A companion star in the SED modeling of the stellar system HD 142527

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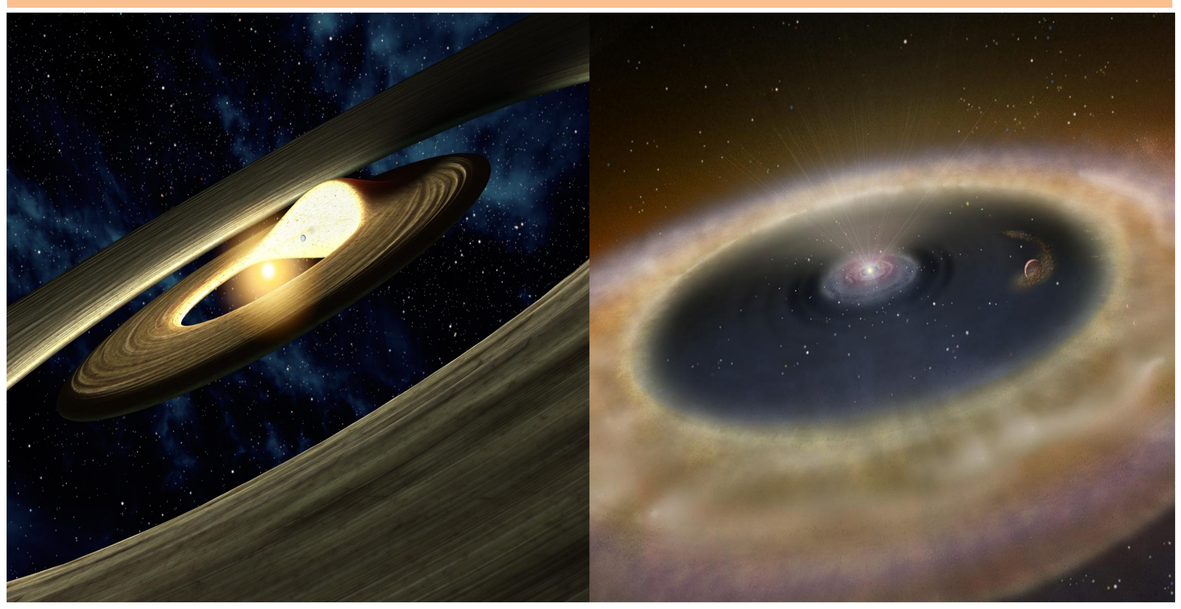
ABSTRACT

The discovery of a companion of the Herbig Ae/Be star HD 142527 motivates the study of the effect that produces on the SED. The main change on the system configuration is the formation of a gap in the disc, following the orbit of the secondary star. Due to this change, a wall forms (outer edge of the gap), which is frontally illuminated by stellar radiation.

We present a model for the SED, taking into account all the components: a disc with two gaps (one produced by the stellar companion and the other by potential planets), three walls (two associated with the gaps and the other with dust sublimation), optically thin streams of material in the gap and the stars.

Our main results are the following: a successful SED model can be constructed when it is included the effect of a companion star, and the optically thin material required to fit the spectrum is located in a halo as pointed out in some works, but also inside the gaps. The size of the modeled halo is smaller than the value found in a previous model of the system, being easier to explain the height above the midplane, where the material is located.



SED MODELING OF DISKS WITH GAPS

Disk(s) around stellar systems are a ubiquitous feature of the initial stage in the life of stars. Along with this, the paradigm of planet formation requires such a system. This leads researchers in the last decades to a strong effort in understanding the processes leading to the formation of planetary systems in disks. There are several direct and indirect ways to detect the presence of planets. In one category, there is the detection by transits and in the latter is the modeling of SEDs (D'Alessio et al. 2005, Nagel et al. 2010,2012, Espaillat et al. 2007,2008,2011).

In this work, we concentrate on the latter, complementing it with information extracted from images, where there is not a direct evidence of planet(s). During the first stages of planet formation, the protoplanets dynamically interact with the disk. One of the consequences of this is that massive planets open gaps. In the same vein, a star immersed in the disk can open a gap or even an inner hole if it is massive enough. Now, there are images of gaps where the evidence points out that they are formed by planets , but in many cases, we depend on the modeling of the SED.

The HD 142527 stellar system was previously modeled using a disk with a gap assumed to be formed by a planet (Verhoeff et al. 2011). The detection of a possible stellar companion for this system (Biller et al. 2012) motivates us to revisit the modeling of this system. A model consistent with a stellar companion would be helpful in the future, in order to pursue a study of the possible configurations of planets or more low mass stars responsible to shape the disk.

THE STELLAR SYSTEM HD 142527

The HD 142527 Herbig Ae star is associated with the Sco OB2-2 star-formation region, so we adopt a distance of d=145pc to this system. This stellar system was imaged in the near-infrared by Fukagawa et al. (2006). In their observation, two bright arcs opposite to one another and a spiral arm are clearly seen. This observation is complemented with mid-infrared images of the same system by Fujiwara et al. (2006), where arclike emission on the outer disk is also present. Fukagawa et al. (2006) suggest that a companion is responsible for these features, on the other hand Fujiwara et al. (2006) comment that the part of the inner rim of the outer inclined disk, which is located along the line of sight, explains the opposite arcs observed. The estimated semimajor axis is 14au (Biller et al. 2012).

As a reference, we take the modeling of this system presented by Verhoeff et al. (2011). In that work, photometric data from the optical to the millimetric and infrared images are consistently modeled. The model consists of three main components. The first one is a small inner disk with inner and outer radii of 0.3 and 30au, respectively. This disk has a puffed-up inner rim which shadows part of its inner zones. The second component is an optically thin spherical halo with a 30au radius. Finally, the last one is an outer massive disk starting at 130au and ending at 200au with a very high inner wall. The inclination taken is i=20°. A 60au wall is necessary to explain the large IR excess.

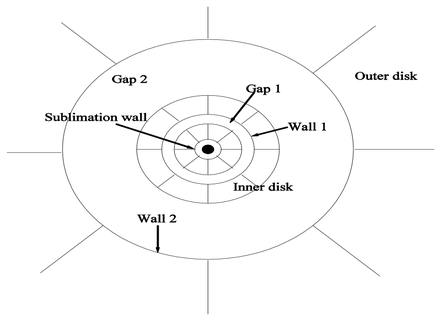


Figure 1: Geometrical structure of the system.

RESULTS

The SED of the disk is calculated using the model of a passive irradiated circumstellar disk around a Herbig Ae star by Dullemond et al. (2001). In the gaps, there is optically thin material that connects the outer with the inner parts of the disk, its emission is calculated as in Nagel et al. (2012). The emission of the outer rim is included using the formalism previously described in D'Alessio et al. (2005).

As in the previous modeling (Verhoeff et al. 2011), the structure of our system includes a large gap between 30 and 130au probably formed by one or more planets. Cassasus et al. (2012) develop a hydrodynamical simulation in order to conclude that a circular planet at 90au is able to carve the disk up to 130au. The optically thin dust inside the gap is consistent with a planet at 90au. We conclude that the material is cold enough to produce the silicates features in the mid-infrared, thus, it is not important for the fitting of the bands but for the fit at larger wavelengths. The importance of including this material is highlighted by Verhoeff et al. (2011), looking at a brightness radial profile that they were not able to fit. A sketch of the system modeled here is presented in figure 1. For the mass of the secondary star, we choose two cases using the range presented in Biller et al. (2012); 0.1 and 0.4 solar masses. We consider that the wall is curved due to the dependency of sublimation temperature on density and its emission is calculated as in Nagel et al. (2013).

From the fitting of the SED, the best model for a 0.1(0.4) solar masses companion star is shown in Figure 2. The mass in dust located in the inner gap and outer gap is $3.52(2.23) \times 10^{-12} M_{\odot}$ *and* $8.88(8.22) \times 10^{-8} M_{\odot}$, respectively. The height of the wall is 46au and the radius of the halo is 5au, smaller than the value found in Verhoeff et al. (2011).

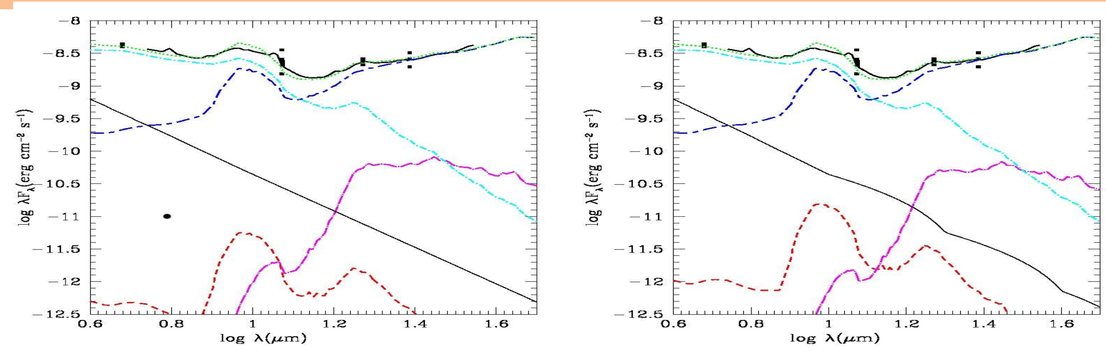


Figure 2: At the left (right), a model with a 0.1 (0.4)solar mass stellar companion. In black the Spitzer data, in red the inner gap emission, in magenta the outer gap emission, in cyan the halo emission, in blue the disk SED and finally in green is represented the best fit.

CONCLUSIONS

The model of Verhoeff et al. (2011) for the SED of the stellar system HD 142527 is taken as a starting point for an improved model. This new model includes the contribution of optically thin material in an inner gap formed by a companion star and also inside the outer gap formed by planet(s) . As in the previous model, there is dust in a halo. The SED fitting with the new distribution of optically thin dust leads to a halo that shrinks in size from 30au (the previous modeling) to 5au. The halo mass is $4.07\times 10^{-12} M_{\odot}$, considerably lower than the amount in the halo of Verhoeff's model.

As pointed out by Verhoeff et al. (2011), a spherical halo of dust is not easy to obtain. A possible mechanism is dynamical excitation of planetesimals by an inwardly migrating planet (Krijt et al. 2011). For a 3-planet system, the interaction with an outer disc of planetesimals results in 100-1000au clouds (Raymond et al. 2013). Stirring of material up to a height of 5au (this model) requires a weaker interaction with planets than the excitation required to produce a 30au halo (Verhoeff's model). Thus, a highlight of this work is that the new halo configuration is easier to explain. However, it is important to say that the size of the halo is not consistently calculated with a simulation of the interaction of the bodies in the system with the gaseous-dusty structure.

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