§14. Charging of Dust Particles in Weak Magnetic Field - Charge of Floating Dust -

Tomita, T., Kawamura, G.,
Ishihara, O. (Yokohama Natl. Univ.)

In order to study the absorption cross-section of electron to dust particle, the electron orbit is investigated in the field of the negatively charged spherical dust immersed in the uniform magnetic field. For the weak magnetic field the closest radius r_{min} is linearly proportional to the strength of magnetic field,

$$\bar{r}_{\min}(\alpha_e,\mu_e)=\bar{r}_{\min 0}(\alpha_e)+\gamma_e(\alpha_e)\mu_e. \quad (1)$$

Here

$\alpha_e \equiv |eq_d|/(2\pi\varepsilon_0 b_{in} m_e v_{e,\,in}^2)$, $\mu_e \equiv b_{in}|eB_0|/m_e v_{e,\,in}$,

b_{in} = impact parameter, $v_{e,\,in}$ = initial speed, $\bar{r}=r/b_{in}$,

and γ_e is the constant of proportion, which depends on α_e and $\bar{r}_{\min 0}$ is the closest radius in the absence of magnetic field, which is obtained from the OML theory:

$$\bar{r}_{\min 0}(\alpha_e)=\frac{1}{2}(\alpha_e+\sqrt{\alpha_e^2+4}). \quad (2)$$

The linear approximation is valid in the range $\mu_e < 0.4$ for $\alpha_e = 1.0$. In the case of the larger α_e the upper limit of μ_e for the linear approximation becomes smaller, e.g. 0.04 for $\alpha_e = 10.0$. The dependence of the coefficient γ_e on the parameter α_e is investigated numerically. The least square curve indicates

$$\gamma_e=-0.114\alpha_e^{1.962}. \quad (3)$$

This dependence is approximated in this study as:

$$\gamma_e=-0.114\alpha_e^{2.0}. \quad (4)$$

By using Eq. 4, the absorption cross-section is obtained. The un-normalized closest radius is expressed from Eq. 1:

$$r_{\min}(\alpha_e^*,\mu_e^*)=r_{\min 0}(\alpha_e^*)+\gamma_e(\alpha_e^*)\mu_e^* b_{in}^2, \quad (5)$$

where

$$r_{\min 0}(\alpha_e^*)=\frac{1}{2}(\alpha_e^*+\sqrt{\alpha_e^{*2}+4b_{in}^2}), \quad (6)$$

$$\gamma_e(\alpha_e^*)=-0.114\alpha_e^{*2}/b_{in}^2, \quad (7)$$

$$\alpha_e^*\equiv b_{in}\alpha_e=\frac{-eq_d}{4\pi\varepsilon_0}/\frac{m_e v_{e,\,in}^2}{2}, \quad (8)$$

$$\mu_e^*\equiv\mu_e/b_{in}=|eB_0|/m_e v_{e,in}. \quad (9)$$

This closest radius corresponds to the effective finite dust radius R_d to the absorption. From this result the absorption cross-section of an electron to the dust is obtained easily.

$$\sigma_{ab}^e=\pi b_{in}^2$$
$$=\pi(R_d+0.114\alpha_e^{*2}\mu_e^*)(R_d+0.114\alpha_e^{*2}\mu_e^*-\alpha_e^*) \quad (10)$$

In the case without magnetic field ($\mu_e^*=0$) the absorption cross-section becomes the conventional one from the OML theory:

$$\sigma_{ab0}^e=\pi R_d^2(1-\alpha_e^*/R_d)=\pi R_d^2(1+\frac{eq_d}{2\pi\varepsilon_0 R_d m_e v_{e,\,in}^2}) \quad (11)$$

The charge of the floating dust particle is determined from the condition of equal particle fluxes of ions and electrons to the dust particle. The ion absorption cross-section is expressed by the OML theory, where the effect of magnetic field is negligibly small:

$$\sigma_{ab0}^i=\pi R_d^2(1+\frac{Z_i Z_d e^2}{2\pi\varepsilon_0 R_d m_i v_i^2}), \quad (12)$$

where m_i, Z_i and v_i are the mass, charge and speed of plasma ions. The charge state of the dust is Z_d (> 0). In the case of the mono-energy charged particles, the equal particle flux gives the relation.

$$\sigma_{ab}^e(Z_d;R_d,\varepsilon_e,B_0)=\sqrt{\frac{m_e\varepsilon_i}{m_i\varepsilon_e}}\sigma_{ab0}^i(Z_d;R_d,\varepsilon_i). \quad (13)$$

In the case of R_d = 1 mm, $\varepsilon_e = \varepsilon_i$ = 1, 10 eV, the dependence of the dust charge Z_d as a function of the weak magnetic field B_0 is shown in Fig.1. The charge state of the negative dust particle increases from 6.63×10^5 to 6.86×10^5 for the 1 eV ions and electrons in the magnetic field of 10 G. This increase of charge state comes from the increase of the electron absorption cross-section in the magnetic field. For the higher energy of plasmas with 10 eV, dust charge is found to increase from 6.63×10^6 to 6.70×10^6 due to the effects of magnetic field.

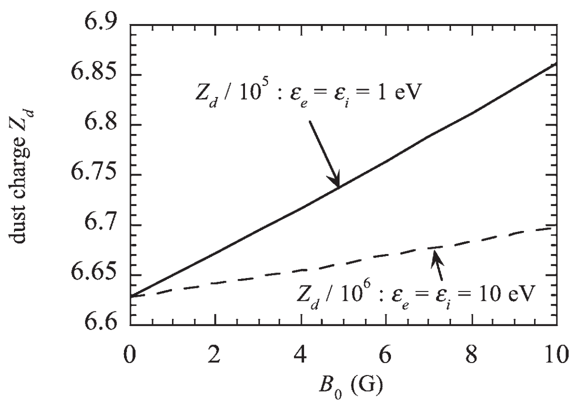

Fig.1 Charge of floating dust as a function of weak magnetic field B_0, where dust radius R_d = 1 mm and particle energy of ions and electrons = 1, 10 eV.