Deriving the gas and dust disk structure of the transition disk HD 135344B (SAO 206462) from multi-instrument observations

A. Carmona (IPAG, Grenoble),
C. Pinte (IPAG), W.-F. Thi (IPAG), M. Benisty (IPAG), F. Ménard (UMI-FCA Chile, IPAG),
I. Kamp (Groningen), C. Grady (Eureka Sc., GSFC), J. Olofsson (MPIA, Heidelberg),
A. Roberge (NASA, GSFC), P. Woitke (St. Andrews) + GASPS collaboration + PIONIER team (Grenoble)

Messages of this poster:

- ★ ***We suggest that the inner-most disk of HD 135344B is composed of carbonaceous grains at 0.08<R<0.2 AU.***
- ★ ***The inner cavity has ~10^{-5} M⊙ of gas inside the cavity. The surface density of the gas inside the cavity must increase with radius. The g/d ratio is > 100 inside the cavity.***
- ★ ***The outer disk a mass of a few 10^{-3} M⊙. The g/d ratio should be lower than 50 at R>30 AU.***

1. Motivation:

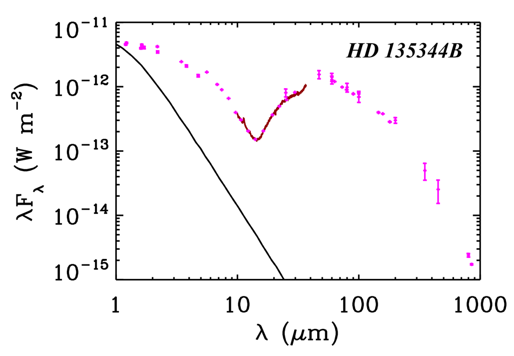
Transition disks are protoplanetary disks that display evidence for a cavity in their disk structure.
These cavities might indicate the presence of young planets.

- ★ ***What is the disk gas mass and surface density inside and outside the cavity?***
- ★ ***What is the dust content inside the cavity?***
- ★ ***How is the disk structure related to planet formation?***

The goal of this project is to derive the gas and dust disk structure of the F4Ve (pre-) transition disk HD 135344B (in particular inside the sub-mm cavity), from **simultaneous** radiative transfer modeling of multi-instrument multi-wavelength gas and dust observations.

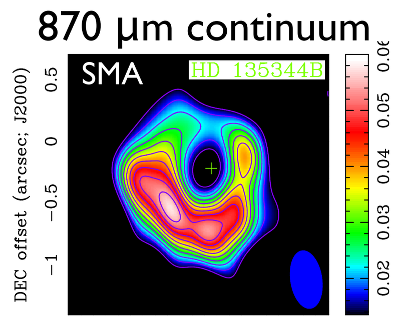
2. Principal observational constraints

SED

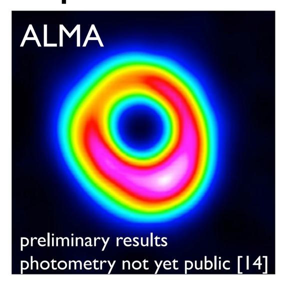


The SED suggests the presence of a gap [1]. No silicate emission at 10 μm [15].

870 μm continuum

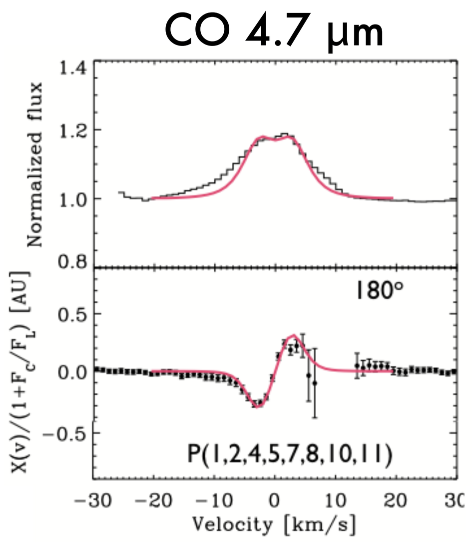


430 μm continuum



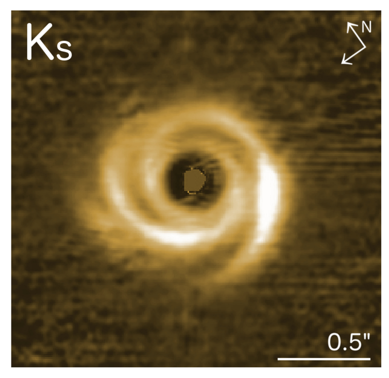
Cavity radius: 45 AU.
Emission inside a 33x70 AU beam centered on the star at 870 μm (3σ) : 10.5 mJy [2,3]

CO 4.7 μm



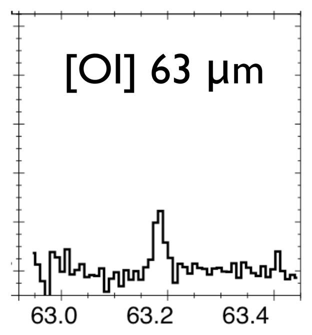
CO 4.7 μm emission (tracer of warm gas) extending **at least 25 AU** (d =140 pc) [4]

H and K-band

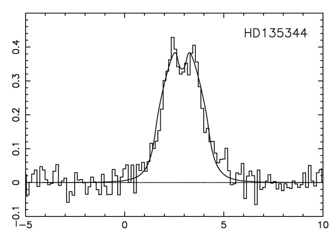


Scattered light emission **down to 28 AU** [5,13]

[OI] 63 μm



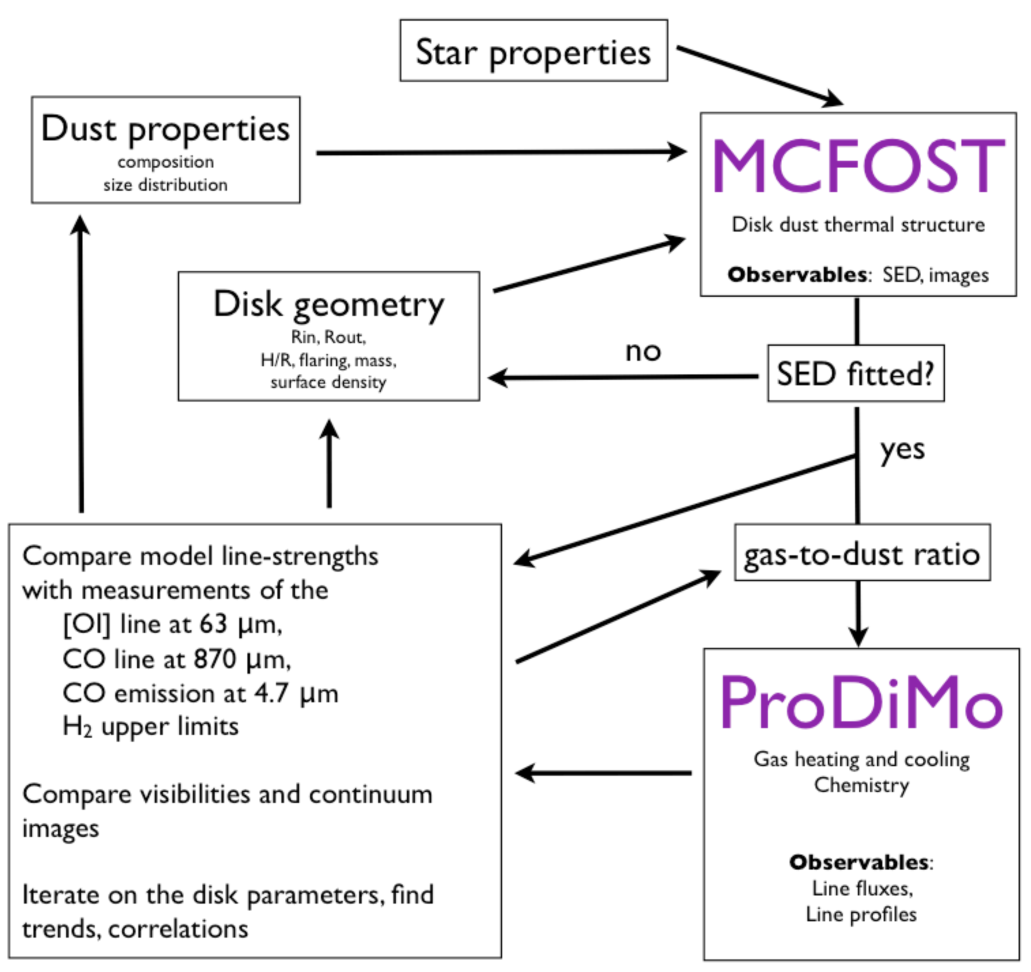
CO 2-1



Herschel [6] and JCMT [7] gas detections

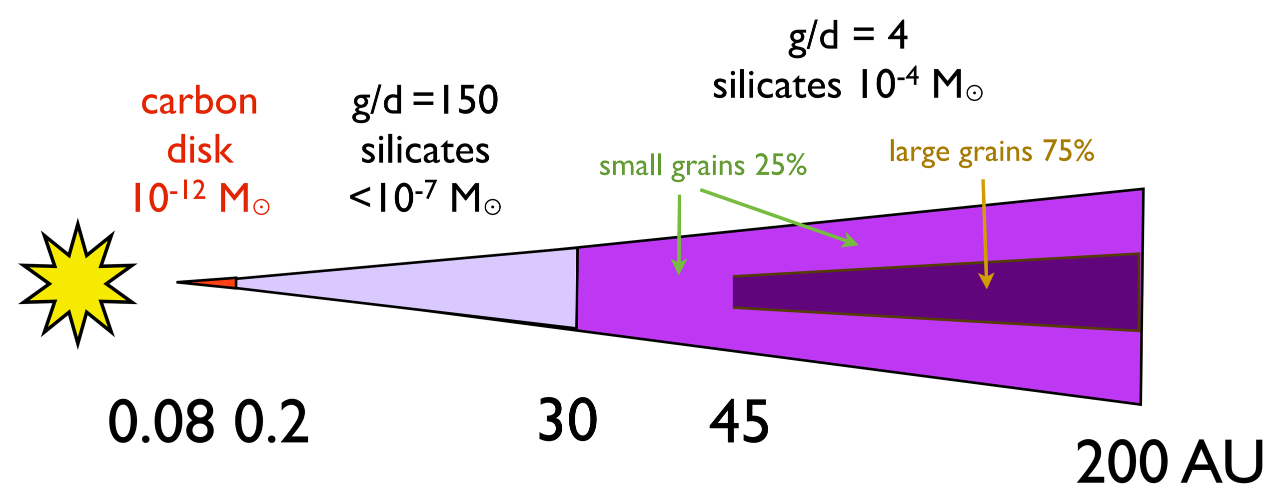
3. Methodology

We use the dust Monte Carlo radiative transfer code MCFOST [8] to fit the SED and derive the density and thermal structure of the disk. Then we use the thermo-chemical radiative transfer code ProDiMo [9,10] to calculate the gas heating and cooling balance, the chemistry, and predict gas emission lines. We compare the model predictions with multi-instrument observations and constraints from the literature.

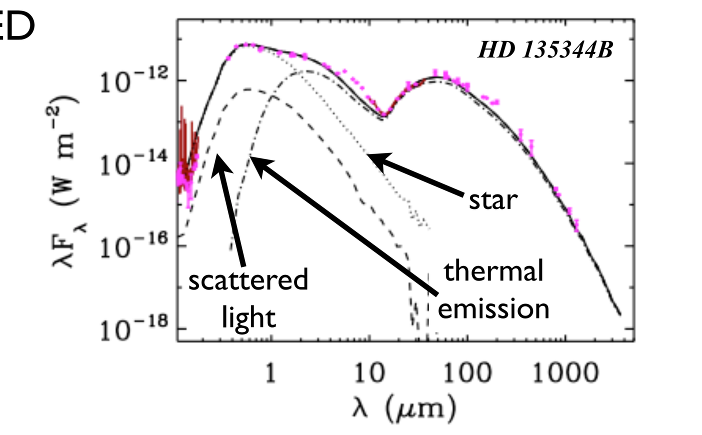


- ★ Grids of models around good dust and gas solutions are calculated to find the most likely values of the disk parameters.
- ★ Best models are tested for consistency with near-IR interferometry data.

4. Results



Modeled SED

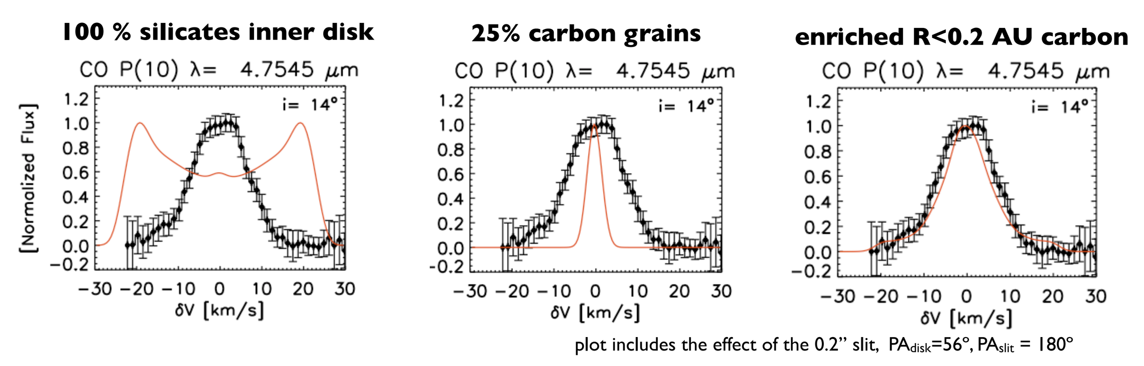


Line Fluxes

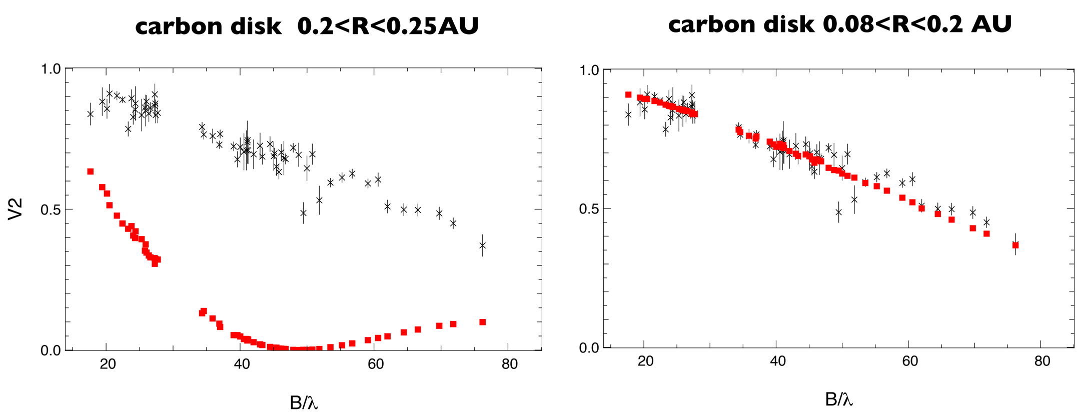
	[O I] 63 μm	[O I] 145 μm	[C II] 157 μm	^{12}CO J3-2 1.27mm	^{12}CO J2-1 870 μm	ν =1-0 P(10) 4.7545 μm
Observed	3.6–4.8E-17	<4.6E-18	<6.4E-18	1.2E-19	8.0E-20	1.5E-17
Model	3.4E-17	1.6E-18	1.7E-18	1.5E-19	4.7E-20	2.3E-18 70%

% of flux inside the slit

I. To fit to the CO P(10) line and the SED **simultaneously** we required a **carbon enriched inner disk** (R<0.2 AU). Inner disks of 100% astro. silicates, or with an uniform mixture of carbon/silicate grains that fitted the SED produced CO ro-vibrational line profiles inconsistent with the observations.

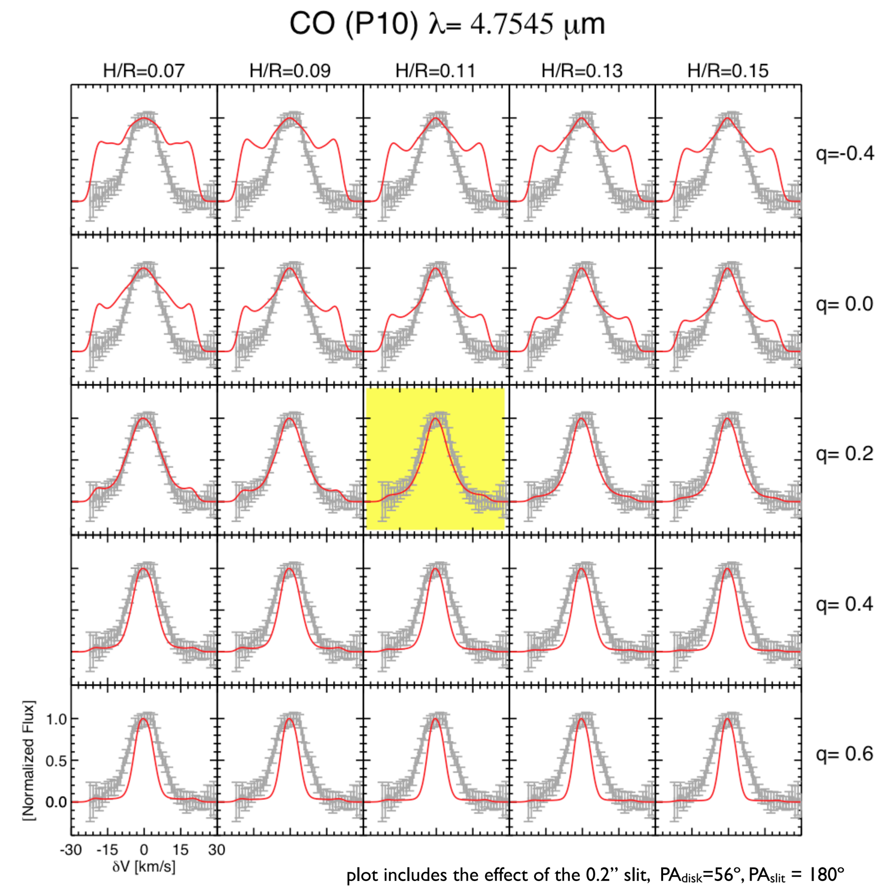


II. VLTI/PIONIER H-band interferometry indicates that the **emission originates at R<0.2 AU** (inside the silicate sublimation radius). The visibilities (black) are reproduced by a disk of carbonaceous grains at 0.08< R <0.2 AU (red).

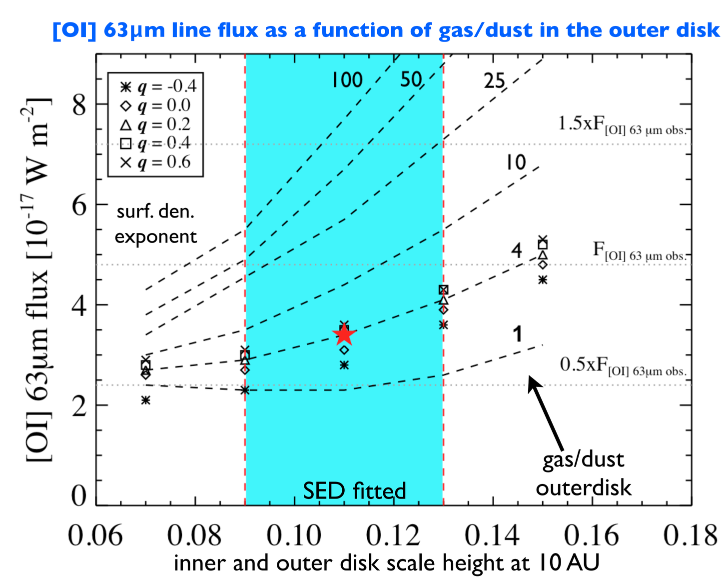


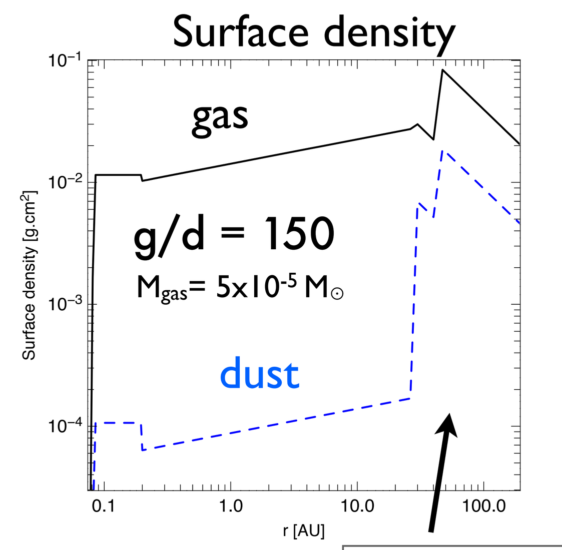
III. The CO P(10) line indicates that the surface density of the gas at R<45 AU **must increase as a function of the radius** (i.e. surface density power law exponent q>0).

CO (P10) λ= 4.7545 μm

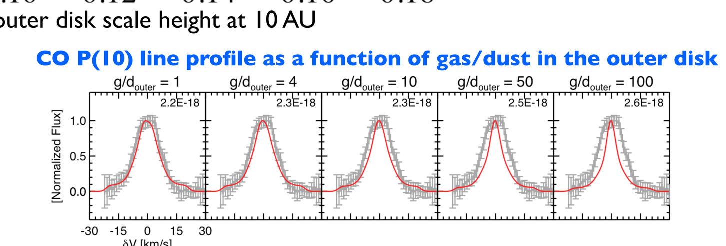


IV. The CO P(10) and the [OI] 63 μm line fluxes are best reproduced by disks with a gas-to-dust ratio > 100 in the inner disk (R< 30), and **a gas-to-dust ratio < 50 in the outer disk.** The best model that describes the [OI] 63 μm flux has a smooth gas surface density at 30 AU.





g/d = 4
M$_{gas}$=4x10^{-4} M⊙



5. Conclusions

- ★ Our model suggest ~10^{-5} M⊙ of gas inside the cavity.
- ★ To reproduce simultaneously the SED, the CO P(10) line, and near-IR interferometry data, we propose that the disk is composed of carbonaceous grains (10^{-12} M⊙) from 0.2 AU (silicates sublimation radius) down to 0.08 AU (corotation radius).
- ★ Our model has 10^{-7} M⊙ of dust assuming a dust size 0.1<a<1000 μm. This consistent with the SMA 870 μm measurement. Lower dust masses are possible. ALMA 430 μm photometry of the inner cavity [14] (when public) would be useful to better constrain M_{dust} and the dust size distribution inside the cavity.
- ★ An increasing gas surface density as a function of the radius in the inner cavity is consistent with the expected effect of a single migrating jovian planet. This planet, if sufficiently massive, could be responsible of the spiral patters observed [5,13].
- ★ We find in our models that the total gas mass of the disk is a few times 10^{-3} M⊙, lower than the total gas mass of 2x10^{-2} M⊙ expected for a primordial disk with similar total dust mass of 10^{-4} M⊙. HD 135344B is an evolved disk.
- ★ The HD 135344B disk structure proposed could be applied to other (pre-)transition disks with CO 4.7 μm emission extending several AU.

References

[1] Brown et al. 2007;
[2] Brown et al. 2009;
[3] Andrews et al. 2011;
[4] Pontoppidan et al. (2008);
[5] Muto et al. 2012;
[6] Meeus et al. 2012;
[7] Dent et al. 2005;
[8] Pinte et al. 2006;
[9] Woitke et al. 2009;
[10] Thi et al. (2013);
[11] Lahuis et al. 2007;
[12] Carmona et al. 2011;
[13] Garufi et al. 2013;
[14] Perez et al. 2013 (in prep);
[15] Geers et al. 2006;

Acknowledgements

We acknowledge funding from the Agence Nationale pour la Recherche (ANR) of France under contract ANR-2010-JCJC-0504-01 and from European Commission's 7th Framework Program (contracts PERG06-GA-2009-256513 FP7-SPACE SPA.2011.2.1-01).

Calculations were performed at Service Commun de Calcul Intensif de l'Observatoire de Grenoble (SCCI) on the FOSTINO super-computer.