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ORDINARY MEETING, February 4, 1867.

Captain E. Gardiner Fishbourne, R.N., C.B., Hon. Treas., in the Chair.

The minutes of the previous Meeting were read and confirmed.

The following Paper was then read:—

ON FALLING STARS AND METEORITES. *By the* Rev. Walter Mitchell, M.A., *Vice-President, Vict. Inst.*

THE term Meteor, taken in its literal signification as a "thing in the air," is sometimes used so as to include all atmospheric phenomena, such as clouds, rain, snow, rainbows, mock suns, &c.; but in a more restricted sense it is applied to falling stars and flaming bodies seen passing through the atmosphere. A falling star is a phenomenon with which every one must be familiar. Yet familiar as it may be, it is far more frequent than many would suppose. A star is seen to shoot across a portion of the heavens, vanishing as suddenly as it appeared, sometimes leaving a slight luminous track behind it, to mark for a few moments its course. Generally speaking, few of these falling stars are seen on the same night; but there are occasions when they are so numerous as to fall for hours together in perfect showers,—so numerous as to be compared to a dense snow-storm where every flake is a burning star. Brilliant and startling as was the display last November, when between six and seven thousand falling stars are estimated to have pursued their fiery course in one hour, and at the time of the maximum display at the rate of one hundred per minute, this falls short of the awful majesty of some of the star-storms that have been observed.

A remarkable display of falling stars, seen by Humboldt when travelling in South America, was thus described by him:—"Towards the morning of the 13th November, 1799, we witnessed a most extraordinary scene of shooting meteors. Thousands of bolides and falling stars succeeded each other

during four hours. Their direction was very regular from north to south. From the beginning of the phenomenon there was not a space in the firmament equal in extent to three diameters of the moon which was not filled with bolides or falling stars. All the meteors left luminous traces, or phosphorescent bands, behind them, which lasted seven or eight seconds." Mr. Ellicott, an agent of the United States, thus describes the same phenomenon, as seen by him from the sea between Cape Florida and the West-India Islands:—"I was called up about three o'clock in the morning, to see the shooting stars, as they are called. The phenomenon was grand and awful. The whole heavens appeared as if illuminated by skyrockets, which disappeared only by the light of the sun after daybreak. The meteors, which at any one instant of time appeared as numerous as the stars, flew in all possible directions, except from the earth, towards which they all inclined more or less; and some of them descended perpendicularly over the vessel we were in, so that I was in constant expectation of their falling on us." This particular display of falling stars seems to have been visible from the equator to Greenland in America, and was also observed at Weimar in Germany.

On the 13th of November, 1833, another splendid shower of falling stars was observed over the whole of North and a considerable portion of South America, some of the meteors being of a very large size,—one described as greater than the full moon appears when in the horizon. Another, over the Falls of Niagara, remained for some time almost stationary in the zenith, emitting streams of light. No wonder that many, calling to mind the vision of St. John the Divine, when "the stars fell unto the earth, even as a fig-tree casteth her untimely figs, when she is shaken of a mighty wind," felt awestruck, and imagined that the day of wrath was come. "I was suddenly awakened," says a South Carolina planter, "by the most distressing cries that ever fell on my ears. Shrieks of horror and cries for mercy, I could hear from most of the negroes of three plantations, amounting in all to about six or eight hundred. While earnestly listening for the cause, I heard a faint voice near the door calling my name. I arose, and taking my sword, stood at the door. At this moment, I heard the same voice still beseeching me to rise, and saying, 'O my God, the world is on fire.' I then opened the door, and it is difficult to say which excited me most,—the awfulness of the scene or the distressed cries of the negroes. Upwards of one hundred lay prostrate on the ground, some speechless, and some with the bitterest cries, but with their hands raised, imploring God to save the world and them. The scene was truly awful; for

never did rain fall much thicker than the meteors fell towards the earth; east, west, north, and south, it was the same."

Notwithstanding, says Humboldt, the great quantity of falling stars and fire-balls of the most various dimensions which were seen to fall at Potsdam on the night of the 12th and 13th November, 1822, and on the same night of the year 1832, throughout the whole of Europe from Portsmouth to Orenburg on the Ural river, and even in the Southern hemisphere at the Isle of France, no one seemed to remark the coincidence of so many of these displays happening on the same day of the month. Olmsted and Palmer were the two principal scientific men who described the great meteoric shower of 1833 in America. The latter, calling to mind that the date of the shower described by Humboldt and Ellicott in 1799, was the 13th of November, first suspected the periodicity of these showers,—a fact fully confirmed by a historical investigation into the dates of extraordinary showers of meteors.

On the 9th and 10th of November, 1787, many falling stars were observed at Manheim, in southern Germany. Besides the manifestations already mentioned on the 13th November in the years 1799, 1822, 1832 and 1833, on the same day of the month in 1831, at four o'clock in the morning, a great shower of falling stars was seen by Captain Bérard on the Spanish coast near Carthagena. On the same date in 1834 a similar shower, though not so great as that of 1833, was seen. Olmsted was the first to remark that nearly all the falling stars on the 13th of November, 1833, seemed to radiate from one point in the heavens, namely near the star γ in the constellation Leo. The point of radiation did not change, but followed the apparent height and azimuth of the star during the continuance of the shower. This remarkable fact has been confirmed by observation of all the showers witnessed on this date since 1833. According to Enke's computation, this radiant point in space marks the direction in which the earth was moving on the 13th of November in its annual course round the sun.

The periodical appearance of falling stars on the same day of the year, all radiating from a point in the direction of the earth's motion, led Humboldt to conjecture that at that particular period the earth was passing through a ring or belt of minute planetary bodies, which were then drawn within the sphere of the earth's attraction,—a conjecture since pretty generally adopted. He also conjectured that there was, owing to the earth's or other planetary disturbance, a gradual retardation of the November phenomenon, owing to the change of the points where the ring of meteoric bodies intersected the earth's course. He sought for records of falling stars in an-

cient histories. On the night when king Ibrahim Ben Ahmed died, in October, 902, there fell a heavy shower of shooting stars "like a fiery rain," on which account that year was called the year of stars. On the 19th of October, 1202, the stars were in motion all night, and "fell like locusts." On the 21st of October, O.S., 1366, stars fell in such multitudes that they could not be counted. On the night between the 9th and 10th of November, 1787, many falling stars were observed at Manheim. Adopting the conjecture of Humboldt as to the gradual retardation of the November shower, others, more than twenty-three years since, ventured to predict that the great November shower of shooting stars and fire-balls intermixed, falling like flakes of snow, would not recur till between the 12th and 14th of November, 1867, taking for granted that the great November star-showers occurred once in thirty-three years, when the earth intersected the hypothetical ring of minute planetary bodies.

These showers are not equally visible from all parts of the earth's surface. The shower of 1799 was only seen in America; those of 1831 and 1832 were only visible in Europe; those of 1833 and 1834 only in the United States of America; and while a very splendid meteoric shower was seen in England in the year 1837, a most attentive observer at Braunsberg, in Prussia, on the same night, which was there uninterruptedly clear, only saw a few shooting stars, radiating from no particular point of the heavens, between the hours of seven in the evening and sunrise the next morning.

Though such occurrences as the great star-shower on the 19th of October, 1202, and 21st of October, 1366, seem to indicate a gradual retardation of the November shower, the relation of Theophanes, one of the Byzantine historians, that in November of the year 472 the sky appeared to be on fire over the city of Constantinople with the coruscations of flying meteors, may make us pause before assuming the November shower to be the retardation of the October phenomenon. Again, in the year 1766, just before the fearful earthquake at Quito, Humboldt states that the volcano of Cayambe was so enveloped with falling stars for the space of an hour, that the inhabitants fancied the mountain on fire, and endeavoured to appease Heaven by religious processions. The year corresponds with the 33-year period; but as the earthquake occurred on the 21st of October, the shower would seem to belong rather to the October manifestations of the 19th of October, 1202, and 21st of October, 1366. This should caution us not to generalize too hastily on a few recurrences of similar dates. Again, not to speak of the November showers for two years pre-

viously and for three years successively to that of 1833, the showers of 1787 and 1822 cannot be brought into the 33-year period of maximum manifestations of falling stars.

Besides the November period, there is another well-marked periodical fall of stars between the 9th and 14th of August. The 10th of August (St. Lawrence's day) was traditionally famous for "the fiery tears of St. Lawrence." As early as 1762, Muschenbroek remarked the large number of falling stars in the month of August. But the periodic return on St. Lawrence's day was first shown by Quetelet, Olbers, and Benzenberg. Bessel and Erman pointed out that the radiant point for the August shower was in Perseus. In April it is probable that there may be another period. On the 25th of April, 1095, "innumerable eyes in France saw stars falling from heaven as thickly as hail;" and on the 25th of April, 1800, a great fall of stars was observed in Virginia and Massachusetts; it was a "fire of rockets that lasted two hours." On the night of the 6th and 7th of December, 1798, Brandes counted 2,000 falling stars. At Quito on the 4th of February, 1797, shortly before the terrible earthquake of Riobamba, stars were seen to fall in swarms.

It may be well to remark that the train seen to follow a shooting star is no mere optical delusion, produced by the impression of light remaining impressed on the retina. It sometimes continues visible for a minute, or even longer, and even changes its shape. The falling stars which ordinarily occur, that is, which cannot be traced to any periodic display, and do not seem to emanate from any particular point of the heavens, are termed "sporadic." Eight is supposed to be the mean number to be observed in the course of an hour on any night. Perhaps they are more abundantly seen at some places than others. Burnes, describing the clear atmosphere of Bokhara, says, "At night the stars have uncommon lustre, and the Milky Way shines gloriously in the firmament. There is also a never-ceasing display of the most brilliant meteors, which dart like rockets in the sky: ten or twelve of them are sometimes seen in an hour, assuming every colour,—fiery red, blue, pale and faint." Jansen, again, describing the night scenes of the Java Sea, says, "The starlight, which is reflected by the mirrored waters, causes the nights to vie in clearness with the early twilight in high latitudes. Numerous shooting stars weary the eye, although they break the monotony of the sparkling firmament. Their unceasing motion in the unfathomable ocean affords a great contrast to the seeming quiet of the gently-flowing aërial current of the land breeze. But at times, when 30° or 40° above the horizon, a fire-ball

arises which suddenly illumines the whole horizon, appearing to the eye the size of the fist, and fading away as suddenly as it appeared, falling into fiery nodules; then we perceive that, in the apparent calm of nature, various forces are constantly active, in order to cause, even in the invisible air, such combinations and combustions, the appearance of which amuses the crews of ships."

The Reports of the British Association on Meteors from 1848 to 1853, from observations so zealously collected by the late Mr. Baden Powell, show how very frequent are the phenomena of fiery meteors, and what remarkable appearances some of them present. Considering the difficulty of determining the height of bodies presented so suddenly, and so transitory in their appearance, it is no wonder there should be considerable discrepancy among calculators. Olmsted thought the radiant point in Leo of the November meteors could not have been less than 2,238 miles above the earth's surface. Humboldt considers that the heights at the points of which shooting stars begin and cease to be visible fluctuate between 16 and 140 miles. Professor Brandes gives from 240 to 400 miles, and Olbers considers all determinations for elevations beyond 120 miles doubtful, owing to the smallness of the parallax. Brandes ascribes a diameter varying from 80 to 120 feet for shooting stars, and a luminous train extending from twelve to sixteen miles. The relative velocity of their motion he computes to be from 18 to 36 miles per second, their motion being frequently opposite to that of the earth.

Having now described the phenomena of the falling stars, and the larger meteors that accompany them, we proceed to the consideration of another class.

The falling stars, and the larger fire-balls sometimes associated with them, make their appearance suddenly, and, after describing an arc in the heavens, are as suddenly extinguished without passing below the horizon. No sound is heard to accompany this phenomenon. There is another class of fire-balls which are seen to traverse the whole vault of heaven, seen often simultaneously over a large extent of country, whose course can sometimes be traced as passing, for instance, from one end of Great Britain to the other,—of large apparent magnitude, and of such brightness as sometimes to emit a light dazzling even at midday, and superior to the light of the sun. They are sometimes seen to burst into fragments with an explosion heard over a large area.

In the year 1676, on the 21st of March, O.S., about two

hours after sunset, a large meteor passed over Italy: it came over the Adriatic Sea as if from Dalmatia, crossing the country in the direction of Rimini and Leghorn, disappearing out at sea towards Corsica.

It was heard to make a hissing sound as it passed, like that of artificial fireworks. At Bologna the head of the meteor appeared larger than the moon in one diameter, and above half as large again in the other. At Leghorn it was heard to give a very loud report, like a great cannon; immediately after which another sort of sound was heard, like the rattling of a great cart running over stones. Its velocity was estimated at 160 miles per minute, its height about 38 miles, and its lesser diameter about half a mile. Another meteor was observed to pass over all England on the 19th of March, 1718. It was seen by Sir Hans Sloane in London at about a quarter after 8 at night. He was surprised by a sudden light far exceeding that of the moon. Turning towards it, he observed a large spherical meteor not so large as the moon, near the Pleiades, whence it moved after the manner of a falling star, but more slowly, in a seeming direct line, descending beyond and below the stars in Orion's belt. Its brightness was so dazzling that he was obliged to turn his eyes several times from it, as well when it appeared as a stream as when it became pear-fashioned and a globe. It left behind a track of a faint reddish-yellow colour, that continued for more than a minute. He heard no noise. Through Devon and Cornwall, and along the opposite coast of Bretagne the meteor was heard to explode. The report was like that of a very great cannon, or, rather, a broadside at a distance, followed by a rattling noise, as if many small-arms had been promiscuously discharged. Halley estimated the height of this meteor at 60 miles, and its rate at 300 miles per minute.

A similar meteor was observed in England on the 11th of December, 1741, while the sun was shining brightly in a serene sky, and was heard to explode in Sussex. A friend of Humboldt, in the year 1788, at Popayan, found his room lighted up at noonday by a meteor, while the sun was shining brightly in a cloudless sky.

Hundreds of such meteors have been described, and though explosions have been heard over parts of the country favourable for recovering anything solid if it fell from a meteor, in but some four or five cases has anything been picked up likely to have fallen from a meteor; and out of these few cases some are considered doubtful.

We now proceed to consider another phenomenon,—the fall

of stones or hard masses of iron from the heavens. In spite of many recorded instances in ancient and modern times, the account of these falls was regarded with scepticism by the scientific world.

In the year 1794 Chladni published a tract at Riga, on the supposed origin of a mass of iron found by Dr. Pallas in Siberia, which the Tartars called a holy thing, and asserted that it had fallen from heaven. In this tract Chladni called attention to many authentic instances of stones falling from heaven, adducing, among others, the testimony of the celebrated Cardan, that in the year 1510 he himself had seen 120 stones fall from heaven, one weighing 120 and another 60 pounds;—that they were mostly of an iron colour, very hard, and smelt of brimstone.

In the same year that Chladni published this tract, a remarkable shower of stones fell in Tuscany on the 16th of June. This was described in a pamphlet by Ambrose Soldani, Professor of Mathematics in the University of Sienna. In 1795 a large stone, now in the British Museum, fell near Wold Cottage, the house of Captain Topham, in Yorkshire, and was exhibited in London. Mr. Edward King, a fellow of the Royal Society, having received from Sir Charles Blagden some manuscript accounts of the Sienna fall of stones, and having also seen the pamphlets of Soldani and Chladni, called the attention of English men of science to this phenomenon in the first English work on meteoric stones. It is called *Remarks concerning Stones said to have fallen from the Clouds both in these Days and in Ancient Times*, and was published in London in 1796. It is an exceedingly clear, well written, and scientific account of a remarkable phenomenon, to which little can really be added, with all our increase of knowledge on the subject. It was very unfairly treated and ridiculed, at the time it was published, by the reviewers. In 1799, Sir J. Banks received some specimens of stones which were seen to fall at Benares, in Bengal, on the 19th of December, 1798, and perceived a remarkable similarity between these stones and that of the Yorkshire stone, and a specimen of one of the Sienna stones which he possessed. In 1802, Mr. Luke Howard published in the *Philosophical Transactions* a paper entitled "Experiments and Observations on certain Stony Substances which, at different times, are said to have fallen on the Earth." In this paper will be found the first chemical analysis of an aërolite.

The year after this, when an official account was received in Paris of a shower of stones at L'Aigle, in Normandy, on the 26th of April, 1803, the matter was treated with ridicule.

But the Academy of Sciences, influenced doubtless by what had been published in England, deputed Biot to examine the matter. His report being satisfactory, the fall of meteoric stones was admitted to be a well-ascertained fact coming within the domain of science.

Mr. King, in his treatise, refers to Holy Scripture in confirmation of the fall of stones from heaven in these words:—

In the Acts of the Holy Apostles we read that the chief magistrate at Ephesus began his harangue to the people by saying, "Ye men of Ephesus, what man is there that knoweth not how that the city of the Ephesians is a worshipper of the great goddess Diana, and of the *image* which fell down from Jupiter, or rather, as the original Greek has it, "of *that* which fell down from Jupiter." And the learned Greaves leads us to conclude this image of Diana to have been nothing but a conical or pyramidal stone that fell from the clouds; for he tells us, on unquestionable authorities, that many others of the images of heathen deities were merely such.

And again:—

And in Holy Writ also a remembrance of similar events is preserved. For when the royal psalmist says, "The Lord also thundered out of heaven, and the Highest gave his thunder: hailstones, *and coals of fire*"!—the latter expression, in consistency with common sense, and conformably to the right meaning of language, cannot but allude to some such phenomena as we have been describing. And especially, as in the cautious translation of the Seventy, a Greek word is used, which decidedly means *real hard substances made red hot*, and not mere appearances of fire or flame.

Whilst, therefore, with the same sacred writer, we should be led to consider all these powerful operations as the works of God, "Who casteth forth his ice like morsels;" and should be led to consider "fire and hail, snow and vapours, wind and storm, as fulfilling his word," we should also be led to perceive that the objections to Holy Writ, founded on a supposed *impossibility* of the truth of what is written in the Book of Joshua concerning the stones that fell from heaven on the army of the Canaanites, are only founded in ignorance and error.

The earliest record that we have of the fall of an aërolite is of one that fell at Ægos Potamos, 465 B.C. It is so well described by Plutarch in his life of Lysander, that I quote the passage in full, more especially as it throws light on the opinions held by the ancient Greeks on the causes of such phenomena.

There were those who said that the stars of Castor and Pollux appeared on each side the helm of Lysander's ship, when he first set out against the Athenians. Others thought that a stone, which according to the common opinion fell from heaven, was an omen of his overthrow. It fell at Ægos Potamos, and was of prodigious size. The people of the Chersonesus hold it

in great veneration, and show it to this day. It is said that Anaxagoras had foretold that one of those bodies, which are fixed to the vault of heaven, would one day be loosened by some shock or convulsion of the whole machine, and fall to the earth, for he taught that the stars are not now in the places where they were originally formed; that being of a stony substance and heavy, the light they give is caused only by the reflection and refraction of the ether; and that they are carried along, and kept in their orbits, by the rapid motion of the heavens, which from the beginning, when the cold ponderous bodies were separated from the rest, hindered them from falling.

But there is another and more probable opinion, which holds that falling stars are not emanations or detached parts of the elementary fire, that go out the moment they are kindled, nor yet a quantity of air bursting out from some compression, and taking fire in the upper region; but that they are really heavenly bodies, which from some relaxation of the rapidity of their motion, or by some irregular concussion, are loosened and fall, not so much on the habitable part of the globe as into the ocean, which is the reason that their substance is seldom seen.

Damachus, however, in his treatise concerning religion, confirms the opinion of Anaxagoras. He relates, that for seventy-five days together, before that stone fell, there was seen in the heavens a large body of fire, like an inflamed cloud, not fixed to one place, but carried this way and that with a broken and irregular motion; and that by its violent agitation several fiery fragments were forced from it, which were impelled in various directions, and darted with the celerity and brightness of so many falling stars. After this body was fallen in the Chersonesus, and the inhabitants, recovered from their terror, assembled to see it, they could find no inflammable matter, or the least sign of fire, but a real stone, which, though large, was nothing to the size of that fiery globe they had seen in the sky, but appeared only as a bit crumbled from it. It is plain that Damachus must have very indulgent readers, if this account of his gains credit. If it is a true one, it absolutely refutes those who say that this stone was nothing but a rock rent by a tempest from the top of a mountain, which, after being borne for some time in the air by a whirlwind, settled in the first place where the violence of that abated. Perhaps, at last, this phenomenon, which continued so many days, was a real globe of fire; and when that globe came to disperse and draw towards extinction, it might cause such a change in the air, and produce such a violent whirlwind, as tore the stone from its native bed, and dashed it on the plain. But these are discussions that belong to writings of another nature.

Now this passage is most instructive, not only as to the ancient opinions held on the subject of falling stars and meteoric stones; but read by the light of well-known and authentic cases which I will afterwards bring before you, we see that Damachus, in spite of the scepticism of Plutarch and even of some of our modern philosophers, has given

us, in all probability, a most truthful account of a real phenomenon.

Pliny, though sceptical as to the prophecy of Anaxagoras, gives an account, not only of the fall of the stone at Ægos Potamos, but of several others.

The Greeks boast that Anaxagoras, the Clazomenian, in the 2nd year of the 78th Olympiad, from his knowledge of what relates to the heavens, had predicted that, at a certain time, a stone would fall from the sun. And the thing accordingly happened, in the daytime, in a part of Thrace, at the river Ægos. The stone is now to be seen, a waggon-load in size and of a burnt appearance: there was also a comet shining in the night at that time. But to believe that this had been predicted would be to admit that the divining powers of Anaxagoras were still more wonderful, and that our knowledge of the nature of things, and indeed everything else, would be thrown into confusion, were we to suppose either that the sun is itself composed of stone, or that there was even a stone in it; yet there can be no doubt that stones have frequently fallen from the atmosphere. There is a stone, a small one indeed, at this time, in the gymnasium of Abydos, which on this account is held in veneration, and which the same Anaxagoras predicted would fall in the middle of the earth. There is another at Cassandria, formerly called Potidæa, which from this circumstance was built in that place. I have myself seen one in the country of the Vocontii, which had been brought from the fields only a short time before. (*Pliny*, bk. ii., ch. 59.)

From the passage quoted by Plutarch, it is not clear that Anaxagoras predicted the precise day on which a stone would fall from heaven, but, believing that the stars were stony bodies, he predicted that at some time or other some of them would fall from the firmament.

Pliny relates, in the second book of his Natural History, chap. 52, that M. Heremnius, a magistrate of Pompeii, was struck by lightning when the sky was without clouds. He also, in his 57th chapter, gives from ancient monuments several strange meteoric phenomena, not without interest to our subject.

Besides these, we learn from certain monuments, that from the lower part of the atmosphere it rained milk and blood, in the consulship of M. Acilius and C. Porcius, and frequently at other times. This was the case with respect to flesh, in the consulship of P. Volumnius and Servius Sulpicius, and it is said, that what was not devoured by the birds did not become putrid. It also rained iron among the Lucanians, the year before Crassus was slain by the Parthians, as well as all the Lucanian soldiers, of whom there was a great number in this army. The substance which fell had very much the appearance of sponge; the augurs warned the people against wounds

that might come from above. In the consulship of L. Paulus and C. Marcellus it rained wool, round the castle of Caripanum, near which place, a year after, T. Annius Milo was killed. It is recorded, among the transactions of that year, that when he was pleading his own cause, there was a shower of baked tiles.

Livy gives an account of several showers of stones, and states that it was the ancient custom of the Romans to expiate the fall of stones from heaven by a nine days' festival.

After the defeat of the Sabines, when the government of Tullus and the whole Roman state was in high renown, and in a very flourishing condition, word was brought to the king and senators, that it rained stones on the Alban Mount. As this could scarcely be credited, on persons being sent to inquire into the prodigy, a thick shower of stones fell from heaven in their sight, just as when hail collected into balls is pelted down to the earth by the winds. . . . . A festival of nine days was instituted publicly by the Romans also on account of the same prodigy, either in obedience to the heavenly voice sent from the Alban Mount (for that, too, is stated) or by the advice of the aruspices. Certain it is, it continued a solemn observance, that whenever the same prodigy was announced, a festival for nine days was observed. (*Livy*, bk. i., ch. 31.)

The accounts also of prodigies which arrived just at the time of the news of the revival of the war, had occasioned great alarm. At Cumæ the orb of the sun seemed diminished, and a shower of stones fell; and in the territory of Veliternum the earth sank in great chasms, and trees were swallowed up in the cavities. At Aricia the forum and the shops around it, at Frusino a wall in several places, and a gate, were struck by lightning; and in the Palatium a shower of stones fell. The latter prodigy, according to the custom handed down by tradition, was expiated by a nine days' sacred rite; the rest with victims of the larger sort. (*Livy*, bk. xxx., ch. 31.)

Several prodigies were observed at Rome that year, and others reported from other places. In Forum, Comitium, and Capitol, drops of blood were seen, and several showers of earth fell, and the head of Vulcan was surrounded with a blaze of fire. It was reported that a stream of milk ran in the river at Interamna, that, in some reputable families at Ariminum, children were born without eyes and nose; and one in the territory of Picernum that had neither hands nor feet. These prodigies were expiated according to an order of the pontiffs; and the nine days' festival was celebrated, because the Hadrians had sent intelligence that a shower of stones had fallen in their fields. (*Livy*, bk. xxxiv., ch. 45.)

Before the consuls cast lots for their provinces, several prodigies were reported: that in the Crustumine territory a stone fell from the sky into the grove of Mars. (*Livy*, bk. xli., ch. 9.)

I am well aware that, through the same disregard of religion, owing to which the men of the present day generally believe that the gods never give

portents of any future events, no prodigies are now either reported to government, or recorded in histories. (*Livy*, bk. xliii., ch. 13.)

Towards the close of this year (584) it was reported that two showers of stones had fallen, one in the territory of Rome, the other in that of Veii; and the nine days' solemnity was performed. (*Livy*, bk. xliv., ch. 18.)

To come to the Middle Ages: a stone fell at Ensisheim, on the Rhine. It was ordered to be preserved in the church near which it fell, together with a record, which thus commences:—"In the year of the Lord 1492, on Wednesday, which was Martinmas eve, the 7th of November, a singular miracle occurred; for, between eleven o'clock and noon, there was a loud clap of thunder, and a prolonged confused noise, which was heard at a great distance; and a stone fell from the air, in the jurisdiction of Ensisheim, which weighed 260 pounds, and the confused noise was, besides, much louder than here. Then a child saw it strike on a field in the upper jurisdiction, towards the Rhine and Inn, near the district of Giscano, which was sown with wheat; and it did no harm, except that it made a hole there; and then they conveyed it from that spot; and many pieces were broken from it, which the landvogt forbade." After remaining in the church for centuries, it was carried to Colmar during the French revolution. Many fragments were broken from it, which have found their way to many museums; but the remainder of the relic was afterwards restored to the church of Ensisheim.

A pamphlet published at the time, and now preserved in the King's Library, British Museum, gives such a quaint and instructive account of the fall of a meteorite at Aldborough, in Suffolk, that I quote it at some length:—

A signe from Heaven, or a fearfull and Terrible Noise, heard in the Ayre at Alborow, in the county of Suffolke, on Thursday, the 4th day of August, at 5 of the clock in the afternoone. Wherein was heard the beating of Drums, the discharging of Muskets and great ordnance for the space of an houre and more, as will be attested by many men of good worth, and exhibited to some cheife members of the Honorable House of Commons. With a stone that fell from the sky in that Storme, or Noise rather, which is here to be seene in Towne, being of a great weight.—Aug. 12. London: Printed by T. Fawcet, 1642.

Upon Thursday, the 4th day of this instant August, about the hour of foure or five o'clocke in the afternoone, there was a wonderful noyse heard in the ayre, as of a Drum beating most fiercely, which after a while was seconded with a long peale of small shot, and after that a discharging as it were, of great ordnance in a pitcht-field. This continued with some vicissitudes of small shot and great ordnance for the space of one hour and an halfe, and then making a mighty and violent report altogether; at the ceasing

thereof there was observed to fall down out of the skie a stone of about foure pounds weight, which was taken up by them who saw it fall, and being both strange for the forme of it, and somewhat miraculous for the manner of it, was by the same parties who are ready to attest this Truth brought up and shewed to a worthy member of the House of Commons, upon whose ground it was taken up, and by him to divers friends who have both seen and handled the same. Now the manner of finding of this stone was on this wise : one Captaine Johnson and one Master Thompson, men well knowne in that part of Suffolke, were that day at Woodbridge about the lanching of a ship that was newly builded there, who hearing this marvellous noise towards Alborow, verily supposed that some enemy was landed, and some sudden onset made upon the Towne of Alborow. This occasioned them to take Horse and hasten homewards, the rather because they heard the noise of the battel grow lowder. And being at that instant when that greatest cracke and report was made in conclusion, on their way upon an heath betwixt the two Townes, Woodbridge and Alborow, they observed the fall of this stone, which grazing in the fall of it along upon the heath, some 6 or 7 yards, had out run their observation where it rested, had not a dog which was in their company followed it by the scent as was hot, and brought them where it lay covered over with grasse and earth, that the violence of its course had contracted about it. This is the true relation of the finding of this stone, which is 8 inches long and 5 inches broad, and 2 inches thick.

Having described these falls of stones as given by contemporary writers, I will now come to some modern instances. I will first quote from Mr. King the phenomena attending the fall at Sienna.

On the 16th of June, 1794, a tremendous cloud was seen in Tuscany, near Sienna and Radacofani, coming from the north about seven o'clock in the evening; sending forth sparks like rockets, throwing out smoke like a furnace, rendering violent explosions, and blasts more like those of cannon, and of numerous muskets than like thunder; and casting down to the ground hot stones; whilst the lightning that issued from the cloud was remarkably red, and moved with less velocity than usual.

Signor Andrew Montauli, who saw the cloud as he was travelling, described it as appearing much above the common region of the clouds, and as being clearly discerned to be on fire, and becoming white by degrees; not only where it had a communication by a sort of stream of smoke and lightning, with a neighbouring similar cloud; but also, at last, in two-thirds of its whole mass, which was originally black. And yet he took notice that it was not affected by the rays of the sun, though they shone full on its lower parts; and he could discern, as it were, the basin of a fiery furnace in the cloud, having a whirling motion.

The stones that fell were numerous, the largest weighing five pounds and a half—some only a quarter of an ounce. They fell over a space of ground of from three to four miles,

and several were so hot as to burn the fingers of those who attempted to pick them up.

Four years before, a similar phenomenon occurred in France, and was attested by a legal document signed by the magistrates of the municipality and several hundreds of the inhabitants of the district where it occurred. It is as follows:—

In the year 1790, and the 30th day of the month of August, we, the Lieutenant Jean Duby, mayor, and Louis Massillon, Procurator of the commune of the municipality of La Grange-de-Juillac, and Jean Darmite, resident in the parish of La Grange-de-Juillac, certify in truth and verity that, on Saturday, the 24th of July last, between nine and ten o'clock, there passed a great fire, and after it we heard in the air a very loud and extraordinary noise; and about two minutes after there fell stones from heaven; but fortunately there fell only a very few, and they fell about ten paces from one another in some places, and in others nearer, and finally, in some other places farther; and falling, most of them of the weight of about half a quarter of a pound each, some others of about half a pound, like that found in our parish of La Grange; and on the borders of the parish of La Grange, and on the borders of the parish of Creon they were found of a pound weight; and in falling they seemed not to be inflamed, but very hard and black without, and within of the colour of steel; and, thank God, they occasioned no harm to the people, nor to the trees, but only to some tiles which were broken on the houses; and most of them fell gently, and others fell quickly with a hissing noise; and some were found which had entered into the earth, but very few. In witness whereof we have written and signed these presents.

DUBY, Mayor. DARMITE.

On December 13th, 1795, on the afternoon of a mild but hazy day, a report of a violent explosion followed by a hissing sound was heard in the neighbourhood of Wold Cottage, the house of Captain Topham, in Yorkshire. A ploughman saw a large stone fall to the earth eight or nine yards from the spot where he stood. It threw up the mould on every side, and, penetrating through the soil, lodged some inches deep in the solid chalk. The greater part of this stone is now in the British Museum, and weighs forty-five pounds eight ounces.

The next account to which I shall draw your attention is to the great fall of meteoric stones in Normandy which created such a sensation in France, and caused the Academy of Sciences to send a commission of inquiry on the subject, with M. Biot at its head. From this date the fall of meteoric stones has been received as an established scientific fact.

On Tuesday, April 26th, 1803, about one in the afternoon, the weather being serene, there was observed, in a part of Normandy, including Caen, Falaise, Alençon, and a large number of villages, a fiery globe of great brilliancy moving through the atmosphere with great rapidity. Some moments after there was heard at L'Aigle and in the environs to the extent of more

than thirty leagues in every direction, a violent explosion, which lasted five or six minutes. At first there were three or four reports like those of a cannon, followed by a kind of discharge which resembled the firing of musketry; after which there was heard a rumbling like the beating of a drum. The air was calm, and the sky serene, except a few clouds, such as are frequently observed. The noise proceeded from a small cloud which had a rectangular form, and appeared motionless all the time that the phenomenon lasted. The vapour of which it was composed, was projected in all directions at the successive explosions. The cloud seemed about half a league to the N.E. of the town of L'Aigle, and must have been at a great elevation in the atmosphere, for the inhabitants of two hamlets, a league distant from each other, saw it at the same time above their heads. In the whole canton, over which it hovered, a hissing noise like that of a stone discharged from a sling was heard; and a multitude of mineral masses were seen to fall, to the gross number of nearly three thousand. The largest weighed 17½ pounds.

Many meteoric stones have fallen in India. On December the 19th, 1798, at eight o'clock in the evening, a large luminous meteor was seen at Benares, and other parts of the country. It was attended with a loud rumbling noise, like an ill-discharged platoon of musketry, and about the same time the inhabitants of Krakhut, fourteen miles from Benares, saw the light, heard an explosion, and immediately after, the noise of heavy bodies falling in the neighbourhood. The sky had been previously serene, and not the smallest vestige of a cloud had appeared for many days. Next morning, the mould in the fields was found to have been turned up in many spots, and unusual stones of various sizes, but of the same substance, were picked out from the moist soil, generally from a depth of six inches.

Professor Maskelyn, who has devoted such pains to the collection of meteorites in the British Museum, has given in the *Philosophical Magazine* an account of several falls in India, nearly all occurring by day, in a serene sky, and almost all unaccompanied by the appearance of any luminous meteor. Among the most interesting of these is the fall of five stones at Gunduk, on May 12th, 1861. They fell in four spots about three miles apart. Their fall out of a cloudless sky was heralded by a sound like that of ordnance succeeded by several peals of thunder. Those who witnessed the fall of these stones, with one exception, saw nothing peculiar in the sky, and had their attention called to the spot where the stones fell by the dust and gravel thrown up by their fall. The exception was a native, who was taking his cattle to the water when he was startled by three loud reports, and saw in the air on high a "light," which fell to the ground within two hundred yards. Sky serene, weather fiercely hot; but there was a very

small cloud, out of which this witness stated the report and the luminous body to have come. He adds, "there was the loud report, and about the same time I saw the light like a flame; then the stone fell, and in falling made a great noise; and after it fell, the sound was taken up high into the air." He found five pieces of stone; they were hot, as was the sand around, which was thrown to the height of a foot. Two of these fragments brought to this country fit together exactly.

Professor Haughton, of Trinity College, Dublin, gives an analysis of a remarkable meteoric stone which fell at Dhurmsalla, in the Punjab, on the 14th July, 1860, at 2.15 p.m. Contrary to what has been observed in all other cases, the fragments of this stone were said to be cold, and not hot, when they fell. "The cold of the fragments that fell was so intense as to benumb the hands of the coolies who picked them up, but who were obliged, in consequence of their coldness, instantly to drop them."

The last account of the fall of meteoric stones to which I will call your attention is that described by Dr. Smith in the *American Journal of Science*, as taking place in Guernsey county, Ohio, on the 1st of May, 1860. He catalogues twenty-four stones, the largest weighing one hundred and three pounds, and the smallest half a pound. They were scattered over a space ten miles long, by three miles broad. The following are some of the facts he collected from persons on the spot:—

We, the undersigned, do hereby certify, that at about half-past twelve o'clock on Tuesday, May the 1st, 1860, a most terrible report was heard immediately overhead, filling the neighbourhood with awe. After an interval of a few seconds, a series of successive reports, the most wonderful and unearthly ever before heard by us, took place, taking a direction from meridian to south-east, where the sounds died away like the roaring of distant thunder, jarring the houses for many miles distant.

This is the testimony of those who heard the noises, but did not witness the fall of the stones. Among others who saw stones fall, Mr. Preben affirms:—

I heard the reports and roaring as above described, and a few seconds afterwards, I saw a large body or substance descending and striking the earth four or five hundred yards from where I then stood; and that I, in company with Andrew Lister, repaired to the spot, and about eighteen inches beneath the surface found a stone weighing fifty pounds.

Mr. Noble states:—

I distinctly heard the roaring and sounds as above described, and a few seconds after the above report, I saw descending from the clouds a large body that struck the earth above a hundred and fifty yards from where I then

stood, and I immediately repaired to the spot, and about two feet beneath the surface found a stone weighing forty-two pounds. A second or two after seeing the first stone, I saw another descend and strike the earth about the same distance from where I stood. I also took the last-mentioned stone from the earth about two feet beneath the surface; both the above stones, when taken from the earth, were quite warm. I also saw a third stone descend.

As to the temperature of the stones, we are told that several of the largest stones were picked up ten minutes after their fall, and are described as being about as warm as a stone that had lain in the sun in summer. One fell among dry leaves that covered it after it had penetrated the ground; the leaves, however, showed no evidence of having been heated; no appearance of ignition was discoverd in places or objects with which the stones came in contact at the time of their fall; so that their temperature must have been far short of red heat, while it may not have reached that of 200°.

It may further be remarked that the day was cool, and the sky covered at the time with light clouds. No thunder or lightning had been noticed that day, nor could anything unusual be seen in the appearance of the clouds. Immediately on hearing the report, one observer looked in the direction it came, and noticed the clouds closely, but could not see anything unusual.

Those who were in the district where the stones fell, and witnessed their fall, saw no fire-ball or meteor. Others at a considerable distance, however, saw a ball of fire flying with great velocity; to one it appeared as white as melted iron. Another saw a ball of fire of great brilliancy emerging from behind one cloud and disappearing behind another. The course of this meteor seemed to be over the district where the fall of stones occurred. Whether these two phenomena were connected, is a point of some importance to be determined.

On other occasions, when a bright meteor has been observed by those at a distance from where a shower of stones has fallen, no meteor, but only a cloud, has been seen by those witnessing the fall of the stones. Professor Shepherd, who has devoted his life to the collection of meteorites and of all the facts connected with them, remarks that "only four or five large detonating meteors, out of several hundreds whose paths have been observed with more or less precision, have been known to throw down stones."

Generally speaking, but little damage has been done by the fall of meteorites. Humboldt relates that, on the 4th of September, 1511, a monk at Crema, near Milan,—another

monk in the year 1650, and in 1674 two Swedish sailors on board ship, were struck dead by aërolites.

These meteoric stones have been divided into three classes: aërolites, siderolites, and aëro-siderolites. The first class, the aërolites, comprise the greatest number of meteoric stones that have been seen to fall. They all, wherever they have fallen, whether in Europe, Asia, Africa, or America, present a most striking resemblance to each other. They are stony masses, covered with a very thin black rind, where they have not been broken after their fall. Internally, they are of a greyish white, and of a somewhat gritty structure, like coarse sandstone. They consist of various silicates interspersed with isolated particles of nickeliferous native iron, meteoric pyrites, &c.

Professor Daubrée proposes to divide these aërolites into two classes—(1) Those which give after fusion a crystalline mass, and (2) those which give a vitreous mass. The first corresponds to those meteorites composed principally of magnesian silicates, and the second to those composed principally of aluminous silicates; the latter being extremely rare, Professor Daubrée having found four specimens only out of 150 different stones preserved in the collections examined. It is certain, says M. Daubrée, that some terrestrial rocks, and at their head lherzolite, present a composition identical even in its variations with that of the common type of meteorites. This lherzolite is a common eruptive rock in the Pyrenees, and is considered generally to be a massive variety of pyroxene. The structure of aërolites, though chemically identical with some of the basaltic or eruptive rocks, is not mechanically the same. Mr. Clifton Sorby, in his microscopical researches into the composition of meteorites, states that "some isolated portions of meteorites have also a structure very similar to stony lavas"; and again: "this sometimes gives rise to a structure remarkably like that of consolidated volcanic ashes; so much so, indeed, that I have specimens which might at first sight be mistaken for sections of meteorites."

The second class of meteorites—the siderolites—consist of a sponge-like body of nickeliferous native iron, whose cavities are filled more or less with crystals of siliceous minerals, principally olivine. Of those preserved in the British Museum, not one has been observed to fall from the sky. The third class, called the aëro-siderolites, are composed almost entirely of masses of native iron, more or less combined with nickel. Out of eighty specimens preserved in the British Museum, only five have been seen to fall from the heavens. The remainder are believed to be meteorites, for the following reasons. Such

masses have been known to fall, and they all possess the same characteristics as those that have fallen. Native iron, that is, iron in a metallic state, is very rarely found on the earth's surface, and when found, only in very small particles, owing to the ease with which iron combines with oxygen. Iron, again, when obtained from the ore, is rarely combined with nickel. The masses, when found, have been in positions far removed from any iron ore from which they could have been formed; and, lastly, when these meteoric irons are cut and their surfaces are polished, the application of a dilute acid sometimes, but not always, brings out on their surface crystalline lines and figures, like those sometimes seen formed by frozen moisture on a sheet of window-glass in frosty weather. These are called after their discoverer, "Witmannstaetten figures." No one has succeeded in producing these figures by acting on ordinary iron, whether cast or malleable, in the same manner; not even in the case of iron axle-trees, which have become crystalline after long use. M. Daubrée, by using a peculiar furnace producing a very great heat, established the fact that fused meteoric iron will not reproduce the figures, and that malleable iron melted with nickel in the same proportions as found in meteoric iron, would not produce the Witmann-staetten figures artificially, until from two to ten per cent. of phosphide of iron was added to the mixture.

Meteoric iron is sometimes malleable; at others, scarcely so at all. Knives made from malleable meteoric iron by the Esquimaux may be seen in the British Museum. In the year 1620 a mass of meteoric iron fell in the Punjab, and was dug out of the earth while still violently hot. It was conveyed to the court of the emperor Tchanjire, who ordered a sabre, a knife, and a dagger, to be forged from this iron of lightning. After a trial, the workmen reported that it was not malleable, but shivered under the hammer; and it required to be mixed with one-third part of common iron, after which the mass was found to make excellent blades. I need not, perhaps, remind you that there is no similarity of structure whatever between any of the known meteorites, and the concretionary balls and oblong masses of iron pyrites washed out of the chalk cliffs of Dover, and often sold to the visitor as genuine thunderbolts.

I must also tell you that the existence of nickel and cobalt combined with iron is no proof that the mass in which it is found is necessarily a meteorite. On June 21st, 1855, Sir R. Murchison read a short paper before the Royal Society "On a supposed aërolite found in the trunk of an old willow-tree in the Battersea Fields." This "aërolite" contained a large per-centage of iron, and also traces of nickel, cobalt, and manga-

nese. It was pronounced to be an undoubted meteorite by most competent authorities, and was supposed to have fallen into the tree, and to have been imbedded in the timber by its growth. Some circumstances caused a degree of scepticism to be entertained as to the meteoric origin of the mass; a further search was made. Digging about the root of the tree, several similar masses were found, having the same chemical composition, but possessing other characteristics which showed that they were nothing more than the slag of an old iron-furnace which once stood near the spot, and a piece of which must have been thrown up into the fork of the tree.

It will readily be imagined that the fall of meteorites was no sooner established as a fact, than philosophers speedily invented theories to account for their appearance. Ignoring the theory of Soldani, "that the stones were generated in the air by a combination of mineral substances, which had risen somewhere or other as exhalations from the earth; and the more precise one of Mr. King, who traced the origin of these meteorites to the matter projected from our own volcanoes into the upper regions of the air, and then condensed by chemical and electrical forces; the most popular theory for many years was to ascribe their origin to lunar volcanoes. Herschel, senior, fancied he saw numerous volcanoes in an active state of combustion in the moon, though modern observers tell us that this was a delusion.

Laplace, Biot, Brandes and Poisson all adopted the theory of lunar volcanoes, and calculated the projectile force necessary to throw the volcanic ashes of the moon so far within the earth's sphere of attraction as to bring them to its surface. Laplace put this force as not greater than five or six times that of an ordinary cannon. The reason why the lunar rather than the terrestrial volcanic origin of the meteors was chosen, was because of the moon's supposed freedom from water on its surface, or moisture in its atmosphere, if it had any; it being assumed that the native iron could not be formed in the presence of oxygen or water.

The discovery, however, of the large number of bodies called the asteroids, caused the complete abandonment of the lunar theory, and the adoption of what is now called the cosmical origin of meteorites.

Bode, the astronomer, discovered a peculiar arithmetical law in the distances of the planets from the sun. Assuming the distance of Mercury to be as 4, the following is very nearly the order of the distances of planets from the sun:—

Mercury	$= 4.$
Venus	$= 4 + 3 = 7.$
Earth	$= 4 + 3 \times 2 = 10.$
Mars	$= 4 + 3 \times 2^2 = 16.$
———	$= 4 + 3 \times 2^3 = 28.$
Jupiter	$= 4 + 3 \times 2^4 = 52.$
Saturn	$= 4 + 3 \times 2^5 = 100.$
Uranus	$= 4 + 3 \times 2^6 = 196.$

It will be observed that there is a blank between Mars and Jupiter, which has been supplied by the discovery of not one, but a series of ninety small planets. In 1801, Piazzi discovered Ceres; in 1802, Olbers discovered Pallas; in 1804, Harding discovered Juno; and in 1807, Olbers again discovered a fourth—Vesta. These four small planets lie between Mars and Jupiter; their orbits intersect each other, and their mean distance from the sun agrees with Bode's law. Herschel, senior, called them asteroids. Herschel, junior, in writing his most admirable *Popular Astronomy* (by far the best in any language), in 1833, laughs at what he calls the philosophical dream of Bode, which led to their discovery, in these words :—"This may serve as a specimen of the dreams in which astronomers, like other speculators, occasionally and harmlessly indulge."

From the fact that the orbits of these four asteroids all intersect in one point, Olbers, the discoverer of two of them, conjectured that they were fragments of one planet. Lagrange determined the force necessary to blow the planet into pieces. This theory led to a careful mapping and survey of the heavens in the zone of the asteroids' path; and now the asteroids number ninety—and how many more "fragments" may be discovered no one can conjecture. Sir John Herschel withdrew this passage from the larger astronomy which he published a few years since—somewhat prematurely some may think; for the discovery of Neptune proved that Bode's law of distances altogether failed as far as that new member of the planetary system was concerned. Now, whether deservedly or not, the destruction of Olbers' planet is generally consigned to the limbo of hypotheses, as no better than a mere philosophical dream.

The history of the discovery of this ring of small planetary bodies circulating between Mars and Jupiter is very instructive. It shows us that discoveries may be made, even by a law deduced from numerous observations and coincidences, capable of mathematical expression, which may, after all, turn out to be no law of nature at all, in the philosophical sense. Since the small planetary bodies revolving round the sun

between Mars and Jupiter have been found to be so numerous, and many of them so very small in diameter, the lunar origin of the meteorites has been altogether abandoned. The popular theory now is that all the meteoric phenomena I have been describing—the falling stars, the flaming meteors or fire-balls, and the meteoric stones which have fallen from the heavens—are connected together, and are all due to the attraction, within the limits of our atmosphere, of interplanetary masses, similar to those forming the ring of asteroids between Mars and Jupiter.

In the first place it must be remarked that no law of periodicity whatever has been observed in the fall of meteoric stones. Looking over a list of all the observed falls of meteoric stones, I can find no periods of maximum numbers of falls near the same day of the month. A few years ago it seemed as if more falls occurred at one period of the year than at others; but the addition of recent observations to the list proves such deductions to have been fallacious. For instance, looking at the list, the 13th of December would seem at first sight to give a period for the fall of meteoric bodies. Up to the year 1813 four stones fell in different years on the 13th of December, and one on the 14th, and no others were recorded as falling in that month. Since that year seven falls have been recorded in December, not one of which on any day near the 13th and 14th. The first five recorded instances for the month of December must therefore be regarded as simply a curious coincidence of dates, especially as the dates for every other month fail to point out the existence of any periodical days for the fall of meteorites.

The same want of period-days applies to the fire-balls, or large flaming meteors, or bolides as they are sometimes called, passing very near the earth's surface, and often exploding with a loud report.

With regard to the falling stars, I have already observed that the remarkable period-days for their manifestation apply only to what we may call the great showers, or star-storms. Falling stars are seen at all places on the earth's surface more or less frequently by night, every night in the year. The periodical showers, such as those of August and November, are not seen every year. They appear for a few years perhaps in succession, and then almost disappear altogether for several years in any notable number on those particular period-days; so much so that before the great fall of last year, one French scientific observer, devoting himself to the observation of falling stars, was altogether sceptical as to the existence of these periodic days.

The theory which attributes falling stars, fire-balls, and meteoric stones, to the attraction of minute planetary or cometary bodies revolving round the sun, within the sphere of attraction, seems to be the following. An immense number of such bodies are scattered through what is called inter-planetary space. When these bodies are drawn within the sphere of the earth's attraction by its disturbing force pulling them out of their orbit, they enter within the limits of the earth's atmosphere. Coming into this atmosphere, even where, from its height above the earth's surface, it is very greatly attenuated, nevertheless, the friction produced by their passing through this attenuated atmosphere, with their own planetary velocity of motion, combined in most instances with that of the earth itself, produces such an enormous heat as to inflame the matter composing the body, and in most instances to convert all its solid particles into vapour. A falling star, therefore, is caused by the passage of an inter-planetary body with enormous velocity through the earth's atmosphere, causing its rapid combustion and speedy dissipation into vapour. Attempts have been made (though I cannot but regard all such calculations as most fallacious) to calculate the velocity necessary to produce the combustion of a meteoric mass, such as a meteorite, at some forty or fifty, or even a hundred miles' height from the earth's surface, and the light which would be emitted by a given mass of matter; this, too, in spite of our admitted ignorance of the density, or rather tenuity, of the atmosphere at such heights.

Some of these bodies are supposed not to be entirely consumed, but their apparent track as a luminous body is supposed again to be produced by their passage through a portion of the earth's atmosphere, as they dip only through a part of the atmosphere in their motion through space. According to this theory, other flaming meteors or fire-balls consist of masses of matter too large to be so dissipated into vapour, which move for a longer time through the lower regions of the earth's atmosphere, till the nucleus of the meteor bursts by the action of intense heat, and meteoric stones and masses fall to the earth.

The wandering small planetary bodies are supposed to be more thickly distributed in some parts of space than others, like the ring of known and observed planetoids between Mars and Jupiter. Two or more such rings are supposed to intersect the earth's path. Such a ring would be subject to perturbation by the earth's attraction, causing a change in the periods at which it would intersect the earth's orbit. Great star-showers are supposed only to occur when a rich or thickly

studded part of the ring is swept into the earth's atmosphere. As a period of maximum star-falling occurs about the 13th and 14th of November in periods of thirty-three years, this period gives the clue as to the period when the ring approaches most nearly the earth's orbit, and also accounts for the maximum showers being manifested in less intensity a year or two before and after these periods, and not in the interval between. The coincidence of last year's display has been everywhere quoted as a triumphant demonstration by mathematical calculation of the truth of this whole theory. I call that a coincidence, for which we may more fairly perhaps be indebted to the law of probability than to any more abstruse calculation of the retrogression of the nodes of the assumed ring of planetoids. For in the first place the number of recorded recurrences of falling stars on these period-days is far too small to found so great a theory, when we consider that they are merely maximum manifestations of a nightly phenomenon of greater or lesser intensity. That the recurrence of the 33-year period has but three occurrences in its favour,—the years 1799, 1832, and 1866, even making allowance for an increase of a year for the last display; the star-storm of 1799, which has been imported into this periodical display, being, as I have before observed, a mistake, as it occurred not in November, but in the month of October. On the other hand, within these limits the great November showers of 1787 and 1822, as well as many others of less brilliancy, cannot be brought within the period of the thirty-three years. Again, the ancient October displays, which have been regarded as a proof of the gradual alteration of the planetary ring's intersection of the earth's orbit, are more readily accounted for without this alteration as being connected with that of 1799. If the planetary origin of falling stars is to be made out, it can only be demonstrated by a much larger collection of facts than have yet been observed.

Again, the inclusion of the meteorites and flaming meteors or fire-balls in this planetary theory, only tends to throw doubt upon the theory.

In the first place the passage of fiery meteors in the lower atmosphere coursing over the earth, and then exploding, or of clouds casting stones to the earth, has never yet been found to accompany the great displays of falling stars. Both these phenomena seem destitute of any period-days whatever. Nor yet has the connection of flaming, bursting meteors with the fall of meteoric stones been at all made out as conclusive; out of many hundred recorded instances where stones have been seen to fall, only some four or five have been shown to be connected with any appearance of a fire-ball. Even in these

cases, except perhaps in one instance, the fire-ball was not seen by those witnessing the fall of the stone. So that it is doubtful whether the two phenomena were connected. And in the only instance in which a fire-ball and a meteoric cloud shooting stones to the earth were observed to be identical, it by no means follows that that fire-ball was identical in composition or nature with ordinary fire-balls.

Again: we are to suppose that, when the earth passes through those parts of space the richest in planetoids, all those producing the phenomena of falling stars are reduced by frictionally developed heat into vapour. And yet these bodies, assumed to be identical in composition with meteoric stones, thus converted in such extraordinary numbers into vapour, are followed in no known instances by any remarkable showers of meteoric dust. Again: the meteoric stones which reach the earth pass through a much denser portion of the earth's atmosphere without being so dissipated. If we are to account for this latter fact on the supposition that they are larger planetary masses than those causing a falling star, we are to suppose that the larger bodies are found in those parts of the planetary ring in which the planetoids are most sparsely scattered. Again: I cannot at all account for the smaller bodies being totally dissipated into vapour in the highest regions of the atmosphere, where the density and consequent friction of the moving mass is the least, with the appearance of every meteorite that has been seen to fall. These indicate the action of an intense heat indeed, but penetrating only a line or two into the thickness of the stone. According to Professor Thomson's and Professor Joule's estimate, every meteorite that has reached the earth from the supposed planetary ring ought to have been fused into vapour, like those supposed to produce the falling stars. The meteoric stones, so far from reaching the earth in a state of fusion, are not even red-hot. We have seen that they have fallen on dry leaves without setting them on fire. If the case reported by Professor Haughton is to believed, on the testimony of the natives who handled the stone after it fell, it was so far from being hot, that it was colder than ice.

On the whole, I cannot but conclude that the modern theory of the planetary origin of falling stars, fire-balls, and meteoric stones, is far from being supported by the facts which have been recorded;—that the common origin of these three phenomena has by no means been proved;—and that the planetary origin and combustion of the falling stars cannot be admitted, if we refer the meteoric stones to the same source.

This is just one of those subjects where a confession of

ignorance is the best wisdom, and where science will be better served by a close and honest observation of phenomena than by faulty, ill-digested theories. In conclusion, I would remark that, for aught we know to the contrary, falling stars may be an electrical phenomenon, somewhat like, but differing in intensity from, the aurora borealis. They both seem to appear in the upper regions of our atmosphere; both seem to radiate from fixed points; both can be imitated artificially by the passage of electricity through rarefied gas or air; both have many points of resemblance. Moreover, both phenomena seem to be connected. Aurora has been seen more than once to accompany the display of falling stars. It has also been noticed that the passage of a falling star through the sky has lit up, as it were, a flash of aurora, where it had not previously been seen; showing, at least, some connection between the phenomena.

Again: there are electrical displays, such as the fires of Elmo, and globular lightning, and fire-balls slowly advancing on the sea, and bursting as an electric shock on a vessel, which would seem to show that some of the fiery meteors at least might be referred to an electric origin.

With regard to the origin of meteorites, the first English theory of their terrestrial origin has not lost all supporters, They are identical in chemical and, in some measure, even in mechanical structure, with our own volcanic rocks.

The phenomena which so persistently accompany the fall of meteoric stones by no means accord with their supposed passage through the atmosphere with planetary velocity. They fall to the earth with no greater velocity than they would attain by falling from the clouds they are seen to be projected from. Tons upon tons of dust, rich in the shells of foraminifera of South America, are carried into the atmosphere by tornadoes. This dust rises above the trade winds, descends after a flight of thousands of miles, and covers areas of many square miles of the ocean in the Atlantic or Mediterranean. If wind can thus carry dust and sand, who can tell what vapours of metals and other materials may be projected from our volcanoes? Some electrical condition of the atmosphere may condense these vapours, just as masses of ice are formed in mid-air by the same agency. The same crackling, rumbling sound which presages the formation of masses of ice in the atmosphere is a never-failing accompaniment to the mysterious cloud which projects its stony mass to the earth. Electricity can reduce metals from their combinations, as well as resolve them into vapour. At any rate, this theory is not wilder than many others which have been framed about meteors. It is not

wilder than that which gives the sun its heat by a constant shower of meteors, the arrest of whose motion supplies the heat lost by the sun by constant radiation; or the opposition theory, which, instead of pelting the sun with meteors, accounts for these meteors as masses of vapour escaping from the bubbling, boiling surface of the sun, and projected with such velocity as to reach the earth after condensation by the extreme cold of planetary space.

The CHAIRMAN.—I am sure you will allow me to return thanks to Mr. Mitchell for this very interesting and instructive paper. In this age there is so great a tendency to attach so much to authority, that it is very valuable to see how very little authority is sometimes worth, and how great is our ignorance and how little our knowledge of that which we profess to know very well. We shall be glad to hear any gentleman who has any remarks to add or suggestions to offer.

Mr. REDDIE.—I think the paper that we have heard this evening (which I am sure we have all listened to with much pleasure) is one that scarcely admits of discussion. That is one of the disadvantages of having very good papers. We had Professor Kirk's paper at our penultimate meeting, and Mr. Mitchell's paper to-night, both giving us such able discourses on the subjects they treat of, that there is nothing left for us to say. (Hear, hear.) Mr. Mitchell will complete his paper for our *Journal of Transactions*, I beg leave to say, although the latter part of it was delivered *extempore*. With reference to some of his remarks, I should be very glad if he could collect some of the various reports respecting the recent meteoric shower as seen at different places. I think they would demonstrate the truth of what he has said as regards the uncertainty there must be as to the real heights of those bodies; for the accounts have varied so much that either the witnesses must have stated very incorectly what they saw, or else they did not all see the same things. If you will take the accounts published in London and different parts of England, and others at Malta, you will observe that both as to the numbers of the falling stars, and in various other particulars, they do not agree with one another. And I think it will yet prove that most probably this is an electrical phenomenon, in which there are brilliant scintillations, all more or less tending in one direction. But there is certainly a great discrepancy as to the quantity of those observed; and I may say even as to their apparent distances from the earth. Even in this country I observe in the various accounts in *The Times* there was a great difference as regards the number of the meteors; and even people in the same house, describing what they saw, gave different accounts to one another the next morning. I think it is almost impossible to consider that those majestic slow-moving fire-balls (one of which I saw two years ago, in November, the only one I have ever seen in my life, it was about the size of the moon, and moved in a south-westerly direction,) can be considered similar either to those heavy masses of meteoric matter, or to those mere scintillations called falling stars. You

might just as well consider them as actually falling stars, because they are like the stars in heaven ; for although we call them falling stars, we know they have nothing in common with stars. I am sure Mr. Mitchell's account will be a most valuable record on the subject in our *Transactions*, and it will very likely complete No. 4 of our *Journal*.

Professor OLIVER BYRNE.—I have a few remarks to offer to you, and they are based upon demonstration, and not conjecture. I am going to base what I have to say upon what Archimedes based his mechanics. It is, "the law of sufficient reason," carried out by Leibnitz, and made great use of by Laplace. It is known to all philosophers, who make use of it to prove one thing, but reject it when you want to prove another. Leibnitz made great use of it, and I should have said that our very learned and worthy Vice-President has brought before us a subject that requires our most serious consideration, because it is the only index we have left, it is really the only weather-vane by which men can discover the motions of the heavens. Now, I have taken 13 of the principal stars, and I have calculated their positions up to the 1st January, 1867, and their proper motions and declinations. It was a great deal of labour, and I am sure that each of these stars loses place, as regards the observer, by 600 or 700 yards. The pole star and others have travelled 666 yards out of their places. These stars all move, and there is a delusion in astronomers about them ; they all say they have a proper motion, and it is a curious thing that all the negative quantities of these 13 great stars differ but 16″ from all the positive motions of the larger stars in the heavens—

The CHAIRMAN.—The difference between the positive and the negative quantities.

Professor BYRNE.—This motion takes place, which I am going to prove by the law of sufficient reason. No philosopher has ever been able to prove the parallelogram of forces ; and all attempts to prove have failed when the quantities compared are incommensurable. If these had relations to one another, we could get a law, but it is impossible. If you give me the diagonal of the square, no one can tell the length of the side—the diagonal may be 20 feet, but you cannot tell the length of the side—that seems simple, yet it is impossible that any one can find it out. The diameter of a circle may be 10 feet, no one can tell the circumference. There is no law for the incommensurability of quantities, and the law of sufficient reason will not apply. What I am going to prove will be proved with the exception that I am not taking incommensurable quantities, and the only specimen of human reasoning totally perfect is the 5th Book of Euclid, because it takes in the doctrine of incommensurable quantities altogether ; and consequently what I am going to say is subject, not to comparison with incommensurable quantities, but quantities that can be measured by practice. I suppose I have taken the right motion of the stars ; but to show I have not done so, my empirical rule differs 16 seconds, which is very small. We will take 13 of the larger stars, and each one in its turn operates upon its neighbour. The question is this,—the conclusion I am coming to, the object I wish to prove is this,—and

I wish to prove it in this way, that the actions of the forces of these stars act on one another. If I take hold of this book, and Mr. Mitchell attempts to pull it at an angle to me, and I pull it at the same angle, there is no reason why the book will fall to him or to me, if both pull at the same angle with the same strength. It will remain in the position in which it is, and consequently obey neither one nor the other. There can be no action in the matter, and there can be no motion in the stars unless some force is operating in favour of one rather than the other. When a man tells me that this meteoric stone came down on the ground with a certain velocity, it depends on the short time in which it stopped; it is not in the velocity,—the force depends on the shortness of the time. (Question.) This may be very awkward; I will try and do my best, because Mr. Mitchell's paper bore on the velocity and force of the aërolites falling on the earth. I returned from the subject to the equal pulling of the proper motion of the fixed stars, showing the balancing of one another (which I did not like to read one by one), not all going one way, but balancing one another. There is no system of the law of gravitation whatever, it is a secondary thing compared with the actions of the stars on one another—

Mr. Reddie.—You began with the fixed stars, and then you passed from them to the planets; but the difficulty is to understand how you mean to connect them together and with the subject of meteors.

The Chairman.—Keep to the question.

Professor Byrne.—Am I in order? I am afraid I wish to carry the thing one way too far; but to go back to the force of a body and the blow it gives, as an aërolite coming any distance; does that depend upon the impression so much as the space of the time in which the body comes. My whole object in rising is this, to show that there is an action in the fixed stars, upon which the force of gravitation is secondary—

Mr. Reddie.—I do not think this question of the fixed stars has anything to do with meteors.

Professor Byrne.—I got up to show that it had. Mr. Chairman, I submit I got up to show that. Perhaps Mr. Reddie will show me that it had not, and I will then sit down.

Mr. Reddie.—It is not for me to do so. I should be sorry to interrupt unnecessarily any gentleman when speaking, but now I must throw myself on the good-nature of the meeting. I must say, that I do not see that Mr. Byrne has shown that there is any connection between the fixed stars and meteors; and I do think it irregular to go into such elaborate questions as he has entered upon, when we have a specific subject before us. If, however, the other question is to be gone into, I think we ought to have it treated a little more coherently; and if Professor Byrne will write a paper on the motions of the fixed stars, which it appears to me is a totally distinct subject, I am sure we shall all be most glad to hear him. Professor Byrne is a great mathematician, and is entitled to bring those things forward; but we must keep to one subject at a time; and I certainly do not understand how these remarks of Professor Byrne can be considered as having any reference to the

paper of Mr. Mitchell, if Mr. Byrne will excuse me for saying so. He knows I am a sincere friend of his, and that I should be glad to hear him upon any point connected with astronomy, but pray let us have it at the proper time and place. (Hear, hear.)

Mr. WARINGTON.—I should like to ask one question of Mr. Mitchell. I never before heard the theory started, which seems a probable one, that the origin of the shooting stars is electrical rather than cosmical. And I would ask, whether there is anything in the phenomena of the aurora borealis similarly periodical, as to particular seasons or days of the year, with the periodical display of meteors? Because, if there is any such periodicity here also, it would very materially help out the hypothesis. I am not aware whether there is anything of the kind, and, perhaps Mr. Mitchell will tell us.

The Rev. WALTER MITCHELL.—In reply to Mr. Warington, I may state that I am unacquainted with any period days marking a great display of aurora borealis. I only wished to point out several analogies between the two phenomena. In some latitudes the aurora is almost nightly visible, like the display of falling stars in other latitudes. Then there is something similar in the intermission of the brilliant displays of both phenomena—the aurora appearing in lower latitudes for a few years, and then disappearing altogether, like the maxima exhibition of falling stars. With regard to the period days of falling stars, I may state that these are not the only meteoric phenomena (using the term meteor in its widest sense), which are periodic. There are certain latitudes where the return of the monsoons and the change of the trade winds occur with such regularity as to allow their prediction nearly to a day. In defence of the theory first put forth by Soldani as to the terrestrial origin of meteorites, I think many facts might be urged, though I doubt whether they would be considered sufficient to demonstrate its truth. The majority of meteorites are admitted to be identical in composition with solid masses ejected from our own volcanoes. These masses, for aught we know, might have been projected in a state of vapour, and might remain for some time uncondensed in our upper atmosphere. Or, if condensed, they might remain, as Professor Shepherd has stated, in minute subdivision till condensed into a solid mass by some such known agency as electricity. We know that some metals do evaporate like water, and their vapour ascends like that of water into the atmosphere; mercury is an instance. We are ignorant, because our analysis is not sufficiently sensitive to tell us, how many of the constituents of meteorites may be diffused through our atmosphere. If not in a state of vapour, yet in a state of minute subdivision, such constituents could be carried by the upper trade winds thousands of miles. Vessels on the Mediterranean and in the Atlantic sometimes pass through a red fog for days together. A red dust may be collected on the rigging of ships, and Professor Ehrenberg has shown that this dust is composed for the most part of the shells of foraminiferæ, which have been wafted thousands of miles from the plains of South America by the upper trade winds. These fogs, covering as they do some hundreds of square miles, must contain many tons of material

thus wafted by the winds. Under certain meteoric conditions, this minutely subdivided matter returns again to the earth. Just as, in ordinary conditions of the atmosphere, the moisture descends to the earth as rain or snow, we know that under certain more extraordinary conditions, large masses of ice are formed, supported during that formation contrary to the laws of gravity, and then hurled to the earth. There appears some analogy between this latter phenomenon and that of the formation of a meteorite. The peculiar noise, like a discharge of small arms, which heralds the fall of a meteorite from a cloud, in a somewhat modified form, accompanies the formation of blocks of ice in the air. We know, as in the beautiful test for arsenic discovered by Marsh, that a solid metal arsenic may be combined with an invisible gas, hydrogen, and form together an invisible gas. When this is combined with oxygen, a spark of electricity is sufficient to combine the oxygen and hydrogen into water, and precipitate the arsenic in a pure metallic state. May there not be some analogy between this fact and the formation of meteoric iron? I may add, as it appears to militate against the electrical origin of falling star storms, that I have ascertained that no disturbance was observed in the delicate magnetic needles of Greenwich Observatory during the late November display. On the other hand, I believe that it is recorded that the most delicate electrometers have not been in the slightest degree affected during a magnificent display of aurora borealis.

The Rev. Dr. IRONS.—I think Mr. Warington's point was this. There is admitted to be a certain moment of periodicity respecting the wonderful displays of the meteors called falling stars, and we know that the last shower was predicted. Could you affirm anything about displays of the aurora borealis being predicted? because, if not, it would seem hard to connect the two things together—the one being predictable, and the other casual.

The Rev. WALTER MITCHELL.—I may say in reply to this question that I do not know of any display of aurora borealis being predicted with the same degree of precision as to any particular day as these exhibitions of falling stars, but I have called attention to the fact that the maximum appearance on any day does not follow any period of years; that for a number of years in succession so few stars have been seen to fall on the 13th or 14th of November, or from the 10th to the 12th of August; that certain of the French observers, one of whom devoted attention night after night to counting them, gave up altogether the theory of periodicity. I might perhaps say that the prediction of the meteoric display of 1866 was a philosophical "fluke"—it was a fair guess from probabilities founded upon the years 1766, 1799, 1833. It was a good guess to say 1866; but, as I have before pointed out, there have been displays between those years which have not and could not have been predicted; that of 1766 was included by mistake; nor can we predict whether in November, 1867, we shall have a more abundant shower of falling stars than we had last year, or in 1864 or 1865.

The CHAIRMAN.—I quite agree with Mr. Mitchell that there is no periodicity with regard to meteoric showers, for I have been a great deal in tropical latitudes, where falling stars are constantly seen night after night,

and displays so brilliant that it would be said, if such displays occurred in England, that these were some of the great periodical exhibitions of falling stars, and the whole argument of periodicity would be brought into question at once. I think there is a mixing up of these questions of falling stars and meteorolites, that are perfectly distinct. With respect to the latter, I remember in 1829 being at Malta, when one of them came through the roof of the house in which I was. It was associated at the time with thunder and lightning; and a spire of one of the churches was struck. I can quite understand that a certain condition of the atmosphere would facilitate the formation of these bodies from the elements, as has been suggested. Captain Maury has mentioned that he has called these bodies floating in the atmosphere "tallies;" a "tally" being a mark a sailor puts on a rope, in order that he may know the particular use to which it is appropriated. So Maury terms these "tallies," and has thus been enabled to mark out the circuits of the winds. Thus by volcanic action these things are carried into the upper regions of the atmosphere, above the influence of the trade winds, carried along by the upper return current, and then come down to windward, having gone against the trade winds apparently, but in reality having risen above them. I must say, in justice to Professor Byrne, that he may have been a little discursive, but what he was going to say was not altogether from the point; and I did not stop him because he was endeavouring to show that the fixed stars are not at those extreme distances they are imagined to be, and that the sun has not got the motion astronomers assert, but that they have mistaken an oscillatory for a direct motion. I think that was his object, and I think his remarks were pertinent in this way, because, if astronomers err so widely with respect to the distances of heavenly bodies, you cannot expect them to be accurate in their suppositions respecting evanescent bodies, as to which Mr. Mitchell said it would be impossible to make calculations, and it is mere charlatanism to attempt it. Then, with respect to these masses striking the earth, they cannot go with the enormous velocity which is supposed, because in all the records concerning them, they are merely said to have penetrated a few inches into the earth, which shows that the velocity cannot be very great; and we know that at the trials of rifled guns mentioned in *The Times*, the shot has penetrated the ground for fifteen or twenty feet.

The Rev. WALTER MITCHELL.—One passed quite through the butt at Woolwich recently.

The Meeting was then adjourned.