Flare-driven X-ray ionization and chemistry in protoplanetary disks

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Young stars often produce powerful explosions called flares—sudden releases of magnetic energy that generate intense X-ray radiation lasting for several hours. These X-rays play an important role in shaping the physical and chemical conditions of the surrounding protoplanetary disk. In particular, flares are a unique source of hard X-rays with energies above about 10 keV in a protoplanetary system. These high-energy photons can penetrate deep into the disk and ionize gas without undergoing absorption by disk materials [1]. While observations have indicated that time variability in stellar X-ray luminosity affects disk ionization [2], theoretical models [e.g., 3] have often neglected the detailed properties of individual flares and their hard X-ray emission.

In our study, we develop a model of time-varying X-ray emission from flares, based on solar/stellar observations and theories [4]. We combine this model with radiative-transfer and chemical network calculations to quantify how flare-driven X-rays change the ionization state and chemistry in the disk. Our results show that a single flare (energy ~10^{35} erg) can temporarily raise ionization rates to levels higher than those produced by galactic cosmic rays, leading to enhanced formation of molecules such as HCO^+ and N_2H^+. These findings highlight the importance of flare-driven X-rays as a driver of ionization and chemistry in protoplanetary disks. I will also discuss the potential impact of multiple flares and their role in the disk's chemical evolution.

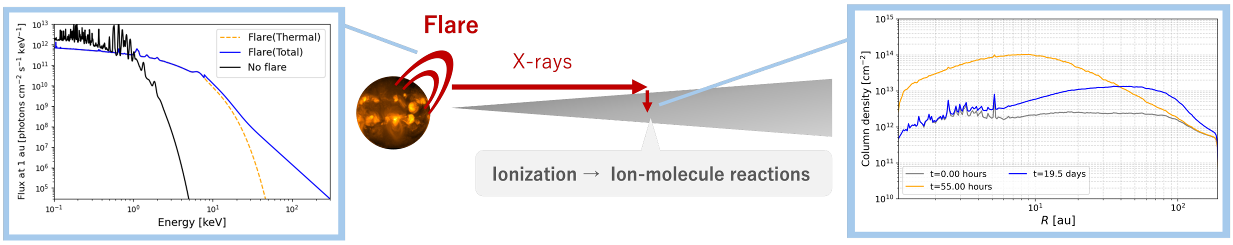

Figure 1: A schematic picture of this study. We model an X-ray spectrum of the stellar flare (left figure) and study the chemical responses (right figure: HCO+ column density before (gray line) and after the single flare (blue and orange lines)).

References

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