Water Molecules in the Circumstellar Disks of T-Tauri Stars

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Abstract

Planets form in disks around newly formed stars. A detailed study of the gas in disks around classical T-Tauri stars is critical to understanding the thermal, chemical, and dynamical processes through which solar systems are formed. Recent high S/N data taken using the Spitzer IRS for a sample of T-Tauri stars show that water is a common element in the spectra. By comparing the H_2O emission lines with models, we can learn about the distribution of temperature within the disk, and learn about mixing processes within the disk. We studied a sample of T-Tauri stars observed using the mid-infrared spectrograph on Gemini, reducing the data and building routines in IDL to analyze the data.

Background

Disks around T-Tauri stars are where planets form. T-Tauri stars are approximately solar mass stars with accretion disks and lifetimes of a few million years (Carr & Najita, 2008). Carr & Najita found that the mid-infrared spectra of T-Tauri stars are rich with emission lines due to H_2O and other organic molecules. Water plays a substantial role in the formation of planets and a study of water is important to understanding the formation of planetary systems (Glassgold, 2009).

We cannot directly observe the proto-planetary disks because the disks are too small and too far away to be visually resolved. We can infer what is going on in the disks by analyzing H_2O emission lines in the spectra of T-Tauri stars. Recent observations of a sample of T-Tauri stars made using the Spitzer Infrared Space Observatory indicate that H_2O emission lines are common in the spectra (Carr & Najita, 2011).

By modeling the emission lines of water, we will learn where water forms in the disk, how spread out it is within the disk, and by comparing the data with non-LTE (local thermodynamic equilibrium) models, we can learn about the temperature distribution within the disk (Carr & Najita, 2008). We learn where water forms by measuring the Doppler shift of the emission lines. If water forms at radii closer to the

We may also learn about vertical and radial mixing within the disk. Disk chemistry models predict the presence of water at AU radii, but we do not expect to see water in the hot upper atmospheres of the disk where the emission lines form(Carr & Najita, 2008). Radiation from the star breaks molecular bonds in these regions, so we do not expect to see molecular lines in the spectra. The water is likely being brought to the hot upper atmospheres by vertical mixing. The presence of water in the emission spectra of these disks is an indicator that there is vertical mixing going on in the disk, and by studying the H_2O emission lines, we may be able to learn more about the mixing processes within T-Tauri disks.

Data Source

The data for this study was taken in 2007 at the Gemini Observatory using TEXES, a mid-infrared spectrograph, operating in its highest resolution mode (R=100,000). The raw data was taken from the spectrograph and then put into analyzable form using a FORTRAN routine developed by the PI, John Carr (Naval Research Laboratory).

It is difficult to observe in the infrared portion of the spectrum because of the many sources of infrared light. The atmosphere, Earth, and telescope all emit in the infrared and therefore corrections must be made for these noise sources. To find the atmospheric contribution, the observing team pointed the telescope at a dark part of the sky and collected the spectrum. To account for the noise due to the telescope, the observing team put a blackbody object whose characteristics and spectra are known in front of the telescope, and then a spectrum was collected. By subtracting the known blackbody spectrum from the collected spectrum, the observing team determined the noise contribution of the telescope. In the data reduction routine, the sky contributions are divided out from the target spectra.

Procedure

We modeled the data using Gaussians via a routine I developed in IDL. Based on the output from the Gaussian routine, we calculated the radial velocity of the water and the full-width half-maximum of each of the Gaussians. From this information, we can conclude the location and spread of the water in the disk.

Then we compare the data to models created using code written by John Carr at the Naval Research Laboratory. The models include parameters for temperature variation, vertical mixing and radial mixing. The models synthesize a spectrum and then we compare the two spectra by running a cross-correlation between the two spectra. The strongest correlated models will give us a good idea of what's going on in the proto-planetary disks.

Progress and Future Work

This summer I worked on getting the FORTRAN routine up and running so that the data could be reduced again. I also worked on IDL routines to analyze the data. A colleague of mine worked on getting the modeling code working and creating models. I plan to run the raw data through the FORTRAN routines again to see if I can get a better product for analysis. I also plan to continue work on the IDL routines and analyze the data.

Conclusion

This study is a step forward in our understanding of the formation and evolution of the solar system. Through the detailed analysis of gas in the planet-forming disks around classical T-Tauri stars, we can understand the chemical, thermal and dynamical processes that result in the formation of planets.

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References

Carr, J. S., & Najita, J., ApJ, 733,102, 2011

Carr, J. S., & Najita, J., Science, 319, 2008

Glassgold, A. E., Meijerink, R., & Najita, J. R., ApJ, 701, 142 (2009)