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ORIGINAL ARTICLE

The influence of negatively charged heavy ions on the kinetic Alfven wave in a cometary environment

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Abstract Kinetic Alfven waves are important in a wide variety of areas like astrophysical, space and laboratory plasmas. In cometary environments, waves in the hydromagnetic range of frequencies are excited predominantly by heavy ions. We, therefore, study the stability of the kinetic Alfven wave in a plasma of hydrogen ions, positively and negatively charged oxygen ions and electrons. Each species was modeled by drifting ring distributions in the direction parallel to the magnetic field; in the perpendicular direction the distribution was simulated with a loss cone type distribution obtained through the subtraction of two Maxwellian distributions with different temperatures. We find that for frequencies $\omega^* < \omega_{cH^+}$ (ω^* and ω_{cH^+} being respectively the Doppler shifted and hydrogen ion gyro-frequencies), the growth rate increases with increasing negatively charged oxygen ion densities while decreasing with increasing propagation angles, negative ion temperatures and negative ion mass.

Keywords Kinetic Alfven wave · Stability · Multi-ion · Negative-ion cometary plasma

1 Introduction

Hydromagnetic wave activity has been observed in distinct space environments: in the distant magnetotail (Tsurutani and Smith 1984), in the magnetosheath (Anderson et al. 1982), upstream of the Earth's (Hoppe et al. 1981) and other planets' bow shocks (Smith and Lee 1986) and upstream of interplanetary shocks (Tsurutani et al. 1983) especially near comets. In the space plasma environments nearer to our earth, Alfven wave activity was frequently observed in the auroral regions by the spacecraft FREJA. The strong electric spikes associated with magnetic and density fluctuations were interpreted as kinetic Alfven waves (KAWs) and were proposed as contributing to auroral plasma energization (Louarn et al. 1994). Other emissions in these regions also coincided with Alfven wave activity from a few Hz to tens of Hz; these emissions were linked to the evolution of nonlinear KAWs (Wahlund et al. 1994a). Again, the broadband electrostatic turbulence identified as ion acoustic waves was thought of as evolving from solitary kinetic Alfven waves (Wahlund et al. 1994b). A more recent evidence was the observation of small scale large amplitude KAWs/spikes at the plasma sheet boundary layer (PSBL), at altitudes of 4–6 R_E (Wygant et al. 2002). Another example is the observation of the drift kinetic Alfven wave in the vicinity of a reconnection X-line in the earth's magnetopause. These waves were observed to propagate outwards from the X-line suggesting that reconnection is a source of KAWs. Interestingly, energetic O^+ observed in these waves indicate that reconnection is a driver of auroral ion outflow (Chaston et al. 2005).

Alfven wave activity was also observed in cometary environments. Specifically, Alfvenic turbulence was detected in the magnetic field (Tsurutani and Smith 1986a, 1986b) and in the electron distribution (Gosling et al. 1986) at comet Giacobini-Ziner by the ICE spacecraft. Similar turbulence was also detected by Giotto (Neubauer et al. 1986) and Vega (Reidler et al. 1986) spacecrafts at comet Halley. In addition to these observations, Alfvenic turbulence was also observed

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