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Numerical Simulation of Ion Beam Acoustic Instability by Single Ion Beams

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Abstract

The broadband electrostatic noise has been observed in the boundary layer region of the earth's magnetosphere. These electrostatic waves were believed to be generated by drifting ion beams in the magnetotail.

We have shown the numerical simulation result of ion beam acoustic instability in the magnetotail. This instability heats both background and beam ion in the boundary layer of neutral sheet observed by satellite.

요 약

최근에 지구 자기권의 magnetotail 부분에서 주파수 범위가 매우 넓은 정전기적 교란이 발견되었다. 이 불안정성은 이 지역에서 발견되는 이온층으로부터 날라오는 이온빔에 의하여 발생된다는 사실을 알고 있다.

Magnetotail 속에서 일어나는 이온빔 acoustic 불안정성의 콤퓨터 모의실험 결과를 제시한다. 이 불안정성으로 인하여 위성에 의하여 관측된 이온들의 heating이 얻어짐을 확인하였다.

I. Introduction

The most frequent and intense broadband electrostatistic noise (BEN) whose frequency band is from 10 Hz to 10 KHz(local plasma frequency), has been observed in the boundary layer region of the earth's magnetosphere. These electrostatic waves were observed in the geomagnetic tail at radial distances R∼30-40 R_E, where R_E is the earth's radius. A first observation of BEN was made by IMP 7 satellite Scarf et al.(1974). Later and more detailed study of BEN by IMP 8 satellite shows that the electric field intensity can vary from $50\mu V/m$ to $5mV/m$ and extends over a broad range of frequency from about 10 Hz to several KHz Gurnett et al.(1976). They also noted that the BEN occurs predominantly near the boundary layer of the neutral plasma sheet.

Shortly after these observations in the geomagnetic tail, the BEN was also observed in the auroral zone Gurnett et al(1977), whose frequency ranges from 5 Hz to 2 KHz, with peak intensity at 10-50 Hz. The BEN is most intense during an active aurora and may be associated with electromagnetic auroral hiss.

From the particle data of IMP 8, it was found that the BEN was associated with anisotropic ions streaming either sunward or antisunward. The anisotropies in the ion velocity distribution were observed near the boundary layer of the plasma sheet. These single beams, either earthward or tailward, observed in the plasma sheet boundary layer have an order of several Key energies Decoster et al.(1979). These particles were accelearated in the region of 40-50 R_E away from the earth. This acceleration mechanism is not yet identified. Along with single ion beams either tailward or earthward, two counter-streaming ion beams prossibly due to distant tail acceleration are observed Eastman et al.(1981), Williams(1981). In addition to Kev ion beams, Sharp et al. (1981) observed colder ion beams at tens or hundreds of eV streaming tailward due to an ionospheric soure through double layer. The composition of the cold streaming ions is primarily H^+ and O^+ which are of ionospheric origin. It was suggested that the BEN is generated by currents or possibly energetic ions observed in that region.

II. Simulation model

In order to explain the generation of BEN in the geomagnetic tail, several investigations Grabbe and Eastman(1984), Huba et al.(1978), Ashour-Abdalla et al.(1978), Dusenbery et al.(1985) have been made. Omidi(1985) solves a modified dispersion relation numerically to show the possible mechanism of generation of BEN. Most of theoretical attempts done is limited to linear theory. However, in the presence of large amplitude of wave, nonlinear effects should be taken in account. Here in this work, we consider simulation study of BEN driven by single ion beams in the magnetotail using reasonable plasma parameters.

III. Simulation Results

In order to study the simulation result of electrostatic instability driven by single ion beams, we try to consider a simulation model which consists of neutral plasms sheets and single cold ionspheric ion beam. We use 2-1/2 dimensional simulation model - two coordinate space(x, y) and three velocity space (v_x, v_y, v_z) in a uniform magnetic field B_o which lies in the y axis, B=(O, B, O). The simulation parameters $\Omega_e/\omega_{pe}=0.2$, $_e=\Delta$, and $m_i/m_e=1936$, where Ω_e, ω_{pe}, e, Δ m_i, and m_e and the electron gyrofrequency, plasma frequency, Debye length, grid size ion mass, and electron mass, respectively. Full particle dynamics for the motion of both ions and electrons are used. The other parameters are following: $T_i/T_b=25$, $T_e/T_i=4$, $n_i=n_b=1/2\ n_e$, $v/v_i=5$, where v, v_i, n_i, n_e, n_b are the ion beam drift speed, background ion thermal speed, background ion density, electron density, and beam ion density, respectively.

Fig. 1 shows the electron and ion velocity distributions at t=0 and t=3240 ω_{pe}^{-1}. Fig. 1(a) and (b) indicate electron perpendicular and parallel velocity distributions, respectively. These results show a small amount of electron heating occurs by obliquely propagating beam ion acoustic wave. Fig. 1(c) and (d) show beam ion perpendicular and parallel velocity distributions. Beam ion acoustic wave heats ion beam perpendicular and parallel velocity distributions. Beam ion acoustic wave also heats background ion parallel and perpendicular velocity in Fig. 1(e) and (f). These heatings occurs due to the quasi-linear heating in the presence of electrostatic instability.

Fig. 2 also shows the time history and frequency spectrum of typical Fourier modes due to these instabilities. Fig. 2(a) and (b) indicate both time history and frequency spectrum of obliquely propagating mode(3, 4) with $\theta\sim37^\circ$, where $k_x\sim0.3$ and $k_y\sim0.4$, respectively. The time history of the potential shows that it reaches roughly at $|e\,\phi_k/Te|\sim0.2$.The corresponding electric field intensity is estimated to be $|E| = |k\phi_k|\sim 0.5\mu V/m$, for $k\sim0.5$, $n_e\sim1\ cm^{-3}$ and $T_e\sim400$ eV. Fig. 2(c) and (d) indicate both time history and frequency spectrum of obliquely propagating mode(4, 4) with $\theta\sim45^\circ$ where $k_x\sim0.4$ and $k_y\sim0.4$, respectively. Fig. 2 (e) and (f) indicate both time history and frequency spectrum of obliquely propagating mode (5,4) with $\theta\sim51^\circ$, where $k_x\sim0.5$ and $k_y\sim0.4$, respectively. Clearly slowly growing signal with beam acoustic wave frequency, $\omega = kc_x\,(n_b/n_c)^{1/3}kv\cos\theta$, has also bean observed.

IV. Discussions

Here we have shown the excitation mechanism of BEN by obiquely propagating beam ion acoustic wave in the boundary layer of neutral plasma sheet. Even though the power spectra of each Fourier mode indicate the presence of sharp peaks, summation over the Fourier modes, which corresponds to a single point measurment by a satellite, reveals a broader spectrum (A shour-

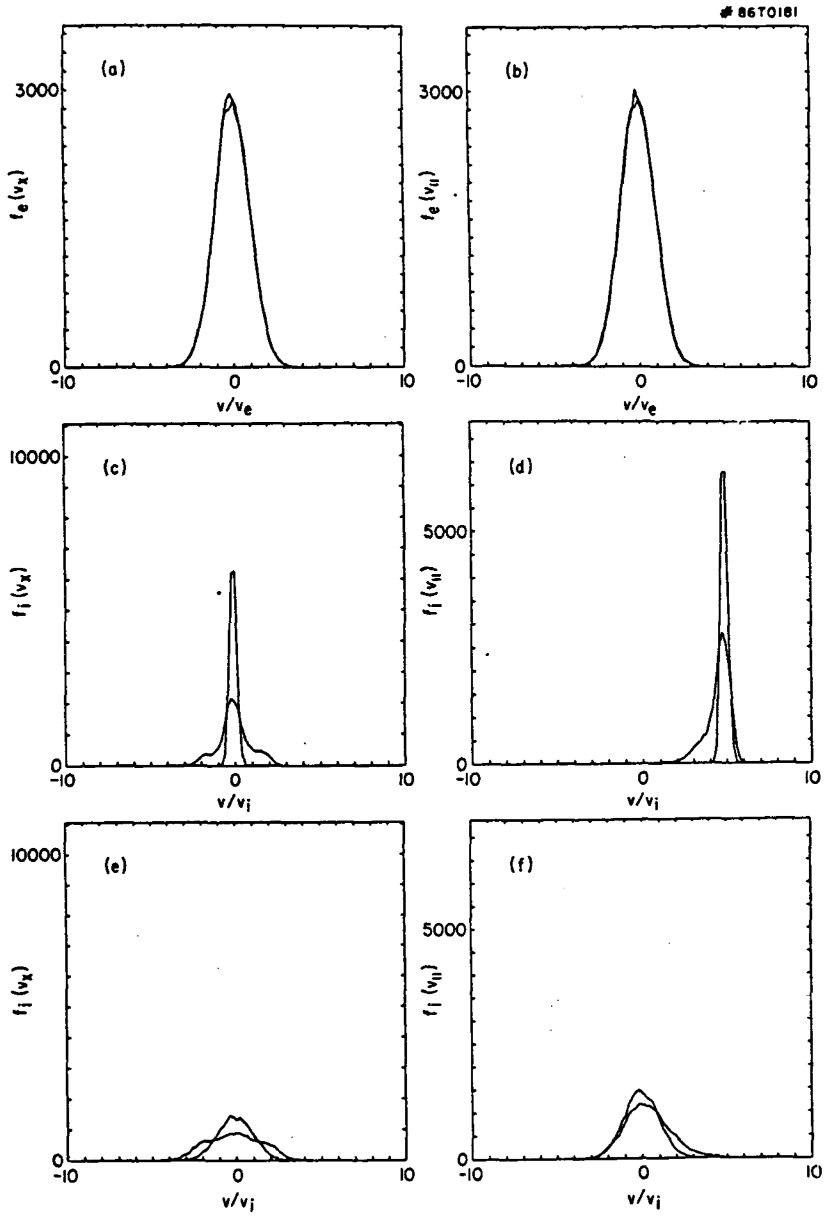

Fig. 1. Electron perpendicular velocity distribution(a), electron parallel velocity distribution to the external magnetic field(b), beam ion perpendicular velocity distribution(c), beam ion parallel velocity distribution(d), background ion perpendicular velocity distribution(e), backgroun ion parallel velocity distribution(f) at initial and final time.

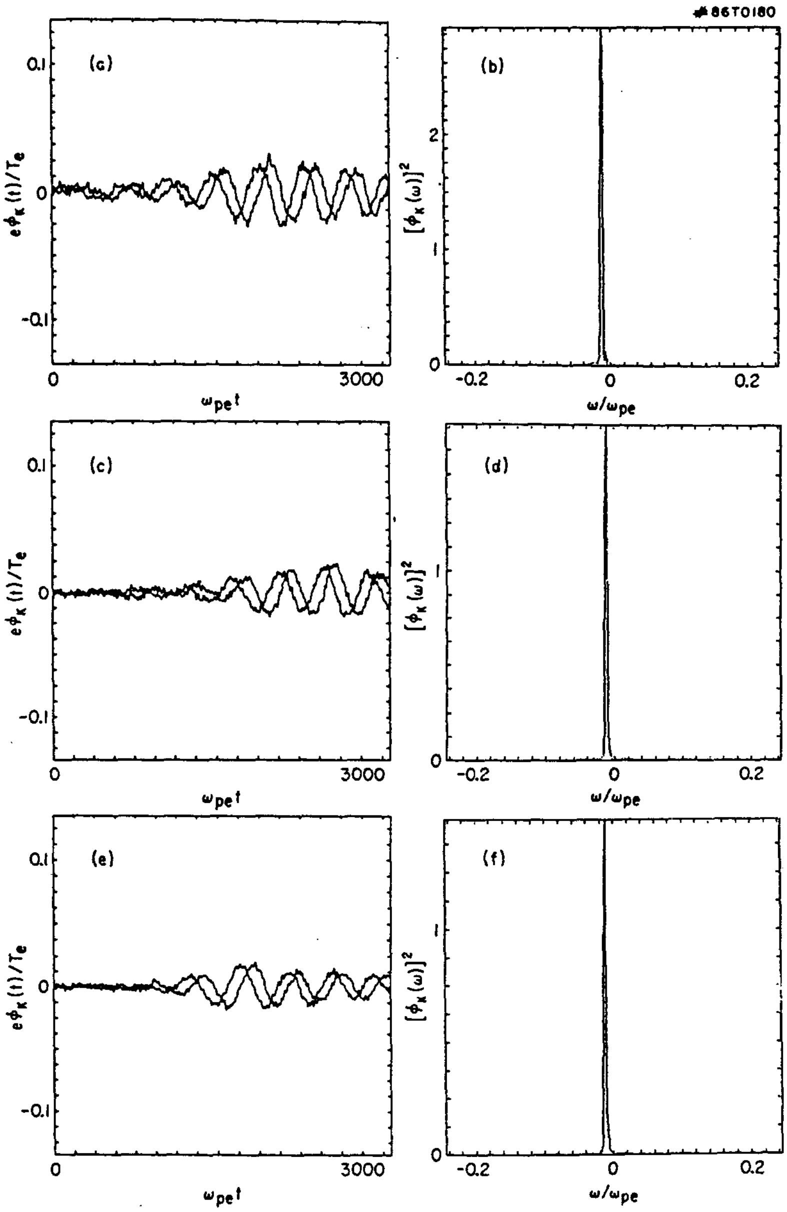

Fig. 2. Time history of Fourier mode (3,4) (a) and its power spectrum (b). Time history of Fourier mode (4,4) (c) and its power spectrum (d). Time history of Fourier mode (5,4) (e) and its power spectrum (f).

Abdalla et al, 1986). We have identified the possible mechanism for BEN and their nonlinear saturation mechanisms and effects on ion acoustic waves, a detailed comparision of the simulation of the simulatation studies using parameters closely resembling those of space data.

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