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Visual observations of Geminid meteor shower 2004

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Abstract. Based on 19 hours of effective visual observations with a group of 5 observers, we detected a total of 2352 Geminid meteors from Japal - Rangapur Observatory, a low latitude station. From three days observations of Geminid meteor shower during 11-14 December, 2004, we observed that the peak activity of the shower occurred at 20:30 hrs UT on 13 December with a maximum rate of 257 meteors per hour. The Geminid meteor shower activity produced more number of faint meteors compared to bright meteors on the peak day. The population index value is also high on the peak day of the activity leading to a conclusion that the shower contains more number of small size particles at the centre of the stream. Here we present an analysis of the activity profile of the shower, the magnitude and directional variation of the shower. The luminosity class distribution of the shower is also presented and discussed.

Keywords : Geminid meteor shower - visual observations - magnitudes - population index

1. Introduction

The Geminid meteor shower is one of the strongest and best known meteor showers currently visible on earth. The shower produces a high activity of meteors around 13-14 December, each year with radiant α (Right Ascension) = 113° and δ (Declination) = +32° located in the Gemini constellation (Lovell, 1954). The appearance of the Geminid shower is a relatively recent phenomena for earth based observations. The shower has been observed almost without fail since the 19th century, but was not reliably observed prior to that (Herschel, 1865). The first record of the shower was made in 1862 (King,

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1926). The Geminid meteor stream produces an annual meteor shower of high activity, approximately ZHR = 100 (Spalding, 1984).

The interest in this particular shower is due to the fact that the parent object, asteroid 3200 Phaeton, generally accepted to be associated with the stream is not obviously of cometary nature(Whipple, 1983). The stream is also unique because of an extremely short orbital period of 2.6 years as that of the asteroid. Furthermore, its orbital elements are extremely different to all other major showers intersected by the earth (Rendtel et al., 1995). According to modeling, the Earth will continue to intersect the Geminid meteoroid stream until about the year 2100 (Hunt et al., 1985). From the long term visual observations, a shift in the rate maxima of approximately $0^\circ.31$ within 38 years corresponding to about $0^\circ.008$ (approximately 0.2 hours) per year was found (Rendtel, 2004).

Visual observation is one of the most reliable and accurate method in meteor studies. The observations were carried out at Japal Rangapur Observatory ($17^\circ 05.6' N$, $78^\circ 43.7' E$, elevation 695m) during 11-14 December 2004, incidentally moonless nights. The observational site is far away from city lights ($\sim$ 60 Km), the light pollution is relatively less.

2. Observations

The observations were carried out with the help of a well trained group of five observers. Four of them were seated comfortably back to back facing four directions watching the whole sky. Another observer was seated in the middle, to keep noting the individual events as reported by the observers. If an observer wants a break for a few minutes, he handsover his observing area to his immediate next observer. In this way we continuously recorded the direction and luminosity class of individual meteors in every minute. The details of visual observations recorded are given in Table 1. All the timings are "IST=UT+05:30 hrs".

On 11/12 December, the sky was clear and limiting magnitude observed as +6.0 mag., but occurrence of meteors were less (only about 10 -15 meteors per hour). The magnitude of meteors is rather difficult to measure precisely at a glance. Roughly the luminous class "Faint" in Table 1 ranges from +6.0 to +3.0 mag, "Bright" ranges from +2.0 to −2.0.

On 12/13 December, the observations were taken from 22:50 to 06:00 hrs (LT), and about 585 meteors were recorded, including sporadic meteors. The weather was almost the same as that on 11/12 December. The precise details such as observing intervals, the cloud cover, and the limiting magnitudes were recorded separately for each observational day.

Table 1. Visual observations of the 2004 Geminid Meteor shower, showing the number of meteors seen in various directions, the numbers in each brightness class, and the numbers with enduring trains. Indian Standard Time = UT + 5.5^{h}.

Date	Time (UT)	E	W	N	S	Faint	Bright	Train	shower	sporadic.
11/12	19.00 – 19.59	15	8	8	16	41	6	–	44	3
	20.00 – 20.59	10	10	9	16	39	6	2	42	3
	21.00 – 21.59	18	13	9	26	60	6	9	59	7
	22.00 – 22.59	13	7	4	12	35	1	5	34	2
	23.00 – 23.59	12	7	8	10	34	3	–	29	8
12/13	17.20 – 17.59	23	8	10	17	53	6	2	55	4
	18.00 – 18.59	27	38	11	30	98	8	2	95	11
	19.00 – 19.59	26	40	21	34	115	6	5	112	9
	20.00 – 20.59	29	40	17	38	120	4	2	101	23
	21.00 – 21.59	33	28	18	21	91	9	1	84	16
	22.00 – 22.59	35	23	24	28	106	4	3	95	15
	23.00 – 23.59	35	21	20	36	103	9	2	96	16
13/14	16.00 – 16.59	28	67	7	34	128	8	7	125	11
	17.00 – 17.59	43	78	22	47	176	14	4	181	9
	18.00 – 18.59	35	85	15	32	155	12	6	163	4
	19.00 – 19.59	77	107	19	63	257	9	5	257	9
	20.00 – 20.59	69	86	20	49	219	5	5	212	12
	21.00 – 21.59	66	41	13	47	156	11	3	163	4
	22.00 – 22.59	55	36	30	42	152	11	2	159	4
	23.00 – 23.29	27	17	5	27	71	5	1	75	1

On 13/14 December, the observations were started a little earlier, i.e., at 21:30 hrs. The sky was clear without any clouds up to 02:30 hrs. But from 02:35 hrs onwards, the clouds covered some part of the sky and most of the time the cloud was high and thin, just covering 10-25 per cent of the sky. Around 05:00 hrs, almost the whole sky was cloudy with most of it becoming opaque. On this day, from 21:30 to 05:30 hrs, a total of 1388 meteors were recorded including sporadic meteors. Peak of the shower occurred on 13/14 December at 02:00 hrs with maximum hourly rate of 257 meteors, and at peak hours the rate increased to 5 meteors per minute.

Unfortunately clouds prevented further observations on 14/15 December, so there were no observations on that day. Results are in good agreement with the first global analysis of visual observations by the International Meteor Organization.

3. Methodology

A measure of a shower's activity is commonly expressed in terms of Zenithal Hourly Rate (ZHR), which is the number of meteors a single standard observer would see per hour if the sky was dark enough for a stellar limiting magnitude of +6.5 and shower's radiant were at the zenith. The ZHR is given by

$$ZHR = (N/t_{eff}) * r^{6.5-L_m} * sin(h_r)^{-\gamma} * c_p^{-1} \quad (1)$$

where N is the number of shower meteors recorded during the effective observing time t_{eff} in hours, with the Limiting Magnitude L_m and h_r, altitude of the radiant at the observation time. L_m is defined as the faintest star visible in the observer's field of view. An estimate of the sky limiting magnitude is made by counting the number of stars visible in certain selected regions of the sky. An exponent $\gamma > 1$ has been proposed (Bellot, 1995) as a proper correction. For visual observations, since we do not use observations for which the radiant is less than 20^o altitude, we adopt γ =1.0 like Brown and Rendtel (1996) and Arlt (1998) did. The population index r, defined as

$$r = N(M + 1)/N(M) \quad (2)$$

where N(M) is the total number of meteors of magnitude M or less, was calculated from the linear part of the logarithm of meteor number, N, versus meteor magnitude M. It was obtained from the slope of a best least squares fit regression line through the logarithmic true meteor numbers (Figure 2). t_{eff} = 1 throughout the observation period except twice where it is 0.6 and 0.5. The perception correction C_p is observer dependent and it is derived by comparing the observed sporadic rates with the expected sporadic rates seen by a standard observer. For a single standard observer it varies between 0.4 and 2.5 and has a median value close to 1.0(Jenniskens,1994). For a group of observers watching different azimuthal directions the correction factor apply : C_p = 1.8 for 2 observers, C_p = 2.4 for 3 observers and C_p = 2.9 for 4 observers as suggested by Jenniskens (1995). For our observations a correction factor C_p = 2.9 would be applied. During the observing period sometimes the field of view was not completely clear and considering the factor based on the number of meteors missed as being proportional to the field fraction obscured. We adopt C_p in the range of 2.1 to 1.4. The parameters chosen for data reduction are listed in Table 2.

4. Results and discussion

Analysis of the mean hourly rates throughout the active nights of the shower shows peak around 02:00 hours (Figure 1). Oliver (1960) and Lokanadham (1980) got two peaks during the observational nights with a minor peak before midnight followed by the main maximum peak around 02:00 hours. Our observations show the major peak around the same time, but do not show any minor peak. This may be an effect of the radiant being at an altitude lower than 20^o at the commencement of observation and we could not notice any minor peak activity as earlier observers' did, but the calculated ZHR rates show some trend of minor peak before midnight (nearly 16:30 hrs UT) besides main peak around 20:30 hrs UT as shown in Table 2. There was a slight increase in sporadic activity on 12/13 December at 20:00 hrs UT possibly due to activity of minor showers on that particular day.

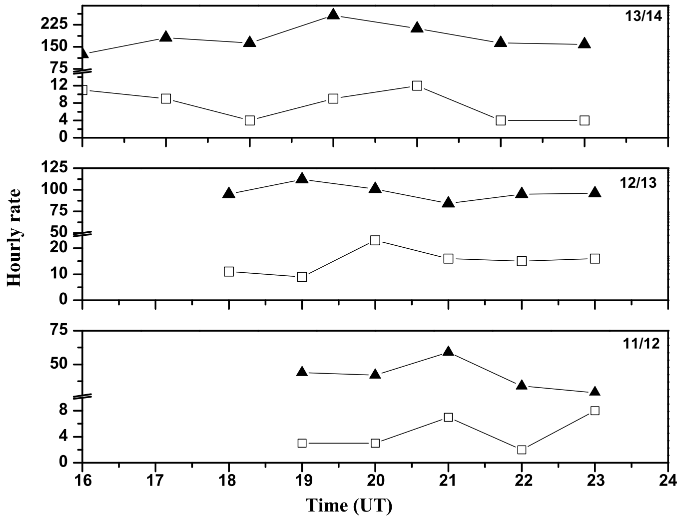

Figure 1. Variation of Mean hourly rate during Geminid Meteor Shower 2004. (Triangle) represents shower rates and (Square) represents sporadic rates.

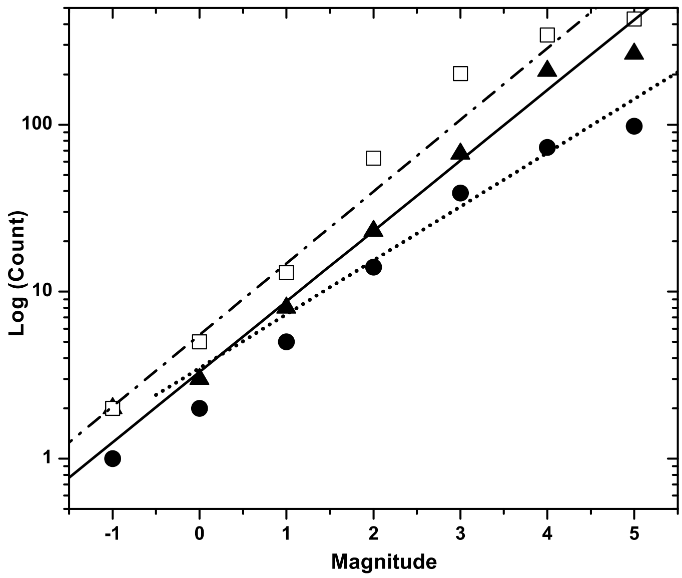

Figure 2. Luminosity class distribution of the shower with a group of four observers. (circle) represents 11/12 night, (Triangle) represents 12/13 night and (square) represents 13/14 night.

Table 2. The corrected Zenithal Hourly Rates (ZHR).

Date	Time (UT)	T_{eff}	N	L_m	$\sin(h_r)^{-1}$	c_p	ZHR.
11/12	19.00 – 19.59	1	47	5.5	1.15	2.1	52
	20.00 – 20.59	1	45	5.5	1.035	2.1	44
	21.00 – 21.59	1	66	5.5	1	2.1	63
	22.00 – 22.59	1	36	5.5	1.035	2.1	35
	23.00 – 23.59	1	37	5.2	1.15	2.0	53
12/13	17.20 – 17.59	0.6	59	5.5	2.0	2.1	228
	18.00 – 18.59	1	106	5.5	1.414	2.1	183
	19.00 – 19.59	1	121	5.5	1.15	2.1	176
	20.00 – 20.59	1	124	5.5	1.035	2.1	161
	21.00 – 21.59	1	100	5.5	1	2.1	126
	22.00 – 22.59	1	110	5.4	1.035	2.0	166
	23.00 – 23.59	1	112	5.3	1.15	2.0	207
13/14	16.00 – 16.59	1	136	5.5	2.92	2.1	500
	17.00 – 17.59	1	190	5.5	2	2.0	502
	18.00 – 18.59	1	167	5.2	1.414	1.9	362
	19.00 – 19.59	1	266	5.2	1.15	1.8	497
	20.00 – 20.59	1	224	5.2	1.035	1.6	465
	21.00 – 21.59	1	167	5.2	1	1.4	421
	22.00 – 22.59	1	163	5.2	1.035	1.4	412
	23.00 – 23.29	0.5	76	5.2	1.15	1.4	398

Since the population index is necessary for computing the mass index S and mean hourly rate, the individual population indices r, were calculated according to Koschack and Rendtel (1990). From the linear regression part of the logarithm of number of meteors to the meteor magnitude, the width of the magnitude class is found to be 1 (Figure 2.).

The population index r can be related to mass index S as (McKinley, 1961)

$$S = 1 + 2.5log(r) \tag{3}$$

We found from these observations, that the population index r = 2.0 for 11 December and r=2.64 for 12 and 13 December, corresponding mass indices are S = 1.752 and S = 2.054 respectively. These values are comparable to the values obtained by Arlt and Rendtel (1994). Our observations show high mass distribution indices indicating a low activity of larger size particles in the stream followed by the dominant appearance of smaller size particles with low mass distribution indices.The population index value is more on peak activity day leading to a possible conclusion that the shower contains more number of smaller size particles at the centre of the stream. By knowing different values of population index r, we have calculated the Zenithal Hourly Rates (ZHR) of the Geminid shower for three days of observation. The ZHR values are given in Table 2. We have calculated ZHR at every minute using the present time as the central time of the t_{eff}.

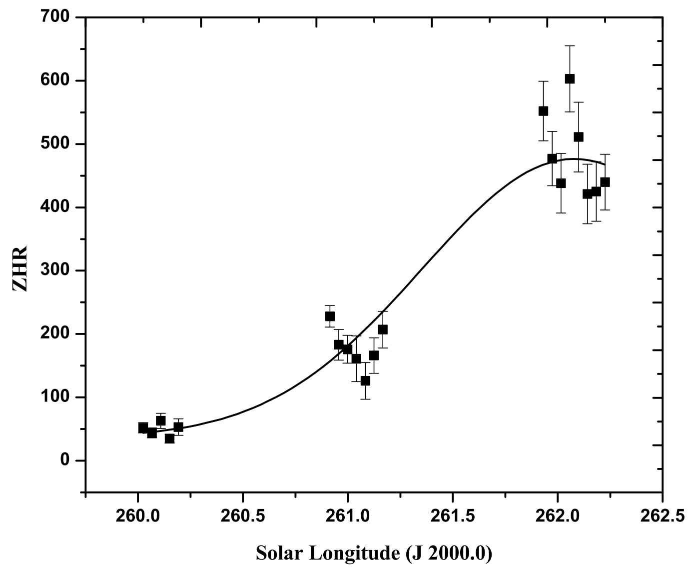

Figure 3. Variation of ZHR with solar longitude on peak activity day during Geminid Meteor Shower 2004.The solid curve represents the gaussian fit to the data.

This method is similar to the Time window - smoothing method by Wu and Williams (1994). In Figure 3, we can see the comparison of our results with IMO results. Our results show a maximum ZHR value of over 500 at the solar longitude $\lambda_o = 262.05 \pm 0.15$ which is a bit early in the trend found by Rendtel (2004) suggesting 262.16°-262.17°. The variation in ZHR values with solar longitude observed during shower period are comparable with the rates of the first global analysis of Geminid meteor shower 2004 by the IMO obtained from 46 observers (IMO 2005). The solid curve in Figure 3 represents the Gaussian fit to the data which shows the trend of the Geminid meteor shower.

The magnitude distribution of the occurrence rate during Geminid meteor shower period is shown in Figure 4. The percentage occurrence of bright meteors is high on 11/12 (dotted line), whereas that of faint meteors on 12/13 (solid line) and 13/14 (dash dotted line). This may be due to different particle size distribution of the shower activity on different days.The meteoroid distribution inside the stream is not uniform, as the earth encounters different parts of the stream on different days, observations may receive different sizes of meteors on different days resulting in the magnitude shift of the peak in Figure 4.

Conclusions

The occurrence of peak activity is observed on 13 December at 20:30 hours U.T which corresponds to solar longitude $\lambda_o = 262.05 \pm 0.15$. We found that the values of popula-

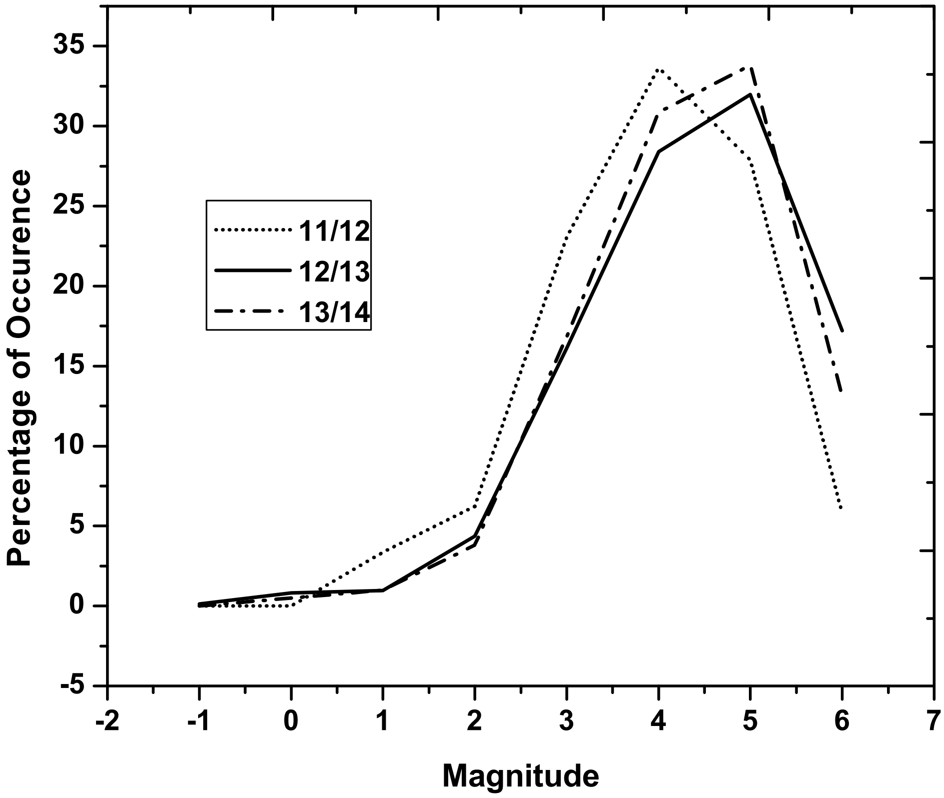

Figure 4. Magnitude distribution of Geminid meteors. Short dotted lines represent 11/12 night, solid line represents 12/13 night and dash dotted lines represent 13/14 night. The magnitude shift in the peak shows different size distribution of meteroids inside the stream on different days.

tion index r = 2.0 (S = 1.752) for 11 December and r=2.64 (S = 2.054) for 12 and 13 December.The population index value is more on peak activity day leading to a possible conclusion that the shower contains more number of smaller size particles at the centre of the stream.The magnitude distribution gives the percentage occurrence of bright meteors which is high on 11/12, whereas that of faint meteors on 12/13 and 13/14 because of size distribution of particles of the shower differently on different days.

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