Inefficient Magnetic Accretion Heating in Protoplanetary Disks: Evolution of The Snow Line

*Shoji Mori[1], Xuening Bai[2], Satoshi Okuzumi[3]

1. Department of Astronomy, The University of Tokyo, 2. Tsinghua Center for Astrophysics, Tsinghua University, 3. Department of Earth and Planetary Sciences, Tokyo Institute of Technology

The structures of the inner region of protoplanetary disks are essential for understanding the formation process of terrestrial planets. The gas temperature in the region is thought to be determined by accretion heating, which is conventionally attributed to turbulent dissipation. Because the turbulent dissipation occurs in the disk, the released heat accumulates in the disk and thereby effectively increases the disk temperature. However, recent studies have suggested that the inner disk (a few AU) is largely laminar, with accretion primarily driven by magnetized disk winds, as a result of nonideal magnetohydrodynamic (MHD) effects from weakly ionized gas, suggesting an alternative heating mechanism by Joule dissipation.

Purpose of this study is to investigate the accretion heating with the nonideal MHD effects and to understand thermal structure in the inner disk region. We perform local stratified MHD simulations including nonideal MHD effects and investigate the role of Joule heating and the resulting disk vertical temperature profiles. We find that Joule heating occurs at several scale heights above the midplane, making the midplane temperature much lower than that with the conventional viscous heating model. Also, 80 % of the accretion energy is flown out by the disk wind. Our results further suggest that the midplane temperature in the inner region is almost entirely determined by irradiation heating. We also discuss the evolution of the water snow line based on our results and the formation process of the earth.

Keywords: Protoplanetary disks, Magnetohydrodynamic simulation, Snow line

