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Is there something like a typical TTauri disk in Taurus/Auriga?

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Introduction:

GASPS (Gas in Protoplanetary Systems, Dent et al. 2013) is a Herschel Open Time key program studying the evolution of gas in protoplanetary disks across the age and mass spectrum. PACS was used to survey the Taurus/Auriga molecular cloud (140 pc, 1-3 Myr) in the continuum and in several gas lines such as [OI] 63 μm, 145 μm, [CII] 158 μm, OH, H_2O, and CO. The goal was a statistical study of gas in these disks in particular potential correlations between the different observables. The [OI] 63 μm is the strongest cooling line detected within the target sample of 76 class I-III objects; 9 of them are known transitional disks. Howard et al. (2013) report a tight correlation between the [OI] 63 μm line flux and the neighboring continuum flux for disk sources not associated with detected jet/outflows and excluding the transitional disks.

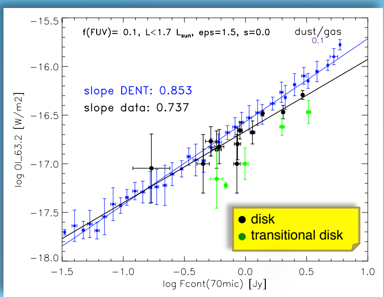
Interpretation using the DENT grid of models:

We use the DENT grid (Disk Evolution with Neat Theory) of 300 000 parametrized disk models (Woitke et al. 2010, Kamp et al. 2011) to understand the physics behind the observed correlations and to assess the possible diversity in disks surrounding low-mass stars at the evolutionary stage of 1-3 Myr. We separate the sample in "protoplanetary disks" (12 sources) and "transitional disks" (5 sources) and leave out disks for which outflows or jets have been identified.

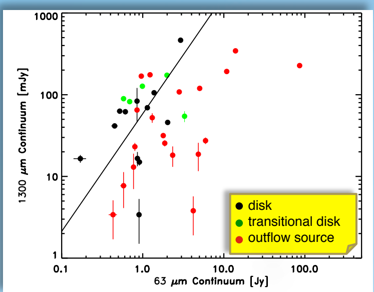
In this poster we focus on the following observed correlations:

1) Correlation [OI] 63 μm vs continuum at 70 μm (Howard el al. 2013)
2) Non-correlation [OI] 63 μm vs. continuum at 850 μm (Howard et al. 2013)
3) Correlation [OI] 63 μm vs. [OI] 145 μm and CO(J=18-17) (Alonso, Riviere-Marichalar et al. in prep.) and correlation [OI] 63 μm vs. H20 63.3 μm (Riviere-Marichalar et al. 2012)

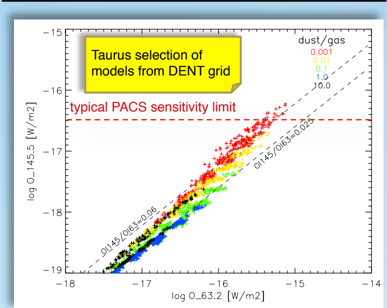
[OI] 63 μm vs. 70 μm continuum (Fig.1)



[OI] 63 μm vs. 1300 μm continuum (Fig.2)



[OI] 63 μm vs [OI] 145 μm (Fig.3)



Observed Taurus disk sample

effective temperature	$T_{eff} < 5200$ K
stellar luminosity	$0.3 < L_{star} < 1.7\ L_\odot$
stellar mass	$M_{star} \leq 1\ M_\odot$
UV luminosity	$L_{FUV}/L_{star} \sim 0.07$
inner disk radius	$R_{in} = R_{sublimation}$
outer disk radius	$R_{out} \leq 300$ AU

Disk properties

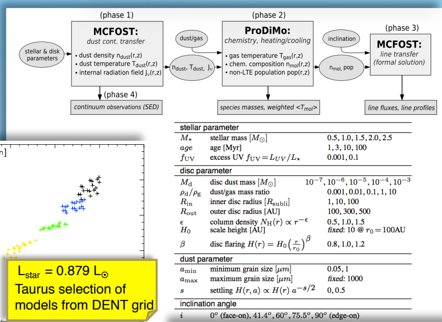
If we select from the DENT grid those models that are compatible with the observed Taurus disk sample (above), we can reproduce the observed values of observed [OI] 63 μm line and 70 μm continuum fluxes (Fig.1). The DENT grid is very coarse (see tables in Fig.6). However, we find a trend towards

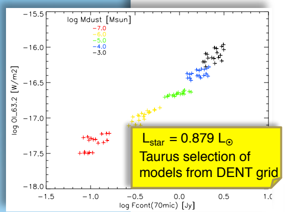
- a dust-to-gas ratio of 0.1 to 0.01
- models without settling of grains (s=0)
- surface density power law $\Sigma(r) \sim r^{-1.5}$

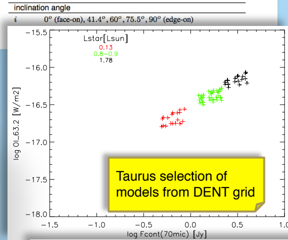
There is no clear correlation between the [OI] 63 μm line and the 1.3 mm continuum (Fig.2, data from SMA, Andrews et al. 2013). However, the 1.3 mm and 70 μm continuum trace different grain populations and the former is biased towards the outer disk midplane. For comparison, DENT results (for 1.2 mm vs 70 μm) are shown in Fig.6.

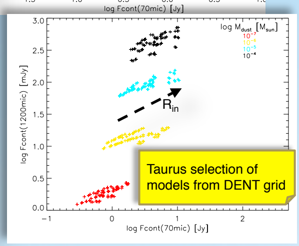
The Taurus selection from the DENT grid is consistent with none of the GASPS Taurus disk sources being detected in the [OI] 145 μm line (Fig.3).

The DENT grid (Fig.6)







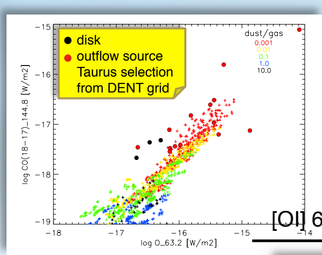


Physics behind correlation

Explanation 1: The [OI] 63 μm line and the neighboring continuum originate from the same region (Howard et al. 2013).

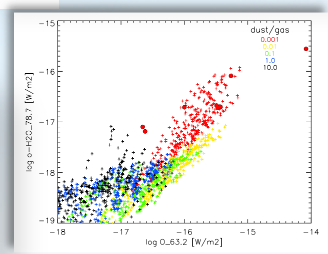
Explanation 2 (Fig.6): We find that the selected disk models are not very optically thick at 70 μm. Hence, the continuum scales with M_{dust} and T_{dust}. Dust temperature and [OI] 63 μm line strength both scale with L_{star} (L_{FUV}). The slope then follows from the different functional behavior of the fluxes with M_{disk} and L_{star}. Models with large inner radius (transitional disks) fall systematically under the correlation (see Fig.1).

[OI] 63 μm vs CO(J=18-17) (Fig.4)



The Taurus selection from the DENT grid cannot reproduce the CO (J=18-17) line flux, but the models do show qualitatively the same correlation with [OI] 63 μm as the observations (Fig.4).

[OI] 63 μm vs H_2O 63.3 μm (Fig.5)



Since the DENT grid does not contain the H_2O 63.3 μm line, we show instead the 78.7 μm line with similar E(upper level) (Fig.5). The correlation of the H_2O line with [OI] and 70 μm continuum and the very high densities/temperatures needed to excite the line point to a disk rather than outflow origin (Riviere-Marichalar et al. 2012). Applying the DENT grid results could indicate a high gas-to-dust mass ratio in the inner disk (Fig. 5), where this line originates (inside a few AU).

References

Andrews, S.M., Rosenfeld, K.A., Kraus, A.L, Wilner, D.J. 2013, ApJ 771, 129
Dent, B., Thi, W.-F., Kamp, I., & GASPS team 2013, PASP 125, 477
Howard, C., Sandell, G., Vacca, W.D., et al. 2013, ApJ 776, 21
Kamp, I., Woitke, P., Pinte, C., et al. 2011, A&A 532, A85
Kamp, I., Tilling, I., Woitke, P., Thi, W.-F., Hogerheijde, M. 2010, A&A 510, 18
Riviere-Marichalar, P., Menard, F., Thi, W.-F. et al. 2012, A&A 538, L3
Woitke, P., Pine, C, Tilling, I., et al. 2010, MNRAS 405, L26
Woitke, P, Kamp, I., Thi, W.-F. 2009, A&A 501, 383