RevMexAA (Serie de Conferencias), **35**, 56–57 (2009)

CVS0 224: A TRANSITIONAL DISK IN THE 10 MYR 25 ORI AGGREGATE

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RESUMEN

Presentamos observaciones ópticas e infrarrojas de CVSO 224, el único disco de transición localizado dentro del grupo 25 Orionis (con ~10 Maños) de Orion OB1a. El espectro IRS de *Spitzer* revela un disco ópticamente grueso, truncado a ~ 7 AU, cuya región interior está rellena con polvo ópticamente delgado, que asemeja la estructura del único disco de transición con ~10 Maños de edad que se ha estudiado en detalle, a saber, TW Hya. Tal como en TW Hya, los granos de esta región han crecido hasta tamaños de μm, significativamente más grandes que en las regiones internas de los discos de transición en Taurus. El perfil Hα en el espectro HECTOCHELLE de CVSO 224, revela alas anchas, indicativo de acreción magnetosférica, a pesar de la clasificación previa como WTTS para este objeto. La tasa de acreción de masa derivada es ~10 veces más baja que en TW Hya, pero consistente con el decaimiento esperado de la tasa de acreción de masa con la edad.

ABSTRACT

We present optical and infrared observations of CVSO 224, the sole transitional disk located within the ~10 Myr year old 25 Orionis group of Orion OB1a. The *Spitzer* IRS spectrum reveals an optically thick disk truncated at ~ 7 AU, with an inner region filled with optically thin dust, reminiscent of the structure of the only other ~10 Myr year old transitional disk studied in detail, namely, TW Hya. As in TW Hya, the grains in this region have grown to μm sizes, significantly larger than in the inner regions of the transitional disks in Taurus. The Hα profile in our high resolution HECTOCHELLE spectrum of CVSO 224 reveals broad wings, indicative of magnetospheric accretion, despite the previous classification of WTTS for this object. The derived mass accretion rate is about 10 times lower than in TW Hya, but consistent with expected decay of mass accretion rate with age.

Key Words: accretion, accretion disks — stars: pre-main sequence

A new class of pre-main sequence disks has been characterized in recent years, specially with observations obtained with the IRS spectrograph on board *Spitzer*. These are the *transitional disks*, which we define as disks with fluxes similar to those of optically thick disks in the mid-infrared and longer wavelengths, and much lower than optically thick disks in the near-infrared (Calvet et al. 2002; Uchida et al. 2004; D'Alessio et al. 2005; Calvet et al. 2005a; Espaillat et al. 2007). To explain the significant drop of opacity resulting in the flux deficit in the near-infrared, the inner disk regions have to be significantly depleted of small dust grains. Several possibilities have been given to explain this clearing. These include photoevaporation (Clarke et al. 2001), inside-out evacuation induced by the MRI (Chiang & Murray-Clay 2007), rapid dust growth and settling (Lin & Ida 2004), and planet and gap formation (Quillen et al. 2004). Comparison of the mass of the disk and the mass accretion rate in the inner disk predicted by various models with observed values led Alexander & Armitage. (2007) to conclude that planet formation was the most likely explanation for most of the transitional disks studied so far. Moreover, the recently identified pre-transitional disks, with a gap in the optically thick disk rather than a hole (Espaillat et al. 2008), further supports this interpretation.

However, many questions remain to be answered before we can claim understanding of the transitional disk stage in the context of the overall evolution from primordial, optically thick disks to debris disks. To address this question, we need samples of transitional disks in populations of different ages. Most transitional disk studies have focused on objects located in 1–5 Myr old star-forming regions. This is due in part to the difficulty in identifying older re-

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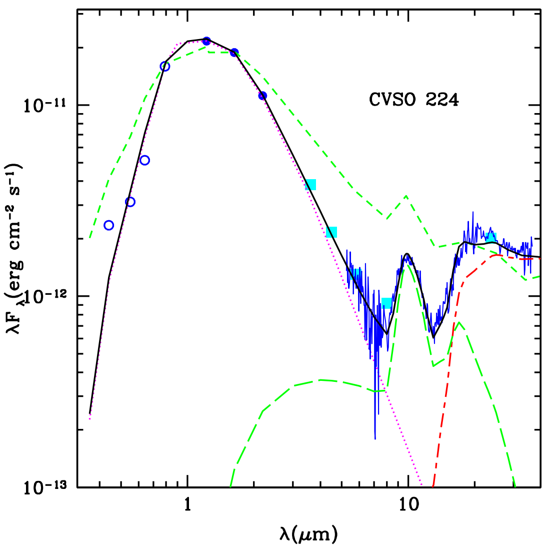

Fig. 1. Spectral energy distribution of CVSO 224 and disk model (solid line). The short dashed line is the median SED of Taurus, a proxy for the SED of optically thick, full disks. The dotted line is the photosphere. The contribution to the SED from the exposed wall at the truncation radius (long-short dashes) and from the optically thin dust in the cleared region (long dashes) are also shown (from Espaillat et al. 2008).

gions, specially distributed populations, since they are no longer associated with molecular clouds, and in part to the decreasing frequency of stars with disks as populations age. So far, the only 10 Myr old transition disk studied in detail is TW Hya, belonging to a group which mostly formed low mass stars, akin the population in Taurus-Auriga.

We report here observations and interpretation of another 10 Myr old transitional disk, discovered in our photometric/spectroscopic survey of the Orion OB1 subassociations, aiming to characterize the low and intermediate mass counterparts of the OB stars in the subassociations of Ori OB1 (Briceño et al. 2005, 2007; Hernández et al. 2005, 2006). This disk belongs to the recently discovered aggregate around 25 Ori, with an age of $\sim$ 10 Myr and kinematic properties clearly distinct from younger subassociations of Ori OB1 (Briceño et al. 2007). Less than 10% of the objects in the 25 Ori aggregate have disks, as indicated by *Spitzer* IRAC and MIPS photometry, and among these only one transitional disk has been identified, that around the star CVSO 224 (Hernández et al. 2007). Figure 1 shows the spectral energy distribution (SED) of this object, which includes the IRS spectrum and IRAC and MIPS photometry obtained in our *Spitzer* programs, as well as optical photometry and 2MASS near-infrared data (Espaillat et al. 2008). This star was originally classified as non accreting using the equivalent width of the Hα line (Briceño et al. 2005). However, in a high resolution spectra obtained with the multifiber Hectochelle spectrograph (Szentgyorgyi et al. 1998) as part of our spectroscopic follow-up program (Briceño et al. 2007), the Hα profile consists of a narrow central chromospheric profile with superimposed broad, high velocity wings, formed in magnetospheric accretion flows. Modeling of the wings following the procedures of Muzerolle et al. (2001) yields a mass accretion rate of $\sim 10^{-10}\ M_{\odot}\ \mathrm{yr}^{-1}$, consistent with the low mass accretion rate expected at that age (Calvet et al. 2005b). With this value and stellar parameters inferred from the optical photometry and spectroscopy as input, we have modeled the SED following the method of D'Alessio et al. (2005), and found that the outer disk is truncated at $\sim$ 7 AU. In addition to the gas accreting onto the star, a small amount of dust grains fills the disk inside this radius. Analysis of the silicate profile shows that these grains have grown to a maximum size of a few μm. The contribution to the SED from each of these components is shown in Figure 1. We note that there seems to be no dependence of hole size with age. In addition, we note that the only two 10 Myr old transitional disks analyzed in detail so far have extended inner optically thin regions where dust has grown to sizes a factor of 10 bigger than in the younger objects of Taurus.

REFERENCES

Alexander, R. D., & Armitage, P. J. 2007, MNRAS, 375, 500
Briceño, C., et al. 2005, AJ, 129, 907
Briceño, C., et al. 2007, ApJ, 661, 1119
Calvet, N., et al. 2002, ApJ, 568, 1008
Calvet, N., et al. 2005a, ApJ, 630, L185
Calvet, N., et al. 2005b, AJ, 129, 935
Chiang, E. I., & Murray-Clay, R. A. 2007, preprint (astroph/0706.1241)
Clarke, C. J. et al. 2001, MNRAS, 328, 485
D'Alessio, P., et al., 2005, ApJ, 621, 461
Espaillat, C., et al., 2007, ApJ, 664, L111
Espaillat, C., et al., 2008, ApJ, 689, L145
Hernández, J., et al. 2005, AJ, 129, 856
Hernández, J., et al. 2006, ApJ, 652, 472
Hernández, J., et al., 2007, ApJ, 671, 1784
Lin, D. N. C., & Ida, S. 2004, in ASP Conf. Ser. 323, Star Formation in the Interstellar Medium, ed. D. Johnstone, F. C. Adams, D. N. C. Lin, D. A. Neufeld, & E. C. Ostriker (San Francisco:ASP), 339
Muzerolle, J., et al. 2001, ApJ, 550, 944
Quillen, A.C., et al. 2004, ApJ, 612, L137
Szentgyorgyi, A. H., et al. 1998, Proc. SPIE, 3355, 242
Uchida, K. I., et al. 2004, ApJS, 154, 439