Properties of the *transitional disks* in five young stellar clusters

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Introduction

• Transitional disks are protoplanetary disks 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, radially-continuous disks, and a steeply rising excess at the mid- and far-infrared wavelengths.

• With Spitzer-IRS spectra it is possible to identify transitional disks and characterize the structure and contents of the gaps/holes, in very large samples of objects within nearby associations.

• SpT distribution of our sample of transitional disks among five star-forming regions: G-M

• Transitional disks may be classified in three categories by their disk structure. TD: Transitional disks with an inner hole (central clearing). (or CTD as canonical transitional disk (Muzerolle et al. 2008)); WTD: Transitional disks with weak excess at < 10 μm, indicating an optically thin inner disk separated by a gap from the optically thick outer disk.; PTD: Pre-Transitional disk (Espaillat et al. 2007, 2008), showing excess similar to the median at < 5 μm, indicating an optically thick inner disk separated by a gap from the optically thick outer disk.

Transitional Disk Structure and Properties

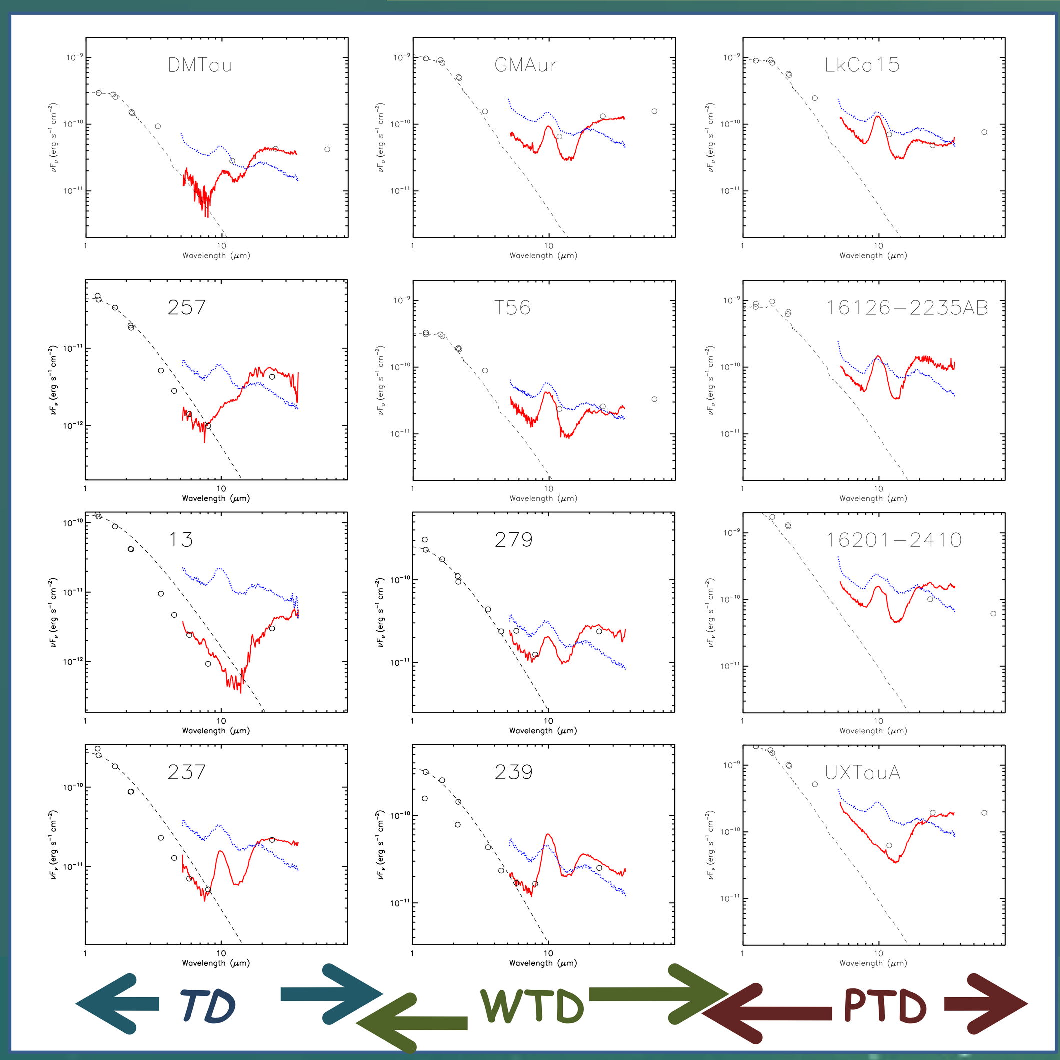

Fig 1. SEDs of various kind of transitional disks. Blue dotted line represent Class II median of that region and Red line represent the IRS spectrum

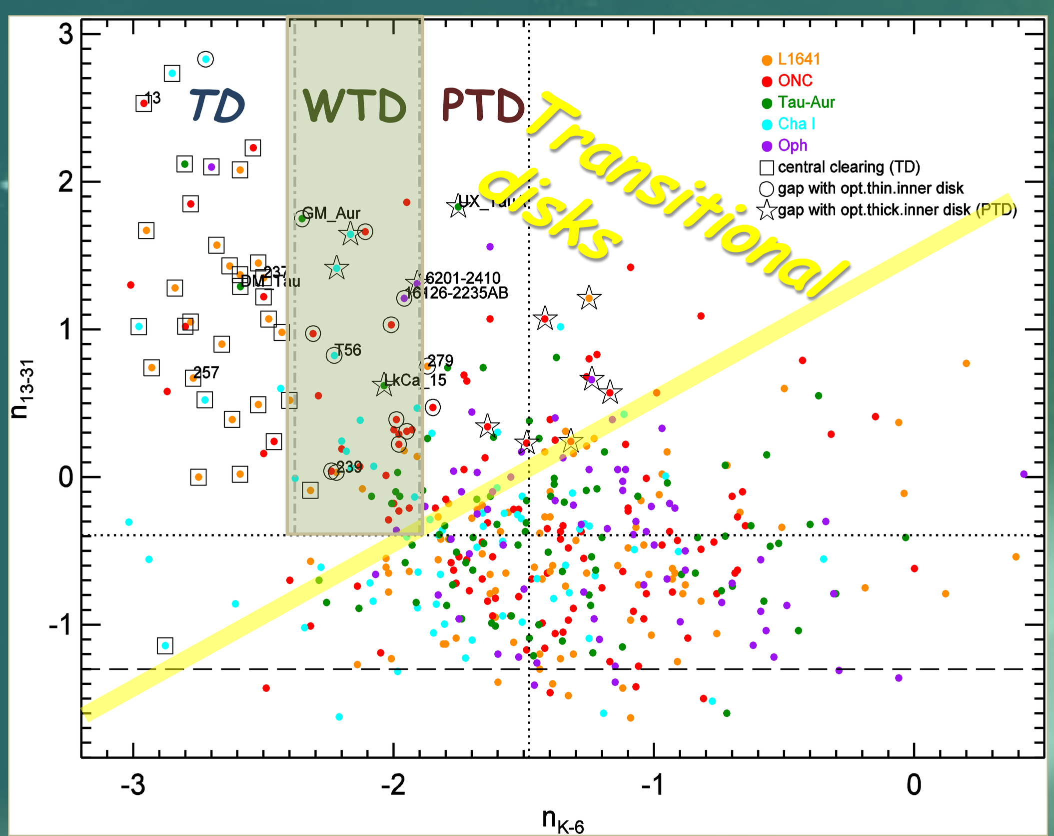

Fig 2. n_{13-31} vs. n_{K-6}. Transitional disks are well separated from the ordinary Class II and Class III objects. Most transitional disks are located in the upper left area (above median of n_{13-31} and below median of n_{K-6}).
Dotted line : medians; Dashed line : n_{13-31} of full disk; gray area : transition area between TD and PTD.

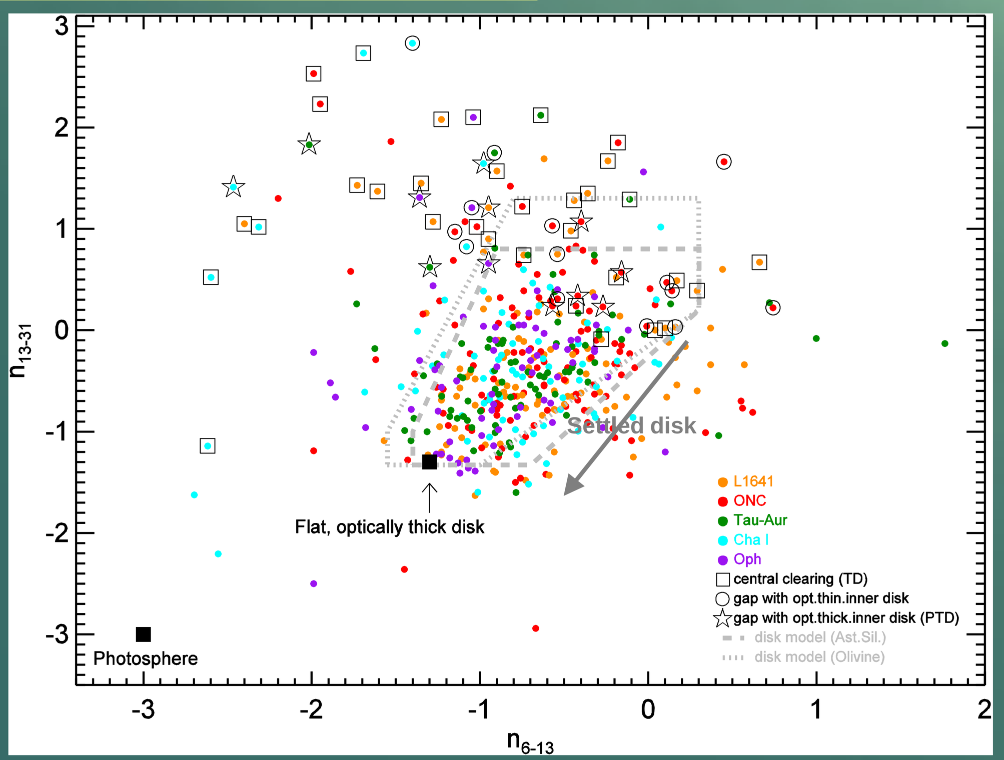

Fig 3. n_{13-31} vs. n_{6-13}: Settled disks lie in the direction of the arrow; Transitional disks are well separated from the main distribution of Class II YSOs.

The spectral index ($n_{\lambda 1-\lambda 2}$) measure of the slope of the SEDs between two wavelengths, λ_1 and λ_2.

$$n_{\lambda_1-\lambda_2} = \frac{\log(\lambda_2 F_{\lambda_2}) - \log(\lambda_1 F_{\lambda_1})}{\log(\lambda_2) - \log(\lambda_1)}$$

The equivalent width of the 10 μm silicate emission feature (EW(10μm)) is a measure of the amount of optically thin dust per unit area of optically thick disk.

$$EW(10\mu m) = \int_{8\mu m}^{13\mu m} \frac{F_\lambda - F_{\lambda,con}}{F_{\lambda,con}} d\lambda$$

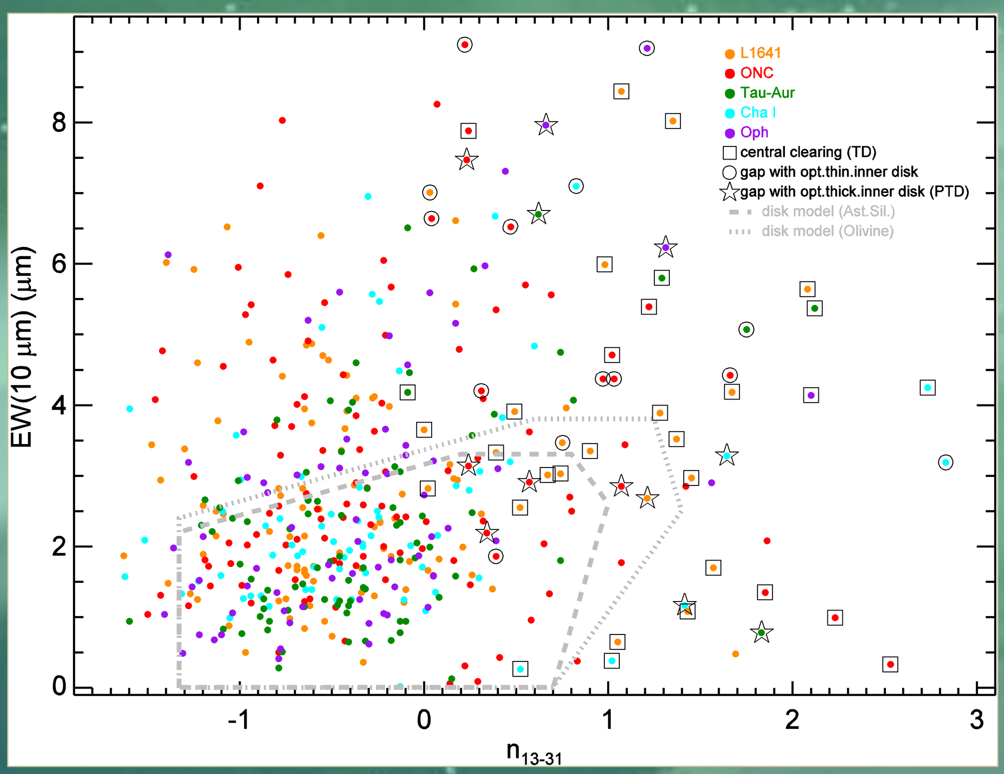

Fig 4. EW(10 μm) vs. n_{13-31}. There are several outliers which cannot be accounted for by the accretion disk models (e.g. D'Alessio et al. 2006).

Sample size and transitional disk frequency

region	ONC	L1641	Tau	Cha I	Oph
ClassII+III	127	114	85	71	71
TD+WTD +PTD	20	24	5	8	4
TD	8	19	2	4	1
WTD	5	3	1	2	1
PTD	7	2	2	2	2
median age	< 0.8 Myr	~1 Myr	~1.5 Myr	~2 Myr	~ 2.1 Myr
Distance (pc)	400-500	400-500	140	160	120-160

Table 1. Summary of some properties of each region and number of sample.

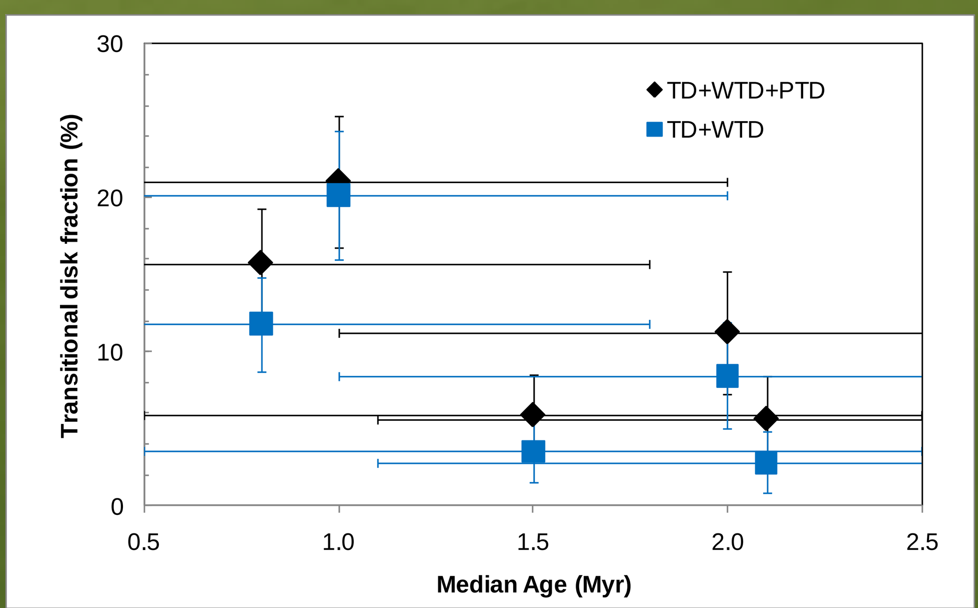

Fig 5. Transitional disk fraction vs. median cluster age. Transitional disk fraction of each region is a fraction from the sample of Class II+III.

Are transitional disks older than full disks?

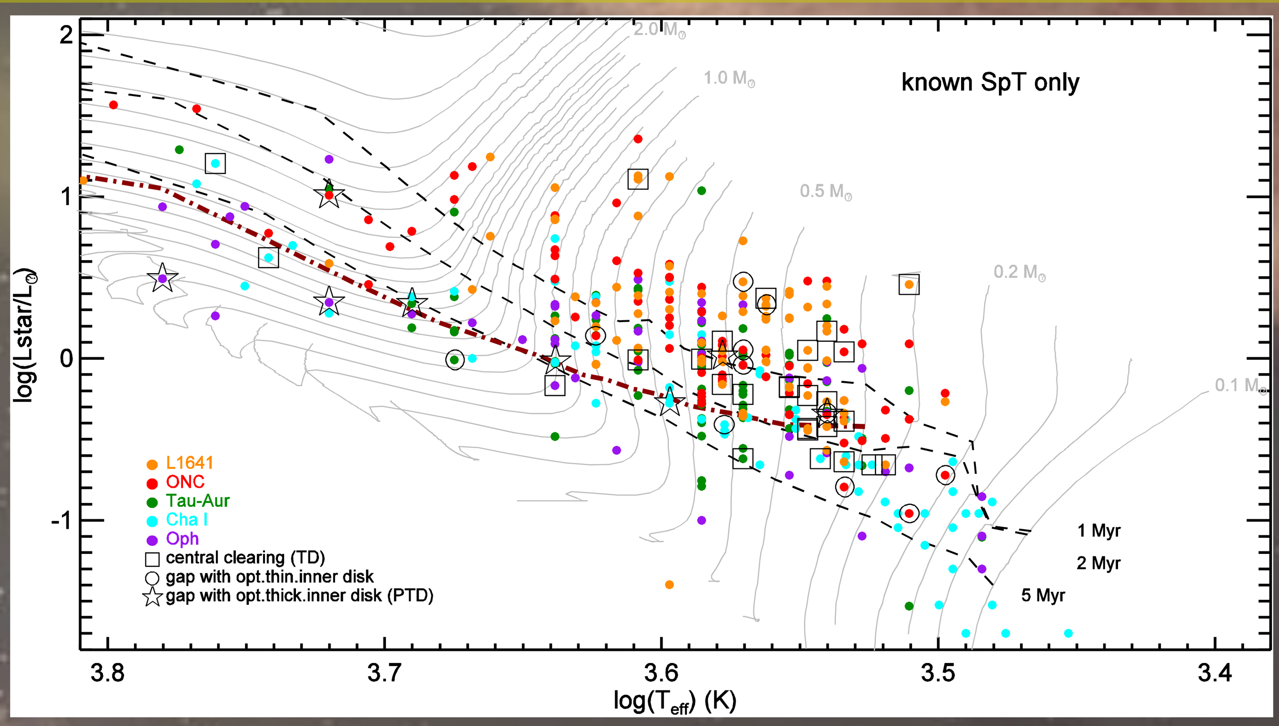

Fig 6. HR diagram for transitional disks. Evolutionary tracks and isochrones are from Siess et al. (2000) (Z=0.02). Isochrone ages of various types of transitional disks range from < 1 Myr to > 5 Myr. The average disk life time in Tau-Aur (Bertout et al. 2007) is also shown as brown dash-dotted line for reference..

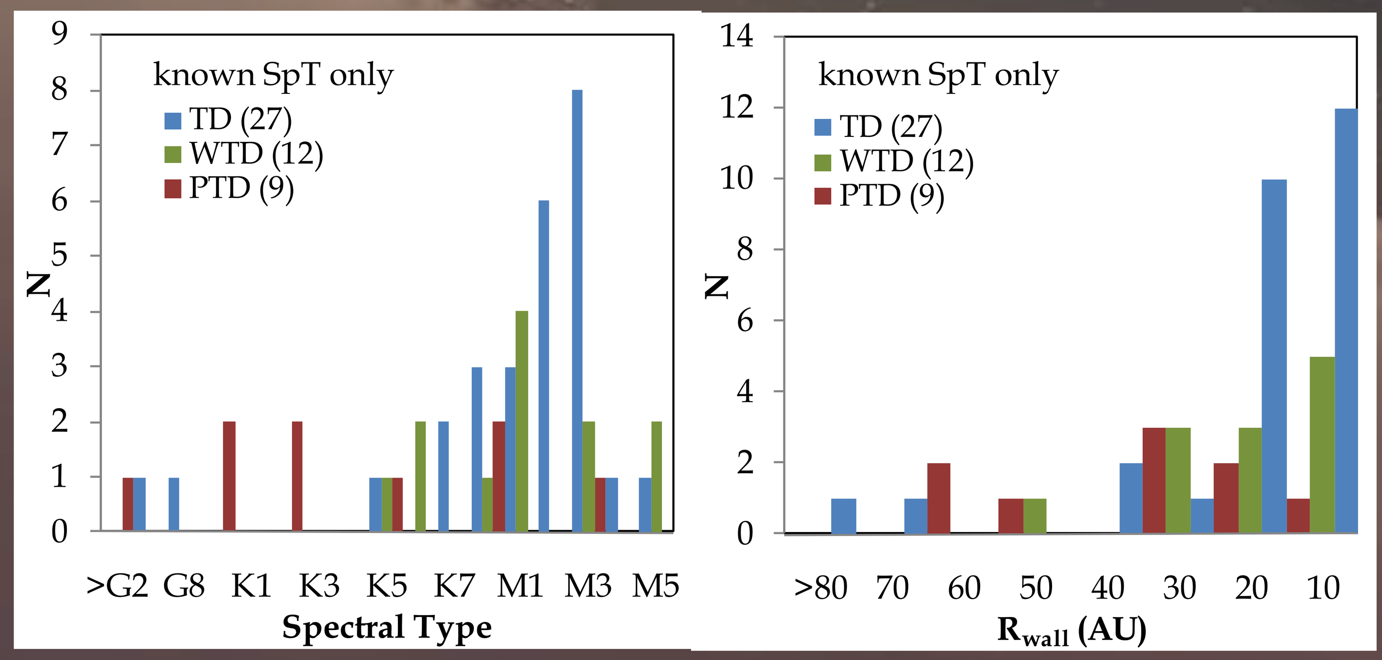

Fig 7. (Left): Spectral Type distribution among transitional disks. Most TDs are late-type stars and most PTD are early-type stars.; (Right): R_{wall} distribution among transitional disks. PTDs tend to have larger R_{wall}. Large fraction of TDs have R_{wall} < 20 AU.

Trends of Transitional Disks

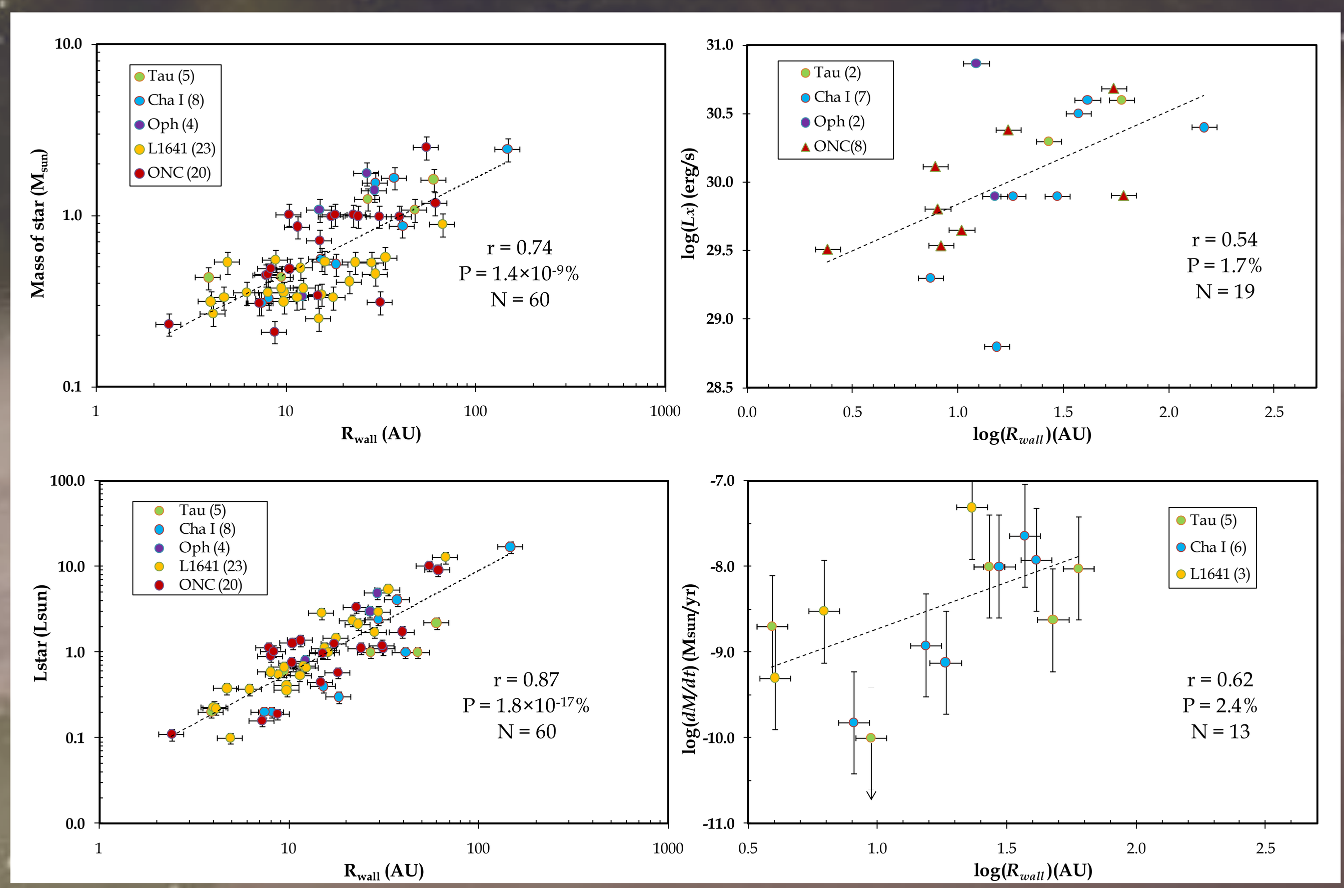

Fig 8. Trends among transitional disk properties. (L_x data of Tau, Cha I, and Oph region are taken from WGACAT (White et al. 2000) (circles). ; L_x data of ONC region are from Chandra (triangle).)

Summary & Preliminary Results

❑ n_{13-31} vs. n_{K-6} is a good method to separate transitional disks from the optically thick full disks. n_{K-6} is a good indicator for distinguishing TD from PTD (See Fig 2).In their spectra, transitional disks show different disk structures which cannot be explained by standard full disk models (d'Alessio et al. 2006). See Fig 3 and Fig 4 .

❑ The frequency of transitional disks identified from the IRS spectra in the five star forming regions studied here range from 6% to 21%. The fraction of transitional disks in each region, and that in each type of transitional disks, are not strongly correlated with the median isochronal age of each stellar cluster (See Table 1 and Fig 5).

❑ TDs are seen dominantly among later type and younger stars, and PTDs seem to be seen more among early type and older stars. (See Fig 6 and Fig7). Also R_{wall} of PTD tends to be larger than that of TD (See Fig 7). This is consistent with the gravitational effects of sub-stellar companions, like giant planets, being responsible for the gaps in the disks.

❑ The significant correlation found between R_{wall} and M_{star} (L_{star}) is consistent with the well known dependence between binary separation and system stellar mass. The correlations found for L_x and dM/dt with R_{wall} are not as strong as those seen for of M_{star} and L_{star}. More L_x and dM/dt data needed to explore potential trends.

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Background Image : Artist Conception of transitional disks and pre-transitional disk (NASA/JPL-Caltech/T. Pyle (SSC))