

METEORIC SHOWERS.

(From the Edinburgh Review for January.)

BOUNDLESS in their extent as they are intricate in their device, the paths of space are known to be traversed by luminous and solid bodies not less complicated in their structure, than in the infinite variety of the tracks which they pursue. Within the last quarter of a century, theory has added the planet Neptune to the system of orbs revolving round the sun. The minor planets, with four of the same tribe discovered early in the present century, number, at the present time, more than ninety. Satellites have been added to the trains of Saturn, Uranus, and Neptune, and a new ring to the Saturnian system. With a slow but sure step astronomy yearly enrols a new list of stars in the mystical rank, whose order and arrangement, a fortuitous concourse of atoms, cosmical vortices, or last, but not least, the nebular hypothesis, were invented to explain. Breaking the bounds of order, but not exceeding the domain of calculation, comets of long and short periods have recently enlarged the class of those excentric luminaries, whose place in the solar system was first determined by Newton and by Halley. It would indeed be strange if the long despised, and much neglected subject, though familiar phenomenon of shooting stars did not receive a passing ray from the light shot athwart the remotest bounds of space by these great discoveries. The continued fall of fiery meteors and of meteorites first aroused in Chladni a spirit of inquiry; and fostered by Olbers, who was the first to predict the discovery of a multitude of minor planets, by Howard in England, by Vanquelin, Fourcroy, and Laplace in France, and by Klaproth in

and Laplace in France, and by Klaproth in Germany, the astronomical theory of luminous meteors came into existence. But this theory was quite in its infancy when Humboldt described, as a local phenomenon, the extraordinary apparition of meteors, witnessed by him on the morning of November 12th, 1799. He states in his account of that shower, that "the oldest among the inhabitants of Cumana remembered that the earthquakes of 1766 were preceded by similar phenomena." Humboldt afterwards ascertained that the spectacle seen by himself and Bonpland at Cumana was visible at the same time, and noted with equal admiration and astonishment over a considerable portion of the inhabited globe.

The immediate cause of the prediction of an unusual meteoric shower after an interval of thirty-three years, was the unexpected recurrence of this phenomenon in America, with surpassing grandeur, on the morning of November 13th, 1833—a circumstance which led Quetlet, the now veteran astronomer at the Observatory of Brussels, to anticipate the return of a similar meteoric shower, on the night of the 10th of August, 1837, from the records of similar phenomena, collected by himself, in various chronicles and annals. That prediction was also verified, and the St. Laurence's meteors very rarely miss their appointment on the nights of the 9th or 10th of August in each succeeding year.

Before tracing the history of the November shower to its results, and the connected theories of luminous meteors that have been adopted to explain it, we shall proceed to give our own impression of the scene as it appeared to us in Scotland in an unclouded sky, on the morning of November 14th, 1866. We chose for our

of November 14th, 1866. We chose for our place of observation a station upon the highest ground in the immediate neighbourhood, where no obstacle prevented our taking the most perfect notes of the surrounding scene. The night began with clouds and showers of rain; but shortly before midnight a change of the wind to the north-west dispelled the obscurity, and the fixed stars appeared about midnight with un wonted clearness. It was in fact from this time an exceptionally fine observing night. The constellation of the Lion was seen, just pawing the horizon in the east; and a few shooting stars already began to enliven the scene,—about as many as might be seen on a fair 10th of August night—one or two in a minute, proceeding from the expected quarter. To us who had watched a clear space of the sky for half-an-hour on the preceding morning, in the vain expectation of seeing some precursor of the expected apparition, which did not make its appearance, the first symptoms of the real meteoric shower caused unmixed satisfaction. A vapour spreading over, and concealing the sky for a moment, gave our hopes a temporary check. It passed, and at half-past 12, three meteors near together, appearing all at once, drew our attention to the spot whence they diverged. This was in the Lion's "sickle," not far from the centre of its curve; but on this point we reserved our decision, inasmuch as momentary stars, a little off the spot, about this time also attracted our attention. Like a star or planet on a stormy night peeping through a break, and immediately again hidden by the flying scud, three or four of these winking lights were seen to peep out in succession, about midway between the second and fourth stars which compose the curve of the "sickle."

stars which compose the curve of the meteor.
So suddenly did these appear, and so imperceptibly did they fade away, that it was not without a certain difficulty that the eye could persuade itself of their reality. Nevertheless, the occasional breaking out of meteors near the place, moving slowly outwards, with very short paths, made it obvious that they were shooting-stars seen in the line of their motion, or "end on," and uniform in their characters with the other meteors of the shower. The imperceptible gradation of their light from first to last appeared to be their chief and most striking feature. From these, and other observations during the shower, we fixed upon the spot last named as the principal point of radiation of the whole display, as long as a concentration of the meteors made it easy to determine it with exactness. A flash of lightning of remarkable brightness was seen, about twenty minutes before 1 o'clock, but although the horizon was quickly scanned in all directions, no trace or residue of a meteor could be detected. The same phenomenon occurred once or twice before, and afterwards, although not so vivid; but no thunder or other meteoric sound was heard to follow this, nor, indeed, any of the other brilliant exhibitions of the night. Our curiosity to know if it originated from a meteor arose from the circumstance that the first large meteor falling in our view, took place about seven minutes before the flash. This left at disappearance, near the north-western star of the great square of *Pegasus*, a luminous streak which remained in sight four minutes, moving like a wand, or like a plait of straw wafted by the wind, towards the north-eastern star, when it disappeared. The direction of the current in which this and three other separate light clouds, seen to be noticed in their order, drifted before

soon to be noticed in their order, drifted before they disappeared, was towards the south, or to a few points west of south. The second large meteor to which we have alluded, took place a few minutes after the first, traversing Ursa's square; and the portion of the luminous streak which was longest visible, remained in sight nine minutes. It was remarkable for forming the first half, and not, as usual, the last portion of the train. As it collected itself into a knot

it grew visibly brighter, just as a row of gas-lights, seen one behind another, look brighter than a single flame. It wanted now a quarter of 1 o'clock, and once already four meteors had been seen breaking out, close together, all at once. From this time until 1 o'clock the numbers rose; the sky, seldom without a streak, sometimes appearing scored by three or four bright lines at once, of quickly fading light, some twenty degrees or less, but others forty degrees, or even more than forty degrees in length.

Towards 1 o'clock, ten minutes were lost in in-door preparations, and on resuming our watch at ten minutes past 1, it would be difficult to say to what the appearance of the shower might be compared, unless it was to the course of arrows: as when the English bowmen stepped to the front at Agincourt, and discharged against the foe—

“ With Spanish yew so strong,
Arrows a cloth-yard long,
That like to serpents stung,
Piercing the weather.”

Straight and parallel was the direction, and swift and uniform the speed of this “vastly extended system of bodies, moving with entire

extended system of bodies, moving with entire harmony and concert." In every quarter of the heavens the appearance was the same. Meteors for the most part as bright as the principal fixed stars, and many brighter; a large proportion comparable to Sirius, and some to Jupiter, sped through the firmament right and left, in a stream so fast and copious, that like drops of water upon a standing pool, to count them all might well have tasked the mind. We are ourselves conscious that by a natural process of "lumping together" we attained only a proximate estimate of the numbers of the display. About one hundred and twenty radiations in a minute was the total number, which, making the proper allowances, we reckoned to be visible about this time; and again at twenty minutes past 1 o'clock, nearly the same enumeration was obtained. In this last interval a slight lull could be perceived, if that might be called a lull in which a burst of six or eight meteors near together breaking out all at once, would sometimes decorate the sky. The brightness of one meteor frequently obliterated that of all the rest appearing simultaneously with it. After its disappearance the eye, half dazzled, would return to its wonted place, and would forthwith find the space of blue sky from which it wandered, scored with the streaks of two, three, or more meteors, whose transit in the interim had totally escaped observation.

The decline of the shower from twenty minutes after 1 o'clock was rapid, but not by any means more rapid, than the steps by which it gained its greatest height. At half-past 2 o'clock, the number of the meteors appeared to be nearly the same as it had been at midnight. At a quarter after 2 o'clock, the third large meteor of the morning made its transit, and disappeared close to Aldebaran, the last obser-

disappeared close to Aldebaran, the last deposited portion of the streak forming a silvery cloud which remained plainly visible five minutes. It drifted with the current before mentioned, and disappeared close to Orion's head. The fourth, large meteor, at twenty minutes before 3 o'clock, escaped our view, but the dazzling light which it threw around, and its train, became conspicuous objects. The latter, shaped exactly like a hoof-mark, or like a fiery footprint in the sky, we presently detected between the square and tail of the Great Bear. At first no wider than six diameters of the moon, the ring expanded for a quarter of an hour, until the horns of a stag were fairly represented, the animal's brow being at the hindermost foot, one point at the Pointers, and the point of the other horn at the tail of *Ursa Major*. The whole length which it attained, before it vanished, was not less than fifty degrees, which it reached by opening out in the manner described, and by stretching itself at the same time towards the south. A comparison with the notes of another observer in the north of England enables us to fix the central height of this terrific object at forty-five miles above the county of Fife, in the neighbourhood of the Frith of Tay.

It remains only to speak of the colours, and other peculiarities of the meteors. An orange yellow colour was predominant, or at least very common, in the head. Many were white; a few green, or blue. The head frequently outstripped, or shot *ahead* of the streak, which was brightest and widest at the central part, but the most enduring portion (as in our first two splendid examples) was either the first, or the last deposited portion of the train, apparently according as some material substance was developed or encountered by the meteor in the

veloped or encountered by the meteor in the earlier, or later portion of its path. The colour of the streaks was white or steel-grey; in a multitude of instances verging into blue, or more often into emerald green. The contrast of orange and green colours in the head and streak of short slow-moving meteors near the radiant point, sometimes produced, in such meteors, a brilliant Iris-like appearance. The greatest angular speed of flight was from twenty-five to thirty degrees in one second, which was also about their average length of path and duration. The streaks endured much longer—some of them four or five seconds—but the generality not more than two or three. A peculiar compactness of the light or luminous appearance was remarked in many of the streaks, as if they were made up of *yellow gold-dust*. The most enduring, as they faded, took an undulating or serpentine form, in figure and proportions not unlike the spiral tendrils of a climbing plant.

Altogether about 8000 meteors were visible from our point of observation from midnight until 3 o'clock. At the Royal Observatory, Greenwich, the total number visible during the same hours was 7724 meteors of every description. Two maxima of frequency took place,—the first when meteors appeared at a rate of 118 per minute, between one and ten minutes after 1 o'clock; the second when the rate was 123 meteors per minute, at twenty minutes past 1 o'clock. The rate of frequency at the height of the shower was fully double what it was twenty minutes before or after these two moments of the crisis or greatest abundance of the meteors. At places where a watch was kept on the mornings of the 13th and 15th, the number of meteors noted was less than might

number of meteors noted was less than might be seen on any ordinary night.

As regards its geographical extent the shower is described in nearly the same terms ; its duration and the moment of its maximum was the same at Rome, in Malta, Spain, France, Germany, and England. Allowing from fifty minutes to an hour for the difference of time between Greenwich and Rome or Malta, the greatest abundance of the meteors "like a flight of swallows," or "like a shower of hail," which happened there, soon after 2 o'clock, is evidently the same phenomenon which reached its climax, and passed it, soon after 1 o'clock, in London. The mortal fear in which poachers are said to have left their pursuit and fled from the hills in the upper district of Banffshire, was inspired at the same moment among the peasants of Monticelli near Rome, who looked with awe and trepidation upon what they mistook to be the end and consummation of the world. The meteors were seen by thousands at Bonn,

Cologne, and Münster, in the neighbourhood of the Rhine, like rockets falling ; at Saragossa like the burning shells and hand-grenades scattered in the assault and defence of that town ; and from the pass of Mont Cenis, an unusual, because elevated view of the meteors, of rare beauty, was obtained. At how many more points in Central Europe, and perhaps in Asia, they were visible at the same time, accounts not yet received, but probably on their way, it is confidently expected, will amply testify. In America the shower appears to have been invisible, and Europe was the continent on the favoured side of the Atlantic Ocean. From Sir Thomas Maclear, the zealous astronomer who

Thomas Maclear, the zealous astronomer who directs the observatory at the Cape of Good Hope, we have just received the following communication, and we publish it with the remark, that since the time when Humboldt's meteors returned both at the Mauritius and in Europe, on the morning of the 13th of November, 1832, this is the first occasion on which a star-shower has been seen, at one time, in both the north and south hemispheres of the globe :—

“ Cape of Good Hope, 1866, November 19th.

“ In the early part of the night of the 13th few meteors, or shooting stars, appeared. At 1 h. 3 m. a.m. on the 14th, the volcano burst forth with awful grandeur from the neighbourhood of Regulus, + orange-coloured meteors, leaving streaks of green, mingled with ordinary-looking ‘shooting stars,’ dashing along in a south-westerly direction. The scene was beyond description. Little beyond counting and general direction could be attended to ; and thus with little variation, the projectiles continued till daylight. The total number counted amounts to two thousand seven hundred and forty-two.”

Not to enter into the niceties of chronological disquisitions, a few extracts from the records of former appearances will suffice to describe the early history of the shower :—

A.D. 902. On the morning of the 13th of October (o.s.), “ an infinite number of stars scattered themselves like rain, from right to left ; and that year was called the year of stars.”

A.D. 931. On the morning of the 16th of October (o.s.), there were seen “ more than a hundred shooting stars moving in different directions.”

A.D. 934. On the morning of the 14th of October (o.s.), there happened “ signs in the sky as of the stars falling.”

A.D. 1002. On the morning of the 15th of October (o.s.), “ thousands of small stars appeared in the constellation *Cancer* ; and among them two stars as large as a quart measure, which went, one to the star *Sirius*, the other to *Sagittarius*.”

A.D. 1101. On the 17th of October (o.s.) “ the stars were seen to fall from heaven.”

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A.D. 1202. Towards daybreak on the 19th of October (O.S.), "stars shot hither and thither, at Bagdad, and flew against one another, like a swarm of locusts."

A.D. 1366. On the morning of the 22nd of October (O.S.) "the stars fell from the sky in such numbers that the sky and the air seemed to be in flames, and even the earth appeared ready to take fire."

A.D. 1533. On the morning of the 25th of October (O.S.), "many thousand stars were seen to fall, and clash together, so that the sky appeared to be in flames."

A.D. 1602. On the morning of the 27th of October (O.S.), "there were several hundred shooting-stars great and small, mixed and confused, which followed each other in the same direction."

A.D. 1698. On the 9th of November (N.S.), an unusually large number of meteors were seen at Geneva.

A.D. 1799. On the morning of the 12th of November (N.S.), "thousands of falling stars and bolides succeeded each other during four hours." The shower thus described by Humboldt at Cumana was equally seen near the Equator; in Florida, Labrador, and Greenland; at Hull in England, and near Weimar in Germany.

A.D. 1832. On the morning of the 13th of November (N.S.), the sky was filled with a multitude of meteors "so great that it was impossible to count them," at Mauritius, Mocha, and Orenburg; and generally in Europe; but the meteors were not visible in America.

A.D. 1833. On the morning of the 13th of November (N.S.), from between two and three o'clock until daybreak, an astonishing meteoric display was perceived in North America, and it was confined apparently to that continent, where it extended from Cuba to Greenland, and from Newfoundland to the far Western States.

At Boston, shortly before 6 o'clock, shooting-stars were falling "about as thick as the flakes of snow in common snow-falls. The number of meteors falling, during the fifteen minutes before 6 o'clock, was computed to have been more than 8,660,"—a rate per minute, be

seen more than 5,000, — a rate per minute, as it observed, *five times more rapid than the maximum in the recent great November shower.*

The meteors of this last-mentioned exhibition were of all sizes, from that of a point to three times the apparent diameter of the planet Venus, and one was judged to be nearly as large as the apparent size of the moon. Occasionally a bright flash, like moderate or distant lightning, indicated the passage of a still larger body. Sometimes prismatic colours were developed in the streaks of the smaller meteors, and towards daybreak many were observed of a faint but decided green. The duration, and singular shapes assumed by the luminous streaks, was a striking part of the display. Some appeared like a half circle, others like waves, or like the undulating folds of a serpent, occupying the space traversed by the meteor; and, generally, changing their shape and position a little during their continuance, as if moved by the wind. A very remarkable one was seen about twenty minutes before 6. The meteor was three or four times the diameter of Venus, and it left a luminous train occupying several degrees, in the shape of the human arm half bent, which was distinctly seen for at least fifteen minutes. It was estimated by Professor Twining that the height of the meteor, at its first appearance, exceeded eighty miles, and the point of its extinction was nearly thirty miles above the earth's surface. The luminous cloud which it left, drifted from its place towards the east, with the speed of three or four miles in a minute, whilst the velocity of the meteor itself, in its transit, was not less than fourteen miles in a second.

The fixity of the point of radiation, or *direction* of the meteors with reference to certain stars of the constellation Leo was first noticed

stars of the constellation Leo, was first noticed towards 5 or 6 o'clock, on that morning, in connexion with the shower, by Dr. Olmsted, Professor Twining, and by Dr. Palmer. Professor Twining states that its place was at the bisection of a line between the first and fourth stars, or at the bisection of a line between the second and fifth stars of the curve of the "sickle." In every particular respect, one and the same phenomenon has obviously been reproduced, only in a somewhat less eminent degree, in the great shower we have recently witnessed.

Two remarkable facts were elicited in connexion with its return in the year 1833. *First*, the meteors exhibited the character of annual periodicity; for the appearance of the meteors in America, in the year 1833, took place on the same date (November 13th), as that on which they were seen in Europe in the preceding year. *Second*, the novel discovery was made of the existence of a radiant-point, or centre of divergence of the meteors, situated at a spot in some part of the constellation Leo, from which, as if from a common origin the meteors of the shower appeared to stream *outwards*, in whatever quarter of the sky they appeared. No plausible explanation, Olmsted showed, could be given of the former peculiarity, without assigning a *celestial*, and not a *terrestrial*, origin to the meteors; and he apprehended that the point of radiation of the meteors is in reality the vanishing point of straight lines,

nearly parallel to each other, seen in perspective. In the next place, the extraordinary swiftness of the meteor, *not less* than fourteen miles in a second, observed by Professor Twin-

miles in a second, observed by Professor Twining, and the apparent fixity of the radiant-point (independent of geographical position), warranted Professor Twining in concluding "that the earth passes through a whole system of bodies, vastly extended, yet moving with entire harmony, and concert, independent of every terrestrial cause or agency," and that, in fine, each meteoric body *has an orbit*, in which it is in rapid motion round the sun.

It was not possible, from the small base-line of the two apparitions in 1832 and 1833, to construct an approximate orbit of the meteoric bodies. Correct, although of course fragmentary descriptions of the former appearances of the November star-shower have, however, fortunately been preserved from very early times. A brief summary of the accounts of such occurrences is given above. It presents the reader with a short synopsis of the earlier descriptions of the phenomenon, as they are unfolded by Professor H. A. Newton, in his exposition of "The Original Accounts of the Displays in Former Times of the November Star-shower." These descriptions afford Professor Newton data for "a determination of the length of its cycle, its annual period, and the probable orbit of the group of bodies around the sun."

All these dates, when allowance is made for change of style, are found to advance, regularly, in the year, at a uniform rate of about three days in a century, which can be accounted for partly by allowing for the difference between the lengths of the tropical and sidereal years, and partly by supposing that the place where the earth encounters the meteors is not fixed, but that, on the contrary, the node, as it is called, of the meteoric orbit is slowly but steadily advancing round the sun in the same direction

advancing round the sun, in the same direction as that in which the earth, at the same time, is moving in pursuit of it. Astronomers are warranted in concluding from this simple fact, even if it were unsupported by evidence of any other kind, that whatever may be the dimensions of the meteoric orbit, and whatever may be the position of the orbit of the meteoric group with respect to the orbit of the earth, the motion with which the meteoroids circulate in their orbits is *retrograde*, or performed in the reverse direction to that in which all the known planets revolve around the sun. The speed of the encounter, and the lucidity of the display, are accordingly much greater than would be the case if the meteors were revolving in the same direction as the earth, whenever the earth, as it must do after the lapse of a certain number of years, falls in with the meteoric system, on its path.

The above thirteen dates, from the "year of stars," A.D. 902, down to the year of the "Great November Shower," A.D. 1833, are found to agree very nearly, and to be *perfectly* reconcilable with a single meteoric period, if during two or three years at the end of each cycle of about one-third of a century, the earth is supposed to meet with an extraordinary shower of meteors in November. Those of the years 1832 and 1833 were seen respectively, in Europe and America. Many steps of the series are evidently missing; and this might naturally be expected to take place, if the shower occurred under geographical conditions unfavourable to its visibility; but the *intervening* years of every cycle are, on the other hand, entirely blank. A ring of meteoric bodies, evenly distributed round the sun could not, obviously, explain this circumstance; because the earth would, in such a case,

stance ; because the earth would, in such a case, fall in with an extraordinary number of the November meteors every year. A group of meteoric bodies, performing one entire revolution in about thirty-three years, would produce the required cycle ; and the bodies returning, at the end of that time, to the position where they must encounter the earth, might do so in two or three successive years, if the meteors were distributed along an arc of twenty-five, or thirty-five degrees of its circumference ; because the earth would pierce through a part of the system, in that case, for two or three Novembers in succession. The ring of bodies must therefore be supposed not continuous, but the meteoric bodies to be principally condensed towards some one part of its circumference. On the other hand, a ring of the kind just described, if it revolved in less time than the earth by about eleven days, would produce the same result ; because the earth, returning at the end of one year to the place where the meteors were encountered, would find that the cloud of bodies had gained eleven days, or about one thirty-third part of a revolution, and the earth would then pierce through the cloud at a different place. At the end of two years the cloud would gain twenty-two days, and the earth would then pass by it ; and at the end of thirty-three years the cloud of bodies would have gained one entire revolution, and would have returned to the position where it must again encounter the earth, and a new series of extraordinary displays would commence.

The supposition of a nearly circular orbit like that of the earth, but retrograde, is made highly probable by the fact, first pointed out by Encke, that the earth, at the moment of the great November shower, in 1833, was moving

great November shower, in 1833, was moving towards the very point of the ecliptic, in Leo, from immediately above which the meteors broke out; so that the direction of their speed, like that of the earth's speed at the moment, was almost exactly perpendicular to the distance of either from the sun. The meteors accordingly move in an orbit, which probably differs very little from a circle somewhat smaller than, and but little inclined (seventeen degrees) to, the orbit of the earth. They return to the node in 354·621 days. Their motion is retrograde; and their velocity (allowing for the attraction of the earth) is 20·17 miles per second, corresponding to a speed of transit through the atmosphere, amounting to 38·7 miles, or nearly forty miles per second.

The cycle appears to repeat itself four times in 113 years, so that reckoning from some date between November in 1832 and in 1833, as the commencement of a cycle, the year in which there was most reason to expect an extraordinary shower was 1866; in which it was anticipated that on the morning of the 14th of November, the western Atlantic would be visited by the meteors. Had the earth been but a few hours farther advanced on its journey before encountering the meteors at the recent remarkable apparition of the shower, its revolution in that brief interval would have placed the continent of America, instead of the Old World, as was actually the case, under the immediate focus of the shower.

The Report of a Committee of the British Association,* presented by Mr. Glasher, on Observations of Luminous Meteors for the year 1865, contains one of the earliest notices of the appearance of a shower connected with the present great meteoric epoch. This took place at

sent great meteoric epoch. This took place at Malta on the morning of the 13th of November, 1864, and affords an interesting verification of the theory just advanced. The earth at two

* The Committee consisted of Robert F. Greg, Esq., Professor Brayley, and Professor Alexander Herschel.

o'clock on that morning, and again at daybreak on the morning of the 13th of November 1865, when a large display of meteors was noted at the Royal Observatory, Greenwich, was within half a degree of the position which it occupied at the height of the great November Shower, on the morning of the 14th of November, 1866. For the present, the agreement of the observed facts with the existing theory is, so far, complete. Yet it requires attention that a ring of the kind described, if it revolved in *more* time than the earth takes to complete its revolution, by about eleven days, instead of in *less* time (as above supposed), would be a form of the hypothesis which would agree equally well with the observations. The grounds upon which preference is given to the above supposition are at present, from the paucity of data alone, in some degree and to a certain unavoidable extent, provisional. Observations on the present shower must assist to remove the uncertainty. Should the ambiguity still be found to exist, the return of the shower must be watched for on the morning of the 14th November 1867, so as to ascertain if the condition of the cycle at the present time, is one of increasing progress, or if, in accordance with the prediction, its manifestations have already passed their climax.

The dense crowd of meteors encountered by the earth in about three hours, on the morning of the 14th November 1866, cannot have been smaller than the width of the moon's orbit in extent, reckoned in the direction in which the

extent, reckoned in the direction in which the earth passed through the throng. Supposing with Chladni that the meteors owed their light, and doubtless, too, their heat (during their passage through the rarest parts of the atmosphere), to the compression of the air before them, the question in the next place to be considered will be, the probable constitution of the material particles of which this vast assemblage of millions of individuals is composed.

Stony or metallic masses are projected from a large class of luminous meteors, to which the term meteorites—including aërolites, siderolites, and siderites—has been applied. Of such bodies, a catalogue, contained in a recent work by P. A. Kesselmeyer, on the "Origin of Meteorites," supplies the dates and places of fall of between six and seven hundred individuals. The pamphlet, although singular in its object in attempting to uphold a theory of the terrestrial origin of meteorites, is yet a very valuable essay on the subject of the geographical distribution of meteorites. From the maps of the continents, upon which the place of each fall up to the year 1860 is faithfully laid down, it appears that 130 stone-falls of the list, since the beginning of the last century, belong to Europe alone; a rate of sixty a-year, if extended uniformly over the whole surface of the globe. This computation of the number of meteorites fallen in with by the earth is certainly far below the mark. Von Schreibers reckons the number at 800; and other writers at even a higher figure. *One meteorite in a day* is, therefore, not an exaggerated estimate.

The height of the fireballs from which they fall, and their speed, greatly resembles that of the November meteors. A striking example of this was recently presented by the luminous

This was recently presented by the luminous meteor which scattered a shower of stones, on the evening of the 14th May, 1864, in the neighbourhood of the town of Orgueil in the south of France. The fireball shot from a height of between thirty and sixty miles above the earth, to a height of ten or twelve miles above Nohic, near Orgueil, where it disappeared, with a speed rated at twelve or thirteen miles in a second. Humboldt termed aërolites "pocket planets," partly on account of their distinct petrological character, and partly because the speed of their arrival from a foreign locality, makes known that, like the planets, they roam in wide and spacious orbits around the sun.

Aërolites are fragments, evidently of larger rocks; generally heavier than granite, sometimes compact like marble, or trap, resembling in structure trachitic porphyry; at other times possessing a loosely coherent, almost earthy, texture, with considerable varieties of mineralogical composition. They consist of a flinty-grey cement, or breccia-like volcanic tufa, in which is imbedded a multitude of fragments of broken crystals, spherules, metallic iron in grains, and here and there a small nest or spangles of yellow iron pyrites. The usual grains of metallic iron are sometimes wanting in the aërolites of Juvenas and Stannern, whilst in the siderolite of Mainholtz they exceeded the stony part in bulk; and the mass of meteoric iron which fell at Agram, in Croatia, on the 26th of May 1751, was capable of being forged into nails, so entirely free from earthy admixture is the iron of which the siderite is composed. Pure siderites, or masses of meteoric iron, have rarely been seen to fall, but specimens of native iron, occasionally met with upon the surface of the earth, are evidently of meteoric origin, deposited there by meteors, the antiquity of whose fall is

there by meteors, the antiquity of whose fall is unknown. The metals nickel, chromium, cobalt, tin, copper, and lead, and others, have successively been discovered in meteoritic masses. Carbon occurs in the form of graphite; and phosphorus and sulphur in combination with iron. Alkaline and the other earths, especially magnesia, form, with silica and iron, the flinty part of their structure, almost identical with certain volcanic lavas, but strikingly distinguished from all terrestrial scoriæ by the occurrence of iron, in meteorites, in the metallic state. So great is the heat to which their exterior surface is exposed, in the fireball that attends their passage through the air, that a thin black crust, or molten substance of the mineral, envelopes them completely; and they not unfrequently reach the ground so hot, that one which fell at Eichstadt, in Bavaria, on the 19th of February 1785, was first cooled in snow before it could be handled.

The first chemical analysis of meteorites, by Edward Howard, and the foreign chemists already named, at the beginning of the present century, which made known the existence of the metal nickel as a characteristic ingredient of meteoric irons and stones, and those of Berzelius, Wohler, and others, in later times, succeeded in establishing the fact that no elementary substances have hitherto been found in meteorites which are not already known to exist upon the earth. Whether this is true regarding the mode of their chemical combinations, is a matter not yet sufficiently ascertained. The meteorites of Orgueil, besides the usual inorganic constituents, contain six per cent. of a black amorphous organic substance, composed of the organic elements, carbon, hydrogen, and oxygen, in proportions quite similar to those in which they occur in lignite and peat; in other

which they occur in lignite and peat ; in other words, a veritable *humus*. M. Wohler infers from all the facts, that wherever meteorites originate, organic matter—and hence probably, also, organised matter—*organisms* in fact—must have an existence. The various annals of science, and the journals and proceedings of philosophical societies, contain many such researches. Indeed, the literature respecting meteorites constitutes already a brance of study by itself, which under the name of "Aërolitics" has for its theme the splendid collections of meteorites at present to be found in the galleries of most of the great mineralogical museums. A work entitled an "Index to

Aerolitic Literature" has lately been published by Dr. Otto Buchner, by means of which the original accounts of meteorites may be consulted, and the facts respecting them are collected.

Considering the number (some hundreds of aërolites which the earth encounters, meet at all points of its orbit, indiscriminately, every year, and that the uniformity of the mineral composition of meteorites implies a similar unity in their origin, the body most probably to be regarded as the native source of meteorites, both from its dimensions and from the central position which it occupies in the solar system, is evidently the sun itself, or at least that portion of matter closely enveloping the sun, which reflects to us its light, and which presents to us in the twilight the appearance of the zodiacal light. Professor Brayley has inferred that the incandescent aëriform matter, which, rising in torrents from the nucleus of the sun, produces the phenomena of the solar spots, by piercing through its envelopes, consists of the elementary substances, principally

sists of the elementary substances, principally metals, including those characteristic of meteorites, which Kirchhoff, by means of the spectroscope, has discovered to exist, in the gaseous form, in the solar atmosphere. These, he also infers, are condensed into masses of the nature of bubbles, but of enormous magnitude, which, suffering further condensation, become the particles of the zodiacal light, from which they are projected in the form of what he terms "meteoritic masses," subsequently to become meteors and meteorites. Professor Brayley has supported these views by the induction, new to science, that the "structural characters of meteorites are those of bodies which have been originally condensed from heterogeneous vapours—the mingled vapours of uncombined elementary substances variable in their nature, and requiring different temperatures for their maintenance in the gaseous form, but all existing originally at a very high temperature."* In the absence of any evidence that we possess to the contrary, it is reasonable to suppose that the material particles which compose that envelope should, like the sun, have a certain uniformity of composition, and that at least some among them may have some tangible size. They may also be situated at as great a distance from the sun as the earth itself. Microscopical tests applied by Mr. Sorby to the stony crystals found in aerolites, do strongly favour the opinion that they have been repeatedly broken up and metamorphosed by partial fusion, and that they were originally consolidated from a state of vapour;—all of which are conditions of matter, supposed to exist most eminently in the immediate neighbourhood of the surface of the sun.

Among the variety of bodies which the theory of Chladni represents to us, as existing in circulation round the sun, and which may be supposed to

tion round the sun, and which may be supposed to be arrested by the earth, so as to produce in its atmosphere the phenomenon of shooting stars, at least one zone exists, composing apparently a distinct order of bodies by itself, almost uniformly distributed in a ring about the sun. This ring gives rise to the "meteors of St. Laurence," as they are called, which are seen with considerable regularity every year on the nights of the 9th and 10th of August. Other zones, each apparently composing a different ring-system, are encountered, but not so regularly, on the 2nd of January, the 20th of April, the 19th of October, and the 12th of December, producing showers of the same kind, but not so conspicuous as the star-showers of August and November. Zones, not so rich in individual meteors, may be conceived to be fallen in with by the earth on every night, and in this manner produce the familiar appearance of shooting stars throughout the year. The position of these circular or elliptic rings, so far as they are known, accommodate themselves to no regular system, and the meteoroids which revolve in them neither belong exclusively, nor even largely to a disk, or to a lentiform group about the sun, like that which the zodiacal light is supposed to indicate. The orbits of the rings are not in general circular, as may be inferred from the ascertained great velocity of shooting-stars ; but both by the levity of their substance and the incongruity of their orbits, periodical and non-periodical shooting-stars appear to resemble the nuclei of comets, which, like Biela's comet, may intersect the earth's orbit, and may have gradually become extinct.

When the levity of cometary matter is considered—which Sir John Herschel describes (by its effect in not dimming the light of certain feeble stars) as lighter than the lightest haze—

feeble stars) as lighter than the lightest haze—it is not to be wondered at that, in the words of M. Quetelet, “no person has yet been able to handle the material of a shooting-star.” Certain astronomical distinctions exist between aërolites and the class of periodical shooting-stars, which appear to reduce, if not entirely to remove, the contingent possibility of the event. Out of the large number of authentic aërolites preserved in mineralogical collections, two only—one on the 10th of August, and one on the 13th of November—are recorded to have fallen on star-shower dates. On the other hand, five or six meteorites, on the epoch of the 13th-14th of October, belong to a date when star-showers so far as is at present known, do not make their appearance. Meteorites, moreover, with very rare exceptions, fall in the afternoon; but the time of the greatest frequency of shooting stars is in the morning hours of the day, before dawn. On these grounds a distinction is drawn between shower-meteors and aërolites, and the former are termed by Professor Newtown “Meteoroids,” while Professor Brayley includes both, or rather the bodies which become shower-meteors and aërolites, under his designation of “Meteoric masses.” Meteoroids, Professor Newton suggests, cannot be regarded as the fragments of former worlds, but may rather be described as the materials from which new worlds are forming. Mr. Brayley inclines, in the same manner, to suppose that “the earth was originally produced by the aggregation and coalescence of meteorites, or of greater masses into which this had previously coalesced.”

Both shower-meteors, and aërolites, it may be, are gradually consolidating into larger bodies by collision, yet nothing, it is thought,

... will cause the meteors of the 14th of November to precipitate themselves in the form of stones upon the earth. Either from their inflammable nature, their specific lightness, or loose texture, their power of penetrating the atmosphere appears to be extremely small, notwithstanding their unusually large size and brightness. Upwards of seventy meteors of the November Shower observed at Newhaven, and at other places in the United States of America in 1863, were found to be fifteen miles higher than the level of ordinary shooting-stars, the result suggesting to Professor Newton that the shooting-stars of the 14th of November consist of more inflammable materials than those of other meteoric showers. No apprehension need accordingly be entertained, that the atmosphere would not prove a perfect shield, in the event of the return of the shower, to check their penetration, and to keep them at a safe distance from the sphere of human habitations.

* Proceedings of the Royal Society for March 23, 1865, vol. XIV., p. 124.