Geminids

Almost 50 Years of Visual Geminid Observations

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An analysis of the activity profile of the Geminid meteor shower from 1955–2002 is made using visual observations of meteors. Currently, the rate maximum occurs at $\lambda_\odot = 262\fdg16 \pm 0\fdg04$ (J2000). A shift in the maximum of $0\fdg008$ per year is derived from a comparison of the 1955 profile and the average profile of the period 1988–1997.

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1 Introduction

The Geminid meteor shower is among the strongest and best known meteor showers currently visible on Earth. It recurs each year around December 14. The radiant is well above the horizon all night for northern hemisphere observers. Hence each individual observer can collect data for up to 13 hours per night. This guarantees a good overlap of data series obtained from different longitudes. However, conditions are poor for Geminid returns coinciding approximately with the Full Moon. The bright moonlight ruins the observing conditions for visual observers and in those years the rate and magnitude data are of limited quality.

For most major showers there are detailed reports of rich appearances which occurred many centuries ago. Yet the Geminids were not noticed before the 19th century. This hints at a rather rapid orbital evolution of the stream and indicates that changes may become detectable within a period of the order of 50 years.

According to modelling, the Earth will continue to intersect the Geminid meteoroid stream until about 2100 (Hunt et al., 1985). Much of the interest in this peculiar shower is due to the fact that the parent object, (3200) Phaethon, is not of obviously cometary nature. This correlates well with the finding that the bulk density of Geminid meteoroids derived from photographic images is higher than for other streams. Recently, Babadzhanov (2002) gave $\varrho = 2.9 \pm 0.6$ g/cm^3 for the Geminids. Furthermore, its orbit is extremely different to all other major showers intersected by the Earth (Table 1).

The unique orbit of the stream in the innermost region of the Solar system should have several consequences. All evolutionary processes are expected to happen on short time scales because the parent object as well as the meteoroids see frequent approaches to Venus and Earth. Furthermore, all effects of the Solar radiation are much stronger than in the case of long-period meteoroid streams. All these effects will change orbital elements, particularly the semimajor axis a and the eccentricity e, within a few orbital periods. In the case of the Geminids we speak about time scales of a decade. Even if there is a periodic particle release from the parent object, we cannot expect filaments as discussed with the Leonids, for example. Consequently, we should not find variations of the spatial density distribution which are stable for a number of consecutive returns. Surprisingly, McIntosh (1974) found periodic variations in radar data (2:1 in radar flux) and associated these with a 3:5 commensurability of the average orbital periods of the Geminids and the Earth. This could be explained with freshly ejected particles which spread rapidly as described above. Hence possibly existing structures in the stream are expected to remain observable only for a short period.

Here we present an analysis of the activity observed with visual techniques of the Geminid meteor shower near its time of maximum for the years 1955–2002 (Table 2). Data from 1988 onwards are stored in the IMO's Visual Meteor DataBase (VMDB). Further reports, mainly from the 1970s, were transformed into VMDB-compatible records. Finally, data from the Czech Ondřejov Observatory (Ceplecha, 1957) and the Slovak Skalnaté Pleso Observatory (Grygar & Kohoutek, 1958) are used. The process of data collection and processing is not yet finished, because some more early data were included recently extending the period further backwards.

2 Observational results & Discussion

The first step to calculate ZHRs is the calculation of the population index r as a function of solar longitude. This way we determine the portion of missed meteors depending on the limiting magnitude for each observer and interval.

As mentioned above, the majority of the Geminid data is collected during moonless returns. Furthermore, this data is not affected by disturbing illumination. Hence we use this in a first step to look for significant variations in the population index r among the individual Geminid returns. Also, the (scarce) moonlit data yield similar values of r, of course with a larger scatter. Consequently, we use an average profile derived from moonless Geminid returns (Figure 1) for the computation of the ZHR profiles.

While the 1988–2002 ZHR profiles are collected and analysed according to the standardized IMO methods, the older data did not include the full information. Therefore we did not apply any perception correction. As pointed out, the status of the analysis of the data prior to 1988 is still preliminary.

At the current stage of the analysis, we determined ZHR profiles for the 1955 return and an average for the

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Table 1 – Orbital elements of Geminid meteoroids (averages) and the parent object (3200) Phaethon (from the IMO Visual Handbook, Rendtel et al., 1995).

	Ω	ω	i	e	q	a	P
Geminids							
Lindblad (1971), phot.	260°.3	324°.8	23°.6	0.896	0.140 au	1.466 au	1.57 a
Lindblad (1987), phot.	260°.2	324°.3	23°.5	0.899	0.143 au	1.414 au	1.68 a
Betlem et al. (1994), phot.		324°.5	24°.4	0.900	0.139 au	1.39 au	1.64 a
Porubčan & Gavajdová (1994), phot.	260°.2	324°.7	24°.4	0.901	0.137 au	1.39 au	1.63 a
Ueda & Fujiwara (1994), TV	260°.3	324°.4	24°.1	0.89	0.15 au	1.3 au	1.5 a
Kashcheev & Lebedinets (1967), radar	260°	326°	24°	0.89	0.14 au	1.31 au	1.5 a
1936–1945	261°.1	324°.3	24°.4	0.905	0.137 au	1.456 au	1.76 a
1946–1955	260°.9	324°.3	24°.0	0.899	0.140 au	1.392 au	1.64 a
1956–1965	259°.4	324°.9	23°.3	0.896	0.139 au	1.341 au	1.55 a
1966–1975	261°.5	324°.2	23°.6	0.886	0.148 au	1.309 au	1.50 a
1976–1985	261°.3	325°.1	23°.4	0.883	0.146 au	1.278 au	1.44 a
Photographic data for the 5 decades from Porubčan & Cevolani (1994)							
(3200) Phaethon	265°.4	322°.0	22°.2	0.890	0.139 au	1.271 au	1.43 a

Table 2 – Summary of Geminid data available for the current analysis.

Year(s)	$T_{\text{eff}}(h)$	Geminids	Total	Remarks
1955	160	5757	7227	Czech and Slovak data (see text)
1971–80	112	2764	4041	AKM, McLeod, WAMS
1981–90	1154	27424	42787	IMO-VMDB, AKM, McLeod, WAMS
1991–02	2673	81116	113868	IMO-VMDB
All data	4099	117061	137923	
1991	874	30080	42955	Best observed individual return

period 1988–1997. Of course, the 10 year period may smear out some short periodic characteristics. Such periodic variations are described as occurring in radar data (e.g. McIntosh, 1974). But one main aspect of this study is the long-term behaviour of the stream's occurrence.

Interestingly, the kind of 'double peak' clearly visible in the 1988–97 data is also visible in the 1955 curve (Figure 2) although the 1955 observations ended close to the peak time and the descending branch of the ZHR profile is missing. This hints at a rather constant shape of the profile. Modelling of the Geminid stream (Fox et al.,

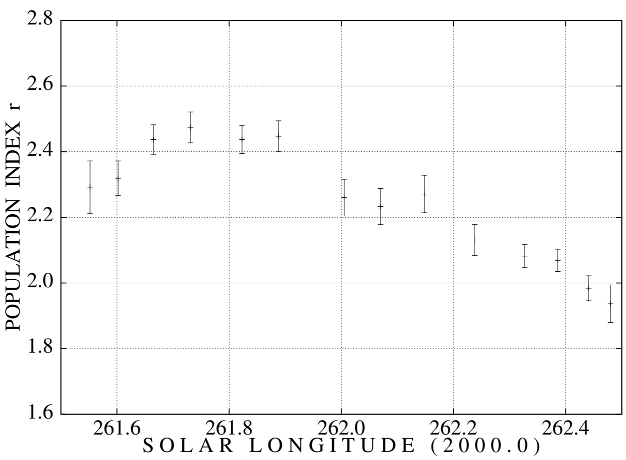

Figure 1 – Average profile of the population index r derived from moonless returns of the Geminids between 1988 and 1997.

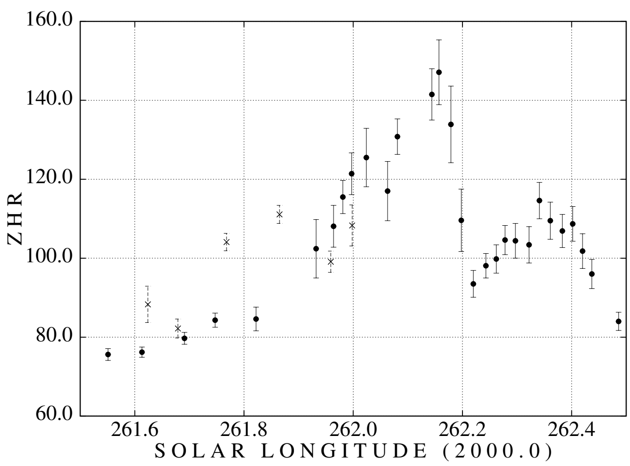

Figure 2 – ZHR profiles of the Geminids, showing the average profile of the 1988–97 returns (dots) and the ascending branch of the 1955 profile (crosses).

The Perseids one revolution trail ecliptic crossing relative to the Earth orbit. Year symbols indicate the start of each year. The black dots mark the nominal trail-center location. The crosses indicate the meteoroids ejected (in 1862) at the distance of 1.7 AU before perihelion.features. For example, we may suspect that the dip in the last three data points of the 1955 curve corresponds with the obvious dip found in the ZHR graph for the 1988-97 period. Assuming that this is the case, we find the position of the first peak of the 1955 Geminids at $\lambda_{\odot} = 261\overset{\circ}{.}85$. The respective position in the 1988–97 data is $\lambda_{\odot} = 262\overset{\circ}{.}16$. Since the center of the latter period is 1993, we obtain a shift of approximately $0\overset{\circ}{.}31$ within 38 years, corresponding to about $0\overset{\circ}{.}008$ (≈ 0.2 hours) per year. If the 1955 return represents the average situation at that time, the drift is about 2/3 of the predicted change — but in the wrong direction. Trying to compare the dips in the two rate profiles we may estimate a difference of $0\overset{\circ}{.}26$. Of course, this result is rather preliminary. Furthermore there is another uncertainty: the ZHR values of the 1955 return were computed with the average r-profile shown in Figure 1. Hence we should assume that the r-profile for the 1955 return is similarly shifted. However, with an average limiting magnitude of the order of 6.0, a value of $r \approx 2.4$ instead 2.2 yields a 5% increase of the ZHR, not much exceeding the size of the error bars. With the inclusion of further, as yet unprocessed data, the respective figures will become more reliable.

3 Conclusions

The almost 50-year study of the Geminid stream presented here makes it clear that visual meteor observations provide a useful diagnostic of stream activity as has been found in other cases such as the Perseids (Brown and Rendtel, 1996) and the Leonids (e.g. Arlt et al., 2001). Such systematic studies are currently only possible on the basis of visual and radar data. The general profile of the Geminids seems to remain stable. A shift of the Geminid peak of about $0\overset{\circ}{.}008$ (≈ 0.2 hours) per year is derived from data obtained between 1955 and 1997.

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References

Arlt R., Kac J., Krumov V., Buchmann A., and Verbert J. (2001). "Bulletin 17 of the International Leonid Watch: First global analysis of the 2001 Leonid storms". *WGN*, **29**, 187–194.

Babadzhanov P. (2002). "Fragmentation and densities of meteoroids". *A&A*, **384**, 317–321.

Betlem H., ter Kuile C., van't Leven J., and van Vliet M. (1994). "Geminiden 1990: Fotografische resultaten (1) Baanelementen". *Radiant*, **16**, 33–38 (In Dutch).

Brown P. and Rendtel J. (1996). "The Perseid meteoroid stream: characterization of recent activity from visual observations". *Icarus*, **124**, 414–428.

Ceplecha Z. (1957). "Visual Geminids 1955". *Bull. Astron. Inst. Czechosl.*, **8**, 129–131.

Fox K., Williams I., and Hughes D. (1983). "The rate profile of the Geminid meteor shower". *MNRAS*, **205**, 1155–1169.

Grygar J. and Kohoutek L. (1958). "Geminids 1955". *Bull. Astr. Inst. Czechosl.*, **9**, 13–18.

Hunt J., Williams I., and Fox K. (1985). "Planetary perturbations on the Geminid meteor stream". *MNRAS*, **217**, 533–538.

Kashcheyev B. and Lebedinets V. (1967). "Radar studies of meteors". *Simthson. Contr. Astrophys.*, **11**, 183–199.

Lindblad B. (1971). "A computerized stream search among 2401 photographic meteor orbits". *Smithson. Contr. Astrophys.*, **12**, 14–24.

Lindblad B. (1987). "Physics and orbits of meteoroids". In *The evolution of the small bodies of the Solar System*, page 229. Soc. Italiana di Fisica, Bologna.

McIntosh B. (1974). "Geminid meteor shower; further note on the distribution of particles around the orbit". *Bull. Astron. Inst. Czechosl.*, **25**, 362–365.

Porubčan V. and Cevolani G. (1994). "On the activity and orbit of the Geminids meteoroid stream". *Il Nouvo Cimento*, **17C**, 243–248.

Porubčan V. and Gavajdová (1994). "Search for fireball streams among photographic meteors". *Planet. Space Sci.*, **42**, 151–155.

Rendtel J., Arlt R., and McBeath A. (1995). *Handbook for Visual Meteor Observers.* IMO, Potsdam.

Ueda M. and Fujiwara Y. (1994). "Television meteor radiant mapping". In *Proceedings of 'Meteoroids' conference, Bratislava.*