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Dependence of Circumsubstellar Disk SEDs on System Inclination

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Abstract. The spectral energy distributions (SEDs) have being simulated for 1120 systems that contain brown dwarfs with different physical parameters and protoplanetary disks that are inclined at different angles. The SED's shape dependence on disk inclination toward the observer is discussed.

Keywords. circumstellar matter, stars: low-mass, brown dwarfs, planetary systems: protoplanetary disks.

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1. Introduction

The spectral energy distribution (SED) of a protoplanetary disk and hosted star (or substar) depends on the astrophysical properties of the central object, age of the system, and disk inclination. The results presented take into account all of these parameters and based on the: (1) physical model for substellar evolution (Pisarenko *et al.* 2007); (2) temperature distribution calculation model for passive flat disks (Chiang & Goldreich 1997); (3) geometrical model for SED's calculation (Zakhozhay 2011, Zakhozhay 2011, Zakhozhay *et al.* 2011); (4) disk size dependence from central objects mass (Zakhozhay 2005).

2. Results

An atlas of 1120 SEDs was created for systems with different parameters:
- substellar masses within the range 0.01-0.08 M_{sun};
- protoplanetary disks with different inclination angles (0°-80°);
- system ages are 1-30 Myr;
- substars and protoplanetary disks irradiate like a black body;
- distance from Sun to substar is 10 pc;
- disk's inner radius is the central object radius and sublimation radius at 1Myr.

Figure 1 shows how the shape of the SED depends on inclination of the systems, without and with an inner hole. Figure 2 shows how the system's SED is affected by the presence of an inner hole for systems located face on and inclined on 60° toward the observer. On small inclination angles, flux from the gapless systems will always be bigger because the emitting area of such a disk is bigger. But high inclination angles correspond to higher flux from the systems with inner holes. The explanation for this is the following: when the disk has no inner hole, its inner edge starts to cover a part of the central object at the moment when the inclination becomes $j > 0°$. When the disk inner hole is present, the inner edge of the disk starts to cover the part of the central object over large angles (the exact value for which depends on the system's geometrical parameters; it is $\sim 75°$ for the systems shown here). As flux from the central object always gives a dominant

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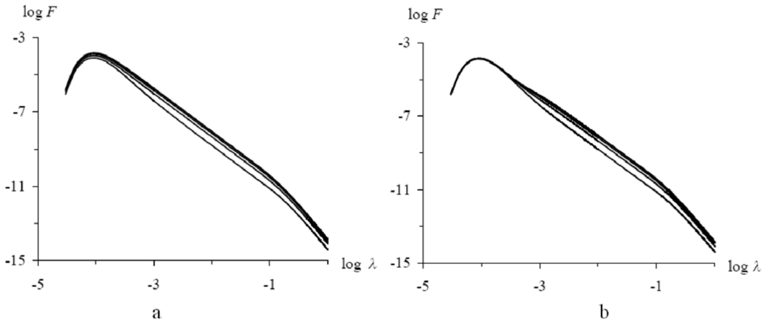

Figure 1. SEDs for substars with disks without inner holes (a) and with it (b), with substellar mass equals to 0.08 M_{sun} and age 1 Myr. Different lines correspond to different system inclinations (from top to bottom): 0°- 80° with step 20°. F - radiant flux, $erg/(cm^2 \cdot s \cdot cm)$, λ - wavelength, μm.

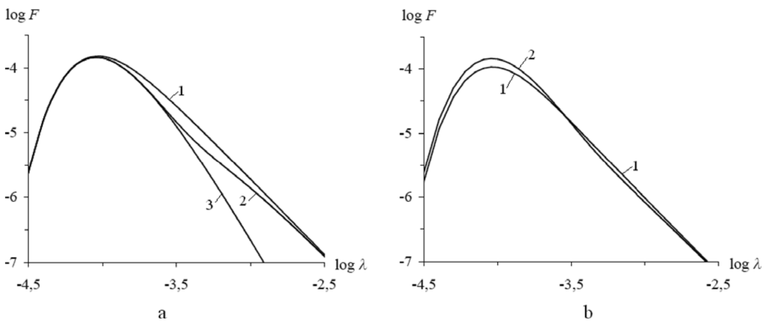

Figure 2. SEDs for the systems that contain a substar with mass 0.01 M_{sun} and age 1 Myr. (a) - The SEDs for systems that are located face on (0°), and (b) - systems that are inclined on 60°. On each panel are shown (1) - SED for gapless disk, (2) - SED for disk with inner hole and (3) - substellar back body irradiation. F - radiant flux, $erg/(cm^2 \cdot s \cdot cm)$, λ - wavelength, μm.

contribution to the total flux, the SED for a system with an inner hole will have a bigger maximum.

3. Conclusions

The shape of the SED for a brown dwarf with a protoplanetary disk strongly depends on the system inclination. Systems that are located face on have a maximum flux and when the inclination angle toward the observer is growing, the flux intensity decreases. The shape of the SED strongly depends on the presence of an inner hole, thus, different geometry calculation models should be used for gapless systems and systems with and without inner holes. The correct determination of the disk inclination relating to the observer permits us to identify the geometrical parameters for the true disk and central object and, thus, to obtain the real physical parameters of the central object such as mass, age, and size.

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