Mid-Infrared Spectra of Transitional disks in the Orion A cloud

K. H. Kim (U. Rochester), D. M. Watson (U. Rochester), P. Manoj (U. Rochester), W. J. Forrest (U. Rochester), B. Sargent (STScI), E. Furlan (JPL), N. Calvet (U. Michigan), C. Espaillat (U. Michigan), M. K. McClure (U. Michigan), S. T. Harrold (U. Rochester), L. E. Allen (CfA), J. Muzerolle (Steward), S. T. Megeath (CfA)

ABSTRACT

We present 5-40 micron Spitzer Infrared Spectrograph spectra of the transitional disks in the Orion A molecular-cloud complex. Transitional disks -- T Tauri stars with little excess at short infrared wavelengths but excesses similar to ordinary Class II YSOs at longer wavelengths -- are thought to owe their distinctive spectral energy distributions (SEDs) to wide central holes or gaps in YSO disks. Here we extend our study of these objects in the nearest star-forming regions to the Orion clouds, a sample twice as large as that in the Tau-Aur-Cha-Oph regions. We identified 34 new transitional disks in Orion A. We compare the SEDs of transitional disks with the median SED of Class II YSOs in Orion A, and assess the disk structures and properties with simple models. We also compare the characteristics of the transitional disks in Orion A with those found in the nearest clouds, to shed light on differences in the evolution of these objects in the variety of star-forming environments found in Orion.

INTRODUCTION

Transitional disks are protoplanetary disks around young stars that have inner clearings or radial gaps on AU scales. They are thought to represent an evolutionary stage in between that of Class II objects and Class III objects. The SEDs of these disks exhibit a significant deficit of flux in the near-infrared (at < 10 μm) wavelengths relative to those of the optically thick full disks, and a steeply rising excess at the mid- and far-infrared wavelengths.

In a previous study we identified 17 transitional disks in the nearby star-forming regions of Tau-Aur, Cha I, and Oph. Here we extend our study to the Orion A cloud.

Orion A, which is at a distance of ~ 414 pc (Menten et al. 2007), contains largest known young clusters within 1 kpc of the Sun. The prominent among these clusters are the Orion Nebular Cluster (ONC) and L1641. The median age of these clusters is thought to be ~ 1 Myr (Gålfalk & Oloffson 2008).

OBSERVATION

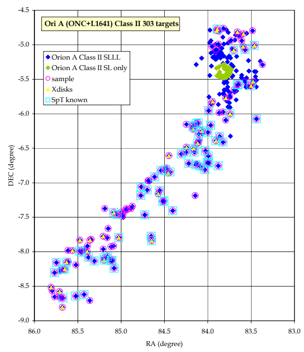

Fig 1. 303 Class II YSOs observed in Orion A (IRS GTO).

Sample

- Analyzed the spectra of 141 YSOs (32 in ONC, 109 in L1641)
- Identified 34 transitional disks (10 in ONC, 24 in L1641)

ANALYSIS

- *Extinction Correction* : IRS spectra and photometry were dereddened using the derived E(J-H) and the extinction law from Mathis (1990) for R_V=5.0
- *SpTs and Teff* : For objects with unknown SpT, we adopt the mean E(J-H) of the objects with known SpT , and the Teff corresponding to the median SpT (K5; 4350K)
- *Median spectrum of Class II objects* from 48 objects with known SpT

Model for T_d and R_{wall}

- We first subtracted a power law fit to the IRS spectrum from 5 to 8 μm to extract the effects of stellar photosphere and/or inner disks, if there is excess over 5-8 μm.
- T_d (wall temperature) was estimated from fitting the residuals with two componets : ((1)dust emission from the optically thin atmosphere of the wall (2) a blackbody with Td for the optically thick layers of the wall as shown in Fig 2.

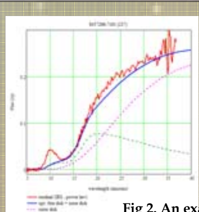

Fig 2. An example of the simple model

- Location of the wall (R_{wall}: inner edge of the optically thick outer disk) :

$$R_{wall} = \sqrt{\frac{L_*(1-A_{UV})}{4\pi\sigma T_d^4 \varepsilon_{IR}}}$$

A_{UV} : the effective albedo at stellar wavelengths.

ε_{IR} : the effective emissivity at mid-infrared wavelengths.

Transitional disks Trends

	number of samples	M_star vs. R_wall		T_eff vs. R_wall	
	N	r	p	r	p
OriA-ChaI-Tau	46	0.582	0.0022	0.447	0.186
OriA(known SpT)-ChaI-Tau	26	0.777	0.0003	0.693	0.0086
OriA	34	0.453	0.72	0.369	3.179
OriA(known SpT)	14	0.567	3.449	0.603	2.255
L1641-ChaI-Tau	36	0.751	0.00001	0.649	0.186
L1641(known SpT)-ChaI-Tau	23	0.859	0.00001	0.715	0.013
L1641	24	0.616	0.134	0.629	0.1
ONC	10	0.639	4.681	0.45	19.176

Note : r is the linear correlation coefficient; p is the probability of obtaining a correlation this large or larget from a randm distribution of N objects

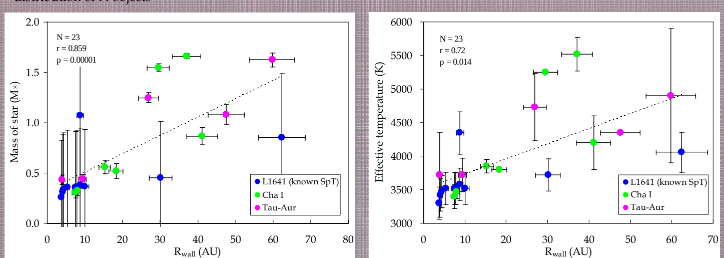

Fig 3. Central stellar mass ($M_\odot$) and effective temperature (T_{eff}) plotted against the location of the wall (R_{wall}) for the transitional disks in L1641, ChaI and Tau-Aur.

Examples of Ori A Transitional Disk SEDs

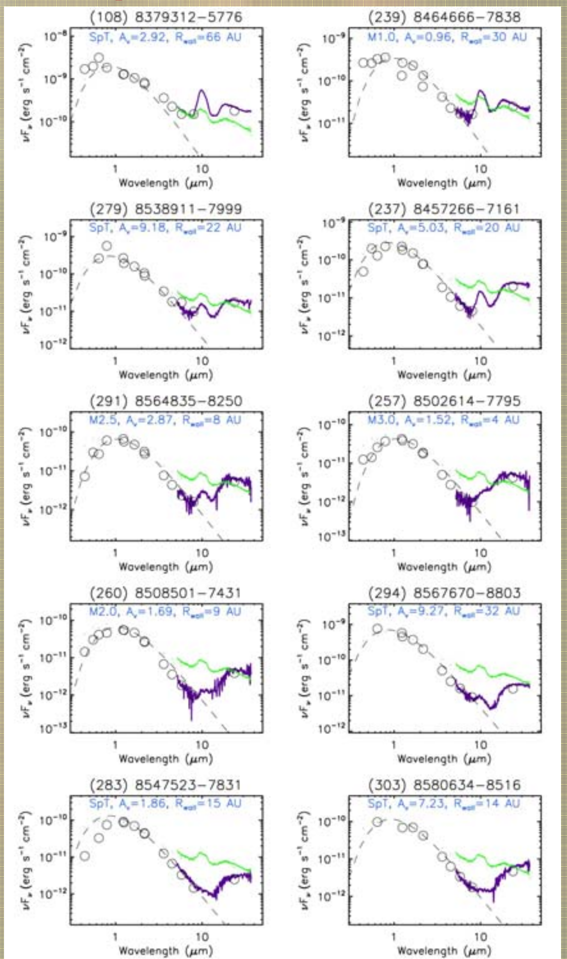

Fig 3. SEDs of Transitional disks. Extinction corrected IRS spectra (purple line) and the photometric points (circles) are shown together with Ori A Class II median spectrum (green line) normalized to the H band. Dashed line is the stellar photosphere corresponding to the effective temperature (see Analysis for details) normalized to the H band. Adopted spectral types (if unknown, SpT), A_v, and the estimated hole sizes (R_{wall}) are indicated for each target.

SUMMARY

- We identified 34 new transtional disks among 141 young stars in Orion A.
- Transitional disks in Orion A appear to have somewhat smaller hole sizes compared to that of the transitional disks in the nearby clouds of Tau-Aur and Cha I. However, transitional disks in Orion A occur more frequently around low-mass stars than they do in the nearby clusters in Tau-Aur and Cha I, and the gap radii tend to be proportionally smaller than those found in the nearby clusters.
- Location of the wall (R_{wall}) is tightly correlated with effective temperature and stellar mass for the transitional disks in L1641, Cha I, and Tau-Aur. The trend in Orion is similar in magnitude to that in the nearby clusters, which have environments similar to L1641. As discussed by Kim et al (2008), this correlation is consistent with gap formation by the effects of companions: stars, brown dwarfs or giant planets. In the nearby clouds, planets must be responsible in the majority of the cases; the same might therefore be true of Orion.

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