§28. Nonlinear Dust-charging and Electrostatic Waves in a Dusty Plasma

Nejoh,Y. (Hachinohe Inst. Tech.)
Sanuki,H.

The increase of recent interest in plasmas containing charged, micrometer-sized dust particles has arizen not only from the increase of observations of such plasmas in space environments such as cometary tails, planetary rings and magnetospheres, and the lower ionosphere of the Earth, but also from their presence in laboratory devices. Since the dust-charge variation affects the characteristics of the collective motion of the plasma, the effect of variable-charge dust grain particles is of crucial importance in understanding dusty plasma waves. However, not many theoretical works on the effect of variable-charge dust grain particles have been done in dusty plasmas. Hence, we focus our attention on electrostatic ion waves in an unmagnetized dusty plasma having trapped electrons. We show the dependence of the dust grain-charge on the electrostatic potential, ion temperature and density. Our results show the dependence of the dust charge number on the parameters such as the potential, trapped electrons, ion temperature and density.

In this study, we consider a collisionless, unmagnetized three component plasma consisting of non-Boltzmann electrons with a temperature T_e, warm ions having a temperature T_i and negatively charged, heavy, dust grains with the speed v_d. We assume that the charging of the dust grain particles arises from plasma currents due to the electrons and the ions reaching the grain surface, and the current due to the secondary electron emission. In this case, the dust grain-charge is determined by the charge-current balance equation. We describe the normalised equation for the charge number Z as follows:

$$\left(\frac{\partial}{\partial t}+v_d\frac{\partial}{\partial x}\right)aZ = -n_e e^{aZ} + n_i\frac{(\tau - aZ)}{\sqrt{\mu\tau}} + I_S \quad .$$

Here, $a=e^2/rT_e$, $\mu=m_i/m_e$, $\tau=T_i/T_e$, and v_d and I_S denotes the dust velocity and the current due to the secondary electron emission. As an example, we show the dust-charge fluctuation in Fig.1, in the case where $\delta=n_i/n_e=500$, $\tau=0.2$, $\mu=1836$, $a=10^{-4}$, $v_d=1.2c_s$. Here, c_s is the ion-sound velocity in this system.

In order to study the possibility of the existence of nonlinear waves, we show a Sagdeev potential in Fig.2. The dust-charge is of crucial importance in the sense that the dust-charge drastically changes due to the parameters such as the floating potential of dust grains, electrostatic potential of the plasma, dust to ion mass ratio, ion temperature and density. The effect of the ion temperature decreases the dust charge number. We understand that the existence of nonlinear electrostatic waves varies due to the floating potential of dust grain particles.

In a recent plasma experiment, it has been suggested that electrostatic waves may be responsible for the trapping of micrometer- and submicrometer-sized contamination particles within the plasma. In this situation, our results are important in understanding the charging mechanism of the streaming of dust grain particles and investigating the possibility of the existence of the nonlinear waves in dusty plasmas.

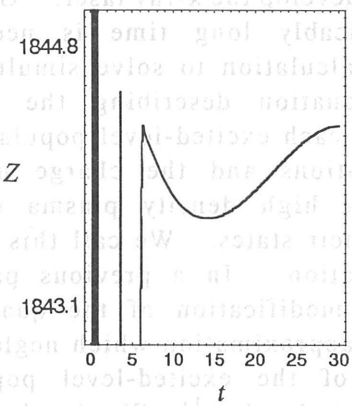

Fig.1. The dust-charge fluctuation on the grain surface.

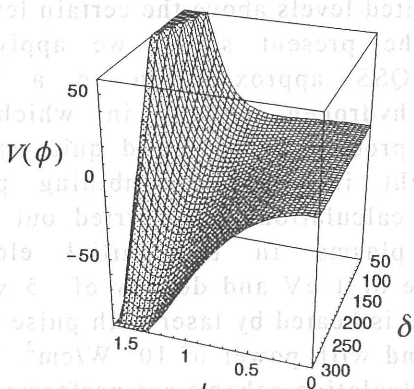

Fig.2. The Sagdeev potential of this system.

References
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