. 142° 35′, and lat. 10° 27′ N. Now it must be regarded as a very significant fact, that if this point is projected on the plane of the ecliptic it would be very nearly in a line with a tangent to the earth's orbit on the 13th of November. It follows, therefore, that the earth is moving very nearly towards their radiant point. Taking the velocity of the earth in its orbit at twenty miles per second, and the mass and source of the meteors as stationary (excepting, of course, the retrograde velocity imparted to the mass by the earth's attraction, and which would increase the collision), then the compression suddenly exerted on the meteoric matter, and on a portion of the earth's atmosphere, must be enormous, and far quicker than the rate of diffusion which gases are known to possess. Portions of the earth's atmosphere must be arrested, as it were, and its motion partly communicated to unmixed and contracting portions of the meteoric matter, which manifests itself by intense heat. The common experiment of compressing air in a glass syringe, thereby igniting various substances, will give some idea of the heat actually developed. From the suddenness of compression, there would not be time to allow at first the radiation of this heat; consequently ignition must occur, attended, probably, with new chemical combinations, and when that commences, a few seconds suffice to dissipate the smaller meteors; and the larger ones, when they reach the denser atmosphere near the earth, remain for a time suspended (as proved by actual observation);

further contraction then ceases, their heat is radiated, and their gases become diffused in the atmosphere.

That these November meteors differ from the aerolites which have been known to have reached the earth at various times, is clearly proved by none having reached us in a solid state, notwithstanding their extraordinary numbers. The presence of aerolites is also accompanied with loud reports, which are absent in the case of these meteors; surely if they were solid bodies some would have reached the earth and exploded.

Their retrograde motion might be cited as another proof.

It is worthy of note that during the month of December the earth is situated on the sun's equatorial plane, and it appears that it is near its equatorial regions that all the forces emanating from the sun (motion included) are principally exercised.

Notes on the Zodiacal Light. By J. S. Webb.

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Having recently met with an account by Signor Respighi of some spectroscopic observations of the Zodiacal Light, I felt interested to ascertain how far the facts indicated are compatible with the theory broached by Mr. Skey, in the paper he read at our meeting in March last (see preceding article). Looking for other information on the subject to assist the inquiry, I was surprised to find how little was to be obtained. This being so, I have thought that I should render what I have to say more interesting by prefacing it with a general account of this interesting and ill-understood phenomenon.

The account of the Zodiacal Light given by Sir John Herschel is substantially the same as that to be found in Mr. Skey's paper. It has remained unchanged throughout the successive editions of his "Outlines of Astronomy," although some interesting additions to our knowledge of the subject have been made in the meantime. I think Mr. Skey has been somewhat misled by this, as he lays stress on the fact that the Zodiacal Light is, as stated by Herschel, only visible about the vernal and autumnal equinoxes, and for a few weeks before and after those dates, whilst in point of fact it is visible all the year round, or nearly so. This error does not, as it appears to me, invalidate Mr. Skey's theory, but a knowledge of it would probably have led him to alter his diagram (Pl. XIV.) somewhat, and to avoid some of the remarks he has been led to make.

After a search through all the books accessible here which were likely to afford any information, I found the best account of the Zodiacal Light where I least expected it, namely in the introductory notes to Keith Johnston's "School Atlas of Astronomy." These notes are by Mr. J. R. Hind, and I