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Mesospheric sodium over Gadanki during Geminid meteor shower 2007

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Resonance LIDAR system at Gadanki has been used for observing the mesospheric sodium during the night of 12-13 Dec 2007 when the peak activity of Geminid meteor shower occurred. Geminid meteor shower is observed along with the co-located MST radar in the altitude range 80-110 km. Sodium density profiles have been obtained with a vertical resolution of 300 m and a temporal resolution of 120 s with sodium resonance scattering LIDAR system. The sodium layers were found to exist in the altitude range 90-100 km. The enhanced Geminid meteor rates were recorded with the co-located MST radar in the same altitude range. The sodium concentration in the atmospheric altitude of ~93 km is estimated to be 2000 per cc where the meteoric concentration of Geminid is maximum and reduced to around 800 on the non activity of Geminid. These observations showed that the sodium levels in the E-region are found to be increasing during meteor shower nights at least by a factor of two.

Keywords: Geminid meteor shower, Mesospheric sodium

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1 Introduction

Geminid meteor shower is one of the prominent meteor showers associated with an asteroid having a period of 1.4 years. The shower occurs every year during 9-16 December with maximum rate of occurrence on the night of 13-14 December. The radiant position of the shower is 113° α (right ascension) and +33° δ (declination) located in the constellation Gemini[1]. The shower has been observed visually since 1862 (ref 2) producing an annual peak activity rate of about 100 [ZHR]. The Geminid shower has been observed using VHF Radars in recent times. The activity of the Geminid shower has been studied with MST Radar located at Gadanki (13.5°N, 79.2°E) in 2007 along with the co-located Resonance Lidar for studying the sodium deposition during the shower.

The metallic elements like sodium, iron, potassium and calcium gets deposited in the lower thermosphere (80-110 km) region due to ablation of meteoroids[3-6]. Of these metallic species, the occurrence of sodium layers is a common phenomenon at low and high latitudes but is rare at mid latitudes[7-10]. The objective of this paper is to establish the part played by meteor showers in the metallic ion layer formation at mesospheric heights over low latitude regions like Gadanki (13.5°N, 79.2°E, dip 12.5°N, magnetic latitude 6.3°). The earlier works from this site were confined to the study of the characteristics of the sporadic sodium layers occurring at these heights but not on its generation mechanism.

2 Observations

MST Radar was operated in meteor mode to observe Geminid meteor shower echoes during 10-14 December 2007 between 2000 and 0600 hrs LT on every night. The technical details of the Radar system are given in ref 11. The Doppler spectra of meteor echoes have been recorded continuously with the beams E_{20}, W_{20}, Z_x, and N_{20} in successive cycles. The radar parameters were selected such that the PRF 1000 Hz with a pulse width of 8 µs. Each data frame had 34 range bins at 1.2 km intervals in the range 79.95-119.55 km. The in phase (I) and quadrature (Q) samples for each bin were averaged making the effective sampling interval of 4 ms. The data were processed offline to separate the frames containing signatures of meteor echoes (the meteor echoes can be differentiated from other echoes as they have a sharp rise followed by an exponential decay). The meteor echoes were found very frequently in time and height during peak active periods of the Geminid meteor shower.

The observations of sodium deposition in the mesospheric region over Gadanki have been taken with the co-located Sodium Resonance Scattering LIDAR operating at a wavelength of 589 nm simultaneously with MST Radar observations of Geminid meteor shower. The broadband sodium lidar system at Gadanki was set up in a monostatic configuration. The power aperture product of the Lidar system was approximately 0.35 Wm^2. The detailed Lidar specifications are given in Table 1. The details of Lidar system and obtaining the profiles of sodium have been discussed by Bhavani Kumar *et al.*[12]. The Lidar observations were conducted on the peak night of Geminid meteor shower on 12/13 December 2007 and for two hours on 15 December (during 0100 - 0300 hrs LT) because of unclear clouds.

3 Results and discussions

3.1 Geminid meteor shower occurrence characteristics

The Geminid meteor shower variations were recorded during 2000-0600 hrs LT on 11-14 December and are presented in Fig. 1. The peak rate of occurrence has been observed during the night of 12/13 December. Figure 2 shows the semi-diurnal variation of the Geminid meteor shower during the peak night of 12/13 December and non-active day 14/15 December. The maximum rate of occurrence was observed during 0200-0400 hrs LT. The heights of occurrence of Geminid meteor trails is computed from the average of several profiles obtained during different times of the whole night of Geminid meteor shower and presented in Fig. 3. It is observed from Fig. 3 that the maximum number of meteors occurred in the height range 90-105 km with a maximum at 100 km. No bi-model distribution of the meteor flux was observed as also reported by Ryabova[13].

3.2 Sodium Lidar observations

The sodium profile obtained with the Resonance Scattering Sodium Lidar on the peak night of Geminid shower along with non-active day is presented in Fig. 4. The profile values, thus, plotted were the averaged values of sodium densities occurred through out different times of the observation period at the corresponding heights.

The Resonance Sodium Lidar observations of Sodium (Na) layers at mesospheric and lower thermospheric heights are very important to delineate the characteristics of the Na layer. During Lidar observations, it was noticed that the sudden formation of dense thin sodium layer superposed on variations of normal sodium layer. Such an enhanced layer was called as Sporadic sodium layer (SSL). The thickness of SSL is typically of the order of 1-2 km full width at half maximum (FWHM). These characteristics of Na layers found in Fig. 4. are obtained during Geminid

Table 1—Specifications of Sodium Lidar

Transmitter	
Pump Laser	
Continuum, USA make power Lite model 8020	
Repetition rate	20 Hz
Energy (per pulse)	200 mJ max
Laser beam size	8 mm
Pulse width	6 ns
Line width	1 cm^{-1}
Dye Laser	
Continuum, USA make Jaguar Narrow scan model D90DMA	
Tunable range	330-740 nm
Tuning mechanism	Dual Grating
Dye used	Sulfo-Rhodamine–B(Kiton Red)
Energy (per pulse)	25 mJ
Grating resolution	2400 lines/mm
Precision	1 pm
Divergence	set to 1.0 mrad
Line width	0.05 cm^{-1} or 2 picometer
Stability	0.05 cm^{-1o} $C^{-1}h^{-1}$
External beam expander (CVI, USA)	10×
Divergence (After beam expander)	100 μrad
Receiver	
Telescope diameter	750 mm, Newtonian type
Field of view	1.0 mrad
IF filter CW	589.0 nm
IF filter FWHM	1.0 nm
Peak transmission	60%
PMT	12 dynode, low dark current (1nA), room cooled type (Hamamatsu make R3234-01)
Quantum efficiency	8%
Gain of PMT	2.5 × 10^7 units
Data acquisition system	
Type	single photon counting
Model	EG & G Ortec, MCS-plus
Maximum counting rate	100 MHz
Bin width	2 μs
Number of bins per pulse	1024

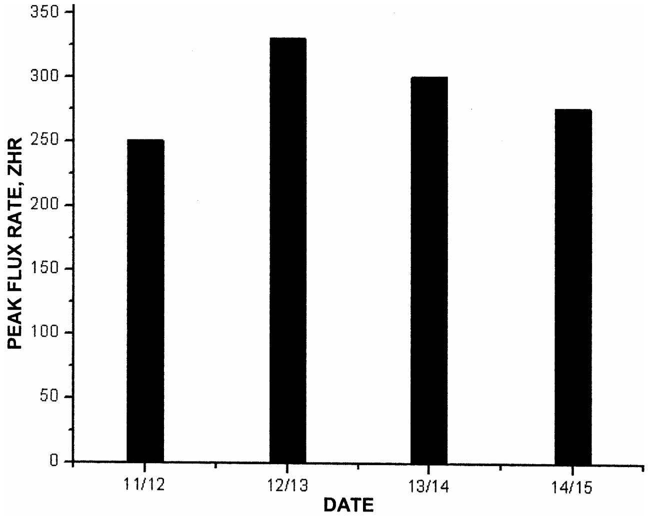

Fig. 1—Day-to-day variation of the rate of Geminid meteor shower

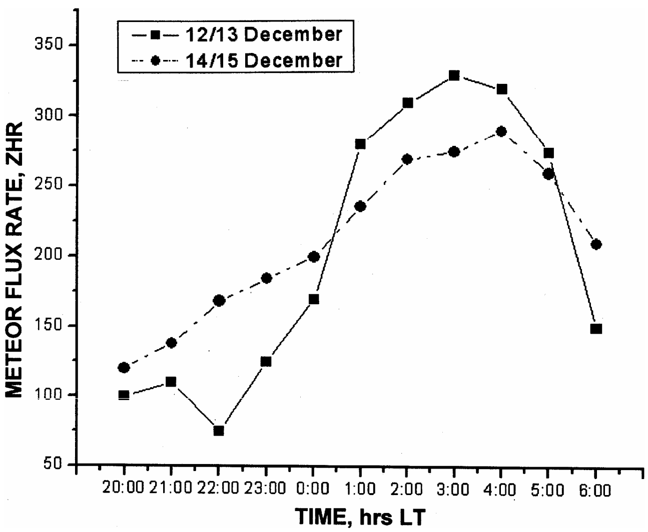

Fig. 2—Diurnal variation of Geminid meteor shower on 12/13 December 2007

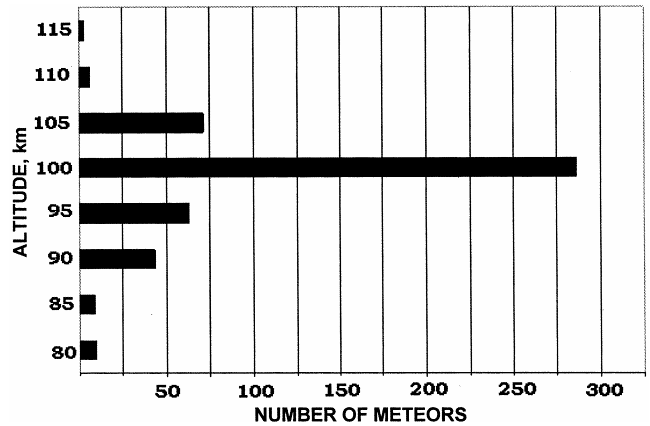

Fig. 3—Height distribution of Geminid meteor shower on 12/13 December 2007

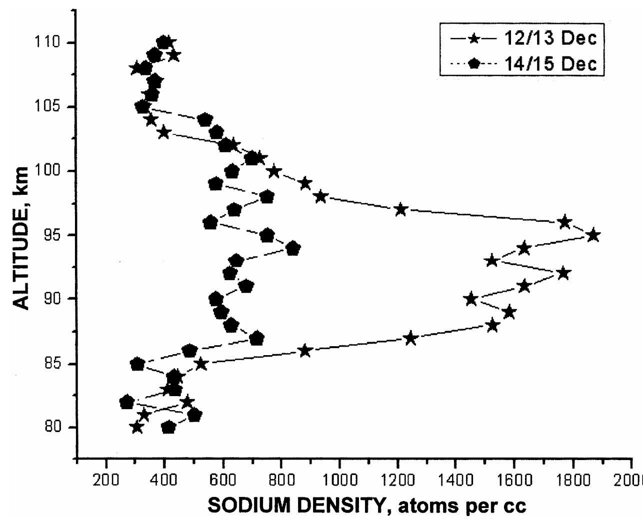

Fig. 4—Sodium profile of Geminid meteor shower

meteor shower which also shows the comparison of sodium density on peak day (12/13 December) to less activity day (14/15 December). The formation periods of SSL vary from few minutes to few hours and these layers are found to be confined to the height range of 90-100 km with maximum density of Na at ~93 km. These characteristics of SSL are consistent with the earlier observations[14].

4 Conclusions

From the MST radar observations of Geminid activity, it can be inferred that the meteoric stream is composed of thick dense particles which were accumulated because of fresh release from parent asteroid due to extremely short revolution period (1.4 years). As a result, no significant variation in the meteoric activity on successive days was observed even though a considerable decline in the activity on other days was noticed. The lidar observations of sodium layers at the low latitude site Gadanki (13.5°N, 79.2°E) along with the MST Radar observations of Geminid meteor shower gives considerable evidence: to rule out the generation mechanism behind the formation of SSL; the meteor showers deposit Na in the E region heights over the thin layers of Sodium; and is enhanced almost by double during the major meteor showers like Geminids (evident from Fig. 4) so that SSL occur over Gadanki. The characteristics of sodium ion layer observed are in agreement with those reported earlier from this site. It is observed from Figs 3 and 4 that there is no exact correlation between the height of occurrence of meteors and the altitude region of sodium ion layer formation as the meteors entering the Earth at higher speeds undergo differential ablation and different elements are released from the meteors at different times of their flight depending on the volatility of the elements present and the entry speeds of incoming meteors. Hence, the Lidar-observed trails provide the information on late phase of ablation of the trail producing the meteoroids and strictly speaking the Lidar-observed altitude distributions of meteor trails cannot be taken to consider intrinsic meteor altitude distribution.

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