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Dynamics of charged dust particles in the magnetic field related to the dust infall problem in protoplanetary disks

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In Protoplanetary disks, the velocity difference occurs between the rotational speed of gas and dust particles due to the pressure gradient of the disk gas. Since the motion of dust particles is affected by the headwind of gas, dust particles lose angular momentum and eventually fall into a central star. However, since in the region close to the central star we can expect a finite magnitude of the intrinsic magnetic field and a high ionization rate due to the strong radiation from the central star, the effect of Lorentz force possibly plays important role in the dynamics of charged dust particles. For the discussion of the effect of Lorentz force in the dust infall problem, we quantitatively evaluate the effect of background magnetic field to the charged dust particle.

By assuming minimum mass solar nebula model and constant plasma beta throughout the disk, we estimate the gyroperiod of charged dust particles. We also assumed the charge state of dust particles by referring the observation result of charged particles in the Saturnian E-ring by Cassini spacecraft [e.g., Horanyi et al., 2004]. For the case that the gyro period approximately equals to the stopping timescale by headwind (e.g., Weidenschilling, 1977) of gas at 1 AU, dust particles with the radius of 1 cm should be charged ~10^{17} e (e: elementary charge).

The charge state of dust particles with the radius of 1 um measured in the Saturnian E-ring has been has been reported to 1000 e (e.g., Horanyi, 2004). Assuming that these dust particles collide and coalesce each other and become 1cm sized dust and that the charge state is proportional to its volume, we obtain 10^{15} e for 1 cm dust particles. In the present study, we study the relation between the radius and charge state of dust particles and the validity of the model assumed in the present study for protoplanetary disks so as to discuss electromagnetic effect to the dust particle quantitatively.

Keywords: protoplanetary disk, dusty plasma