Art. V.—*On the Tails of Comets;* by Henry M. Parkhurst.

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In predicting the form and position of a comet's tail, I adopt the theory of Professor Pierce:

"Each particle of the matter which composes the tail is supposed to move in a hyperbolic orbit, with the sun in the focus of the opposite branch, under the influence of a repulsive force emanating from the sun, and decreasing by the law of the inverse square of the distance." (Gould's Astronomical Journal, vol. v, page 186.)

The application of the formulæ gives for any required time one line only, commencing at the comet and extending indefinitely. Professor Pierce adopted, in his computations upon the tail of Donati's comet (Gould's Astr. J., vol. vi, page 51), an excess of repulsive force $1\frac{1}{2}$ times that of gravitation, making his comparisons with the front edge of the tail, and arbitrarily adopting such a repulsive force as best to explain the observations. For the purpose of comparing with the center of the tail, I adopted in my computations a repulsive force exactly equal to and replacing gravitation as the more probable law. On comparison with the observations, however, I find that the computed line closely agrees in nearly every instance with the observed right hand edge of the tail; and I shall, therefore, adopt that as the standard of comparison. Although the comet apparently moved in the other direction, yet in fact that was the front edge of the tail.

Most of the earlier observations were furnished to me by W. S. Gilman, Jr., of New York City, and all the later ones by Lewis Swift of Rochester, whose observations continued several days after the comet had ceased to be visible in New York City.

From June 12 to June 30, I have only the record of the direction of the tail, without reference to stars (G), agreeing with computation. On July 1, the tail "pointed to and reached 55 of Camelus." (P.) The computed line passes nearly through that star. On July 7, the front edge was seen a little to the left of 63 Arg. 749. (Bonn Catalogue.) (P.) The computed line passes a small fraction of a degree to the left of the star. On July 13, the last day when the head of the comet was favorably seen, "the right edge just touched *o* Ursa Major" as seen by Mr Swift, and passed $\frac{1}{2}°$ to the left of it according to my own record. The computed line passes $\frac{3}{4}°$ to the left of it The curvature on this evening was commonly noticed. Computation indicates an arc of about 15°. On July 14, "*h* U. Maj. was in the middle of the tail." (S.) Allowing for the recorded width, it should be in the middle of the tail. On July 17, "v was exactly in the center," and "its left edge just touched α." (S). These are each within $\frac{1}{2}°$. On July 18, "it passed over α," (S.) and α U. Maj. was within the range of the computed tail. "θ and F (φ) were not only in the center of the tail but in line with its axis." (S.) They were within $\frac{1}{4}°$ of the computed center, and very nearly in the computed line of its axis at that point. On July 19, "the tail passed midway between α and β, but touched neither." (S.) The computed line passes nearly centrally between them. "Its left edge just touched δ." (S.) Here is an inaccuracy; for it could not have touched δ without passing over β. On July 20, it passed "midway between β and γ U. Maj., and centrally over δ." (S.) This agrees with computation. On July 21, the last day of its visibility, γ U. Maj. was seen "at its right edge, perhaps 1° within it." (S.) The computed line is 1° to the right of γ. "λ and μ U. Maj. were seen in the center of luminosity." (S.) This agrees exactly with computation. "No curvature perceptible." Computation indicates that the tail increased its curvature until about the 13th, a few days earlier the tail being too short for it to be perceptible, and a few days later the curvature itself becoming too small to be perceptible.

In all these cases the accordance of the right hand edge of the tail with the computed line was as close as the nature of the observation would admit. But among the observations kindly furnished me by Mr. Gilman, the accuracy and faithfulness of which I cannot doubt, are two which I cannot in fairness omit. On July 3, he recorded the place of the tail as wholly to the right of the two stars 65 Arg. 606, 607. The computed line passes to the left of those stars. As he did not use a diagonal prism, and inverted his chart in making the comparison, it seems impossible that he should have put it upon the wrong side, especially as his attention was also directed to the star 65 Arg. 599, near the other edge. On July 6, he recorded the place of the tail as passing through the star 63 Arg. 749, the chief star of an unmistakable group. The computed line passes nearly a degree further east. On this diagram you will see that the observed lines, before and after, are nearly parallel, and that these two widely deviate. You will also see, that in each case, connecting the observed point in the tail with the position of the head on the previous evening produces a line parallel to the rest; and although Mr. Gilman himself does not conceive it to be possible that he connected the position of the tail on one day with that of the head upon another, or that he could have even seen the comet on July 5, which was Sunday, I can find no other satisfactory solution of the discrepancy; and that explanation would substitute two observations accurately agreeing with the computations, for two which are entirely inconsistent with the remainder of the series. Perhaps I should add that these observations, and indeed all the observations but one, were made without any expectation that they would ever be of value.

In predicting the width of a comet's tail, it may be assumed to bear a certain ratio to its length. Up to the time of the disappearance of the nucleus, the ratio of one-sixth was sufficiently exact. The tail was then approaching us, and on this account would be expected to appear to grow wider as well as longer. Assuming that it remained unchanged in form, it should have been about six times as wide on July 21 as on July 13. But instead of being 18° wide, it was seen to be only "$4\frac{1}{2}$°, possibly 5°."

I have refrained from alluding to an important point with regard to the front edge. When the tail is coming directly toward us, the front edge becomes the medial line. When the tail is 4° wide, assuming the right hand edge to be the front edge would involve an error of 2°; or, if the tail were 18° wide, as computed, it would involve an error of 9°. There is no such error; therefore, there is no visible portion of the tail to the right hand of the true front edge. If the tail is flat, lying in the plane of its orbit, we may readily understand why it should be so foreshortened when directed toward us. Indeed, this proves too much; for if it were as thin as Saturn's ring, it should have appeared as a mere line instead of being 5° wide. If the form of the section were elliptical, it would account for the observed width on the 21st of July; but when the tail was first seen, the earth was fully 11° above its plane, as seen from the comet, and the tail would have appeared much narrower in all the observations before July 13. The dark line behind the nucleus cannot indicate a hollow conical tail, for a diminution of the central light by $\frac{1}{20}$th part would hardly be perceptible; but that dark line, and the dark lines separating the different envelopes, are perfectly consistent with the theory of a thin flat tail.

There is another important fact. The front edge was toward the right until July 20; but at noon of July 21 the earth passed through the plane of the orbit. On the evening of July 21, therefore, when the tail was 5° wide, the front edge should have been either at the left hand, or at any rate at least 2° from the right hand edge; and yet the latter agreed with the line computed from the same formulæ with those of all the preceding days; and although the tail was seen for five days in succession, during which the earth passed through the plane of the orbit, there is no apparent discrepancy between the computed line and the observed position of the *right hand* edge of the tail.

A diagram I have constructed illustrates several results necessarily depending upon the hyperbolic theory. The black line represents the orbit of the comet of 1843, so far as included within the radius of the earth's orbit. The red lines, starting from the orbit, and after passing their perihelion points radiating in nearly straight lines from the sun, represent the hyperbolic orbits of particles of matter, leaving the head of the comet at the given times.

In these computations, also, I have adopted 1 as the ratio of repulsion. Had Coggia's comet possessed sufficient luminosity to be visible on July 24, it would have afforded a test of the true amount of repulsive force; but as its plane was still turned almost directly toward us when the tail was last seen, a variation in the assumed amount of the repulsive force makes no appreciable difference in its position; and the streamers seen extending from the convex side of the tail of Donati's comet suggest the theory that upon every formation of a new envelope, a small portion of the matter was endowed with a repulsion at least ten times that of the rest of the matter forming the tail.

The blue lines circling around the sun connect the positions of the particles in their hyperbolic orbits at given times, and therefore represent the visible and the invisible tail of the comet. The particles leaving the head of the comet thirty days before it reaches its perihelion, follow nearly behind it, with continually retarded motion, and when the head of the comet reaches the sun, those particles have only passed over half that distance, and are just about to commence their outward course. In receding from the sun the motion is gradually accelerated until the particles reach the same distance from the sun at which they left the head. The moment they pass outside of that point they are irrevocably lost. A reconversion of the repulsive force into attraction would not avail, but they must fly, unless intercepted, beyond the confines of our solar system.

Particles leaving the head of the comet at a later date pursue a somewhat similar course, coming nearer to the sun, but all at about the same time turning and flying off into space. The nearer they come to the sun before commencing their hyperbolic course, the more violent is the repulsion, and the greater their outward velocity. The particles which leave the head of the comet exactly at the perihelion, pursue a line almost directly from the sun, but about 66° from the axis of the comet's orbit. These particles commence their outward course with a velocity sufficient to carry them outside the earth's orbit in a little over two days; and that velocity remains nearly uniform in consequence of the sudden removal of the matter beyond the sphere of the sun's forcible action. Consequently, when we undertake, for the 30th day after the perihelion passage, to trace the entire tail which has left the head during the preceding 60 days, we must pursue a curve commencing at the position of the head of the comet, passing to the right and downward, crossing the perihelion line at a distance from the sun one-third greater than that of the planet Neptune, and re-entering the earth's orbit above.

How much of this will be visible? As we follow the tail from the head it becomes fainter, first, because it is more distant from the sun, and therefore less illuminated. Another reason is that it is more diffused from its rapid expansion like the fire from a catharine wheel, the portion of the tail forming a certain arc, continually forming nearly the same arc of a larger circle. But is that all? Here is a portion of the tail above, more illuminated than the head of the comet itself, and which occupies less than one-fourth the space traveled over by the comet while it was issuing.

While the dark line in the center of a comet's tail seems to disprove the theory naturally suggested by the fact of the front edge being the line of computation, that the resistance of the ether is the cause of the expansion of the tail, the ether may have a perceptible effect upon its form and position. Had the sun an ether of its own, carried with it through that still more rare ether which brings to us the pulsations of light, the effect of the ether upon the tail would be only that resulting from the motion of the comet itself; but leaving the ether behind it in its course toward the constellation Hercules, it will tend to sweep the tail back from that point: and here we may find a possible explanation of the apparent wafting of the tail out of the plane of its orbit, leaving the front edge still on the right, and causing a thin, flat tail to have a visible width tenfold greater than it would have had if strictly in the plane of the orbit.

Note.—Observations in England on July 9, 14, 17, 18, 19 and 21, confirm the positions above given, but are not sufficiently definite for exact comparison. The theory of Prof. Norton (Am. Jour. Sci., 1861), that the width of the tail arises from the variation of the repulsive force exercised upon different particles of the cometary matter, and its thickness from the repulsion of the nucleus itself at the time of emission, I had not seen when the above was written. I have computed a new line consisting of particles equally repelled and attracted, and I find that it nearly corresponds with the former computed line, or with the observed right hand edge of the tail, apparently indicating that the tail was, from some cause, chiefly south of the plane of the orbit. The theory of Prof. Norton affords a plausible explanation of that cause.

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