Mid-infrared variability in spectra of pre-transitional disk sources AB Aur and MWC 758: preliminary results from SOFIA-FORCAST observations

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Introduction

Protoplanetary disks orbiting low mass stars (< 2 M$_\odot$) show a progression—from active accretion to planetary systems with debris disks—which can be parameterized by the slope of the infrared (IR) spectral energy distribution (SED). Some sources show very little near-IR (NIR) emission compared to the mid- and far-IR (MIR/FIR), suggesting an optically thin inner hole and/or gap in the dust distribution. These so-called "transition" and "pre-transition" disks may represent stages in disk evolution between the younger, optically thick disks and more evolved, optically thin disks (Fig. 1).

Low-mass transitional and pre-transitional disk sources are often variable in the optical through the MIR. Numerous studies have been carried out on the NIR/MIR variability of these sources. One of the interesting results of this work has been the discovery of time-dependant spectral variations wherein the NIR flux drops while the MIR increases—commonly known as the "see-saw" effect—on week long timescales, which may be due to perturbations driven by unseen protoplanetary companions [1–3].

In contrast, very few IR monitoring studies of (pre)-transitional disks for higher mass (HAeBe) stars have been carried out, and so little is known about their variability.

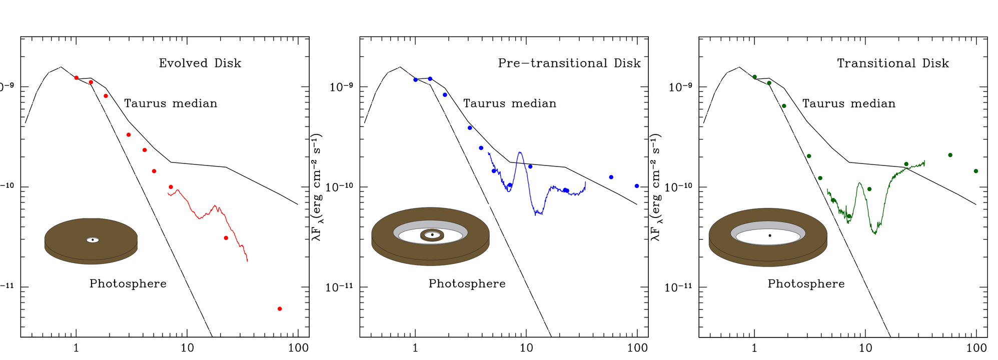

Figure 1: From left to right, representative SEDs of an evolved disk (RECX 11) [4], a pre-transitional disk (LkCa 15) [5], and a transitional disk (GM Aur) [6]. For the full disk, progressing outward from the star (black) is the inner disk wall (light gray) and outer disk (dark brown). Pre-transitional disks have an inner disk wall and inner disk followed by a gap, then an outer wall and disk. The transitional disk has an expanded inner hole followed by an outer disk wall and outer disk. Figure from [7].

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Objective

Our objective is to carry out both short and long term monitoring in the NIR/MIR of a handful of HAeBe stars known to have (pre)-transitional disks in order to compare the nature of their variability to that of their lower mass counterparts.

Observations

We were awarded 12 hours in OC5 on SOFIA with FORCAST in low-resolution grism mode (R$\sim$100) to carry out short-term monitoring from 5—40 μm of 3 high-mass stars known to have pre-transitional disks: AB Aur, MWC 758, and HD 100546.

- Our primary goal was to look for "see-saw" variations in the mid-IR SED on weekly to monthly timescales and compare to similar variations in low-mass stars.
- Our secondary goal was to look for longer term variations by comparing our observations with ISO and Spitzer archival data.
- Only 4 out of 10 "visits" were scheduled ($\approx$5.5 hours), so we could only assess short term variability for one of our targets (MWC 758).
- We also obtained FORCAST photometry to assess and improve flux calibration accuracy. Standard SOFIA Pipeline data products are of excellent quality; no additional reduction was required.

Resulting pipeline-reduced and calibrated spectra for MWC 758 and AB Aur are shown in Figs. 2 and 3.

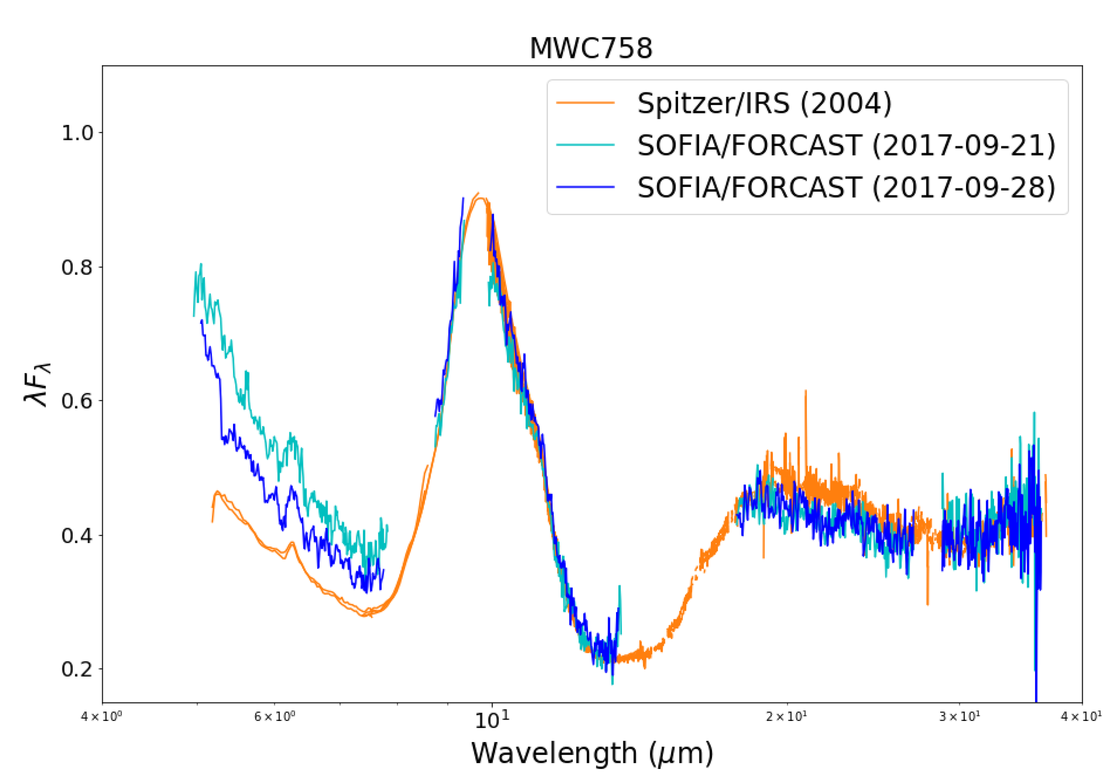


Figure 2: MIR spectra of MWC 758 as observed by Spitzer/IRS (2004) and SOFIA/FORCAST (2017). Spitzer data obtained from the Spitzer Heritage Archive (http://sha.ipac.caltech.edu/).

Preliminary Results

We have compared our SOFIA/FORCAST spectra to archival Spitzer/IRS and ISO/SWS data (where possible) in order to assess longer-term variability (see Figs. 2 and 3):

AB Aur: Our SOFIA observations reveal a significant increase in emission at longer wavelengths (> 18 μm) since previous ISO and Spitzer observations, but no change at shorter wavelengths (4—8 μm). Though relatively quiet in the optical, AB Aur is variable in the near-IR on short timescales [8]; understanding the connection (if any) between the MIR and NIR variability requires additional, simultaneous observations from 1 to 40 μm.

MWC 758: The two FORCAST observations separated by 7 days are nearly identical. (The difference in flux in the 5–8 μm range may be due to slit alignment issues.) When compared to the Spitzer IRS data (2004), there is an increase in flux at 5–8 μm, but the differences at longer wavelengths are minor and may be related to changes in the shape of the 20 μm silicate feature.

HD100546: The overall spectrum (not shown) is remarkably similar to that observed by Spitzer/IRS in 2006 for $\lambda > 10$ μm. Additional observations are needed, however, to assess near-IR variability in both the short- and long-term.

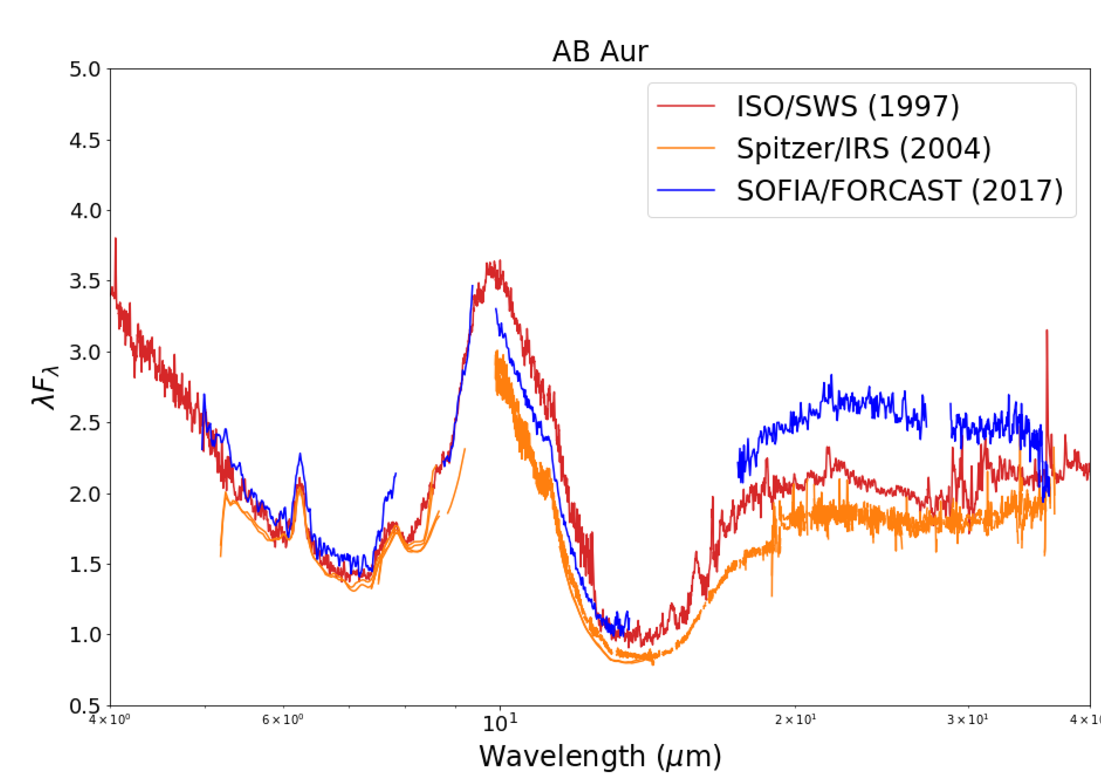
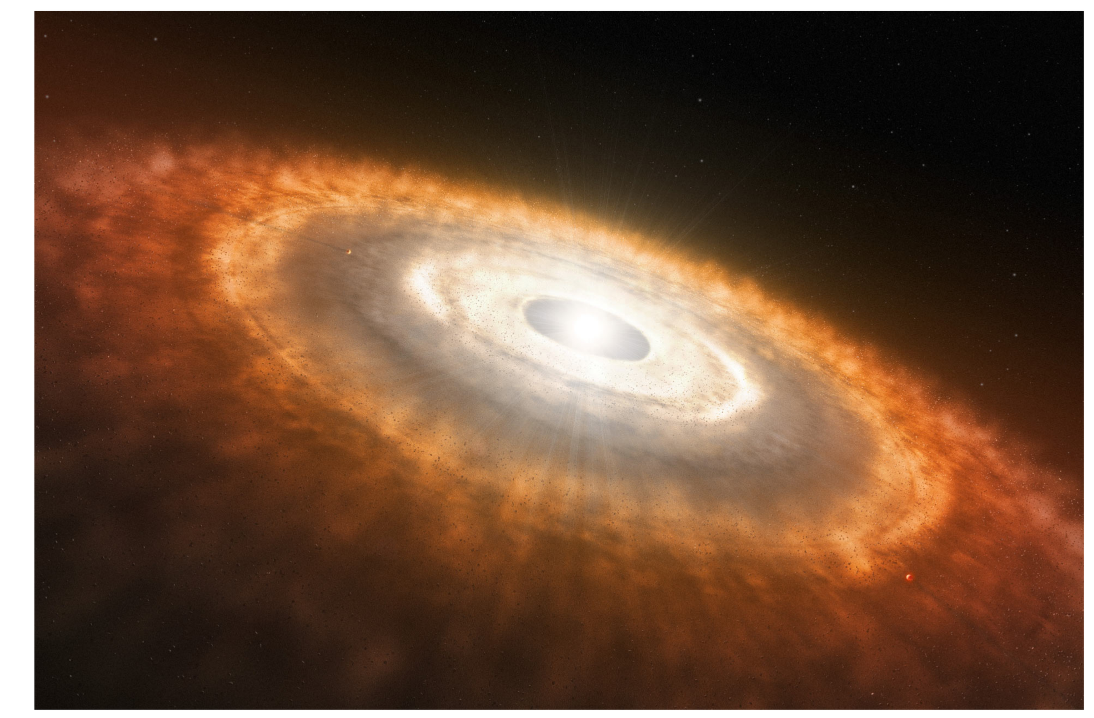


Figure 3: MIR spectra of AB Aur as observed by ISO/SWS (1997), Spitzer/IRS (2004), and SOFIA/FORCAST (2017). Spitzer and ISO data obtained from the Spitzer Heritage Archive (http://sha.ipac.caltech.edu/) and NASA IR Science Archive (IRSA,https://irsa.ipac.caltech.edu/), respectively.



Artist rendering of a pre-transitional disk (L. Calcada / ESO).

Conclusions

These initial observations show that at least two of our sources show significant SED variations in the 5–40 μm range on multi-year timescales. Understanding these changes in spectral shape will require additional modelling (underway) as well as coordinated, simultaneous NIR to MIR observations so that the connection between inner and outer disk variability can be better differentiated.

References

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