THE CORE OF THE METEOR STREAM ASSOCIATED WITH COMET HALLEY

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ABSTRACT : Data on 240,000 meteor echoes recorded in 1958-1967 with the Springhill Meteor Radar, have been used for determining the structural features of the Eta Aquarid stream. A zone with a distinct enhancement in meteor rates was located at solar longitudes of 43° to 47°. The core of the stream, corresponding to the four peak days, extends from the orbit of the comet to a distance of 0.08 A.U. Other observations, from both hemispheres, support these results.

The Earth approaches the orbit of Comet Halley twice a year, reaching a minimum distance of 0.154 A.U. in October and 0.065 A.U. in May. Two meteor showers - Orionids and Eta Aquarids - are observed in these periods (Fig.1). Series of observations of both showers since the beginning of this century, including visual and radar techniques, have been analyzed by the author (Hajduk 1970,1973); many similar structural features (shower width, density variation, presence of condensed zones etc.), together with similar orbital characteristics, lend support to the connection of these showers and their association with Comet Halley. The difference in the approach distance permits examination of the shower structure by comparing the inner and outer part of the stream.

A total of 240 000 radar meteor echoes, recorded in 670 hours during the period of May 1 - May 10, 1958-1967 have been used for the present analysis. Part of the data was published by Millman and McIntosh (1964 and 1966) and by the author (Hajduk 1973). The unpublished data are used with the kind permission of the Herzberg Institute of Astrophysics. The 7-hour intervals used were centered at the time of the meridian transit of the radiant. Details are to be published elsewhere (Hajduk 1979).

The shower activity varies in year-to-year apparitions. The amplitude between the maximum and the minimum for ten-day means of the hourly meteor rate may reach a factor of 1.5. At the same time the position of the peak rate in solar longitude may change between $40 < L_S < 48$ (Hajduk 1973). In spite of these variations, the summary of the data from the whole 10-year period gives a very smooth curve of activity, indicating a central part with enhancement in meteor rates amounting to 15% relative to the outer part of the shower plus the sporadic background (see Fig.2a). A simultaneous enhancement of 25% for echo dura-

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tions exceeding 1 second suggests a higher concentration of larger particles in this zone (Fig.2b). A double peak with a small dip in between is the main characteristic of the central zone. The activity falls steeply on both sides of this central zone and then decreases gradually, reaching the background level at about $+10^{\circ}$ and -10° from the middle (McKinley 1961, Cook 1973). However, the position of the peak given by Cook (1973) as $L_S = 42.4$ and by McKinley (1961) and Levin (1956) as $L_S = 43$ should be improved, according to our Fig.2, to $L_S = 45.1 \pm 0.1$, and about 0.1° earlier for brighter meteors, as the Ottawa 1-second echoes are well beyond the range of visual magnitudes (Millman and McKinley 1956). This change removes a considerable part of the discrepancy between the time of shower maximum and that of the closest approach of the Earth to the orbit of Comet Halley.

Comparison with other optical and radar observations from both hemispheres lends support to the improved timing of the shower, to the width of its core, as well as to its double maximum. Radar meteor echo data from the Southern hemisphere, as observed in 1960 and 1963-65 and published by Ellyett and Keay (1963) and Keay and Ellyett (1969), have been examined in the same way as the Ottawa data. The results containing the mean hourly meteor rates from the Eta Aquarid period for 7-hour intervals centered at the time of the shower radiant culmination, are shown in Fig.2c. A similar reexamination of visual observations of Eta Aquarids from New Zealand (McIntosh 1929 and 1935) by constructing mean hourly rates for all the years covered by observations (1928-1933) leads again to a similar shape of the activity curve (Fig.2d). The points at L_S of 45° and 46° have been attributed previously to random fluctuations (Lovell 1954). The position in solar longitude of the primary and secondary maxima is different in individual returns of the shower (see Fig.1 in Hajduk, 1973). However, summarizing the number of maxima and of secondary maxima (with 1/2 weight) for the different solar longitudes, from the observations from 1910 to 1971 included in the mentioned paper, yields again a double peak around $L_S=45^{\circ}$, as shown by Fig.2e. A preliminary analysis of the Ondřejov radar data and Southern hemisphere visual data on Eta Aquarids observed in 1970-1978 also confirms all the main features of the shower activity curve (Hajduk and Buhagiar 1979).

The position of the Earth crossing the stream of Comet Halley near its two nodes, as calculated by Kresák (1950), is seen in Fig.3. The Pe-axis is perpendicular to the orbital plane of the comet and the w-axis is perpendicular to the comet's motion. From the gradual change of the distance between the Earth and the comet orbit (assumed to coincide with the centre of the stream) it is clear that the zone of peak activity detected for Eta Aquarids at $43 < L_S < 47$ does not correspond exactly with the minimum distance from the comet orbit; it is shifted slightly towards the sunward boundary of the stream. If we identify this zone with the core of the stream, with axis identical with the comet orbit, then the radius of the core is about 0.08 A.U. A stable condensed zone, especially for larger particles, was found in the Orionid shower as well (Hajduk 1970), but at a distance twice as large as in the case of Eta Aquarids. This zone is located at $207 < L_S < 209$, slightly shifted towards the outer boundary of the stream. In both cases the dense zones are encountered by the Earth before it reaches the point of minimum distance from the comet orbit. As the straight line connecting the dense zones of both showers (in particular the maxima at 46 and 208°) intersects the comet orbit, the zones may have a common origin, perhaps as a conse-

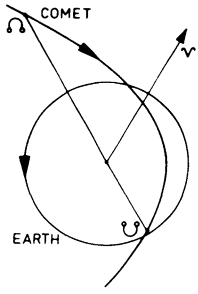

Fig. 1. The orbits of the Earth and Comet Halley

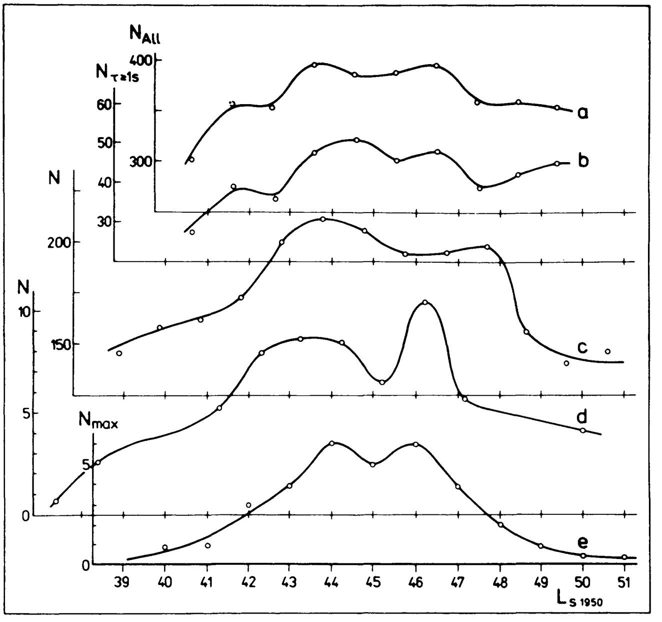

Fig. 2. Mean meteor hourly rates during the Eta Aquarid shower period: a) Ottawa radar data (1958-1967) - all echoes; b) Ottawa radar data (1958-1967) - echoes with duration $\tau \geq 1s$; c) New Zealand radar data (1960, 1963-65); d) New Zealand visual data (1928-33); e) number of peak rates from visual and radar data (1910-1971).

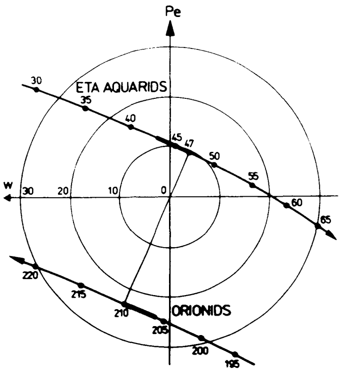

Fig. 3. The passages of the Earth through the stream.

quence of ejections preferring one plane perpendicular to the rotation axis of the comet. This could also explain a greater spread of the stream along the polar axis in comparison with that in the plane of the comet orbit, as obtained by Kresák (1950). The asymmetric position of the cores of the Eta Aquarid and Orionid streams with respect to the present orbit of Comet Halley may be of evolutionary significance. According to the estimate by Plavec (1954), the occupation of the whole orbital ellipse by meteoroids released at a single ejection should take about 15 revolutions. The fact that these meteor streams appear annually, in comparable abundance, for the whole period of revolution of the parent comet, would set the lower limit of their age at more than 1000 years. At the same time, the well established presence of local irregularities suggests that the age is not much greater, certainly not more than 10,000 years. After the formation of a closed elliptic ring, the position of the stream in space is essentially determined by the averaged (secular) perturbations, whereas the position of the comet within the stream is controlled by the interplay of random perturbations. This would make the comet wander with respect to the stream center, and the displacement at any instant would be indicative of the integrated difference between the real and averaged perturbations experienced since the formation of the ring. A continuing supply of fresh ejecta would reduce this di-

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fference in the vicinity of the comet. It will be interesting to see the changes of the structural pattern around the forthcoming perihelion passage of Comet Halley in 1986.

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DISCUSSION

Sekanina: A two component distribution of eta-Aquarids is well-known from the results of the Harvard-Smithsonian Radio Meteor Project. In fact, the branches separated so well that they have been classified as different streams.
Kresák: Yes; but I understand that the abundance of the Halleyids in your data is not comparable with that of the eta-Aquarids.

Note: Summary of this paper was presented by Ľ. Kresák.