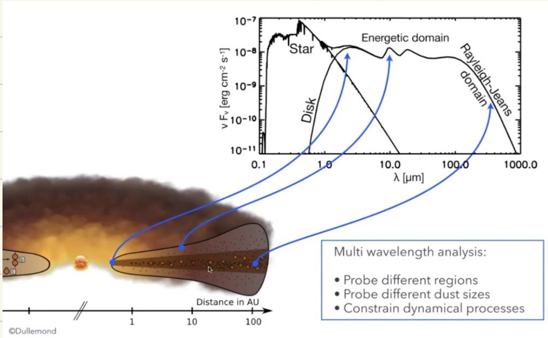
Dust grain evolution (observation) M. Benisty Sagan Summer Workshop

1. observation: dust grains $\mu m \sim cm$

wavelength → grain size → regions in PPDs

due to opacity $\underline{\kappa_\nu}$ observation: dust size ~ order of wavelength



2. optically thin:

$F_\nu \propto M_{dust} \cdot \underline{B_\nu(T)}\ \underline{\kappa_\nu} \Rightarrow F_\nu \propto M_{dust} \cdot \nu^{2+\beta}$

$B_\nu \propto \nu^2 \quad \kappa_\nu \propto \nu^\beta \qquad M_{dust} \cdot \nu^\alpha \qquad \alpha < 3$. large grains

spectral slopes

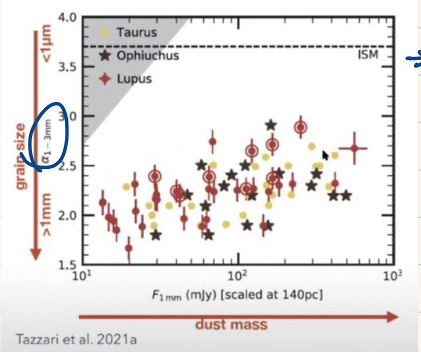
measure the spectral slope: constrain dust grain size

optically thick: $F_\nu \propto B_\nu(T) \cdot$ disk area

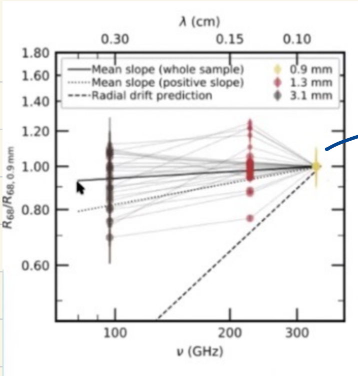
3. star-forming region disk survey

observations at different wavelengths eg: for Lupus 0.88 mm, 1.3 mm, 3 mm

→ reconstruct spectral index



→ all disks have $\alpha < 3$ ⇒ grain growth !

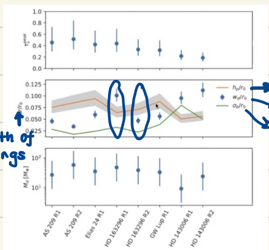


Tazzari et al. 2021b

radial extend is similar at three wavelengths

→ challenges radial drift → require the presence of dust traps

4. evidence of dust trapping → prove dust trap helps grain growth



Dullemond et al. 2018

width of rings

→ pressure scaleheight

→ measured width of rings w_d/r_0

→ angular resolution σ_b/r_0

$w_d > \sigma_b$ ⇒ rings are resolved

$w_d < h_p$

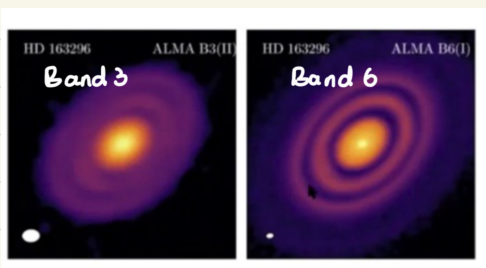
} ⇒ dust trapping

Ring 1 for HD163296: not a dust trap

Ring 2 for HD163296: a dust trap

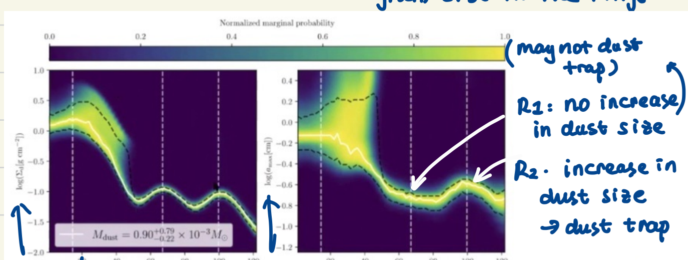
5. evidence for growth in dust traps

same disk in different wavelengths → derive spectral index → constrain the maximum grain size in the rings



Band 3

Band 6



Sierra et al. 2021

(may not dust trap)

R1: no increase in dust size

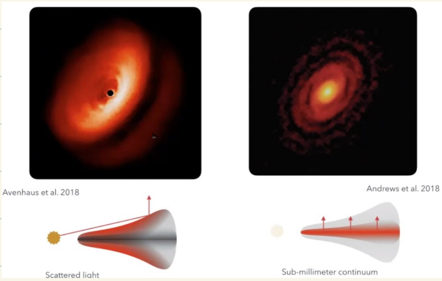
R2: increase in dust size → dust trap

dust radial distribution

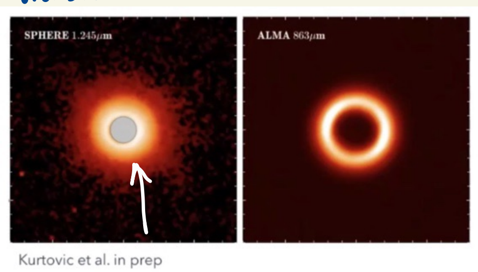
maximum dust grain size

R1: traffic jam due to local physical processes

6. scattered light & continuum



7. transitional disk



small dust well-coupled with gas flows inward

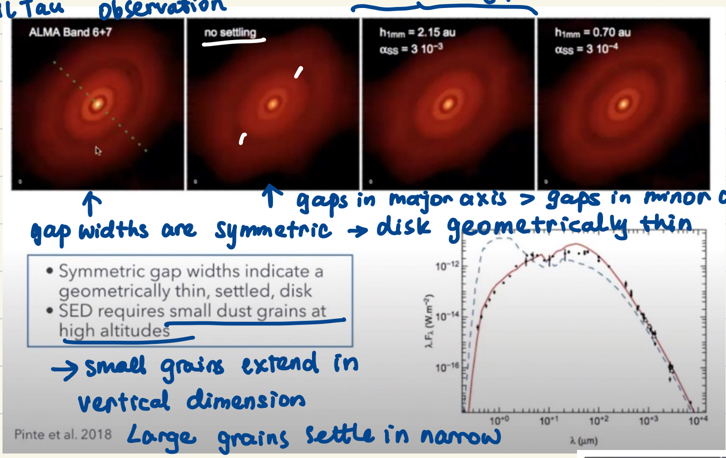
→ simulation cavities carved by 1 MJup planet

small grains are inside the ring in mm → can be used to constrain the pressure gradient.

8. dust vertical settling

HL Tau observation

modelling prediction



gap widths are symmetric → disk geometrically thin

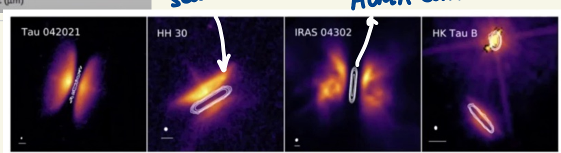
gaps in major axis > gaps in minor axis ⇒ projection effect along major axis

→ small grains extend in vertical dimension

Large grains settle in narrow mid-plane

scattered light

ALMA continuum



Summary:

1. Dust grains grow & drift to region of high pressure.
2. pressure bumps are dust traps where grains grow.
3. Direct observations of planetismals in disks is not possible
4. Difficult in measuring dust sizes
5. Properties of dust, like porosity, is not well-studied
6 Connecting dust growth at different stages is needed.
7. Missing global modelling of multiple dust tracers.