

Ionization of protoplanetary disks by galactic cosmic rays, solar protons, and supernova remnants

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Galactic cosmic rays and solar protons ionize the present terrestrial atmosphere, and the air showers are simulated by well-tested Monte-Carlo simulations, such as PHITS code. We use the latest version of PHITS to evaluate the possible ionization of protoplanetary disks by galactic cosmic rays (GCRs), solar protons, and by supernova remnants. The attenuation length of GCR ionization is updated as 118 g cm^2 , which is approximately 20% larger than the popular value. Hard and soft possible spectra of solar protons give comparable and 20% smaller attenuation lengths compared with those from standard GCR spectra, respectively, while the attenuation length is approximately 10% larger for supernova remnants. Further, all of the attenuation lengths become 10% larger in the compound gas of cosmic abundance, e.g. 128 g cm^2 for GCRs, which can affect the minimum estimate of the size of dead zones in protoplanetary disks when the incident flux is unusually high. In this presentation we further discuss our recent progress.