NaCl Line Emission to probe the Physicochemical State of the Hot Disk around IRAS 16547-4247A

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Massive protostellar disks feature high-temperature regions ($\gg$ 100 K) driven by intense stellar irradiation and high mass accretion rates. Recent ALMA observations of these disks have detected gas-phase emission from refractory molecules like NaCl, making them excellent sites for understanding the chemistry of rocky material in such high-temperature environments. However, high surface densities make these disks optically thick, and dust grain growth introduces significant scattering. Notably, ALMA observations of the massive protostellar disk IRAS 16547–4247a revealed nearly equal intensities for two NaCl transitions with distinct excitation energies, highlighting the need to account for radiative transfer effects.

In this study, we developed a radiative transfer code assuming a plane-parallel disk structure with dust scattering to constrain physical and chemical disk properties from the NaCl emission. We focus on the Band 6 observations of the IRAS16547-4247 disk, including the three NaCl lines with Eu/kB=107 K, 626 K, 1128 K, respectively. By simultaneously fitting the three emission lines and the continuum quantitatively we evaluated how optical depth and scattering influence line intensities and profiles.

While continuum emission typically matches blackbody radiation in optically thick disks, we demonstrate that dominant scattering attenuates the continuum, enabling line formation. We have derived parameters such as temperature, optical depth, dust emissivity, and NaCl abundance. The derived abundance indicates that approximately 1% of total sodium exists as gas phase NaCl. This value is orders of magnitude higher than that predicted by equilibrium calculation models, which suggests a state of chemical non-equilibrium. This discrepancy necessitates further investigation using detailed chemical network modeling. By establishing these quantitative constraints, this study paves the way to bridge disk physics with astrochemistry and astromineralogy.