Possibility to locate the position of the H_2O snowline in protoplanetary disks using high-dispersion spectroscopic observations with ALMA

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Inside the H_2O snowline of protoplanetary disks, water evaporates from the dust-grain surface into the gas phase, whereas it is frozen out onto the dust in the cold region beyond the snowline. H_2O ice enhances the solid material in the cold outer part of a disk, which promotes the formation of gas-giant planet cores. We can regard the H_2O snowline as the surface that divides the regions between rocky and gaseous giant planet formation (e.g., Hayashi et al. 1981, 1985). Observationally measuring the location of the H_2O snowline is crucial for understanding the planetesimal and planet formation processes, and the origin of water on Earth.

The H_2O snowline in the disk midplane around a solar mass T Tauri star is thought to exist at only a few au from the central star. Therefore, the required spatial resolution to directly locate the H_2O snowline is on the order of 10 mas (milliarcsecond) around nearby disks (~100-200 pc) , which remains challenging for current facilities. The velocity profiles of emission lines from protoplanetary disks are usually affected by Doppler shift due to Keplerian rotation and thermal broadening. Therefore, the velocity profiles are sensitive to the radial distribution of the line-emitting regions.

In this study (Notsu et al. 2016, 2017), we propose the method to locate the position of the H_2O snowline in protoplanetary disks through the observations of H_2O line profiles, on the basis of our calculations. First, we calculated the chemical composition of a T Tauri disk (T_{star}~4,000K, M_{star}~0.5M_{sun}) and a Herbig Ae disk (T_{star}~10,000K, M_{star}~2.5M_{sun}) using chemical kinetics. We confirmed that the abundance of H_2O is high not only in the inner region of H_2O snowline near the equatorial plane but also in the hot surface layer and photodesorption region of the outer disk.

Next, we calculated the H_2O emission line profiles, and investigate the properties of candidate water lines across a wide range of wavelengths (from mid-infrared to sub-millimeter) that can locate the position of the H_2O snowline. Those identified lines have small Einstein A coefficients (~10^{-6}-10^{-3} s^{-1}) and relatively high upper state energies (~1000K). The total fluxes tend to increase with decreasing wavelengths. In disks around Herbig Ae stars, the position of the H_2O snowline is further from the central star compared with that around cooler, and less luminous T Tauri stars. Thus, the H_2O emission line fluxes from the region within the H_2O snowline are stronger for the Herbig Ae disks.

In this presentation, we introduce results of our calculations explained above, and discuss the possibility of observations with ALMA to locate the position of the H_2O snowline.
In addition, recently we have calculated the H_2O line profiles in the wavelength region of ALMA band 5. We wll also introduce those results.

Reference; Notsu, S., et al. 2016, ApJ, 827, 113

Notsu, S., et al. 2017, ApJ, 836, 118

Keywords: H_2O snowline, Protoplanetary disks, Chemical reactions, High-dispersion spectroscopic observations, Molecular emission lines, Planet formation

