Progress in Meteor Science

Articles in this section have been formally refereed by at least one professional and one experienced, knowledgeable amateur meteor worker, and deal with global analyses of meteor data, methods for meteor observing and data reduction, observations with professional equipment, or theoretical studies.

A Global Analysis of the 1993 Geminids

Rainer Arlt and Jürgen Rendtel

The analysis of global data of the 1993 Geminids shows a maximum ZHR of 130 ± 8 at $\lambda_\odot = 262°.1 \pm 0°.1$. This is a somewhat higher peak ZHR than in 1991 and 1992. Similar to previous returns, the rate profile is slightly skew, with a more steep decrease after the peak. Problems occur with the correction of perception because of the distribution of observational data. The lowest value of population index of $r = 2.27 \pm 0.03$ coincides with the rate maximum.

1. Introduction

After the splendid coverage of the Perseid event in August 1993 by observations from around the world other showers have been somewhat disregarded for the excitement of the Perseids. Although the weather in central Europe was not favorable for Geminid watches, the well-established net of observers in other parts of Europe, in America, Asia, and Australia delivered a good deal of observations which enabled us to present this analysis. The authors would like to thank the following 133 observers who contributed their observations to this study for their efforts:

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Due to interference from the Moon, the 1992 Geminids could not be monitored appropriately. Not even 1400 shower meteors were recorded in 1992; too small a number to permit a global analysis. (A raw estimate of the activity showed a maximum of $\mathrm{ZHR_{max}} = 100 \pm 20$ at $\lambda_\odot = 261\overset{\circ}{.}9 \pm 0\overset{\circ}{.}2$ for the 1992 Geminids.) The last comprehensive study of the Geminids presented in this Journal dealt with the 1991 Geminid return. The analysis routines of the *Visual Meteor Database (VMDB)* were used for investigating both the 1991 and 1992 returns. The present paper regarding the 1993 return is based on 20 700 shower meteors seen in 668 observation hours. The analysis routines of the *VMDB* were also applied to obtain the results presented in this paper.

2. The population index

The individual population indices r were computed according to [1]. To be used in the analysis, the individual magnitude distributions must contain at least five consecutive classes with at least three meteors each, the faintest class being at least 2 magnitudes brighter than the limiting magnitude. The width of the magnitude classes is 1. As the r-value is deduced from linear regression, the correlation coefficient should be larger than 0.98.

The observations in 1993 concentrated around the maximum. Although a good profile was obtained for the period between December 12 and 15 no reliable r-value could be found for the days before and after this period. The first and last value calculated from the 1992 data (at $\lambda_\odot = 260\overset{\circ}{.}44$ and $\lambda_\odot = 262\overset{\circ}{.}31$, respectively) turned out to be almost identical with the figures for the same position in 1991. Therefore, we used the r-profile of 1991 (Figure 1 and Table 1 in [2]) to complete the 1993 values since the population index is necessary for computing the hourly rates. The values added are at $\lambda_\odot = 259\overset{\circ}{.}0$ with $r = 2.7 \pm 0.1$ and at $\lambda_\odot = 264\overset{\circ}{.}0$ with $r = 2.5 \pm 0.1$. The profile is shown in Figure 1. The entire profile is smooth with no significant variations, and shows the same general shape as in 1991. Centered at the rate maximum of the shower, the population index r reaches its lowest value. However, the difference in r-value between the center and the outer parts of the Geminids is lower than for other major showers (Perseids 1991 and 1992: $r = 2.9$–1.9 [3]; Quadrantids 1992: $r = 3.7$––2.1 [4]). This emphasizes the unique constitution of the Geminid meteoroids [5]. This is also obvious in the small portion of Geminid meteors showing train phenomena compared to particularly the Perseids.

3. The activity profile

Knowing the change of r with time we are now going to calculate the zenithal hourly rates (ZHR) of the Geminids by the general reduction formula

$$\mathrm{ZHR} = \frac{n \times r^{6.5-\mathrm{lm}} \times F}{T_{\mathrm{eff}} \times \cos z},$$

where n is the number of Geminids and lm, F, and T_{eff} are the limiting magnitude, field correction, and effective duration of the observation, respectively. The angle z is the zenithal distance of the Geminid radiant.

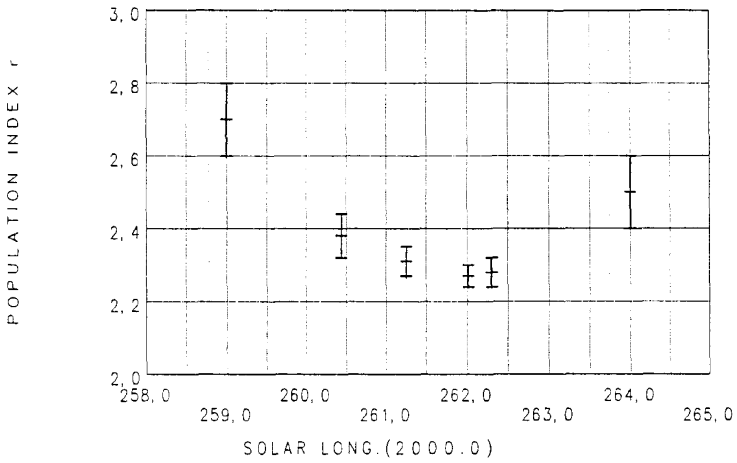

Figure 1 – Profile of the population index r of the 1993 Geminids. The values at $\lambda_\odot = 259°.0$ and $\lambda_\odot = 264°.0$ were added from the profile of 1991 as the 1993 data did not yield a reliable result.

Table 1 – The population index r of the 1993 Geminids

$\lambda_\odot(2000.0)$	Obs	Geminids	r	$\overline{\text{lm}}$
259.00	4	155	2.70 ± 0.10	5.94
260.44	16	1157	2.38 ± 0.06	6.44
261.26	52	6086	2.31 ± 0.04	6.31
262.03	92	11001	2.27 ± 0.03	6.29
262.31	56	5923	2.28 ± 0.04	6.29
264.00	2	102	2.50 ± 0.10	6.25

Table 2 – Intervals for the averages of the Geminid ZHRs.

Period	Interval length	Interval shift
250°.00 – 260°.50	2°.00	1°.00
260°.50 – 261°.55	0°.60	0°.30
261°.55 – 261°.70	0°.40	0°.20
261°.70 – 262°.50	0°.20	0°.10
262°.50 – 263°.00	0°.50	0°.25
263°.00 – 270°.00	2°.00	1°.00

The individual ZHR values were averaged over bins given in Table 2. The averages were weighted by the reciprocal correction factor $\cos z/(r^{6.5-\text{lm}} \times F)$.

The choice of the intervals and their lengths depends on the shape of the profile and the number of observational data. Still, many observers concentrate on the near-peak period only. In order to derive a complete profile, Geminid data are required for the entire activity period. Because of the lower numbers of shower meteors, even more intervals would be necessary to obtain good values of r and certain averages of the ZHR. On the other hand, the variations of r and rates seem to be negligible in these branches, and we may average over longer intervals than near the maximum. The choice of the intervals requires us to calculate a first, rough profile, from which the most appropriate splitting is taken.

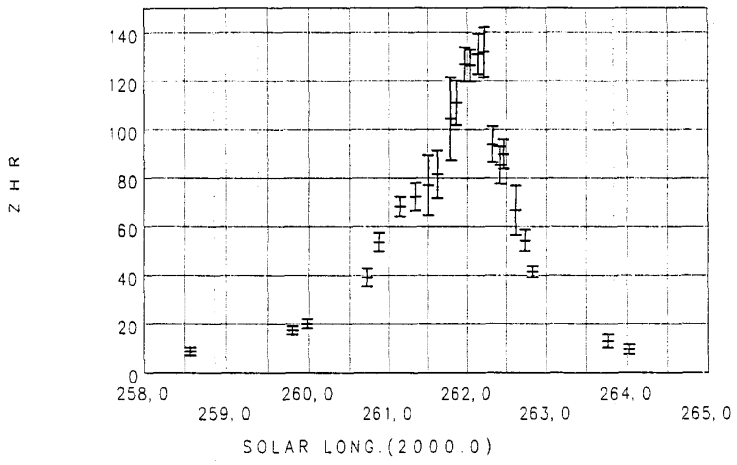

Figure 2 – ZHR-profile of the 1993 Geminids. The values are given in Table 3. The maximum ZHR of 130 ± 8 occurs at $\lambda_\odot = 262\overset{\circ}{.}1$. The profile is skew as theoretically calculated by Fox et al. [6]

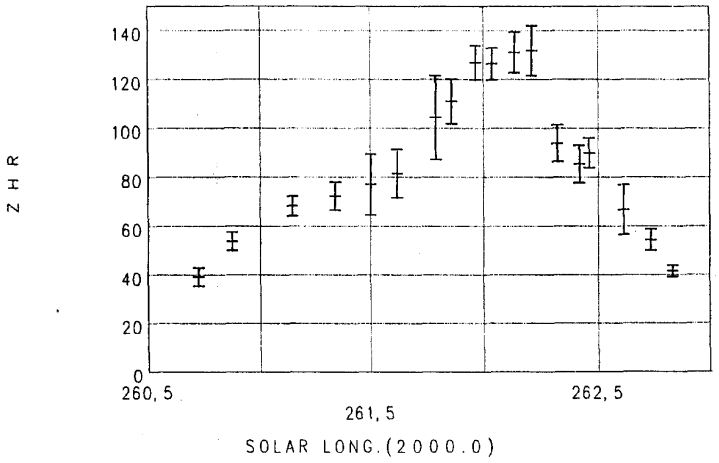

Figure 3 – Detail of the ZHR-profile around the maximum of the 1993 Geminids. In the period between $\lambda_\odot = 261\overset{\circ}{.}8$ and $\lambda_\odot = 262\overset{\circ}{.}3$ the ZHR exceeds 100. This may be regarded as a kind of ZHR plateau with relatively small rate variations.

When averaging the ZHRs, the procedure rejects outliers which lie off the mean by more than 1.645σ, i.e., values which lie outside a confidence interval of 90%.

In recent analyses, we tried to compensate systematic errors by deriving personal perception coefficients. These factors were obtained from the average offset of one observer's rates from the mean ZHR in certain periods. The periods should show relatively constant activity or, at least, a monotonic behavior with a slight slope. The 1993 Geminid data concentrated near the maximum; there is little chance to find a period fulfilling the above criteria. We are actually dealing with slopes in both directions. Other periods would include a tiny minority of the observers participating. Therefore, we did not apply perception coefficients to the activity profile. This again underlines the necessity to not restrict observational efforts to the maximum night, but to cover also the other periods.

In Figure 2, we show the complete activity profile obtained from the 1993 observations. The shape of the profile looks very much like the theoretical profile calculated by Fox et al. [6]. Furthermore, it is smoother than the 1991 profile [2]. This may be partly due to the above described effects of the perception coefficients. Figure 3 clearly shows that there is a period of several hours length in which the high ZHR varies rather little. This kind of plateau has been found in previous analyses as well (e.g. [2]).

Table 3 – ZHR-profile for the 1993 Geminids. The Geminid rates based on the r-values given in Table 1. Int. gives the number of available intervals, GEM lists the number of Geminid meteors included in the respective sample. For comparison, the number and hourly rate of sporadic meteors in the same intervals is given as well. r refers to the used population index for the intervals and is interpolated from the profile determined first.

$\lambda_\odot$ (2000.0)	Int	Gem	ZHR	Spor	HR	$\overline{\text{lm}}$	r
255.154	11	27	4.4 ± 1.6	96	16.6	6.12	2.70
255.519	25	54	4.2 ± 0.8	198	16.1	6.02	2.70
255.947	19	37	4.1 ± 0.7	142	16.8	5.92	2.70
257.632	15	62	8.8 ± 2.3	155	21.6	6.04	2.70
258.569	29	158	8.8 ± 1.6	336	18.0	6.51	2.69
259.791	102	1072	17.5 ± 1.7	883	14.0	6.33	2.51
259.974	84	971	20.1 ± 1.9	681	13.6	6.24	2.46
260.724	42	731	39.2 ± 3.7	413	22.0	6.23	2.35
260.871	87	2583	53.7 ± 3.8	900	19.5	6.24	2.34
261.146	82	3737	68.2 ± 4.1	987	17.7	6.28	2.31
261.341	43	2224	72.2 ± 5.7	559	17.1	6.31	2.30
261.503	6	339	77.0 ± 12.4	59	13.3	6.35	2.30
261.622	9	376	81.5 ± 9.9	111	24.2	5.96	2.29
261.791	12	573	104.4 ± 17.2	203	36.0	6.54	2.28
261.861	36	1460	111.0 ± 9.2	477	35.1	6.49	2.28
261.968	86	2960	126.9 ± 7.0	625	22.7	6.23	2.27
262.039	118	4031	126.4 ± 6.5	663	17.1	6.13	2.27
262.135	109	3834	131.1 ± 8.3	554	15.1	6.20	2.27
262.212	70	2747	131.8 ± 10.2	414	15.3	6.20	2.27
262.323	23	1204	93.9 ± 7.5	210	15.9	6.15	2.28
262.418	11	483	85.3 ± 7.7	85	14.6	6.26	2.29
262.461	4	96	89.9 ± 6.1	43	38.9	6.10	2.30
262.614	31	931	66.7 ± 10.2	500	28.0	6.37	2.31
262.732	66	1593	54.3 ± 4.4	955	27.7	6.37	2.33
262.832	36	690	41.5 ± 2.3	465	27.6	6.35	2.35
263.770	15	95	13.0 ± 2.7	219	31.2	6.40	2.45
264.029	22	111	9.6 ± 2.0	333	29.6	6.39	2.47
265.075	17	34	4.1 ± 0.8	180	22.5	6.12	2.50
265.642	14	31	3.8 ± 1.0	110	13.0	6.28	2.50
266.198	4	13	3.0 ± 1.3	44	9.4	6.64	2.50

4. Conclusions

The 1993 Geminid return did not show peculiarities. There occurs a kind of plateau ZHR ($\lambda_\odot = 261°.8$ to $\lambda_\odot = 262°.3$) with a maximum centered at $\lambda_\odot = 262°.1$.

The peak ZHR is 130 ± 8, and is thus somewhat higher than the peak rates observed in the previous years. For comparison, in 1991 a maximum ZHR of 110 ± 10 was observed at $\lambda_\odot = 262°.3$ [1]. The shape of the profile is very similar to the theoretical profile derived by Fox et al. [6].

We found that the introduction of perceptions derived from near-peak intervals only is not appropriate. On the contrary, these perceptions may lead to apparent structures. Perhaps

this happened in the 1991 analysis [2], where a more rough profile has been derived after the perceptions were included. A revision of the detailed data may bring further light into the application of the perception coefficients.

We urgently ask all observers to watch the shower also in the nights before and after the maximum. We know that December nights are not the most pleasant ones to sit outside–but it will be worth the effort. The last conclusion, however, holds for each shower for which a profile analysis is intended.

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