Interplay between dust and MHD turbulence in protoplanetary disks: electric-field heating of plasmas and its effect on the ionization balance of dusty disks

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Magnetorotational instability (MRI) is a viable mechanism of driving turbulence in protoplanetary disks. The activity of MRI depends largely on the ionization degree of the disk gas, which in turn depends on the amount of tiny dust grains that efficiently capture ionized gas particles (e.g., Sano et al. 2000). Understanding the interplay between dust and MRI turbulence is essential for understanding dust evolution and subsequent planetesimal formation in the disks.

In this study, we focus on the heating of electrons by turbulent electric fields and investigate how this affects the ionization balance of protoplanetary disks containing small grains. Previous studies have assumed that electrons in the disks have the same temperature as the neutral gas. However, this is not necessarily the case in MRI-driven turbulence, in which turbulent electric fields can significantly heat up electrons (Inutsuka & Sano 2005). This heating promotes collisions between the electrons and grains, leading to a reduction of the ionization degree (Okuzumi & Inutsuka, in prep.). We have studied how this effect limits the saturation level of MRI turbulence in protoplanetary disks. For a minimum-mass solar nebula with the grain radius of 0.1μm and dust-to-gas mass ratio of 0.01, we find that the saturation level of MRI turbulence is significantly lowered inside 70 AU from the central star. We also find that the grains in the region are so charged up negatively that the resulting electrostatic repulsion likely affects the their collisional growth.