EPSC Abstracts
Vol. 5, EPSC2010-64, 2010
European Planetary Science Congress 2010

Dusty plasmas in Earth's magnetosphere

Yu.N. Izvekova and S.I. Popel
Institute for Dynamics of Geospheres, Moscow, Russia (besedina_yn@mail.ru / Fax: +7-499-1376511)

Abstract

Dusty plasma formation in Earth's magnetosphere is considered. Sources and properties of dust particles in the magnetosphere are described. The main consequences of the presence of dusty plasmas in Earth's magnetosphere are discussed.

1. Introduction

Plasma containing charged (solid or liquid) nano- and microscale particles is called as dusty plasmas. In our Solar System plasma–dust systems are solar wind, ionospheres and magnetospheres of the planets, planetary rings, intermundane plasma–dust clouds, etc. Dusty plasmas of Earth's magnetosphere play a crucial role because data obtained from observations of the magnetosphere are the main source of the knowledge about interplanetary dust.

Elementary composition of dust particles in Earth's magnetosphere corresponds usually to that of carbonic meteoroids of chondritic classes C1 and C2 and include Mg, Al, Si, S, Ca, Cr, Mn, Fe, Ni. At the same time, the particles of nano- and microscale olivinic agglomerations and glass with embedded metal and sulphides (often found in the magnetosphere) were not observed as micrometeoroid matter. Although the existence of conventional density for the matter of all interplanetary dusts is supposed usually, the density of the dust matter varies in a wide range. Moreover, often dust grains have so complicated form that the use of the term "density" is not correct. In Table 1 sizes and densities of dusts in the magnetosphere are given [1].

Dust particles in Earth's magnetosphere acquire charges as a result of dust particle interaction with electrons and ions of magnetospheric plasmas as well as the solar radiation. This process is the crucial one for the formation of a dusty plasma in the magnetosphere. Here, we present briefly the description of dust particle charging and dust particle dynamics and discuss the main consequences of the presence of dusty plasmas in Earth's magnetosphere.

Table 1: Radii and densities of cosmic dust particles

Radius, cm	Density of dust particle matter, g/cm^3
1.0e-5	2.9
1.44e-5	2.85
1.77e-5	2.82
2.04e-5	2.8
2.98e-5	2.72
4.51e-5	2.59
6.63e-5	2.45
1.02e-4	2.26
2.36e-4	1.8
5.57e-4	1.38

2. Charging and dynamics of dust particles

The key process in the formation of dusty plasmas is dust particle charging. This process in the magnetosphere occurs in different ways. The main mechanisms of magnetospheric dust charging are absorption of electrons and ions from ambient plasmas by dust grains, secondary electron emission, photoelectric emission and collisions between dust grains. In passing of dust particle through different areas of the ambient plasmas, its charge does not remain constant. The balance of the electron and ion currents to the particle determines the charge of the grain Q by the equation:

$$\frac{dQ}{dt} = \sum_i I_i, \qquad (1)$$

where I_i includes the microscopic electron and ion currents from the ambient plasma to dust particle, the secondary electron emission current, and the photoelectron emission current. All these currents depend on the parameters of the plasma, properties of the material of dust grain, its size and velocity, and undisturbed value of the dust particle charge. For very small nanoscale particles the use of Eq. (1) is restricted because of the quantization of the dust particle charge.

Investigations of the dynamics of dust grains in the Earth's magnetosphere are carried out as a rule in an inertial frame of reference connected with the centre of the Earth. The equation describing the dynamics of a dust takes the following form:

$$m\frac{d^2\mathbf{R}}{dt^2} = \mathbf{F}_G + \mathbf{F}_{LP} + \mathbf{F}_L + \mathbf{F}_{SG}, \qquad (2)$$

where $\mathbf{F}_G$ is Earth gravity force, $\mathbf{F}_{LP}$ is light pressure force, $\mathbf{F}_L$ is Lorentz force, and $\mathbf{F}_{SG}$ is solar gravity force. To determine the dust dynamics the set of Eqs. (1)–(2) should be solved self-consistently.

3. The main consequences

The main influence of dust grain charging is the diffusion of dust grain orbits in the magnetospheric plasmas. Systematic variations of dust grain charges caused by changes in the plasma parameters, and the modulations of plasma currents appearing due to the modulation of dust grain speeds can result in the transport processes of the particles inside the magnetosphere as well as the dust particle exchange between the magnetosphere and its environment.

The quantities of the dust particle charges can reach large values (such as 10^5-$10^6 e$, where e is the electron charge). The dust particle diffusion along the magnetic field can significantly (10-100 times) exceed the usual diffusion of the Brownian particle, while the diffusion in the direction perpendicular to the magnetic field occurs in the same manner as in the usual magnetized electron-ion plasmas.

Dust can influence significantly the width of the transient layer of the magnetopause within the open magnetosphere model, in which magnetic lines from the Earth connect with interplanetary magnetic field [2]. The most important element in the open magnetosphere model is the magnetic field reconnection process, which occurs at the magnetopause. The evidence of the magnetic field reconnection has been demonstrated by observations carried out with the aid of ISEE spacecraft. Theory description of physical phenomena occurring during magnetic field reconnection is often based on the Parker-Sweet diffusion model [3] where the transient layer is determined by the effective frequency characterizing the electron momentum loss. In dusty plasmas, strong anomalous dissipation appears which is due to the effect of absorption of plasma particles on dust grains. Thus the effective frequency characterizing the electron momentum loss is modified in the dusty plasmas and the effects of electron-dust particle interaction can determine the width of the transient layer of the magnetopause.

Acknowledgements

This study was supported by the Division of Physical Sciences, the Russian Academy of Sciences (the basic research program ``Plasma physics in the solar system"). S.I.P. is also supported by the Dynasty Foundation. The authors express their thanks to Prof. Lev M. Zelenyi for useful discussions stimulating research of plasma-dust systems in space plasmas and for the formulations of new problems.

References

[1] Divine, N., Fechtig, H., Gombosi, T.I. et al: The comet Halley dust and gas environment, Space Sci. Rev., Vol. 43, N 1, pp. 1-104, 1986.

[2] Vladimirov, S.V., Tsytovich, V.N., Popel, S.I., and Khakimov, F.Kh.: Modulational Interactions in Plasmas, Kluwer Academic Publishers, 1995.

[3] Parker, E.N.: Sweet's mechanism for merging magnetic fields in conducting fluids, J. Geophys. Res., Vol. 62, N 4, pp. 509-520, 1957.