SIMULATION STUDY OF THE GENERATION OF ELECTRON CYCLOTRON HARMONIC (ECH) WAVES

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ABSTRACT

Electron cyclotron harmonic (ECH) and whistler mode waves are generated by a loss cone ring and temperature anisotropy. To examine the detailed properties of ECH waves and ensuing wave-particle interactions, we performed two-dimensional (2.5D) electromagnetic particle-in-cell (PIC) and Vlasov simulations. The heating of the cold electrons and their effects on the saturation of the ECH waves will be determined. The generation and saturation mechanisms of electromagnetic waves will also be discussed.

INTRODUCTION

ECH waves are observed in the Earth's magnetosphere in the nightside near-Earth equatorial region. Observations indicate that a loss cone feature in the electron distribution function generates ECH waves, which result in pitch angle diffusion and the formation of a highly anisotropic "pancake" type of distribution in the low energy electron population. Electrostatic and electromagnetic waves are driven by loss cone distributions in the presence of cold plasma, which is known to strongly affect the linear dispersion properties of ECH waves. We perform simulations on the generation of ECH waves assuming an unstable velocity distribution function in a uniform periodic system. The unstable plasma is composed of a hot free energy source and a cold background component. The free energy source consists of a ring in velocity space in the direction perpendicular to the static magnetic field. The presence of the cold background electrons causes the free energy source to be unstable to the growth of ECH waves.

SIMULATION RESULT

When the ring velocity is much faster than the thermal velocity of hot electrons, the growth rate of ECH waves becomes much larger than that in a realistic loss cone distribution function. Our PIC simulation showed that the combination of cold background electrons and hot ring electrons is unstable to excite electrostatic ECH waves and electromagnetic whistler mode waves by different instabilities. The perpendicular temperature of cold electrons increases faster through an interaction between the cold electrons and ECH waves. The distribution function of hot electrons moves towards isotropy through interaction with electromagnetic whistler mode waves. The saturation mechanism of ECH waves is the heating of cold electrons in the perpendicular direction, while the saturation mechanism of electromagnetic waves is the diffusion of hot electrons in the parallel direction. As we decrease the ring velocity, the growth rates of both ECH and electromagnetic waves become smaller and the saturation level of these waves also becomes lower. In a PIC simulation run with a ring velocity close to the thermal velocity of hot electrons, the initial noise level is already higher than the saturation level of the instability due to the enhanced thermal fluctuations of PIC codes. Therefore the low-noise level of Vlasov codes is essential to study the generation of electrostatic ECH waves and electromagnetic whistler mode waves excited by a weekly unstable distribution function such as realistic loss cone distribution functions.