Now

$$\begin{pmatrix} tr\ x^{n-1} \\ tr\ x^{n-2} \\ \vdots \\ tr\ 1 \end{pmatrix} = M^{-1} \begin{pmatrix} a_1 \\ 2a_2 \\ \vdots \\ na_n \end{pmatrix}$$

and hence we have, for $1 \le i \le n$,

$$tr\ x^{n-i} = ia_i + (i+1)a_{i+1}c_{n-1} + (i+2)a_{i+2}c_{n-2} + \cdots + (n-1)a_{n-1}c_{n-i+1} + nc_{n-i}.$$

It can also be verified that $c_{n-i}$ is a polynomial in $a_{n-1}$ of degree $i$ with leading coefficient $(-1)^i$, so that $tr\ x^i$ is a polynomial in $a_{n-1}$ of degree $i$, with the same property. This yields a fairly explicit formula for the traces of powers of a linear transformation in terms of the entries of the companion matrix.

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Received 11 April 2003; accepted 17 April 2003

# A new plasma wave over low latitude ionosphere during Leonid meteor storm

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**Leonid meteor storm is a unique astronomical event that occurs once in 33 years. In order to investigate the effect of Leonid meteor storm over low latitude ionosphere, rocket measurements of plasma parameters were carried out on 18 and 20 November 1999 from Sriharikota, India. The meteoric activity was at its peak on 18 November 1999. Results obtained on plasma waves using a high frequency Langmuir probe revealed for the first time, an experimental evidence for the presence of sub-meter scale size plasma wave over low latitude E-region. The peak amplitude of the plasma wave occurs at 105 km with a magnitude of ~4% of ambient electron density. The ambient plasma conditions during these measurements imply that the causative mechanism for the generation of this plasma wave is different from well known gradient drift waves.**

LEONID meteor shower associated with comet Tempel-Tuttle occurs every year during 17–18 November with a typical meteor zenith hourly rate (ZHR) of around five[1]. However, Leonid meteor storm occurs once in about 33 years with intense ZHR of a few thousands[2,3] when the above comet approaches inner solar system. In the literature[3,4], *in situ* measurements during an intense meteor storm is not available from a low latitude region prior to the present rocket measurements during Leonid storm 1999. Two RH-300 Mark-II rockets (F.1 and F.2) carrying high frequency Langmuir probe sensor mounted on booms perpendicular to spin axes of the rockets were launched from Sriharikota (13.7°N, 80.2°E, dip lat. 6.0°N) on 18 and 20 November 1999 respectively at 7.25 and 7.03 IST (Indian Standard Time = UT + 5.30). The launch of F.1 coincided with the peak activity of Leonid meteor storm, while the launch of F.2 happens to be when the activity reduced to one-third. The ambient electron densities ($n_e$) and fluctuations ($\Delta n_e$) in them which represent the plasma waves were measured along the trajectories of the rockets. Earlier studies[5–7] on plasma waves during normal days revealed only gradient drift waves over a low latitude station like Sriharikota. However, over magnetic equator, other plasma waves known as type I waves[5,8,9] associated with equatorial electrojet have also been observed. The above two types of plasma waves have a cut-off scale size of a few meters[5,9].

Figure 1 depicts the telemetry raw data from a high frequency (100 Hz to 3 kHz) channel representing the fluctuations in the electron densities corresponding to about 105 km altitude obtained on 18 November 1999. The expanded portion of the diagram corresponding to the time interval when high frequency fluctuations are observed in Figure 1 *a*, is given in the bottom panel of the diagram as Figure 1 *b*. During a time interval of 0.02 s, forty peaks are seen in Figure 1 *b* which correspond to ~ 2 kHz wave frequency in the rocket frame of reference. Similar features were observed on 20 November 1999. It can be noticed from Figure 1 *a* that these high frequency fluctuations are found only on certain durations revealing that these fluctuations are geophysical and anisotropic in nature. Taking into consideration measured vertical velocity of the rocket (~ 1 km/s) at 105 km altitude, the observed 2 kHz plasma waves (in Figure 1 *b*) correspond to a scale size of about 50 cm. Thus, an evidence for the presence of sub-meter scale size of the plasma waves is reported here for the first time from a low latitude E-region of the ionosphere.

Figure 2 depicts the altitude profiles of electron density along with the average values of the amplitudes of the plasma waves observed on 18 November 1999. Considering the errors in the measurements, wave amplitudes greater than ~0·5% have physical significance. The plasma waves are observed to confine in the altitude region of 100 to 120 km with a maximum amplitude at an altitude of 105 km. From Figure 2 it is clear that the absence of plasma waves in a steep electron density gradient region (90–94 km) and a presence of maximum

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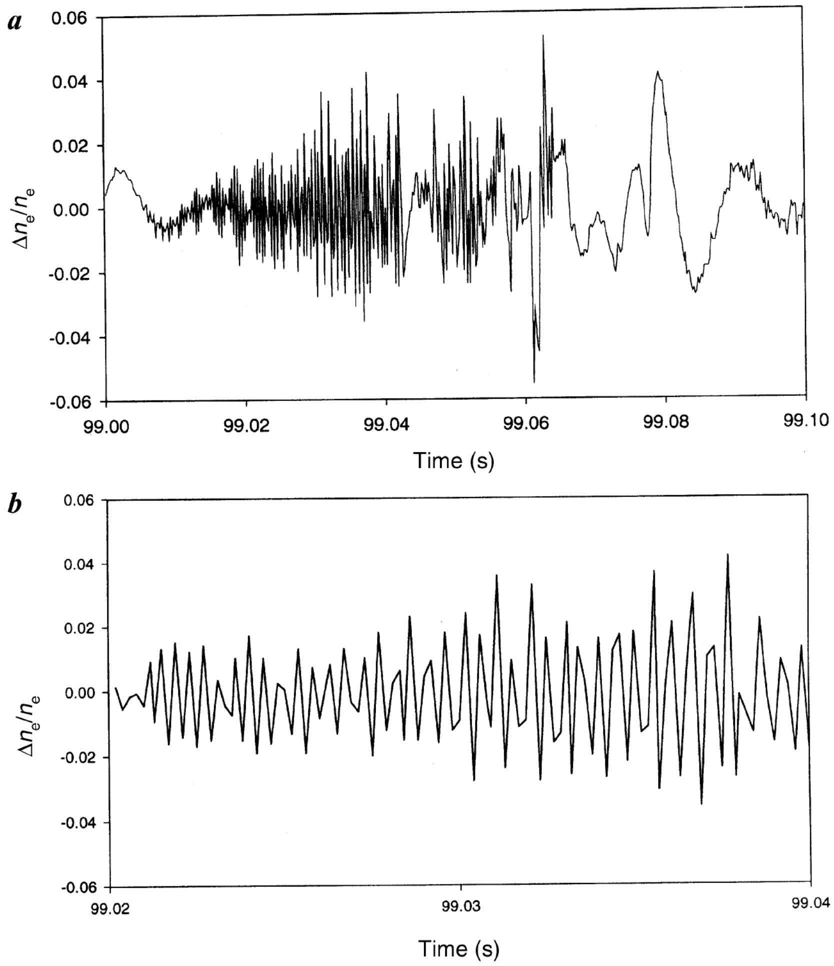


**Figure 1.** *a*, Telemetry record of plasma waves at around 105 km observed on 18 November 1999; *b*, Expanded portion of figure corresponding to the time interval of 99.02 to 99.04 s.

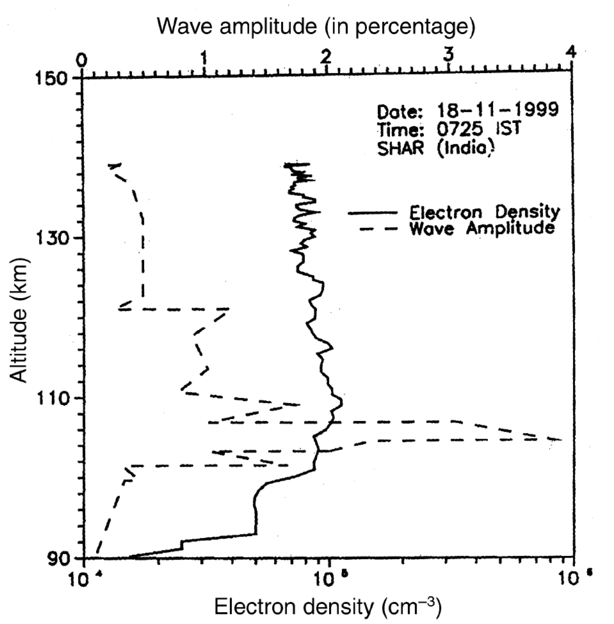


**Figure 2.** Altitude profiles of amplitude of plasma waves along with electron densities observed on 18 November 1999.

amplitude of plasma waves at 105 km where electron density gradient is negligibly small reveal that the causative mechanism for the generation of these plasma waves is different from well known gradient drift waves[5–7] observed over low latitudes. The fluctuations observed near the rocket apogee are non-geophysical in nature[5] and are associated with subsonic motion of the rocket[10].

The plasma waves of a few meter scale sizes over magnetic equator are known to exist as type I waves[8,11,12] when the electron drift velocity driven by Hall polarization field associated with equatorial electrojet exceeds ion thermal velocity (350 m/s). As the polarization field associated with equatorial electrojet reduces by an order of magnitude over Sriharikota[13], the type I waves are unlikely to exist over low latitude. Several rocket flight experiments[7] conducted earlier from Sriharikota and the radar experiments[6] from nearby site located 100 km west of this station also support the non-existence of type I wave over such location. Thus, an experimental evidence for a new kind of plasma wave over low latitude during Leonid 99 meteor storm is reported in this communication.