

ON THE ANOMALOUS TAILS OF COMETS

By E. E. BARNARD

It seems to be the custom in general to give to the Sun the main credit for all the phenomena of a comet's tail, the supposition being that the comet itself merely supplies the material for the Sun to work upon. This idea could generally be reconciled with the facts known previous to the revelations made by the photographic plate. But the photographs of the last ten or twelve years have shown us new phenomena, many of which cannot be reconciled to the old ideas of a comet's tail. They are entirely of a revolutionary nature and are not easily explained. I have long suspected that other agencies besides the Sun entered into the making of these phenomena, and I now believe there are three main causes which often combine to produce the results shown in photographs of some of the recent comets. These are:

First, the Sun, which produces in the nucleus of the comet a disturbing action, and which influences the general direction of the tail-producing particles.

Second, the comet itself. A strong ejective power seems to be seated in the comet, by which the matter forming the various tails is ejected. That this is true is shown by the fact that straight minor tails or streams of particles are often seen to issue at large angles to the direction of the main tail. Such peculiarities are quite contrary to the effect produced by the Sun. It would seem that this power is great enough to overcome entirely the direct pressure of the Sun's light.

These small tails, as I have said, are generally straight. One would expect the pressure of the Sun's light to bend them more or less toward the radius vector, but this does not seem to be the case. It would therefore appear that the Sun has but little influence on these small divergent tails.

It is probable that if, after the nucleus becomes active, the effect of the Sun's repulsive force were removed, tails would be shot out

from the head of the comet in all directions. This is, of course, not opposed to the generally accepted theory of cometary tails.

Third, an outside influence that has no concern whatever with the comet itself and whose effect is purely an accident of circumstances. This is shown in the remarkable and rapid distortions and deflections of the tail or tails. There is clear evidence that this is some sort of resistance offered by some kind of medium not uniformly distributed in the planetary spaces. It may be a meteor swarm of sufficient density to break the comet's tail, or to distort or deflect it. There is no question but these sudden distortions or deflections are independent of any action of the Sun or of the comet itself. Their causes may not necessarily be due to meteor swarms or streams. As I have suggested elsewhere,¹ there may be currents of resistance of some kind moving about the Sun capable of producing these phenomena, of which we know nothing at present. If so, their presence would be indicated alone by the distortions they produce in comet tails. That these influences do not permanently exist throughout the solar system is shown by the fact that only occasionally does a comet show their effect. The average comet with a tail usually shows only phenomena that can be satisfactorily explained by the first two causes.

Encounters with such a medium would readily explain the sudden brightening up of some comets when long past their greatest theoretical brightness—such, for instance, as shown by Sawerthal's comet in May 1888; or it might account for the breaking up of such a comet as Biela's. Whatever the supposition may amount to, there is forced upon us the fact that some outside influence beyond the control of comet or Sun entered into the production of the peculiarities of the tail of Brooks' comet in October and November 1893.

I have already² called attention to the remarkable disruption of the tail of this comet, as shown on the photographs between October 20 and 23, 1893, but the phenomena of November 2 and 3 of that year have not yet been studied. The photographs made on these last two dates perhaps bear as strikingly as those of October on the question at issue, and they more clearly show the deflection of the tail. At the Astronomical Congress in September 1904, at St. Louis, I exhibited a lantern slide made by superposing the two orig-

¹ *Monthly Notices*, **59**, 355, 1899.

² *Popular Astronomy*, **12**, 1, 1904.

PLATE VIII

North



II
1893, Nov. 3,
16^h 0^m to 17^h 30^m
P. S. T.



I
1893, Nov. 2,
16^h 0^m to 17^h 25^m
P. S. T.



Combination
of I and II

Scale: 1 mm = 3

COMET 1893 IV (BROOKS), SHOWING ANOMALOUS TAILS

inal negatives, star for star, which would thus show on one plate the two pictures of the comet separated by the amount of motion in the one day's interval. This method does not appear to have been used before for showing the changes in a comet's tail. As the two plates covered essentially the same region of the sky, the stars of the last plate were easily superposed on those of the first night; and when an exact register was made, the effect was the same as if two instantaneous exposures of the comet on the two dates had been made on the same plate, using the same guiding star for both exposures. If one examines thus these two photographs of this comet, he is forced to the conclusion that the deflection of the tail in the interval between the two photographs cannot be explained by any of the ordinary causes that go to produce the phenomena of a comet's tail. In this case the computed position angle of the radius vector for the two dates was nearly the same, 324° . In the photographs the two tails should therefore be parallel to each other. But there is a difference of some 15 degrees between the two. (Observed position angle: November 2, 322° ; November 3, 306° ; the deflection comes from the direction in which the comet was moving.) The strange thing is that the ends of the tails seem not to have changed their position in space while the head has advanced in the comet's path. This phenomenon is almost exactly reproduced in the photographs of November 6 and November 7. There was little change in the computed position angle of the radius vector for some time, and if at about this date any other two successive plates of the comet are superposed, it will be seen that the tail has moved essentially parallel to its first position.

In the accompanying plate the large picture is a composite made by superposing the two negatives of November 2 and November 3. This exhibits well the peculiarities I have mentioned of the lagging of the end of the tail, as if it were delayed by a resistance of some kind. In this picture there are two regions of greater brightness where the tails combine. The first of these is at α 12^h 35^m 2 , $\delta + 28^\circ$ $12'$. This one is mainly due to the tail of November 2. The second is in α 12^h 30^m 4 , $\delta + 28^\circ$ $24'$ (1855). It is due mainly to the tail of November 3.

A few points with respect to the individual pictures which are also given on Plate VIII may aid in the study of the photographs.

Photograph of 1893, November 2.—The length of the tail to the abrupt end is $3^{\circ}.7$; the extreme length of the tail, $5^{\circ}.4$; while the small narrow tail which runs northwest from the head is 2° long.

Photograph of 1893, November 3.—The extreme length of the tail is 5° . There is a large detached mass $5^{\circ}.0$ from the head, the position of the center of which is α $12^{\text{h}} 32^{\text{m}}.0$, $\delta + 28^{\circ} 25'$ (1855).

The following are the positions of the head of the comet as taken from the *B.D.* charts:

1893, November 2, $16^{\text{h}} 42^{\text{m}}$, Pacific Standard Time

α $12^{\text{h}} 45^{\text{m}}.2$, $\delta + 25^{\circ} 14'$ (1855)

1893, November 3, $16^{\text{h}} 45^{\text{m}}$, P. S. T.

α $12^{\text{h}} 46^{\text{m}}.8$, $\delta + 26^{\circ} 6'$ (1855)

In comparing these two pictures, I am not able to identify with certainty any one feature common to both photographs. The changes have doubtless been so rapid that nothing forming the tail in the first case remains as a part of it in the second case. I do not think that even the small, narrow tail running to the northwest is the same in both photographs. The detached mass at the end of the tail on November 3 might be supposed to be the bright mass at the end of the tail of November 2, but I do not believe this is so, for the changes were entirely too rapid for it to have lasted twenty-four hours. Yet one is tempted to believe them the same, for the end of the tail seemed to be detained in that region. I do not think it necessary to call attention to any other details, for the photographs will speak for themselves in this matter.

A list of the brighter stars shown on the photographs may be of use in the study of the peculiarities of the tails.

These are quite easily identified on the photographs. Referring to the picture of November 2, No. 1 is $\frac{1}{2}^{\circ}$ west of the abrupt end of the tail. Nos. 2 and 3 are the two stars $\frac{1}{2}^{\circ}$ west of the middle of the tail. Nos. 4 and 5 are the two 1° west and south of the head. No. 6 is the one close west of the tail, 1° back from the head. Nos. 7 and 8 are the two $1\frac{1}{2}^{\circ}$ east of the end of the tail, No. 8 being the eastern of the two.

I have previously shown¹ in the photographs of Borrelly's comet

¹ *Astrophysical Journal*, 18, 210, 1903.

B. D. No.	Mag.	α (1855)	δ	Current No.
+27°2158	7.9	12 ^h 33 ^m 47 ^s .3	+27° 56'.3	1
+26.2383	6.8	12 36 9.5	+26 55.2	2
+26.2385	7.5	12 36 27.5	+26 27.4	3
+24.2493	6.5	12 39 25.7	+24 56.5	4
+24.2495	7.1	12 40 51.6	+24 53.5	5
+25.2568	6.0	12 41 43.6	+25 38.6	6
+28.2153	6.2	12 42 15.8	+28 20.4	7
+28.2156	5.0	12 44 41.4	+28 20.0	8

of 1903 that in that comet, at least, the tail really moved bodily out from the comet at a comparatively slow velocity, small in comparison with the velocities often attributed to comet tails, at the same time partaking of the onward motion of the comet; and that, if disconnected from the comet at any moment, it would continue to drift in space for at least several hours as a visible body.

This all fits in closely with the idea of a disruptive effect due to the tail meeting with some resisting medium in the case of Brooks' comet.

I am aware of the theories necessary to account for the apparently extraordinary flight of the tails of the great comets of 1843 and 1882 around the Sun, which would absolutely preclude the idea of an actual onward motion of the tail for any considerable time. Such conditions were, however, evidently entirely anomalous, and were due to the extremely close approach of these bodies to the Sun. Perhaps the velocity with which the particles leave a comet under the influence of the Sun's light varies inversely as the squares of the distances from the Sun, and hence in the case of such comets as those just referred to the initial velocity of the particles might be many thousands of times that of the particles leaving Borrelly's comet. In the comet of 1843 the particles would probably have a velocity of as much as 100,000 miles (160,000 km) a second.

From these considerations it is evident that every active comet should be photographed as often as possible. Photographs made on the same night will be especially valuable, and these should be made as frequently as possible during the night. It is from such photographs alone that the progressive changes can be followed intelligently. The changes from day to day in a comet are so very great

that it is usually not possible to connect certainly any phenomena of one night with that of the night before, as no part of the tail would be likely to live over the interval. But from successive photographs on the same night—especially when the comet is bright enough to permit short exposures—the actual changes may be observed and measured with certainty.

If an active circumpolar comet were to appear here in the winter time, it would be possible to get five or six or more successive pictures with exposures of from one to two hours. From such photographs the actual history of the changes could be studied, and in all probability with the most remarkable results.

The day-to-day history of a comet has too great an interval, and the changes are not necessarily at all connected. It is the hour-to-hour history that must be studied to understand the changes taking place in the comet. In the case of a very bright comet, exposures at intervals of half an hour should be made as long and as continuously as the conditions will permit. By this means it will be possible to determine the exact value of the motion of the particles in the tails of various comets, or of the same comet, at different distances from the Sun. The true law of the velocities of these particles with respect to the Sun and comet will thus become known independently of any prevailing theory.

Is it not more likely that the different tails of a given comet are all made up of the same kind of particles, and that the cause of their different directions is not so much due to different densities as to the fact that they are ejected toward different parts of space by a force residing in the comet itself? This would seem to me to be a more reasonable supposition than that the repellent action of the Sun had sifted out various elements of the comet and shot them forth with velocities conformable to their densities. It is not improbable that different comets are much alike in their chemical composition. The spectroscope has certainly not shown them to be of very diverse elements.

The tail is doubtless made up of particles of matter that recede from the comet in a general direction away from the Sun. This is evidently due to an influence exerted by the Sun upon the particles of the comet. There may be many tails, some of which diverge from

the radius vector by considerable angles. They are straight streams of matter apparently shot out by the nucleus quite in defiance of the Sun's power to force them in the direction of the radius vector. If these were entirely due to the expulsion of matter from the comet by the pressure of the Sun's light, these widely diverging tails would not be possible. It would appear that the generally accepted theory of comet's tails at least needs much modification. More credit must be given to the comet for the production of its tails than has heretofore been accorded it.

YERKES OBSERVATORY,
October 13, 1905.