8-13 micron spectroscopy of YSOs: Evolution of the silicate emission feature

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Abstract

In this study, 8-13 μm spectra of ~20 stars ranging from YSOs to debris disks and optically thick (Hβ-1.0 μm) to extremely extended (Hβ<0.05 μm) were obtained using the Long Wavelength Spectrometer at the W. M. Keck Observatory. The evolution of the silicate feature from optically thick (Hβ<0.05 μm) to extremely extended (Hβ>0.5 μm) stars and complete absence in other "debris" disks in same ISO observations of high-excitation masers (YSOs) indicates that emission is in related rates and complete absence in other "debris" disks seen in ISO observations of high-excitation masers (YSOs) indicates that emission is in related rates and complete absence in other "debris" disks seen in ISO observations of high-excitation masers (YSOs). In a few objects, the silicate feature is more complex, with absorptions at 9.7 and 18 μm seen in high-excitation masers (YSOs). The observations appear to be at a transitional stage where the star is just becoming visible in the optical. This is in contrast to the earlier difference between intermediate maser Herbig Ae stars and solar T Tauri stars of the same age. For some, but not all, of the Herbig Ae stars in the sample, the emission (Hβ) has a bump at ~11 μm, similar to the emission from crystalline silicate dust in comets and the debris disk (β) Pictoris. All of the T Tauri stars, however, show the classical emission/absorption features which have been attributed to amorphous silicates, although some T Tauri stars show a silicate feature which is a much broader than that found in the debris disk. It is unclear whether crystalline silicates are truly absent in T Tauri stars, for either larger crystalline silicate grains would not exist in the 8-13 μm region, but may be visible through the infrared lattice modes accessible from space-based observations.

Previous observations of continuum fluxes for the sources in our sample were collected from the literature in order to form the Spectral Energy Distributions (SEDs) shown in the left of the observed spectra.

Photometric spectra

These spectra were found to be similar to the stellar photospheres as indicated by a blackbody fit in the SEDs shown here. The possible exception is HD 20398, which may be slightly older by emission from circumstellar material. Evaluation of these maximum deviation from the stellar photosphere will be performed.

Evolutionary temperatures

The trend found for HAEBE stars here (left panel) is similar to that observed by M01 (Massey et al. 2001), embedded sources showing amorphous SiC in absorption, followed by stages of dust processing (and possibly grain growth) and finally the production of silicate/iron oxide/and calcium carbonate features for debris disks. Two significant differences are: 1) for low mass stars, crystalline silicate only found in one source, in the course of a debris disk, and 2) low mass stars found Hartmann (H2004), but we are not sure if there is related to grain growth but not necessarily crystallization.

Silicate emission spectra

For 19 of the observed YSOs, the silicate feature appears in emission. Presented above are the continuum subtracted spectra, obtained by connecting the two endpoints of the spectrum in a manner which is common with the SEDs. The peak is in the 9.7 and 18.0 micron, ISO spectra from Boyton-White et al. (2003) of the amorphous silicates in the photosphere and the higher velocity crystalline, forsterite-rich spectrum of HD 100546. The vertical dashed line indicates the position of the peak of the amorphous silicate band observed for the DM in VY CMa. Connections among the type of silicate emission features and grain size and composition were evaluated quantitatively and are discussed here.

Silicate emission spectra

The plot describes the evolution feature strength and shape. As noted in van Boekel et al. (2005), the 9.7 μm is correlated to grain growth. We find it is similar for TTS and HAEBE. The ratio of the 8.6 to 9.7 μm is using crystalline emission (H2004) & 9.7μm, demonstrating the grain-size evolution, indicating the core shape of these silicate emission features is not purely size dependent.

Evolution

• An evolutionary sequence from absorption in young, embedded sources, to emission in transition disks, and complete absence in older "debris" disks, seen in ISO observations of high-excitation mass YSOs. (M01, 1999) confirmed and extended here to ~10-500 μm.
• Silicate spectra of most TTS were found to be similar to the ISM, in contrast to most HAEBE stars. Crystalline silicates are also absent in TTS or in cooler or larger grains.
• Silicate in emission spectra were evaluated using the quantitative method of Eggleston & Sil(C 2001) and are consistent with optical data of amorphous silicates (90%) of which some are similar to those predicted by Draine et al. (2002).
• The peak shape and feature strength are correlated for TTS and Y HAEBE in our sample (as in van Boekel et al. 2003), attributable to changes in grain size from 10-12 μm. Except for 1T Tauri F (H2004) and 9.7μm HAEBE HD 79726, which show strong emission at 11.3 μm, differences are not so large due to changes in grain size.
• The strength but not the shape of the large silicate emission feature was correlated with the fractional infrared luminosity (optical depth of the disk).
• Some variations in shape of the silhouette with time were observed, but did not appear to be related to any major class of the star nor the shape of the silicate emission feature.