Metamorphosis of a BD Disk: Flared Becomes Flat

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Abstract

We conducted mid-infrared observations of the brown dwarf candidate Cha Hα2. We find that the predicted silicate feature does not appear in its spectral energy distribution (SED). In order to interpret the lack of this feature, we carried out analytical calculations adopting both flared and flat disk geometries. We show that, independently of the chosen parameter set and chemical composition, the flared disk model cannot explain the measured fluxes. On the contrary, the SED emerging from a flat disk fits well the observations.

KEYWORDS: *accretion, accretion disks – circumstellar matter – stars: individual (Chamaeleon Hα2) – stars:low mass, brown dwarfs*

1. The importance of Brown Dwarf disks

Brown Dwarfs (BDs) occupy the substellar mass domain. Having masses lower than 75 M_{Jup}, they are unable to burn hydrogen steadily. In spite of the rapidly growing number of known BDs (Basri, 2000), we do not know if they form like planets or like stars. Proposed scenarios include:

▹ star-like formation via fragmentation and disk accretion (Elmegreen, 1999)
▹ ejection of stellar embryos from multiple systems (Reipurth & Clarke, 2001)
▹ formation in circumstellar disks like giant planets.

The presence of disks and their properties are crucial in distinguishing between the various scenarios: a truncated disk (size of a few AU) would support the ejected stellar embryo hypothesis, a non-truncated one is the sign of stellar-like accretion, while BDs formed like planets should have no dust around them.

Since the emission of warm (100 - 400 K) circumstellar dust peaks around 10 μm, mid-infrared (MIR) excess emission - arising from dust grains close to the star - is the best tool to search for circumstellar disks. Up to now, only few BD candidates with MIR excess have been identified in the ISO archive, all of them located in the Cha I star-forming region (Persi et al., 2000). Their spectral energy distribution (SED) have been interpreted by Natta & Testi (2001) using a model based on scaled-down disks around pre-main-sequence stars. They followed the Chiang & Goldreich disk geometry which has been rather successful in describing SEDs of T Tauri and Herbig Ae/Be stars (Chiang & Goldreich, 1997).

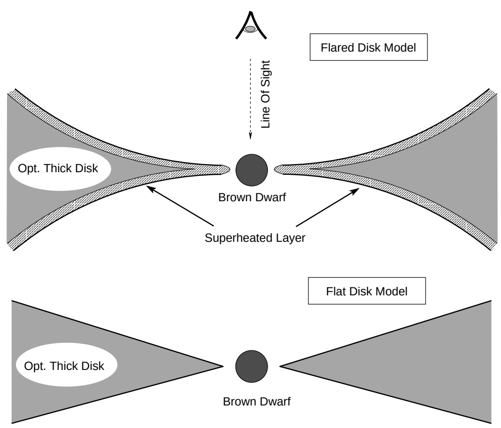

Figure 1: Cross sections of the flared and the flat disk model. The shaded area represents the optically thin superheated layer in the flared disk. This region is the source of the silicate emission feature. The flat disk lacks this disk atmosphere.

2. The flared disk model

The main assumption of the Chiang & Goldreich model is the flaring of the disk, which introduces a superheated surface layer, called the disk atmosphere (see Fig. 1). The major components of this model are: the star, the optically thin disk atmosphere and the optically thick disk interior. In the MIR the stellar radiation is well approximated by a black body, while the optically thick disk emission is given by a power law $F_\nu \propto \lambda^{5/3}$. A simple analytical formula (Natta et al., 2000) is used to describe the optically thin disk atmosphere, which is producing a strong silicate emission around 9.6 μm (Si-O stretching mode).

3. Towards the flat disk model

We observed the BD candidate Cha Hα2 at 9.8 and 11.9 μm using the TIMMI2 camera at the 3.6m/ESO Telescope at La Silla, Chile. Since we find the same

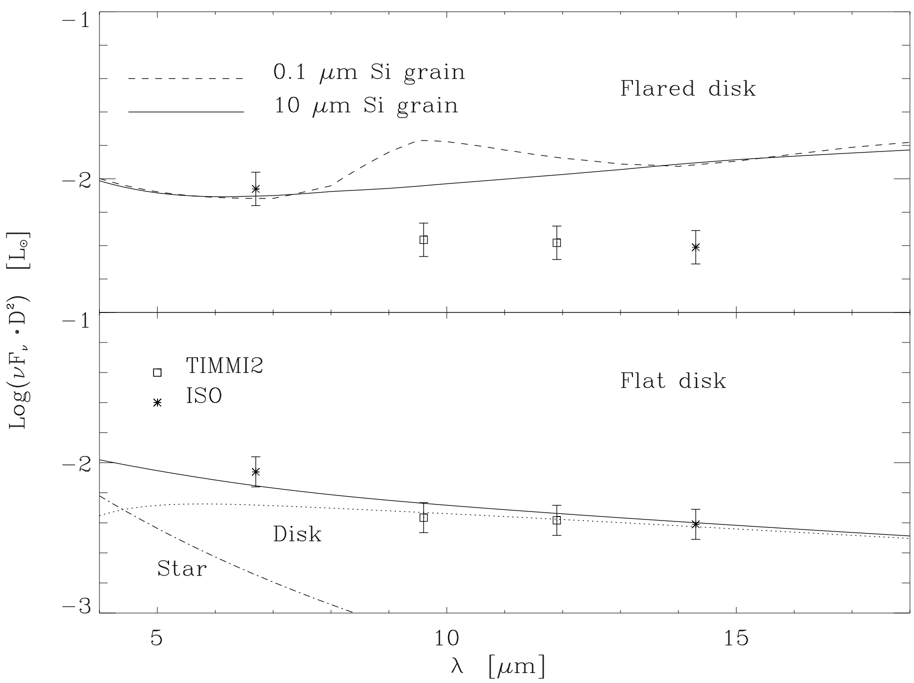

Figure 2: Upper panel: Modelled SED of a flared disk using two different silicate grain sizes. The silicate feature appears in emission for small 0.1 μm grains. The squares and the stars are measurements from TIMMI2 and ISO. Lower panel: Best fit model for an optically thick flat disk. The parameters of the model are as follows: D= 160 pc, $T_\star = 2550$ K, $M_\star = 0.08\ M_\odot$, $L_\star = 0.035\ L_\odot$, $R_{in} = 4.5\ R_\star$, $R_{out} = 100$ AU.

flux densities at the peak and on the wing of the feature, we exclude the presence of any silicate feature. This contradicts the prediction of Natta & Testi (Natta & Testi, 2001). We find that changing the disk geometry (inner and outer radii, scale height, inclination) is insufficient to fit the flared model. Altering the optical properties (or composition) of the dust grains has a stronger effect: the absence of the silicate feature could be explained by the lack of this dust component or the presence of large grains (radii larger than 5 μm). However, we stress that the power law continuum, predicted by the flared model, does not fit our data.

A much simpler and more straightforward solution is the assumption that the BD is surrounded by an optically thick flat disk. We assume a power law disk with a surface density of $\Sigma \propto R^{-3/2}$ and a temperature of $T \propto R^{-3/4}$, typical of reprocessing and viscous disks (Shu, 1990). Since this disk is entirely optically thick, its SED is independent of the dust properties. The model does not show any feature. The continuum of a power-law flat disk has the observed slope. In Fig. 2 we compare the measurements with model predictions.

4. Conclusion

We prove that the lack of the silicate feature in the SED of the BD candidate Cha Hα2 cannot be explained by a T Tauri-like flared disk geometry. Our calculations show that an optically thick flat disk model reproduces the observations.

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