SHOOTING STARS.

We have seen that Chladni, in his "Reflections on the Origin of Divers Masses of Native Iron, and Notably of that Found by Pallas in Siberia," published in 1794, considered shooting stars to be exactly the same as meteors, fireballs, or bolides, only passing at great distances from the surface on the earth. That distance he held to be the only cause of the small apparent dimensions they offer to our view. But observation has revealed a circumstance which prevents our adopting those notions respecting their real nature.

At certain epochs there occurs a considerable increase in the number of shooting stars seen within a given time. The frequency of their appearance even becomes so great as to give it all the character of a veritable shower of stars. If shooting stars and bolides were really identical, the latter, together with the showers of aerolites which often accompany them, ought especially to show themselves at the same time as the grand displays of shooting stars. Now, nothing of the kind takes place. The two sets of phenomena appear to have no connection whatever with each other. Shooting stars seem to be of a nature peculiar to themselves; and it is only by studying them directly that we can hope to obtain information respecting the cause of this curious phenomenon.

No doubt, as soon as it is granted that meteors are solid bodies existing in space, which the earth falls in with while revolving in her orbit, it is very natural to admit that something analogous is the cause of shooting stars, and to regard them also as betraying the presence of certain bodies in the portion of space traversed by the earth. Nevertheless, the capital circumstance just pointed out, and from which it results that meteors and shooting stars constitute two distinct orders of phenomena, has raised and left doubts respecting the real nature of shooting stars. Some philosophers have persisted in assigning to them a purely atmospheric origin, and have even endeavored to find in them a clue to the meteorological phenomena of which our atmosphere is the seat. Recent discoveries, however, have removed all doubt upon the subject; the atmospheric theory of shooting stars must henceforth be abandoned. We will succinctly follow Mr. Delaunay in his statement of the clear and precise notions respecting this matter which we now possess.

The first thing to be done, in the study of shooting stars, is to ascertain their distance from us. The observations required for that purpose are very simple. Two observers stationed at different spots sufficiently distant from each other, will not behold the same shooting star to be tracing the same course across the firmament. The straight lines drawn from the two places of observation to the shooting star will cross at that point (namely, the shooting star), and then diverge until they reach two different points on the celestial vault. Other circumstances being the same, the two points of the celestial sphere on which the shooting star is projected at any given instant, for each one of the two observers, will be the more distant from each other the nearer the shooting star is to the earth. Hence it will be easily understood that, by certain calculations which there is no need to detail here, the height of a shooting star above the earth's sunface may be ascertained from data, furnished by its simultaneous observation at two different spots. It is the same process as the method employed by astronomers to determine the parallax of a heavenly body, and consequently its distance from the earth.

The first observations in accordance with this method date from 1798. They were made by Brandes and Benzenberg, then students in the University of Gottingen. Until then, there existed no observations of shooting stars: except that Bridone, in his "Tour through Sicily," states that he saw them exactly the same, from the summit of Mount St. Bernard, in Switzerland, and of Mount Etna in Sicily, as on the sea shore. The conclusion was, that a very considerable altitude may be assigned to shooting stars. By comparing the different results obtained between 1798 and 1863, Alexander Herschel (the grandson of William) found the average height of a shooting star above the earth to be, at the commencement of its appearance, one hundred and thir teen kilometres, and at the end eighty-seven. Mr. Newton, of New Haven United States, arrived at the respective numbers of one hundred and eighteen and eighty-one kilometres; Father Secchi, of Rome, found them to be one hundred and twenty, and eighty kilometres respectively. The agreement between these different results is as satisfactory as can be wished. We may fairly take Secchi's figures as representing in round numbers the average height of a shooting star above the earth, at the beginning and at the end of its appearance. Those figures, reduced to English miles, also in round numbers, are seventy-five and fifty respectively. Seventy-five miles above the earth's surface being not an extreme but an average height, it must be allowed that the first appearance of shooting stars occurs at a very considerable altitude.

The velocity with which shooting stars move is more difficult to determine than their distance from us. It is certain that their speed is great, compared with the velocities which we have occasion to observe on the surface of the earth; but the numerical value of that speed still remains so indeterminate that it is absolutely impossible to make it the base of any conclusions. It cannot be employed for determining the orbit described in space by the moving body to whose presence the phenomenon is due. Nevertheless, the determination of that orbit is very important, and it will be easily understood that observers have turned their attention in that direction.

When it is proposed to determine the orbit of a new star, planet, or comet, the first thing is to observe it as accurately as possible, in three different positions. The data furnished by these three observa ions suffice to deduce from them the orbit of the star; and the more distant from each other the three positions are in which the moving body has been observed, the more correct is the result. A like mode of proceeding is evidently impracticable for determining the orbit described by a shooting star. The short duration of its visability does not allow it to be observed in three distinct positions with the requisite precision; which precision ought to be all the greater, because the three successive positions can only extend over a very small arc of the trajectory of the moving body. It is only by combining the knowledge of the position of the shooting star, at a given instant, with the amount and direction of its velocity at that instant, that we can hope to succeed in determining the orbit which it describes. The great difficulty of the question lies in discovering the rate and the direction of the velocity. It has just been stated that it is almost impossible to make this much-needed discovery by direct observations. Astronomers have succeeded in overcoming the difficulty by considering the phenomenon of shooting stars as a whole, instead of persisting in the observation and study of these luminous bodies one by one.

The most striking feature of the curious phenomenon we are examining, is the occurrence of extraordinary displays of shooting stars. Brandes relates that, on the 6th of December, 1798, while travelling to Breme in a public conveyance, he counted four hundred and eighty through one of the diligence windows; from which he reckons that at least two thousand must have appeared in the heavens during the course of the night.

In the night from the 11th to the 12th of November, 1799—the above dates are important to note—Humboldt and Bonpland witnessed, at Cumana, in South America, a perfect shower of shooting stars. The phenomenon, already remarked in the evening, acquired great intensity in the middle of the night, and continued to increase until 4 in the morning, when it gradually diminished until daylight. Bonpland says that there was not a portion of the sky equal in extent to three times the moon's diameter, which was not every instant full of shooting stars. The inhabitants of Cumana were frightened at this unusual sight. The oldest amongst them remembered that the great earthquakes of 1766 had been preceded by a similar phenomenon.

These extraordinary facts were in some measure forgotten, when a fresh shower of shooting stars was observed in America on the 13th of November, 1833. Professor Olmsted, of New Haven, published a very important memoir on the subject. Calculating from the data sent to him, he estimated the number of shooting stars, which were seen at certain spots during the nights of the 12th and 13th of November, at more than two hundred thousand. The numerous accounts recorded of this event, and the publicity given to it by the journals, recalled the general attention in this direction, and everybody began to watch the case more carefully than hitherto. Regular observations of shooting stars were organized, and little by little there resulted from them a clearer idea of the general course and march of the phenomenon.

In Olmsted's opinion, the grand November display was periodical, and ought to recur every year at the same epoch. It was ascertained, in fact, that every year, about the 12th and 13th of November, there was a very marked increase in the number of shooting stars appearing in the sky; but that was far from reproducing the extraordinary spectacle beheld in America in 1833. In 1837, the astronomer Olbers wrote: — "Perhaps we shall have to wait till 1867 before we witness a repetition of the magnificent phenomenon presented to our view in 1799 and 1833:" a bold prediction which we saw completely realized a year sooner, namely, in 1866. The remembrance, by the inhabitants of Cumana, in 1799, of the grand shower of shooting stars beheld in 1766, doubtless contributed not a little to Olbers' belief in the periodical return of a like exhibition every thirty-three or thirty-four years.

But even in its reduced proportions in the years following 1833, the November phenomenon was not the less interesting to study. And soon afterwards M. Quetelet announced to the Academie of Brussels that the night of the 10th of August rivalled, in respect to the number of its shooting stars, that of the 13th of November. The facts fully confirmed his assertion; and the more closely they were observed, the more importance they gave to these periodical meteoric displays.

The first singular circumstance remarked was, the variation of the intensity of the phenomenon at different epochs of the same year. An *annual variation* was soon indubitable. Afterwards, by watching what takes place, not during the course of an entire year, but every night, it was found that, even in this short interval of time, there is a manifest variation in the frequency of shooting stars. This gives us a *diurnal variation*, taking a day to mean twenty-four hours. Moreover, although these so-called stars are seen to shoot from every quarter of the heavens, close examination shows that the different quarters do not furnish equal quantities of shooting stars. There is also, in this ressect, a variation, which is called the *azimuthal* variation. For instance, a great many more shooting stars start from the east than from the west; while, on the other hand, about as many come from the north as from the south.

The existence of these variations, annual, diurnal, and azimuthal, was for a long time the stumbling-block of the astronomical, or cosmical, theory of shooting stars; namely, the theory which attributes the phenomenon to the earth's successively encountering, while travelling through space, a multitude of small bodies dispersed in it. These variations were the ground on which some philosophers refused to acknowledge shooting stars to be anything else than atmospheric meteors, entirely originated and developed in the atmosphere which surrounds the earth. Thus, Humboldt, in his "Cosmos," says:—"It is difficult to guess what influence a more advanced hour of the night can exercise on these phenomena. If it were established that, under different meridians, shooting stars began to be visible at a fixed hour, we should be obliged to admit (if we wish to maintain the astronomical theory) the supposition—improbable in itself—that certain hours of the night, or rather of the morning, are more favorable to the inflammation of shooting stars, and that, during the preceding hours, some of them remain invisible."

In fact, if the phenomenon of shooting stars be occasioned by the earth's meeting a multitude of small bodies dispersed in space, what can be more natural than to admit that these encounters take place as much at one date as at another—as much at one hour of the night as at any other hour of the night; in short, that the phenomenon will occur without any periodical variation?

M. Delaunay, however, clearly shows that in consequence of the earth's motions of translation and rotation, uniformity in the appearance of shooting stars cannot exist. On the contrary, he demonstrates that, with the astronomical theory of shooting stars, the annual, diurnal, and azimuthal, variations must necessarily occur at every localify, under the very circumstances which are observed to show themselves; so that these remarkable peculiarities, which were long considered very serious objections to the astronomical theory, are really, on the other hand, proofs of its truth. We learn from this how mistrustful we ought to be of the first impressions which strike our minds, however probable they may appear, until they have been submitted to scrupulous and searching examination.

The reasoning by which M. Delaunay works out his proposition is too lengthy and too full of illustrative details to find room here. The inquiring reader, who does not care to take anything for granted, is referred to the original "Notice," which is so lucid and logical as to be easily understood by any clear-headed person familiar with French, who will peruse it slowly and with steady attention. We, therefore, simply repeat the statement that the three variations—annual, diurnal, and azimuthal—observed in the appearance of shooting stars, instead of contradicting the astronomical or cosmical theory of that phenomenon, and furnishing, as was believed, capital objections to its adoption, are, on the contrary, completely in harmony with it. According to that, then, there is reason to think that shooting stars are due to the earth's successively encountering a vast number of small bodies which circulate in celestial space, which reach from all quarters with velocities absolutely equal among themselves, or at least very nearly equal. Moreover (it has been concluded from the characters presented by the diurnal variation), the velocity in space of shooting stars must be greater than that of the earth in her orbit, and but slightly different from the velocity which would cause a comet travelling from the depths of space to make a near approach to the earth.

Another observed fact: At the times when the phenomenon of shooting stars occurs in its greatest intensity, namely, about the 12th and 13th of November, and the 9th and 10th of August, the shooting stars, instead of coming indifferently from all the regions of space, come almost all from determinate directions. One set, those of November, started from the constellation of the Lion; the others, those of August, from the constellation Perseus. This circumstance led to the separation of the shooting stars into two distinct classes. One class consisted of the regular streams which the earth periodically encounters every year, at epochs of the same date; those are periodical shooting stars. The others, on the contrary, wandering singly in space, in all possible directions, fall in with the earth indifferently on all sides; they are called, after Olbers, "sporadic" shooting stars. The shooting stars of the periodical November flood have received the special name of Leonides, from the constellation Lion, whence they seem to issue; those of the August flood, in like manner, have received the name of Perseides.

A further step in the inquiry was this:—M. Schiaparelli, having found the orbit described by the swarm of the Perseides, afterwards discovered a remarkable and wholly unexpected agreement between it and the orbit of a large comet observed in 1862, which orbit is a very elongated ellipse. This identity of the two orbits might have been the result of pure chance, in which case it would have been of little importance. But a second fact of the same kind soon showed that the idea of an accidental coincidence must be given up. The orbit of the Leonides was found to coincide with that of a comet discovered in the beginning of 1866. The hint being thus unmistakably given, by two remarkable instances, of the coincidence of the orbits of a swarm of shooting stars and of a known comet, other analogous facts were searched for. It was speedily seen that the shooting stars of December 10 describe in space the same ellipse as the famous comet of Beila, and, moreover that the shooting stars of April 10 move in the orbit of the first comet of 1861.

These results have thrown great light upon the question of shooting stars. A comet which follows in space the same route as a swarm of shooting stars must be regarded as forming an integral part of that swarm. It is no other than a local concentration of the matter of the swarm—a concentration sufficiently intense to render its mass visible, even at great distances from the earth. It follows that shooting stars are of the same nature as comets. They consist of small masses of cometary matter which circulate in space, unperceived by us in consequence of their diminutive size, and only become visible when they penetrate the earth's atmosphere. Like comets, or at least like the less dense portion of those heavenly bodies, they are in the state of gas. All observers are aware that the fixed stars are visible, without any sensible diminution of their brightness, through the tails of comets. Shooting stars present the same degree of transparency, as was plainly stated by M. Coulvier-Gravier long before Schiaparelli's discovery of the identity of comets and shooting stars. "Eight times," he wrote in 1869, "but eight times only have we seen the nucleus of a fixed star of the first magnitude through a shooting star, also of the first magnitude. If this fact is confirmed, as I believe, it will result that the matter which gives birth to a shooting meteor is transparent."

We are now, therefore, enabled to form a clear idea of the nature and cause of the phenomenon of the shooting stars, which may be stated in the following terms:—

Masses of nebulous matter, scattered throughout the stellar spaces, and presenting a high degree of diffusion, are brought within the limits of our planetary system by the paramount influence of the sun. At the same time, whether by the same action of the sun or of the large planets near which they pass, they undergo a progressive change of form, in consequence of which they are drawn out and lengthened into parabolic or elliptic streams or bands. By reason of their extreme diffuseness, the matter of which they are composed is far from occupying the totality of the space throughout which their diverse portions are scattered. Instead of that, it is divided into a multitude of partial masses, a sort of flakes of excessive lightness, lying more or less apart from one another, and having nothing in common but the simultaneousness of their movements in directions and with velocities which scarcely differ from each other.

When the earth, in her travels through space, meets with one of these streams or bands, a great number of the vapory flakes composing it penetrate our atmosphere. The great velocity with which this penetration takes place gives rise to a sudden and considerable compression of the masses of air lying in the path of these ethereal projectiles; whence a great development of heat, and perhaps inflammation of the matter of the projectiles themselves, if that matter be of a nature to combine with one of the elements of our atmospheric air. Hence also those rapid luminous trains beheld in the sky, which cease when the temperature produced is sufficiently lowered, either by the slackening of these little gaseous masses arrested in their course by the earth's atmosphere or by the cessation of their combustion in the midst of that same atmosphere.

If, in any portion of the primitive nebulous mass and of the stream into which it is transformed, there exist a greater concentration of matter, so that, by the mutual attraction of its molecules, that matter resists dispersion into isolated flakes, this nebulous nucleus (so to call it) will pursue the same path in space as the other material portions in the midst of which it was originally situated. And if it can be perceived in space at great distances from our earth, it will constitute for us a comet forming part of the meteoric stream originating from the rest of the matter of the primitive mass. We have seen that observation has already allowed us to ascertain the occurrence of several such instances.

A meteoric stream which crosses the earth's orbit at one point of its circuit, and whose different portions take several years to pass this point of meeting, ought to be traversed by the earth every year at the same epoch. Hence the periodical flushes of shooting stars which annually occur with variable intensity, according to the varying closeness to each other of the nebulous flakes in the different portions of the stream which the earth successively encounters. As to the shooting stars called "sporadic," they may be the result, either of nebulous flakes arriving singly from the depths of space, or rather of the portions of meteoric streams which have been closely approached by different planets, but still without being absorbed into their atmospheres, and which have consequently been dispersed in all directions by the powerful attractions which they have momentarily experienced from these planetary masses.

The resistance which the air opposes to the movement of the little wandering masses which appear to us in the shape of shooting stars, usually produces no more than a rapid decrease of their velocity; but exceptions to the absolute regularity of that resistance may occasionally occur, causing those changes of direction by virtue of which shooting stars sometimes appear to dart in a serpentine, or even an abruptly altered, path. As to the action of atmospheric currents or winds, to which the eccentric motions of a few shooting stars have been attributed, it is evidently incapable of producing any sensible effect, in consequence of the exceedingly great difference between the feeble speed of those atmospheric currents and the enormous velocity of the little nebulous masses which traverse them.—*All the Year Round.*