SPATIALLY RESOLVED SPECTROSCOPY AND FAR-INFRARED PHOTOMETRY OF THE TRANSITIONAL DISK AROUND HD 141569A. A. J. Weinberger, *Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC (weinberger@dtm.ciw.edu)*, E. E. Becklin, *Department of Physics & Astronomy, UCLA, Los Angeles, CA*.

HD 141569A is a 5 Myr old Herbig AeBe star in transition from a primordial to debris phase (Weinberger et al. 2000). The disk around HD 141569A still contains a substantial amount of gas in CO (Zuckerman, Forveille, & Kastner 1995). Yet the amount of dust radiation in the infrared, L_{IR}/L_{*}=0.01, suggests that only about 1 Earth mass of dust remains. Here, we investigate the dust quantity and composition of the disk as a function of distance from the star. We combine spectral information on the disk from R$\sim$120 spatially resolved spectroscopy of PAH molecules with Spitzer far-infrared photometry of the system.

Spatially resolved mid-infrared spectra of the disk encircling HD 141569A show abundant polycyclic aromatic hydrocarbons. Observations were made with the Long Wavelength Spectrometer at the W. M. Keck Observatory on 6–7 May 2004. A 0.”5 wide slit was placed along the major axis of the disk. The instrument provided a spectral range of $7.7 - 12.3$ μm at resolution R$\sim$120 and an unvignetted field of view of 8.”6 with 0.08 arcsecond pixel^{-1}. The disk was detected out to 90 AU, i.e. out almost to the maximum radius of 100 AU seen in previous mid-infrared imaging.

Lines from PAHs are detected at every radius (Figure 1), and their line-to-continuum ratios actually increase with radius. We find a best fit for the PAH spectrum using small ionized PAHs of 0.45 nm in radius, although a range of sizes up to $\sim$2 nm may be present. When we attempted to add small silicate grain emission into the model, the best fit traded off continuum with silicate *absorption.* No silicate emission is observed.

Qualitatively, the presence of PAHs within 100 AU and lack of crystalline silicates together favor the cold coagulation dust model of Li & Lunine (2003) for the dust production. In this model, the large bodies now being evaporated near the star formed in the interstellar medium and incorporated PAHs at that time. However, the increase in the PAH line strength with distance implies a larger number of PAHs at large distances. This is not possible without either pileup or increased production. Pileup is extremely unlikely because these small grains are the ones most subject to radiation pressure. Even in the presence of gas drag, they are ejected rapidly (Takeuchi & Artymowicz 2001).

Moreover, the absence of silicates is odd for a young disk. Spectra of young stellar disks are typically dominated by emission from small ($<$1 μm) amorphous silicate dust similar to those seen in Solar System comets. During planetary formation, this primordial material grows into planetesimals, and may be modified by alteration in large parent bodies. Debris disks are generated by collisions of these larger bodies, and most are dominated by larger ($>$10 μm) grains (Jura et al. 2004). In principle, the size and composition of this dust should reflect parent body processes and collisions.

Other Herbig AeBe disks have been seen with similar PAH spectra. However, the lack of silicates in these disks has been explained either by high optical depths that keep the small silicates cold and therefore not radiating at 10 μm (Meeus et al. 2001) or by dust distributions that preclude hot grains (Meeus et al. 2002). Neither explanation readily applicable to HD 141569. Its disk is optically thin, and the spatially resolved spectra isolate the dust continuum at 10–20 AU, where silicate grains would be $\sim$200 K.

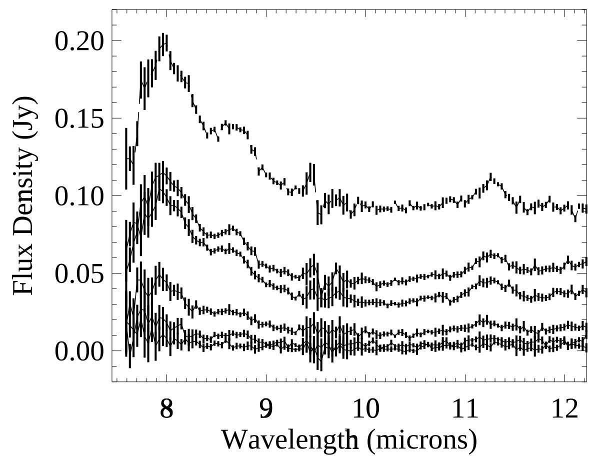

Figure 1: Spectra of the HD 141569A disk starting with one centered on the star (highest flux) and extracted every 24 AU in radius from the star out to 120 AU (solid lines). The contribution from the photosphere, modelled as a blackbody at 10000 K has been subtracted from the total spectra to reveal the purely disk spectra. At every radius, the presence of PAHs is observed by the peaks at $\sim$8, 8.6, and 11.2 μm.

Extensive modeling of the disk has been undertaken by a number of authors to assess the grain sizes and compositions (e.g. Marsh et al. 2002; Li & Lunine 2003). Infrared photometry provides a critical input to such models. The combination of emission and scattering data has resulted in estimates of the optical depth and albedo of the disk grains and the suggestion that the disk contains water ice (Weinberger et al. 1999; Marsh et al. 2002).

Models of the SED have previously relied upon ground-based and IRAS data at 12 – 100 μm. In three separate measurements by two groups (see Figure 2), the ground based 10–12 μm fluxes are only about half of the IRAS flux density (Sylvester et al. 1996; Fisher et al. 2000; Marsh et al. 2002). This problem has been treated as an uncertainty in models or overlooked. The spectral energy distribution of HD 141569 in the 12 μm region is approximately flat with a color temperature of $\sim$200 K. Color correcting to this temperature pushes the 12μm IRAS point higher, making it more discrepant with the ground-based measurements. Finally, the ground-based

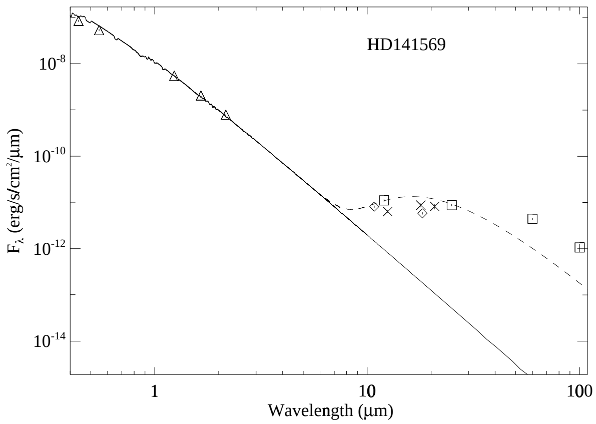

Figure 2: Spectral energy distribution of HD 141569A showing the infrared photometry from IRAS Faint Source Catalog (squares), Fisher et al. 2000 (diamonds), and Marsh et al. (2002) (crosses). The stellar photosphere is shown in the solid line, as a NextGen model (Hauschildt et al. 1999) fit to the Tycho-2 and 2MASS visible and near-infrared photometry (triangles). These have not been corrected for reddening. Purely as an illustration of the color temperature of the excess rather than as a real model of the dust emission, a blackbody curve at 175 K is shown through the IRAS 12 and 25 μm points.

18 μm measurements do not agree with IRAS or each other, to within their stated uncertainties.

One possible explanation for the discrepancy is a beam size effect. The ground based images were measured in beams of size $\sim$5 $''$, while the IRAS measurements have a beam size of $\sim$1 arcmin. This would imply a large 12 and 25 μm flux from very far from the star, where the disk grains should be cold. This would be plausible only if HD 141569 B and C, the M-type stellar companions to HD 141569A, had substantial infrared excess. To test this hypothesis, we observed all three stars with the Keck Telescope. We measured a 12 μm flux density on HD 141569B of 9$\pm$3 mJy, consistent with a predicted photospheric flux density of 10 mJy. We obtained an upper limit of 3 mJy (1σ) for HD 141569C, consistent with a 12 μm flux density arising purely from its photosphere as well.

At 60–100 μm, cirrus contamination may be present in the IRAS images of HD 141569. HD 141569 is located in projection near molecular clouds that contain substantial molecular hydrogen and dust emission.

To resolve the uncertainties in the mid and far-infrared flux from the disk and to search for disks around the companions, we are obtaining Spitzer/MIPS photometry of the HD 141569 system. These observations were scheduled, but not yet executed, by the time of the PPV abstract deadline.

References

Fisher, R. S., Telesco, C. M., Pina, R. K., Knacke, R. F., and Wyatt, M. C. 2000, ApJ, 532, 141

Hauschildt, P. H., Allard, F., Ferguson, J., Baron, E., & Alexander, D. R. 1999, ApJ, 525, 871

Jura, M. et al. 2004, ApJSS, 154, 458

Laor, A. & Draine, B. T. 1993, ApJ, 402, 441

Li, A. & Draine, B. T. 2001, ApJ, 554, 778

Li, A. & Lunine, J. I. 2003, ApJ, 594, 987

Marsh, K. A. et al. 2002, ApJ, 573, 425

Meeus, G. et al. 2001, A&A, 365, 476

Meeus, G. et al. 2002, A&A, 392, 1039

Sylvester, R. J., Skinner, C. J., Barlow, M. J., and Mannings, J. 1996, MNRAS, 279, 915

Takeuchi, T. & Artymowicz, P. 2001, ApJ, 557, 990

Zuckerman, B., Forveille, T., & Kastner, J. H. 1995, Nature, 373, 494

Weinberger, A. J. et al. 1999, ApJ, 525, L53

Weinberger, A. J. et al. 2000, ApJ, 544, 937