Solitons and nonlinear waves in space plasmas

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Recent measurements made on the ESA/NASA Cluster mission to the Earth's magnetosphere [1] have provided first detailed measurements of magnetosonic solitons in space [2]. The solitons represent localized enhancements of the magnetic field by a factor of 2-10, or depressions down to 10% of the ambient field. The magnetic field signatures are associated with density depressions/enhancements A two-fluid model of nonlinear electron and ion inertial waves in anisotropic plasmas [3-4] explains the main properties of these structures. It is shown that warm plasmas support four types of nonlinear waves, which correspond to four linear modes: Alfvénic, magnetosonic, sound, and electron inertial waves. Each of these nonlinear modes has slow and fast versions. It is shown by direct integration that the exponential growth rate of nonlinear modes is balanced by the ion and electron dispersion leading to solutions in the form of trains of solitons or cnoidal waves. By using a novel technique of phase portraits it is shown how the dispersive properties of electron and ion inertial waves change at the transition between warm and hot plasmas, and how trains of solitons ("mirror modes") are produced in a hot, anisotropic plasma. The applicability of the model is illustrated with data from Cluster spacecraft.

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[2] K. Stasiewicz, (2004), Theory and observations of slow-mode solitons in space plasmas, Phys. Rev. Lett., 93(12), 125004, doi:10.1103/PhysRevLett.93.125004.
[3] K. Stasiewicz, (2004), Reinterpretation of mirror modes as trains of slow magnetosonic solitons, Geophys. Res. Lett, 31, L21804, doi:10.1029/2004GL021282.
[4] K. Stasiewicz, (2005), Nonlinear Alfvén, magnetosonic, sound, and electron inertial waves in fluid formalism, J. Geophys. Res., 110, A03220, doi:10.1029/2004JA010852.