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Transition disk candidates in the NGC 2264 cluster – Disk diagnostics

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Abstract. Disk holes are inferred from infrared observations of T Tauri stars, indicating the existence of a transitional phase between thick accreting disks and debris disks. Using data from the observational multiwavelength campaign CSI2264, we analyzed 410 stars belonging to NGC 2264 and found about 7% transition disk candidates. We characterized these star-disk systems using disk parameters and we compared them with star–disk systems with full disks and diskless. We were able to evaluate the influence of disk evolution on the observed disk characteristics.

Resumo. Buracos no disco de acreção são inferidos a partir de observações de estrelas T Tauri no infravermelho, indicando a existência de uma fase de transição entre disco espesso e disco de pedregulhos. Usando dados da campanha observacional CSI2264, analisamos 410 estrelas pertencentes a NGC 2264 e encontramos cerca de 7% de candidatas a disco de transição. Caracterizamos estes sistemas de disco–estrelas usando parâmetros de disco e comparando-os com sistemas disco-estrela com disco completo e sem disco. Avaliamos a influência da evolução do disco sobre as características de disco observadas.

Keywords. Stars: formation – Stars: variables: T Tauri – Accretion disk

1. Introduction

Young low mass stars (~ 1 Myr and $M \leq 2M_{\odot}$) are surrounded by a circumstellar disk from which they can still accrete. It is known that the disks are planet formation sites. Therefore understanding disk dissipation is essential to study how planets form.

The inner disk gas can be dissipated by accretion to the star through the stellar magnetic field, by photoevaporation from the central star high-energy radiation (Alexander et al. 2014; Owen 2016) and the disk material may also be driven out of the system through disk winds and jets (Pelletier & Pudritz 1992; Shu et al. 1994). The disk can also be consumed in the coagulation of grains and planets formation (Hollenbach et al. 2005).

Transition disks are systems with a hole in the inner disk and are characterized by a lack of emission, above the photospheric level, in NIR wavelengths and an emission excess like a thick disk in mid-infrared bands (Owen 2016). We searched for transitional disk candidates belonging to the young stellar cluster NGC 2264 (~ 3 Myr and d ~ 760 pc; Dahm 2008) to characterize them in terms of their infrared excess. We fitted spectral energy distribution models to the data available for all the stars in our sample.

2. Observation

We used data from the *Coordinated Synoptic Investigation of NGC 2264* (CSI 2264) that was an international campaign which involved simultaneous and high-resolution observations (Cody et al. 2013), that included photometric data from the CoRoT satellite (40 days, 2011), u band from Megacam (CFHT). We also used photometric data from catalog surveys, such as near-infrared JHK_S from 2MASS, $UBVR_cI_c$ from Rebull et al. (2002), IRAC and MIPs data from the Spitzer Telescope and observations from the Wide-field Infrared Survey Explorer (WISE) performed at wavelengths 3.4, 4.6, 12.0 and 22 μm (Wright et al. 2010).

3. Results

3.1. SED model

Our sample of stars is composed of 410 T Tauri stars that were observed with both *Spitzer*/IRAC (Teixeira et al. 2012) and CFHT/Megacam (Venuti et al. 2014), to select the systems with the largest number of measured stellar, accretion and disk parameters.

We constructed SEDs (spectral energy distributions) of all these stars and modeled them with the Hyperion SED model[1] (Robitaille 2017). We found 28 transition disk candidates (stars with inner hole according to the SED modeling and that have 24 μm flux above photospheric level), 212 stars with a full disk and 170 diskless stars (see Figure 1). This number of transition disks (~ 7 % of the total of 410 stars that we analyzed) confirms that disk dispersal is rapid compared to disk lifetime as reported in the literature (Owen 2016).

3.2. Disk diagnostics

The $\alpha_{\rm IRAC}$ index (the slope of the SED between 3.6 μm and 8 μm (Teixeira et al. 2012)) allows a classification of inner disk evolution, as shown in Fig. 2. Transition disk candidates are generally located among anemic disk that corroborates the depletion of the dust in the inner disk. All the flat spectra and thick disk systems are indeed classified as full disks according to their SEDs and most of the naked photospheres correspond to the diskless SED systems.

A transition disk system has a hole in the inner disk, this hole is characterized by a lower quantity of dust compared to the outer part of the disk. Then, we expect that transition disks show little excess in NIR and some excess in MIR (Owen 2016). A way to check if our transition disk sample obeys this criteria is to build color-color diagrams comparing near and mid-infrared fluxes. In Fig. 3 we show $K_S - [8.0]$ vs. $K_S - [24]$ diagrams. We

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[1] We using the version v1.1 of the modular sets of synthetic spectral energy distributions.

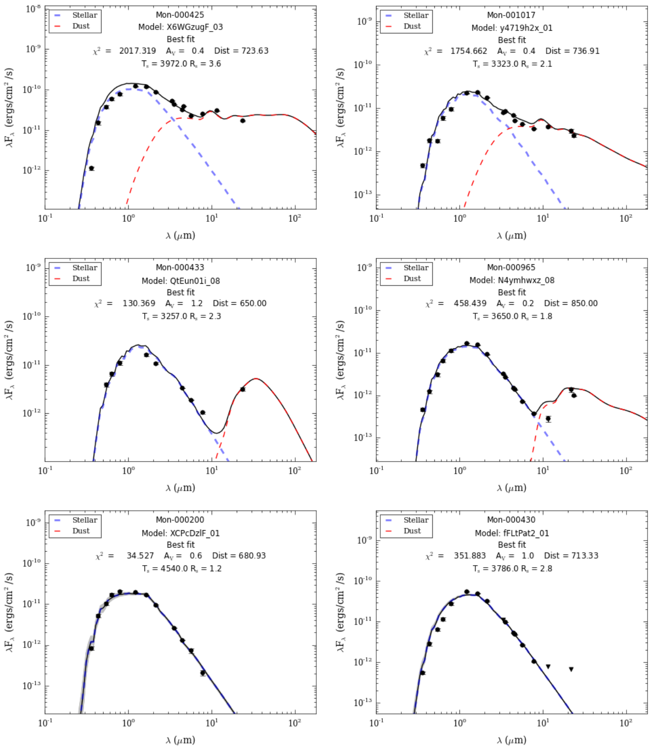

Figure 1. Examples of SEDs for systems with full disk (top), transition disk candidate (middle) and diskless stars (bottom). The circles show literature observed data from U to 24 mμ (Rebull et al. 2002; Wright et al. 2010). The black solid line is the best data fit (based on χ^2) of the Hyperion SED model and the dashed lines are stellar and dust emission components (Robitaille 2017, 2011).

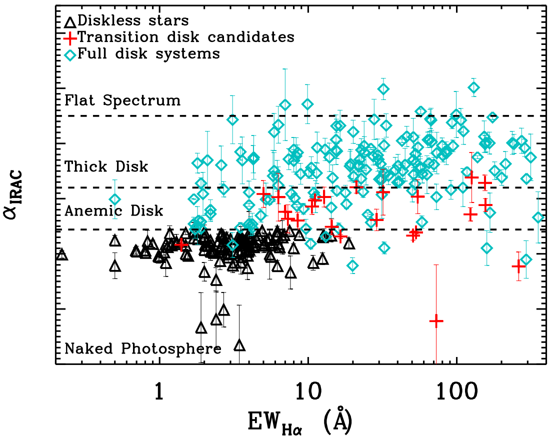

Figure 2. Slope of the spectral energy distribution from 3.6 μm to 8 μm from Teixeira et al. (2012) as a function of Hα equivalent width (Sousa et al. 2016; Dahm & Simon 2005).

can see that stars with full disks present excess above the photospheric emission in the inner and outer parts of the disk, while transition disks present emission in the outer disk as full disk systems but lower emission in the inner disk. Unfortunately, we do not have *Spitzer* data for the diskless stars, which we expect to show no excess emission at all wavelengths, as seen, e.g., in Owen (2016).

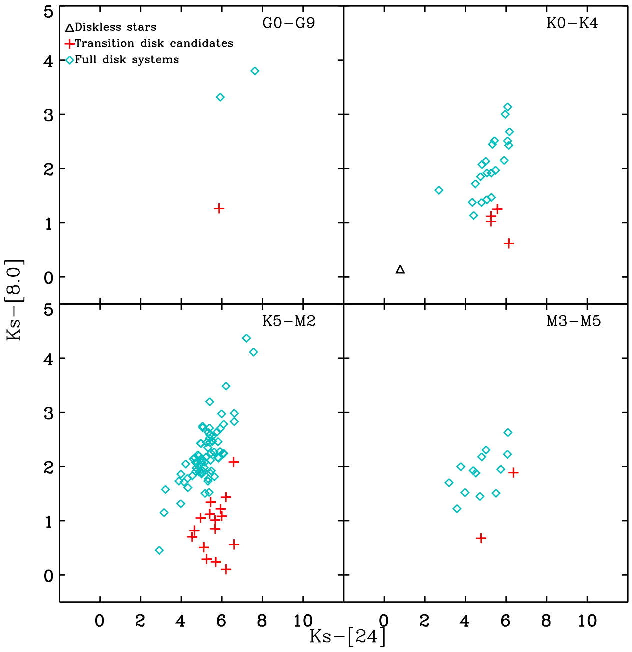

Figure 3. NIR and MIR color-color diagram for stars belonging to the NGC 2264 cluster.

4. Conclusions

- We modeled the SED of all our sample of 410 T Tauri stars and we found 212 full disk systems and 177 diskless stars. SED modeling also showed that 28 of the 410 T Tauri stars of the NGC 2264 that we analyzed presented inner disk holes. This represents 7 % of our sample and confirms that transition disks are a rapid phase of disk evolution.
- Transition disk candidates have dust in the inner disk similar to anemic disks, according to α_{IRAC} classification as seen in the α_{IRAC} analyze.
- In color-color diagram classification we can see two different populations: Stars with full disk have excess, above the photospheric emission, in the inner and outer parts of the disk, transition disk systems present weak dust emission in the inner disk, and present dust emission in the outer disk like a star with full disk.

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