V.—*On the Iron Meteorite which fell near Mazapil, Mexico,
during the star-shower of November 27th, 1885.*

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Read January 17, 1887.

Of meteoric irons which have been seen to fall, only eight are recorded, namely: that of Agram, Croatia, May 26, 1751; of Charlotte, Dickson Co., Tennessee, Aug. 1, 1835; of Braunau, Bohemia, July 14, 1847; of Tabarz, Saxony, Oct. 18, 1854; of Victoria-west, South Africa, in 1862; Nejed, Arabia, spring of 1865; of Nedagolla, India, Jan. 23, 1870, and of Rowton, Shropshire, England, April 20, 1876.

It has become my privilege to be able to add a *ninth* fall to this short list, and one, as its history proves, which is of more than ordinary scientific importance.

It seems probable that at last we are to know something positive of the composition of comets, which bodies have, up to this time, given us nothing tangible whereupon we could base our conclusions. Astronomers now generally believe that comets, shooting-stars, meteors, and meteorites, all have a common origin; and the history of this iron meteorite of Mazapil will help us very materially to agree with this belief.

"The only objection," states Prof. Hubert A. Newton, "that has been urged against the relationship of meteorites to the star-shower-meteors, and the only objection which has apparent force, is the fact that no meteorites have been secured"—as yet—"that are known to have come from the star-showers." "But," he further states, "since star-showers are surely related to comets, it is reasonable to look for some relation of meteorites to the bodies and systems, of which the comets form a part;" and "if at any time," (Nature, Vol. 19, p. 315, 1879;) "a real connection can be traced between meteorites and shooting stars, we may begin to hope for a solution of this interesting but difficult problem."

On the 27th of August last, I received from my personal friend, Prof. Bonilla, of Zacatecas, Mexico, the meteorite hereinafter described. It came to me as a most generous gift, and with it came the very surprising information, that *it had been seen to fall*, at about nine P. M. of the twenty-seventh of November, 1885, during the periodical star-shower of the "Bielids."

Such was the remarkable importance of this fall, as shown by its history, and the possibility of its relation to Biela's comet, that I hesitated to announce it publicly, preferring to delay, until the full evidence could be substantiated in all its particulars. This has now been accomplished; and I feel free to present to science what seems to be, beyond doubt, *a fragment of a comet*.

The general appearance of this meteorite gives ready credence to the account of its fall. Its freshness of surface, which shows in a beautiful manner the *flow* of the melted crust, as the mass rotated in its rapid flight through the atmosphere; the presence of unusually large nodules of an amorphous graphite; the very slight superficial oxidation, and the general dissimilarity to other meteorites of the region;—all point to a confirmation of the data of its fall.

When received, it weighed about 3950 grammes. Its present weight is 3864 grammes, or ten pounds, four and one quarter ounces troy. This discrepancy is included in the pieces detached for the purposes of chemical analysis and in obtaining a large surface for the development of the crystalline structure—the so-called figures of Widmanstätten.

Very naturally, the fall of this mass of iron might be viewed as merely a co-incident phenomenon with the November "Bielids" of 1885; but, to arrive at a thorough understanding of its true relation, let us consider the evidence of its fall and the history of Biela's comet, as set forth in the communication of Prof. José A. y Bonilla, who is Director of the Astronomical Observatory at Zacatecas, Mexico.

(Translation.) "It is with great pleasure that I send to you the Uranolite (skystone) which fell near Mazapil, during the night of the 27th of November, 1885. That you may the better appreciate the great scientific interest which this Uranolite pos-

sesses, I would state that everything points to the belief that it belongs to a fragment of the comet of Biela-Gambart, lost since 1852.

"I will first give the history of this celestial wanderer, and then my reasons, as an astronomer, for believing that it belongs to the comet of Biela.

"As Director of the Zacatecas Observatory, I am naturally attentive to all celestial phenomena; and remembering that in Nov., 1885, when our planet should pass through the node of the orbit of the disintegrated comet of Biela, there should happen the rain of falling-stars, which occurs periodically from the 26th to the 29th, I requested my pupils and various other people in different towns of the State of Zacatecas to note the fall of stars on those dates—especially on the evening of the 27th—and endeavor to count them, apprising me of their observations.

"I, myself, in the observatory, prepared for observations as follows:—Firstly, to locate with exactness the position of the radial point of the falling stars—determining their co-ordinates of right ascension and declination;—secondly, to obtain instantaneous photographs of them by means of dry-plates;—thirdly, to study the meteors by means of the spectroscope;—fourthly, to count the number of falling stars and note the hour of their maximum number in Zacatecas time;—fifthly, to fix among the constellations the paths of some of them, at least those most noteworthy.

"The sun having set at 5.20 P. M. (local time), I eagerly looked to the place in the heavens where the constellation Andromeda should be. Hardly had twilight vanished, at 5.47, when I could already distinguish the three principal stars of this group. At 6.20, I noticed near Alpha of the triangle the first falling star, and little by little the number increased. At midnight—two hours and a half after Gamma-Andromedæ had passed the meridian—the phenomenon had attained its greatest intensity, as I counted in thirty minutes two hundred and forty meteors shooting in all directions and not at all from the same point.

"With a six-inch equatorial I took the position of the *radial point*, from which *most* of the stars came, and its co-ordinates I made out as follows:

"Right ascension 1h. 54m. Declination $+ 43^{\circ}$.

"I took several photographs, but in truth they did not prove satisfactory. Either from the difficulty in focussing, or because I did not expose them for the proper length of time, the negatives did not seem worthy of mention after I had examined them on the day following. After an exposure, I could not develop the negatives at once, for fear of losing my observations; and to develop them was the only test which would have given me an index as to the proper time necessary.

"With the spectroscope I was more successful. To my equatorial, of six inches aperture, I connected a direct-vision Secchi spectroscope with five prisms and cylindrical lens. The spectra which I noted of the falling stars were all identical. They presented a continuous spectrum with the characteristic lines of Sodium, Carbon, Iron, Nickel and Magnesium. I had never seen the atmospheric lines of nitrogen so marked and characteristic, even when observing the sun near the horizon. The existence of these nitrogen (azote) lines I explain by the extremely high temperature acquired by the air from the contact of the meteors. It is estimated by some that, on coming into the terrestrial atmosphere, these bodies possess a speed of from 30 to 60 kilometers per second (Wiess estimates 14.9), and that the air so violently compressed instantly acquires a temperature of 3000 to 4000 degrees.

"It was impossible for me to determine the trajectory of this maze of stars, as they were flying in all directions like firework-bombs; nevertheless, the greater number started from a radial point in the direction ϵ Persei and Algol.

"As to the number of stars which fell into the atmosphere from 6.20 P. M. until three in the morning—when a thick mist from the northeast prevented further observation—it was impossible to fix accurately, from the multiplicity of duties which engrossed me. However, my assistant, who was charged with this duty, pencil in hand, and marking from time to time the number counted, noted twenty-seven hundred and twenty meteors, or a little over five per minute.

"Other persons, to whom I had recommended the study of the phenomenon, living at various points in the State of Zacatecas, have probably over-estimated the number seen, since one in particular assured me he had counted nearly 6000. Most of

these amateur star-gazers saw the meteors however, but rendered me no other report.

“On the second day of December I received, to my great delight, from Eulogio Mijares, living on the Concepcion Ranch (thirteen kilometers to the east of Mazapil), a stone which he saw fall from the heavens, at nine o'clock on the evening of the 27th of November, 1885. The fall, simply related, he tells as follows, in his own words :

““It was about nine in the evening, when I went to feed certain horses in the corral, when suddenly I heard a loud hissing noise—exactly as though something red-hot had been suddenly plunged into cold water,—and almost instantly there followed a somewhat loud thud. At once I saw the corral covered with a phosphorescent light, and suspended in the air small luminous sparks as though from a rocket. I had not recovered from my surprise, when I saw this luminous air disappear, and there remained on the ground only a faint phosphorescence such as when a match is rubbed. I saw a number of people from neighboring houses running towards me, and they assisted me to quiet the horses, which had become very much excited. We all asked each other what could be the matter, and we were afraid to walk in the corral for fear of being burned. When in a few moments we had recovered from our surprise, we saw the phosphorescent light disappear little by little, and when we had brought lumps to look for the cause, we found a hole in the ground and in it *a ball of light*. We retired to a distance, fearing it would explode and harm us. Looking up at the sky we saw from time to time exhalations or stars, which soon went out, but without noise. We returned after a little and found in the hole a hot stone, which we could barely handle; on the next day we saw that it looked like a piece of iron. All night it rained stars, but we saw none fall to the ground, as they were extinguished while still very high up.’

“This is the simple recital of the ranchman; and the Urano-lite which fell is the one I send to you.”

“From the numerous questions I have asked Sr. Mijares, I am convinced there was *no explosion* or breaking-up on falling.

“Others who saw the phosphorescence, etc., were: Luz Sifuen-

tes, Pascual Saenz, Miguel Martinez, Justo Lopez, and some whose names I have not obtained.

"Upon visiting the place of the fall,—(see map.)

FIG. 1.

Map of Mazapil and vicinity.

I was careful to examine the earth in and around the hole, and by careful washing I obtained a few small bits of iron which must have become detached from the Uranolite when it penetrated the earth. The hole was 30 centimeters deep (one foot).

"Probably the light which was noted came from the volatilization of the surface of the celestial body, due to the high temperature acquired by friction with the atmosphere and from the volatilized matter falling to the earth as an incandescent impalpable powder."

It is now proper to state the history of the meteors of Nov. 27th, 1885, which had their origin in the disintegration of Biela's comet.

As is well known, the comet of 1826 was discovered by the Austrian Captain Biela, at Johannesburg, on the 27th of Febru-

ary. Its orbit was calculated by Gambart, of Marsella, who also discovered that this comet was seen in 1772 and 1805, from the identity of its orbital data. Gambart and Clausen undertook the calculation of the elements of its orbit, and found that its complete revolution around the sun would be effected in seven years approximately. Damoiseau studied minutely the time at which it would again reach its perihelion, taking into account planetary disturbing influences. From these studies it was deduced that the comet would collide with the earth on the 29th of October, 1832, and all Europe was in concern as that period approached.

But on again examining the question, it was found that, although the comet would touch the earth's orbit on the 29th of October, the earth itself would not arrive at the same point until the 30th of November, that is to say, a month later—the distance between the two bodies being twenty millions of leagues.

Later observations, in 1832, corrected the elements of its orbit, and data were obtained as follows :

Reached perihelion in 1832 on Nov. 26th.	
Inclination of plane of its orbit, - - - - -	13° 13'
Longitude of ascending node, - - - - -	110°
Perihelion distance, - - - - -	0.88
Motion, - - - - -	direct.
Duration of revolution, - - - - -	6.62 years.

In 1839 it could not be seen, owing to the unfavorable position of its orbit at the time of its perihelion, in the first days of July, and since it was computably near the sun and lost in its rays.

In 1846 it should have passed through its perihelion on Feb. 12th. From Dec. 21st, 1845, M. Encke, in Berlin, had already observed the comet of Biela, and on the 13th of January, 1846, to the great surprise of the observers, the comet appeared *separated into two portions* (having been seen the day before without alteration), and on subsequent days the parts separated more and more until, on the 12th of February, the day of its perihelion, the distance between the two fragments was already 310,000 kilometers.

In 1852, it should have passed through its perihelion on Sep-

tember 23d ; and since the latter part of August it had been observed by Secchi, still separated into two portions, but much smaller and at a distance of 500,000 leagues. Since then it has never been seen : so that Biela's comet, broken in twain since 1846 to 1852, has been considered as lost.

According to calculation, it should have been seen in 1859, 1866, 1872, 1879, and 1885 ; but though astronomers have eagerly scanned the heavens, *it has never again appeared.*

On Nov. 27th, 1872, there occurred, over all Europe, a shower of meteors such as *never before had happened within the memory of man ; and it is remarkable to note that calculation shows the orbit of Biela's comet and that of this innumerable host of falling stars to be the same.*

Before 1870, astronomers considered meteors as having a planetary origin and as forming rings around the sun, with nearly circular or elliptical orbits and with velocities analogous to that of the earth.

In 1870, Professor Schiaparelli, of Milan, surprised at the velocity of these bodies, which presupposes a parabolic orbit, suspected that they might have, like comets, an origin foreign to our system, and proposed the following theory

—Let us suppose a nebulous mass, or one formed of any kind of widely separated molecules, situated at the limit of the sphere of attraction of our sun, and that being animated with a relative motion, it begins to feel the solar influence. Its volume being very great, its points are situated at greatly varying distances. From this it results, that when such bodies commence to fall toward the sun, the unequally distant points gain unequal velocities. Notwithstanding these differences, calculation proves that, the perihelical distances of the different molecules are soon modified, and the orbits are so nearly alike that the molecules will follow each other, forming a species of chain, or current, which will take some time to pass around the sun. A mass whose diameter is equal to that of the sun, would take many centuries to complete this motion. This current represents physically and visibly the orbit of meteoric bodies, in the same way that a stream of water represents the parabolic trajectory of each molecule as a separate projectile. If, in its course, the earth should encounter such a procession of bodies, it would pass through them and many

would strike it, combining their own velocity with that of the terrestrial globe. Were the chain a long one, the earth would thus pass through it each year at the same point, encountering in each passage different bodies from those met with before. It is therefore easy to calculate the position of this current. Schiaparelli has made the calculations for the currents of August and November, and by a fortunate circumstance found that two well known comets have orbits which coincide in every particular with two chains of meteors.

This theory was fully confirmed by the falling of meteors on Nov. 27th, 1872. I have already stated that on that day the earth should pass, as in 1832, very close to Biela's comet, and that for some days all Europe was alarmed for the consequences of such an encounter.

The earth did, indeed, cross the orbit of Biela's comet, on Nov. 27th, 1872, and on the same date in 1885; but it then met with a disintegrated body, broken into *millions of fragments*. We have already spoken of the fact that, in 1846, astronomers were witnesses of the initial breaking, and that up to 1852 those twin comets still travelled side by side, and that from that time they have not been seen except in countless fragments.

Let us compare the meteoric showers of 1872 and of 1885.

On Nov. 27th, 1872, all Europe saw this magnificent spectacle. It could not be seen in America, as at the time of gréatest intensity of the phenomenon the sun was above the horizon.

~~Let us listen to what Abbé Secchi says in a letter to the then~~ perpetual Secretary of the Academy of Sciences of Paris (Lectures on Astronomy, Vol. 5, Flammarion): "We have had a brilliant appearance of meteors on the 27th of November. I was not notified of the phenomenon until 7.30 P. M., when it had been in full activity for an hour. We observed it thenceforward with the closest attention. From that time until 1 A. M., we counted 13,892 meteors, but a great number could not be counted. The entire sky was ablaze; it was literally a rain. The majority of the stars were small; nearly ten per cent. were of the second magnitude, ~~nearly two per cent. of the first.~~ There were many spherical ones. The radial point was, at 8 P. M., in that space comprehended by the constellations of Aries, the Triangle and the Fly; it passed at once to the base of the

Triangle, and finally, at midnight, had reached a point equidistant from the Triangle and the head of Medusa. The maximum was at 8.30 P. M., and the greatest number 93 per minute. After 11 P. M. the number diminished greatly, and by midnight there were intervals of quiet. Between 12.30 and 1 A. M., 87 only were counted. The velocity of these meteors was generally slow; the most striking traced curvilinear arcs; the heads were white in color and the tails red.

Magnets were not affected. *It is worthy of note, that the earth, during this phenomenon, was in the node of the orbit of Biela's comet.*

Many observers noted the same facts as the distinguished Director of the Roman Observatory; and as it would be too arduous a task to copy here the report of each of them, even in abstract, I will review only the most important. Facchini, at Mazzarino, counted 12,950 meteors, from 9h. 30m. to midnight. In Callanisetta, M. Zona counted 28,000 during the entire night; in Matara, 38,513; in Mondovi, 30,881. The Abbé Denza, at Moncaliera, counted 33,400 from 6 P. M. to midnight, and estimates the maximum at 8 o'clock; remarking that it was a very rain of fire, similar to that seen at the explosion of bombs.

This beautiful rain of stars was also observed in France. At Nice, by Feyssere and Maccario; at Bordeaux, by Lespiault and Roussaune; at Grenoble, by M. Breton; at Chambéry, by M. Vallet; at Mâcon, by Lemoisy; etc., etc. The observers at Mâcon fixed the *radial point* with the following co-ordinates:

Right ascension, 2 h. Declination, 40°.

This point corresponds to the constellation of Andromeda. They add: "Among these meteors we observed a sphere, or globe, of fire, reddish in color, of from 5-6 minutes in diameter, which fell at 10 h. 50 m. from Procyon, and proceeding toward the horizon without leaving a trail, disappeared behind the roof of a house. We observed many brilliant stars, the majority being of the second magnitude. They generally described very short paths of from 5 to 6 degrees length, all leaving trains. Before they disappeared, they seemed to resolve themselves into a luminous dust. One of them showed no apparent nucleus, but looked like a *small phosphorescent cloud*."

In England, the observations were exclusively those of Alexander Herschel. The phenomenon was not less noteworthy than in France or Italy. To give further observations would be a useless repetition.

The great display of meteors of Nov. 27th, 1885, is even more important than that just described ; 1st,—Because it lasted a longer time, since it was observed over the whole world ; 2nd,—Because of the greater number of meteors seen.

In "*L'Astronomie*," (published in Paris, by Camille Flammarion,) Nov., 1885, "Falling Stars" were noted as one of the principal observations to be made during the month (p. 439). "On the nights of the 27th, 28th and 29th of November, there will be seen a great number of luminous bodies which relate to the comet of Biela-Gambart, and which caused in 1872 the great shower of falling stars. The line enclosing the region whence they emanate is very irregular, and the centre is found not far from the double star *Gamma-Andromedæ*." From this notice, all astronomers prepared to study the phenomenon.

This prediction was fully confirmed, as was also the conjecture that these meteors belonged to the disintegrated comet of Biela.

I quote from the "*Comptes rendues*" of Dec. 7th, 1885, p. 1210, papers by M. Flammarion, to the Academy of Sciences, of Paris :—"Let me note the observations made by the Flammarion Scientific Societies of Marseilles, Brussels and Jaën. From these three points, so distant from each other, they agree as to the magnificence of the sight and in fixing upon 6 P. M. (Paris time), as the hour of maximum number. (This would be 11 A. M. in Zacatecas.)

"M. Bruguier, president of the first mentioned of these societies, counted nearly 4000 meteors in ten minutes, emanating from three radial points, the most important being near *Gamma-Andromedæ*.

"M. Vuilmet, of Brussels, states that the spectacle was a marvellous one, that at 6 P. M. the sky was literally aflame, and with watch in hand one observer counted 160 meteors per minute in a single quarter of the heavens. M. Folaché, in Jaën, records the magnificent sight which the sky presented as "traversed in every direction by a multitude of falling stars."

M. Arcimis, in Madrid, wrote that he had counted 50 stars per minute at the maximum hour of the fall.

At Liège, M. Hebert saw among the multitude of meteors, one that, upon reaching star 41, of Aries, suddenly changed its course and left a luminous trail which lasted 12 minutes. M. Dupuy, at Nyon (Drôme), made the same observation.

At Prague, M. Zenger counted 14,000 meteors.

At Argel, M. Dupart states that the phenomenon commenced on the 26th.

At Tunis, M. Denisson fixes the maximum at 7 P. M.

At Suez, M. Borghetti mentions that the stars seemed to fall from the zenith like snow.

At Constantinople, M. Naviogordato states that the rain of stars was observed there and also at Athens, Smyrna and Jerusalem, in its full magnificence.

The French observers are all in accord as to the beauty of the display and the position of the radial point. We will refer principally to M. Lange de Ferrieres, at Rupt y Courtois in Muges; Haizeaux, at Guincourt; Riveau, at Grenouillé; Fedesche, at Aubenas; Bachelier, at Civray; Rouchet, at La-Roche-sous-Briancçon; Gully, at Rouen; Michel, at Mave; Bougé, at Nantes; Hillaire, at Vendœnyre; Annoy, at Montauban, etc.

In America, the phenomenon was also observed. Sr. Felipe A. Labadie, Mexican Consul at Nogales, Arizona, (Longitude $110^{\circ} 47'$ West of Greenwich; Latitude $31^{\circ} 30'$ North), states that "on the 27th he saw a fine shower of falling stars, and in twenty minutes (from 9h. 40m. to 10 P. M.), he counted 115. Without exception they came from Andromeda."

In Caracas (Venezuela), M. J. M. Zébar writes me, "there were a great many meteors seen here on the 27th, all proceeding from Andromeda. They began 6h. 38m., P. M."

In fact, the phenomenon was noted all over the world, and it would be useless to cite further observations.

I will only add what was recorded in the "*Revue Mensuelle d'Astronomie populaire*" (Paris, Flammarion, February, 1886):

"The rain of shooting-stars of the 27th of November, 1885."

"We may add materially to the numerous notices which we published in our last number. We do not wish, however, to be too prolix regarding these observations, which but confirm one

another; but it is of interest that the phenomenon was visible from all portions of the globe.

"From the island of Reunion, at the southeast of Africa, M. Dubuissou informs us that the meteoric shower was observed in all its grandeur from twilight to 1 A. M. The celestial fireworks were so marvellous that uneducated people believed that there would be no stars left in the sky. The maximum fall seems to have occurred at 9 P. M. (5h. 30m. Paris local time). The same observations are sent to us from the islands of Mauritius and Madagascar.

In the United-States, the phenomenon was observed at Bloomington, Indiana, by Prof. Daniel Kirkwood; at Princeton, New Jersey, by Prof. C. A. Young, (who estimated the radial point at 2° to the northeast of *Gamma-Andromedæ*); and also by others."

As before stated, from what I have quoted regarding the numerous observations made in America, Turkey, Sweden, Belgium, Italy, Switzerland, Spain, Portugal, etc., and of the observers scattered throughout England, Germany, Austria and Russia, it cannot be doubted that the cosmical dust proceeding from the disintegration of Biela's comet enveloped the earth and was seen, as meteors, from its every part.

The conclusion thus derived from all these data is that the meteoric-shower of Nov. 27th, 1885, was of more importance than that of 1872.

M. W. Meyer,* of Berlin, has calculated the elements of these bodies and compared them with those of Biela's comet (see table below), and there can be no doubt of the identity of their orbits:

	<i>Biela's Comet, 1852.</i>	<i>Meteors, 1872.</i>	<i>Meteors, 1885.</i>
PERIHELION T	- Sep. 23.	Dec. 27.	Dec. 28.
LONG. OF NODE Ω	- $246^{\circ} 19'$	$246^{\circ} 6'$	$245^{\circ} 55'$
INCLINATION i	- $12^{\circ} 33'$	$12^{\circ} 40'$	$12^{\circ} 35'$
LONG. OF PERIHELION π	$109^{\circ} 36'$	$110^{\circ} 18'$	$111^{\circ} 53'$
ECCENTRICITY e	- 0.7559	0.7518	0.7538
LOG. OF THE PERIHELION			
DISTANCE, LOG. q ,	- 9.9348	9.9376	9.9332

(N. B.—These elements are with regard to the apparent equinox of 1885. η .)

* "L'Astronomie," Feb., 1888, p. 69

Time of revolution—6 years and one-half, gives for the greater semi-axis 3.482. That of the comet was: 1806—3.567; 1826—3.560; 1832—3.537; 1846—3.520; 1852—3.527. There was therefore a constant diminution of the major axis of the ellipse, which is confirmed by the orbits of the Bielid meteors.

The small number of meteors seen to fall at Zacatecas, compared with those seen in Europe, may be easily explained. European observers agree in fixing the time of maximum fall at 6 P. M. of the 27th, Paris time. The corresponding time at Zacatecas was 11 A. M. of the same day. At this hour, Andromeda was below the horizon at Zacatecas, while at Paris it was at the zenith; so that observations at Zacatecas was made seven hours *after the maximum* as determined in Europe.

As already stated, the number of meteors counted in 9 hours was 2,720; whereas among the European observers, Abbé Denza, for example, estimate those counted by him in four hours at 39,546; on the other hand the observations are quite in accord with those of Consul Labadie, at Nogales, made at the same time, since he estimates 115 meteors in 20 minutes, and Pro. Bonilla and his assistants, 240 in 30 minutes.

Let us consider the possibility of one of these shooting-stars reaching the earth's surface. It is certain that three different velocities are possessed by a meteor before and during its fall, *i. e.*: Its velocity in its orbit; its acquired velocity when attracted by the earth, and its velocity in falling. We can easily estimate its orbital velocity, since we know the elements of its orbit. From calculations made by Alexander Herschel (*Lectures on Astronomy*, Vol. 5, p. 222), it is known that such bodies enter into the atmosphere of the earth with a minimum velocity of 19,000 metres per second. From the moment that terrestrial attraction affects them, they are compelled to abandon their original orbits and follow a new path (the curve made being parabolic), which is equal to the velocity of the earth through space multiplied by the square root of 2. As the mean velocity of our planet, in its orbit, is 29,640 metres per second, that of the meteor is 42,570. As these bodies have a direct motion, that is to say, the same as that possessed by the earth, their relative speed diminishes to 13,000 metres per second. But, on entering our atmosphere, these small bodies that have the temperature of

planetary space (-200° F.), compress the air strongly, and becoming heated their speed rapidly diminishes to between 500 and 1200 metres. There is therefore a great amount of momentum lost apparently; one portion has been used in compressing the air and the other has been turned into heat,—the temperature of the body increasing up to $2000-3000^{\circ}$. If the meteor be small, it will be entirely vaporized in the higher atmosphere; but if the mass be great the outer portion only will be volatilized, and the remainder will strike the earth's surface before being entirely burned away. As these bodies fall lower and lower into the more dense atmosphere their velocity diminishes proportionally, so that, upon striking the earth, they fall at the rate of 30–50 metres per second. We therefore perceive it to be possible for many meteors to fall upon the earth before being entirely dissipated, since it all depends upon the size of the mass.

As the greater portion of Biela's comet is now in small fragments, with here and there a larger one, as our observations have proved, it is a perfectly possible occurrence for some of these to fall upon the earth before being entirely dissipated.

I have stated already that in the Bielid shower of 1872, the Abbé Secchi saw many *spherical meteors*, and Lemoisy, at Mâcon, saw a sphere disappear in the horizon behind a house-top. Many observers saw, in 1885, *spherical meteors* quite close to the earth although they were not seen to strike. By all these data and observations we learn of the great importance of the Uranolite of Mazapil.

The very circumstantial story of the fall of this meteorite, coupled with the relative observations of the Bielids at Zacatecas, is interesting in the extreme, and we can scarcely disconnect the two occurrences as a mere coincidence.

No explosion, as is usual when meteorites fall to the earth, was heard by Sr. Mijares, or his neighbors, but in this particular similar cases could be cited. Very probably the explosion, if there was one, occurred high in the atmosphere and at a great distance from Mazapil. “The aërolite which fell at Stålldalen, Sweden, at 11.50 A. M., on June 28th, 1876, was visible as a meteor over a great part of Sweden. It appeared as a large pear-shaped mass, of a blinding whiteness to some, and of a fiery-red to others. It emanated from a point in Cepheus, and became

luminous at an estimated height of 250 miles above the earth. *It is remarkable that it was not visible at the point where the meteoric mass fell*, probably on account of a small cloud of compressed matter collected in front of it.”—(*Science for All*.)

The fifty-six pound meteorite, which fell, at 3 P. M. on Dec. 13th, 1795, near Wold Cottage, Thwing, Yorkshire, England (within ten yards of where a laborer was working), is remarkable for the very reason that “*no thunder, lightning, or luminous meteor accompanied the fall*; but in adjacent villages there was heard an explosion, likened by the inhabitants to the firing of guns afar off, while in two of them the sounds were so distinct,—of something singular passing through the air towards Wold Cottage,—that several people went to see if anything had happened to the house or grounds.”

A careful comparison of the Agram Iron* Meteorite, with that of Mazapil, brings to light a most marked similarity of detail, though the Agram iron weighed nearly 70 German “Pfunds” (39,200 grams) or seven times more. The surface hollowings and the general irregular flat shape show the same occult cause in the origin of both of these masses of celestial iron.

The Mazapil iron in its size (3,864 grammes=10 lbs. 4½ oz. troy), is nearly like the irons of Rowton (7¼ lbs.), Nedagolla, (11 lbs.), Charlotte (9½ lbs.), and Victoria-West (6 lbs. 6 oz.), which were *all seen to fall*.

FIG. 2.

Widmanstätten figures on Mazapil Meteoric-iron.
Natural size.

* See Beiträge zur Geschichte und Kenntniss Meteorischer Stein und Metall-massen, Dr. Carl von Schreibers, Wien, 1820, Tab. VIII.

In its crystalline structure (see fig. 2, exact natural size), it closely resembles the iron of Rowton, since it exhibits lines at nearly right angles (cubic) in the Widmanstätten figures. It is also similar to the iron of Juncal, and of La Caille, and very probably, if it was cut in other directions, a more marked resemblance could be seen, especially in the twinning lamellæ and cubic structure.

The bands of iron-nickel in the Mazapil iron average one millimetre broad. In Brezina's classification it belongs among the the Holosiderites, in his "Trenton-gruppe (Omtr)" of "mittelelere lamellen." It does not contain much plessite, but is mostly kamacite, and the bands present a shimmer at different angles, thus showing uniform crystallization.

Mr. O. W. Huntington has lately shown* "that the features of the Widmanstätten figures are due to the elimination of incomputable material during the process of crystallization," and that "these meteoric masses show cleavages parallel to the planes of all the three fundamental forms of the isometric or regular system, *i. e.*, the octahedron, the cube, and the dodecahedron;" and further that he "is strengthened in the opinion that the process of crystallization must have been very slow."

Where the surface-crust of the Mazapil iron has been accidentally detached, it shows, without etching, the Widmanstätten figures.

Troilite (ferrous-sulphide) and Schreibersite (nickel-iron-phosphide) have been identified on the surfaces prepared for etching. Carbon (as graphite) is disseminated throughout the mass between the lamellæ, and as nodules of considerable size extruding from the surface. Eleven of them can be counted on one side, one of nearly an inch in diameter. This graphite is very hard and seemingly amorphous; scattered through it is troilite in thin plates as a mechanical mixture. Of quite exceptional occurrence is the presence in this iron of such quantities of carbon; and it is noteworthy that the spectroscope showed this element as present in the Bielid meteors of Nov. 27, 1885. The illustration (plate 1), which is three-fourths natural size,

* Proceedings of the American Academy of Arts and Sciences, May 12, 1886.

shows several of these extruding nodules of carbon.

The lines of flow of the melted crust are beautifully shown, especially when slightly magnified, and exhibit well the surface-fusion due to the rapid flight of the body through the earth's atmosphere.

That the motion of the mass in its flight was rotary, is clearly proven by the abutment of the crust-particles against the projecting surfaces and the striæ of the crust at these places, which resemble, in minute forms, limonite iron ore. The abrasion due to impact was very slight, and seemingly not more than would have happened had the mass been dropped a few hundred feet. Some places were noticed where very small pieces had been detached by the force of the impact, but in all not over 2 or 3 grams were thus lost.

The analysis, by J. B. Mackintosh, E. M., confirms the oft-noted similarity in the composition of meteoric-irons; to show this forcibly I here append a few analyses made on irons *seen to fall*:

	<i>Mazapil.</i> MACKINTOSH.	<i>Rowton.</i> FLIGHT.	<i>Charlotte.</i> ‡ SMITH.	<i>Estherville.</i> § SMITH.
Iron,	91.26	91.25	91.15	92.00
Nickel,	7.845	7.825	8.05	7.10
Cobalt,	0.653	0.371	0.72	0.69
Phosphorus,	0.30		0.06	0.112
	100.058	100.203	99.98	99.902

Lawrencite (ferrous-chloride) was noticed, by its deliquescence on the surface of the meteorite, in the deeper depressions, which deliquescence I would state, has all occurred since last August, as the surface of the mass did not show any oxidation when received.

No effort has as yet been made to analyze the graphite or to find the quantity of occluded gases in the Mazapil iron,—for the reason that such a task would only result in a repetition of the labors of Flight, Mallet, Graham and others.

‡ Am. Jour. Sci., X, 1875, pp. 349-352. Com. Rend., LXXXI, 1875, pp. 84-87.

§ Fell May 10, 1879, and consisted of metallic nodules surrounded by silicates. Am. Jour. Sci., XIX, 1880, pp. 459-463.

Concerning the evidence of the nearness of the Bielids to the earth's surface, it has long ago been shown, by Brandes and Benzenberg, that "their height varied from 40 to 90 miles while luminous," and that if they are not entirely dissipated in the earth's atmosphere they must fall to the surface. That they are all tangible bodies of greater or less size, is positively evidenced by their luminosity.

Of possible other fall of fragments of Biela's comet to the earth, on Nov. 27th, 1885, I will quote briefly a few observations which bear upon this problem :

M. de Bull, at Liege, saw "one of the meteors after its *explosion* (sic.) leave a train which lasted 15 minutes." *Ciel et Terre*, No. 21, Jan. 1, 1886, p. 491.

Capt. D. Wilson-Barker notes, while on the S. S. Dacia, at Suez, that "in one exceptional case the track (of a meteor) was visible for eight minutes, and for a longer time with a glass." *Roy. Ast. Soc., Mon. Notices*, Jan., 1886, p. 122.

Prof. N. R. Leonard states that "Prof. Cowgill, who observed at Manhattan, Kansas, saw a meteor *below the clouds* (the sky being completely clouded over) at 12h. 50m. and during the few hours following, thirteen others were seen in like manner." *Sidereal Messenger*, Feb., 1886, p. 58.

This latter observation and that of Prof. Leonard, at Iowa City, Iowa, are the nearest records that I have been able to find that serve to corroborate the observations at Zacatecas. Especially does the testimony of Prof. Cowgill bear upon the remark of Prof. Barnard (*Sid. Mess.*, March, 1886, p. 78), that "probably the *larger particles* of this meteoric swarm lie on the outside." That the shower was *intermittent* is evidenced by the record, viz. .

Prof. Newton, at Yale, and Prof. Young, at Princeton, agree in a diminished shower at 8 P. M. (local time), while "Prof. Leonard, at Iowa City, made the following counts: From 8h. 36m. to 8h. 51m. (local time), 100 meteors, or over 6 per minute.—From 9h. 10m. to 9h. 30m., 100 meteors, or 5 per minute.—From 10h. 2m. to 10h. 20m., 50 meteors, or less than 3 per minute." *Sid. Mess.*, Feb., 1886, p. 58.

For "The story of Biela's Comet," in its entirety, I refer the reader to the beautiful account by Prof. H. A. Newton, (in the

American Journal of Science, for February and June, 1886,) and I assure you "it shall be to you as interesting as a novel," and "what is known is therein sharply separated from what is conjectured."

Not a few astronomers would have us believe that comets are the 'scavengers of space,' and have accreted their mass and obtained their motion by the simple laws of gravitation and of chemical affinity; but a careful study of meteoric masses—which are but the debris of comets—leads us to look for their birth-place within some sun or in regions where tremendous pressure must have had an existence; else the remarkable quantities of occluded gases and the otherwise plutonic character of meteorites remain inexplicable. Let us turn to the lately advanced theory of Mr. Richard A. Proctor, for an explanation of great plausibility, and which seems to answer all the known conditions of comets and their attendant trains. Before stating his conclusions in abstract, I would remind the reader that he must first bring himself to believe that a body has power enough, within itself, to project a part of itself beyond the sphere of its own attraction. If you can believe this, then Mr. Proctor's theory is at once acceptable. He states*: "All the evidence tends not merely to show but to prove, that all orders of meteors, and therefore all orders of comets, came from the interior of bodies like the suns and the planets, when in the sunlike stages of their respective careers. All the evidence tends further to prove that sunlike bodies have the power of ejection which this theory of meteoric origin requires. It is to the sunlike stage of any planet's life that we are to look for the time when ejection of the kind required was possible; and our sun is the only case of a sunlike body we can inquire into. If he cannot eject solid bodies, neither could any body when it was a sun, But cannot and does not the sun eject solid bodies?"

"Those who imagine the eruption prominences to be what they seem to be—jets of glowing gas—may be disposed to answer in the negative. But in reality nothing can be much less likely than that the jet-shaped streaks of hydrogen were themselves ejected. Manifestly they indicate the tracks of denser bodies,

* Letter to the Editor of the New York Tribune, Sep. 20, 1886.

not themselves visible, because the spectroscope will not show bodies near the sun which shine with all the spectral colors (as such bodies would), but only those which shine with a few special tints (as the glowing hydrogen along the track of such bodies would shine)."

"Nor need we wonder that bodies ejected from the sun's interior are solid even from the time of their exit, when we remember how the expansion of the compressed vapors driven forcibly upward from a solar volcano (far below the visible surface) would result in a very rapid cooling, by which a portion of the vapor would necessarily condense into the solid form. In fact this is the very process which Sorby recognized as indicated by the microscopic structure of meteorites.

"It may doubtless be the case that of ejected meteoric bodies far the greater number return to the sunlike orb ejecting them. But if only one flight, consisting perhaps of thousands of small bodies, escapes from our sun in a year, of how many millions of such flights has he been the parent! His hundreds of millions of fellow suns have been doing and are doing like work; the thousands of millions of planets have done similar work in the past; each flight would be a comet, each component body a meteor, and all that is known of comets and meteors would be explained by this account of their origin."

I cannot close this already too long paper without expressing my heartfelt obligation to Professor Bonilla for the interesting data concerning this meteorite, and for the gift of the meteorite itself, and to Mr. Mackintosh also, for his kind interest in making the chemical analysis.