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Cosmic rays in star and disk formation processes

Kengo Tomida[1], Shigeo Kimura[1,2], Shinsuke Takasao[3]
[1] Astronomical Institute, Tohoku University, [2] Frontier Research Institute for Interdisciplinary Sciences, Tohoku University, [3] Department of Earth and Space Sciences, Osaka University
e-mail (speaker): tomida@astr.tohoku.ac.jp
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Angular momentum transport by magnetic fields is one of the key processes in star and disk formation, and non-ideal Magnetohydrodynamic (MHD) effects strongly affect the disk formation and evolution [1]. The rates of the non-ideal MHD effects depend on the ionization rate as well as dust properties, and the ionization rate depends on many physical processes such as cosmic rays, ionizing radiation, and decay of radioactive nuclei. Therefore, it is of crucial importance to understand how these ionization processes work in star formation processes.

Cosmic rays are one of the most important ionization processes in star and disk formation processes. While cosmic rays from the interstellar space can propagate into star forming clouds, shocks in jets and protostellar flares driven by magnetic reconnection can internally accelerate cosmic rays within star forming clouds.

In this talk, I will discuss acceleration and propagation of cosmic rays in star forming clouds and their impact on the disk formation and evolution. Based on MHD simulations of star and disk interaction, we found that giant protostellar flares are driven by magnetic reconnection in the innermost region of a protoplanetary disk [2]. These flares are very energetic and release up to a few 10^{38} erg every 20-30 orbital periods, producing hot ejecta This is consistent with X-ray observations of protostellar flares.

Motivated by this work, we constructed a model of non-thermal radiation from these flares [3]. We first calibrated the model based on solar flares and extended it to the protostellar flare regime. We found that such flares are good sites of cosmic-ray acceleration and produce broad emissions from radio to gamma-ray. The emission can be observed with the Cherenkov Telescope Array and other future observatories at various wavelengths.

References

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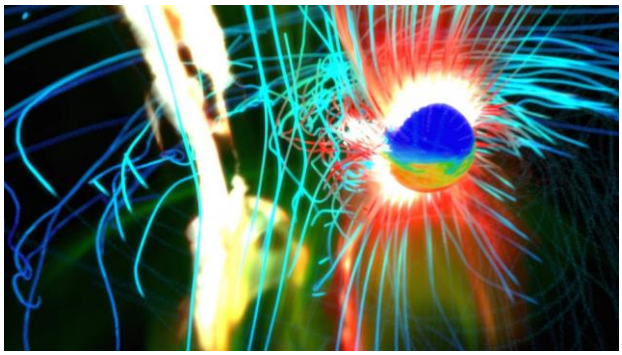

Figure 1. Hot ejecta produced in a giant protostellar fare driven by magnetic reconnection in a protoplanetary disk [2]. Lines indicate magnetic field lines and the yellow to white region is hot gas.

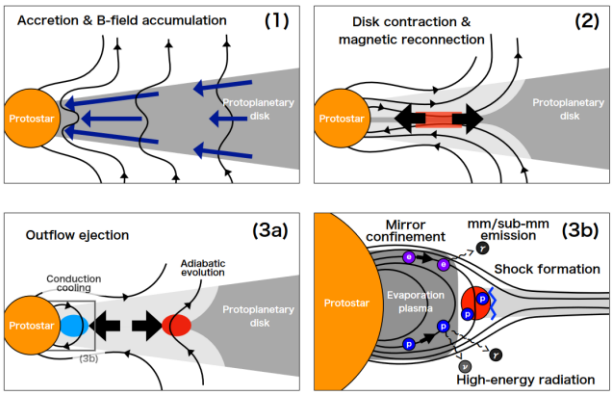

Figure 2. A schematic picture of acceleration of cosmic rays and production of non-thermal emissions [3].

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