

NOTES ON METEORITES.¹

VIII.

THERE can be little doubt that it is to the varying conditions produced by the outflows in both directions along the radius vector, to which reference was made in the last article, that the various appearances put on by the axis of comets' tails are due. Thus, in Coggia's comet, to take an instance, the perihelion passage of which took place on August 27, on June 10 the axis was brighter than the rest of the tail, but by July 10 the bright axis was replaced by one of marvellous blackness, which was one of the features of the comet at that time, and this dark axis expanded as perihelion was approached.

The tail is always curved, but if the earth lie in the plane of the orbit the curvature cannot be seen.



FIG. 27.—Great comet of 1861, seen on June 30, when the earth was in the plane of the orbit.

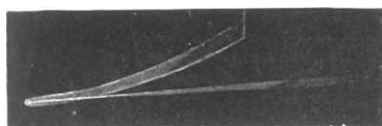


FIG. 28.—Same comet seen on June 15.

The accompanying woodcuts will explain how the solar repulsion produces this curvature, and how the curvature will depend upon the velocity due to repulsion.

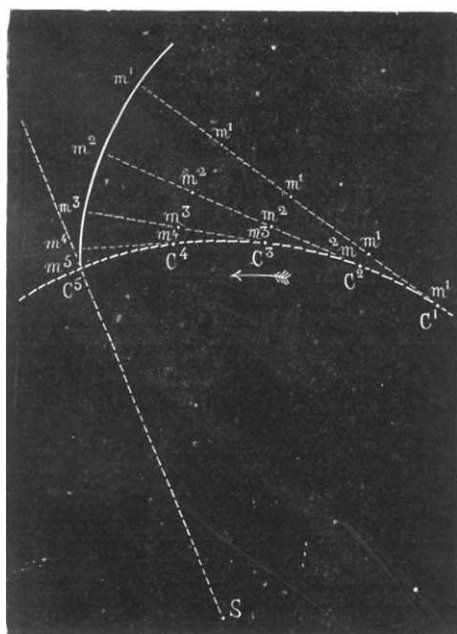


FIG. 29.—Slight repulsion; great curvature.

Fig. 29, which I owe to M. Faye,² represents the successive positions of a series of molecules emitted by the nucleus of a comet so as to constitute the axis of the tail. A density is imagined such that the repulsive force exactly counterbalances the solar attraction: thus their motion, solely due to the tangential velocity of the comet, takes place in a straight line.

¹ Continued from p. 236.

² "Forms of Comets," NATURE, vol. x. p. 268.

To again simplify matters, this rate is supposed constant, as if the orbit were a circle.

On the first day, the comet being at C^1 , a molecule m^1 is detached and subsequently follows the line $m^1 m^2 m^3$. On the second day, a molecule m^2 , likewise leaves the nucleus at C^2 , and subsequently describes the tangent $m^2 m^3 m^4$. Similarly, on the third day, for a molecule m^3 ; and so on. If we join by a continuous line the series of positions occupied at the same time, the fifth day, by all these molecules, m^5, m^4, m^3, m^2, m^1 , we shall have the curvilinear axis of the tail; this will be, in this particular case, the involute of a circle. This construction accounts for the three laws which have been ascertained as the result of observation: (1) the tail, at its origin, is sensibly opposed to the sun, S ; (2) the tail is curved backwards on its path; (3) the axis of the tail is a plane curve situated in the plane of the orbit.

If the density of these molecules were still smaller, the repulsive force would prevail over the solar attraction, and the molecules would describe no longer straight lines, but sections of an hyperbola whose convexity would be turned towards their common focus, S (see Fig. 30).

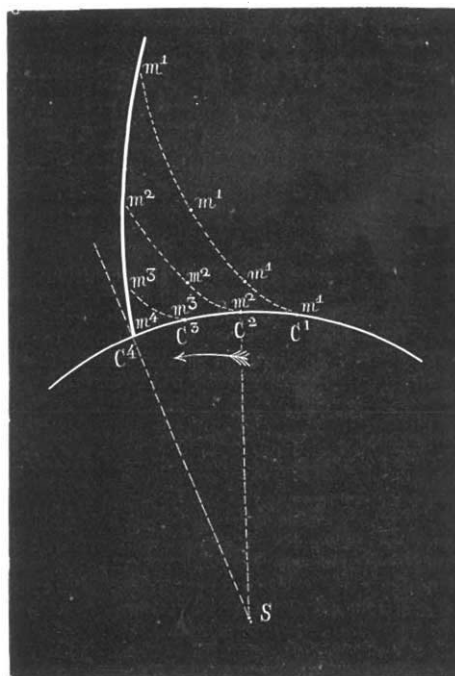


FIG. 30.—Here the velocity is greater and the tail is straighter.

The series of points m^1, m^2, m^3, m^4 , emitted at C^1, C^2, C^3, C^4 , by the comet, gives a curve like the former one, but with a curvature much less pronounced and nearer to the radius vector.

Now the single tail we have been considering will depend upon the repulsive action upon molecules of similar density, and that very small.

But suppose there are in consequence of collisions among the members of the swarm, several gases given off which can retain their gaseous form, and suppose they are of different densities. Then it is evident that a winnowing process will be set up, and that the molecules of smallest density will be repelled with the highest velocity; and given these varying densities, we must get more tails than one—one, in fact, for each representative density.

M. Bredichin, of the Moscow Observatory, has in fact shown that there are three distinct types of tails. In the first class, the tails are long and straight, and the repellent energy of the sun upon the small particles is about twelve times as great as the energy of his gravitational attraction. The particles therefore leave the nucleus with a high velocity, generally about fourteen or fifteen thousand feet per second. The greater this velocity in relation to the rate of travel of the comet, the straighter of course will be the tail, because the particles forming it do not lag behind. In the second type, the energies of the

attraction and repulsion balance each other, or nearly so, and the tails of this class are plummy and gently curved. In this case the particles which go to form the tail leave the head with a velocity of about 3000 feet per second. Tails of the third type are short and strongly bent, the repellent energy being only about one-fifth of the attractive energy of the sun, and the velocity of the particles leaving the head is only about 1000 feet per second.

Many comets exhibit tails of more than one type, and it was conjectured long ago that such tails were composed of different kinds of matter.

Bredichin went further, and defined the composition of the different kinds of tails which he had classified, by referring to the molecular weights of the materials which would give the relative values of the repulsive and attractive forces necessary for tails of the different types. He thus found that the long straight tails of the first type would be probably formed by hydrogen, since this substance, on account of its exceeding lightness, would be little influenced by gravity, while at the same time strongly influenced by the solar repulsion. The second type of tails he considered to be made of hydrocarbons, since hydrocarbons have a molecular weight such that the repellent and attractive forces of the sun upon their particles may be nearly equal. Iron, on the other hand, would be more subject to the action of gravity, on account of its greater weight, and was therefore taken as adapted to tails of the third type.

There is nothing extravagant in these suppositions, for we know that all the substances in question do exist in comets, and it is evident that much is to be learnt from a continuation of the inquiry, but at the outset we can see that iron vapour cannot in space remain as vapour to form a tail.

We know that the short-period comets get less brilliant with every approach to perihelion, and that some do not even throw out a tail, and we can easily ascribe both these results to the fact that after several such appulses the vapours liable to be driven out of the meteorites by temperature get less and less.

If this be so, we may regard a comet with many tails as one which for the first time undergoes perihelion conditions.

If it be conceded that the tails of comets are in part composed of hydrogen and compounds of carbon with gases such as oxygen, an explanation seems to be suggested of many recorded phenomena, while at the same time it seems more probable that the repulsive force would act continuously upon permanent gases rather than on condensable vapours, such as iron vapour, to take an instance.

Suppose that the sun has been formed by the coming together of meteors, whether brought by comets or not, it is obvious that with equal temperatures of the sun the repellent action would be the same on the permanent gases given off by the meteorites, whether in large or small groups. In the larger groups there would be possibly more collisions, and therefore greater possibilities of higher temperature of the meteorites.

This action would surround the sun, as it were, by a cordon, inside which, to take instances, neither hydrogen nor oxycarbon-compounds could enter. Hence we should have a sun without hydrogen, carbon, or oxygen.

But while, as demanded on this view, the quantity of carbon and oxygen is extremely small, even if the latter exists at all, the quantity of hydrogen is enormous.

This difference can, however, be accounted for by the idea which has been suggested on several other grounds, that the hydrogen which plays such an important part in the sun's economy and in the economy of all stars hotter than the sun is really produced locally by the dissociation of the vapours of the chemical elements which form the sun and the meteoritic constituents which still reach it in the shape probably of iron and silicates.

We know perfectly well (from Duner's work chiefly, in stars of the class III. *b*) that when the sun gets cooler its atmosphere will consist almost exclusively of carbon compounds; and indeed one of the last scenes in the drama of world-formation seems to be the gradual approach of the "cordon" to which I have referred, as the radiant energy of the star is diminished, thereby enabling all the permanent gases in the system to gradually approach the primary; and it is not impossible that the great differences of density of the interior and exterior planets may be connected with this state of things.

Before passing on, it is well to recur to the question, Why should not vapours be also repelled from the cometary nucleus and its envelopes?

No doubt they are; but it is straining the facts to suppose that they would not be condensed by the cold of space before they

had been repelled any great distance; the enormous lengths of some comets' tails would seem to negative any such possibility.

Some of these lengths may be given in miles:—

Comet 1843 (I.)	...	...	198,800,000 miles
" 1680	...	...	149,000,000 "
" 1847 (I.)	...	...	130,800,000 "
" 1811 (I.)	...	...	109,400,000 "
" 1860 (III.)	...	...	21,700,000 "

With regard to the rate at which the tails are thrown out it may be stated that, in the case of Donati's comet, between September 23 and October 10 the tail had increased from 15,000,000 to 55,000,000 miles, or, speaking roughly, the tail had increased by 2,000,000 miles a day.

If we are justified in considering that the materials of the comet thus repelled to form the tail are non-condensable gases, such as the hydrogen and the carbon compounds which are actually found in meteorites, we have in this fact probably the *vera causa* of the so-called occlusion of these gases by meteorites. That is, one set of meteorites—a comet—may be giving off these gases, while other meteorites, which have never been members of such a large swarm, may occupy regions of space swept over by the gases repelled from the comet.

But if it be agreed that it is not probable that, say, the vapours of iron and magnesium could retain their vaporous condition so long as the hydrogen and the carbon compounds—there can be no doubt that they start on the common journey in consequence of the repulsive action outside the track of the comet—then we shall expect to find condensed particles of iron, nickel-iron, and magnesium or their compounds; and here again we have a *vera causa* for the chondrites which enter so largely into the composition of meteorites.

The tail of a comet being thus formed at the expense of the materials composing the head, the materials removed from the head can never be returned to it because of its insufficient gravitational power over them, and moreover they can no longer traverse the same orbit as the comet to which they originally belonged, because they have already been turned out of that course by the forces attending the development of the tail. The small tail-forming meteoric bodies thus become distributed throughout the space occupied by our system, and give no further trace of their existence, unless they happen to break into our atmosphere and appear as shooting-stars.

Comets must thus degenerate, so far at all events as their easily volatilized constituents are concerned, with each perihelion passage, but as the majority of them only approach the sun at long intervals of time they do not suffer much in this way. Some of the short-period comets get less and less brilliant at each successive perihelion passage, and others are then observed entirely without tails, all the available tail-forming material having been used up and dispersed into space.

It is a fact well worthy of consideration that on many occasions pulsations exactly resembling those observed in auroræ have been observed in comets' tails.

This subject is thus referred to in Guillemin's book on comets:—

"Kepler is the first observer who has made mention of the changes. 'Those,' he says, 'who have observed with some degree of attention the comet of 1607 (an apparition of Halley's comet) will bear witness that the tail, short at first, became long in the twinkling of an eye.' Several astronomers—Kepler, Wendelinus, and Snell—saw, in the comet of 1618, jets of light, coruscations, and marked undulations. According to Father Cysatus, the tail appeared as if agitated by the wind; the rays of the coma seemed to dart forth from the head and instantly return again. Similar movements were observed by Hevelius in the tails of the comets of 1652 and 1661; and Pingré, describing the observations of the comet of 1769, made at sea, between August 27 and September 16, by La Nux, Fleuriën, and himself, thus describes the phenomenon of which he was a witness:—'I believe that I very distinctly saw, especially on September 4, undulations in the tail similar to those which may be seen in aurora borealis.' The stars which I had seen decidedly included within the tail were shortly after sensibly distant from it.

"M. Liäis has given the following account of the observations made by him of the great comet of 1860:—'On the evening of July 5, whilst I was observing the comet at sea, I saw a rather

intense light from time to time arise in those portions of the tail that were furthest from the nucleus. Sometimes instantaneous, and appearing upon a small extension of the extremity of the tail, which then became more visible, the fugitive gleams reminded me of the pulsations of the aurora borealis. At other times they were less fleeting, and their propagation in rapid succession could be followed for some seconds in the direction of the nucleus near the extremity of the tail. These appearances then resembled the progressive undulations of the aurora borealis, but even in this case they were only visible in the last third of the length of the tail. The gleams in question were similar to those that I remember to have seen in the tail of the great comet of 1843, and which were observed by very many astronomers."

The American observers of Donati's comet in 1868 described a number of brighter bands "like auroral streamers" crossing the tail and diverging from a point between the nucleus and the sun.¹

This point is one well worthy of subsequent inquiry. I have brought together evidence to show that in the aurora one of the chief factors in the production of the spectrum is meteoric dust.

If this be conceded, we have meteoric dust in all probability very slowly falling through our atmosphere at a height at which its pressure is very low, the luminosity both of the dust and the atmosphere being produced by electricity. Whether the electricity is produced by the movement is a matter on which at present we are quite ignorant, but if it be eventually shown that all auroræ follow well-recognized star-showers a certain amount of plausibility will be accorded to the notion.

However this may be, we must in the case of the aurora regard the permanent gases in the air as a constant, and the dust as the variable.

But if we wish to assimilate these displays with comets' tails, we must in the latter case consider meteorites in space as the constant, and the permanent gases repelled from the comet as the variable.

Prof. Tait, assuming that the head of a comet is a swarm of meteorites or stones, varying in size from a marble to boulders 20 or 30 feet in diameter, has shown that all the various cometary phenomena may be explained. His researches have not yet been printed *in extenso*, but the following general statement gives a summary of the results of his calculations which appeared in *Good Words* some time ago.

Firstly, with regard to the masses of the comets. The total mass of a comet cannot be very great, for, as we have seen, no measurable disturbance of planetary orbits has been known to be produced, and this small mass is just as likely to be due to scattered solid masses as to one continuous gaseous mass, and indeed we know that this is so. In the case of comets of but small masses, the component meteorites would be small and far apart. Then with regard to the transparency of the comet, it is calculated that a meteorite 25 feet in diameter at a distance of half a million miles from us could not totally eclipse a star of the same size as our sun, even if it were at such a distance as to be barely visible to the naked eye. Again, if some of the meteorites were large enough to eclipse the stars behind the comet, the eclipse would be of very brief duration, and we should see the star as if nothing had happened. In order for the comet to reduce the light of a star seen through it by one-tenth, it would require to be 300 miles thick, supposing the stones to be 1 inch cube and 20 feet apart.

While the swarm which builds up the comet is coursing round the sun as a whole, the individual members will themselves gravitate towards each other; and if we suppose the whole mass to be 1/1000 that of the earth, and the meteorites to be uniformly distributed in a sphere 20,000 miles in diameter, those coming from the outside to the centre of the group would have a velocity of about 500 feet per second. The stones colliding will generate heat, and some gas will be evolved; some members of the mass will be quickened, while other constituents of the mass will be retarded in their motion, and in this way we have a probably sufficient explanation of the various forms which the telescope has revealed to us. And then finally Prof. Tait goes on to show that the result of these collisions would be such a smashing up of the constituents of the swarm that much finely-attenuated material would be left behind, sufficient to reflect sunlight, and to give rise to the phenomena of the tail.

Webb, p. 197.

If in the imaginary swarm the mass of each stone be 100 pounds, and its velocity, due to attraction, be 500 feet per second, the heat resulting from the impact of two of them would be quite sufficient to volatilize a portion, and to make the outsides of the stones white-hot. Stones of this weight would be about 10 inches cube, and in the swarm considered there would therefore be about 136,000,000,000,000,000,000 of them. At the rate of one collision per second, there being about 31,436,000 seconds in a year, there would be a possibility of one collision per second for 2,150,000,000,000 years. There would therefore be material for such collisions for a period of over two million years even at the extravagant rate of one million per second, and on the assumption that no stone comes into collision with another more than once.

The whole mass being 1/1000 that of the earth, and the space occupied being 250 times that occupied by the earth, the stones in question being 10 inches cube will only occupy about 1/8000 of the space through which they are distributed; the average distance apart would be about 17 feet. The swarm would reflect about half as much sunlight as a slab of the same material in the same place, but it would probably be too opaque to transmit starlight. By making the stones larger, and thus increasing the distances between them, the luminosity would be retained, while at the same time the swarm would be sufficiently transparent. It thus seems to suit the hypothesis better if we regard the separate stones to be greater than 10 inches cube.

J. NORMAN LOCKYER.

(To be continued.)

THE FORCES OF ELECTRIC OSCILLATIONS TREATED ACCORDING TO MAXWELL'S THEORY. BY DR. H. HERTZ.¹

I.

Note by the Translator.

THE early part of the following paper is no doubt familiar to the more important persons in this country, and therefore need perhaps hardly have been translated. Nevertheless, as these experiments of Hertz form a sort of apotheosis of Maxwell's theory, it is natural to reproduce this portion as well as the rest; and inasmuch as Hertz did not at first express his discoveries in Maxwellian language, it is interesting to see how he regards the matter since his conversion, and how he now presents his ideas to foreigners.

I have translated the paper because it seems to me a remarkable example of clear theoretic insight in conjunction with great experimental skill, because it is pleasantly written, and because it deals in a powerful manner with a profoundly interesting subject.

I can hardly hope to have escaped errors in translating, but the original paper in *Wiedemann's Annalen* for January of this year is very accessible.

OLIVER J. LODGE.

The results of the experiments on quick electric oscillation which I have carried out appear to me to lend to Maxwell's theory of electrodynamics an ascendancy over all others. At first I interpreted these experiments in terms of older notions, seeking to explain the phenomena in part by means of the co-operation of electrostatic and electro-magnetic forces. To Maxwell's theory in its pure development such a distinction is foreign. I wish, therefore, now to show that the phenomena can also be explained in terms of Maxwell's theory without any such distinction. If this attempt succeeds, questions about special propagation of electrostatic force, being meaningless in Maxwell's theory, are at once settled. And besides this special aim, a closer insight into the play of forces concerned in rectilinear oscillations is not without interest.

The Formulae.

In what follows we have only to concern ourselves with forces in free ether. Let X, Y, Z , be the components of electric force acting on the points x, y, z ; let L, M, N be the corresponding components of magnetic force; let t be the time, and let A stand for $\sqrt{(\mu K)}$. Then, according to Maxwell, the time-rate of change of the forces is dependent on their distribution in space in the following way:—

¹ Translated and communicated by Dr. Oliver Lodge.