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CENSUS OF PROTOPLANETARY DISKS IN YOUNG STELLAR REGIONS

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RESUMEN

Estamos estudiando de forma sistemática poblaciones de discos protoplanetarios en regiones estelares jóvenes, abarcando un rango de edades entre unos pocos millones de años (Myr) hasta aproximadamente 10 Myr. Usando la resolución espacial y sensibilidad del Telescopio Espacial Spitzer, con sus instrumentos IRAC y MIPS, hemos identificado y caracterizado discos protoplanetarios alrededor de objetos estelares jóvenes con diferentes masas y localizados en diferentes grupos estelares. Encontramos que, a 5 Myr la frecuencia de discos alrededor de estrellas de masa intermedia (tipos espectrales B, A y F) es más alta que la observada en estrellas de baja masa (tipos espectrales K y M). Esto está en contradicción con la tendencia esperada para la evolución de discos primigeneos, en donde estos discos se disipan más rápidamente al ser la estrella de mayor masa. Ya que, a 3 Myr aún se observa que la frecuencia de discos es mayor en estrellas de menor masa, nuestro trabajo indica que a 5 Myr los discos de segunda generación comienzan a dominar la población de discos alrededor de estrellas de masa intermedia. Este resultado observacional concuerda con modelos teóricos de evolución de sólidos en el disco, en donde a 5–10 Myr las colisiones entre planetésimos comienzan a producir gran cantidad de polvo llegando a un punto máximo de colisiones en cascada a 10–20 Myr cuando el pico de la distribución de tamaños de sólidos en el disco alcanza un máximo.

ABSTRACT

We are carrying out a study of disk populations in young stellar regions spanning an age range from few Myr to ∼10 Myr. Using the unprecedented sensitivity and spatial resolution provided by the Spitzer Space Telescope with its instruments IRAC and MIPS, we have identified and characterized protoplanetary disks around young stellar objects (spanning a wide range of stellar masses) in several stellar groups. We find that for stellar groups of ∼5 Myr or older the disk frequency in intermediate mass stars (with spectral types from late B to early F) is higher than for low mass stars (with spectral types K and M). This is in contradiction with the observed trend for primordial disks evolution, in which stars with higher stellar masses dissipate their primordial disks faster. At 3 Myr the disk frequency in intermediate mass stars is still lower than for low mass stars indicating that second generation dusty disks start to dominate the disk population at 5 Myr for intermediate mass stars. This result agrees with models of evolution of solids in the region of the disk where icy object form, which suggest that at 5–10 Myr collisions start to produce large amount of dust during the transition from runaway to oligarchic growth and then dust production peaks at 10–20 Myr, when objects reach their maximum sizes.

Key Words: protoplanetary disks — stars: formation — stars: pre-main sequence

1. GENERAL

Stars are born surrounded by disks due to angular momentum conservation (Hartmann et al. 1998). These optically thick primordial disks, which contain gas and dust, are expected to evolve by accreting gas into the star and planets, while dust grains grow and settle toward the midplane of the disk (Weidenschilling 1997). The dispersal of primordial disks operate less efficiently for stars with lower masses (e.g., Carpenter et al. 2006). Particularly, for low mass stars (K5 or later), 90% of the stars lose their primordial disks by about 5–7 Myr (e.g. Haisch et al. 2001; Hernández et al. 2008), while for objects in the mass range of Herbig Ae/Be (HAeBe; types B, A or F early) stars, the corresponding time scale for primordial disk dissipation is less than 3 Myr (Hernández et al. 2005). The HAeBe stars are the precursors of intermediate mass stars with debris disks (like Vega or β Pic).

We have analyzed the near- and mid-infrared properties of intermediate mass stars in several stel-

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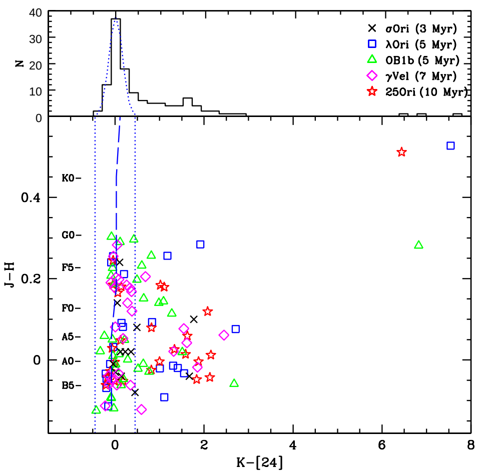

Fig. 1. Color magnitude diagram K-[24] versus $J-H$ illustrating the detection of disks at 24μm. The upper panel shows the distribution of the K-[24] color. Most of the intermediate mass stars are locate at K-[24]$\sim$0.11 exhibiting a Gaussian distribution (dotted line) with σ of 0.18 mag. The 3σ boundaries (dotted lines in the lower panel) represent the photospheric colors.

lar groups mainly located in Orion, the σ Ori cluster ($\sim$3 Myr, Hernández et al. 2007), the λ Ori cluster ($\sim$5 Myr, Hernández et al. 2009), the Orion OB1b sub-association ($\sim$5 Myr, Hernández et al. 2006) and the 25 Ori aggregate ($\sim$10 Myr, Hernández et al. 2006). We also included the γ Vel stellar cluster (Hernández et al. 2008), which has an stellar age of 6–7 Myr. These stellar groups cover an age range in which primordial disks are expected to evolve to second generation disks and planetary systems.

2. DISK DETECTION

Figure 1 shows a K-[24] versus $J-H$ color color diagram for intermediate mass stars. The three stars with K-[24] > 6 are known HAeBe stars in which primordial disks are present. A group of stars (debris disk candidates) do not exhibit emission lines in their optical spectra and exhibit modest excess at 24μm (with K-[24] < 3) comparable to debris disks in older stellar regions. The starless region ($3 <$ K-[24] < 6) suggests that the phase for primordial disk dissipation around intermediate mass stars is very brief.

3. DISK FREQUENCY EVOLUTION VERSUS SPECTRAL TYPES

Figure 2 shows the disk frequency versus spectral types for several star-forming regions (Hernández et al. 2009). Because of observational thresholds (which are almost the same for all stellar groups), the observed disk frequencies in K and M stars reflect the

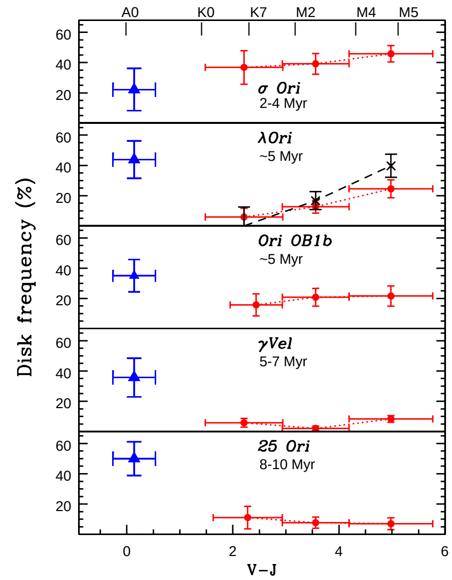

Fig. 2. Disk frequency versus spectral types. We displayed the location of the spectral type sequence, using the standard $V-J$ colors from Kenyon & Hartmann (1995). X's are the disk frequencies from Barrado y Navascués et al. (2007).

primordial disk populations, while the observed disk frequencies in intermediate mass stars encompass both primordial and debris disks. In stellar population of 3 Myr, disk frequencies for A-type stars are lower than disk frequencies around low mass stars in agreement with the expected trend for primordial disk dissipation. In contrast, at 5 Myr and older, disks around A-type stars are more frequent than in low mass stars indicating than second generation dusty disk must dominated the disk population at higher stellar masses. The reversal in the disk frequency at 5 Myr or older suggests that at 5–10 Myr collisions start to produce large amount of dust during the transition from runaway to oligarchic growth (sizes of $\sim$500 km, Kenyon & Bromley 2008).

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