EPSC Abstracts
Vol. 9, EPSC2014-147, 2014
European Planetary Science Congress 2014

On the Stability of the Tangential Discontinuity Interface in Dusty Plasma

A. Ershkovich (1) and P. Israelevich (1)

(1) Department of Geophysics and Planetary Sciences, Tel Aviv University, Ramat Aviv, 69978, Israel

Abstract

Stability of the plane tangential discontinuity (TD) in a multi-component dusty plasma (ions, electrons, neutral particles and charged dust) is considered in Hydrodynamical approximation. Stabilizing role of the frozen-in magnetic field is found to decrease drastically, almost disappears. However, the instability growth rate decreases drastically because of tremendous growth of the plasma density in the presence of dust particles. Therefore, the cometary plasma tail may appear effectively stable so that generation of helical waves type I due to the shear driven Kelvin-Helmholtz instability is suppressed facilitated in dusty objects of such a geometry.

1. Introduction

Discontinuities in fluid are of great interest in Physics, Mathematics and Engineering. First classification of discontinuities in Magnetohydrodynamics (MHD) was given by F. Hofmann and E. Teller in 1950 [1]. The TD interface in Hydrodynamics is always unstable, but in MHD the magnetic field plays stabilizing role. The comprehensive stability analysis for the plane TD interface within Magnetohydrodynamics belongs to S. Syrovatskii [2, 3]. Kelvin-Helmholtz instability (arising due to the velocity shear) may occur in planetary magnetotails [4, 5]. F.W. Bessel was the first to describe in detail helical waves in the cometary tail. These phenomena have been explained by means of Kelvin-Helmholtz instability of cylindrical TD interface [6-8]. Theory of helical waves in cometary tails resulted in the first reliable estimate of the cometary magnetic field [9,10].

A new area of Space Plasma Physics, the Dusty Plasma Physics, arose about three decades ago. An interest to dusty plasma drastically increased in connection with Rosetta-Philae Mission to comet 67P/Churyumov-Gerassimenko and the forthcoming rendezvous with this comet. Modern review on dusty plasma physics was recently given by D.A. Mendis and M. Horanyi [11]. A justified question arises about the dust effects on the stability analysis results obtained while dust is not taken into consideration, and even more generally: whether or not classification of MHD discontinuities [1] may be applied to dusty plasma.

2. Tangential discontinuity stability in dusty plasma

We will apply more simplified description via multi-component fluid (plasma, neutrals, charged and neutral dusty fractions). This treatment is less accurate than kinetic, but, instead, we will get analytical solution of the problem with clear physical meaning.

We consider a seven-component fluid which consists of ions with the charge $Z_i e$ (e>0), mass M_i, number density n_i, and velocity $\mathbf{v}_i$; neutrals (M_n,n_n, $\mathbf{v}_n$), protons (M_p,n_p, $\mathbf{v}_p$), electrons (m,n_e, $\mathbf{v}_e$); positively charged dust particles, negatively charged dust and neutral dust.

Summation of equations for all components yields a single-fluid momentum equation. Assume that the fluid is incompressible and following the analysis performed in [12], we get for the instability growth rate

$$\omega = \frac{\rho_1(\mathbf{k}\cdot\mathbf{v}_1)+\rho_2(\mathbf{k}\cdot\mathbf{v}_2)}{\rho_1+\rho_2} \pm$$

$$\pm\left\{\frac{(\mathbf{k}\cdot\mathbf{B}_1)^2+(\mathbf{k}\cdot\mathbf{B}_2)^2}{4\pi(\rho_1+\rho_2)} - \frac{\rho_1\rho_2}{(\rho_1+\rho_2)^2}[(\mathbf{k}\cdot\mathbf{v}_1)-(\mathbf{k}\cdot\mathbf{v}_2)]^2 + \frac{\rho_2-\rho_1}{\rho_1+\rho_2}\kappa g\right\}^{1/2}$$

where indices 1 and 2 refer to physical quantities at the opposite sides of the interface. Positive terms under the radical have a stabilizing effect, whereas negative terms result in instabilities. The second term is indicative of the Kelvin-Helmholtz instability, whereas the last term is associated with the Rayleigh-Taylor instability if $\rho_2 < \rho_1$.

However, as the fluid density ρ is in a dusty plasma determined by heavy dusty particles, and their density is greater than in a pure plasma by orders of magnitude, the stabilizing role of the magnetic field (first term) becomes negligible in the dusty plasma. For the same reason, the instability growth rate, determined by the second term, decreases drastically. The cometary type I tail becomes effectively stable as the perturbation is moved downstream the tail faster than in grows because of instability.

3. Summary and Conclusions

We arrived at the conclusion that single-fluid equations, in fact, may be obtained by summation of equations for any number of components, and, hence, MHD classification of discontinuities suggested by Hoffmann and Teller [1] may be applied to dusty plasma. Cometary plasma tail remains unstable with respect to the Kelvin-Helmholtz instability, but the presence of the dust may prevent developments of helical waves in the tail.

References

[1]. F. Hoffmann and E. Teller, *Phys. Rev., 80*, 692,1950.

[2]. S. I. Syrovatskii, *JETP, 24*, 622, 1953.

[3]. S. I. Syrovatskii, *Soviet Phys. Uspekhi, 62*, 247, 1957.

[4]. J. F. McKenzie, *J. Geophys. Res., 75*, 5331,1970.

[5]. A. I. Ershkovich and A. A. Nusinov, *Cosmic Electrodyn., 2*, 471,1972.

[6]. A. I. Ershkovich and A. A. Chernikov, *Soviet Astron., 16.*, 374, 1972.

[7]. A. I. Ershkovich, A.A. Nusinov, and A. A. Chernikov, *Planet. Space Sci., 20,* 1235, 1972.

[8]. A. I. Ershkovich, and A. A. Chernikov, *Planet. Space Sci., 21,* 663, 1973.

[9]. A. I. Ershkovich, *MNRAS, 184*, 755, 1978.

[10]. A. I. Ershkovich, *Space Sci. Rev., 25*, 3, 1980.

[11]. D. A. Mendis, and M. Horanyi, *Rev. Geophys., 51*, 53, 2013.

[12]. A. I. Ershkovich, and D. A. Mendis, *Astrophys. J., 269*, 743, 1983