Visual Observations and Activity Analysis of the 2002 Geminids Meteor Shower

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Abstract

The visual observations of 2002 Geminids at "Karvansara-Ye-Shah Abbasi", Semnan, Iran are reported. Based on over 9.4 hours of observing time an activity profile on December 13^{th} and 14^{th} 2002 is given. The maximal Zenithal Hourly Rate (ZHR) equal to 165±10 were noted on December 13.9 UT (λ_{sun} = 261.710). We obtained the presence of the double peak of Geminids activity in 2002 with maxima at λ_{sun} = 261.710 and λ_{sun} = 261.795. Presuming our ZHR to be enough accurate, the comparison between presented calculation and last years reported shows an increase in the activity of this year's shower. The population index *r* reaches two minimum values of 1.7 and 1.6 during the activity.

1. Introduction

The Geminid meteor shower that officially begins on December 7^{th}, seems to have appeared suddenly during the 1860s. Greg, Marsh, Twinning and Herschel confirmed its existence for the first time in 1862. The J2000 coordinates of its radiant are R.A.=7^h 28^m, Dec.=+33°. The first estimations of the shower's strength showed unimpressive hourly rates such as 14. But the rates started increasing during the beginning of the 20^{th} century including a dramatic increase between 1890 and 1930 that led to hourly rates from 40 to 70. The continuous increase has made the Geminid one of the most spectacular annual showers with an approximate ZHR of 140 during the past few years. Many parameters of the shower such as accurate period, magnitude distributions, motion of the radiant and orbital elements have been calculated by many researchers such as Denning (1923), Whipple and Plavec (1947), Roggemans (1989), Rendtel and Arlt (1993), Brown and Rendtel (1997) and Uchiyama *et. al* (2001).

Considering the passage of the meteor stream through the asteroid belt, Green and Davies (1983) discovered the asteroid "3200 Phaethon" as the origin of the Geminid shower. The studies of the stream's particles demonstrate that Phaethon is an extinct comet that has accumulated a thick crust of interplanetary dust grains that has covered its nucleus.

In this study, we are presenting the magnitude and number distributions of the Geminids. We analyzed these distributions using the method of Arlt and IMO, and the parameters derived from observed distributions are compared with the previous studies.

2. Observations

The total numbers of 454 Geminids meteors are observed in 9 hours and 24 minutes on December 13^{th} and 14^{th} 2002, by 12 observers.

This meteor shower was observed in "Karvansara-Ye-Shah Abbasi" (Latitude: 34.77, Longitude: 52.18), Semnan, Iran. Four groups (three observers in each of them) were formed to observe and record the meteors after each group had picked several constellations (mostly 4). Due to the

interference of the clouds, fog and dust, observing was impossible until 21:16 UT and the observation continued until 1:16 UT.
Figure 1 and 2 represents the number and magnitude distributions, as they were derived from our observations. The magnitude distribution of this observation in percent of each magnitude class is also presented in Figure 3.
These profiles show the maximum number of meteors in λ_{sun}=261.71 and second magnitude as the most of the observed meteors.

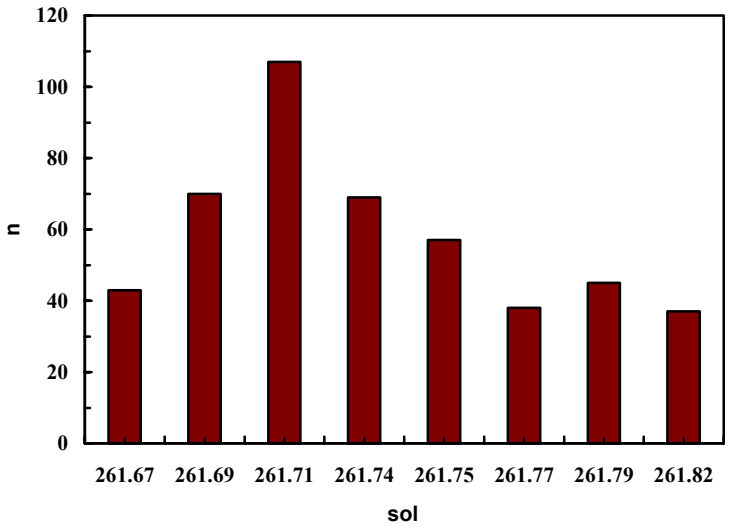

Figure 1 – Number distribution of the 2002 Geminid shower

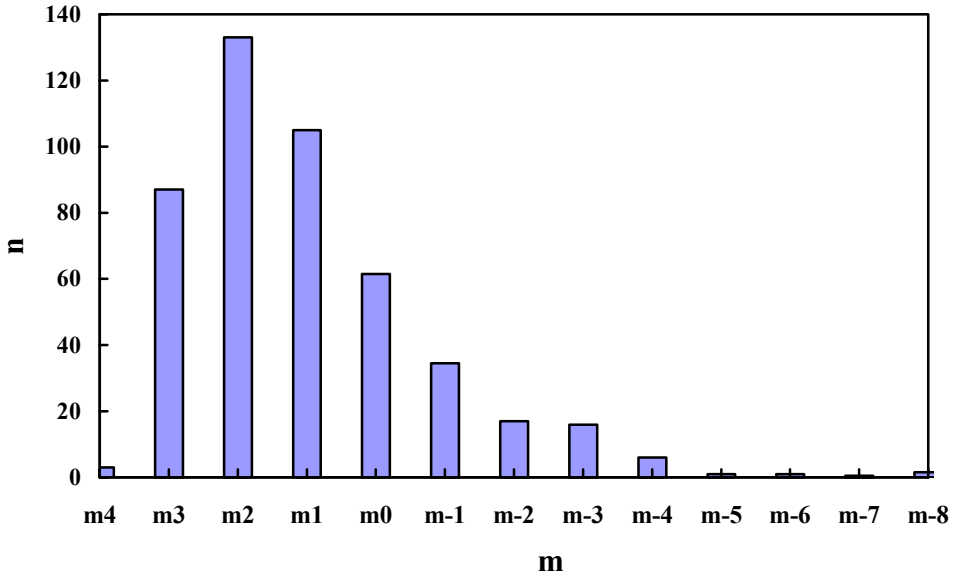

Figure 2 - Magnitude distribution profile

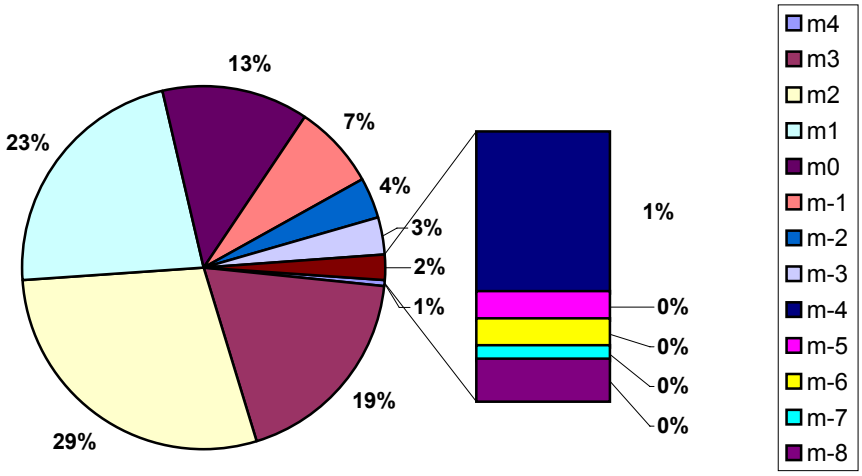

Figure 3 – Magnitude distribution percentage

3. Analysis

The population index - The method used here to obtain the population indices (the method suggested by IMO) consists of the equation mentioned below:

$$\sum N_i \, (lm - m_i) / N$$

where N_i is the number of the meteors observed with the magnitude of m_i (the letter "i" can gain different values considering the magnitude distribution.), lm is the limiting magnitude and N is the total number of the meteors observed in the considering interval. This equation delivers a set of corresponding <Delta m>. Using Table 1, we converted <Delta m> into population indices. This converting table is obtained from several previous Geminids observations (Arlt, 2002). This will give us the *r*-values for our main effective observing times.

r	**<Delta m>**	***r***	**<Delta m>**	***r***	**<Delta m>**
1.5	5.830	2.5	3.291	3.5	2.503
1.6	5.301	2.6	3.180	3.6	2.450
1.7	4.894	2.7	3.079	3.7	2.400
1.8	4.568	2.8	2.987	3.8	2.353
1.9	4.298	2.9	2.902	3.9	2.308
2.0	4.069	3.0	2.823	4.0	2.266
2.1	3.872	3.1	2.750	4.1	2.226
2.2	3.700	3.2	2.682	4.2	2.187
2.3	3.549	3.3	2.618	4.3	2.151
2.4	3.413	3.4	2.559	4.4	2.116

Table 1 – r value table

After the conversion section, we obtained the *r*-value of each interval for each group. Using the equation below (the formula for weighted average), the population index for each interval was calculated,

$$\sum r_i T_i / \sum T_i$$

r_i is the population index of each group and T_i is the effective observing time of the same one. The error for the *r*-value is derived from this equation:

$$\sigma r = r / \sqrt{N}$$

The Zenithal Hourly Rate - The simplest method for analyzing the data of the visual observations is counting the number of the meteors in an effective observing interval (T_{eff}). The same quantity is enough for showing the quantitative value of the shower. But for more accurate calculations we need to take into account a number of corrections. Hence, a new quantity is introduced representing the Zenithal Hourly Rates (ZHR) which is defined as the number of the meteors observed in 1 hour with the best observing conditions (while the radiant is in the zenith and the limiting magnitude is 6.5). The individual ZHRs are computed by,

$$ZHR = N\, r^{6.5-lm} / T_{eff} \sin h_R$$

Where *r* is the population index, lm is the limiting magnitude, N is the number of the observed meteors during T_{eff}, which is the effective observing time in each period (excluding any times during which the observer was not facing the sky, e.g., recording times) and h_R is the altitude of the Geminid radiant for the middle of observing period.
The ZHR for each interval was calculated by,

$$\sum ZHR_n C_n / \sum C_n$$

Which ZHR_n represents the Zenithal Hourly Rate of each group and C_n is the percentage of the sky observed by that group in the same period.
For computing ZHR's error in each interval, this formula was used:

$$\sigma ZHR = ZHR / \sqrt{N}$$

In which N stands for the total number of the observed meteors used for calculating the ZHR.

4. Results

The population index - In order to derive a complete profile, Geminid data are required for the entire activity period. In the present analysis, it has been tried to compensate systematic errors by putting into counter a number of corrections. As explained in the Analysis section, after obtaining the *r*-values for the eight observing intervals, the population index profiles was derived as Figure 4, using Tables 2.

Sol (J2000.0)	Obs.	Geminids	*r*	lm
261.667	4	43	2.0	5.8
261.669	5	70	2.0	5.8
261.710	4	107	2.2	5.9
261.731	4	69	1.7	6.0
261.752	3	57	2.0	5.9
261.774	4	38	1.6	6.0
261.795	4	45	2.1	6.0
261.816	4	37	1.7	5.8

Table 2 – The population index *r* of the 2002 Geminids

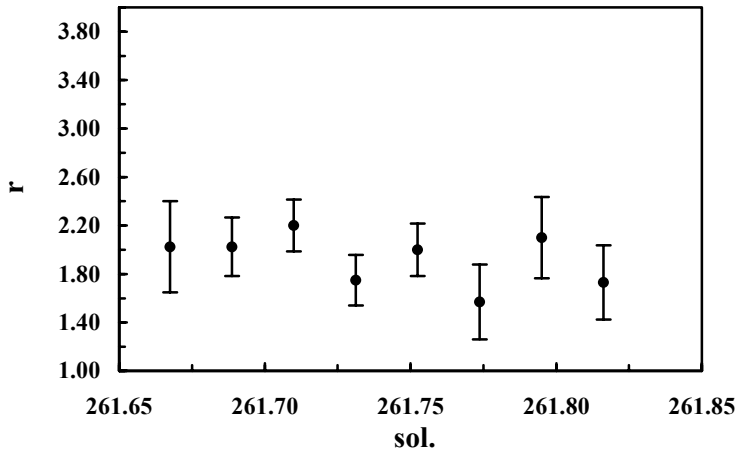

Figure 4 - Profile of the population index *r* of the 2002 Geminid shower

According to Figure 4 the minimum *r*-value of the shower (r=1.6), occurs at sol=261.774, and the maximum value of *r* (2.2) represents the highest activity of the shower.
The average *r* gained from the computations was 1.9.

The Zenithal Hourly Rate - The process of calculating the ZHR values is fully explained in the analysis section. Table 3 presented the ZHR values which calculated from our observations.
The ZHR errors are derived with ZHR division by square root of total meteor number in each interval.

Sol (J2000.0)	Obs.	Geminids	*r*	lm	ZHR
261.667	4	43	2.0	5.8	75±9
261.669	5	70	2.0	5.8	98±7
261.710	4	107	2.2	5.9	165±10
261.731	4	69	1.7	6.0	68±8
261.752	3	57	2.0	5.9	57±9
261.774	4	38	1.6	6.0	46±9
261.795	4	45	2.1	6.0	105±11
261.816	4	37	1.7	5.8	60±7

Table 3 – ZHR values computed for 8 intervals

The maximum ZHR of 165±10 occurs at sol=261.710 as presented in Figure 5. There is another summit in the profile that demonstrates the second peak of the shower at sol=261.795 with ZHR equal to 105±11.

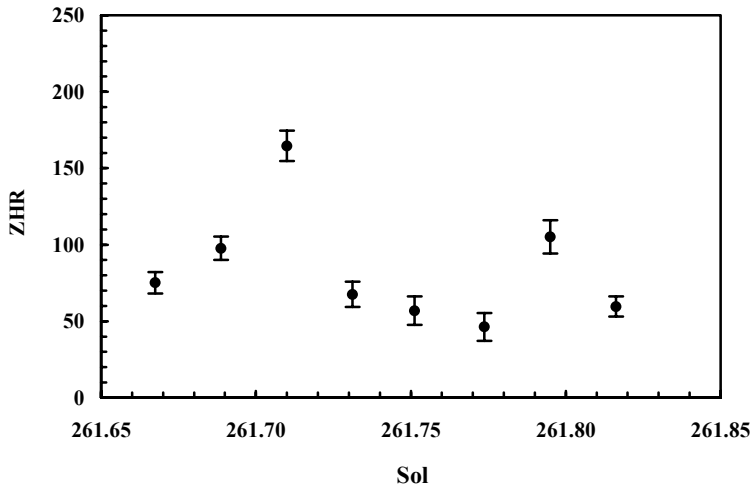

Figure 5 – ZHR profile of the 2002 Geminids

5. Conclusions

The population index profile derived from the present analysis is different from the standard profile that is usually obtained. Due to the high percentage of fireballs with considerable magnitudes among the meteors, the 2002 shower could have been a peculiar one. Two peaks in the ZHR profile are found, one very distinct at sol=261.710° and a less well-defined peak at sol=261.795°. But it should be noted that besides all the corrections, the data used for the analysis was somehow inaccurate and was only based on our observations, not the entire data of this shower. Although, by comparing the results with the report of NMS (Nippon Meteor Society), the two results are considerably similar (the calculated population index by NMS is 2.0 and the total r-value in this report is 1.9).

The last detailed analysis on the Geminid shower presented by IMO was the report describing the 1996 shower, with the minimum r-value of 1.9 during the maximum activity of the shower. The population index calculated for last year's shower was equal to 2.6 which has a considerable difference with this year's shower.

Maximum and minimum of the *r*-profile (neglecting the uncertain far-end value) coincide with the ascending and descending part of the activity curve. This behavior is also visible in both the 1991 and 1996 *r*-profiles.

Considering the population indices (of the maximum annual activity), the activity of the shower during the past few years has been quite stable. Using the table below, the comparing of the computed ZHR of this year with the Zenithal Hourly Rates of the previous years, shows a much stronger activity for the 2002 of the Geminids meteor shower.

Year	Sol (2000.0)	ZHR
1988	262.10	130
1990	262.26	110
1991	262.30	110
1993	262.10	130
1996	262.15	115
1999	262.00	120
2000	262.24	126
2001	262.01	120

Table 4 - Time and ZHR of Geminid maxima derived from global analyses since 1988.

Acknowledgements

The present report is a complex of the results of the calculations and data analysis of the visual observation. The author would like to express special thanks to all the people named below, who contributed their efforts to two major sections of the activity: observing and analyzing:

Observers: A. Ashoori, M. Bazrafshan, S. Feizbakhsh, T. Jalali, T. Kadkhodayan, S. M. Khabbazan, S. Mashhoon, B. Noorizadeh, S. Rahmani, M. N. Sabet, Y. M. Salimi, S. Soltani.
Analyzers: S. Asadi, S. Feizbakhsh, T. Kadkhodayan, P. Lotfian, S. Mashhoon, B. Noorizadeh, H. Pazira, S. Rahmani, F. Seifan.

The author is also grateful to Sh. Jafarzadeh for his help and guidance during the whole process of the work.

References

Brown, P., Rendtel, J. : The Current Geminids Meteorid Stream. In preparation, 1997
Fox, K., Williams, I .P., Hughes, D.W. 1983, Mon. Not. R. astr . Soc., 205, 1155
Halliday, I. 1988, Icarus**,** 76, 279
Koschack, R., Rendtel, J. 1990a, WGN, 18, 44
Koschack, R., Rendtel, J. 1990b, WGN, 18, 119
Koschack, R., Rendtel, J., Arlt, R. 1993a, WGN, 21, 152
Koschack, R., Rendtel, J., Arlt, R. 1993b, WGN, 21, 97
Rendtel, J., Arlt, R., Brown, P. 1993, WGN, 21, 19
Rendtel, J., Arlt, R. 1994*,* WGN, 22, 167
Rendtel, J., Arlt, R. 1997*,* WGN, 25, 75
Roggemans, P. 1989, WGN, 17, 229
Roggemans, P., Koschack, R. 1991, WGN, 19, 184