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

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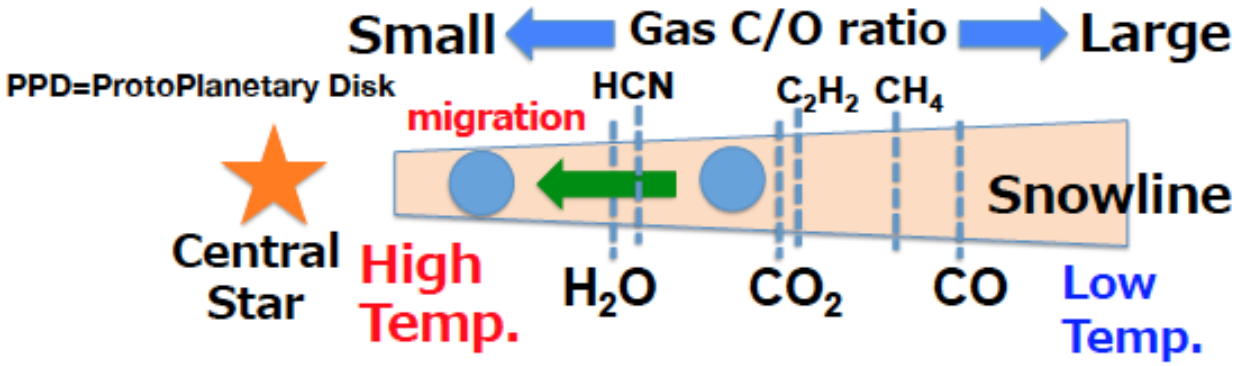
Protoplanetary disks are active environment for the creation of relativley simple molecules (e.g., H_2O, CO, CO_2, HCN) and complex organic molecules (COMs). The emission lines of these simple molecules from disks are detected by the infrared spectroscopic observations using Spitzer space telescope and large ground-based telescopes like VLT, Keck (e.g, Pontoppidan et al. 2010a&b, Mandell et al. 2012).
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 structures of protoplanetary disks and radiative transfer of H_2O lines, and have proposed the method to locate the H_2O distributions of near the midplane of the inner disk, using spectroscopic observations. We have found that we can obtain the information on the H_2O snowline through investigating the profiles of some emissions that have small Einstein A coefficient and relatively large energy in the upper level (e.g., Notsu et al. 2016a, ApJ submitted, 2016b, in prep.).
It is thought that difference in snowlines of oxygen- and carbon-bearing molecules, such as H_2O, CO, HCN, CO_2, will result in systematic variations in the C/O ratio both in the gas and ice (e.g., Oberg et al. 2011, Pontoppidan et al. 2014). In addition, the C/O ratio of atomosphere of some exoplanets (e.g., Hot Jupiter) were measured by recent studies (e.g, Madhusudhan et al. 2014). 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 for T Tauri disk, and investigate the abundance distributions of simple molecules. We then calculated radiative transfer of various lines of simple molecules. We found that through investigating the profiles of lines with various Einstein A coefficients and excitation energies, we can detect C/O ratio distributions of various molecules in disks. For example, HCN lines from a T Tauri disk in 14μm band reflect gas distributions of inner disks. In contrast, HCN lines in 3μm bands reflect those of outer disks. We also discuss the possibility to measure such molecular lines with future near- and mid-infrared spectroscopic observations. In addition, we will discuss the results for Herbig Ae disk case, if we have a time.

Keywords: snowline, protoplanetary disk, chemical reactions, C/O ratio, infrared spectroscopic observation, planet formation



There are radial dependences of Gas & Dust C/O ratio in Protoplanetary disks.

e.g., Pontoppidan et al. 2014

