# *Statistics* of the *transitional disks* in five young stellar clusters

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## *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, radially-continuous disks, and a steeply rising excess at the mid- and far-infrared wavelengths.**

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

• **TD : Transitional disks with an inner hole (central clearing). (or CTD as canonical transitional disk (Muzzeroll 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 comparable excess 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 Property*

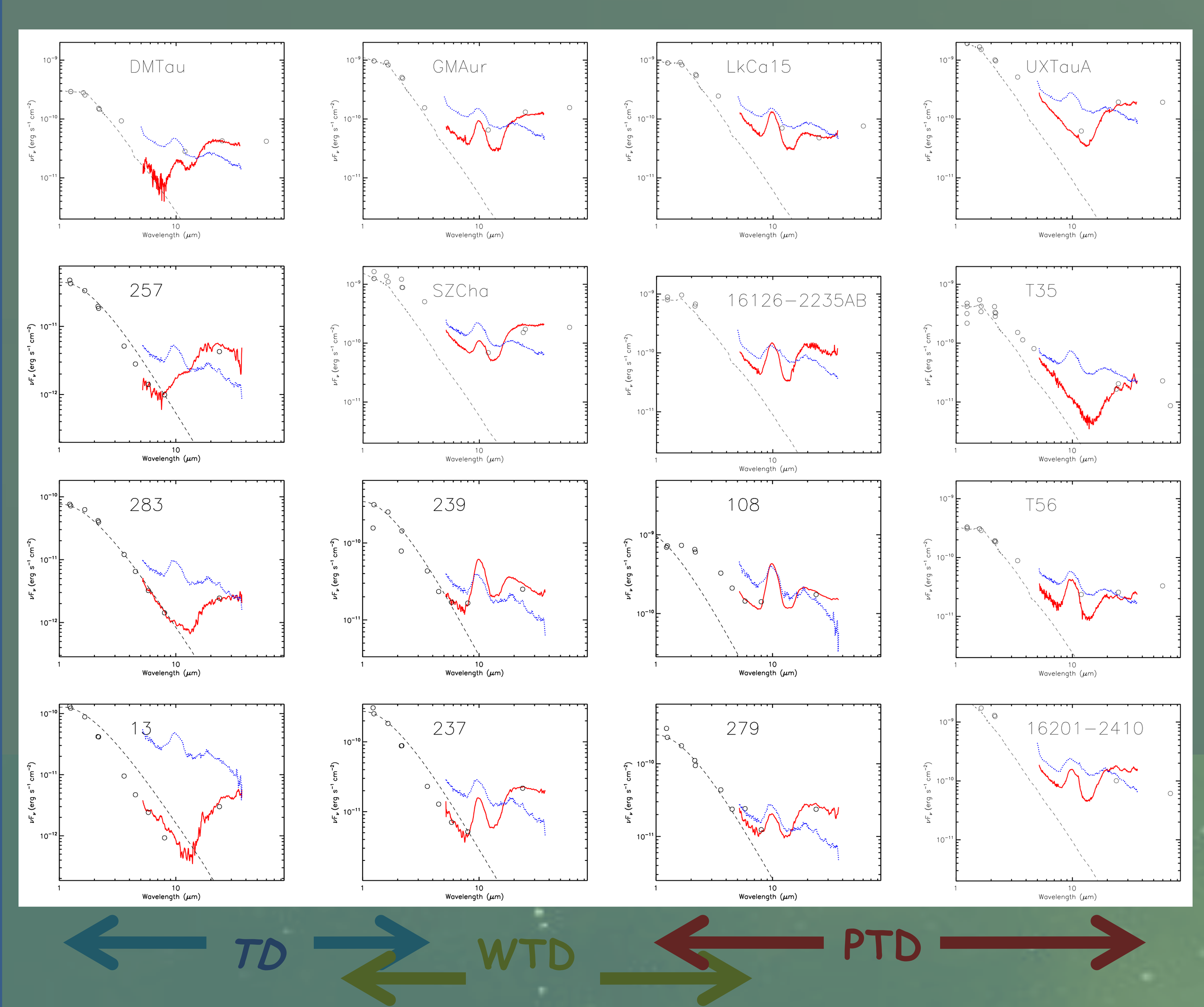


Fig 3. Sample SEDs for various kind of transitional disks.

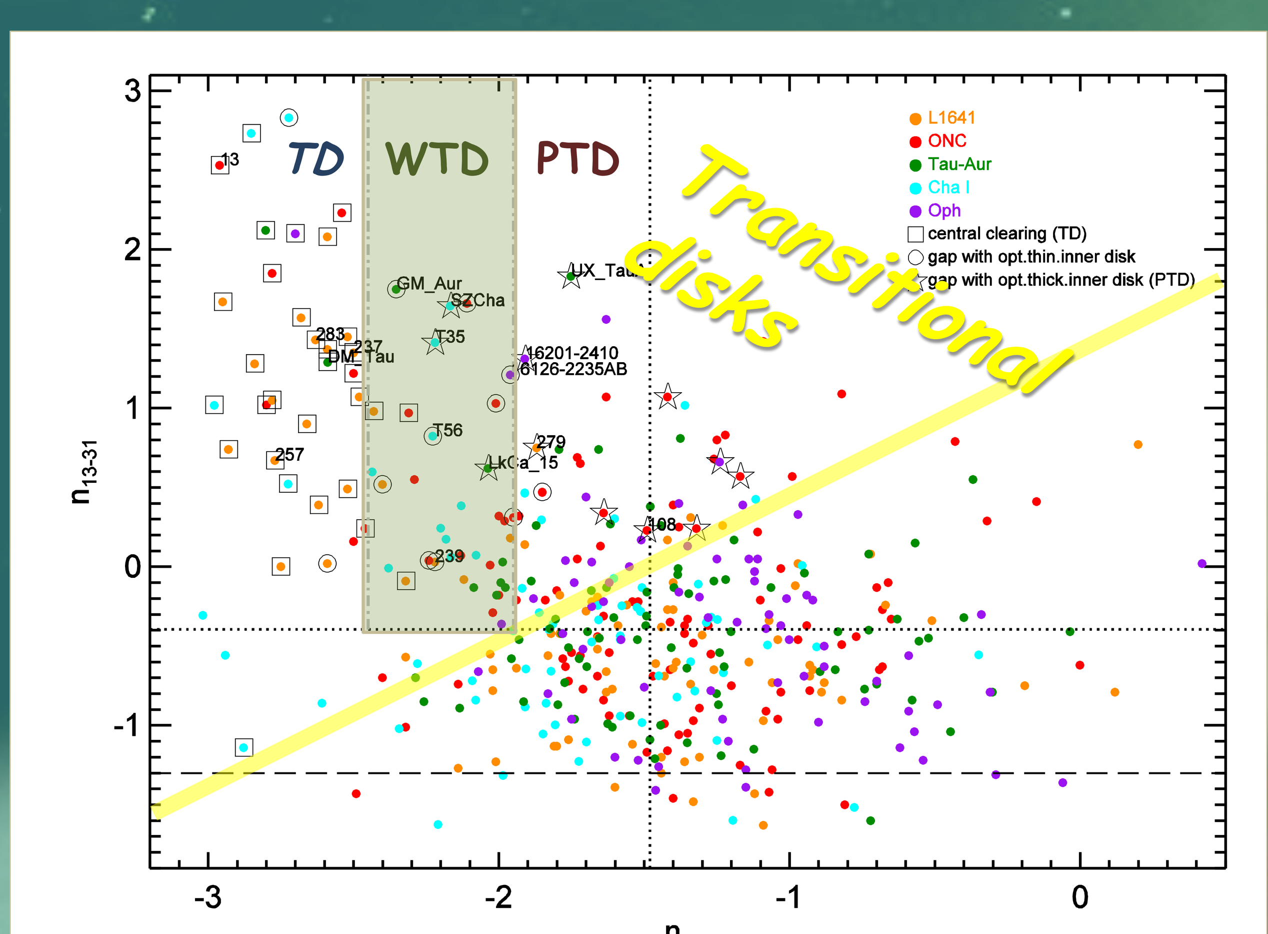


Fig 4. $n_{13-31}$ vs. $n_{K-6}$. Transitional disks are well separated from the ordinary Class II and Class III objects. Most transitional disks are located upper left area (above median of $n_{13-31}$ and below median of $n_{K-6}$). Dotted line : medians; Dash line : $n_{13-31}$ of full disk; gray area : transition area between TD and PTD

*The spectral index* ($n_{\lambda1-\lambda2}$) measure the slope of the SEDs between two wavelengths, $\lambda_1$ and $\lambda_2$ .

*The equivalent width* of the 10 μm ($EW$(10μm)) is a measure for the amount of optically thin dust per unit area of optically thick disk .

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

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

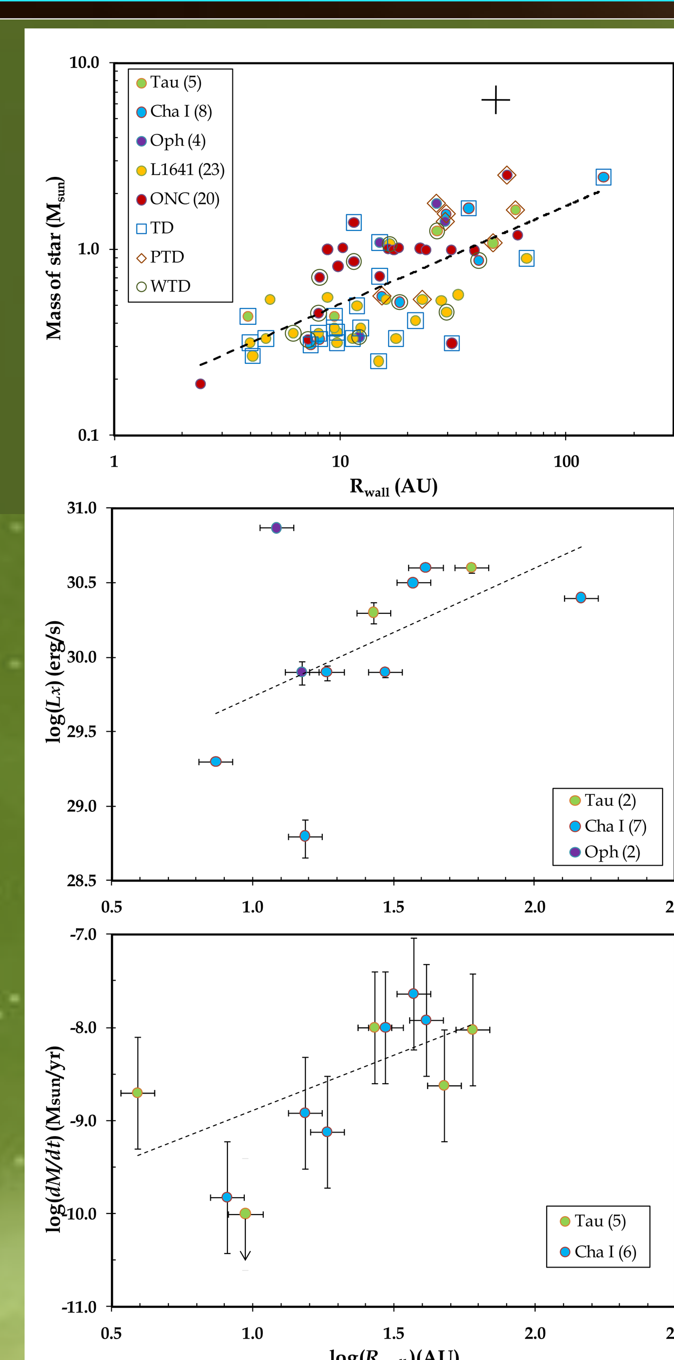


Fig 7. Trends of transitional disks . ($L_x$ data are taken from WGACAT (White et al. 2000)

| property | $M_{star}$ | $L_x$ | dM/dt |
|---|---|---|---|
| Pearson's r | 0.69 | 0.50 | 0.64 |
| N | 60 | 11 | 10 |
| P (%) | $1\times10^{-7}$ | 12 | 5 |

Table 2. Correlation between stellar properties and $R_{wall}$

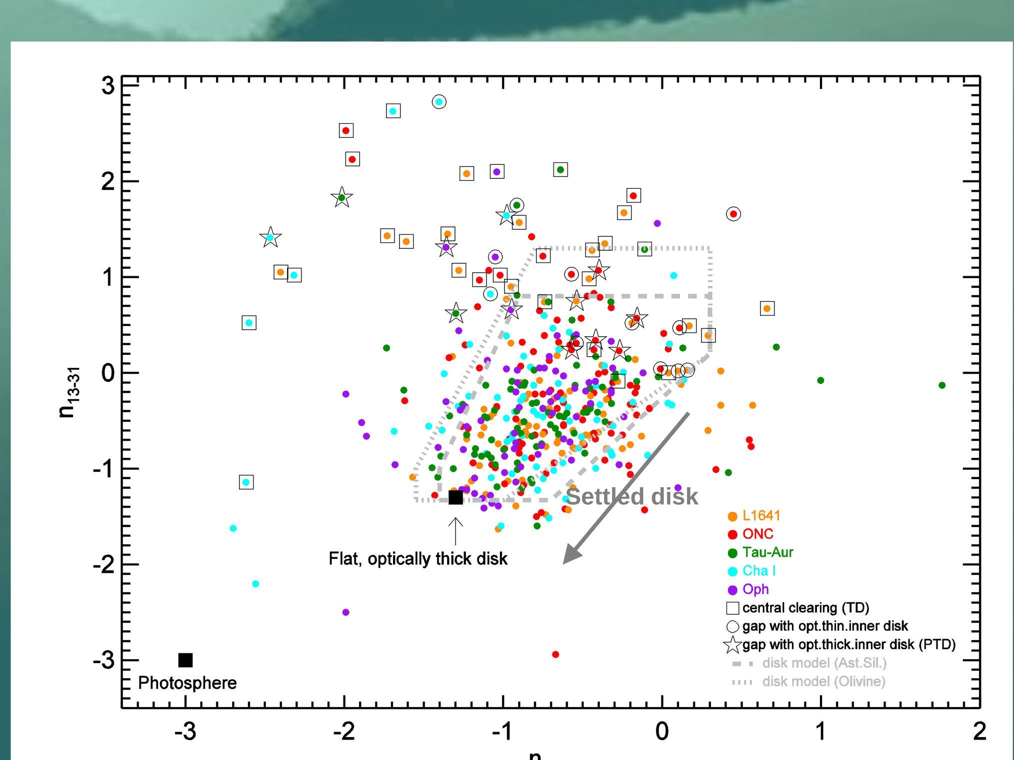


Fig 5. $n_{13-31}$ vs. $n_{6-13}$

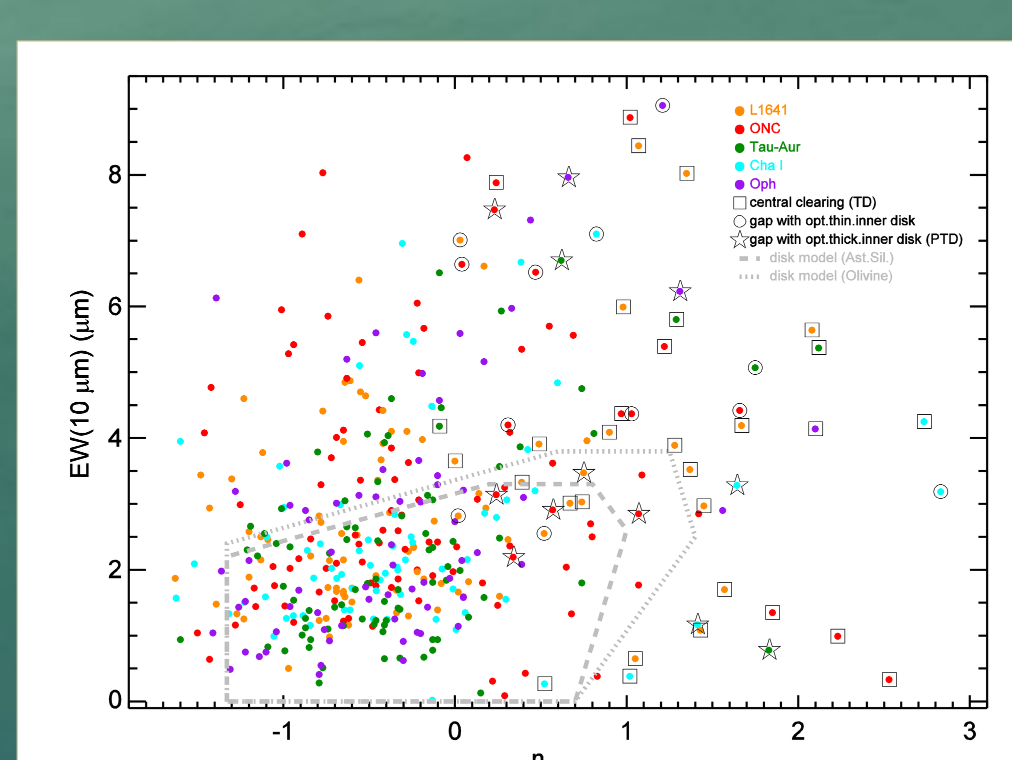


Fig 6. EW(10 μm) vs. $n_{13-31}$

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

## *Sample and frequency*

| region | L1641 | ONC | Tau | Cha | Oph |
|---|---|---|---|---|---|
| Class II+III | 114 | 127 | 85 | 71 | 51 |
| TD+WTD+PTD | 24 | 20 | 5 | 8 | 4 |
| TD | 19 | 8 | 2 | 4 | 1 |
| WTD | 3 | 5 | 1 | 2 | 1 |
| PTD | 2 | 7 | 2 | 2 | 2 |
| F(T+W+P) | 0.21±0.04 | 0.16±0.03 | 0.06±0.03 | 0.11±0.04 | 0.06±0.03 |
| F(TD) | 0.17±0.04 | 0.06±0.02 | 0.02±0.02 | 0.06±0.03 | 0.01±0.01 |
| F(WTD) | 0.03±0.02 | 0.04±0.02 | 0.01±0.01 | 0.03±0.02 | 0.01±0.01 |
| F(PTD) | 0.02±0.01 | 0.06±0.02 | 0.02±0.02 | 0.03±0.02 | 0.03±0.02 |
| median age | ~1 Myr | < 0.8 Myr | ~1.5 Myr | ~2 Myr | ~ 2.1 Myr |
| distance | 400-500 pc | 400-500 pc | 140 pc | 160 pc | 120-160 pc |

Table 1. Summary of some properties of each region and number of sample. F( ) means fraction of sample indicated in ( ) from the sample of Class II+III.

## *Are transitional disks older than full disks?*

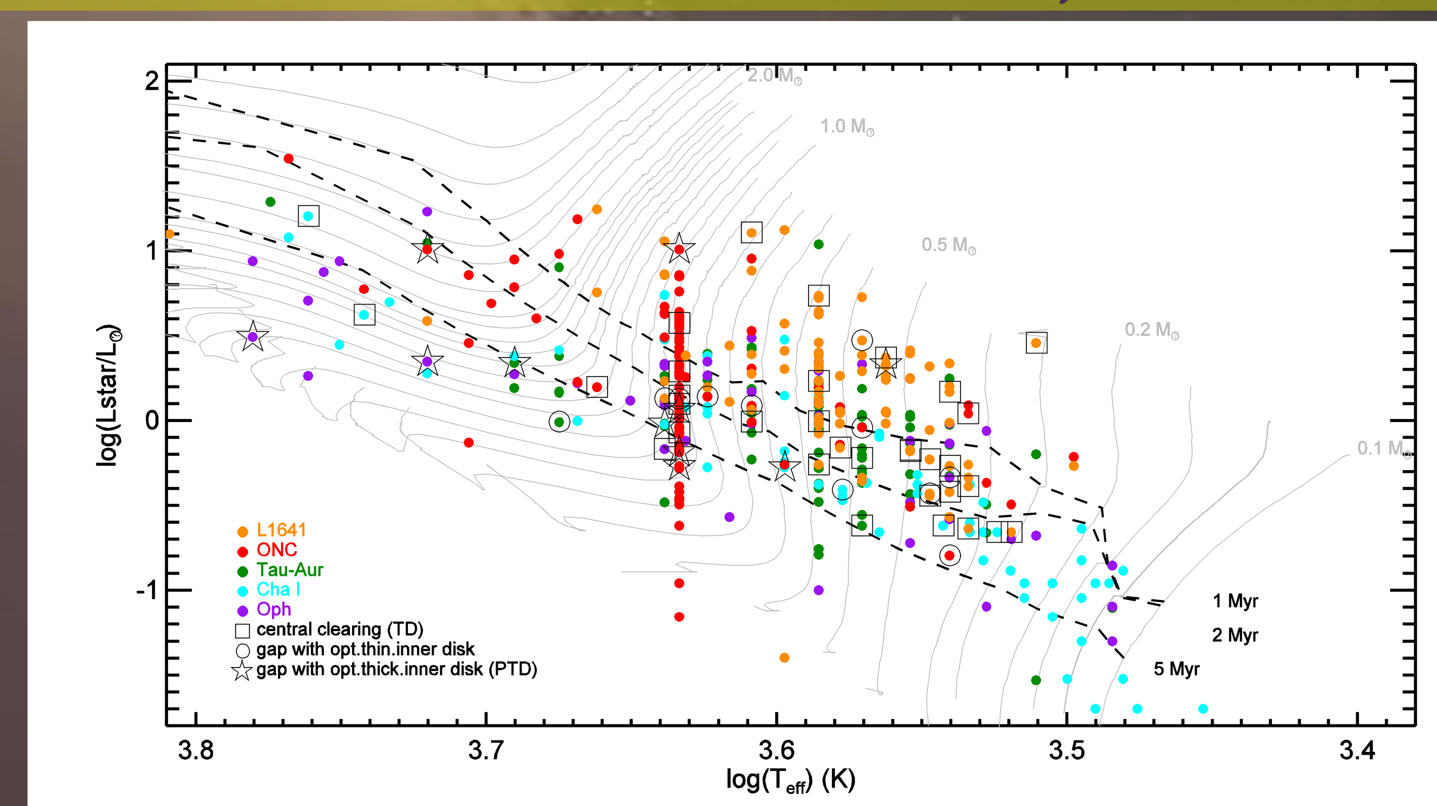


Fig 1. Transitional disks on an evolutionary track (Siess, Z=0.02) (Siess et al. 2000). Ages among various types of transitional disks are spread between less than 1 Myr and greater than 5 Myr

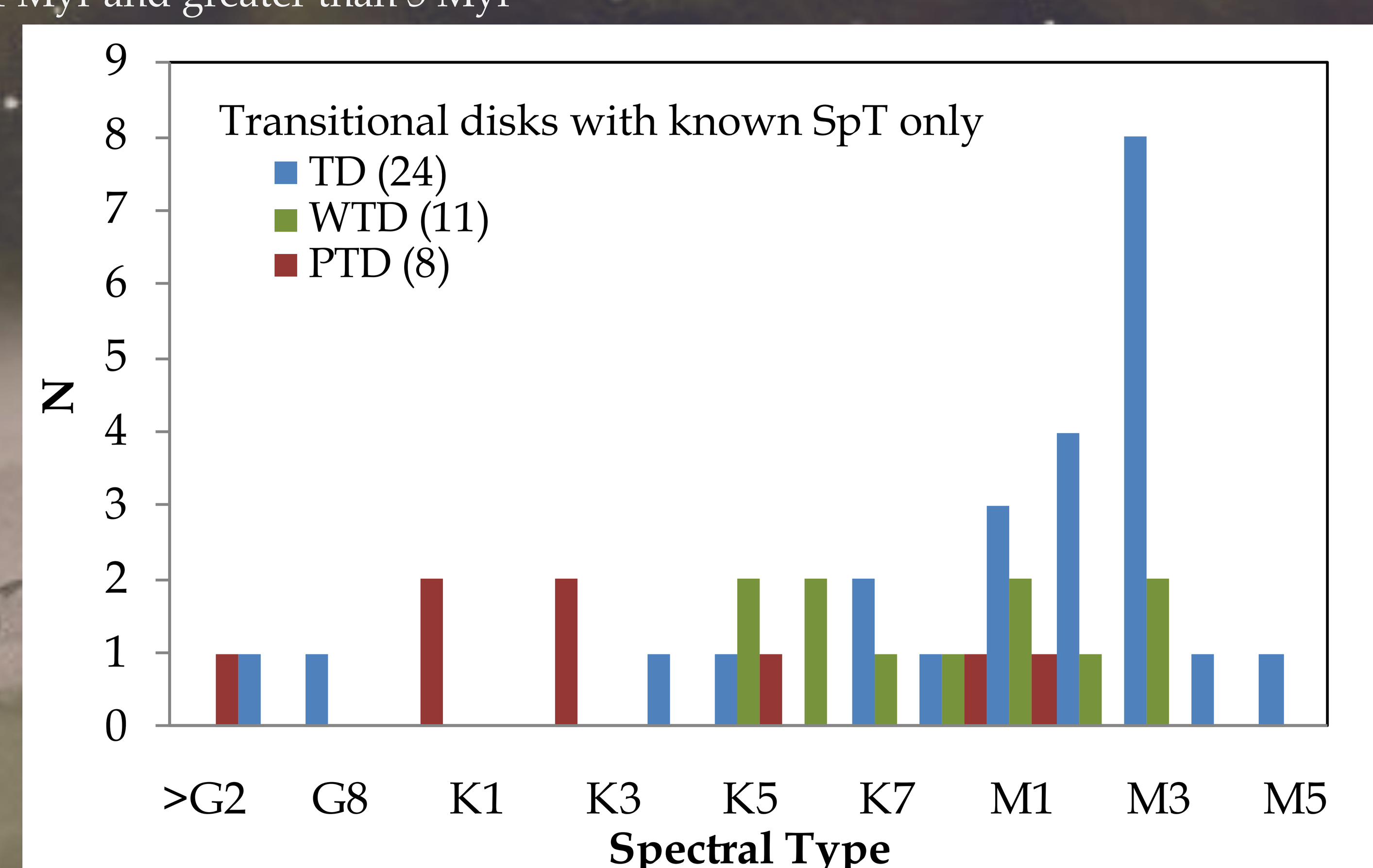


Fig 2. Spectral Type distribution among Transitional disks. TDs are dominant in later type stars, and PTD are dominant in early type stars.

## *Preliminary Results*

❑ The frequency of transitional disks of five star-forming regions (L1641, ONC, Tau-Aur, Cha I, Oph) is 0.12±0.06 . The fraction of transitional disks in each region and that in each type of transitional disks are not strongly related to the median age of each stellar cluster (See Table 1).

❑ $n_{13-31}$ vs. $n_{K-6}$ is a good method to separate Transitional disk from the optically thick full disk. $n_{K-6}$ is a good indicator for distinguishing TD from PTD (See Fig 4). Transitional disks show different disk structure which cannot be explained by standard full disk models (D'alessio et al. 2006) (See Fig 5 and Fig 6) .

❑ The significant correlation between $R_{wall}$ and $M_{star}$ is consistent with a significant dependence between binary separation and system stellar mass. The correlations of $L_x$ and dM/dt to $R_{wall}$ are not significant from current available data. More data on Lx and dM/dt in the near future will help us understand the mechanisms of gap formation and disk clearing.

❑ 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 1 and Fig2). 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.