VARIABILITY STUDY OF ACCRETING T TAURI SYSTEMS WITHIN TAURUS-AURIGA.

J. Leisenring, J. Bary, M. Skrutskie, *Department of Astronomy, University of Virginia, Charlottesville, VA 22904, USA.*

INTRODUCTION

We report results from an ongoing multi-epoch mid-infrared spectroscopic survey of 11 actively accreting T Tauri stars (TTS) in Taurus-Auriga using the IRS spectrograph aboard Spitzer. We have detected both short and long-term variability in the flux and crystalline versus amorphous structure of the 9.7 μm silicate emission feature. In characterizing the modulations of the silicate feature and the short wavelength continuum (5.28 μm), we seek to constrain the mechanisms responsible for the variability. Given that the sources in our survey are among the strongest accretors, we suggest that these variations may be the disk responding to fluctuations in the accretion luminosity. However, this does not discount variations due to changing disk structure along the line of sight.

DISK EVOLUTION SEQUENCE

Forrest et al. (2004) presents some of the first TTS observed with Spitzer and IRS. For five of the six presented spectra, the continuum emission is in excess of that expected from stellar photospheres alone. The broad 10 μm silicate emission complex seen in each of the spectra arises from superheated small dust grains in the upper atmospheres of flared disks. A significant decrease in flux at 11.3 μm is present in several spectra indicating a difference in amorphous versus crystalline structure, as well as grain sizes and shapes. Forrest et al. suggests that variations in the structure of this feature from star-to-star provides evidence of grain processing and a possible evolutionary sequence for TTS. Is this a true evolutionary sequence or could variability account for the diversity of spectral shapes and features in this sample?

OUR SAMPLE

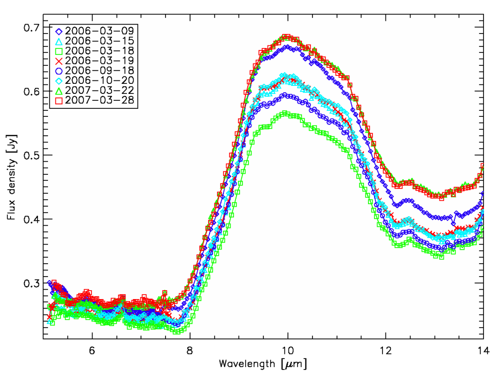


Figure 1: Example of the eight separate observations for one of our 11 sources.

The sources within this sample where selected based on accretion activity and Hα equivalent width strength. For each source, a total of eight spectra have been obtained spaced over a time-span of 1.5 years. The observations were scheduled to be taken in pairs spaced six months apart with each pair consisting of two observations spaced by 5-35 days, allowing us to probe both short- and long-term timescales for variability.

Most of the stars in this sample show intriguing evidence of variability in either the shape of the continuum, strength of emission/absorption features, or the strength, shape, and structure of the 10 μm silicate feature.

CONTINUUM VARIABILITY

Modulation in the shape of the continuum between 5.2 μm and the 10 μm silicate feature is clearly observed for a number of sources with a range of published accretion rates (Fig. 2).

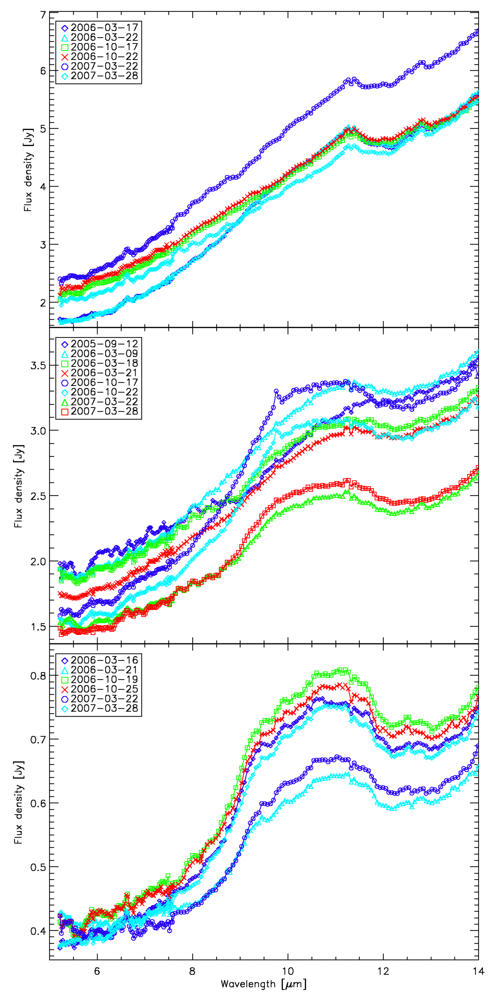
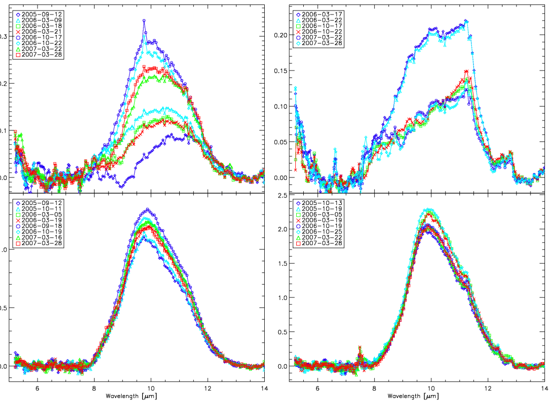
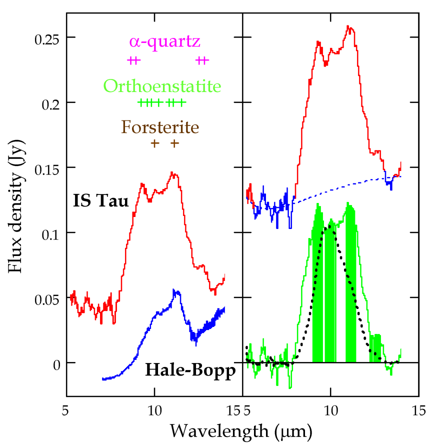


Figure 2: Variation in continuum over time for three sources with a range of published accretion rates. From top to bottom: DG Tau ($\dot{M} = 4.6 \times 10^{-8}$ M_{sun}), XZ Tau ($\dot{M} = 1.8 \times 10^{-9}$ M_{sun}), and DQ Tau ($\dot{M} = 6.0 \times 10^{-10}$ M_{sun})

VARIABILITY OF THE SILICATE FEATURE

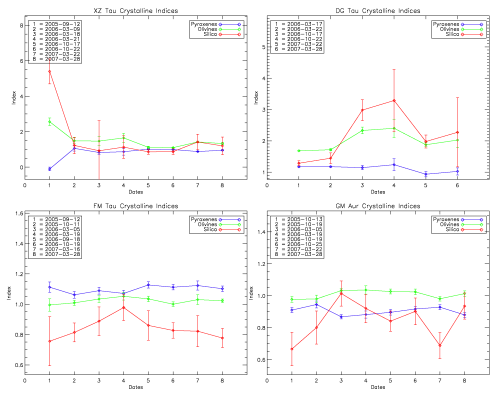


Above, we show the variation of the silicate feature strength for several continuum subtracted T Tauri stars. For XZ Tau (top left) and DG Tau (top right), we note the variation in the shape and strength of the silicate feature. These variations represent a change in emission flux of crystalline versus amorphous material. Also, the short wavelength side of the silicate feature in XZ Tau goes from absorption to emission. Similarly DG Tau shows a strengthening of the silicate feature at this same wavelength. FM Tau (bottom left) and GM Aur (bottom right) show minor morphological variability and both represent a disk containing primarily amorphous grains.



The above plot shows an IRS spectrum of IS Tau with positions of the strongest mineral features indicated at the top. The ISO SWS spectrum of Comet Hale-Bopp is plotted for comparison. The plot on the right shows the reduced spectrum in red with the baseline fit in a dotted blue line. The continuum divided spectrum is plotted in green with the pristine amorphous silicate feature plotted as a black dotted line. The green bars represent the bands within which the silicate indices (below) are determined.

The indices shown below represent the crystalline to amorphous abundances where a value of unity means a purely amorphous profile and increases with increasing crystallinity (Watson et al. 2007). Variations in these indices indicate a real variability in the morphology of the silicate emission feature and the mineralogy of the disk emission. The indices are calculated for pyroxenes (9.21 μm), olivine (11.08 μm), and silica (12.46 μm).



WATER VAPOR ABSORPTION

In the majority of our sources, we see an absorption feature centered between 5.6 and 5.8 μm identified as a water vapor band. This feature has also been observed in FU Ori objects and is thought to be related to the viscous heating of the disk due to the high accretion rates of these sources (Green et al. 2006). An inverted temperature gradient would then be necessary for the presence of water vapor in the outer disk.

Our spectra (most of which are among the strongest accretors) show that the strength of this feature varies significantly in both position and flux on a timescale on the order of six months. However, some sources show a consistent shape and strength of the water band over the entire 1.5 years of observations. If this feature results from viscous heating within the disk, these observed variations may be directly related to changes in the mass accretion rate.

CONCLUSIONS

- These multi-epoch observations demonstrate that the shape and intensity of the continuum and the silicate feature in an individual source varies significantly on timescales as short as a month. These variations may be associated with the response of the disk to the fluctuations in the mass accretion rate and accretion luminosity. The observed variability challenges the notion that an evolutionary sequence can be assigned to single epoch observations of the morphology of the silicate feature and continuum.

- We detect the water vapor absorption band between 5.6 and 5.8 μm and see variability in its strength and position. We suggest these fluctuations may also be associated with a variable accretion luminosity.