Herschel-PACS observation of the 10 Myr old TTauri disk TW Hya

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Planets are formed in disks around young stars. With an age of ~ 10 Myr, TW Hya is one of the nearest T Tauri stars that is still surrounded by a relatively massive disk. In addition a large number of molecules has been found in the TW Hya disk, making TW Hya the perfect test case in a large survey of disks with Herschel–PACS to study directly their gaseous component. We aim to constrain the gas and dust mass of the circumstellar disk around TW Hya. We observed the fine-structure lines of [O I] and [C II] as part of the Open-time large program GASPS. We complement this continuum data and ground-based ^{12}CO 3–2 and ^{13}CO 3–2 observations. We simultaneously model the continuum and the line fluxes with the 3D Monte-Carlo code *MCFOST* and the thermo-chemical code *ProDiMo* to derive the gas and dust masses. We detect the [O I] line at 63 µm. The other lines that were observed, [O I] at 145 µm, [C II] at 157 µm, are not detected. No extended emission has been found. **Preliminary modelling of the photometric and line data assuming [^{12}CO]/[^{13}CO]=69 suggests a dust mass with grain radius < 1mm of ~ 1.9 × 10^{-4} M$_\odot$ (total solid mass of 3 × 10^{-3} M$_\odot$) and a gas mass of (0.5–5) × 10^{-3} M$_\odot$. The gas-to-dust mass may be lower than the standard interstellar value of 100.**

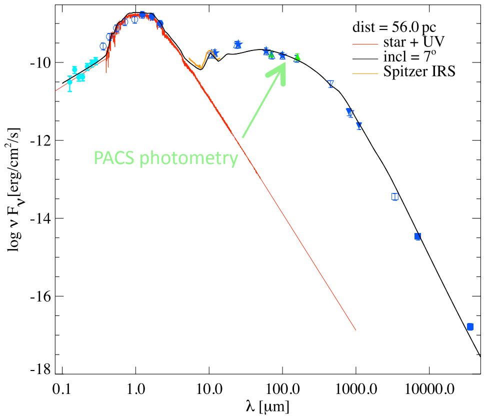

Figure 1 above shows our best fit to the SED and Fig. 2 on your left shows the three observed fine-structure lines. The fluxes and comparison with published predictions are summarized below.

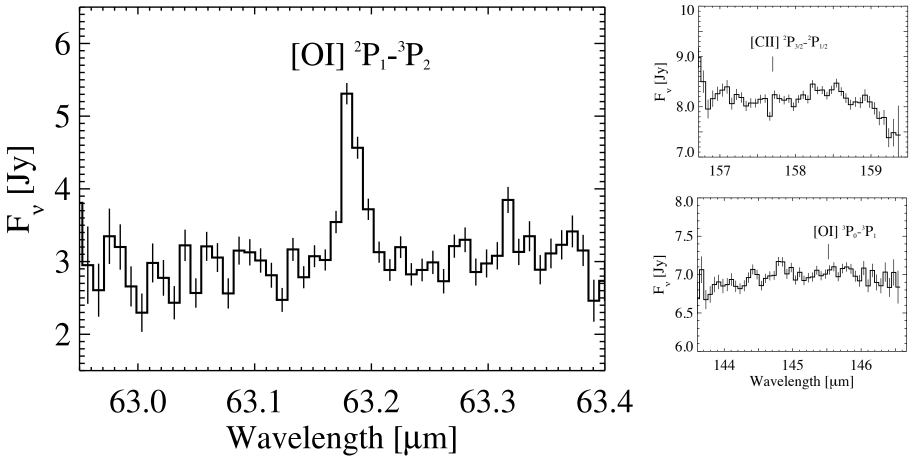

Table 1. Lines observed by *Herschel-PACS*. The errors and upper limits are 3 σ. The calibration error adds an extra ~ 30% uncertainty. The CO data also have uncertainties of 30%.

Line	Cont. flux (Jy)	Obs.	GH08	M08
		(10^{-18} W m^{-2})		
OI $^3P_1 \rightarrow {}^3P_2$	2.9 ±0.14	36.5 ±12.1	103-138	412
OI $^3P_0 \rightarrow {}^3P_1$	7.0 ±0.05	< 5.5	20-34	11
CII $^2P_{3/2} \rightarrow {}^2P_{1/2}$	8.2 ±0.08	< 6.5	0.7-10	0.06
CO 3–2	n.a.	0.42	0.2-0.5	n.a.
^{13}CO 3–2	n.a.	4.4 × 10^{-2}	n.a.	n.a.

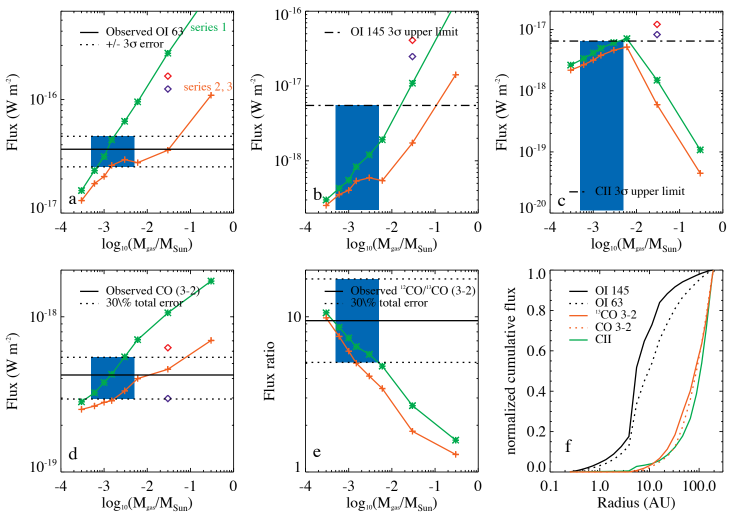

Fig. 3. Three series of model results compared to observations. The blue boxes enclose the model outputs for disk gas mass between 5 × 10^{-4} M$_\odot$ and 5 × 10^{-3} M$_\odot$. Panel a shows the predictions and observation of the OI 63 µm line. The 3σ uncertainty range is plotted as dashed lines. Panel b and c show the predicted fluxes and the 3σ upper limits for the OI 145 µm and CII lines. The two lower panels (d and e) are the comparison between observations and model outputs for ^{12}CO 3-2 emission and the ^{12}CO/^{13}CO 3-2 ratio. Panel f shows the normalized cumulative fluxes for a 10^{-3} M$_\odot$ model (series 1). The diamonds (◇ R_{out}=174 AU model, ◇ R_{out}=120 AU model) show the predictions for TW Hya from GH08.

We modelled the SED and line fluxes with the combined MCFOST-ProDiMo codes. The best fit to the SED is overplotted on the observations in Fig. 1. Fig. 3 shows the results for the line data. The disk parameters for our best model are given in Table 2 below.

Table 2. Disk parameters for the modelling.

		Inner cavity	Outer ring
Fixed parameters			
Stellar mass	$M_*(M_\odot)$	0.6	
Stellar luminosity	$L_*(L_\odot)$	0.23	
Effective temperature	T_{eff}(K)	4000	
Solid material mass density	ρ_{dust}(g cm^{-3})	3.5	
Inner radius	R_{in}(AU)	0.25	4
Outer radius	R_{out}(AU)	4	196
ISM UV field	χ	1.0	
α viscosity parameter	α	0.0	
Turbulent velocity	v_{turb}(km s^{-1})	0.05	
Disk inclination	i	7	
CO isotopologue ratio	[^{12}CO]/[^{13}CO]	69	
MCFOST best fit parameters			
Column density index	ϵ	1	
Reference scale height	H_0(AU)	2.0	10.0
Reference radius		100	100
Flaring index	γ	0.6	1.12
Minimum grain size	a_{min}(µm)	3 × 10^{-2}	
Maximum grain size	a_{max}(cm)	10	
Dust size distribution index	p	3.4	
Dust mass (a <1 mm)	$M_{dust}(M_\odot)$	1.2 × 10^{-9}	1.9 × 10^{-4}
Solid mass	$M_{solid}(M_\odot)$	2.0 × 10^{-8}	3.0 × 10^{-3}
ProDiMo parameter range			
Disk gas mass	$M_{gas}(M_\odot)$	3 × 10^{-4}–0.3	
UV excess	F_{UV}	0.018	
Fraction of PAHs w.r.t. ISM	f_{PAH}	0.01, 0.1	
Cosmic ray flux	ζ(s^{-1})	(1.7–17) × 10^{-17}	

Ref. GH08: Gorti & Hollenbach 2008 ApJ, 683, 287; M08: Meijerink et al. 2008, ApJ, 676, 518; MCFOST: Pinte, C. et al. ,2006, A&A, 459, 797; ProDiMo: Woitke, P. et al. 2009, A&A, 501, 383

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