How to measure snowlines and C/O ratio distributions in protoplanetary disks using infrared spectroscopic observations

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Protoplanetary disks are active environment for the creation of simple molecules (e.g., H_2O, CO, CO_2, HCN) and complex organic molecules (COMs). The emission lines of these simple molecules from disks are detected by the infrared spectroscopic observations using Spitzer space telescope and large ground-based telescopes like VLT, Keck (e.g., [1])

Since protoplanetary disks rotate with Keplerian velocity, the emissions from disks have characteristic profiles due to doppler shift. Analyzing the profiles of lines, we will obtain the information on the distance from the central star of the line emitting regions. We have calculated the chemical structure of protoplanetary disks and H_2O line profiles, and have proposed the method to locate the position of the H_2O snowline in the disk midplane using high-dispersion spectroscopic observations. We have found that the H_2O lines with small Einstein A coefficients and relatively high upper state energies are dominated by emission from the disk region inside the H_2O snowline, and thus their profiles potentially contain information which can be used to locate the position of the H_2O snowline.[2][3].

It is thought that difference in snowlines of oxygen- and carbon-bearing molecules, such as H_2O, CO, CO_2, HCN, will result in systematic variations in the C/O ratio both in the gas and ice [4] [5]. In addition, the C/O ratio of atmosphere of some exoplanets (e.g., Hot Jupiter) were estimated by recent studies [6]. Therefore, the planet forming regions could be confined through comparing the radial distributions of C/O ratio in disks and those of planetary atmospheres.

In this study, we developed our calculations of disk chemical structures, and investigated the abundance distributions of simple molecules. We then calculated various line profiles of simple molecules from disks. We found that through investigating the profiles of various molecular lines with various Einstein A coefficients and upper state energies, we can confine C/O ratio distributions in disks. For example, HCN lines from a Herbig Ae disk in 14μm band reflect gas distributions of the outer disk. In contrast, HCN lines in 3μm bands reflect those of the inner disk surface. We also discuss the possibility to measure such molecular lines with future near- and mid-infrared spectroscopic observations.

References

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