Young Stars & Planets Near the Sun
Proceedings IAU Symposium No. 314, 2015
J. H. Kastner, B. Stelzer, & S. A. Metchev, eds.

doi:10.1017/S1743921315005980

On the Possibility to Identify a Companion in a Protoplanetary Disk

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Abstract. In this paper, I investigate a possibility to detect a brown dwarf companion in a protoplanetary disk based on spectral energy distribution (SED) profile analysis. I present synthetic spectral energy distributions of protoplanetary disks with and without an embedded companion that clears a gap. The computations are performed for a star (0.8 $M_\odot$) and a substellar companion (30 M_J) at an age of 5 Myr embedded in a protoplanetary disk, located at a distance 100 pc from the Sun. Analysis of the SED profile shape indicates that the maximum difference between the fluxes of the systems with and without the companion is ≈ 0.43 Jy at 34 μm.

Keywords. stars: formation, planetary systems: protoplanetary disks

1. Introduction

Planetary systems are formed in protoplanetary disks that surround young stellar and substellar objects. In the first hundred thousand years, such disks could contain hot and massive fragments that later may form giant planets and brown dwarf companions (e.g. Stamatellos & Whitworth 2009, Meru & Bate 2010). Surviving companions clear gaps along their orbital motion (e.g. Fouchet et a. 2010, Meru *et al.* 2014). Observational properties of protoplanetary and debris disks with embedded companions have been studied little so far (e.g. Varnière *et al.* 2006, Gonzalez *et al.* 2012).

In this work, I study the properties of synthetic SEDs, modeled for a stellar object surrounded by a protoplanetary disk with an embedded brown dwarf companion and compare it to an analogous system without a companion. I pay special attention to the fluxes differences and how they change with wavelength.

2. Results

The models have been computed for systems at 5 Myr with a 0.8 $M_\odot$ central object and a 30 M_J substellar companion at 1 AU embedded in a protoplanetary disk (that is extended from 0.1 to 150 AU and is oriented face-on). The system is located at a distance of 100 pc from the Sun. To model the flux from the disk, I followed the approach of Andrews & Willams (2005) and by assuming that disk is composed of an inner region and an outer region. These two regions are separated by a gap cleared by the companion. I assume that there is no emitting material inside the gap and that the width of the gap cleared by the companion is the diameter of the Hill sphere. Fluxes from the star and companion were modeled using the black-body approximation and the physical parameters (temperatures and radii) from Baraffe *et al.* (1998).

Figure 1 shows SEDs of a system with a protoplanetary disk with a companion (black solid line) and without it (gray solid line). It also illustrates the contribution of the star (gray dashed line) and the companion (black dash-dotted line), disk inner region (black

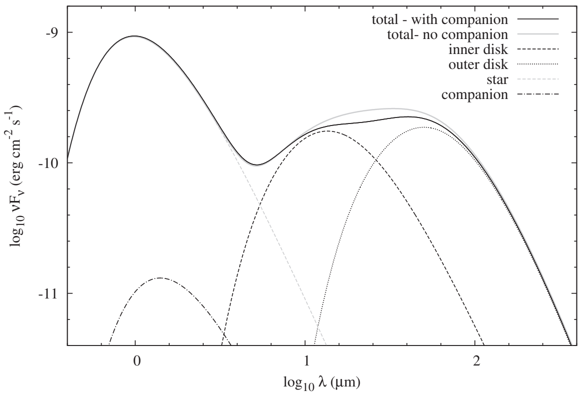

Figure 1. SED of modeled system with a protoplanetary disk and companion (black solid line) that consists of inner (black dashed line) and outer (black dotted line) parts. The flux from the companion is shown with the black dashed-dotted line and that from the star with gray dashed line. The flux from the system with the same parameters but without a companion is shown with the gray solid line.

Table 1. Fluxes from the systems with and without the companion.

λ (μm)	ΔF (Jy)	F_{noC} (Jy)	F_{withC} (Jy)
10	0.02	0.57	0.55
20	0.29	1.63	1.35
34 (ΔF_{max})	0.43	2.93	2.50
80	0.23	4.28	4.06
100	0.17	3.84	3.67

dashed line) and outer region (black dotted line). Visual examination of Figure 1 indicates that the gap cleared by the companion, located at 1 AU, in the protoplanetary disk introduces a flux depression at the wavelength interval 10–100μm. This flux depression is due to the absence of the emitting disk material between 0.77 AU and 1.23 AU from the star. The results of the calculations indicate that the maximum difference between SEDs from the system with and without the companion is ≈ 0.43 Jy at 34 μm. The differences of the fluxes (ΔF) from this system without (F_{noC}) and with the embedded companion (F_{withC}), as a function of wavelength (λ) are listed in the Table 1.

3. Acknowledgments

Z.O.V. acknowledges the travel support from the International Astronomical Union.

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https://doi.org/10.1017/S1743921315005980 Published online by Cambridge University Press