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ACCRETION DISKS AROUND YOUNG BROWN DWARFS. SPECTRAL INDICES FOR THE TWO VISCOSITY PRESCRIPTIONS

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With the vertical structure models of accretion disks around young brown dwarfs (Adame 2010), we construct infrared spectral indices to explore the effects of the variation of two fundamental model parameters: the mass accretion rate and the turbulent viscosity parameter (α or β). The effects of the turbulence on the mean disk flow are modeled assuming the Boussinesq hypothesis (i.e., the Reynolds stress tensor appearing in the Reynold equations are mathematically identical to the viscous stress tensor for a laminar flow). The algebraic turbulent viscosity prescriptions we explore are:

- α-viscosity: $\nu_t = \alpha c_s(T_c)H_p$ (Shakura & Sunyaev 1973; D'Alessio et al. 1998), where c_s is the sound speed at the midplane and H_p the gas scale height. Here, α is a free parameter. We vary α from 10^{-4} to 0.01.
- β-viscosity: $\nu_t = \beta R^3\left|\frac{\partial\Omega_K}{\partial R}\right|$ (Richard & Zahn 1999; Hueso & Guillot 2005; Adame 2010). $\Omega(R)$ is the angular speed of the mean flow. We vary the free parameter β from 10^{-6} to 10^{-4}.

For our fiducial brown dwarf ($M_* = 0.05\ M_\odot$, $L_* = 0.02\ L_\odot$, $T_* = 2838$ K), we construct α and β disk models varying the radially uniform mass accretion rate $\dot{M}$ (from 10^{-12} to 10^{-10} $M_\odot$ yr^{-1}), following the procedures of D'Alessio et al. (2006) and Adame (2010). Variation of both the viscosity parameters and $\dot{M}$ implies a variation on the mass surface density (Σ) of the disk, since $\Sigma(R) \approx \dot{M}/\nu_t$, which have an effect on the amount of stellar radiation intercepted by the disk and ultimately on its emission. The spectral energy distribution of the disk+brown dwarf system is computed for three disk inclination angles (respect to the line of sight), $i = 20°$, $40°$, and $60°$. Then, we construct the spectral indices between 6 μm and 13 μm (n_{6-13}) and between 13 μm and 30 μm (n_{13-30}). Figure 1 shows the comparison of the model indices with the observed Taurus brown dwarf indices (Furlan et al. 2011).

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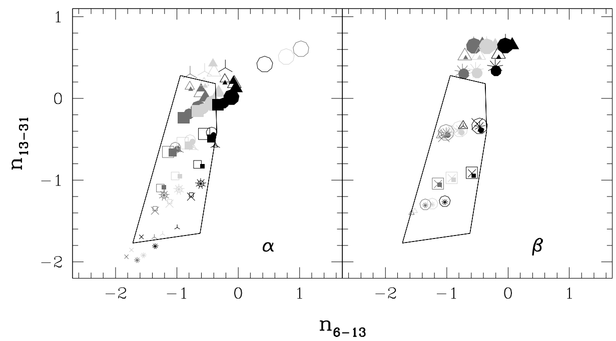

Fig. 1. Model infrared spectral indices. The different symbols represents the value of the dust depletion in the disk atmosphere (0.1% of the original dust content, square; 1%, circle, and 10%, triangle). The size of the points represents the value of the viscosity parameter (the largest points represents the smallest α or β values, whereas the smallest points represents the largest viscosity parameters values), while the filling of the point represents $\dot{M}$ (open points, $\log \dot{M} = -12$, crossed points, $\log \dot{M} = -11$, and filled points, $\log \dot{M} = -10$). Gray hue represents the inclination angle (black, 20°, gray, 40°, light gray, 20°). The polygon depicts the region where the observed Taurus brown dwarf indices lies.

Excluding the models with the largest $\dot{M}/\alpha$ or $\dot{M}/\beta$ ratios (or the smallest $\dot{M}/\alpha$), we find that the grid constructed is capable of explaining the observed spectral indices. The index n_{6-13} is unaffected by the selection of the viscosity prescription, since this region is dominated by the vertical wall emission. However, differences arise when exploring the outermost disk region, from where the mid/far-infrared fluxes (n_{13-30}) emerge.

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