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Distributions of hot molecules in young circumstellar disks

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Thanks to recent progress in astronomical observational technique, it has become possible to detect various molecular line emission from young circumstellar disks. It is expected that forthcoming high spatial resolution and high sensitivity ALMA observation will make it possible to detect molecular lines from planet forming region just near the central star, which will reveal physical and chemical structure of the planet forming region by comparing the observational data and the model calculations.

It is thought that gas-dust interaction has strong influence on the chemical structure near the midplane of young circumstellar disks. Gas-phase molecules freeze on to dust grains and react with each other to form new species in cold and high density region in the outer disk. Once the dust grains move into high temperature region, the icy mantle molecules evaporate into gas and the subsequent gas-phase reactions produce more complicated large molecules.

In this work, focusing on this chemical property of the icy mantle molecules evaporated from dust grains, we investigate the effect of gas accretion flow on the chemical structure near the midplane of the inner disks. First we have obtained the temperature and density profiles of the disks self-consistently by solving equations for local radiative equilibrium and hydrostatic equilibrium in the vertical direction. Making use of this physical structure, we calculate time-dependent gas-phase chemical reactions initiated by the icy mantle evaporation in the hot inner region of accreting young circumstellar disks. Now, the evaporation time of parent molecules is less than one year, while the daughter species are produced from the parent molecules for a time scale of around 10^{4-5} years. We have found that this difference in timescales leads to the difference in the radial profiles of molecular abundances of parent and daughter species. In addition, we examine the dependence of the accretion velocity on the chemical structure in the disks. For example, if the velocity is high, the abundances of parent molecules like CH_3OH are high throughout the disks within the evaporation radius, while those of daughter species like CH_3OCH_3 become higher just in the inner region. If the velocity is low, both parent and daughter species have high abundances just along a very thin ring near the evaporation radius because they are destroyed due to gas-phase reactions before they move inwards via the accretion flow.

Furthermore, using the obtained physical and chemical structure, we calculate the molecular line emission from the disks by solving radiative transfer equation, which shows that the radial distributions of the line emission are observable by ALMA. Our results suggest that the ALMA observations and the detailed model calculation will enable us to make a constraint on the disk accretion velocity in the planet forming region, which will lead to understanding of gas dispersal of young circumstellar disks, and then orbital evolution of solid planets and gaseous planet formation.