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MST radar observations of Perseid meteor shower 2004

D. Venkata Phani Kumar, K. Chenna Reddy and G. Yellaiah*
Department of Astronomy, Osmania University, Hyderabad 500 007, India

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Abstract. There was a special attention for Perseid meteor shower observations in view of the predictions of an intense activity on 11^{th} August 2004 caused by a filament of dust drifting across the Earth's orbit. Results of a systematic study of Perseid meteor shower observations, carried out during 12-15 August 2004 using Indian MST radar are presented. Based on over 27 hours of observing time, we detected 2260 meteor echoes occurring between 80 km and 120 km with a mean height of 103 km. For our observations, the peak activity of the shower occured on 12/13 August, corresponding to solar longitude $\lambda_o = 140.565 \pm 0.16$ with an average rate of 250 meteor echoes per hour. The SNR distribution of the echoes observed during the shower indicates that the smaller size meteoroids are more compared to larger size meteoroids in the perseid meteor stream. The three distinct peaks observed in the shower activity is presented and discussed.

Keywords : meteor shower - Perseids - radar - activity

1. Introduction

The Perseid meteor shower is one of the most intense and active showers occurring in the month of August every year, with radiant co-ordinates α (Right Ascension) = 44^o and δ (Declination) = $+56^o$ located in the Perseus constellation (Lovell, 1954). The parent comet 109P/Swift - Tuttle returned to its perihelion in December, 1992 after a lapse of 130 years, since its last return in 1862. Based on ancient records, Perseid meteor shower

*e-mail: gyh042000@yahoo.co.in

is one of the oldest of all recorded showers (Hasegawa, 1993). Detailed observational history of the stream has been given by Kronk (1988) and Rendtel et al. (1995).

Long term Radar observations of Perseids from 1958-1974 by the Ottawa radar have been used to determine the relative flux of the shower in particle size ranges producing radar meteor echoes with two different echo durations (Simek and McIntosh, 1986). Stream cross-section, sporadic index and shower activity level were determined from 12 years of radar observations of Perseid meteor shower at Ondrejov observatory (Simek, 1987). Forward Scatter bistatic meteor radar observations of Perseids 1992 were performed from Japan and they recognised two peaks as it was known and they showed that the time variation of the meteor flux is not smooth (Watanabe et.al., 1992).

Perseid meteor shower of 2004 was considered to be a special event. Predictions suggest that a new peak could stage a return appearance from 1-revolution rubble trail released in 1862 (Rao, 2004) and produces high intensity of the shower and the filament, like all the rest of the dust in the Perseid cloud, comes from Comet Swift-Tuttle. Other dust in the cloud is older (perhaps thousands of years old), more dispersed, and responsible for the month-long shower that peaks on August 12^{th}. The filament will eventually disperse, too, but for now it retains some of its original ribbon-shape.

In this paper, we report 2004 Perseid meteor shower observations by using Indian MST radar at Gadanki (13.46^{o}N, 79.18^{o}E). In the following sections, the observational method, meteor echo detection method and processing procedure are presented. The results and conclusions are presented in the last section.

2. Observations

Operating at 53 MHz frequency having a peak power of 2.5 MW with a narrow pencil beam pointed in different directions using the Doppler beam swinging technique, Indian MST radar is capable enough to give finer details of meteor echoes. The system description and technical details of the Indian MST radar are given by Rao et.al (1995).

Observations were carried out in meteor mode to observe Perseid meteor shower during 12 - 15 August 2004 between 03:30 hrs and 11:30 hrs UT using Indian MST radar, by setting the sampling range from 80-120 km and the range resolution as 1.2 km. Doppler spectra of the amplitude variation for meteor trails have been recorded continuously throughout the observational period. The beam was switched in four directions with a time series of 2 seconds. The Doppler spectra of the meteor echoes have been recorded with beams E_{20}, N_{20}, and Z_x followed by N_{13} for sporadic-E observations. The probability of appearance of meteor trail in two or more directions simultaneously is very low. As a result, along with the obvious advantage of making measurements in different directions independently, we do not lose any meteor rate statistics in any measurement with our

Doppler beam-swinging mode of operation. The data thus recorded was processed off-line to separate the frames having signature of meteor echoes.

3. Method of analysis

The activity of meteor stream can be studied from various aspects. We confine ourselves here to the echo counting method for radar observations of the shower.We have used 53 MHz MST radar of Gadanki (13.46^{o}N, 79.18^{o}E) to detect the shower activity. The same radar was employed in comparing the 1998 activity of Leonid shower with the visual rates (Lokanadham et al., 2000). In the present observations, hourly rates of meteor occurrence on each night were estimated from the counts of the off- line display of Doppler spectra. The signal to noise ratio of meteor trail signals is high in general, and larger than about 10 dB (Chu and Chian, 1990). The signal with SNR > 10 dB are chosen for the study. Depending on the size of the meteoroid, the meteor echo sometimes spreads over two or more adjacent range bins. To avoid multi-counting of the same echo, the range bin with strongest echo power is selected.

The data available from radar is limited by noise, clutter and other interferences. So a processing method is required to enhance signal and to suppress noise. Spectral averaging method improves signal to noise ratio. The occurrence of different spectra has been studied phenomenologically. A convenient method is to compute the spectral moments from the measured spectra. The spectral moments are computed through numerical integration using expressions given by Woodman (1985). The Zeroth, first and second order moments are calculated by using the following expressions.

$M_0 = {}^n\Sigma_{i=m}\ P_i$ – represents total signal power

$M_1 = 1/M_0\ {}^n\Sigma_{i=m}(P_i\ F_i)$– represents the weighted mean Doppler shift

$M_2 = 1/M_0\ {}^n\Sigma_{i=m}\ P_i\ (F_i - M_1)^2$ – represents the variance, measure of dispersion from central frequency

where $F_i = (i - N/2) / (IPP * n * N)$

'n' and 'm' are the upper and lower limit of the Doppler bins of the spectral window
P_i and F_i are the power and frequency corresponding to Doppler bins
N is the number of FFT points.
IPP is the inter pulse period in microseconds.

Signal to noise ratio SNR in dB is calculated as

$SNR = 10 \log(M_0/N*L)$ dB

where L is mean noise level, on multiplication (N * L) gives the total noise over the whole bandwidth.

4. Results and discussion

Maximum activity was predicted in 2004-2006 (Brown, 1998), because of the close approach of Jupiter to Perseid meteor stream in early 2003. From long term modeling results, Brown predicted that the future activity of the perseids is expected to wax and wane and the strength of the outburst maxima should be quite variable.In the year 2004, in addition to the usual shower activity on August 12, an enhanced activity of meteors are expected late in the evening of 11^{th} caused by a filament of dust drifting across Earth's orbit. This filament, like all the dust in the Perseid cloud, again comes from Comet Swift-Tuttle. The difference is relatively young filament 'boiled' off the comet in 1862. Other dust in the cloud is older (perhaps thousands of years old), more dispersed, and responsible for the month-long shower that peaks on 12^{th} August. The filament will eventually disperse, too, but for now it retains some of its original ribbon shape. Our observational results in the year 2004 are comparable with predictions.

The radar time was allotted for 3 days only and our observations were confined to 12/13, 13/14 and 14/15 August 2004. The shower activity was high on 12/13 with a maximum average hourly rate of approximately 250. As there was no data on 11/12 August we could not see the primary peak in the activity of the shower as reported by some of the observers. The lack of data on 11/12 August prevented us from showing more data points before the occurrence of the peak in the curve of Figure 1. From our observations of the Perseid meteor shower 2004, it is found that the shower is active

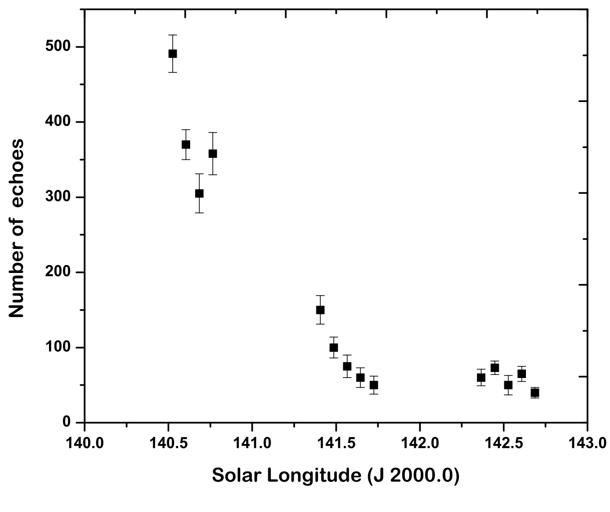

Figure 1. Variation of activity with solar longitude (J 2000.0).

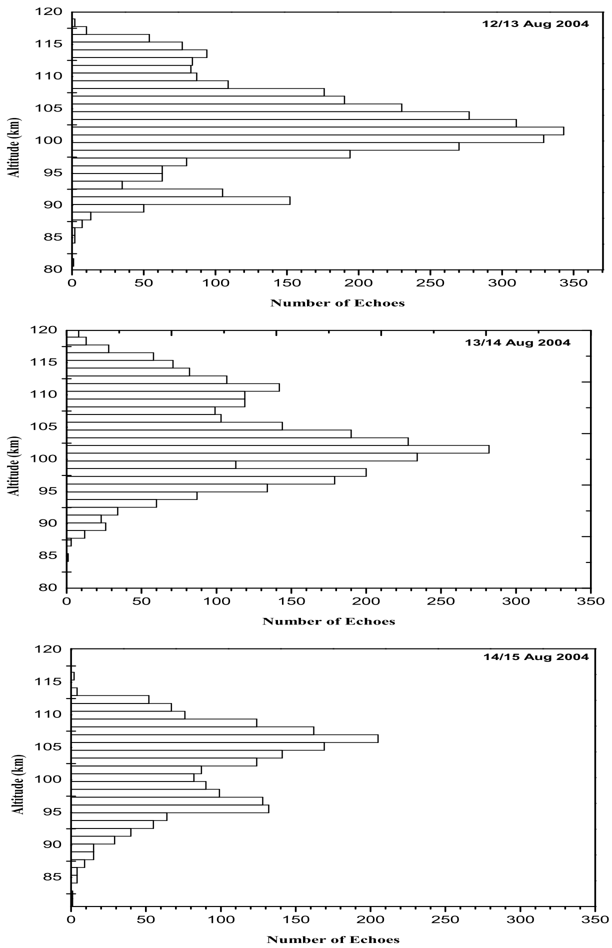

Figure 2. Altitude distribution of Perseid meteor echoes (a) 12/13 (b) 13/14 and (c) 14/15 August 2004.

with a maximum average hourly rate of 250 on 12/13 August. The variation of the shower activity with respect to solar longitude shows that the shower attains its peak value at $\lambda_o = 140.565 \pm 0.16$ (Figure 1). Figure 2 shows the altitude distribution of Perseid meteor echoes. Altitude here corresponds to the range with cosine of radar beam inclination angle. The activity of the shower is found to be more between 80 km and 120 km with peak value occurring at about 103 km. These results are consistent with that of other observations carried by 52 MHz radar (Chu and Chian, 1990). From this figure it is also seen that the Perseid shower activity produces two distinct peaks on 12/13 August. This evidences the fact that the meteor trails at high altitudes are more compared to that of low altitudes due to size distribution of meteoroid particles originated from the parent

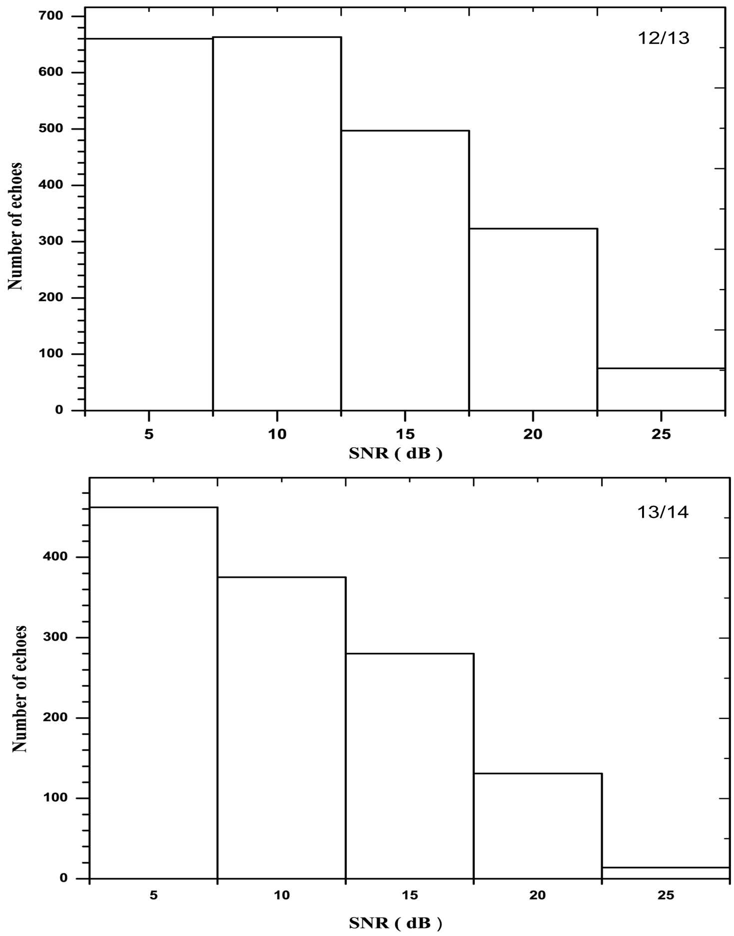

Figure 3. Number of echoes with different SNR's (a) 12/3 August and (b) 13/14 August 2004.

comet. Figure 3. shows the variation in number of meteor echoes with different SNR values. It is seen that the number of meteor echoes observed are more with lower SNR values and less when SNR value is high. The meteor echoes with SNR $\leq$ 5 dB and SNR $\geq$ 20 dB are distributed at altitude range above and below 105 km respectively. This indicates that the occurrence of smaller size meteoroids are more in number at higher altitudes than that of larger size particles (Figure 4). Echoes at lower altitudes have usually longer duration because of slower ambipolar diffusion and thus small diffusion coefficient. It is noticed that the similar distribution observed for meteor echoes with different values of SNR. These observations conclude that the number density of larger size particles is less compared to smaller size particles in the Perseid meteor stream and this is in agreement with the results obtained by other observers.

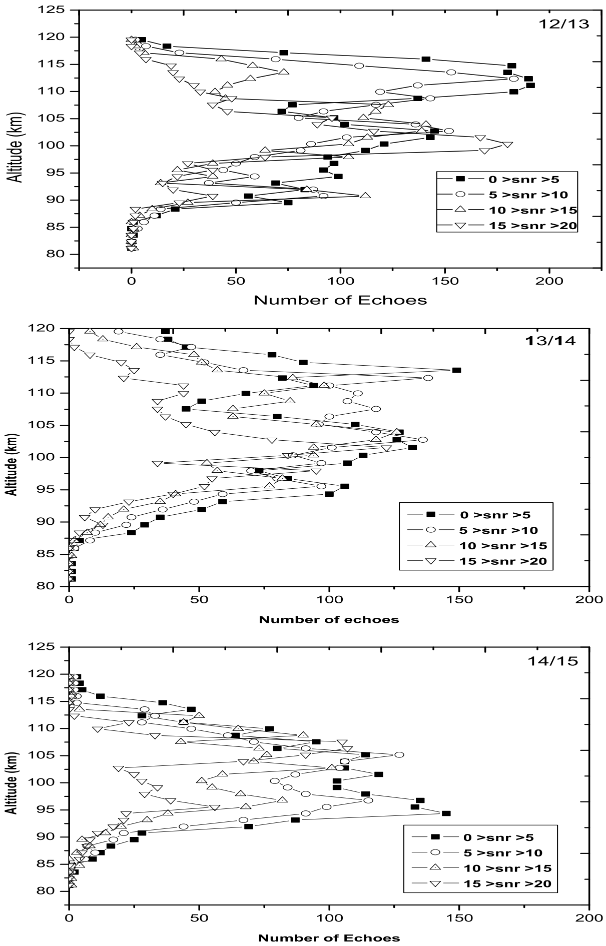

Figure 4. Altitude distribution with number of echoes of different SNR's (a) 12/13 (b) 13/14 and (c) 14/15 August 2004.

From Figure 4 it is also seen that the shower produces three distinct peaks in SNR height distribution curves with more pronounced activity at an altitude of around 115 km, moderate activity at around 100 km and less pronounced activity at around 92 km. Perseid meteor shower produced three discrete peaks of activity at three different heights on 12/13 and 13/14 whereas it is a broad single peak on 14/15 August in the SNR height distribution curves. This can be interpreted as, due to the earth crossing different parts of the meteor stream on different days and the structure and composition of different parts of the stream is different due to addition of new meteoroids released by recent perihelion passage of the parent comet. These results are in agreement with the results of the earlier workers (Koschack and Roggermans, 1991 and Roggermans, 1989). More detailed analysis is required to understand the stream structure.

5. Conclusions

From the observations of Perseid meteor shower 2004, it is found that the shower is active with a maximum average hourly rate of 250 on 12/13 August that corresponds to solar longitude $\lambda_o = 140.565 \pm 0.16$. The altitude distribution shows that the activity of the shower is found to be more between 80 km and 120 km with peak value occurring at about 103 km. SNR values ≤ 5 dB and ≥ 20 dB are distributed at altitude range above and below 105 km respectively. From the height distribution of meteor echoes and the SNR distribution curves, it is seen that the small size meteoroids are mostly drifted to the outer rim of the stream and the large size meteoroids are more concentrated in the central region and they are comparatively more in number and the peak activity is due to these large size meteoroids. The production of three distinct peaks in the shower activity at three different height regions on different observing days can be interpreted as due to the earth crossing different parts of the meteor stream on different days and the structure and composition of different parts of the stream is different due to addition of new meteoroids emitted by recent perihelion passage of the parent comet.

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