ART. XII.—*The Distinguishing Features of Comets considered as Phases of an Electrical Discharge resulting from Excentricity of Orbit;* by BENJ. V. MARSH.

IN the number of this Journal for May, 1861, I endeavored to show that an auroral streamer is a current of electricity, which originating in the upper portions of the atmosphere and following upward the magnetic curve which passes through its base, sometimes extends to a height of at least five or six hundred miles, thus reaching far beyond the supposed limits of the atmosphere, and that the current carries up with it, *at nearly its own velocity*, particles of matter which being rendered luminous by it serve to show its position. Assuming this to be true, I ventured the suggestion that the tail of a comet is probably of the same nature, it being simply an electric current rendered visible by its own illumination of a stream of particles which it is continually transporting with nearly the velocity of electricity itself from the atmosphere of the comet. The object of this paper is to present some considerations which seem to confirm this view.

Comets must either be peculiar in their constitution, or else the features which so remarkably distinguish them from other members of the solar system must be the result of some peculiar influence acting solely upon them. The former seems highly improbable because, with the exception only of the planets, every considerable mass which is known to belong to the solar system, or even to visit it temporarily, is found to be a comet, and we can scarcely imagine that all these masses of matter moving about the sun in every possible direction and approaching from every variety of distance and thus likely to include every variety of material to be found in the solar system should all agree in any peculiarity of composition not to be found in any one of the planets. In viewing the whole solar system the cometary condition appears to be the rule and the planetary the exception—indicating that all the members of the system are capable of putting on the cometary condition, but that in the planets circumstances have not favored its development. Now, excepting the peculiar cometary appearances, the only feature in which it is known that all comets agree with one another and differ from the planets is the excentric form of orbit—*the distance of a planet from the sun is almost constant, that of a comet variable*—and it is to the *variation* in the comet's distance from the sun, and the resulting *contrast of condition* whilst in different parts of the orbit that I would attribute the development of the cometary phenomena.

A planet revolves about the sun at a nearly uniform distance and the action of the sun's rays upon it is nearly constant throughout the whole of its revolution, and, so far as their effects are concerned, it must attain a condition of permanent and stable equilibrium. On the other hand the aphelion distance of a comet is many times as great as its perihelion distance—its motion being virtually a vibration to and from the vicinity of the sun, rather than a revolution about it—and since the amount of light and heat received from the sun diminishes as the square of the distance increases, the comet must alternately be subjected to conditions of the most extreme contrast. For example, the distance of Halley's comet when in perihelion is 56 millions of miles—in aphelion 3370 millions; so that in the former position it receives in a given time 3600 times as much heat and light as in the latter. But the lengths of time during which these exposures continue also differ as widely. In aphelion the motion is so slow that it takes 6½ years to pass over one heliocentric degree of its orbit, while in perihelion the same angular distance is passed in 15·7 hours—so that during a long series of years this comet remains exposed to the cold of these distant regions (the temperature of which may perhaps descend to a point of which we have no conception) while it is receiving but little light and heat from the sun. This cooling process must continue long after it has passed its aphelion because its return is at first so exceedingly slow that it must continue to lose by radiation more heat than it receives from the sun. So that it is only when the time for its perihelion passage approaches quite nearly that the lowest temperature of the mass is attained. It then rushes towards the sun with rapidly accelerated velocity and in a condition contrasting most strongly with that which it must assume when in perihelion. This contrast may not be confined to difference of temperature, but the long deprivation of the solar rays may lead to the attainment of a different condition in reference to the other forces of which the sun seems to be the source. Being precipitated into the immediate vicinity of the sun in this extremely negative condition the solar action upon it must produce changes of the most violent kind, and since all change tends to evolve heat, electricity and light, we need scarcely be surprised that these are developed on a scale of grandeur far surpassing anything with which we are acquainted upon the earth.

That small perihelion distance is not the controlling element is shown by the total absence of the cometary character in the inferior planets, whose orbits lie wholly within the perihelion of many of the comets. Even the great comet of 1825 came but little within the orbit of Mars; and that of 1729 had a perihelion distance of 4·04310, being thirteen times that of Mercury and almost equal to that of Jupiter. So that we see in Mercury a near approach to the sun without the cometary character—and in the comet of 1729 we see the cometary character without a near approach to the sun. Excentricity on the other hand seems to be absolutely essential. All comets move in excentric orbits, and we have no instance of great splendor without great excentricity. Size, perihelion distance and, perhaps, difference of constitution are *modifying* elements, and we may, therefore, have comets moving in very excentric orbits without becoming conspicuous, but inspection of the table below will show that all the most splendid comets have orbits of extremely great excentricity.

Whilst the contrast of condition above referred to evidently originates from excentricity and cannot have place without it, it is equally clear that it must be modified by perihelion distance—and that the excentricity remaining the same, the less the perihelion distance the greater must be the contrast—the proportionate loss of heat by radiation increasing with the temperature of the mass—and a diminution of perihelion distance being equivalent to an increase in the power of the sun's rays, and, consequently, adding to the brilliancy of the results. We must therefore expect the greatest splendor when extreme excentricity is combined with very small perihelion distance. The comets of 1843 and 1680, two of the most splendid on record, afford examples of this combination.

In order to ascertain whether these views harmonized with observed facts, I have prepared the annexed table in which will be found,

1st. The planets, with the extremes and mean of the Asteroid group to No. 55 inclusive.

2d. All the comets the periods of which are known.

3d. Donati's comet, and seven others, being the only conspicuous comets the excentricities of which are given in J. R. Hind's "Catalogue of the Orbits of all Comets hitherto computed," published in 1852.

In the following figure ACBD represents the elliptic orbit of a comet—S the sun's place. AB the major axis—CD a double ordinate through

S.—$a\,b$ a straight line passing through S and meeting the curve in the points a and b, and making but a very small angle with AB.

Let $t =$ time occupied by the comet in passing from a to A.
$t' =$ " " " " " b to B.
$l =$ light and heat received in a given time by the comet at a.
$l' =$ " " " " " b.

Then since the angle B Sb is very small we may without material error assume that Sb = SB, Sa = SA, and that the sectors BSb and ASa are to each other as the triangles BSb and ASa. Also consider l and l' constant during the times t and t' respectively.

Then since the radius vector describes equal areas in equal times,

$t : t' ::$ sector ASa : sector BSb :: triangle ASa : triangle BSb :: Sa^2 : Sb^2.

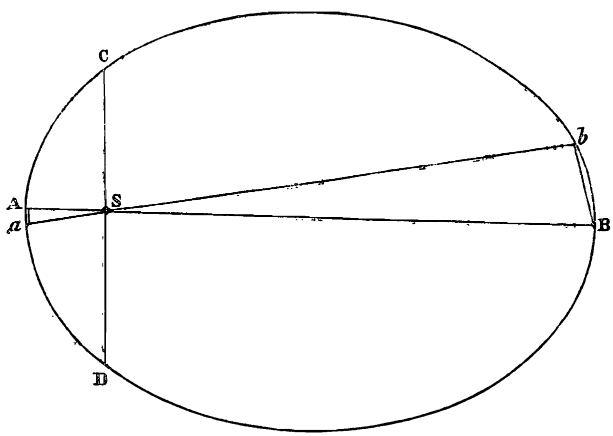
Therefore $t : t' ::$ Sa^2 : Sb^2. But since the light and heat received in a given time vary inversely as the square of the distance,

$$l' : l :: Sa^2 : Sb^2$$

Therefore, $\quad t : t' :: l' : l$

and hence, $\quad t\,l = t'\,l'$

But tl represents the total amount of light and heat received by the comet in passing from a to A; and $t'l'$ represents the total amount of light and heat received by the comet in passing from b to B, and since, if for AB and ab we substitute any other two straight lines intersecting each other at a very small angle in S, the same reasoning will apply, it follows that the whole amount of light and heat received by the comet while passing from D, through its perihelion at A, to C, is equal to that which it receives



during its passage from C, through the aphelion point B, to D—and since the times occupied are to each other as the areas of the segments DAC and CBD, the ratio which these areas bear to each other affords a measure of the *average* contrast in the amount of light and heat received by the comet in a given time on the two sides of the line CD,—that is, in what we may for convenience term the aphelion and perihelion parts of its orbit respectively. So that this ratio seems to furnish the fairest measure of the effects to be anticipated from excentricity of orbit. I have, therefore, given this ratio in the table—as well as that of the aphelion to the perihelion distance—and the square of the latter ratio, representing the relative amounts of light and heat received in a given time in perihelion and aphelion.

		Excentricity.	Perihel'n distance.	Ratio of aphelion to perihelion distance.	Ratio of Light and Heat received in a given time in perihelion to same in aphelion.	Ratio of time spent in aphelion part of orbit to same in perihel'n	Remarks.	
Planets.	Venus, - -	0·00682	0·7184	1·02	1·04	1·02		
	Neptune, - -	0·00872	29·7744	1·02	1·04	1·02		
	Earth, - -	0·01678	0·9832	1·09	1·20	1·04		
	Uranus, - -	0·04660	18·2885	1·10	1·21	1·1		
	Jupiter, - -	0·04822	4·9519	1·10	1·21	1·1		
	Saturn, - -	0·05603	9·0044	1·12	1·25	1·2		
	Mars, - -	0 09325	1·3816	1·21	1·45	1·3		
	Mercury, - -	0·20562	0·3075	1·52	2·30	1·7		
Asteroids.	Harmonia—least excentric of group.	0·04608	2·1627	1·10	1·20	1·1		
	Mean of group to No. 55 inclusive.	0·16430	......	1·39	1·94	1·5		
	Polyhymnia-most excentric of group.	0·33699	1·9009	2·	4·07	3·5	Period.	
Comets of short period.	Faye's Comet,	0·55502	1·7000	3·5	12	5·	7½ years.	Telescopic.
	De Vico's " -	0·61765	1·1864	4·2	17	6·5	5½ "	do.
	Biela's " -	0·75700	0·8564	7·2	52	13	6½ "	do.
	Brorsen's " -	0·79446	0·6500	8·7	75	17	5½ "	do.
	Encke's " -	0·84767	0·3374	12	147	28	3¼ "	do.
Seventy-five year group.	Olbers's " 1815	0·93122	1·2129	28	790	92	74 "	
	Pons's " 1812	0·95454	0·7771	43	1849	172	70½ "	Visible to naked eye—conspicuous tail.
	DeVico's " IV, 1846	0·96225	0·6637	52	2735	227	73¼ "	Just visible to naked eye.
	Halley's "	0·96739	0·5866	60	3636	283	76½ "	Brilliant — tail 30° long.
	Brorsen's " V, 1847	0·97256	0·4879	72	5169	367	75 "	
Conspicuous comets to which elliptic orbits have been assigned, but the periods of which are uncertain.	Comet of 1811—II	0·98271	1·5821	115	13133	733	3065 "	Fine.
	" 1846—VII.	0·98836	0·6334	171	29381	1336	401 "	Pretty conspic's.
	" 1825— IV.	0·99537	1·2408	433	188165	5271	4386 "	Bright, with conspicuous tail.
	" 1811— I.	0·99541	1·0354	434	188625	7132	875 "	A splendid object—tail 25° long, 6° broad.
	" 1858— V.	0·99679	0·5785	624	389376	8925	2000 "	The splendid comet of Donati.
	" 1769.	0·99925	0·1227	2662	7087043	108000	3090 "	Tail 100° long.
	" 1843— I.	0 99989	0·0056	18673	348686158	2000000	376 "	Tail 65° long—seen in daytime near the sun.
	" 1680.	0·99999	0·0062	137173	18816489884	40000000	8800 "	Object of universal attention—tail 70° to 90° long.

From the above table it appears that of the comets of short period, all of which are inconspicuous, the highest ratio of the time spent in the aphelion to that spent in the perihelion part of its orbit is 28, whilst the lowest figure for a comet of any considerable brilliancy is 283 for that of Halley, and for the great comets of 1843 and 1680, the ratios are two millions and forty millions respectively. So far then as can be judged from the limited data at my command, the proposition that splendor is never found without great excentricity is fully confirmed.* It is, perhaps, worthy of remark that the asteroid Polyhymnia approaches in excentricity so near to the comets of short period as to suggest the suspicion that some of the asteroids may yet be found to partake somewhat of the cometary character, and to furnish a connecting link between the planets and comets.

One result of the preceding views as to the origin of cometary phenomena, is that brilliant comets must be expected to have long periods—and such is found to be the fact. Halley's comet has a period of only seventy-six years, but to no other, with any claim to be regarded in the first rank has been assigned a period which is not measured by centuries. Indeed Halley's is the only great comet that is known certainly to have reappeared at all.

* Since the above has been in the hands of the printer, I have seen in the North British Review for November, 1861, the following notice of a work "On the Physical Constitution of Comets. By Olinthus Gregory Downes, F.R.A.S. 4to, pp. 45. London, 1860," viz.:

Page 280. "A hypothesis with a higher claim to notice has been brought forward by Mr. Downes in his work *On the Physical Constitution of Comets.* He assumes 'that comets are of a like physical constitution to the earth, and that the effects which are produced may be due to the operation of laws which are known to prevail upon the earth, viz., the laws of heat and the laws of matter.' He then proceeds to consider what changes the laws of heat would produce on our earth moving in a very excentric orbit. The water would, by the extreme cold at the aphelion, be converted into a powdery cohering mass; and the atmosphere, when congealed also, would occupy the interstices of that mass; and what they could not contain would be deposited on its surface, 'the deposit consisting of crystals of air and water mutually entangled.' On approaching the perihelion, the air crystals would explode, scattering the undissolved crystals in streams of expanding air, the explosions increasing when near the perihelion, and the rejected matter issuing in different degrees from different parts of the nucleus. The attraction of the nucleus will now draw the expanded matter back to itself, and act as a repulsive force carrying it towards the back of the nucleus; and forming a tail, not merely of vapor but of matter. By the issue of jets from the nucleus, Mr. Downes thinks that a rotatory motion may be produced and periodically accelerated. In this way Mr. Downes proceeds to explain the phenomena exhibited in Donati's comet, as observed by Bond and Chacornac; but however much we may admire the ingenuity of the author, we must regret that it has been expended on a speculation which the astronomer and the mathematician alone can bring within the domain of science."

Again. "It has been suggested by some philosophers, that comets are habitable worlds; and Mr. Downes has maintained that they are bodies in the act of preparation for the reception of inhabitants."

Not having any knowledge of Mr. Downes's work except that derived from the above notice, I cannot tell to what extent my course of reasoning may coincide with his. Whilst he anticipates me in insisting upon the *cometizing* effect of excentricity of orbit, our conclusions in other respects appear to be widely different.

Another result is that comets which are destined to become very splendid must begin to show indications of it while yet at a great distance from the sun, their appearance showing the kind of journey from which they are returning.

Prof. Bond remarked this in Donati's comet of which he says: "Up to this time (the middle of August, and six weeks before its perihelion passage) it had remained a faint object, not even discernible by the unassisted eye. It was distinguished from ordinary telescopic comets only by the extreme slowness of its motion, in singular contrast with its subsequent career, and *by the vivid light of the nucleus; the latter peculiarity was of itself prophetic of a splendid destiny.*"

Assuming that probable cause has been shown for believing that the splendor of comets results directly from the excentric form of orbit which produces violent changes attended with the evolution of heat, electricity and light, I would propose to extend the analogy to the aurora still further, and to suggest that whilst the tail corresponds to the auroral streamer the envelopes appear to be the exact counterparts of the concentric envelopes which were observed to surround one of the terminals in some of Mr. Gassiot's experiments referred to on page 315, vol. xxxi, of this Journal*—the whole cometary phenomena being like the aurora, examples on a grand scale of the "stratified electric discharge" in vacuo.

Prof. Peirce states that Donati's comet had a dense nucleus of 150 miles in diameter surrounded by an atmosphere having a diameter of 40,000 miles, and he seems to consider this to be a type of the whole class, the dense nucleus and immense atmo-

* The following quotations from an article "On the Luminous Discharges of Voltaic Batteries when examined in Carbonic Acid Vacuo, by J. P. Gassiot, Esq., F.R.S.," published in the "Proceedings of the Royal Society, vol. x, No. 39," show the character of these envelopes:

Page 394.—Vacuum-tube "No. 146 is 24 inches long and 18 inches in circumference, and has a copper disc 4 inches diameter at one terminal, and a brass wire at the other."

Page 399.—"In 146, with Grove's nitric acid battery, 400 cells, on the completion of the current, the discharges of the battery passed with a display of magnificent strata of the most dazzling brightness. On separating the discs by means of a micrometer screw, the luminous discharges presented the same appearance as when taken from an induction coil but brighter. *On the copper plate in the vessel there was a white layer, and then a dark space about one inch broad; then a bluish atmosphere curved like the plate, evidently three negative envelopes on a great scale.*"

Page 399.—In 187 and 196 (with carbon-balls in the tubes) the discharge of the nitric acid battery elicits intense heat, and probably changes the condition of the vacuum. On the 5th of August, 1859, the discharge in 187 presented a stream of intolerable brightness (I again quote from Dr. Robinson's notes), in which, through the plate of green glass, with which he observed the phenomena, strata could be observed. This soon changed to a sphere of light on the positive ball, which became red hot, *the negative being surrounded by magnificent envelopes,* whilst with the horseshoe magnet the positive light was drawn out into strata."

Page 401.—"When the heating of the potash was further increased, four or five cloud-like and remarkably clear strata *came out from the positive.*"

sphere being always present. The above views harmonize with this conclusion, but require that we consider the atmosphere to be transparent, and invisible, except as different strata are illuminated by electric light—the observed development of the envelopes not necessarily involving any change whatever in the dimensions of the atmosphere, but simply showing the progress of luminous strata which traverse it, coming out from the nucleus just as in Mr. Gassiot's experiments they came out from the positive terminal—whilst the tail is made up of currents of electricity, similar to auroral streamers, rendered visible by their own illumination of streams of particles which they are continually transporting from the nucleus at near the velocity of electricity itself—the light of the tail and envelopes as well as the most of that of the nucleus itself being electric. The failure to detect a nucleus does not prove its non-existence, because, if the whole cometary light be principally electric we should expect the solid nucleus to be slower to assume the luminous condition than its surrounding atmosphere, and hence in all but those in which the development is extreme the electric light will be confined principally to the envelopes and tail so that a small nucleus may readily escape detection.

Doubtless comets derive a portion of their brilliancy from their reflection of the sun's light, but there are strange discrepancies between the observed and calculated brightness which can only be explained by admitting that they are principally self-luminous. If we consider their light electric, we shall cease to be surprised at sudden and irregular variations. As regards the tail, we know that the total amount of matter contained in it must be extremely small—whence, as it occupies an immense space, it must be inconceivably rare—so rare that it can scarcely be supposed capable of reflecting enough of the sun's light to render itself visible even under the most favorable circumstances—so that its being self-luminous seems to me scarcely to admit of doubt.

Recurring to the analogy between the comet's tail and the auroral streamer we find the two identical in appearance, in motion and in proportions, and not very unlike in form—and both are traversed by waves of light which in each case have their origin in the base and travel outwards with great rapidity to the extremity.* The auroral streamer has been proved to be an

* The following quotations from Commr. Gilliss's article in the last number of this Journal, not only furnish an instance of this pulsation, but contain abundant proof of such rapid movements and changes in the different parts of the luminous sectors, streams composing the tail, &c., as seem necessarily to involve electrical velocities, and afford striking analogies to the movements of streams of electricity.

"The constancy of the light near the nucleus was interrupted at intervals by *flashings or pulsations, closely resembling those of the aurora.*"

"The whole appearance of this sector, at first brilliant and well defined, *under-*

illuminated column several miles in diameter and five or six hundred miles in length, which originating in the upper portions of the atmosphere projects itself far beyond its limits, and whilst revolving about the magnetic axis of the earth maintains its rectilinear form. Now it can scarely be doubted that these are electrical currents, and as the visibility of such currents is believed to be due solely to the presence of illuminated matter, we must conclude that the auroral streamer carries up from the atmosphere particles of matter, its illumination of which shows its position. This, of itself, is not a matter of surprise, because the experiments of Plücker and Gassiot have repeatedly shown that electrical currents are not only capable of transporting particles of matter, but that even the hardest metals are unable to resist them. In a recent series of experiments upon electric discharges in vacuo, Mr. Gassiot has shown that with

went various modifications as the night progressed. When first observed, it was nearly symmetrical with respect to the comet's axis. The eastern wing was perhaps a little the longer of the two. There was a dark oval spot near the middle of the fan and a little to the east of the axis; then a faint curved line or lines, concentric with the outer convex boundary, divided the mass into upper and lower strata, each with a cusp on either side. Afterwards the lines appeared broken, giving a mottled appearance to the central zone of the sector, and finally the western cusps seemed to break, and the fan-shape was transformed into a spiral whose centre was in the nucleus. *Meanwhile, during the hours of observation, the dimensions of the whole mass had increased to at least double of the original size,* while the outlines had become so indistinct that it was only with difficulty the general shape could be recognized."

"It was not, at any time, as brilliant as during last night, nor was the dark central line near the axis as marked, but was, as then, *subject to fitful pulsations,* at which periods the increase of light sometimes seemed wholly confined to within 12° or 14° of the nucleus, *at others to flash to the utmost extremity of the coma almost instantly, and again at others, the whole volume appeared to be bent to the westward as a willow branch by the wind.*"

"The great volume of light was within 10° of the nucleus, and at 20° the brilliancy of the coma did not exceed that of the milky way, west of γ Aquilæ. *But its intensity was subject to great changes, when it seemed to flow from the nucleus in a stream steadily increasing for some minutes, and again as slowly fading away.*"

"The coma continued in two distinct branches, of which the western one was curved, and constantly traceable to within a degree of θ Bootis. *During the pulsations it could be seen a degree or two beyond that point.*"

The article on Comets in the North British Review for November, already referred to, contains the following which seems strongly to confirm the electrical character of the phenomena:

"There can be no doubt, that sudden changes of brightness, and slower changes of magnitude, take place in comets. Kepler informs us that the tail of the comet of 1607 then at first short, became long 'in the twinkling of an eye.' Wendelin, Snellius and Father Cysatus saw the tail of the comet of 1618 undulating, as if driven by the wind. Hevelius saw similar movements in the tail of the comets of 1652 and 1661; and Pingrè saw in the tail of the comet of 1769, undulations like those of the aurora, the tail sometimes covering certain stars, and then retiring from them. M. Arago was at first disposed to ascribe these sudden changes to atmospheric vapors passing between the comet and the eye of the observer; but he found in Halley's comet of 1835 satisfactory evidence that the nucleus, the whole or part of the nebulosity, and the tail of a comet, may exhibit almost instantaneous changes of brightness."—p. 274.

electrodes of platinum, silver and several other metals whenever the current from the negative terminal impinged upon the inner surface of the glass vacuum tubes made use of, a deposit was made of whatever metal composed the electrode, the terminal wire presenting the appearance of being corroded by the disruption of the particles carried off by the current. (See "Proceedings of the 31st meeting of the British Association for the Advancement of Science, held September, 1861," wherein it is stated that Mr. G. succeeded in thus obtaining deposits of 14 different metals.) Of the ability of the current to transport particles of matter there can be no doubt—the only question is as to the velocity.* Since the particles can only be supplied by the atmosphere, the formation of a column must be from its base upward —and by carefully noting the time required for a streamer to attain its full height, and knowing that height, we must ascertain its velocity. But we find that the streamer frequently appears to attain its full height instantaneously—the time occupied by its projection to the height of 500 miles being too small a fraction of a second to permit the eye to detect even the direction of the motion. This evidently involves a velocity of many thousand miles per second, and affords great reason to suppose that the particles have a velocity approaching to, if not equalling that of electricity itself—a conclusion which may the more readily be admitted since it cannot be shown that this velocity is in itself less probable than any other. Of course the velocity of the transported particles can never exceed that of the transporting current, but there seems to be no lower limit which it may not be supposed to attain. If we admit this electrical velocity, the phenomena presented by the comet's tail are easily explained, since only a few minutes are occupied in transporting a particle from the nucleus to the end of the tail, that is to a point so distant from the nucleus that the intensity of the current is not sufficient to continue its illumination farther, it disappears finally from our sight and is lost; so that the tail of to-day not only occupies a different position from that of yesterday but they have not a particle of matter in common. The particles which issued yesterday are scattered and lost, and we now see a new tail made up of a new set of particles constantly emitted from the comet. The position and form of the tail at any moment therefore depend solely upon the form and position of the electric currents, and these again must be controlled, either directly or indirectly, by the great disturbing cause of the whole phenomenon, the sun, probably through the agency of a magnetic condition excited in the comet, the existence of which was first suggested, I believe, by Bessel.

* Dr. Hare's views (stated in former volumes of this Journal, and elsewhere), of the convective electrical discharge may be worth consulting in this connection.

The waves of light originating at the nucleus and extending to the end of the tail are doubtless nothing more than unusually large clouds of particles the whole flight of which we can trace. Similar phenomena sometimes take place in the auroral streamer, the eye being able to detect with certainty the upward direction of the motion, showing that in these instances the velocity although so far exceeding any movement of matter with which we are acquainted upon the earth that it may fairly be termed electrical, still falls much below the velocity of electricity itself. The slowest motion of this kind appears to be in the "auroral flashes," which are probably identical with streamers except in that they are spread out laterally (in an East and West direction) thus occupying what Prof. Plücker calls a "magnetic surface." It may be said that if we admit the height of 500 or 600 miles claimed for auroral streamers, it may indicate that the atmosphere extends to that height rather than that particles are carried up by the current. But if the comet's tail is admitted to be identical with the streamer, it affords an answer to this argument, because it cannot be claimed that the comet can possibly have an atmosphere co-extensive with its tail. So that the explanations of the two phenomena support each other.

Again it may be objected that a stream of particles constantly issuing from the comet with the velocity of electricity must speedily dissipate the mass. But this depends upon the rarity of the matter emitted, which may be such that the whole amount lost during a perihelion passage may be very inconsiderable. Some effect of this kind has been suspected by Professors Peirce and Mitchel, who conclude that the decrease in the periodic time of Encke's comet may be due to this cause.

The foregoing considerations seem to establish a pretty strong probability that comets differ from other members of the solar system merely in the form of their orbits—and that if Donati's comet could exchange orbits with an asteroid of equal size there would also be a complete exchange of all the attendant phenomena. The comet before completing a single revolution in its circular orbit would have gone through its paroxysm of electrical excitement, attained a condition of permanent and stable equilibrium with reference to all the effects of the sun's rays and having no longer any other than reflected light would become an inconspicuous object visible only with the aid of a powerful telescope—whilst the asteroid on its return from aphelion would suddenly burst forth as a comet of great splendor.

Philadelphia, Nov. 26th, 1861.