*RevMexAA (Serie de Conferencias)*, **35**, 68–69 (2009)

# EARLY STAGES IN THE EVOLUTION OF PROTOPLANETARY DISKS

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RESUMEN

Las observaciones del telescopio espacial Spitzer constituyen una herramienta importante para el entendimiento de los primeros estados en la evolución del disco protoplanetario y la formación de planetas. Esas observaciones han demostrado que el disco primordial alrededor de estrellas jóvenes se disipa en unos pocos millones de años (Myr) mostrando fuerte dependencia en la masa de la estrella central. Recientes estudios en la asociación estelar Orion OB1 han mostrado que discos de segunda generación (discos de escombros producidos por colisiones en cascada entre cuerpos sólidos en el disco) alrededor de estrellas A pueden surgir en 10 Myr, mientras que el tiempo de vida típico del disco primordial en esos objetos es menor que 3 Myr. En contraste, estudios de la fracción de estrellas con discos en diferentes regiones de formación estelar indican que el tiempo típico de vida del disco primordial alrededor de estrellas de baja masa (tipo espectral K y/o M) es 5–7 Myr, mostrando un decrecimiento sustancial en la emisión del disco entre 1 y 10 Myr. Este trabajo muestra los resultados principales obtenidos al combinar datos de Spitzer, el catálogo 2MASS y datos ópticos proporcionados principalmente por el sondeo de variabilidad del CIDA.

ABSTRACT

Spitzer Space Telescope observations are an important tool for understanding the first stages of protoplanetary disk evolution and planet formation. These observations indicate that primordial disks around young stars dissipate in a few millions of years (Myr), and this evolution shows a strong dependence on stellar masses. Recent studies in the Orion OB1 association have shown that second generation disks (debris disks) around A type stars due to collisional cascades between solid bodies can be formed within 10 Myr, while the lifetime of primordial disks around these objects is less than 3 Myr. In contrast, studies of the fraction of the disk-bearing stars in several star formation regions indicate that the characteristic time for primordial disk dissipation around low mass stars (spectral types K5 or later) is 5–7 Myr, showing an overall decrease in disk emission between 1 to 10 Myr. This contribution shows the main results from studies in the Orion OB1 stellar association combining SPITZER and 2MASS catalog data with optical data obtained in the CIDA Variability Survey.

*Key Words:* planetary systems: protoplanetary disks — stars: pre-main sequence

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Ed. G. Magris, G. Bruzual, & L. Carigi

## 1. INTRODUCTION

Ample observational and theoretical evidence indicates that disks around young stars are an inescapable result of star formation (Hartmann 2005). These star-disk systems evolve in few Myr from optically thick flared disks (composed by primordial material) to debris disks systems (composed by material produced by collisions between solids created in the disks) with a timescale for primordial disk evolution depending strongly on the stellar mass(e.g., Lada et al. 2006; Carpenter et al. 2006).

Extensive IRAC/MIPS surveys of star forming regions provide an unique opportunity to characterize the disk population in a wide range of stellar masses. In particular, we have studied the disk population in three regions located in the Orion OB1 association: the $\sigma$ Orionis cluster (∼3 Myr; Hernández et al. 2007a), the Orion OB1b subassociation (∼5 Myr; Hernández et al. 2006, 2007b) and the 25 Ori stellar aggregate (10 Myr; Briceño et al. 2007; Hernández et al. 2006, 2007b). Optical photometry from the CIDA variability survey combined with optical spectroscopy were used to select members of each stellar group. Our studies reveal a large diversity of disks in these star forming regions indicating that optically thick, debris disks and disk in an intermediate phase (like transitional disks and flatted evolved disks) can be found at 3 and 10 Myr. However, clear trends are found when compare the overall disk population versus the age of the stellar groups.

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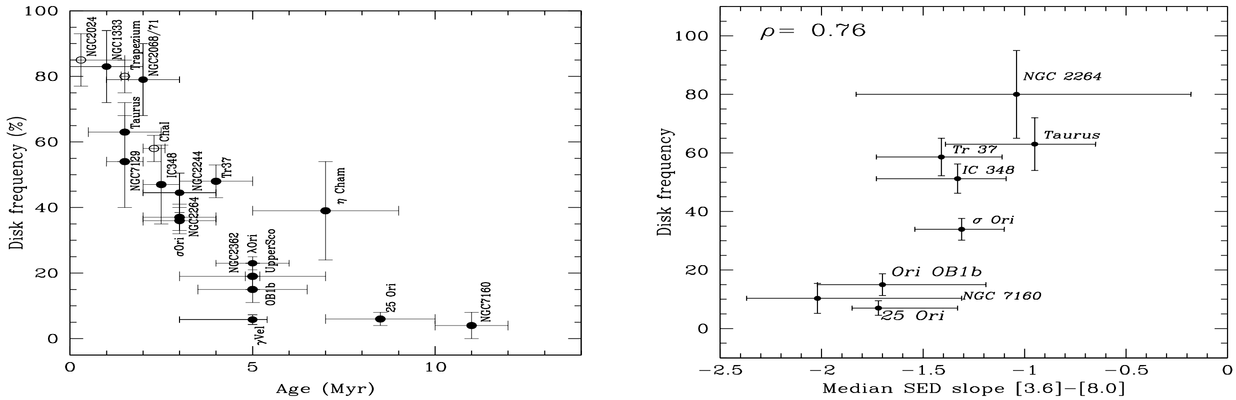


Fig. 1. The left panel shows the fraction of low mass stars bearing primordial disks as a function of the age of the stellar groups studied by Spitzer (solid circles) and groundbase observations (open circles) (for references see Hernández et al. 2008). The right panel shows a correlation bewteen the disk emission (SED slope [3.6]–[8.0]) and the disk frequency in different stellar groups (for references see Hernández et al. 2007b).

## 2. RESULTS

Figure 1 shows the frequencies of late type young stars (T Tauri stars) with near-infrared disk emission in different stellar groups as a function of age (Haisch et al. 2001; Hernández et al. 2005, 2007a, 2008). The disk frequency decreases with increasing age with a time scale for primordial disk dissipation of ∼5Myr (left panel). The left panel of Figure 1 shows that inner disk emission (estimated from the median SED slope in the IRAC spectral range) decreases systematically with age, showing a correlation (correlation coefficient $\rho$=0.76) between disk frequencies and inner disk emission (Hernández et al. 2007b). This suggests that as the star-disk system become older, the disk decreases the photospheric height, possibly due to dust growth and/or settling toward the midplane of the disks, where planetesimals and planets eventually are formed.

In contrast to low mass stars, objects in the mass range of the Herbig Ae/Be (HAeBe) stars (28 M) have a timescale for primordial disk dissipation lower than 3 Myr (Hernández et al. 2005). After the primordial disk is cleared, second generation dust produced by collisions between solids forms debris disk systems. Figure 2 shows a peak in the debris disk phenomenon at 10 Myr as indicated by our observations of Ori OB1a. These observations are in agreement with theoretical predictions (dotted lines), in which the peak is associated to the formation of large icy objects (1000 km) in 10–20 Myr, which stir up the smaller objects in the disk and produce a collisional cascade, in which 1–10 km planetesimals are converted in fine dust grains (Kenyon & Bromley 2005). Stellar groups older that 10 Myr follow the predictions of collisional cascades models.

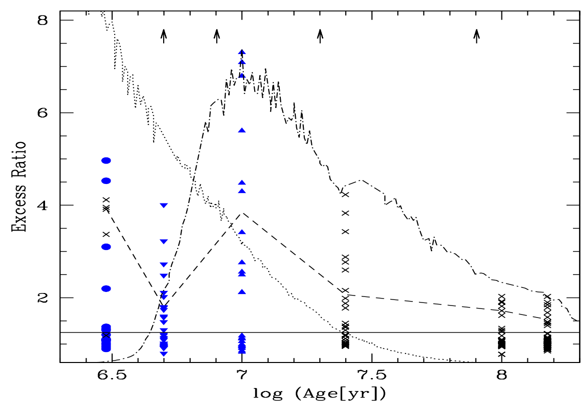


Fig. 2. Plot of 24 $\mu$m excess vs. logarithm of age. The excess ratio is calculated as the ratio of the observed flux at 24 $\mu$m to that expected from the stellar photosphere (see Hernández et al. 2006). Debris disks found in the $\sigma$ Orionis cluster, the Orion OB1b subassociation and 25 Ori aggregated are represented with circles, inverse triangles and triangles, respectively.

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