Indian J. Phys. **76B** (6), 693–697 (2002)

RAPID COMMUNICATION

I J P B
- an international journal

VLF observation during Leonid meteor shower-2002 from Kolkata, India

Sandip K Chakrabarti[1,2,*], S Pal[2], K Acharya[2], S Mandal[2], S Chakrabarti[2,3], R Khan[2,4] and B Bose[2]

[1]S. N Bose National Centre for Basic Sciences, JD-Block, Salt Lake, Kolkata-700 098, India

[2]Centre for Space Physics, P-61 Southend Gardens, Kolkata-700 084, India

[3]Maharaja Manindra Chandra College, 1 Ramkanta Bose Street, Kolkata-700 002, India

[4]Bidhan Nagar High School, BD Block, Salt Lake, Kolkata-700 064, India

E-mail : chakraba@boson.bose res in

Received 25 November 2002, accepted 2 December 2002

Abstract : Using a Gyrator-II Loop antenna tuned at 19.0 KHz, we monitored the meteor shower during 17-24th November, 2002. We observe the primary peak at 3h58m (UT) on the 19th of November, 2002 We distinctly observed several 'headlike' and 'exponentially dropping' signals. The 'headlike' signals were more in abundance on the 18th of November, 2002, one day prior to the actual encounter.

Keywords : Meteors, shock waves, hydrodynamic stability, radio wave (VLF), ionospheric disturbances.

PACS Nos. : 47.20.Ft, 94.20.Vu, 95 85 Bh, 96 50 Kr

1. Introduction

Very Low Frequency (VLF) project of Centre for Space Physics (CSP) has been monitoring VLF activities for quite some time and has detected solar flares as well [1]. During the recent Leonid shower event, the CSP antenna was tuned to 19 KHz and continuous observations were made for seven days In this Rapid Communication we present the first report of this observation.

Leonid meteor showers are observed around 16-19th Noverber for 3-4 successive years after the perihelion passage of the periodic comet Temple-Tuttle (7' ~ 33 Yrs). On February 28, 1998, the comet reached its perihelion and in 1998-2002 the visual observations indicated very good meteor showers. When the earth's orbit crosses the debris left over by the comet on its path in its previous passages, a shower or storm may form, depending on the intensity of events. In 2002, several calculations indicated that there would be two peaks, one would be seen from Europe at around 4.00 UT (due to earth's passage through the dust trail left behind in 1767 A.D.) and the other would be seen from North America at around 10.40 UT (due to earth's passage through the dust trail left behind in 1866 A.D.) [2]. Apart from encountering a rare celestial event, scientists are interested in Leonids because of the prospect of detecting bio-molecules which are thought to have contaminated the earth after being produced in space [3–5]. Furthermore, it has been reported that electrophonic sounds have been recorded during Leonid showers [6,7] which are thought to be due to the fact that Very Low Frequency (VLF) electromagnetic (EM) waves are produced during the passage of a fire-ball. Keay [8] and later Bronshten [9] suggested that these VLFs could be produced due to entangling of earth's magnetic field in the tail of the bow-shock generated by an incoming meteor. More recently, it is thought that the VLFs are produced when a fireball bursts. In any case, the EM radiation emitted is found to have frequency a ranging from a few Hz to about 30 KHz [10]. This range is divided into three parts (a) Ultra-Low-Frequency (ULF, $\nu < 300$ Hz), (b) Extreme Low Frequency (ELF, $0.3 < \nu < 3$ KHz) and (c) Very Low Frequency (VLF, $3 < \nu < 30$ KHz).

*Corresponding Author

In Centre for Space Physics, a team of scientists are engaged in monitoring solar activities continuously using two VLF detectors, one located near Kolkata and the other is located at Malda. Reports on these would be made elsewhere. Presently, we consider only the results of the monitoring of 2002 Leonid meteor shower.

2. Experimental setup

A loop Antenna is made of a square frame of one meter on each side and several turns of shielded single core wire is used to receive the signal. The signal is then amplified and fed into the audio card of a Pentium-IV computer located inside the laboratory. The audio signal is sampled at 3.2 times per second. The antenna is tuned at 19 KHz, away from the nearest 18.2 KHz signal transmitted by VTX3, Indian Navy traffic station at Vijayananarayanam. It is aligned along the East-West direction. The magnetic field of the VLF signal induces a current in the antenna. The antenna at Kolkata station was placed at a height of about 12 meters from the ground. The gain of the receiver is adjusted to obtain a decibel level of around 1500 when there is no signal.

3. Results

Figures 1(a–c) show results of the output from 2.15 am to 12.15 am (−3h15m to 6h45m UT) on (a) 18th, (b) 19th and (c) 20th of November, 2002. The dates on each curve are marked. The otherwise steady result is perturbed due to passages of meteors, and possible atmospheric phenomena such as thunderbolts [6,11,12]. However, the days had very clear skies and no serious 'thunder-bolt' related events were expected. On the 19th of November, at 3h58m UT (9h28m IST), there was a distinct peak comprising of about 70 sub-structures, presumably from individual strong events. (Expected visual rate [Zenithal hourly rate or ZHR] at Kolkata area was around 100 per hour at this time, while the visual observation of the CSP team from Bolpur was 25 per hour in between −1h30m to −0h30m UT). On the 20th of November there was some enhanced activity at around 4h27m UT (9h57m IST) but not as much as on the 19th. It is to be noted that the visual peak was observed by Leonid-MAC team at 4.09 UT [3] very close to the peak found in VLF although several reports [10] indicated that the peak lies between 3h48m to 4h04m UT thereby bracketing our observation.

In Figure 2, we present the results during the peak from 3h30m UT to 4h30m UT. The duration of the shower seems to be from 3h38m to 4h28m, *i.e.* the shower lasted for about 50 minutes. This is similar to what is reported by Leonid-MAC and IMO. Each sub-structure in the peak is similar to an exponential decay curve, but the enhancement of the base (see Figure 1b and Figure 2) indicated that new signals were injected even before the earlier one has time to decay completely. The signal is easily modeled by $\Sigma_i a_0(i)\exp(-t/t_0)$ over the injected period. We also observed two secondary peaks at around 5h UT and 5h45m UT. Some disturbances have been observed but no distinct peak was found at around 10h50m UT when the American peak was supposed to be formed. It is possible that the VLF signal at 19 KHz is washed out while traveling half-way across the globe.

Throughout our observation there were mainly two types of signals. One is 'bead'-like and the other is exponentially decaying. In Figure 3a, we show one example of the 'bead-like' signal, typical of the profile of multiple meteors. However unlike earlier observations [6,7,12] where the signals lasted a few tenths of a second, our observed duration was much longer, several minutes. Also, earlier observers showed sharp spike like features at the beginning, while we missed it during the 'bead-formation'. It is possible that due to our low time resolution (~300 ms), multiple events merged together and long lasting beads were formed. In Figure 3b, we demonstrated a typical signal dropping exponentially

4. Concluding remarks

The VLF project of CSP has been able to observe the peak of the Leonid shower very distinctly at about 3h58m UT on the 19th of November, 2002. We made the observation at a frequency far away from previously reported observations during 1998 and 1999 showers and confirm that the meteors do emit VLF signals even at 19 KHz during their entry in earth's atmosphere.

What could be the cause of the VLF emission and what is the range in which it is emitted? We believe that the bow-shock that is formed in-front of the highly supersonic meteor becomes unstable due to Kelvin-Helmholtz (K–H) instability along with the tangential discontinuity which separates the evaporated matter from the meteor head and the shock-compressed matter in between the bow-shock and the tangential discontinuity. If one considers the bow-shock alone, a strong shock will compress the flow by a factor of $\rho_1/\rho_2 \sim 4$ [13] and the tangential velocity difference would be $\upsilon_1 - \upsilon_2 \sim 0$–$30$ km depending on the location of the bow-shock, highest being at an angle $\theta \sim 30$–$45°$ with the propagation axis and the lowest being at the stagnation point ($\theta \sim 0$) and downstream farther away ($\theta \sim 180°$), where the bow-shock loses its identity. The frequency ν of the K–H instability is given by [13]

$$\nu_{KH}^2 = \frac{1}{4\pi^2}\frac{\rho_1\rho_2}{(\rho_1+\rho_2)^2}(\upsilon_1-\upsilon_2)^2$$

Assuming $\rho_1/\rho_2 \sim 1/4$, we find that anywhere between 0 to 180 KHz could be produced with very small amplitude on both the ends (at the stagnation point of the bow-shock and farther out). It is possible that the earth's magnetic field entangled in the vortices at this K–H unstable interface generate E–M waves of the same frequency.

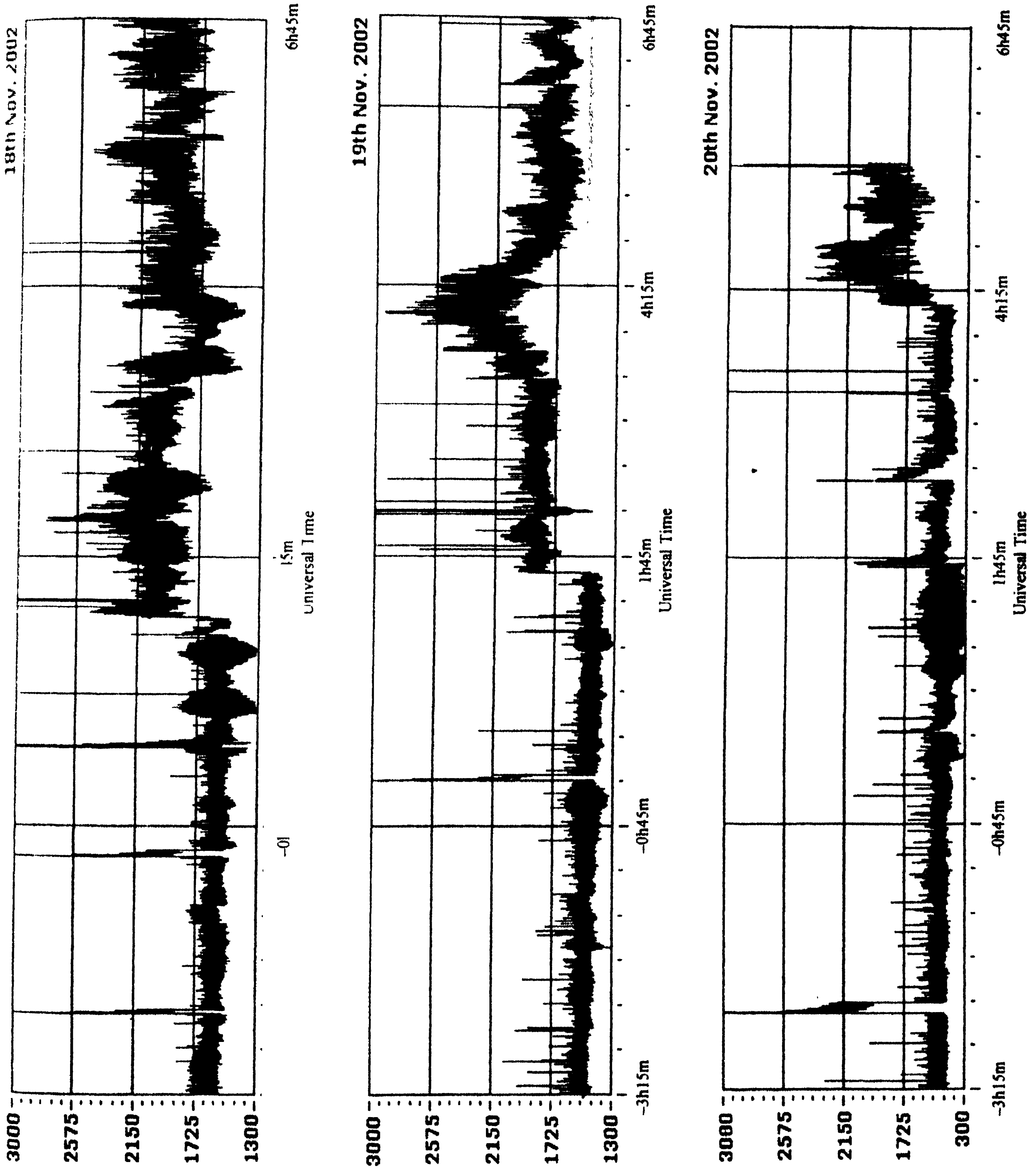

Fig. 1a. Fig 1b. Fig. 1c.

Figure 1(a–c). VLF signal variation during 2h15m and 12h15m IST (-3h15m UT to 6h45m UT) during 18th-20th November, 2002. The peak occurs at 3h58m UT on the 19th. Some 'beadlike' and 'exponentially decaying' signals could also be found.

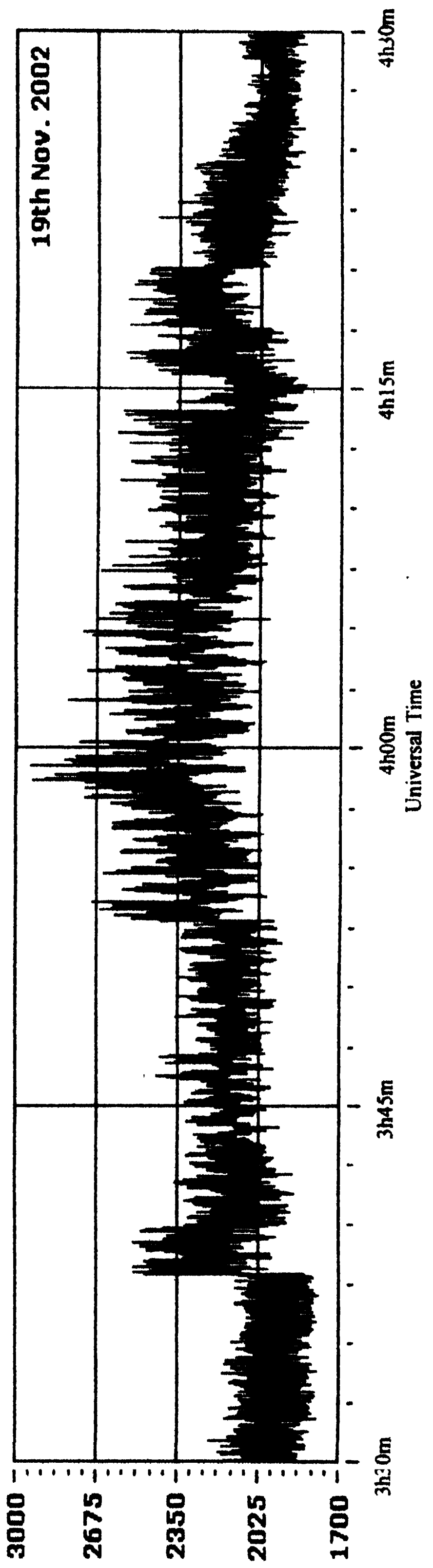

Fig. 2

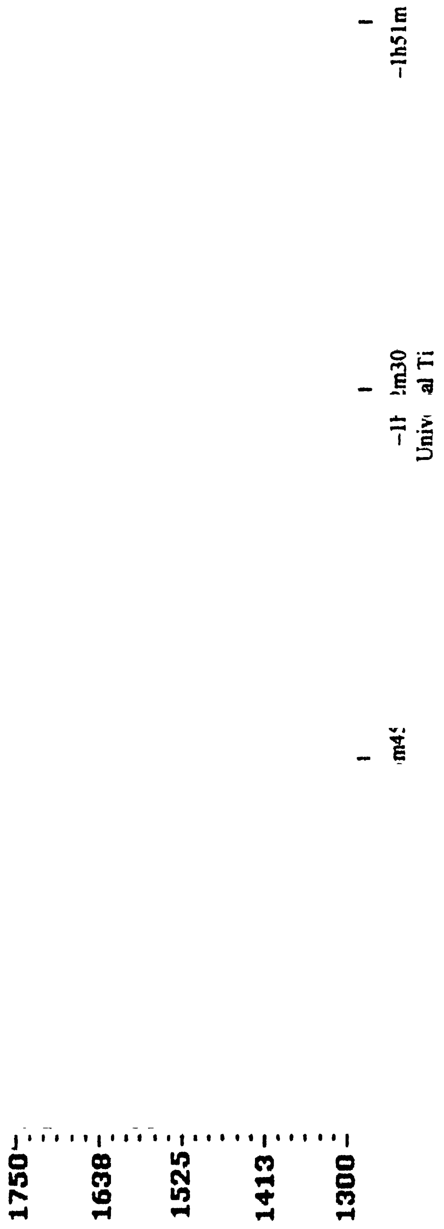

Fig. 3a.

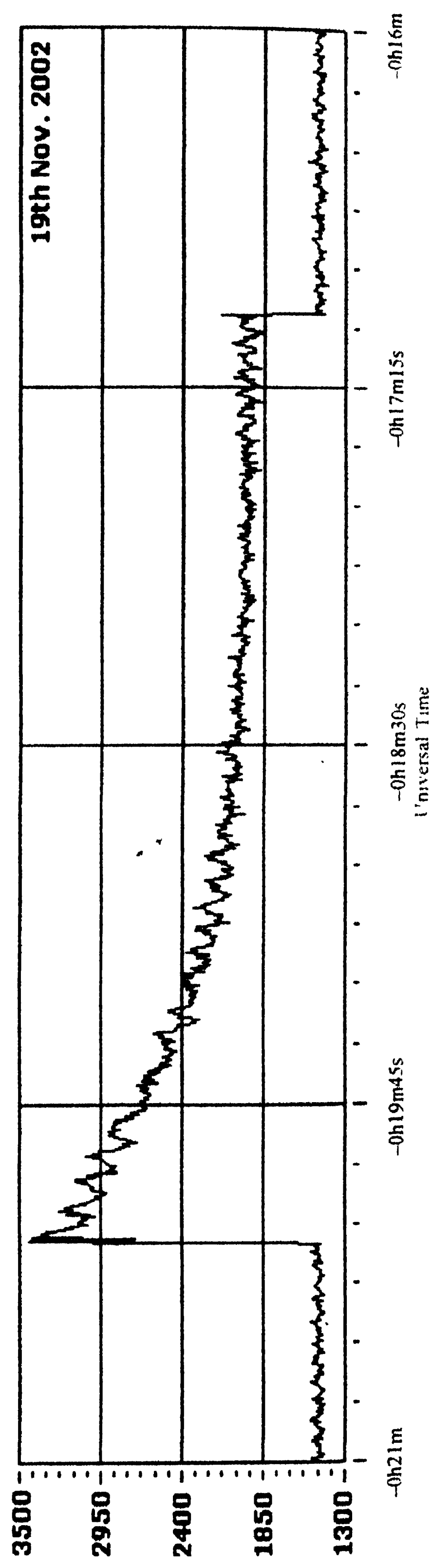

Fig. 3b.

Figure 2. Details of the signal during the peak hour of the Leonid shower on the 19th of November, 2002. The peak is made up of at least 70 distinct events with a duration of about 50 minutes. Primary peak is at 3h58m UT. There were secondary peaks at 5h UT and 5h45m UT.

Figure 3(a–b). (a) Details of a 'beadlike' signal lasting for about three minutes. It is possible that it is made up of superposition of smaller events. (b) Details of an 'exponentially decaying' event. The recovery time scale is about 100 s.

References

[1] S K Chakrabarti *et al Indian J. Phys.* (2002) (Submitted)

[2] http://www spaceweather.com/leonids

[3] http://leonid.arc.nasa.gov/

[4] S Chakrabarti and S K Chakrabarti *Astron. Astrophys. Lett.* **354** L6 (2000)

[5] S K Chakrabarti and S Chakrabarti *Indian J. Phys.* **74B** 97 (2000)

[6] C Price and M Blum *Earth, Moon, and Planets* **82** 545 (2000)

[7] S Garaz *et al Fizika* A **8** 91 (1999)

[8] C S L Keay *Science* **210** 11 (1980)

[9] V A Bronshten *Solar System Res* **17** 70 (1983)

[10] http.//www imo.net/

[11] C S L Keay *Earth, Moon, and Planets* **68** 361 (1995)

[12] M Beech, P Brown and J Jones *Earth, Moon, and Planets* **68** 181 (1995)

[13] L D Landau and E M Lifshitz *Fluid Mechanics* (Pargamon New York) (1962)