VLF observation during Leonid Meteor Shower-2002 from Kolkata

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October 11, 2018

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Abstract

Using a Gyrator-II Loop antenna tuned at 19.0Khz, 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 'beadlike' and 'exponentially dropping' signals. The 'beadlike' signals were more in abundance on the 18th of November, 2002, one day prior to the actual encounter.

PUBLISHED IN INDIAN JOURNAL OF PHYSICS, 2002, 76B, 693

1 Introduction

Very Low Frequency (VLF) project of CSP has been monitoring VLF activities for quite some time and has detected solar flares as well. During the recent Leonid shower event the CSP antenna was tuned to 19KHz 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 November for 3-4 successive years after the perihelion passage of the periodic comet Temple-Tuttle ($T \sim 33$ 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 from Europe at around 4.00UT (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 10.40UT (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 ranging from a few Hz to about 30KHz [8]. 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).

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

The 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 is 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 19KHz, away from the nearest 18.2KHz signal transmitted by VTX3, Indian Navy traffic station at Vijayanarayanarayanam. It is aligned along the East-West direction. The magnetic field of the VLF signal induces a current in the antenna. The antenna near Kolkata 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

Figs. 1(a-c) show results of the output from 2.15am to 12.15am (-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] 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 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 4.09UT [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 Fig. 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 Fig. 1b and Fig. 2) indicated that new signals were injected even before the earlier one has time to decay completely. The signal is easily modeled by $\Sigma a_0(i)exp(t/t_0)$ over the injected 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 10h50 UT when the American peak was supposed to be formed. It is possible that the VLF signal at 19KHz 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 Fig. 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 miss it during the ‘bead-formation’. It is possible that due to our low time resolution (≈ 300ms), multiple events merged together and long lasting beads were formed. In Fig. 3b, we demonstrated a typical signal dropping exponentially.

4 Concluding Remarks

The VLF project of CSP has been able to observe the peak 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 19KHz 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 $v_1 - v_2 \sim 0 - 30$km depending on the location of the bow-shock, highest being at an angle $\theta \sim 30 - 45^\circ$ with the propagation axis and the lowest being at the stagnation point ($\theta \sim 0^\circ$) and downstream farther away ($\theta \sim 180^\circ$), where the bow-shock loses its identity. The frequency $\nu$ of the K-H instability is given by [13],

$$\nu^2_{KH} = \frac{1}{4\pi^2} \frac{\rho_1\rho_2}{(\rho_1 + \rho_2)^2} (v_1 - v_2)^2.$$ 

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.

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Figure Captions

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

Fig. 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 100s.