

P223b Lightning Generation by Streaming Instability in Protoplanetary Disks

Fang Han, Taishi Nakamoto (Tokyo Institute of Technology), Tetsuo Taki (The University of Tokyo)

We investigate the generation of lightning in protoplanetary disks through streaming instability, focusing on its potential role in the formation of chondrules—meteoritic components that provide clues about the environment of the early solar system. Chondrules are believed to form through rapid heating in high-density dust environments, a process that remains largely unexplained (Alexander et al. 2008; Desch et al. 2012). We propose a model where lightning, generated by charge accumulation from particle collisions, serves as a heat source for chondrule formation. Using the open-source code ATHENA (Stone et al., 2008; Bai & Stone, 2010), we calculate the dynamics of gas and particles within the disk, examining how differently sized dust particles moving at various velocities collide and exchange charges. This process leads to the formation of electric fields as charged dust particles spatially separate.

We specifically consider the dust layer in the disk's midplane, a region susceptible to streaming instability and planetesimal formation. We use a two-species dust model with Stokes numbers of 0.01 and 0.1, and a metallicity of 0.03. In high-density dust environments, frequent collisions result in significant charge separation, potentially creating electric fields strong enough to overcome neutralizing currents and trigger lightning. Our findings indicate that in such environments, where self-gravitational collapse also plays a role, the electric fields generated by colliding dust particles can grow strong enough to initiate lightning discharges within timescales of approximately 1.6×10^{-2} Keplerian time.