STRUCTURE OF PERSEIDS FROM VISUAL OBSERVATIONS

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Abstract. A new method of processing of visual meteor data has been worked out and applied to Perseid meteor shower observations. Reduced meteor hourly rates with magnitudes brighter than +3 are proportional to meteor flux densities with a coefficient equals to the effective collecting area. Corrections due to moon light and for meteor path lenghts were applied. Our observations 1972-1979 and 1982-1990 gave similar hourly rate profiles with a maximum rate of 71 meteors at solar longitude L=140.36°. Perseids 1980 and 1981 were about 1.5 times more active. The maximum Perseid activity in 1991-1992 was 119 meteors at solar longitude 139.54°and narrow peaks are observed at the same longitude showing an enhanced activity up to 225 meteors.

1. Introduction

Until the fourties of our century the main method of meteor observations was the visual one. Rapid development of instrumental methods (- photographic, radar, TV, and space probe - measurements) led to the fact that this methods have supplanted practically all visual observations. At present only amateur astronomers are using visual methods. It was considered by many, that visual observations had lost all scientific value because of a lack of accuracy and objectivity. But the ready availability of long-term series of visual observations of several meteor showers carried out in different time zones prompted us to find a new processing method for visual observations so as to use the data for scientific purpose.

The Perseid are one of the most active and most interesting meteor showers. The interest in the Perseids in recent times is due to the return of P/Swift-Tuttle comet which is the parent body of the shower.

2. Observations

Visual observations of Perseid meteor shower were started in Crimean Astronomical Observatory in 1972 and are going on every year up to now. Observations have been carried out by several groups of amateur observers (schoolboys and schoolgirls) under the leadership of experienced observatory staff members.

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Beforehand all of them have had an appropriate training. Most observations have been made in Crimea but sometimes one of the groups have carried out observations in other parts of the Former Soviet Union. We have also used the observational data published by the International Meteor Organization (IMO) for the years 1988-1992 (WGN Report Series 1989-1993) for comparison purposes.

3. Processing

A new method of processing visual meteor observations has been worked out in the meteor department of the Engelhardt Astronomical Observatory. The following principles have been assumed as a basis of the method: 1) reduced zenith hourly rates (ZHR) must be proportional to meteoroid flux densities with masses, greater than a certain value that corresponds to meteors brighter then $+3^m$ for a given velocity, 2) simplicity of the method, 3) as much as possible to exclude subjective factors from the processing. The threshold $+3^m$ has been chosen because it is close to the effective limiting meteor magnitude M_{ef} (Fig.1). A correction for this threshold is minimal so the minimal is also an error of the correction. The simplicity of the method is due to the absence of any corrections which take into account eye sensitivity variations in a field of view. To minimize subjective factors all calculations are made taking into account weights in averaging operations and in the least square method. In practice this fact permits us to use all observation intervals for determination of a shower ZHR profile except those intervals that have no linear parts in the meteor magnitude distributions. We can assume that the distribution of observed meteors N is a Poisson distribution, then the dispersion of N is N+1 and the weight of ln(N) is N where N>>1.

The software of the processing method consist of 9 Turbo Pascal programs. The programs are used firstly for creating the files of primary data, i.e. place coordinates and times of observations, observers, observed meteor numbers, and meteor magnitude distributions. An operator analyzes each magnitude distribution on a PC screen (Fig.1) and selects points in the graph ln(N) vs. M corresponding to a linear part of the distribution curve. Mass distribution parameters S, their rms values and corrections to the third magnitude are calculated by the least square method. Then all S values are averaged in certain intervals of solar longitude chosen by the operator. Averaged S are used for reductions of observed meteor numbers. According to the physical theory of meteors and the observation geometry (Andreev et al. 1983) the reduction formula is:

$$ZHR^* = \frac{Nk}{T(\cos Z)^S},$$

where N is the observed number of meteors, k is the correction to $+3^m$, T is the effective time of observation and Z is the zenith distance of the meteor radiant. Two corrections are still not taken into account: probability of a meteor visual

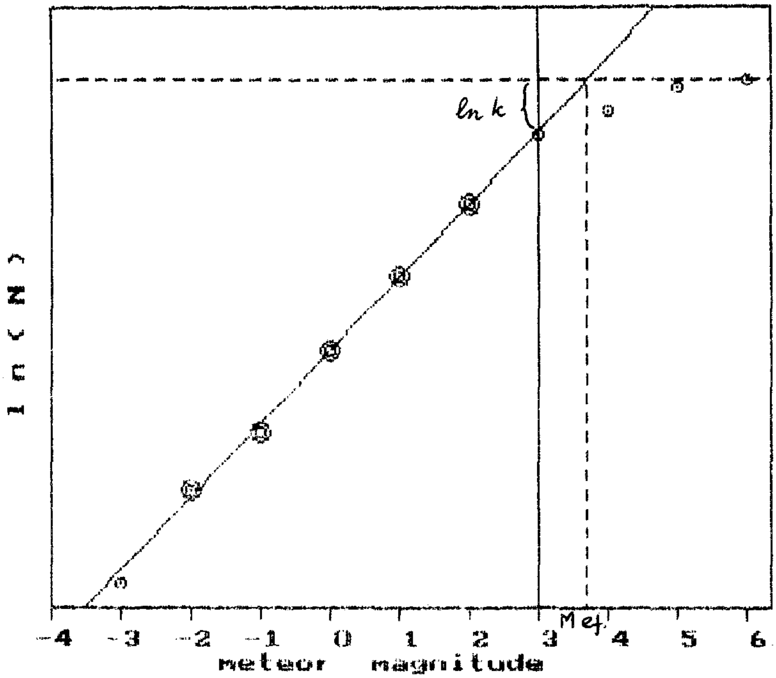

Fig.1: Meteor magnitude distribution.

observation as a function of a meteor path length and the interference of moon light. Both of them depend on the characteristics of the human eye and can not be derived analytically. We have found them by a correlative analysis. The final reduction is:

$$\mathrm{ZHR} = \mathrm{ZHR}^*(1 + 1.3(1 - \sin\mathrm{ZM})^{0.3}(1 - \cos\mathrm{PM}))(\cos\mathrm{Z})^{1.86}, \text{ (for ZM} < \pi/2)$$
$$\mathrm{ZHR} = \mathrm{ZHR}^*(\cos\mathrm{Z})^{1.86}, \text{ (for ZM} \geq \pi/2)$$

where PM and ZM are the phase and zenith distance of the Moon. The meteroid flux density

$$\mathrm{Q} = \textstyle\sum_{\mathrm{ef}} \mathrm{ZHR},$$

where $\sum_{ef}$ is the effective collecting area that can be found from comparisons of results obtained from radar and visual or TV and visual observations. This problem is not considered in the present paper.

4. Perseids

In all 22 years of Perseids observations (1972-1993) have been processed by using the described method. Visual data for 5 years of Perseid observations published by IMO (WGN Report Series 1989-1993) have been processed also. Variations of averaged S values as a function of the solar longitude obtained from Crimean data are shown in Fig.2 and Fig.3 as solid lines. Vertical bars show the dispersion of individual values. There are also shown by dashed lines S variations obtained from IMO data (WGN Report Series 1989-1993) for 1988-1992. The coincidence of the results is rather good. Minimum value of S=1.57 for Crimean data and S=1.54 for IMO data correspond to the solar longitude L=139.6° (2000.0). The analysis of reduced ZHR values shows that for 4 years only out of 22 do the ZHR value differ significantly. These years are 1980-1981 and 1991-1992. Variations of lg(ZHR) values for 18 "quiet" years as a function of solar longitude are shown

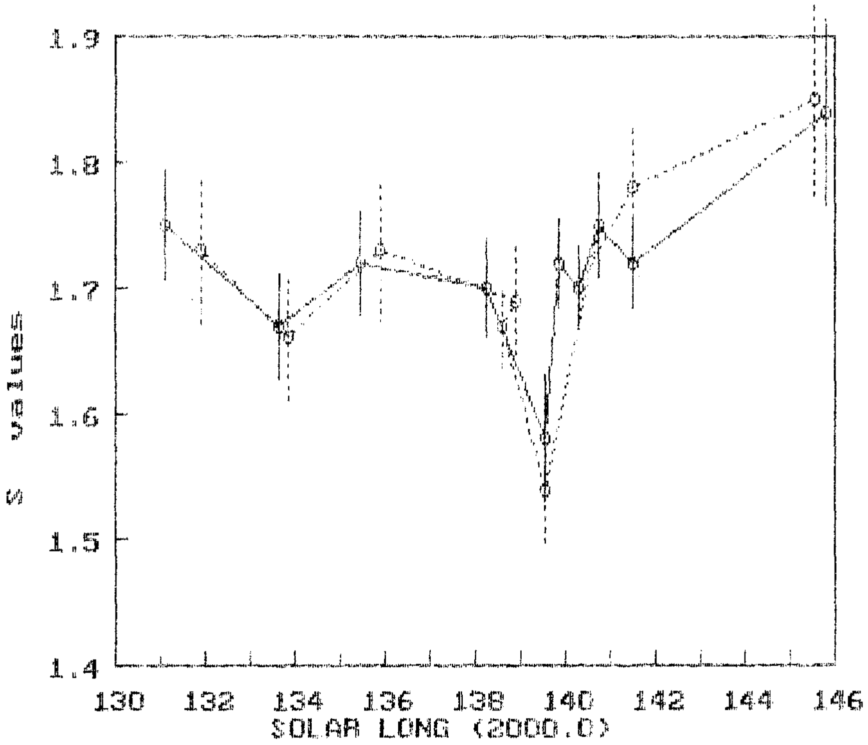

Fig2: Variations of averaged S values as a function of the solar longitude. Vertical bars are rms deviations of individual values.

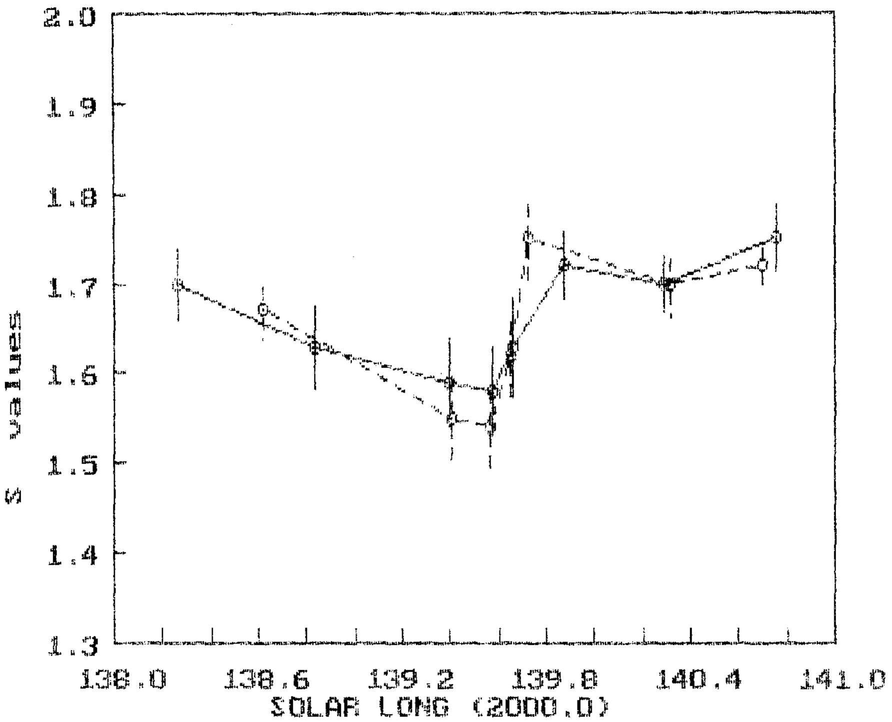

Fig.3: The central part of the Fig.2.

in Fig.4. One notices that all points in the graph are concentrated along the four straight lines that have been found by the least square method. This means that the meteoroid flux density varies inside the meteor stream in an exponential way. The core of the stream has a greater flux radiant than its outer part. Maximum value of ZHR=71 corresponds to the solar longitude L=140.36° and the dense core of the stream is between L=138.22° and L=142.12°. The ZHR profiles for IMO data for 1988-1990 and for Crimean data for the same years are shown in Fig.5. The IMO ZHR values are less than the Crimean ones because their observations have made by individual observers and the effective collecting area $\sum_{ef}$ was less than that of the Crimean observations made by groups of observers. Therefore the IMO ZHR values have been increased by the factor 1.5 to match with the Crimean data in Fig.5. One can see the good coincidence between both sets of data, but the points corresponding of the ascending branch of the profile are placed a little above the mean 18 year profile shown in the graph by straight lines.

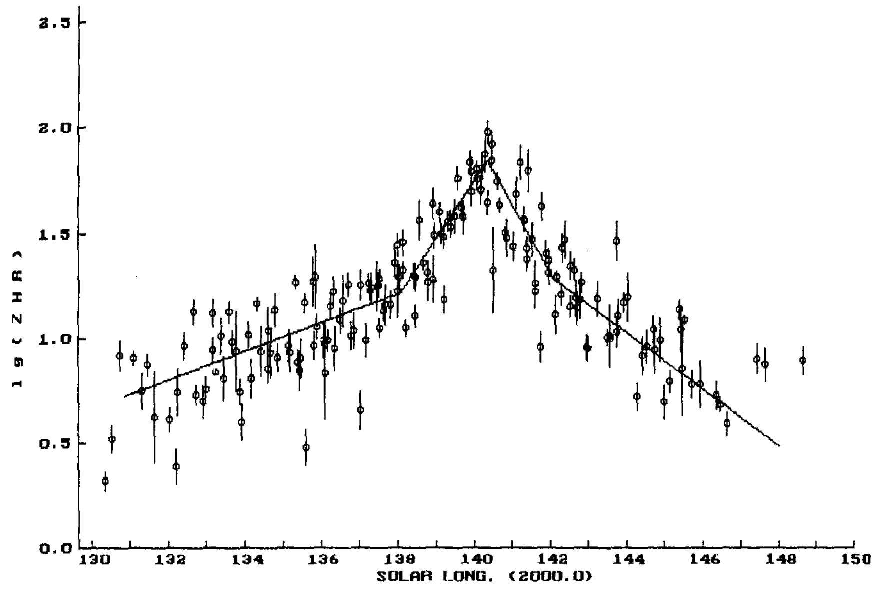

Fig.4: Variation of lg(ZHR) values for 18 years as a function of solar longitude.

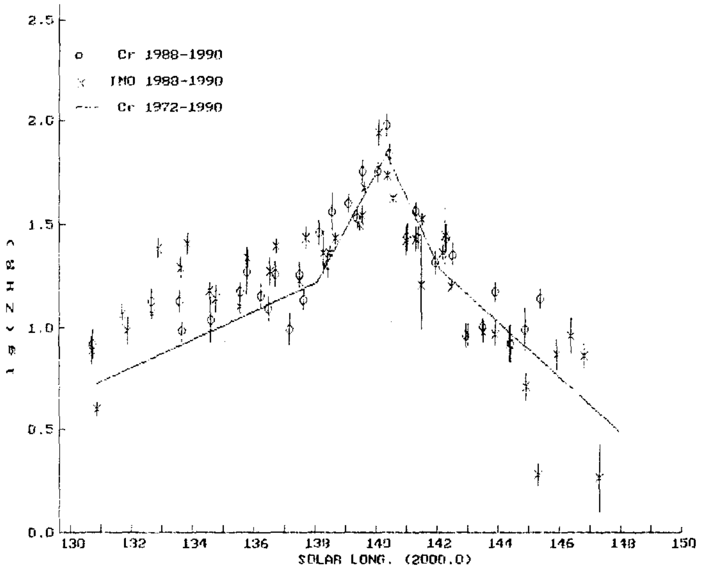

Fig.5: Perseid activity for 1988-1990 from Crimean and IMO data. The solid lines show the mean activity for 18 years.

The two distinct intervals 1980-1981 and 1991-1992 correspond to the times of excepted apparition of P/Swift-Tuttle comet and to the real apparition. Perseid activity relative to the mean level is shown in Fig.6 for 1980, 1981 and 1982. The 1980 shower activity is approximately 1.5 times greater than the normal activity, the same appears in 1981 to the ascending part. In 1982 the activity approaches nearly to the normal value. The shower activity in 1991-1992 relative to the mean level for quiet years (solid line) is shown in Fig.7 for IMO and Crimean data. Crimean observations of Perseids 1993 are not reliable because of a bad weather and are not shown in the graph. IMO data for 1993 we have not yet. The IMO ZHR values have been increased by the factor 2.1 in this case to match them with Crimean ones. The shower maxima shifted to L=139.54° with ZHR=119. Narrow enhancements above the usual broad maximum were observed in 1991-1992 at L=139.54° with activity up to 225 meteors.

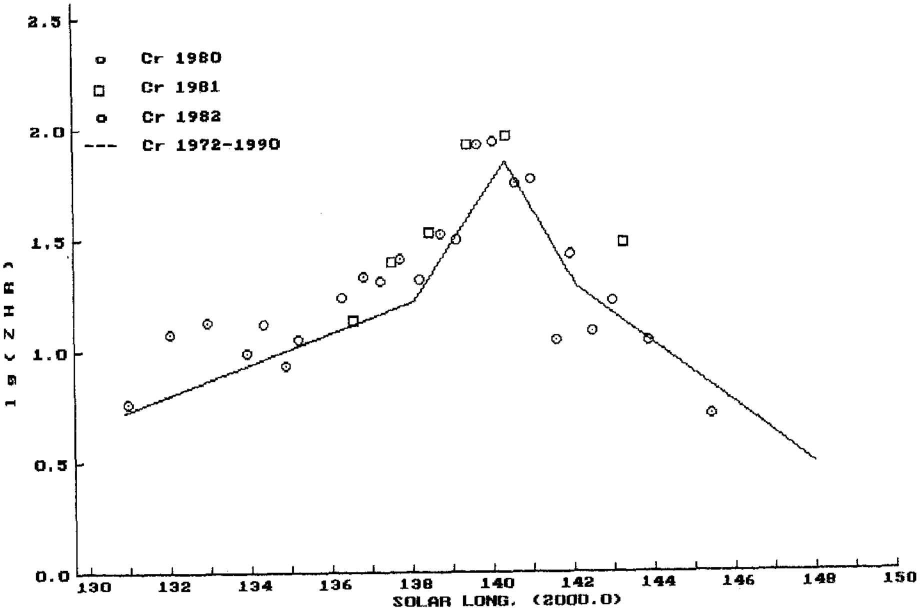

Fig.6: Perseid activity for 1980-1982 relative to the mean level.

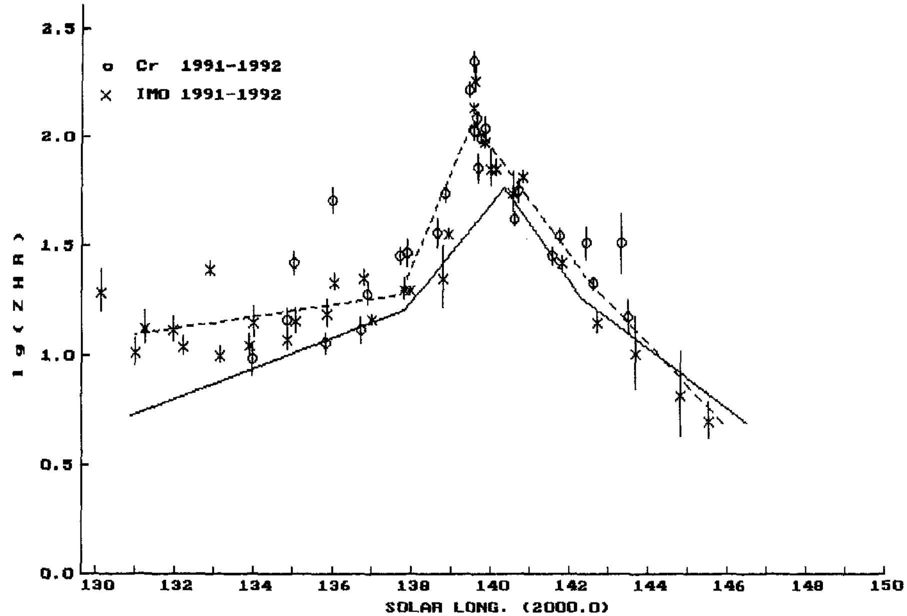

Fig.7: Shower activity in 1991-1992 (dashed lines) relative to the mean level (solid line).

5. Discussion

Our series of 22 years of Perseid visual observations confirm the stream stability in general except for the two time intervals 1980-1982 and 1991-1993. And if the last interval coincides with the comet P/Swift-Tuttle return, the first one is still a puzzle. Narrow peaks of shower activity observed for example in 1980 at L=138.9°and in 1989 at L=139.8° (Belkovich et al. 1990). It is very interesting also to note the dense core existing in the Perseid stream. A similar core we have found in the Quadrantid meteor stream but it is apparently absent in Geminids. The shower maxima in 1991-1992 shifted to the P/Swift-Tuttle node (Marsden 1992) where narrow enhanced peaks were observed also in the last three years. These results do not contradict those of Koshak et al. 1993.

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