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Study of cosmic ray transport in young protostars: Impact of in-situ CR acceleration on hydrogen ionization

The formation of stars and planetary disks is a complex, multi-scale, and multi-physics process. While large-scale numerical simulations commonly incorporate magnetic fields and radiative transfer, the role of cosmic rays remains underexplored. As the primary ionizing agent in the gas-dust mixture, cosmic rays significantly influence its coupling with magnetic fields and the prominence of non-ideal magnetohydrodynamic (NiMHD) effects, which play a crucial role in protoplanetary disk formation. Recent observations indicate an increasing cosmic ray ionization rate toward the centers of active young protostars, suggesting that cosmic rays may be accelerated in these environments. Elevated ionization rates enhance the gas-magnetic field coupling, impacting the magnetic braking mechanism that governs disk formation.

To address this gap, we employ the adaptive mesh refinement code RAMSES to simulate the injection and propagation of cosmic rays from young stellar objects. This study investigates the temporal and spatial evolution of cosmic rays in protostellar environments. I will present 3D numerical experiments solving the two-moment cosmic ray transport equation, incorporating cosmic ray injection, accounting for cosmic ray cooling, and analyzing the impact of varying diffusion coefficients on their spatial distribution. Furthermore, I will examine the extent to which in-situ acceleration contributes to ionization in the protostellar environment.

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