RevMexAA (Serie de Conferencias), **40**, 253–254 (2011)

TRANSITION CIRCUMNSTELLAR DISKS IN LUPUS

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RESUMEN

Presentamos un estudio de discos de transición situados en la región de Lupus que han sido seleccionados en base a datos obtenidos por Spitzer. Varios mecanismos han sido propuestos para explicar su más distintiva característica: agujeros en la opacidad en la parte interna del disco y discos ópticamente gruesos en su parte externa. Ellos son: formación de planetas, crecimiento de los granos de polvo, fotoevaporación, truncamiento del disco por efecto de marea en sistemas binarios cercanos. Hemos llevado a cabo observaciones con óptica adaptiva en el infrarrojo cercano, fotometría submilimétrica, y espectroscopía de alta resolución con el fin de caracterizar estos nuevos discos de transición. Con los datos analizados, proponemos cómo distinguir cuales mecanismos físicos prevalecen en ellos y encontrar candidatos que alberguen planetas en formación para ser estudiados posteriormente con las capacidades de Herschell y ALMA.

ABSTRACT

Based on Spitzer selected YSOs, we present a study of transition disks located in Lupus. Several mechanisms have been proposed to explain their defining characteristic: an inner opacity hole and an optically thick outer disk. These processes are: *planet formation, grain growth, photoevaporation, tidal truncation in close binaries*. We have carried out Adaptive Optics (AO) imaging, submillimeter photometry, and echelle spectroscopy in order to observationally characterize our transition disk sample. With the analyzed data we can distinguish the four scenarios and identify candidate transition disk systems that are currently forming planets. Such objects are excellent targets to be followed-up with Herschel and ALMA.

Key Words: protoplanetary disks — stars: mass-loss — stars: pre-main sequence

1. INTRODUCTION

Circumstellar disks around Pre-Main-Sequence (PMS) stars are the sites of planet formation. Transition objects are pre-main-sequence stars with optically thin inner disks and optically thick outer disks. Different mechanisms have been proposed to explain their inner opacity holes: planet formation, grain growth, photoevaporation, and tidal truncation in tight binaries. These mechanisms, all relevant to disk evolution in general, can be distinguished when disk masses, accretion rates, and multiplicity information are available.

Spitzer surveys of nearby star-forming regions have obtained IR SEDs of many thousands of PMS stars. We have systematically searched the catalogs of the *C2D*, *Gould Belt Spitzer* Legacy Projects (Evans et al. 2003). In particular, we have selected a sample of transition disk systems located in Lupus molecular clouds.

Lupus is one of the main low-mass star forming complexes, with mid M-type pre-main sequence (PMS) stars dominating its stellar population. The complex is located in the Scorpius-Centaurus OB association, hosting several star forming regions. They are at different distances, namely, 150 ± 20 pc for Lupus I, IV, V, VI and 200 ± 20 pc for Lupus III (Comerón 2008). With an age of $\approx$1.5–4 Myr (Hughes et al. 1994; Comerón 2008), Lupus complex constitute an ideal laboratory to look for PMS stars with disk at different evolutionary stages (Wolk & Walter 1996; Andrews & Williams 2005; Cieza et al. 2007), particularly, transition disk systems.

2. OBSERVATIONAL RESOURCES

We run a large and coordinated follow-up program to distinguish between the four mechanisms that may cause the inner opacity holes in transition disk systems. We have obtained disk masses (from submillimeter observations using single dish: LABOCA, APEX), accretion rates (from the ve-

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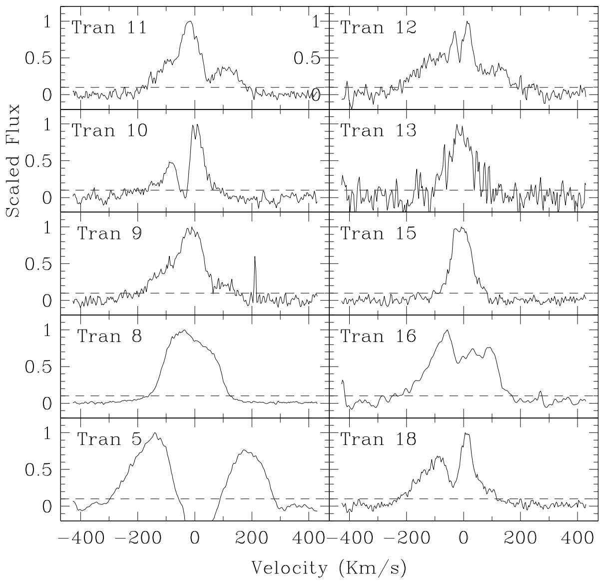

Fig. 1. The Hα velocity normalized profiles of the accreting objects in our sample. The dashed line indicates the 10% peak intensity, where ΔV is measured. They all have $\Delta V > 200$ km s^{-1}.

locity dispersion of the Hα line using echelle spectroscopy: Clay/Mike, Du Pont/echelle), and multiplicity information (from Adaptive Optics imaging VLT/NaCo) during different observing runs.

3. RESULTS

Based on a multiwavelength analysis, we can summarize the first results from the Adaptive Optics, submillimeter, and first-epoch echelle spectroscopy observations, as follows:

(1) The derived spectral classification indicated that most of the systems are M-type stars, in agreement with previous results concerning to the population of Lupus (Comerón 2008).

(2) 50% targets are accreting objects (i.e., have a velocity width >200 km s^{-1} at 10% of peak intensity of Hα profile, see Figure 1). This information allows to estimate the accretion rates.

(3) ~50% of the sample are multiple systems among them three triple systems with an unresolved close binary component. These systems are candidates to have a circumbinary disk.

(4) 40% targets have flux detection at submillimeter, for the remaining systems we derive and upper limit of the disk mass (corresponding to a flux of 3 × RMS).

Combining disk masses, accretion rates and multiplicity data with other information, such as SED morphology and fractional disk luminosity ($L_{\rm DISK}/L_*$), allows to classify the disks as strong candidates for the following categories:

(*a*) 25% Grain growth-dominated disks (accreting objects with negative SED slopes in the mid-IR).

(*b*) 15% Photoevaporating disks (non-accreting objects with disk mass $< 2.5\ M_{\rm JUP}$, but $L_{\rm DISK}/L_* > 10^{-3}$).

(*c*) 35% Debris disks (non-accreting objects with disk mass $< 2.5\ M_{\rm JUP}$ and $L_{\rm DISK}/L_* < 10^{-3}$).

(*d*) 15% Circumbinary disks (a binary tight enough to accommodate both components within the inner hole).

The most remarkable result is that one target shows strong evidence for ongoing giant planet formation (accreting object with positive SED slopes in the mid-IR and no close stellar companion) to be followed-up with Herschel and ALMA.

The comprehensive explanation of the used method and the complete analysis to characterize the sample can be found in Romero, G. A., Schreiber, M., Cieza, L., et al., in preparation.

We thank to Dr. Giorgio Siringo and Dr. C. De Breuck for help performing and data APEX reduction. Support for this work was provided by NASA through the *Spitzer* Space Telescope Fellowship Program. G.A.R. was supported by ALMA FUND Grant 31070021, and ESO-PROJECT 2009. A.R.M. acknowledges financial support from Fondecyt in the form of grant number 3110049, ESO and Gemini/Conicyt (32080023). MRS acknowledges support from Fondecyt (grant 1061199), and the Center of Astrophysics in Valparaiso (CAV). This work makes use of data obtained with the *Spitzer* Space Telescope, which is operated by JPL/Caltech, under a contract with NASA.

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