Multi-technique observations and modelling of protoplanetary disks

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Collaborators

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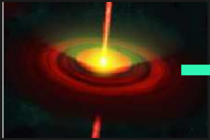
- D.L. Padgett, K. Stapelfeldt (IPAC & JPL/Caltech)
- G. Schneider (Steward Observatory)
- P. Woitke, W.F. Thi, I. Tilling (ROE, Edinburgh)
- I. Kamp (KAI, Groningen)
- J. Cernicharo (DAMIR/CSIC, Madrid)
- the GASPS team

Protoplanetary disks

Gas and dust disks are the birthplace of planets



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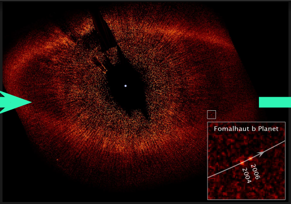


Goal : characterizing the first steps of planet formation

Understanding disk structure as well as dust grain and gas properties to test their evolution processes. For instance:

- grain growth and settling
- gas dissipation
- formation of a large variety of planetary systems

A variety of observations

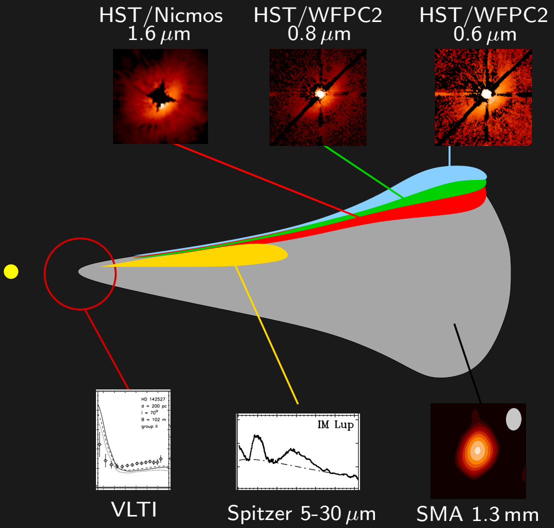
Each approach probes a different part of the disk

Disk modelling must consider as many observations as possible *at once*

Multi-λ modelling

Not so frequent

. . . but necessary!



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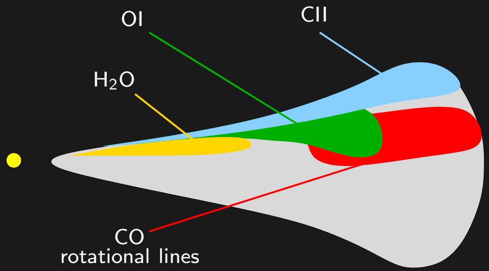


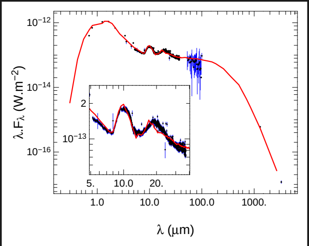
The same is true for the gas phase

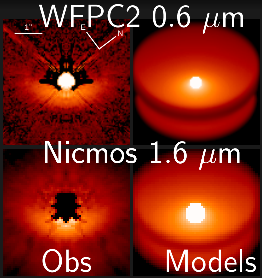
Multi-λ modelling of IM Lupi

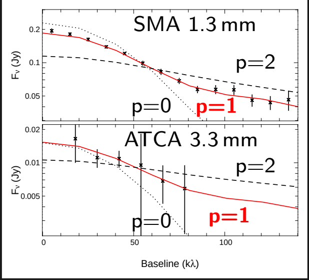
Pinte et al, 2008

RT modelling with MCFOST (Pinte et al 2006)

A single model with mild stratification remarkably reproduces all observations: H(1 mm) $\approx$ 0.5 - 0.75 H(1 μm)







$\Downarrow$ $M_{\rm disk}$, grain growth and settling

$\Downarrow$ $R_{\rm ext}$, i, H_0, grain sizes & composition

$\Downarrow$ Surface density $\Sigma(r) \propto r^{-p}$

IM Lup : quantitative constraints

Pinte et al, 2008

Bayesian probabilities

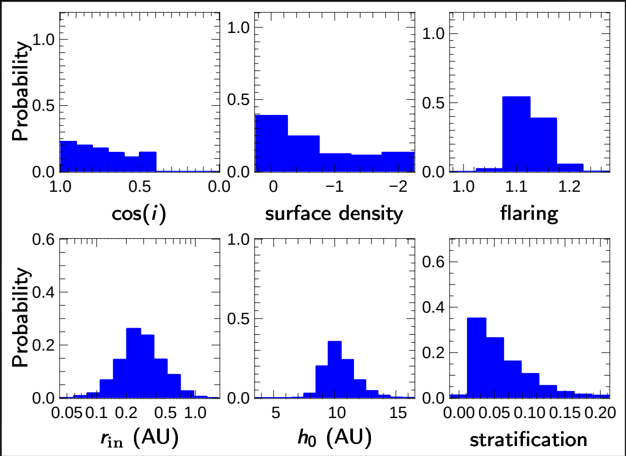
SED + ...

≈ 400 000 models

Some parameters fixed from data (a_{max}, M_{dust}, R_{out})

+ Fitting 6 parameters

Bayesian approach to estimate model parameters



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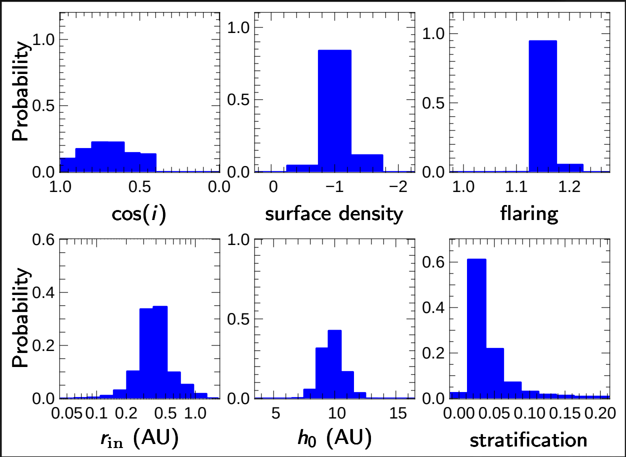

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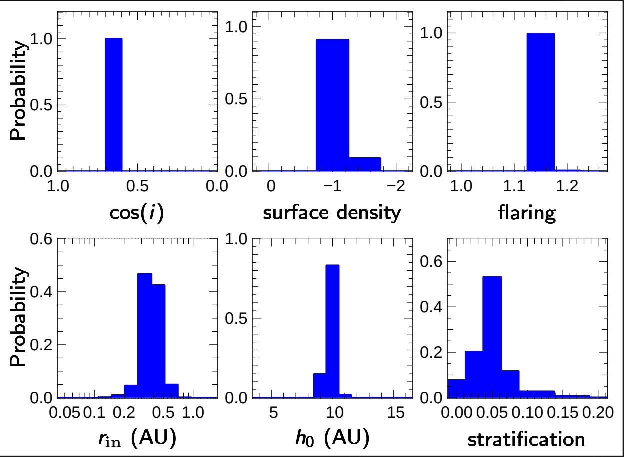

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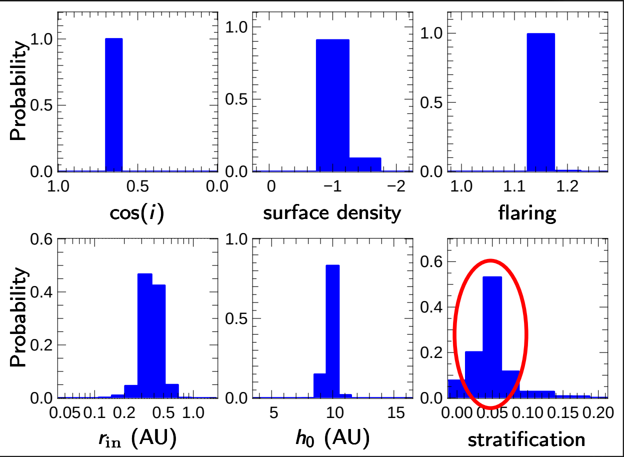


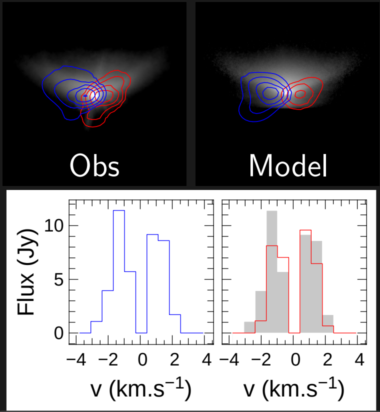
Simultaneous modelling of gas & dust

Detailed model of the dust disk of IRAS 04158+2805
Glauser et al, 2008

Radiative transfer + chemistry

1. Temperature structure, UV flux from MCFOST
2. CO abundance from chemistry model (coll. with C. Ceccarelli)
3. Level populations and emission maps with MCFOST

⇒ central mass (0.3-0.5 $M_\odot$) → age
turbulence (0.2-0.3 $km.s^{-1}$)



Scattered light (*HST*) & $^{12}CO(3\text{-}2)$ (*SMA*)

GASPS and the DENT grid of models

Gas in Protoplanetary Systems (GASPS) key program

Systematic survey of gas and dust in disks (PI: W. Dent)

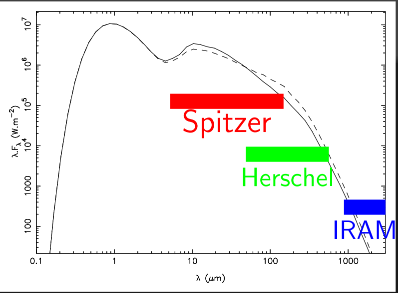
- ≈ 250 disks, 0.3 to 30 Myrs, spectral types: M4 to B2
- PACS: OI, CII, CO and H_2O + continuum

The DENT model grid (see poster B47 by P. Woitke)

- coupling MCFOST & ProDiMo (Woitke et al 2009)
- SEDs + NLTE line fluxes (+physical & chemical structure) for ≈ 320 000 disks models

⇒ dependence of continuum & line observation on star, disk and dust properties

Signatures of dust settling



Far-IR

is the regime where signatures of dust settling are maximum

$\Rightarrow$ probed by *Herschel*

Color-magnitude diagrams

- distinction between settled and non settled disks
- independent of the geometry, dust properties, ...if $T_{\rm eff}$ and $M_{\rm disk}$ known

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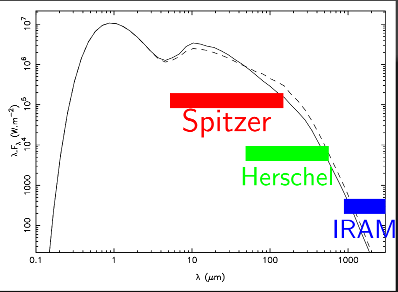

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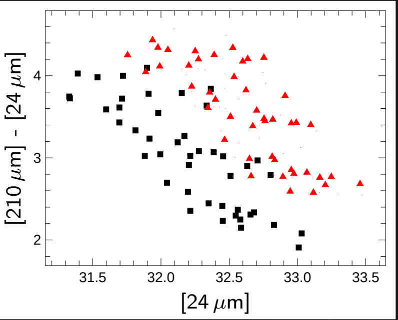


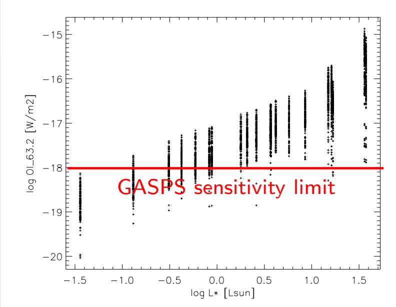
Constraining the gas disk

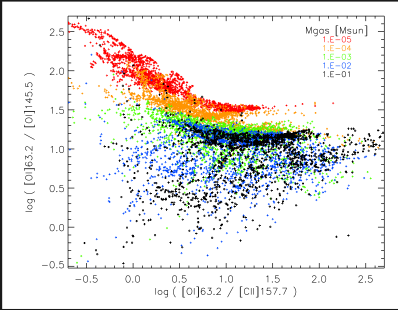
Herschel/PACS

should detect lines even for low luminosity T Tauri stars

First results of the DENT grid

- Most lines scale with stellar parameters: L_{star} and UV excess
- Line ratios eliminate the main scalings
  → information about disk mass and shape





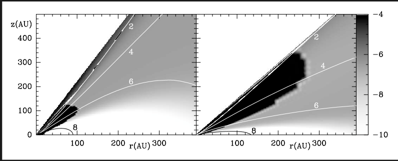
H_2O lines with HIFI

Cernicharo et al, 2009

Dust settling

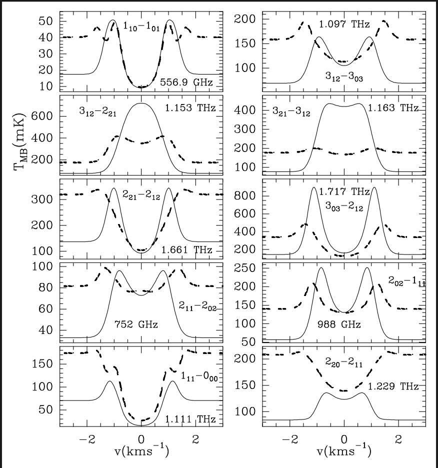
dramatically changes the conditions for water vapor in disk

$\Rightarrow$ H_2O lines powerful tool



But dangerous

strongly depends on collisional coefficients



Concluding remarks

A variety of datasets = finer disk models

- Dust evolution and spatial differentiation are frequent in disks around T Tauri stars
- By combining line and continuum data, more detailed information about the disks

Testing the physics of dust grains towards planet formation

- Grain growth
- Separate dust populations
- dust and gas evolution?

Simultaneous studies of the gas & dust phases

are promising in the context of Herschel and ALMA