The Dust Composition of Transitional Disks

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Transitional disks in Taurus, Chamaeleon I & Ophiuchus

- We analyzed the *Spitzer* IRS spectra of some 200 young stars (later than G0), obtained as part of the IRS GTO program, in the three nearby star forming regions of Taurus, Chamaeleon I and Ophiuchus.
- Identified 17 transitional disks - protoplanetary disks which show evidence for inner holes and gaps in them - in these regions (see Figure 1).
- Transitional disks are believed to be in an intermediate evolutionary stage between that of Class II and Class III objects (Calvet et al. 2005; Kim et al. 2008; Espaillat et al. 2007; Furlan et al. 2008).

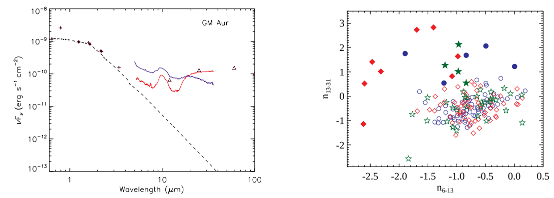

FIGURE 1: *(Left) SED of the transitional disk GM Aur. IRS spectrum of GM Aur (red) and the Taurus Class II median spectrum (blue) are also shown. Transitional disks show a deficit of flux at wavelengths ≤ 10 μm relative to the Class II median and a steeply rising continuum beyond 13 μm. (Right) Plot of continuum spectral indices between 13 and 31 μm (n_{13-31}) and between 6 and 13 μm (n_{6-13}) for young stars in Taurus (blue circles), Chamaeleon I (red diamonds) and Ophiuchus (green stars). The solid symbols represent transitional disks and the open symbols are normal Class II disks. Most transitional disks clearly separate out from the optically thick, full disks in such a plot.*

Narrow silicate profiles of Transitional disks

- The 10 and 20 μm silicate profiles of young stars in our sample show a wide variety in shape and strength.
- Weak profiles which are broad and flat indicate grain processing (presence of large and crystalline grains) in the disk while strong features which are narrow and peaked indicate more or less pristine dust composition (e.g. Kessler-Silacci et al. 2007; Watson et al. 2007; Sargent et al. 2008).
- Most transitional disks in our sample show narrow and strong silicate profiles (see Figure 2) indicating that the dust grains in these disks are relatively unprocessed, which is surprising as transitional disks are believed to be physically more evolved than normal Class II disks.

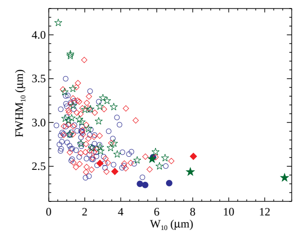

FIGURE 2: *The FWHM and the equivalent width of the 10 μm profile plotted against each other for the young stars in Taurus (blue circles), Chamaeleon I (red diamonds) and Ophiuchus (green stars). The solid symbols represent transitional disks and the open symbols are normal Class II disks. Transitional disks, in general, show narrow and strong silicate profiles indicative of pristine dust grains.*

[The SEDs and the IRS spectra of all the transitional disks in our sample can be found in the pages attached to this poster at the bottom.]

The location of silicate emission and crystallinity in transitional disks

- The structure and geometry of transitional disks are very different from that of the normal Class II disks.
- As a result, the 10 and 20 μm silicate emission originate farther out in the disk, from the tenuous dust in the inner holes/gaps and/or from the dusty inner "wall" at the outer edge of the hole/gap (D'Alessio et al. 2005; Calvet et al. 2005; Kim et al. 2008; Espaillat et al. 2007) (see Figure 3).

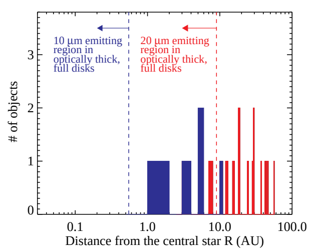

FIGURE 3: *Histogram of the locations of 10 μm (blue) and 20 μm (red) silicate emission in transitional disks. Also shown are the locations of silicate emission in full Class II disks.*

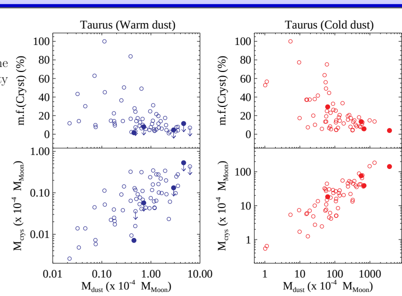

FIGURE 4: *The mass and mass fractions of crystalline grains plotted against the total mass of the emitting dust obtained from the two temperature dust composition modeling of the IRS spectra of young stars in Taurus (Sargent et al. 2008). The warm dust component is responsible for the silicate emission at 10 μm and the cold dust component dominates the emission longward of 20 μm. Solid circles are Transitional disks and open circles are normal Class II disks.*

- Detailed two temperature dust composition modeling of the IRS spectra of young stars in Taurus (Sargent et al. 2008) shows that the transitional disks have relatively low mass fractions of crystalline grains (Figure 4).
- The silicate profiles of transitional disks have larger equivalent widths (Figure 2) indicating that the total mass of the dust contributing to the silicate emission is relatively high (Figure 4).

Since the silicate emission in transitional disks comes from larger disk radii, the emitting area is larger and therefore the total amount of dust contributing to the emission is also higher. Since the surface density of crystalline grains is likely to drop faster with the distance from the central star than that of amorphous grains, the dust farther out in the disk will be dominated by amorphous grains, resulting in the observed low mass fractions of crystalline grains in transitional disks.

- The mass of the crystalline grains in transitional disks (at relatively large disk radii) are comparable to or higher than that inferred for the normal Class II disks (at much smaller disk radii) (Figure 4).
- The mass of the cold crystalline grains inferred from the observed crystalline features longward of 20 μm is $\sim$ 100 times higher than the mass of the warm crystalline grains inferred from the crystalline features at 10 μm (Figure 4).

Transitional disks with high crystalline content

- Four transitional disks in our sample, viz., UX TauA in Taurus, T35 and T56 in Cha I and 16201-2410 in Ophiuchus show strong crystalline (mostly fosterite) features at 19.0, 23.0, 27.0 and 33.6 μm (Figure 5).
- These crystalline features arise at the dusty inner wall at the outer edge of the inner holes or gaps: at $\sim$ 56 AU in UX TauA (Espaillat et al. 2007), $\sim$ 15 AU in T35, $\sim$ 18 AU in T56 and $\sim$ 29 AU in 16201-2410 (Kim et al. 2008).
- The mass fractions of crystalline grains inferred for these objects are in the range of 25% - 35%, which imply high crystalline grain mass in the outer parts of the disks (≥ 15 AU).

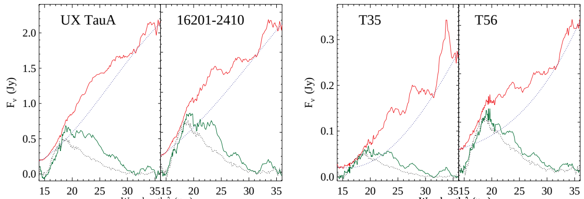

FIGURE 5: *Transitional disks with strong crystalline features longward of 20 μm. Dereddened IRS spectra (red solid line) and the continuum fit (blue dotted line) are shown. Also shown are the continuum subtracted, normalized spectra (green solid line) and a pristine 20 μm profile (black dotted line).*

Summary & Conclusions

- Most transitional disks show narrow and strong silicate profiles indicative of pristine dust composition in the disks.
- Because the structure and geometry of transitional disks are very different, the silicate emission in them arises farther out in the disk than that in normal Class II disks. The apparent pristine dust composition suggested by the narrow and strong silicate profiles of transitional disks is possibly due to the fact that the silicate emission zone in them are at larger disk radii compared to that in optically thick, full disks.
- The total mass of the crystalline dust in transitional disks (within several AU to several tens of AU) is comparable to or higher than that found for normal Class II disks (within a few AU).
- A few transitional disks show high crystalline content in the outer parts (as far out as 56 AU) of the disks.
- The mid-IR spectra of transitional disks allow us to probe dust composition at larger radii in the disk than that is possible for the optically thick, full disks where the silicate emission probes only the inner most parts of the disk (≤ few AU).

References

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