

Physical observations of Comet Arend-Roland (1956 h)

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With 10 plates and 5 figures in the text

SUMMARY

The paper gives an outline of the observations of Comet Arend-Roland made at the Stockholm Observatory. The general day-to-day appearance of the comet during the interval 1957 April 20.8 to May 16.9 is described and is illustrated by means of a series of photographs. The geometry of the tails is studied, and the anomalous tail is explained as cometary matter very strongly concentrated to the orbital plane. A tabulation of position angles of rays and streamers observed on various days is given. Measurements of the large distortion in the ordinary tail, observed on April 27–28, indicate that the disturbance causing the distortion probably occurred on April 27.5. It is suggested that a solar flare of importance 2 – on April 26.3 might be responsible for this disturbance. Envelopes and similar structures around the nucleus, as observed on various days, are described qualitatively by means of schematic figures. Finally, the origin of the anomalous tail is commented upon.

Introduction

For the scheduled appearance of Comet Arend-Roland (1956h) in the northern sky in spring 1957 an extensive series of observations was planned at the Stockholm Observatory. Unfortunately, poor weather on some days interfered with the programme; in addition the Moon and the bright summer nights made the period of observation somewhat short. On several days, however, observations of the following kinds were made:

1. Direct photographs with various instruments:
 - (a) 7 cm comet camera, $f = 20$ cm, emulsions Kodak Tri-X, Ilford HP3, and Ilford FP3.
 - (b) 40 cm astrograph, $f = 2.0$ m, emulsion Kodak 103a-O.
 - (c) 50 cm visual refractor, $f = 8.1$ m, emulsion Kodak 103a-G + filter Schott und Genossen GG 11.
 - (d) 60 cm photographic refractor, $f = 8.1$ m, emulsion Kodak 103a-O.
2. Spectrographic observations with the 1 prism spectrograph at the Cassegrain focus of the 102 cm reflector, emulsion Kodak 103a-F. Part of these observations aimed at a study of polarization effects in the spectrum.
3. Polarigraphic observations of the integrated light by means of the Öhman polarigraph attached to the 40 cm astrograph.
4. Photoelectric measurements of the magnitude and colour of the nucleus and the inner part of the coma.

Table 1. Stockholm Observatory observations of Comet Arend-Roland.

1957	f = 20 cm a = 7 cm	f = 2.0 m a = 40 cm	f = 8.1 m a = 50 cm	f = 8.1 m a = 60 cm	Spectrum	Polariza- tion
April 25	17	8	4		4	
26	9	4	1		1	
27	8	4	1	3	2	1
28	2	1				
May 1	3	3	1	2	2	2
2		4	1	2	2	
6			1	2	1	
16				2		
Observers ^a	KL LOL SL	KL LOL	AE GL-L	AE GL-L	POL US	AE

^a The observers are indicated as follows:

AE	Aina Elvius	KL	Kerstin Lodén
GL-L	G. Larsson-Leander	LOL	L. O. Lodén
POL	P. O. Lindblad	US	U. Sinnerstad
SL	S. Lindgren		

Most of the observatory staff participated in the observations, under the general supervision of Professor Y. Öhman.

The number of plates of items 1–3 above, as obtained on various days, are listed in Table 1. The given calendar days refer to the entire following night. The observers are indicated in the lower part of Table 1.

As regards the publication and discussion of the observations it was decided to split the material in independent papers. The present writer was allotted the task to give a description of the appearance of the comet in general and to discuss the geometry of the tail phenomena in particular. Papers on the polarization of the integrated light and on the photometric analysis of the direct photographs have already been published by Aina Elvius [5] and by Kerstin Lodén and L. O. Lodén [12], respectively.

As indicated in Table 1 no real observations of the comet were made at the Stockholm Observatory previous to April 25, due to the poor weather. Mr. G. Darsenius, Gothenburg, and Mr. R. Fogelquist, Uppsala, have, however, kindly made available to the writer plates and prints showing the appearance of the comet also previous to this day. Through the courtesy of Professor C. Schalén the writer has further had the opportunity to study a series of prints from plates obtained at the Lund Observatory on days subsequent to April 25. Some of these plates supplement the series from the Stockholm Observatory.

The general appearance of the comet

This section gives day-to-day descriptions of the general appearance of the comet, while more specific topics, such as structures of the head and tails, are treated in later sections. In making this compilation reports by other observers have also been used.

1957 April 20.8 U.T.¹ Visual observation by Darsenius. Total magnitude of head about 3^m5, a tail directed away from the Sun with a length of several degrees was observed. The observations were difficult, however, due to the proximity of the Sun.

April 21.9. Visual observation by Fogelquist. The length of the ordinary tail was at least 3°. No anomalous tail was noted by Fogelquist on this day, although the observing conditions were very good.

April 22.9. An excellent photograph by Fogelquist, reproduced in Plate 1, shows the main part of the ordinary tail to have the form of a parabola. The tail has an extension on the west side in the form of a less luminous sector with an angle of aperture of 18°. An anomalous tail in the form of a sector with an angle of about 18° is present. The central part of the anomalous tail is of lower intensity than the boundary regions, but the east side is brighter than the west side and its boundary is better defined. From the plate the length of the ordinary tail is found to be about 15°, while the anomalous tail is about 5° long.

The presence of two anomalous tails on this day has been reported by M. Schürer and P. Wild [17]. These two tails are most certainly to be identified with the bright borders of the anomalous tail as described above.

April 23.9. According to C. Raušal and V. Vanýsek, Brno, [16] the anomalous tail had the form of a sector with an angle of 12°.

April 24.9–25.0. Photographs by Darsenius and by Fogelquist. The ordinary tail, with a length of about 15°, is symmetrical; its western extension has thus disappeared. The anomalous tail has now developed into a luminous ray with a length of about 7° and a diffuse sector, mainly situated on the western side of the bright ray. The photograph obtained by Fogelquist is reproduced in Plate 2.

April 25.9–26.0. Stockholm Observatory plates, photographs by Darsenius, by Fogelquist, and by several other observers. The tails are quite symmetric, the ordinary tail has a length of about 30° and the anomalous tail has the appearance of a narrow, rectilinear ray surrounded by a diffuse envelope. The length of the ray is at least 13°; it seems probable that this limit was set mainly by the increasing opacity of the atmosphere close to the horizon. A plate obtained by O. Wiberg, Finspång, shows within the diffuse envelope, close to the head of the comet, a somewhat brighter fan-shaped extension (Plate 4). This extension is also suspected on several of the photographs taken with the 7 cm camera of this observatory. The astrograph and refractor plates show the ordinary tail to consist of a diffuse paraboloid surrounding a brighter and shorter fan-shaped structure, which is probably composed of a large number of short rays. One longer streamer within the ordinary tail is visible on the astrographic plates (cf. Plate 5); it is bifurcating at a distance of about 35' from the nucleus. The nucleus itself is overexposed on all plates obtained here, but the brightest part of the head has the appearance of a bow, with its concavity towards the ordinary tail. The anomalous tail extends from the vertex of this bow.

April 26.9. Stockholm and Lund Observatory plates. The ordinary tail appears less symmetrical than on the previous day, due to the presence of streamers on the west side of the axis of the diffuse parabolic tail (Plate 6). The anomalous tail is weaker; it is still rather narrow, but is somewhat diffuse on its eastern side. The head of the comet is conspicuously U-formed. The Stockholm refractor plate shows around the nucleus a complicated structure of several envelopes.

¹ Universal Time is used throughout this paper.

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April 27.9–28.0. Stockholm and Lund Observatory plates. Some of the streamers within the ordinary tail are at a distance of about 60' from the nucleus heavily distorted (Plate 7). The anomalous tail is well defined on its western side, but is diffuse to the east. The complicated structure with several envelopes around the nucleus is still more pronounced than previously.

April 28.9. Stockholm Observatory plates, obtained in poor weather. The streamers of the ordinary tail are barely visible, the anomalous tail is also weak.

April 29.9. Lund Observatory plate. The ordinary tail is broken up into three rather distinct beams (Plate 9). The position angles of the axes of the beams differ by about 8° . The streamers are approximately parallel to the axis of the western beam. The weak anomalous tail is sharply bounded on the western side but is very diffuse to the east.

April 30.9. Photograph by Darsenius. Probably due to guiding difficulties the divisions of the tail are not clearly visible.

May 1.9. Stockholm Observatory plates and photograph by Darsenius. The partition of tail in three parts is not as conspicuous as previously. The former western beam is considerably fainter than the eastern one, while streamers enhance the brightness of the central beam (Plate 10). No anomalous tail is visible.

May 2.9. Stockholm Observatory plates. The streamers are considerably fainter than on the previous day.

May 6.9. Stockholm Observatory plates. Only very short streamers close to the nucleus are visible. The main part of the tail is diffuse and of considerable width. The structure at the head is still complicated.

May 16.9. Stockholm Observatory plates. The head appears almost circular and the diffuse tail is rather weak. The plates are fogged by the bright sky light, however.

The geometry of the tails

From the day-to-day descriptions given in the preceding section and from the reproduced photographs the main changes of the two cometary tails may be summarized as follows. Previous to April 25 both tails were asymmetrical in the sense that they showed weaker fan-shaped extensions on the west sides, while the east sides were clearly defined. The position angles of the tails, anomalous tail *minus* ordinary tail, differed by more than 180° . On April 25.9 the tails were symmetrical, the ordinary tail had the appearance of a parabola, and the anomalous tail appeared as a very narrow, extremely long ray symmetrically surrounded by much weaker diffuse light. The position angles differed by almost exactly 180° . Subsequent to April 25 the tails were asymmetrical in the opposite sense, the east sides showed diffuse extensions while the west sides were clearly defined. The position angles now differed by less than 180° . As the Earth passed through the orbital plane of the comet on April 25.7, it is natural to suppose that the changes are mainly due to the change of perspective.

Measurements of the position angles of the axis of the most luminous part of the ordinary tail and of the well defined rectilinear boundary of the anomalous tail are given in Table 2. The measurements are plotted in Figure 1, where also the position angle of the Sun at the head of the comet is shown. The crosses give the position angle of the sharp boundary of the anomalous tail, while the vertical lines indicate the direction of the diffuse extension of the tail. It is evident, especially from inspection of the large scale refractor plates (e.g. the one reproduced in Plate 8), that it is

Table 2. Position angles of the ordinary tail and of the sharp boundary of the anomalous tail.

1957	Ordinary tail	Anomalous tail	Plate
April 22.9	2°	194.2	Fogelquist
25.0	12.5	194.8	„
25.9	16	195.1	„
25.9	15.8	195.0	Stockholm
26.9	20.4	194.0	„
27.9	25	192.5	„
28.9	27.8	192	„
29.9	32	190	Lund
30.9	35		Darsenius
May 1.9	37.9		Stockholm
2.9	39.5		„
6.9	44.5		„
16.9	49:		„

this sharp boundary of the anomalous tail which is of significance for a geometrical interpretation. The estimated error of the measurements of the ordinary tail is about 2° on days when the tail was relatively wide (April 22.9, May 2.9 and May 6.9) or distorted (April 27.9), but the accuracy is greater on other days. The error of the measures of the boundary of the anomalous tail is generally smaller than 1°.

From the measured position angles the deviations, φ_1 and φ_2 , of the axis of the most luminous part of the ordinary tail and of the sharp boundary of the anomalous tail, respectively, from the prolonged radius vector were calculated by means of Bessel's formulae [7, p. 83]. It was assumed in these calculations that the orbital

Fig. 1. Measured position angles of the axis of the ordinary tail and of the sharp boundary of the anomalous tail (crosses). The vertical lines appended to the crosses indicate the direction of the diffuse extension of the anomalous tail. The calculated position angle of the Sun, at the head of the comet, is shown by the continuous curve.

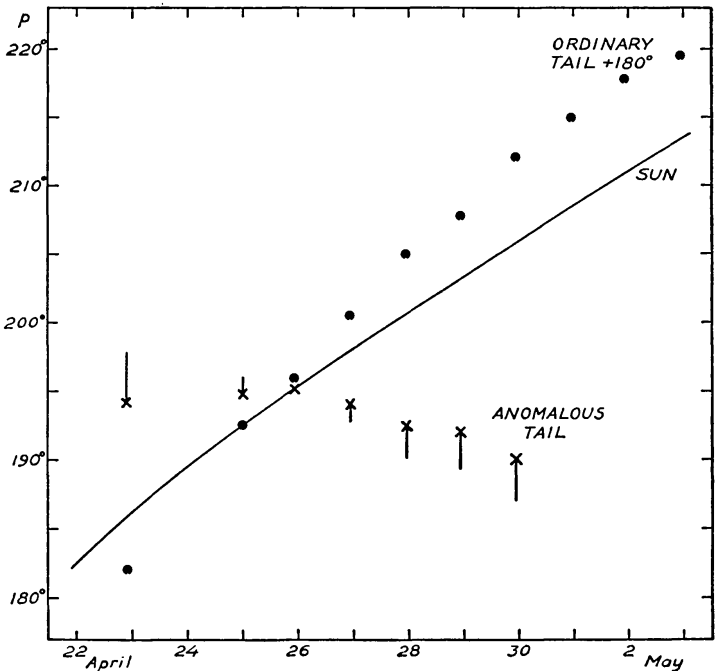


Table 3. The deviations, φ_1 and φ_2 , of the axis of the ordinary tail and of the sharp boundary of the anomalous tail from the prolonged radius vector.

1957	φ_1	φ_2
April 22.9	21°	94°
27.9	45	98
29.9	51	108:
May 2.9	44	
6.9	10	

plane was a plane of symmetry, as is indicated by the symmetrical tail pattern observed on April 25.9. Owing to the proximity of the Earth to the orbital plane of the comet the values of φ_1 and φ_2 are very sensitive to the errors of measurements; in fact the errors of the position angles are multiplied by a factor of about 5 when transported to the plane. In order to minimize this effect the results given in Table 3 are based not on the position angles actually measured but on values read from smooth curves drawn through the dots and crosses in Figure 1.

The geometry of the tails is illustrated in Figure 2. The ordinary tail is schematically depicted as a cone, but in reality it was somewhat curved. Due to the curvature the determination of the position angle of the "axis" of the tail is somewhat ambiguous. As the position angles were determined by considering points at some distance from the nucleus, the values φ_1 given in Table 3 are larger than the values valid for the immediate neighbourhood of the nucleus. A more correct representation of the ordinary tail than that of Figure 2 would therefore show curved structures having the same general direction but being more nearly tangent to the prolonged radius vector close to the nucleus. On the side away from the prolonged radius vector the ordinary tail had an extension of matter more strongly concentrated to the plane, but probably the main part of the tail was also somewhat elongated in the orbital plane. The anomalous tail, on the other hand, was formed of matter *very* strongly concentrated to the orbital plane. From the refractor plates taken on April 25.9,

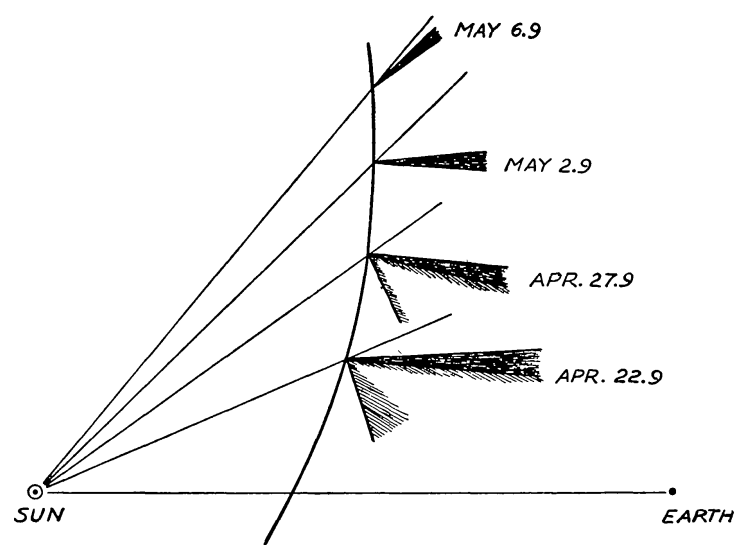


Fig. 2. The geometry of the tails. Shaded areas represent matter strongly concentrated to the orbital plane. The position of the Earth is that of April 25.7, the day of passage through the orbital plane of the comet.

when this tail was seen edge-on, its width, not considering the diffuse envelope, is found as about 30". This corresponds to a thickness of about 13 000 km. The anomalous tail was sharply bounded on the side towards the Sun and more diffuse in the opposite direction. Its extension in the orbital plane towards the ordinary tail was considerable. It was stated above that on April 22.9 the angle of aperture of the tail sector was about 18°, this corresponds to an angle of the order of 24° in the orbital plane. Some photographs, however, seem to indicate that the whole region between the two tails (on the side away from the Sun) was filled by diffuse light. It was also mentioned above that the ray forming the anomalous tail on April 25.9 had a length of at least 13°. The linear extension of the anomalous tail along its sharp boundary was thus at least 25×10^6 km.

It should finally be remarked that the main items of the above analysis was presented at a seminar at the Royal Institute of Technology in Stockholm on May 13, 1957, and was published in the form of a short note a few days later [8]. More complete accounts were subsequently given [9, 10, 11]. Similar explanations of the anomalous tail as composed of matter strongly concentrated to the orbital plane have been given also by several other investigators, for instance by F. L. Whipple [20, 21], by Schürer and Wild [17] by E. B. Armstrong [1], and by B. A. Vorontsov-Velyaminov [18].

Rays and streamers

As indicated in the day-to-day descriptions of the comet, rays or streamers in the ordinary tail were observed on various days. Table 4 gives measurements of position angles and descriptions of these features; by means of these data they are easily identified on the photographs reproduced in this paper.

In order to trace the outward motion of matter from the head of the comet, the distance from the nucleus of three relatively marked features were measured on successive plates. The features in question are: *A*, the bifurcation point in the streamer observed on April 25.9; *B*, the heavy distortion in the streamers of April 27.9; and *C*, another distortion of the same streamers at a greater distance from the nucleus. The positions of the measured points *B* and *C* are indicated in Figure 3.

Table 4. Position angles of rays and streamers.

1957		<i>p</i>	Remarks
April	25.9	18.0	Streamer, bifurcating at a distance of about 35' from the nucleus.
	26.9	9.7	Relatively short streamer, convex towards the axis of the tail.
	27.9	14.1	Long rectilinear streamer.
		17.7	Rather short streamer.
		23.4	Long streamers distorted at a distance of about 1° from the nucleus.
	29.9	27.9	
		25.5	Broad, relatively short streamer.
		27.5	Long and narrow ray.
May	1.9	35.0	Broad feature, probably composed of several individual rays.
	2.9	28.8	Long streamer.
		33.4	Rather short streamer.

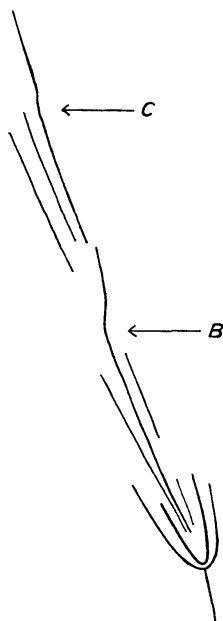


Fig. 3. Distortions *B* and *C* in the streamer pattern of April 27–28.

The measures of the bifurcation point, *A*, are not very satisfactory, as the point is difficult to define due to the acuteness of the angle between the two diverging streamers after bifurcation (cf. Plate 5). The measurements, given in Table 5, of the astrographic plates that can be used for the purpose are therefore only considered to give a rough indication of the outward motion.

In the case of distortion *B*, of April 27.9, the measurements are much more satisfactory. As is indicated in Figure 3 the distance, from the nucleus, of the bend towards smaller position angles was measured. Although the exact position of the bend is not clearly defined, it appears that the measurements on the astrographic plates have an accuracy of about $\pm 1'$. In addition to the plates from this observatory, measurements were made on a photograph obtained at Lund Observatory and on three published photographs of the comet, viz. one from the Kuchino Station of the Sternberg Astronomical Institute, Moscow [19], one from the Palomar Observatory [23], and one from Lowell Observatory, Flagstaff [21]. The measurements are listed in Table 6. It is seen that during the interval of $1^{\text{h}}18^{\text{m}}$, covered by the astrographic plates, the distance of the distortion from the nucleus increased from 51.5 to 61.5 . The Kuchino photograph taken $1^{\text{h}}27^{\text{m}}$ earlier than plate no. A 2401, and the Palomar and Flagstaff photographs, obtained about $5^{\text{h}}40^{\text{m}}$ later than plate no. A 2404, supplement the plates from this observatory in a very satisfactory way.

Table 5. Distance, from nucleus, of the bifurcation point in streamer of April 25–26.

Plate No.	1957	<i>d</i>
A 2389	April 25.853	28':
2391	.897	34
2392	.915	36
2393	.942	38:
2394	.969	38

Table 6. Distances, from nucleus, of distortions *B* and *C* in streamers of April 27–28.

Plate	1957	<i>B</i>	<i>C</i>
Kuchino	April 27.812	43.5	89'
A 2401	27.873	51.5	—
Lund	27.883	51.5	101
A 2402	27.885	54.0	—
A 2403	27.903	56.5	108
A 2404	27.927	61.5	113
Palomar	28.161	82	147
Flagstaff	28.164	84	—

From the plot of the measurements, given in Figure 4, it is evident that the distances of distortion *B* found from the two photographs of April 28.16 are somewhat smaller than would be expected from the approximately linear increase indicated by the previous measurements. It is possible that this is partly due to a real change in the form of the distortion, but a decision on this point is difficult, as the two photographs in question are much stronger exposed than the others. The present measurements do show, however, that no conspicuous acceleration in the motion of feature *B* occurred during the interval April 27.81 to April 28.16. The outward velocity, as given by the observations of April 27, is 48 km/sec if it is assumed that the motion was along the prolonged radius vector, and about 100 km/sec if the motion was in

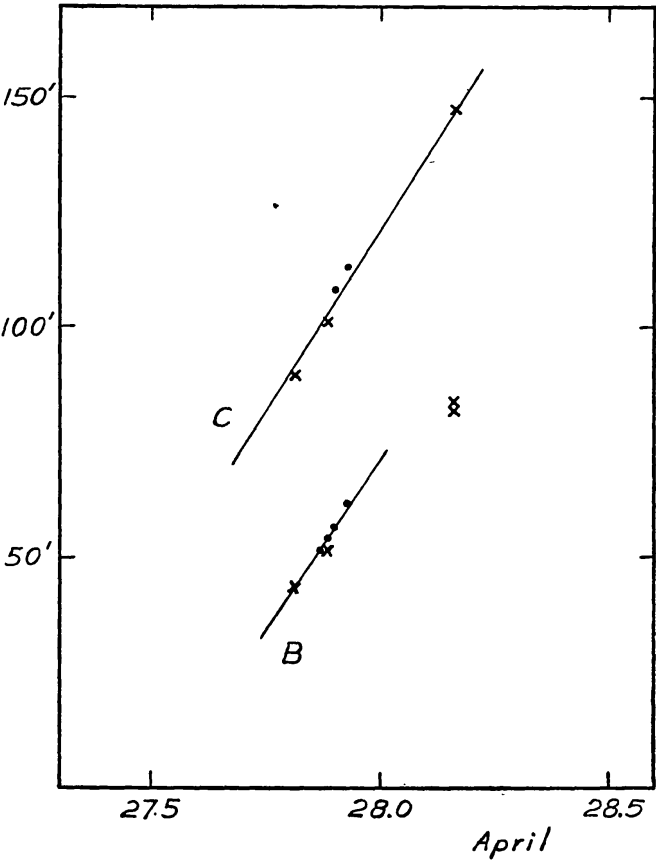


Fig. 4. The distance from the nucleus versus time for the features *B* and *C*. The dots refer to measurements on Stockholm Observatory plates, the crosses to measurements on other photographs.

the direction of the ordinary tail. This latter velocity is probably the more significant one, as the measured bend is situated almost on the axis of the tail.

Feature *C*, a bend analogous to *B*, but smaller and less clearly defined, was measured on two of the astrographic plates and on the Kuchino, Lund, and Palomar photographs. The measurements are also in this case given in Table 6 and are plotted in Figure 4. As these measurements have an accuracy which is slightly lower than in case *B*, no great importance is given to the slight deviation of the points from the straight line. It is remarkable that the straight line fitted to the measurements of feature *C* turns out to be almost exactly parallel to the line through the points referring to feature *B*. The velocity of recession from the nucleus is thus nearly the same for the two features.

It is interesting to note in this connection that F. D. Miller [13] has recently reported an outward velocity of 53 km/sec for a bright feature observed on May 4–5. This value probably refers to motion along the prolonged radius vector and is thus very similar to the velocities found for the features *B* and *C*.

It seems natural to suppose that the large distortion, *B*, originated close to the nucleus. Probably a disturbance of some kind caused the direction of expulsion of molecules forming an already existing streamer, perhaps the one observed at position angle $14^{\circ}.1$ on April 26.9, to change to a larger position angle. This new direction was maintained also after the disturbance had subsided. On this assumption the approximate time for the occurrence of the disturbance is from a linear extrapolation in Figure 4 found as April 27.5. The disturbance may have occurred somewhat earlier than this date, if some time is allowed for the acceleration. As the velocity of feature *C* is very close to that of *B*, and the distortions apparently did not break away from the streamers, it must be assumed that the whole streamer pattern receded from the nucleus with almost the same velocity.

Strong arguments have been presented by L. Biermann [3] for the view that the large accelerations observed in streamers are due to interaction between solar corpuscular radiation and the ionized gas. If the present disturbance was caused by a beam of solar corpuscles, they must have been ejected on April 26. On this day a large number of solar flares occurred, including a very large one, of importance $2+$, first observed at April 26.27 [24]. As the position of the sub-comet point on the solar surface, N 26° , E 25° , was almost 70° E from the position of the flare, an interaction seems hardly possible in this case. The chance for an interaction appears to be much greater in the case of a flare of importance $2-$, first observed on April 26.31 [22]. The position of this flare was N 23° , E 48° , and the sub-comet point was thus situated about 25° W from the flare. No other reported solar flare seems to be more favourably situated than this one.

Envelopes and similar structures

A number of parabolic envelopes on the sunward side of the head is visible on the refractor plates. With few exceptions these features are rather vaguely defined and no attempts have therefore been made to determine their mathematical properties by means of actual measurements. The forms of the envelopes, however, are shown in a qualitative way by schematic drawings in Figure 5, where also the positions and forms of some other discontinuities in the surface intensity are indicated. In the Figure dashed contours refer to diffuse borders, such as the very diffuse outer border of the comet.

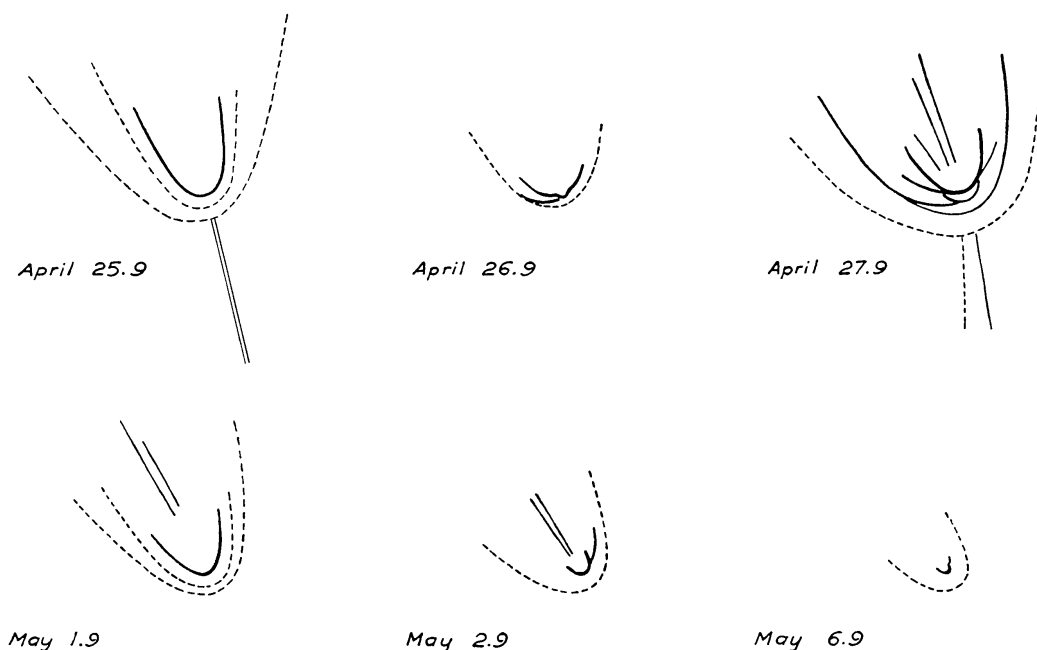


Fig. 5. Envelopes and similar structures at the head of the comet. The most conspicuous features are indicated by the heavy curves, while the dashed contours refer to very diffuse borders.

The inner envelope, which was the most pronounced one, usually appeared rather symmetrical around the axis of the cometary tail. This symmetry was especially marked on April 25.9. On the following day, April 26.9, an extension of the envelope at its vertex had appeared, which developed into a detached bow on April 27.9. On this latter day the head of the comet had a very complicated structure showing branches of several eccentric envelopes somewhat similar to those observed, for instance, in the case of Comet Coggia, 1874 III [4, p. 148]. It is remarkable that both on April 26.9 and April 27.9 the envelopes were most clearly defined on the east side of the head, while later the envelope activity was shifted to the west side. The large inner envelope was rather marked still on May 1.9, although its east side was more diffuse than the west side; but on May 2.9 only its western branch is visible. As shown by Figure 5, from this day onward a smaller envelope was discernible close to the nucleus.

General remarks on the origin of the anomalous tail

As pointed out by several authors [10, 14, 18, 21] a number of comets have shown anomalous tails of about the same character as Comet Arend-Roland. No previous observations are known, however, of a comet exhibiting a spike-formed anomalous tail of a length comparable with the present one.

Among the more thoroughly observed previous objects with anomalous tails Comet 1823 is of special interest for a comparison with Comet Arend-Roland. The transit of the Earth through the orbital plane of Comet 1823 occurred on January 22, 1824, and the anomalous tail was observed from this day until January 31. When brightest the anomalous tail was quite comparable to the ordinary one both with regard to intensity and length. From the descriptions and drawings of the appearance of the

tail, given by W. von Biela [2], by K. L. Harding [6], and by W. Olbers [15], it is obvious that the concentration of cometary debris towards the orbital plane was in this case less marked than in that of Comet Arend-Roland. Th. Bredikhin [7, p. 457] concluded from his study that the direction of the anomalous tail almost coincided with the tangent to the path of the comet. It thus followed after the radius vector and was a pseudo-anomalous tail according to Bredikhin's terminology. (In this terminology true anomalous tails are tails directed more or less towards the Sun but preceding the radius vector.) As the matter forming the anomalous tail in this case moved in the same orbit as the nucleus, the whole assembly was regarded as a train of meteorites, the largest of which was the nucleus of the comet. No forces other than the gravitational attraction were necessary to explain the phenomenon.

In the case of Comet Arend-Roland the pseudo-anomalous tail strongly deviated from the radius vector and also from the tangent to the orbital hyperbola of the nucleus. The orbits of the individual particles forming the tail are thus hyperbolas with eccentricities larger than that of the cometary orbit. This fact and the observed large extension of the tail in the orbital plane, as well as its sharp boundary towards the side of the radius vector, indicate that the matter forming the anomalous tail was subject to a repulsive force of solar origin, which, however, was much weaker than the forces acting upon the particles of the ordinary tail. The large concentration of the particles to the orbital plane shows that the repulsive force was acting in this plane. This seems to preclude the idea that corpuscular radiation could be responsible, as the paths of the emitted solar particles would not be radial at the distance of the comet. Radiation pressure on meteoritic dust may be a possible explanation or, at least, part of the explanation. Another additional mechanism, jet action due to the solar heating of the sunward side of small meteoric particles covered with ices, has been suggested by Whipple [20, 21].

From the large scale photographs it seems evident that the main part of the matter forming the anomalous tail was ejected from a region very close to the nucleus. If this ejection occurred in all directions, as seems plausible, the velocity of most of the ejected particles must be very small as compared with the comet's orbital velocity. In other case the large concentration of matter to the orbital plane could not have been maintained. It should be emphasized, however, that the diffuse halo around the spiked anomalous tail on April 25.9 shows that particles were present also at considerable distances on both sides of the plane.

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P L A T E S



Plate 1. Comet Arend-Roland 1957 April 22, $21^{\text{h}}0^{\text{m}}-22^{\text{h}}0^{\text{m}}$ U.T.
Photo by R. Fogelquist, Börje, Uppsala, with 2.5 cm double
anastigmat, $f = 12$ cm. Emulsion Ilford HP3. Scale $6.5 \text{ mm} = 1^\circ$.



Plate 2. Comet Arend-Roland 1957 April 24, $23^{\text{h}}35^{\text{m}}$ –April 25, $0^{\text{h}}25^{\text{m}}$ U.T. Photo by R. Fogelquist, Börje, Uppsala, with 2.5 cm double anastigmat, $f \approx 12$ cm. Emulsion Ilford HP3. Scale $6.5 \text{ mm} = 1^\circ$.



Plate 3. Comet Arend Roland 1957 April 25, $21^{\text{h}}25^{\text{m}}-22^{\text{h}}55^{\text{m}}$ U.T. Photo by R. Fogelquist, Börje, Uppsala, with 2.5 cm double anastigmat, $f = 12$ cm. Emulsion Ilford HP3. Scale $6.5 \text{ mm} \approx 1^\circ$.



Plate 4. Comet Arend-Roland 1957 April 25, 22^h15^m–23^h15^m U.T. Photo by O. Wiberg, Finspång, with 12 cm astro-camera, $f = 75$ cm. Emulsion Ilford HPS. Scale 9.8 mm = 1°. Note the bright sectors on both sides of the anomalous tail, close to the head.



Plate 5. Comet Arend-Roland 1957 April 25, $21^{\text{h}}35^{\text{m}}-21^{\text{h}}45^{\text{m}}$ U. T. Photo by Kerstin Lodén and L. O. Lodén with the 40 cm astrograph. Emulsion Kodak 103a-O. Scale 54 mm = 1° . Note the streamer bifurcating at some distance from the head.



Plate 6. Comet Arend-Roland 1957 April 26, $21^{\text{h}}46^{\text{m}}-21^{\text{h}}53^{\text{m}}$ U.T. Photo by Kerstin Lodén and L. O. Lodén with the 40 cm astrograph. Emulsion Kodak 103a-O. Scale 54 mm = 1° . Large changes in the general appearance of the comet and in the streamer pattern have occurred, as compared with the photographs from the previous night.



Plate 7. Comet Arend-Roland 1957 April 27, $22^{\text{h}}18^{\text{m}}-22^{\text{h}}30^{\text{m}}$ U.T. Photo by Kerstin Lodén and L. O. Lodén with the 40 cm astrograph. Emulsion Kodak 103a-O. Scale 54 mm = 1° . Large distortions of the streamers are shown.



Plate 8. The head of Comet Arend-Roland 1957 April 27, $22^{\text{h}}37^{\text{m}}-23^{\text{h}}7^{\text{m}}$ U.T. Photo by G. Larsson-Leander with the 60 cm refractor. Emulsion Kodak 103a-O. Scale $5.2 \text{ mm} = 1'$. The original plate shows a very complicated structure at the head of the comet (cf. Fig. 5).



Plate 9. Comet Arend-Roland 1957 April 29, $22^{\text{h}}24^{\text{m}}-22^{\text{h}}34^{\text{m}}$ U.T. Photo by N. Engver with the 18 cm astrograph of Lund Observatory. Emulsion Kodak Oa-O. Scale 42 mm = 1° .



Plate 10. Comet Arend-Roland 1957 May 1, $22^{\text{h}}8^{\text{m}}-22^{\text{h}}18^{\text{m}}$. Photo by Kerstin Lodén and L. O. Lodén with the 40 cm astrograph. Emulsion Kodak 103a-O. Scale 54 mm = 1° .