The Indirect Detection of Liquid Water in Extrasolar Protoplanetary Disks

Anthony J. Terzolo[1], Shane Fogerty[2], and Melissa A. Morris[1,3]
[1] Physics Department, State University of New York at Cortland, [2] Physics and Astronomy Department, University of Rochester, [3]School of Earth and Space Exploration, Arizona State University

Abstract

Phyllosilicates are hydrous minerals that form through the interaction of rock and liquid water. Phyllosilicates are found in abundance in certain types of meteorites originating from the asteroid belt, providing evidence for liquid water in the early Solar System. Most phyllosilicates show a distinct emission in the mid-infrared (MIR) portion of the electromagnetic spectrum, and can be detected in extrasolar disks [1]. We have examined the observed spectra of several candidate extrasolar planetary systems, and have found the signature of phyllosilicates in the extrasolar disk of 1RXS J161410.6-230542. The detection of phyllosilicates in this disk would indicate the presence of liquid water and suggest a similarity to our own Solar System. We present the comparison of our model spectral energy distributions (SEDs) of the protoplanetary disk 1RXS J1614.6-2320542 to observations obtained by the Spitzer Space Telescope.

Background

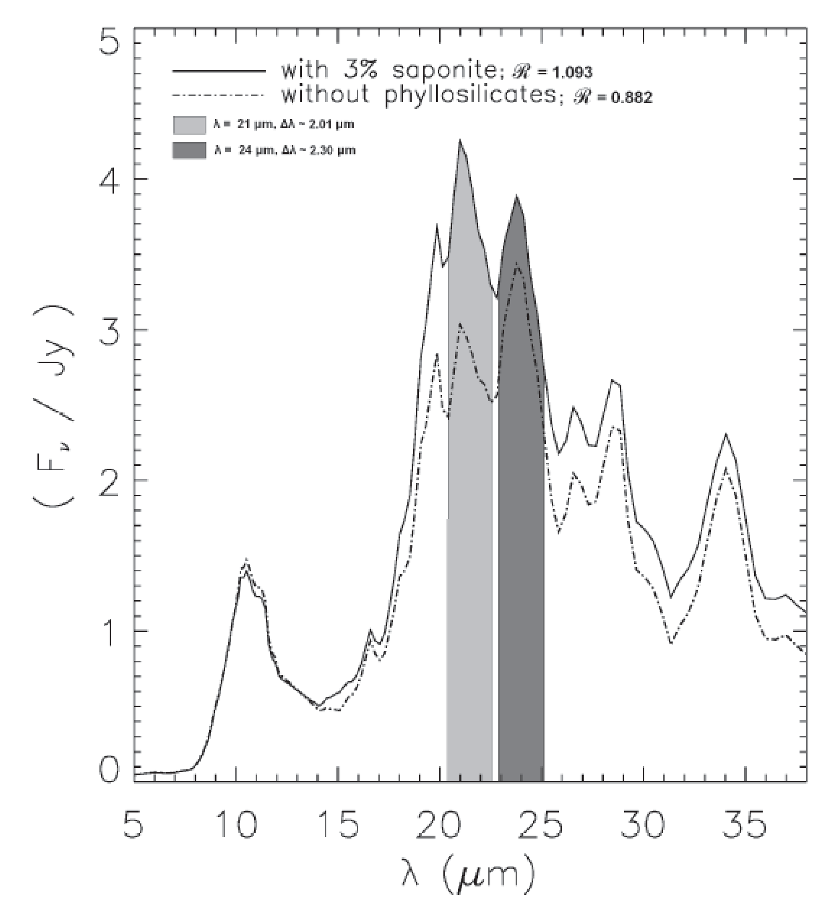

Figure 1. The spectral signature of phyllosilicates, indicating the presence of liquid water [1]. This figure from [1] shows the comparison between model SEDs with and without phyllosilicates.

Phyllosilicates in Meteorites

The most common types of phyllosilicates found in meteorites include saponite, serpentine, montmorillonite, and cronstedtite.

Table 1. Most common types of phyllosilicates found in chondrites [1]

Saponite	*Serpentine*	*Montmorillonite*	*Cronstedtite*
CI	CM	CI	CM
CV	CO		
CR	CR		
Ordinary chondrites			
Interplanetary dust particles			

Methods

- We use the 2-layer disk model of [1], of a passive, flared disk in hydrostatic and radiative equilibrium to compute our model spectral energy distributions. The model includes the spectral contribution of the star, disk, and superheated dust layer. We have have used Kurucz stellar models to calculate the contribution from the central star, and have calculated dust opacities using a distribution of hollow spheres for a population of grains of different compositions, with relative abundances as shown in Table 2. System parameters (where available) and those used to produce model SEDs are shown in Table 3.
- Observations were obtained with the Infrared Spectrograph (IRS) instrument on board the Spitzer Space Telescope, through the Formation and Evolutionary of Planetary Systems Spitzer Legacy Science Program [2], with data reduction performed by the Cornell Atlas of Spitzer/IRS Sources, CASSIS [3].

1RXS J161410.6-230542		
Mineral	With phyllosilicates	Without phyllosilicates
Amorphous Forsterite	.08	.08
Amorphous Enstatite	.01	.06
Crystalline Olivine	.025	.025
Crystalline Enstatite	.005	.005
FeS	.61	.61
Corundum	.21	.21
Hibonite	.01	.01
Saponite	.01	.00
Serpentine	.02	.00
Montmorillonite	.02	.00

Table 2. Relative abundances of minerals used to produce model SEDs.

Object	Temperature (K)	Distance (Pc)	Mass ($R^*/R_\odot$)	i (^{0})	Radius ($R^*[R_\odot]$)
1RXS J161410.6-230542	4963	121	1.01	?	2.21
Model 1RXS J161410.6-230542	5000	121	1.01	20	2.21

Table 3. Stellar parameters (where available) were taken from the Simbad astronomical database and [4-7].

Observations

a

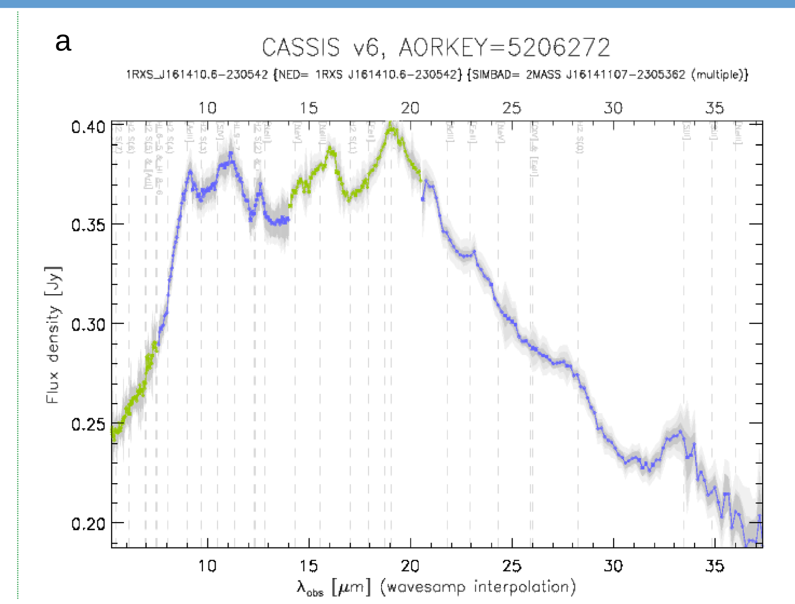

Figure 2. (a) Spectral energy distributions of 1RXS J161410.6-2320542. Courtesy of Cornell Atlas of Spitzer/IRS Sources, CASSIS.

Results

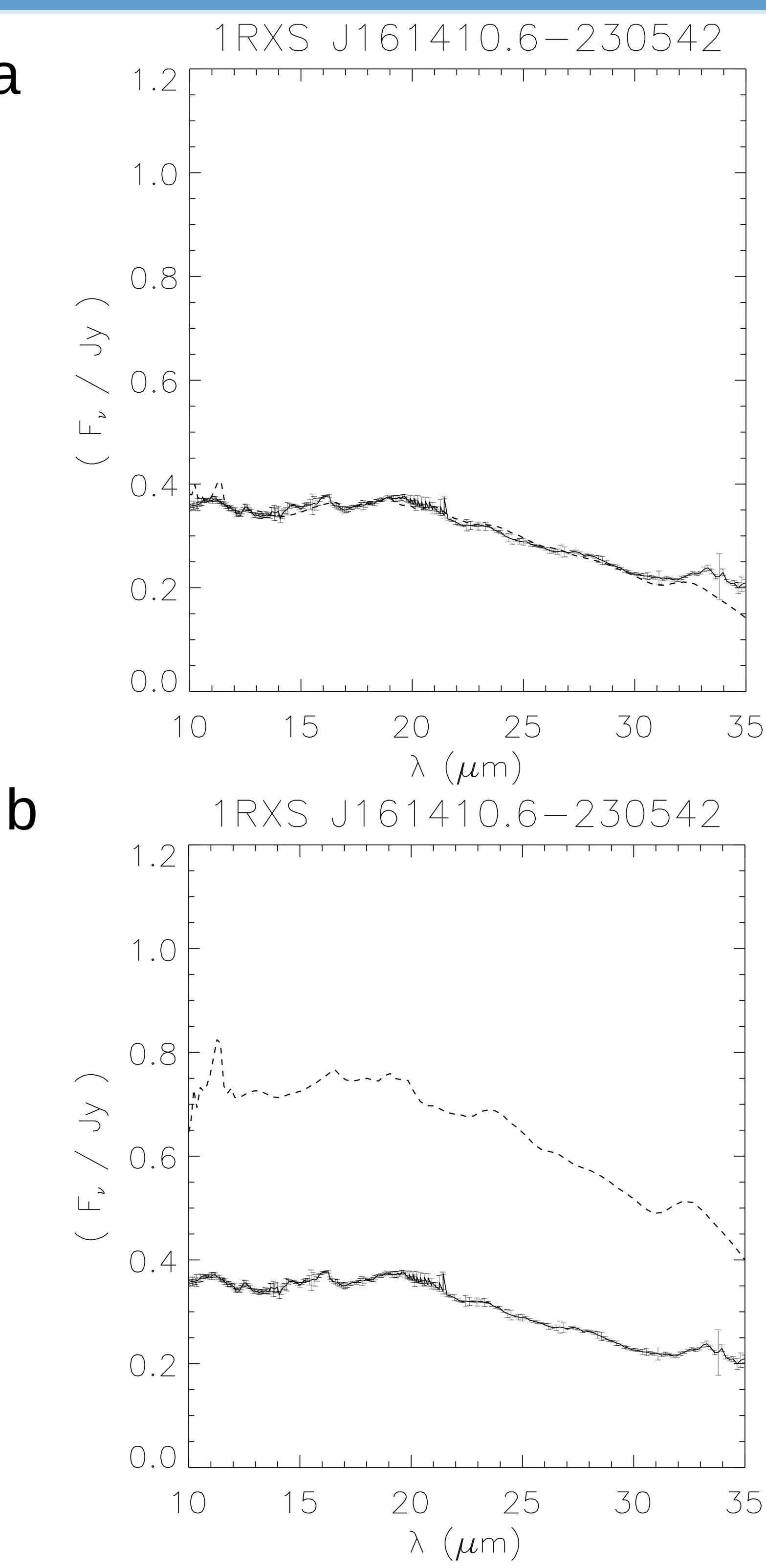

Figure 3. Comparison of model SEDs to the observation of 1RXS J161410.6-230542 range from 10-35μm. 1RXS J161410.6-230542 was modeled (a) with the inclusion of 5% phyllosilicates. 1RXSJ 161410.6-23542 is modeled (b) without phyllosilicates.

Conclusion

We achieve a better fit to the observed spectra in the spectral range ~ 12 – 30 μm with the inclusion of phyllosilicates than without. Our results indicate the likely presence of liquid water in the extasolar protoplanetary disks. In model (a) we achieved an overall X^2 of 3.6 and in model (b) we X^2 increases to 97.43. Since the stellar parameters are known (other than *i*), the large difference in flux is likely due the abundance of phyllosilicates. We plan to continue to refine our model to better fit the spectra of this system at all wavelengths.

References

[1] Morris, M.A., & Desch, S.J., 2009, *Astrobiology*, 9, 965. [2] Meyer et al., 2004, *The Astrophysical Journal Supplement Series*, 154, 422. [3] Lebouteiller, V., Barry, D.J., Goes, C., et al., 2015, *The Astrophysical Journal Supplement Series*, 218, 21. [4] Hillenbrand, L.A., 2005, *Spitzer Imaging and Spectroscopy Disks*, Invited Talk at CalTech. [5] Passucci et al.,2007, *The Astrophysical Journal*, 663, 383. [6] Gudel et al., 2010, *Astronomy & Astrophysics*, 519A, 113G. [7] Rigliaco et al, 2015, *Astrophysical Journal*, 803A, 31

Acknowledgements

M.A.M was supported by NASA Cosmochemistry grant NNX14AN58G and Emerging Worlds grant NNX15AH62G . We also want to thank Cornell for the use of its CASSIS database.