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POSSIBLE EVIDENCE OF METEOROID FRAGMENTATION IN INTERPLANETARY SPACE FROM GROUPING OF PARTICLES IN METEOR STREAMS

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The clustering of micrometeoroid impact events on satellite-borne detectors (see e.g. Hoffmann et al., 1975) poses a question whether similar phenomena can be identified as well among larger particles observable as meteors. In fact, there is a strong conviction maintained by many observers that meteors within the streams are observed to be clustered in pairs or larger groups more frequently than one could expect from chance distributions. The rate of the dispersive effects indicates that the lifetime of any group of meteor particles is very limited. If real, the groups must be due to recent fragmentation of larger meteoroids.

Analyses of the visual observations from this point of view have been applied to several streams. The Andromedids were examined by Kleiber (1888) who concluded that about 14 % of them appeared in pairs. However, later analysis of his data with different sampling intervals revealed contradictory results (Kresák and Vozárová, 1953). The Leonids were studied by Millman (1936) who obtained negative results for this stream. Simultaneous observations of the Perseids on a long base-line in 1950 and 1951 indicated that the shower was composed of separate meteor clouds of different size (Savrukhin, 1951). Results slightly in favour of a non-random grouping of the Perseids were obtained by Millman (1936), as well as by Subbotin and Agazdanova (see Astapovich, 1958). On the other hand, a thorough analysis of the Perseids 1952 by Kresák and Vozárová (1953) showed that the distribution of meteors within this stream was essentially at random.

Analyses based on radio measurements are much more conclusive and nine studies, obtained at different stations with different instrumental equipment, have been concerned with this problem. A common

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result of all these analyses, except for those by McCrosky (1957) and Wylie and Castillo (1956), was the absence of grouping of meteors over a random level (Bowden and Davies, 1957; Briggs,1956; Shain and Kerr, 1955; Poole, 1965; Porubčan 1968).

As for the Poisson distributions, in all cases of sampling intervals between 30 and 0.1 seconds the probability of the distribution being at random (resulting from the chi-square test) was $p > 0.20$. For the distributions of the time intervals between successive echoes, the probability was everywhere greater than 0.10 except for the two distributions obtained by Poole (1965), one of $p = 0.03$ and the other of $p < 0.01$. This was probably caused by the timing accuracy being inconsistent with the high frequency of meteors. Corrections on this effect may be quite considerable in similar cases (Porubčan, 1968).

Of the two investigations claiming the reality of grouping, the first, reported by Wylie and Castillo (1956; see Bowden and Davies, 1957), is lacking accurate quantitative data. The authors have found a significant excess of 30 second sampling intervals containing five or more echoes, over the number expected from the Poisson distribution. Bowden and Davies (1957) believe that the equipment of Wylie and Castillo was not capable of distinguishing satisfactorily between fluctuating echoes and close groups, and this has led to an excess of spurious groups in their results.

The second positive evidence has been put forward by McCrosky (1957), who had analysed the maxima of the Perseids and Geminids 1948 and a sporadic night from May 1949. The number of meteors in one-second and half-minute intervals was compared with that predicted by the Poisson distribution. A very low value of $p = 0.0013$ was obtained for the bulk of data at one-second sampling intervals, which suggested that there was a significant excess of observed pairs and triplets. However, if McCrosky´s data are treated for each night separately, in 30 minute periods, the median values of the probabilities for the Perseids, Geminids and the sporadic night are found to be 0.47, 0.38 and 0.41, respectively in agreement with a random distribution.

All the preceding analyses, except for the early work of Kleiber on the Andromedids, refer to the observations of permanent meteor showers, i.e. to stream structures at their middle and late evolutionary stages. For all these streams of considerable dispersion (high age), the result seems to be definitely negative. Therefore it appeared desirable to apply a similar analysis on a shower of recent origin, the Leonids 1969, where the conditions of the dispersion process at the earliest evolutionary phase may be different.

Excellent data on the 1969 Leonid display were obtained by the Springhill Meteor Observatory high-power radar around the shower maximum on November 17 (8:30 - 9:55 UT, 14160 echoes). According to the low-power radar data by McIntosh (1971), this maximum had a higher proportion of short-duration echoes than that of 1966. Three methods of analysis were used (Porubčan, 1974). First, the frequency distributions of time intervals between successive echoes were compared with that expected for randomly appearing echoes, represented by an exponential law. In the second method the data were distributed into 0.1 and 1 second intervals, and the number of intervals containing n echoes (n = 0,1,2,...) was compared with that resulting from the Poisson distribution. The third method was based on the distribution of the slant-range differences between pairs of successive echoes.

To eliminate the steep progressive changes of meteor rates, the data were divided into five-minute sets and, moreover, those around the maximum were combined into sets of approximately equal one-minute rates. As the antenna of the Springhill meteor radar is omnidirectional, the observed region was confined to a narrower zone by a slant-range limitation of the echoes ($R \leq 200$ km).

The deviations of the observed distributions from both the exponential distribution of time intervals and the Poisson distribution of meteor numbers are entirely consistent with random fluctuations both for the ascending and descending branch of the shower activity. However, there is an excess in a short period around the maximum (8:55 - 9:15 UT), both for the total data and for a sample of $R \leq 200$ km. Median values of the probability of a random distribution being as irregular as observed are less than 0.01 for the bulk of data, irrespective of the methods used. For the sample of $R \leq 200$ km, the Poisson distribution yields p = 0.01, and the time distribution p = 0.27. The latter, relatively high value is apparently due to mutual blending of the echoes in the densest part of the record; according to a rough estimate the loss amounted to 20 % at the time of the maximum. As the Poisson distributions for one-second sampling intervals gave negative results, the dimensions of the non-random groups are small; according to the distributions $\Delta t/\Delta R$ they may be up to 40 km in diameter.

An analysis of the Poisson distributions for 0.1 second sampling intervals around the shower maximum shows that at least 10 % of the population is associated in close groups. The thickness of the layer where clustering occurs is comparable with the diameter of the Earth.

This finding may be indicative of a fragmentation process continuing after the release of meteoroids from their parent comet, in the central region of the stream which is most densely populated. A confirmation of this effect in observations of similar showers would be of considerable interest. Unfortunately, occasions of meeting the dense core of a meteor stream of recent origin are exceedingly rare.

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