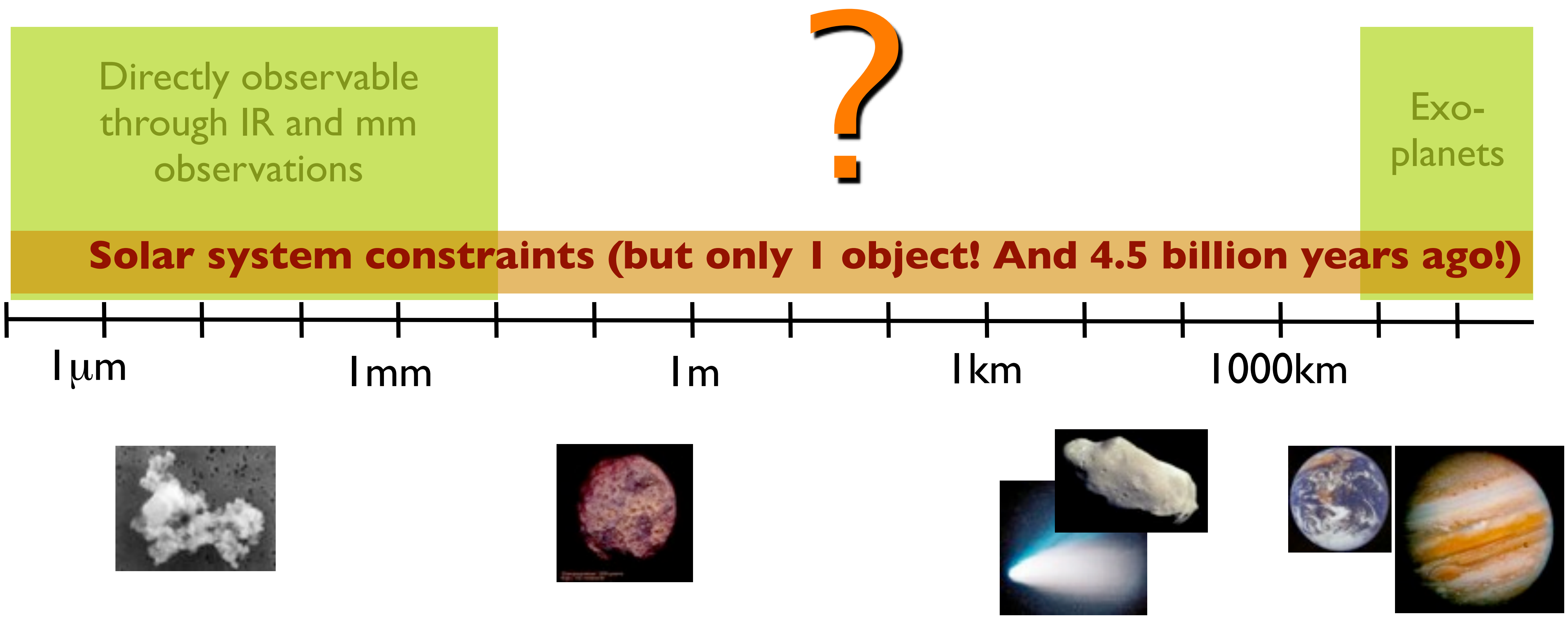
Constraining the initial conditions for planet formation with ALMA, JWST and the ELTs

Leonardo Testi (ESO)

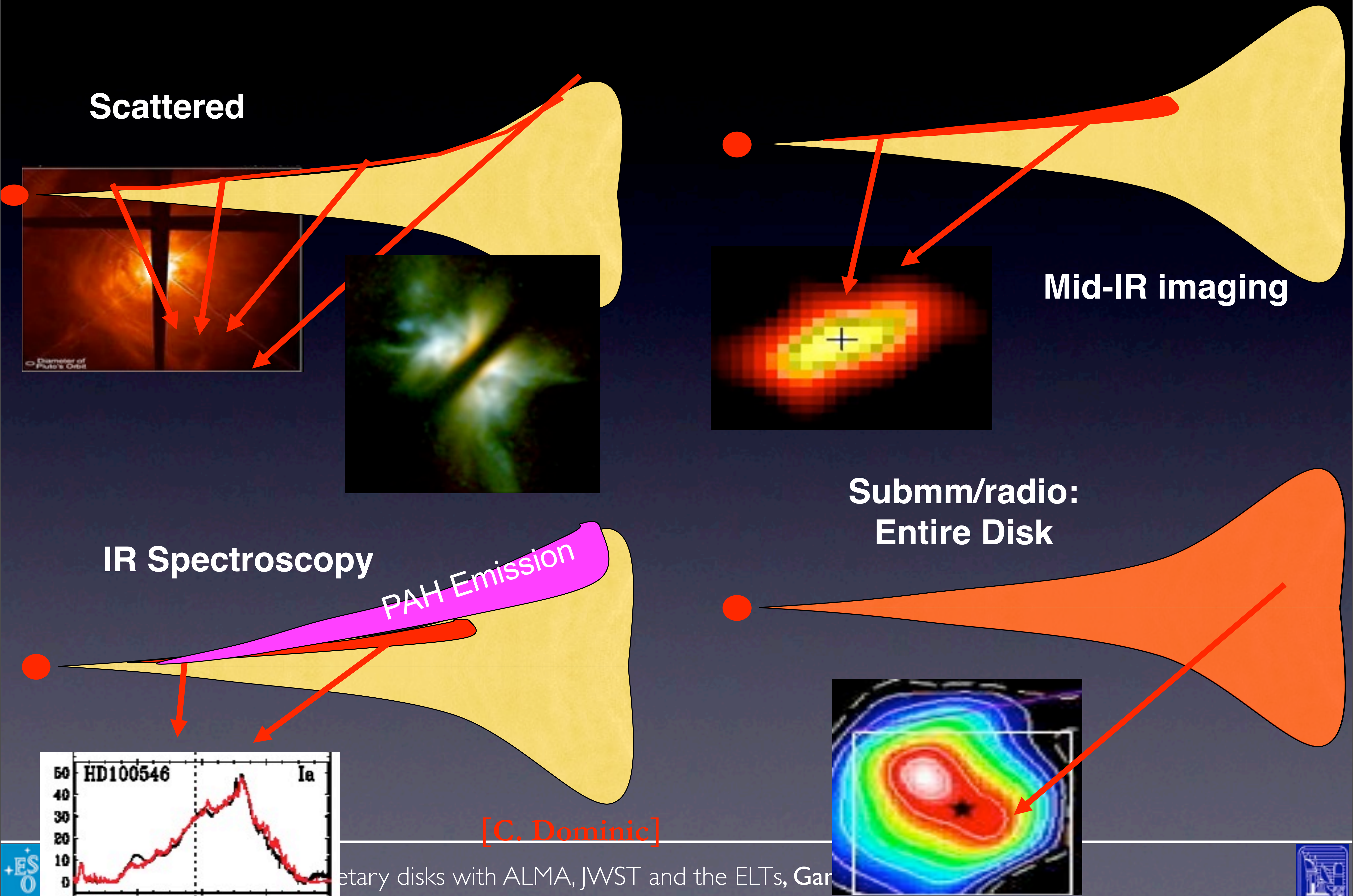
[I just play with keynote these days, real new work by: L. Ricci, T. Birnstiel, F. Trotta]

From dust to planets

Observations provide constraints to models that bridge the "gap"

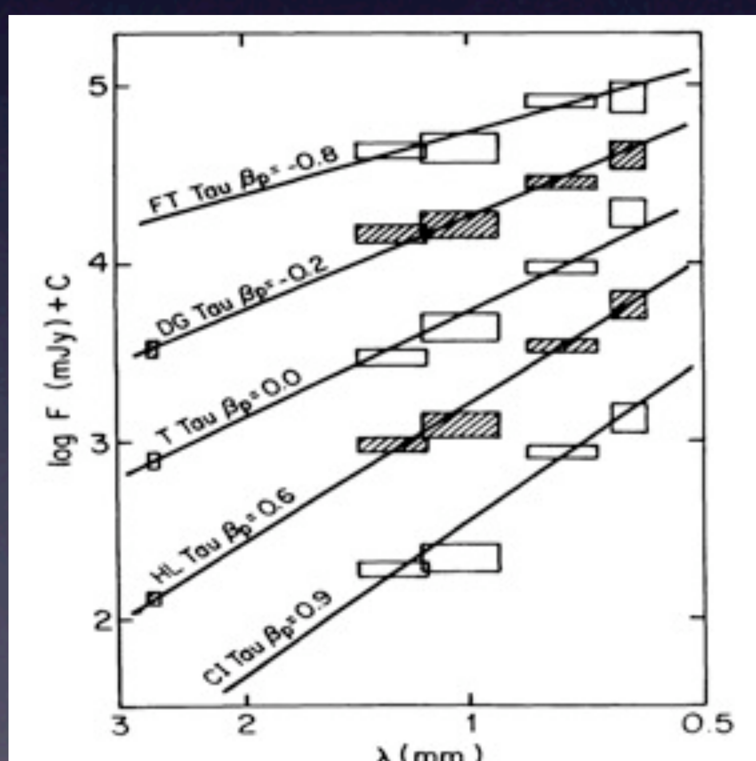


Which observations probe what?

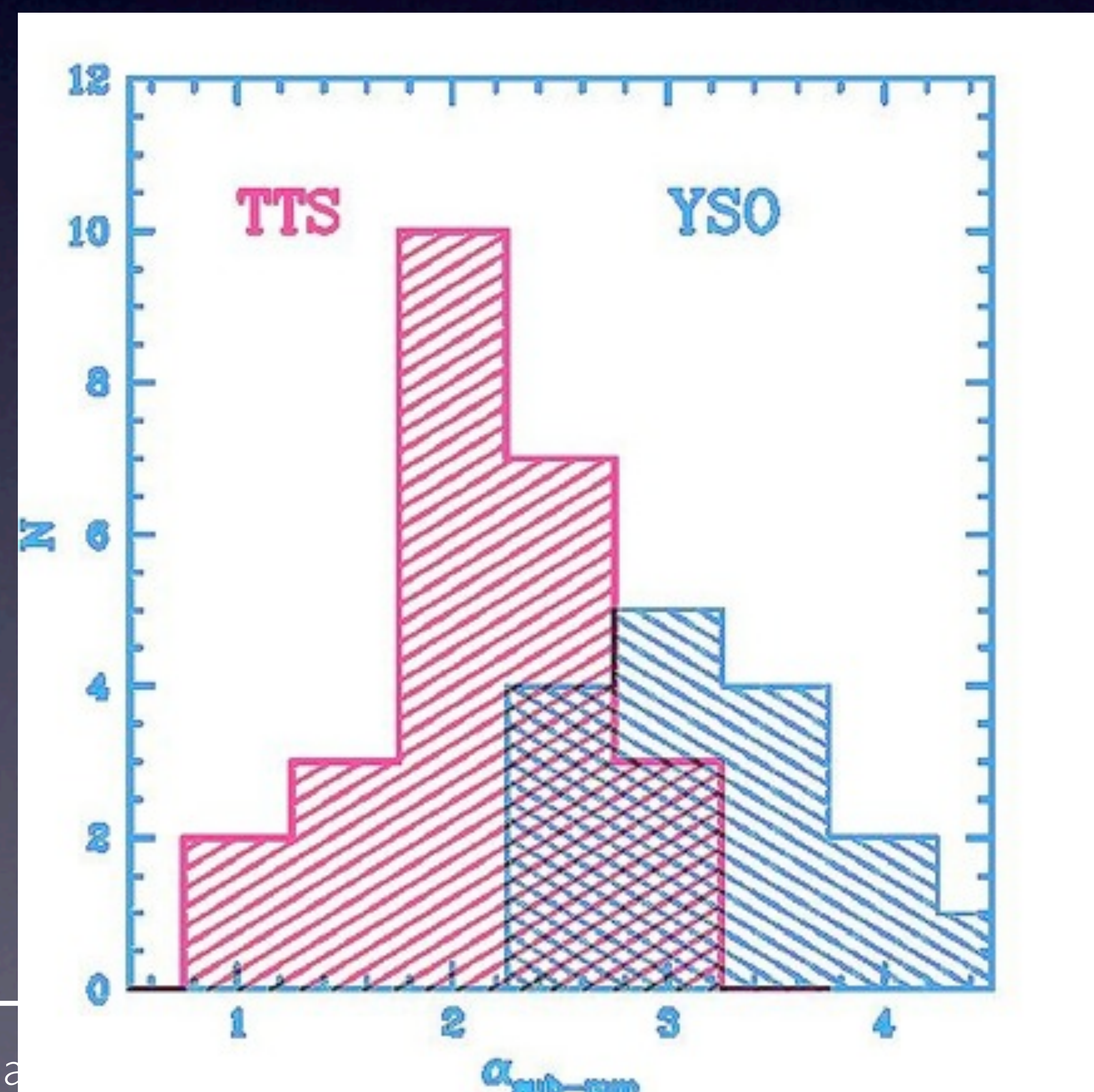


Evolution of dust in disks

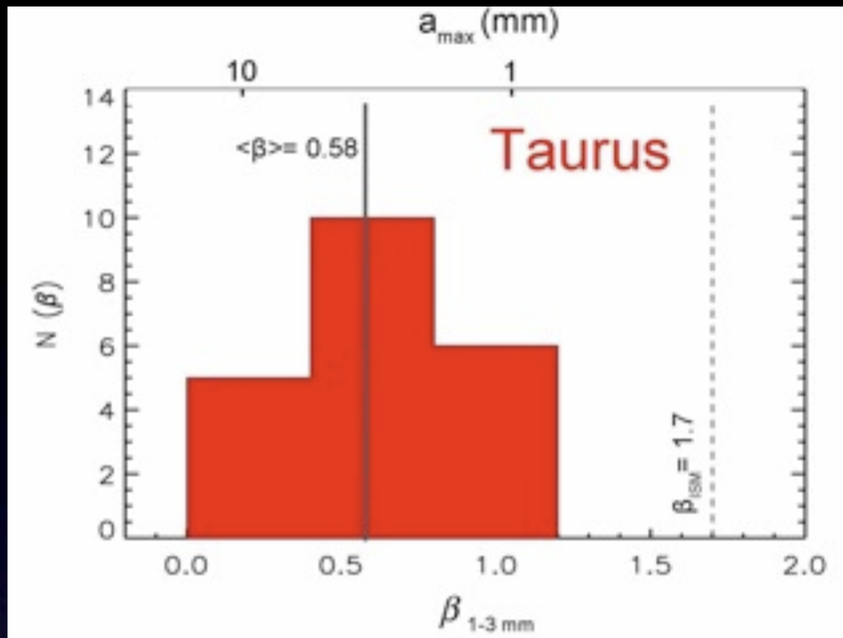
- Search for the presence of large (cm-size) grains
- The basic idea is to search for mm spectra that approach the black body spectrum
    - limit for optically thick disk or grey dust (size>>λ)
- **[$F_\nu \sim \nu^\alpha ; \alpha = 2+\beta ; \kappa_\nu \sim \nu^\beta$]**

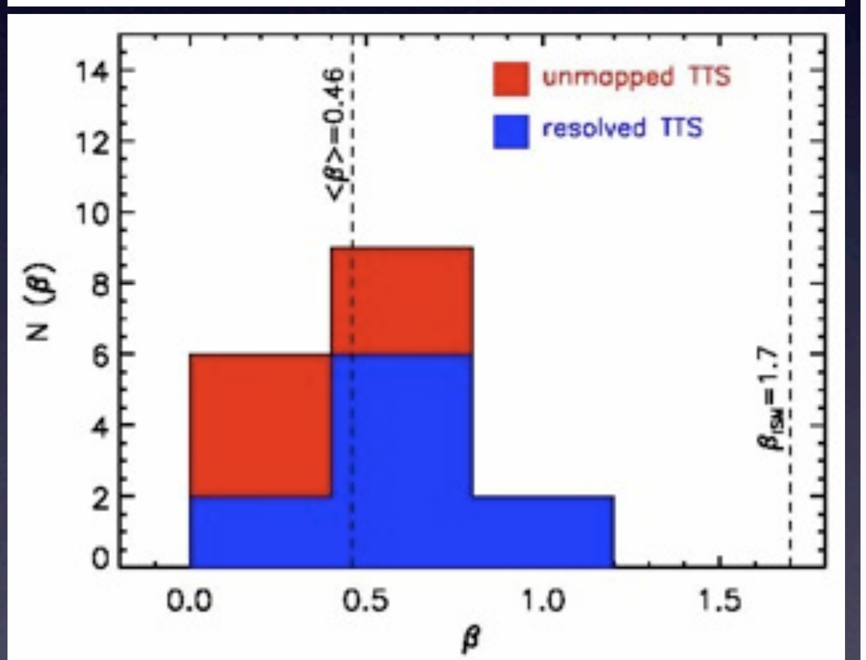


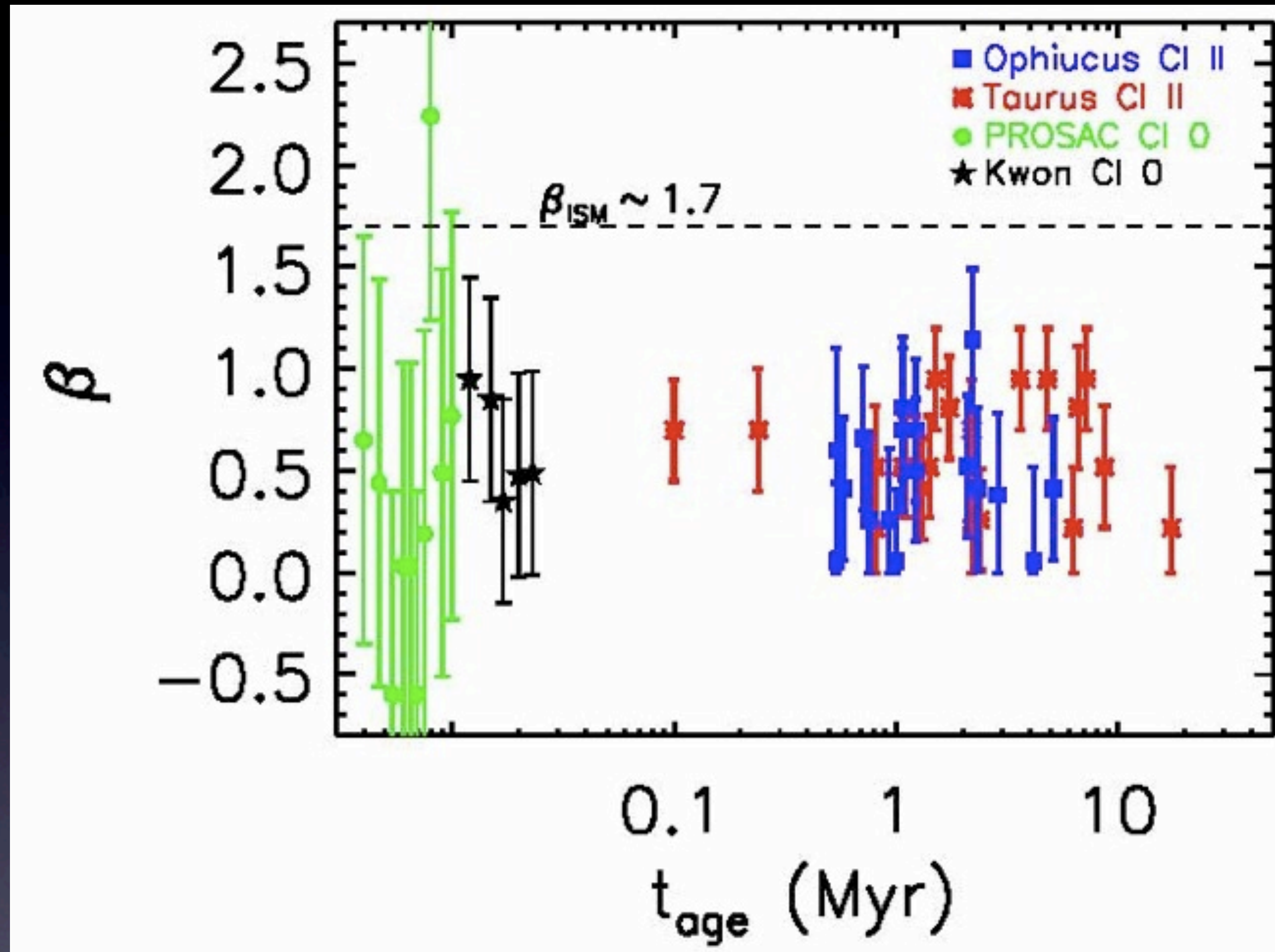
Single dish α_{sub-mm}
(Beckwith & Sargent 1991)



Deep survey for large grains in Tau/Oph





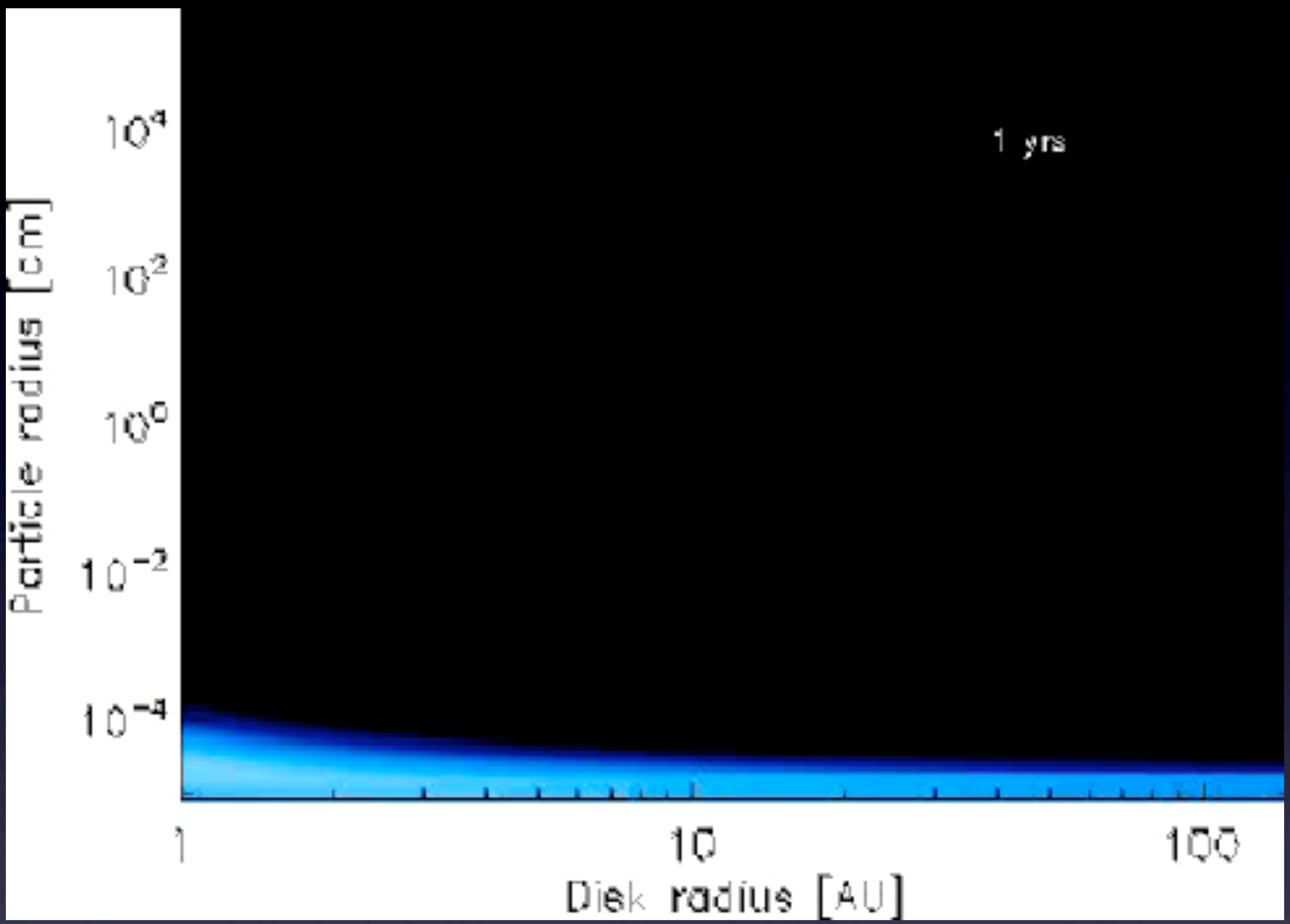


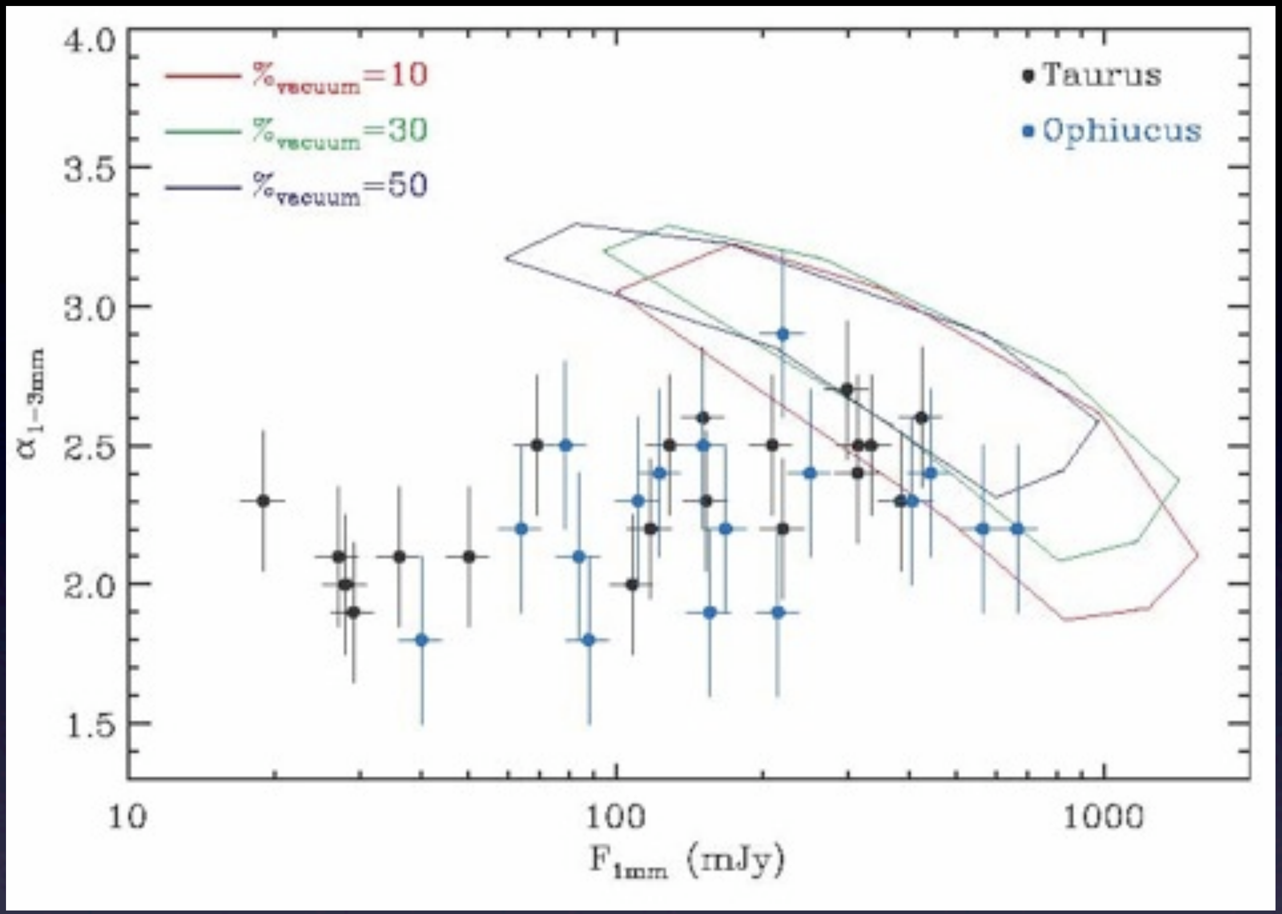
(Ricci, LT, et al. 2010ab)

- Large PdBI, ATCA & VLA survey to measure the long wavelengths emission from disks; 43 single, well characterized young stars
- Most disks have low values of β: early growth, slow evolution

Grain growth in disks: model predictions

(Brauer et al. 2008; Birnsiel et al. 2009)

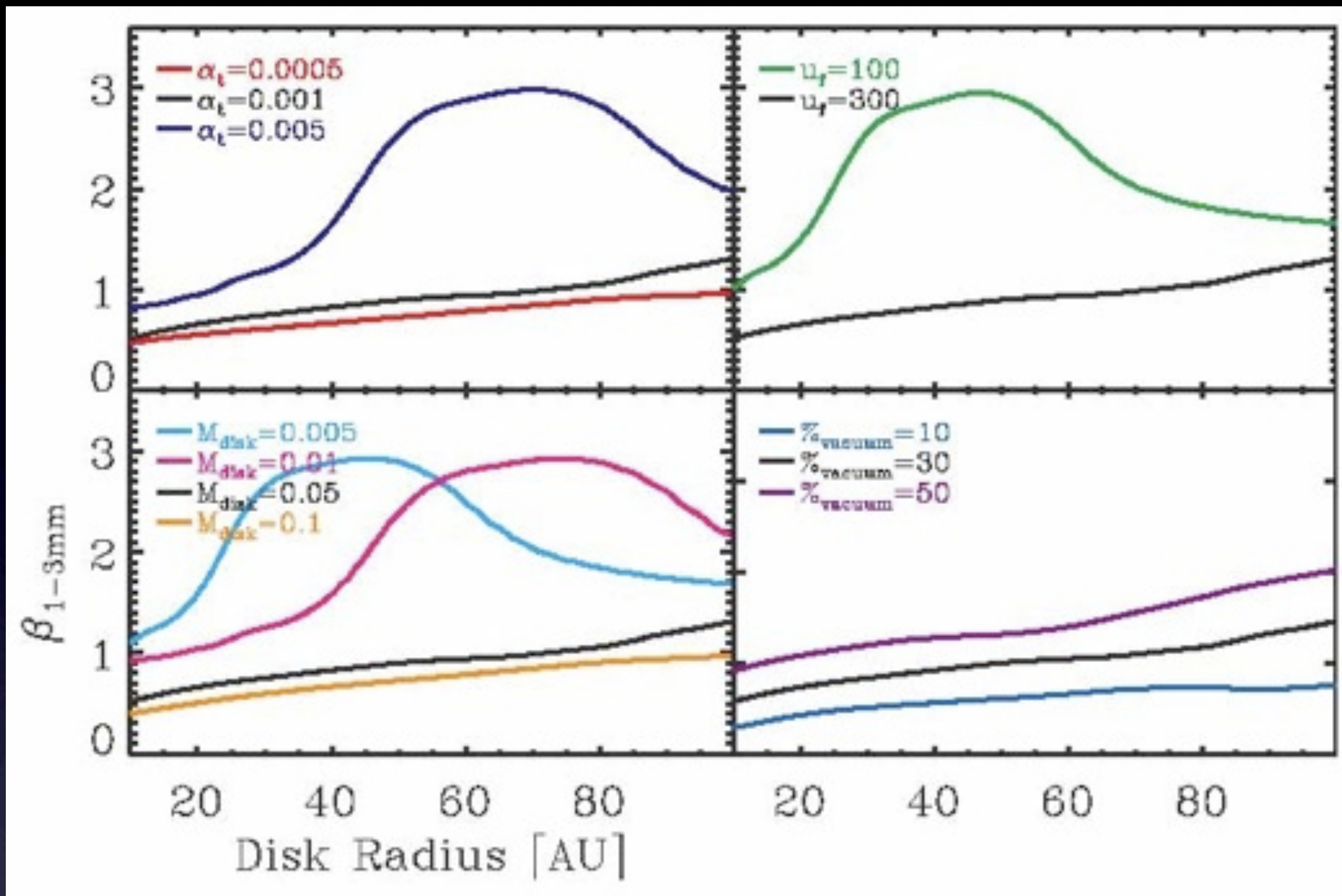


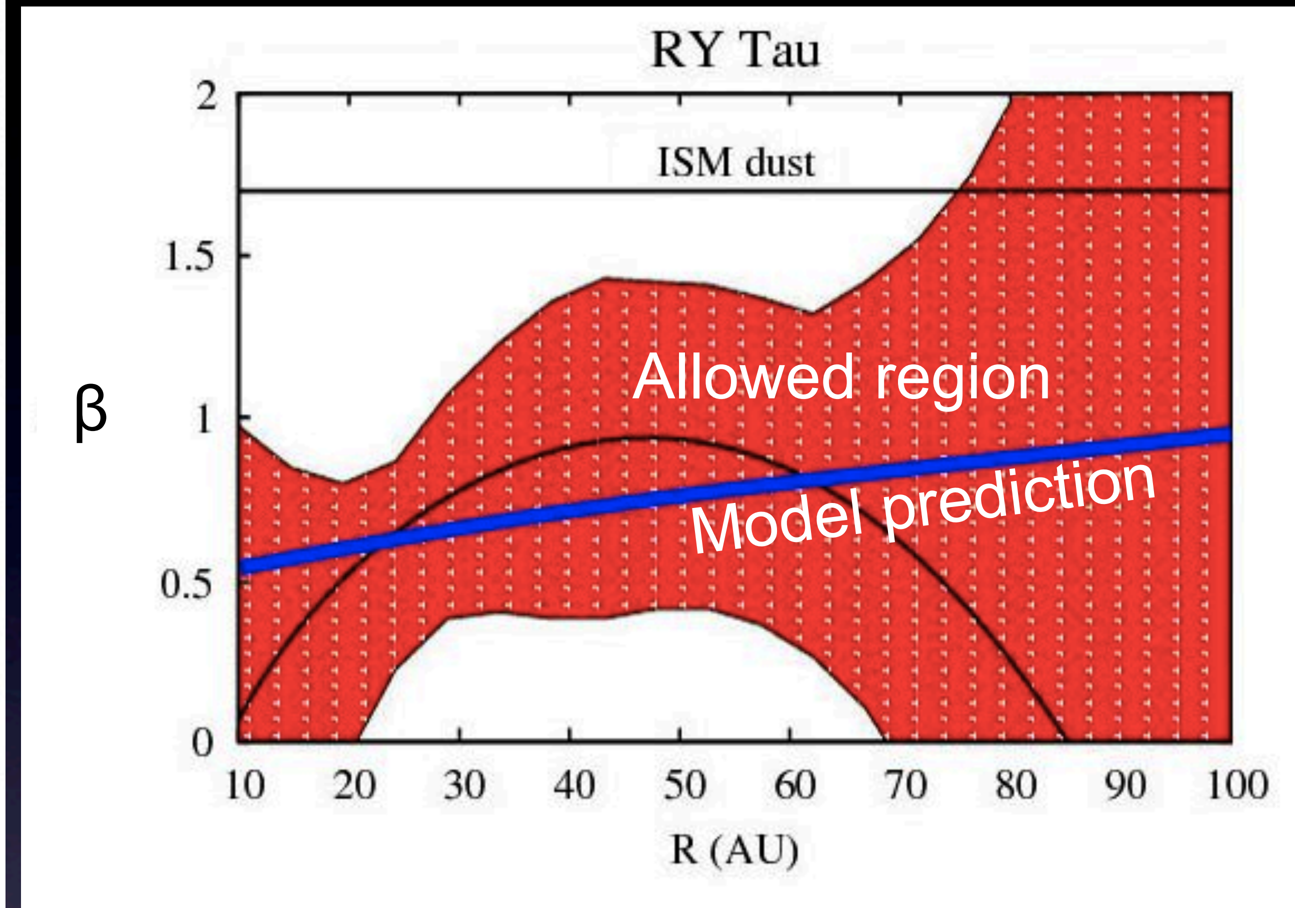


(Birnsiel, Ricci, Trotta, et al. 2010)

- Models predict a radial dependence of the grain growth
- Larger grains at small R, smaller (but still large) grains at large R
  - Qualitative agreement with data, ...but...

Grain growth in disks: model predictions

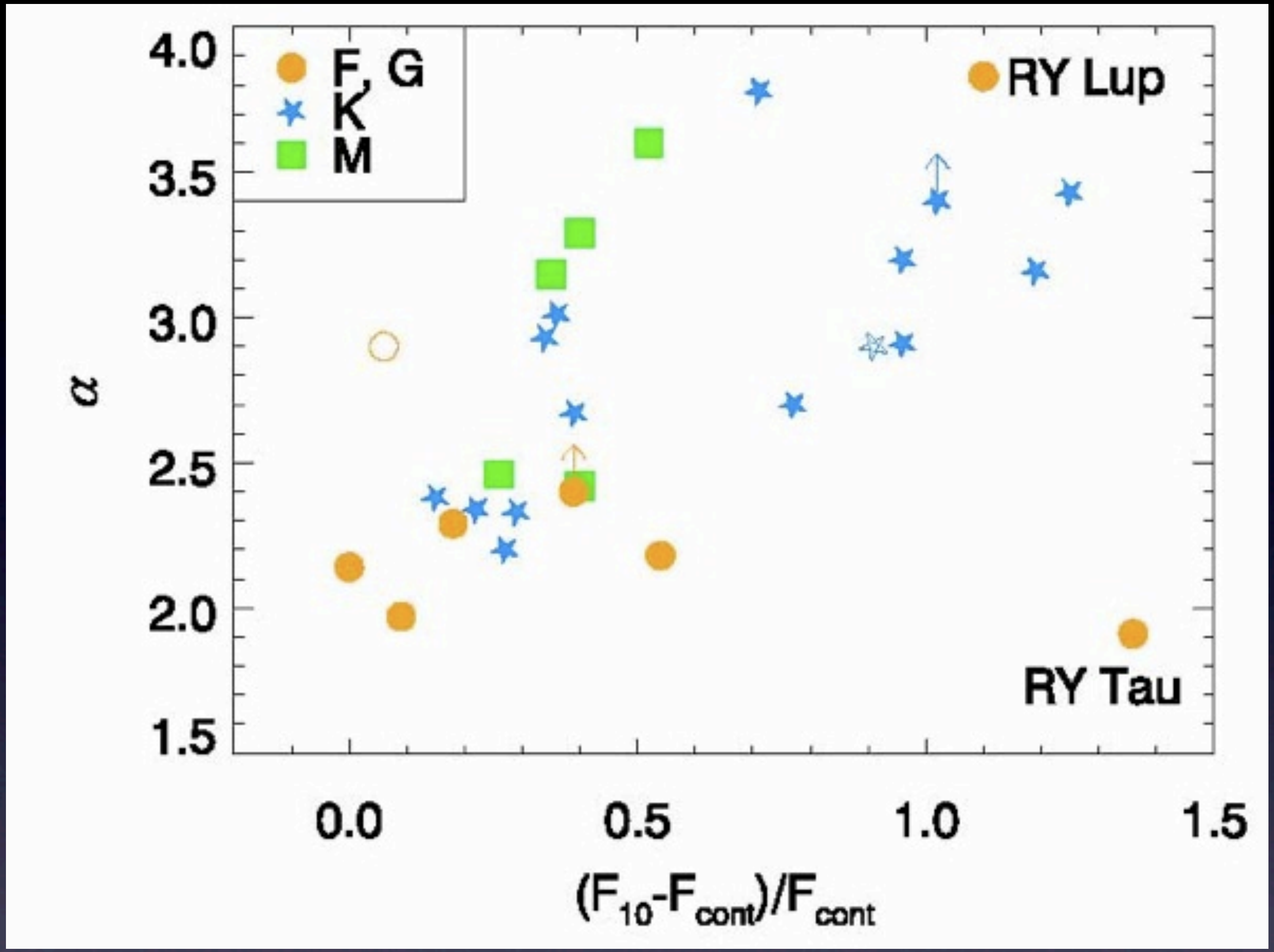




(Data: Isella et al. 2010;
Model: Birnsiel, Ricci, Trotta, et al. 2010)

- Models can be used to predict radial variations of grain growth
- Specific predictions can be tested at mm-waelengths
  - limited to the outer regions of the disks + large errorbars

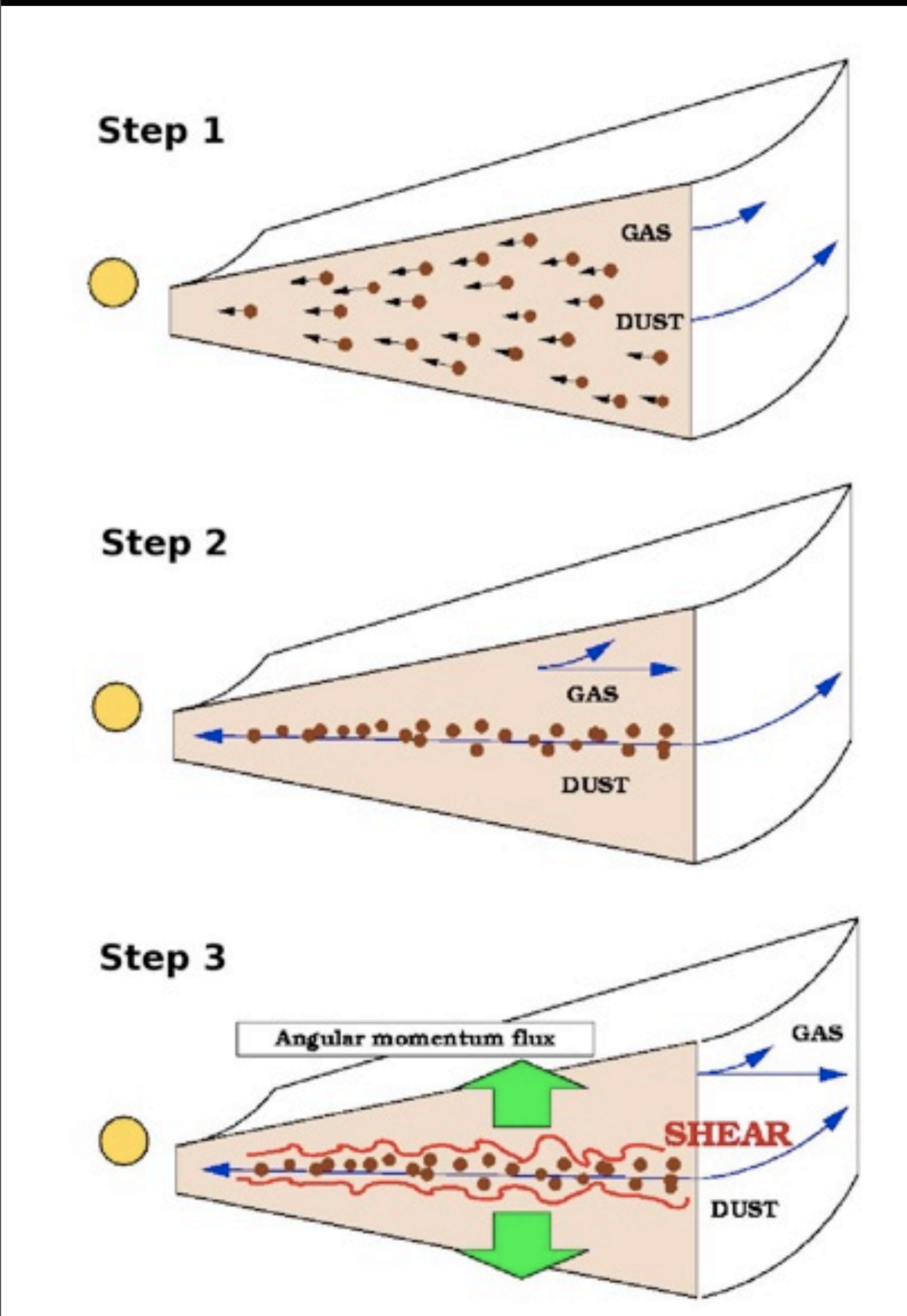
MID-IR probes inner regions



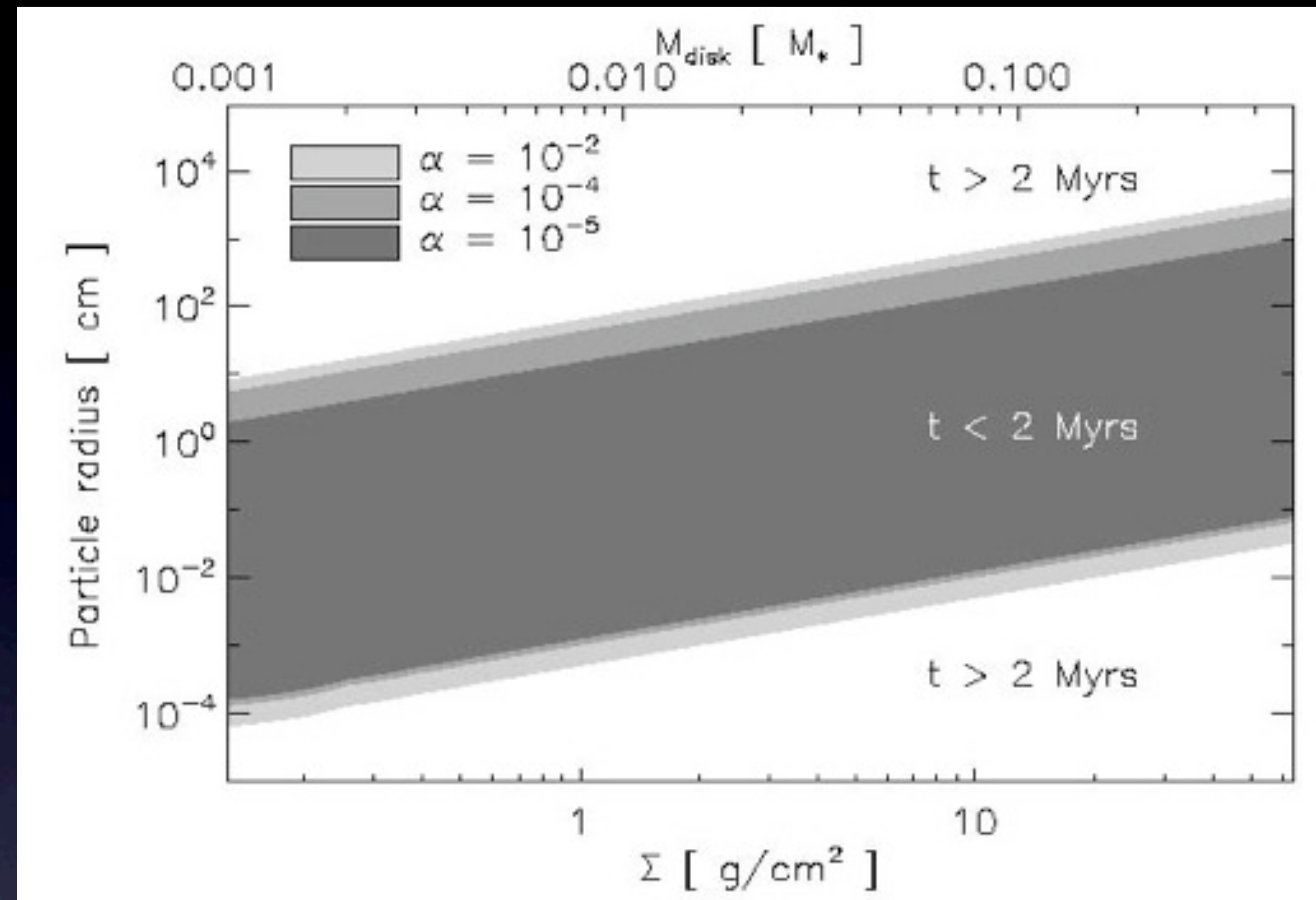
(Lommen et al. 2010)

- Correlation of the dust properties in the inner and outer regions of the disks
  - Qualitative agreement with model predictions, ...but...
  - Samples still limited and biased

Pebbles should not survive in disks!

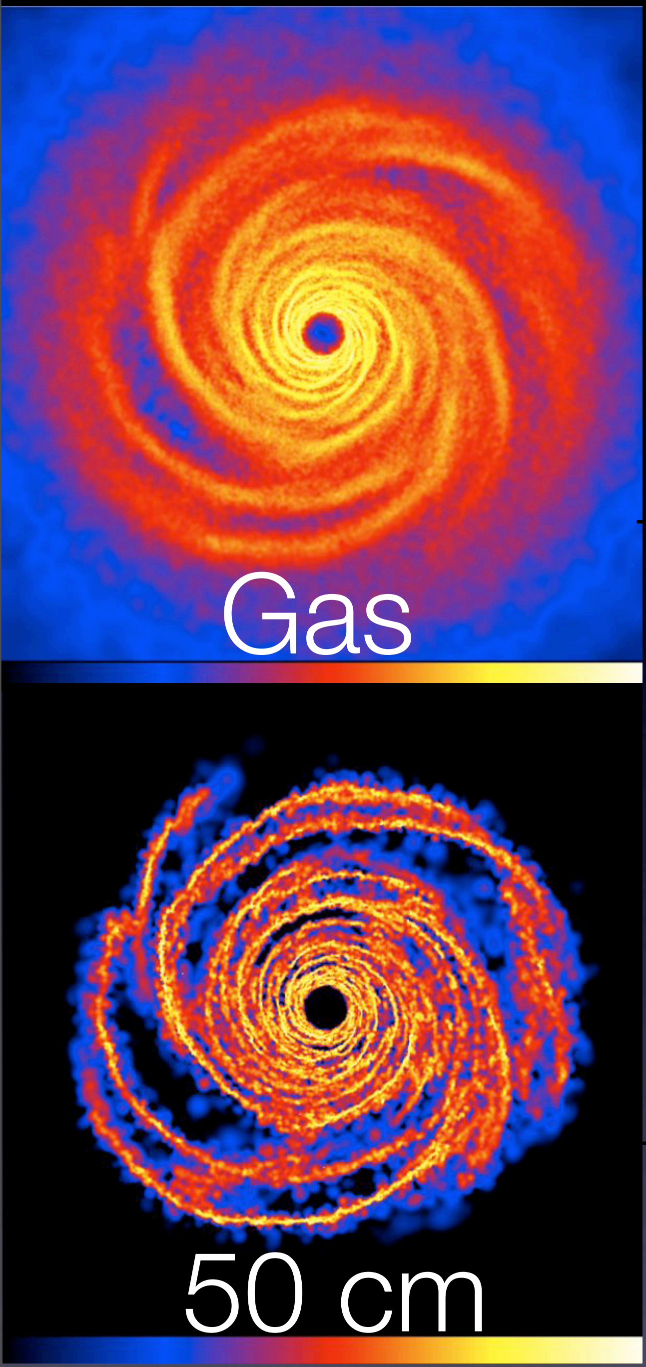


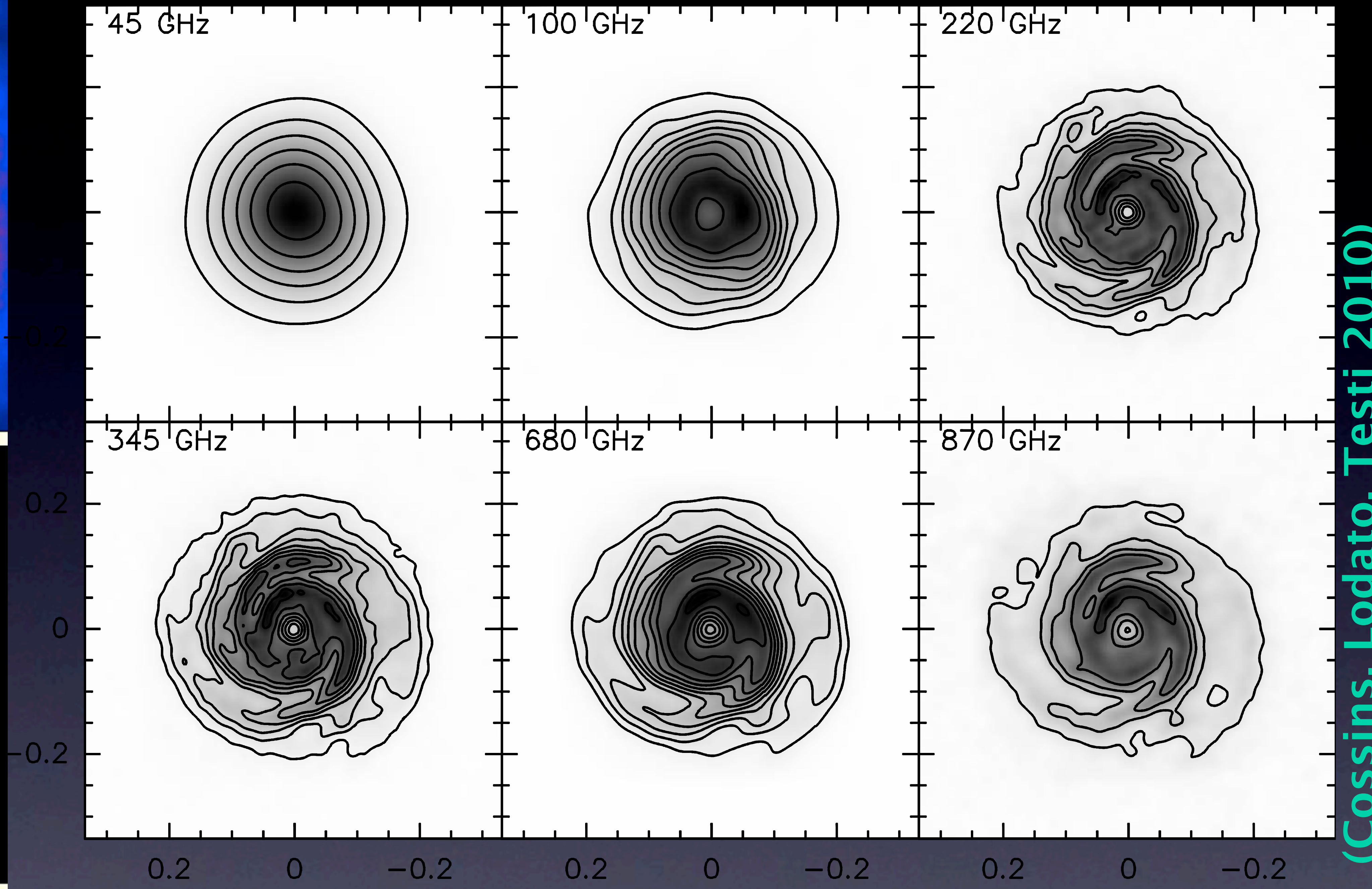
(Brauer et al. 2007, 2008)



- Radial drift of mm-cm size particles at r~100AU can be very fast
- Viscosity, porosity, gas/dust ratio
- Trapping in disk patterns
  - Vortices, spiral arms…

Something must slow down radial drift





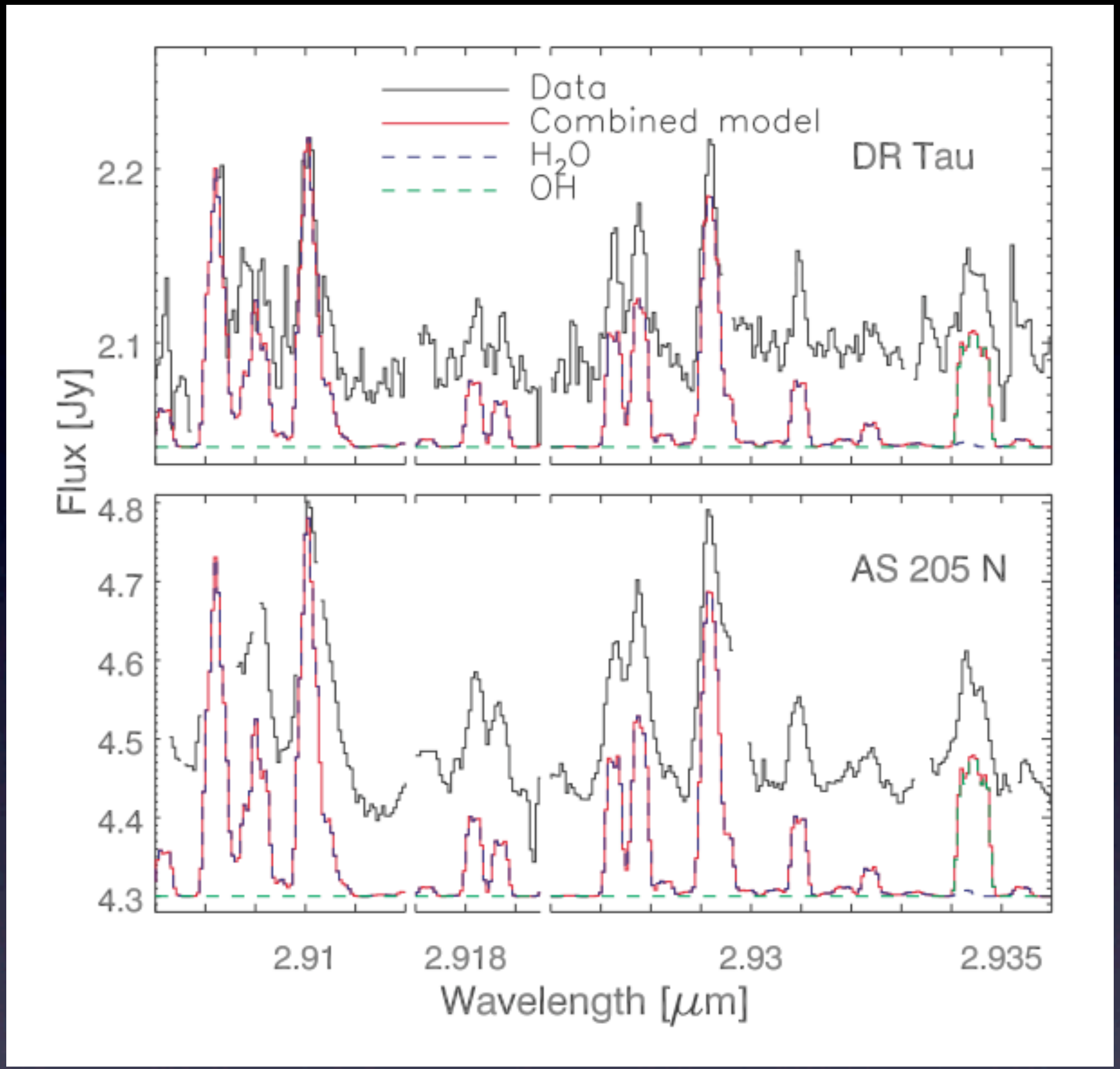
- Grain Trapping: e.g. spiral arms, vortices, density enhancements
- Efficient Gas Removal: photoevaporation, variations of gas/dust

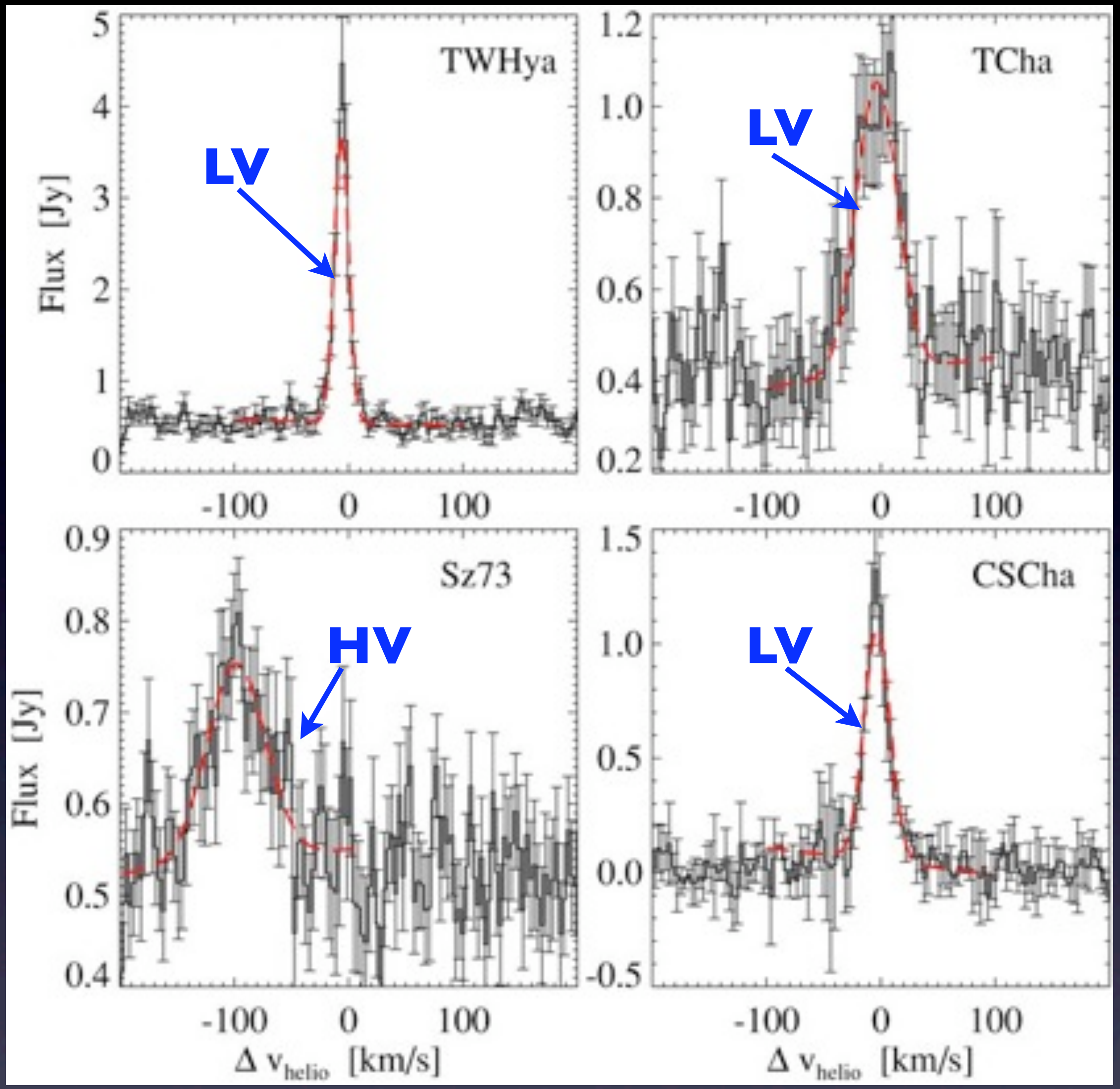
Complementary approaches

- ALMA - cold dust/gas, bulk of disk material
  - Dust evolution, radial dependence of grain properties
  - Molecular gas content, chemistry and evolution
- JWST
  - MIRI: Dust properties, gas content evolution (H2, [NeII], ...)
- E-ELT
  - SIMPLE: resolve spatially and kinematically the inner disk (H_2O, CO, ...)
  - METIS: spatially resolve dust properties, photoevaporation ([NeII])

Probing the inner disk: gas content

(Salyk et al. 2008)





(Photoevaporation evidence from [NeII]
Pascucci & Sterzik 2009)

- Chemistry of the inner disk: e.g. water content
- Gas removal mechanisms: e.g. photoevaporation

Conclusions

- mm observations with ALMA will probe the growth of dust in disks and constrain planet formation theories
- The combination of infrared and millimeter continuum observations will allow to test the physical models for grain evolution in disks
- ALMA will probe the cool molecular component of the disk resolving the chemical, thermal and kinematical structure at large radii
- JWST and E-ELT will probe the physical and chemical processes in the inner regions of the disk