CfA colloquim: High resolution observations of PPD structures

1. Motivation:

a. When and where do planets form ?

b. interation between planets & disks → influence on the formation of other planets

c. processes of disk evolution & planet formation influence on each other.

2. disk features → disk evolution & probing planets

3 Infrared wavelength range → YSO is very bright → high contrast imaging

scattered light imaging: stellar irradiation goes as r^{-2}.

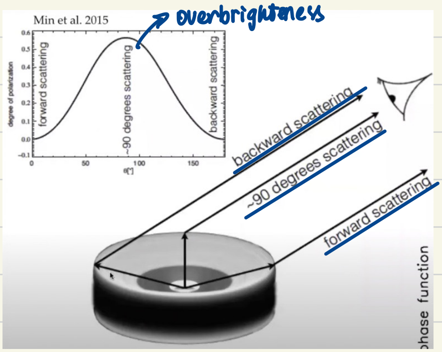
partially polarized { stellar emission: unpolarized ; Scattered by disks: linear polarized } ⇒ subtract two images obtained with two different orientations of polarization

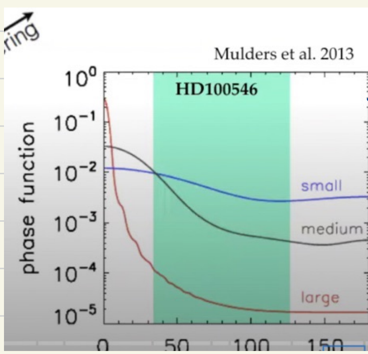
⇒ unpolarized emission from the YSOs cancell out.

→ techniques: polarization differential imaging & coronagraph

But scattering & polarization depend on ① angular distribution of emission ② grain size, composition & porosity ③ projection effects

overbrightness





• large grains have more forward scattering than small grains.

(scatter isotropically → equivalent brightness

4. large scale asymmetries { Herbig Aebe stars ; T Tauri stars }

(multiple) rings, cavities, spiral arms,

SAO206462. HD34700A.

→ multiple planetary systems ?

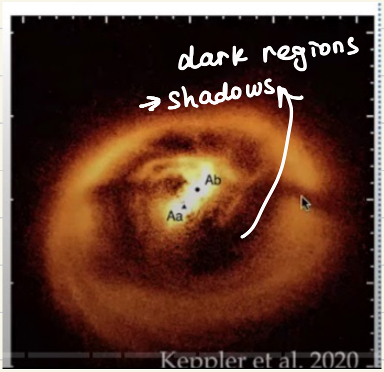
→ multiple rings: reconstruct the shape of the surface

Scattering height $z \neq$ pressure scaleheight. $h \Rightarrow z \sim (3\text{-}4)h$

5.
Spiral arms & origin of spiral arms

inner regions which we cannot access due to the coronagraph are highly perturbed

High NIR excess: dust grains lifted up high to irradiate

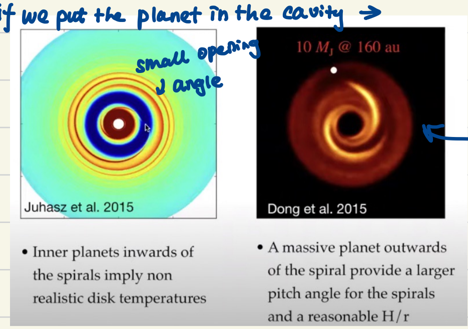


Shadows: some materials very close to the star shield the irradiation

→ disks do not receive stellar irradiation

shadows usually associate with spiral arms & near-IR excess

if we put the planet in the cavity →



we can take this advantage to probe temperature profiles (on later pages)

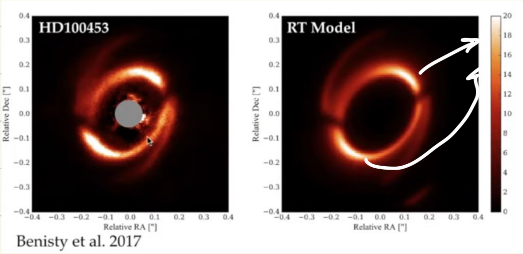
opening angle of spiral arms: depends on temperatures

very open spiral arms → very hot disks (unrealistic)

→ planets out of spiral arms:

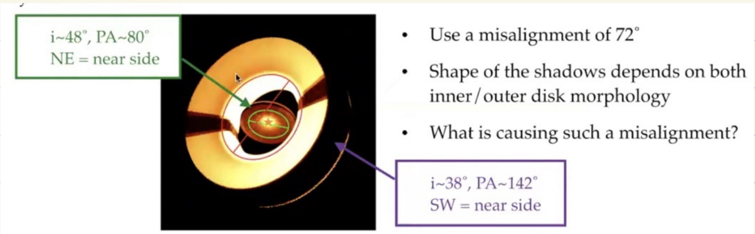
① still need a planet in cavity to create a cavity

⇒ two planets

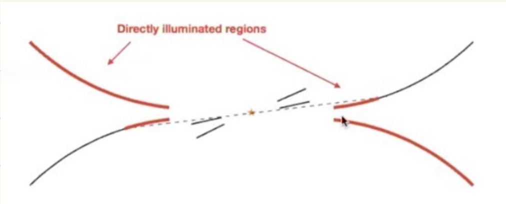


→ overbrightness: modelled by grains that have a very high polarization efficiency along the major axis

→ reproduce the overshadow: misaligned inner & outer disks

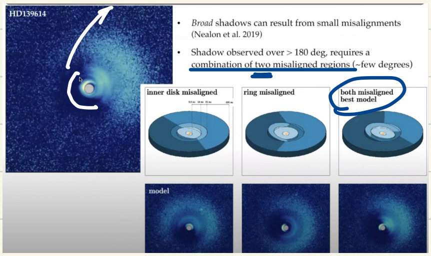


6.
Inner & outer disk misalignment



misalignment of 20-40 degrees.

small alignment → broad shadows



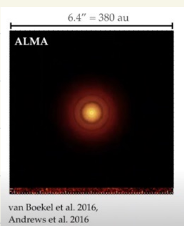
8. variable shadows

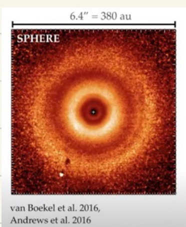
9. radial drift:

ALMA : trace large grains → mid-plane

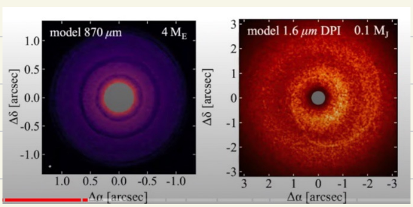
SPHERE : trace small grains → surface layer

} ⇒ spatial extent, gap widths & depths differ





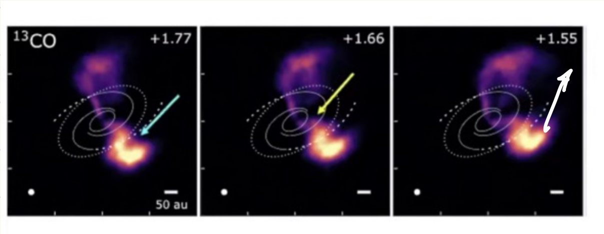
disk observed by ALMA is more compact compare with that observed by SPHERE ⇒ dust radial drift



TW Hya: mm gap carved by Super-Earths

scattered gap carved by Saturn-mass planets.

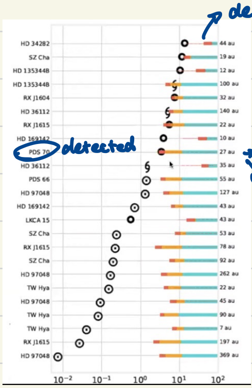
12. spiral arms as tracers of gravitational instabilities



Strong deviation from Keplerian rotation → colocated with spiral arms

13.

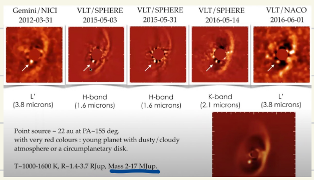
detection limit

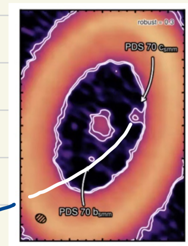


detected

→ PDS 70b

PDS 70c





Isella et al. 2019

→ still accreting gas from disks

5~9 MJup. ~4 MJup

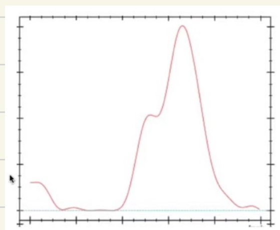
PDS70c. 2.4×10^{-3} Mearth.

Simulations show that $M_{pds70b} > M_{pds70c}$ to ensure that the disk is not too eccentric (Bae. et al. 2019)

→ resolve CPD around b&c

→ two rings PPD

14. disk feature mistaken for a planet HD169142


Benisty et al. in prep

15. Conclusion

a. All disks show features when observing with sufficiently high angular resolution. → can be used to infer the population of embedded planets

b. rings: dust trapping & growth → mixing & settling

c. spirals: measure disk vertical temperature profile

d. local bright features: (seen in scattered light) → structures

e. shadows: could be time-variable; constrain the inner disk structure.