Probing (GIANT)-planet formation by observing the disk-planet interaction

Andrea Isella

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Caltech

CARMA
Combined Array for Research in Millimeter-Wave Astronomy

Talk Outline/Conclusions

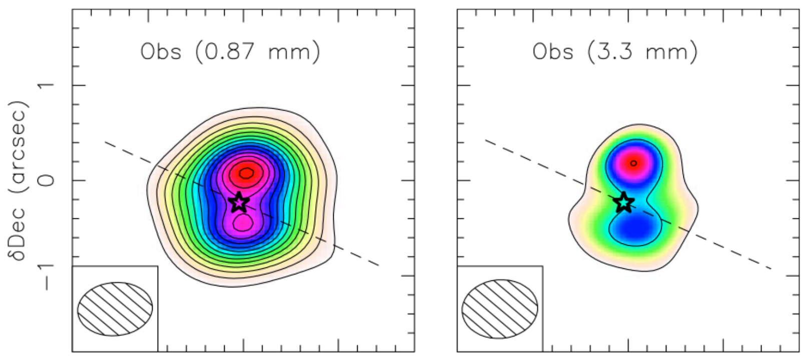
• Several transitional disks with **large (>20 AU)** millimeter cavities show asymmetries in the millimeter-wave continuum emission. I will present the case of LkHα 330 (AI+ 2013, CARMA), SAO206462+(L. Perez+ 2013, ALMA 0), LkCa 15 (AI+ 2012 CARMA,2013 ALMA+VLA)

• I will suggest that disk-(GIANT)planet interaction can explain LkHα 330 observations, and that mm-wave observation can in principle constrain the number, mass, and orbital radius of young giant planets. However, deriving these quantities is challenging due to the degeneracy between dust density, opacity, and temperature.

• I will discuss how ALMA Cycle 1 observations of the optically thin and thick molecular line emission, as well as multi-wavelengths observations of the mm/cm wave dust thermal emission, might help solving this degeneracy and constrain the properties of possible companions perturbing these disks.

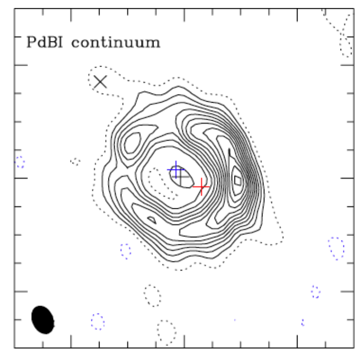
Asymmetries in transitional disks with **large** mm cavities

MWC 758



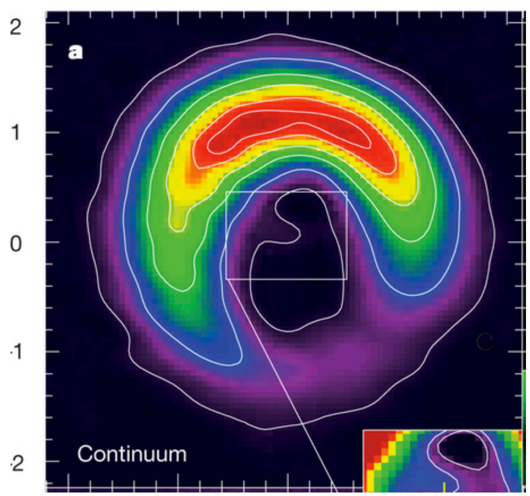
Isella et al. (2010)

AB Aur

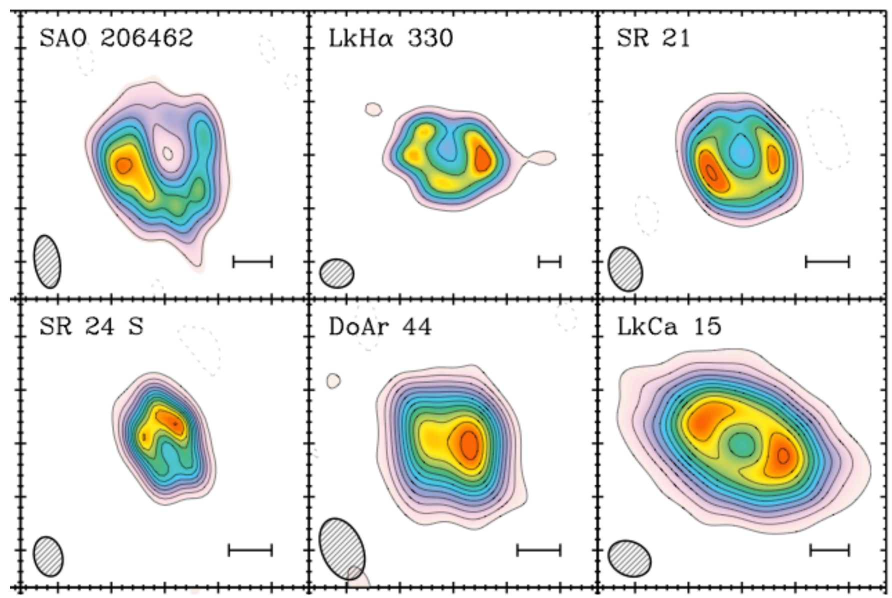


Pietu et al (2005)
Tang et al (2012)

HD 142527

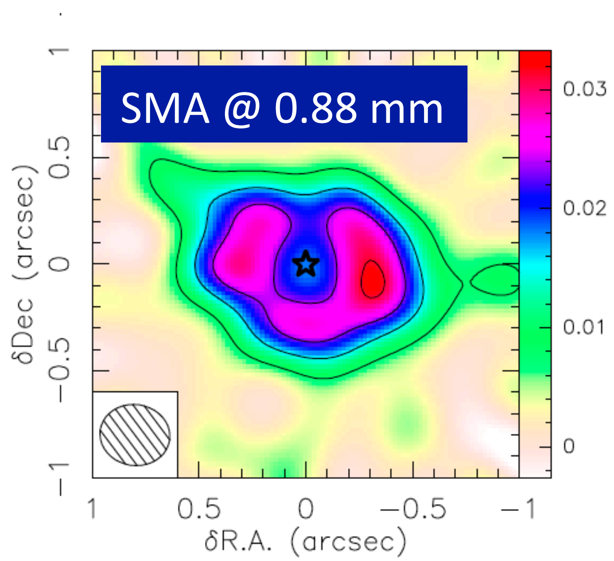


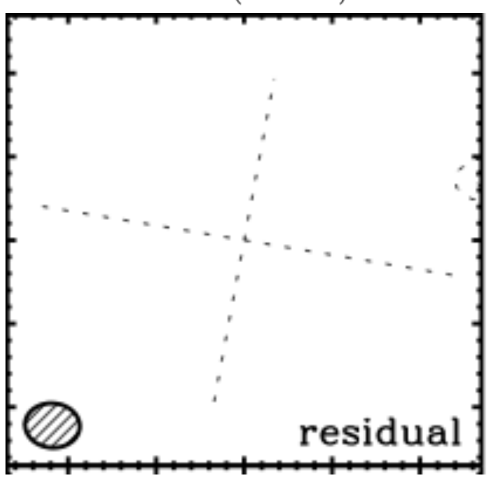
Casassus et al. (2013)



Brown et al. (2008), Andrews et al. (2011)

The case of LkHα 330

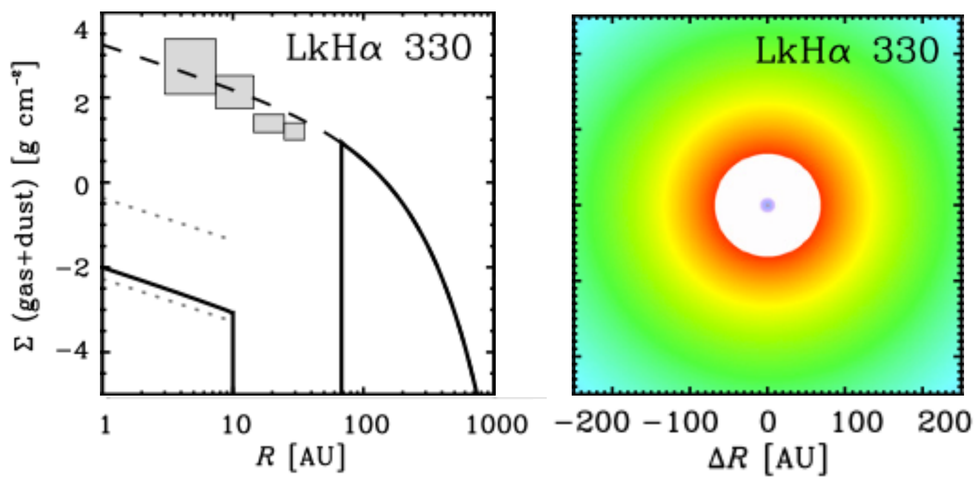




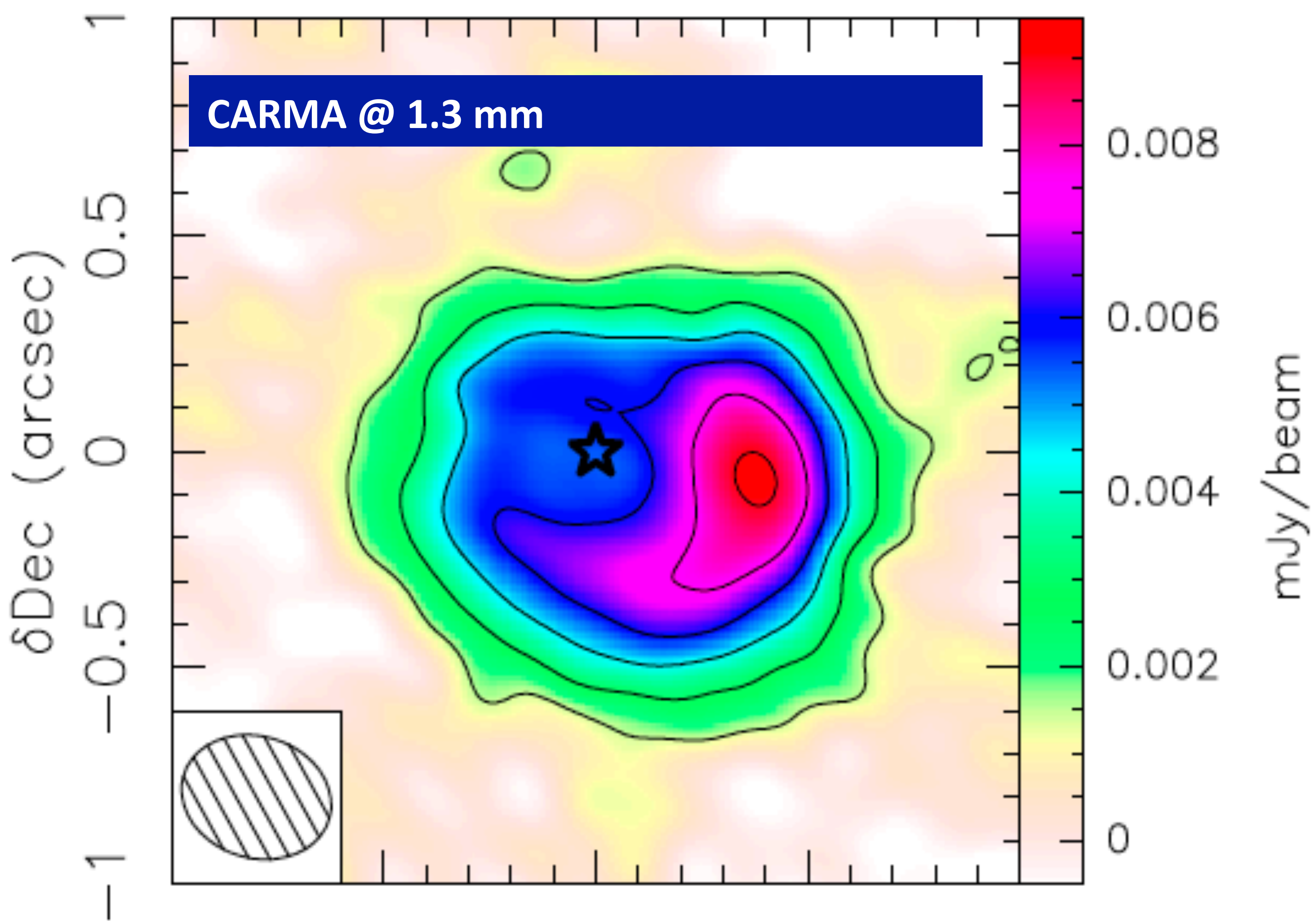
LkHa 330 ID
- Sp.T: G3
- mass: 2.5 Msun
- age: 3 Myr
- location: Perseus (250pc)

Brown et al. (2008,2009), Andrews et al. (2011)

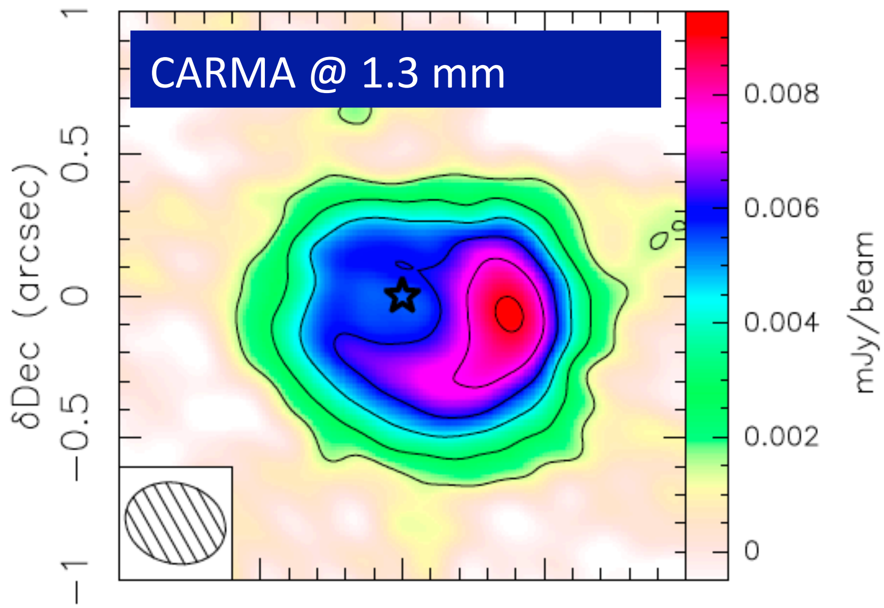
Disk surface density derived from SMA data

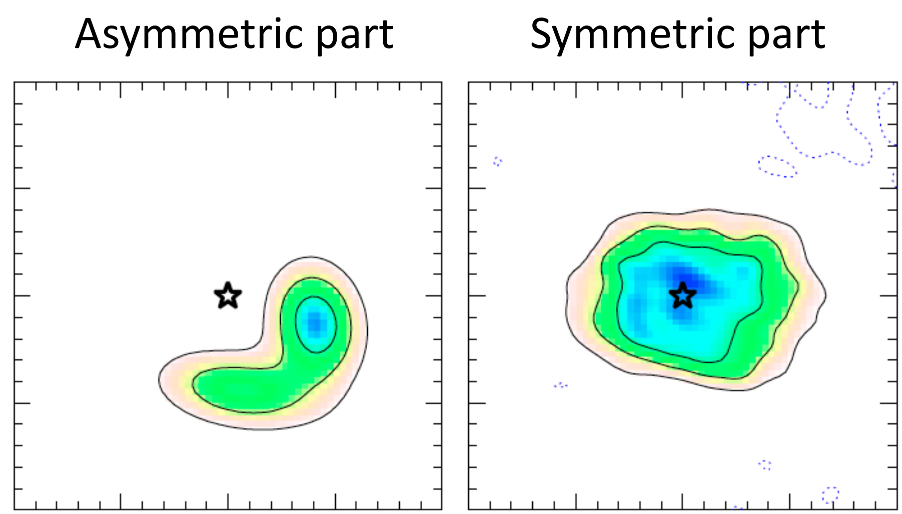


The case of LkHα 330



The structure of the asymmetry



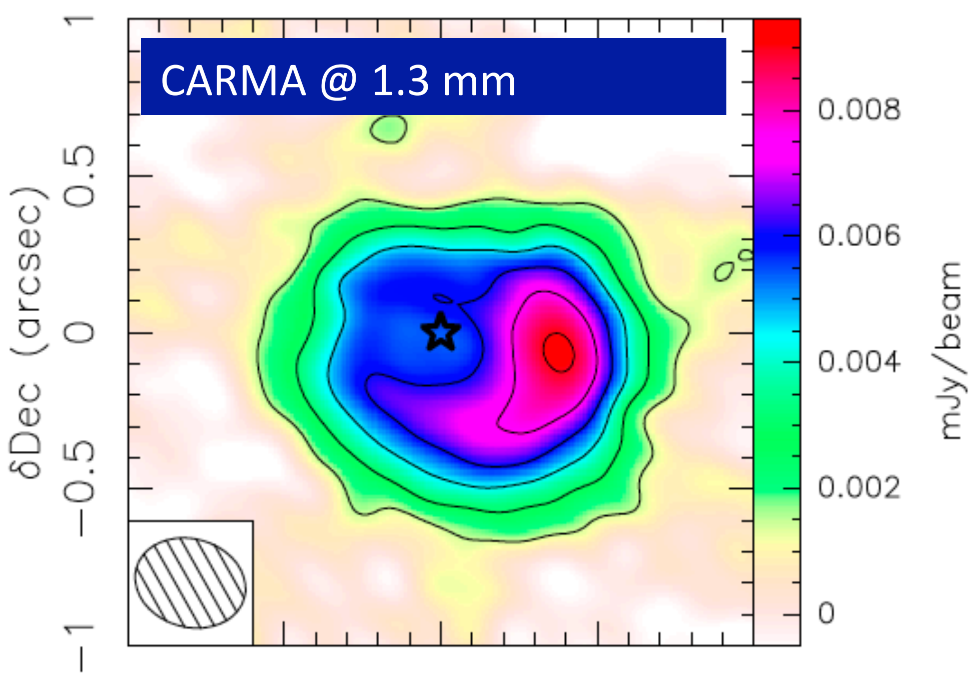


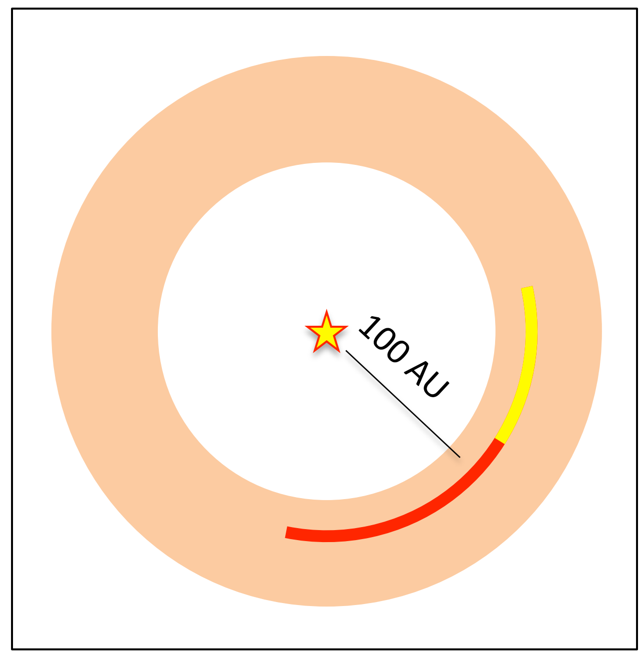
We derive the geometrical structure of the horseshoe asymmetry in the dust emission by modeling the imaginary part of the correlated flux with the Fourier transform of 2D Gaussian functions.

Ask me later if you want to know the details

The structure of the asymmetry

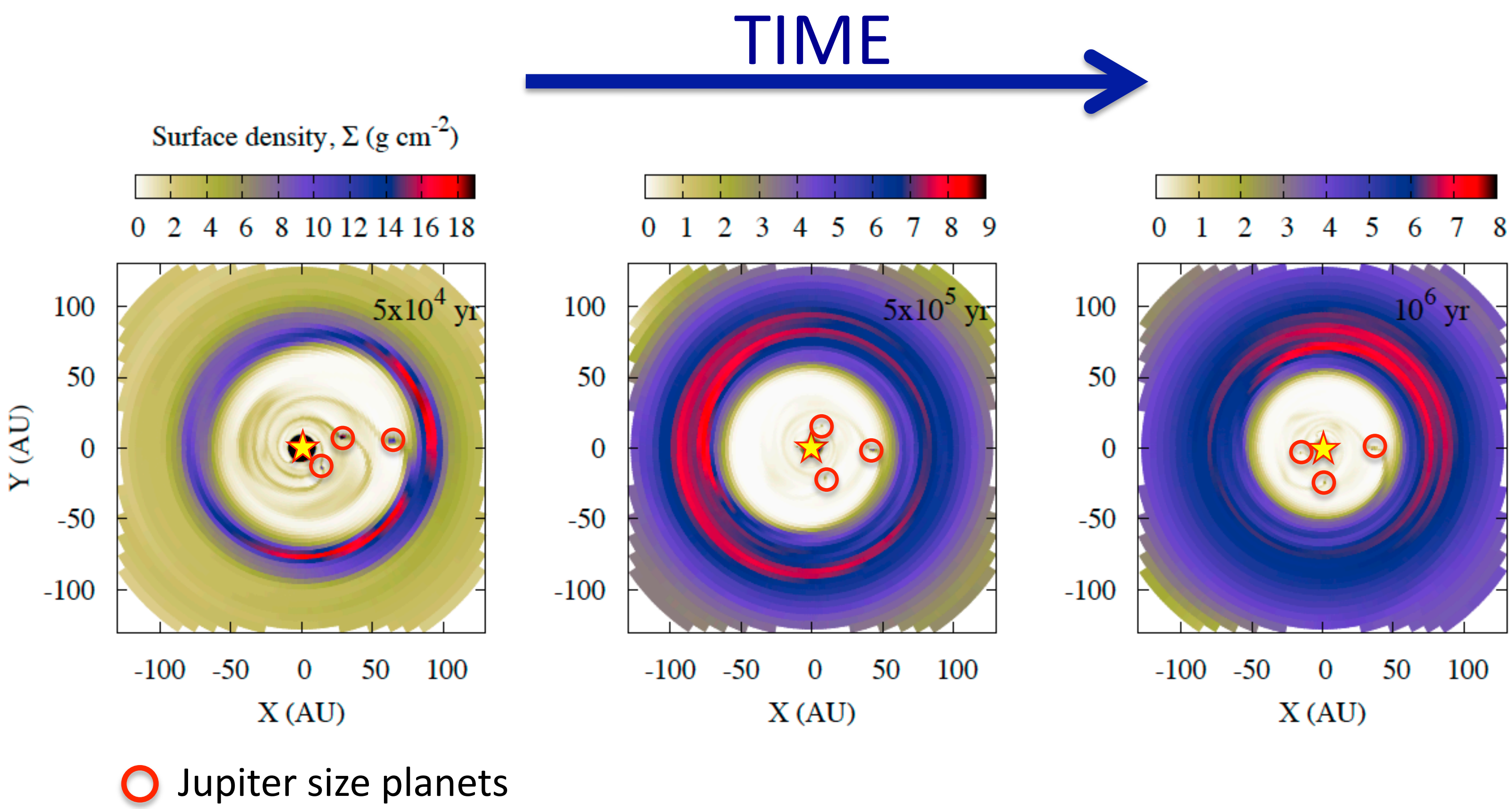
30% of the total mm flux comes from a narrow (dR<25 AU) circular arc located at about 100 AU from the central star that extends by about 90deg in azimuth.



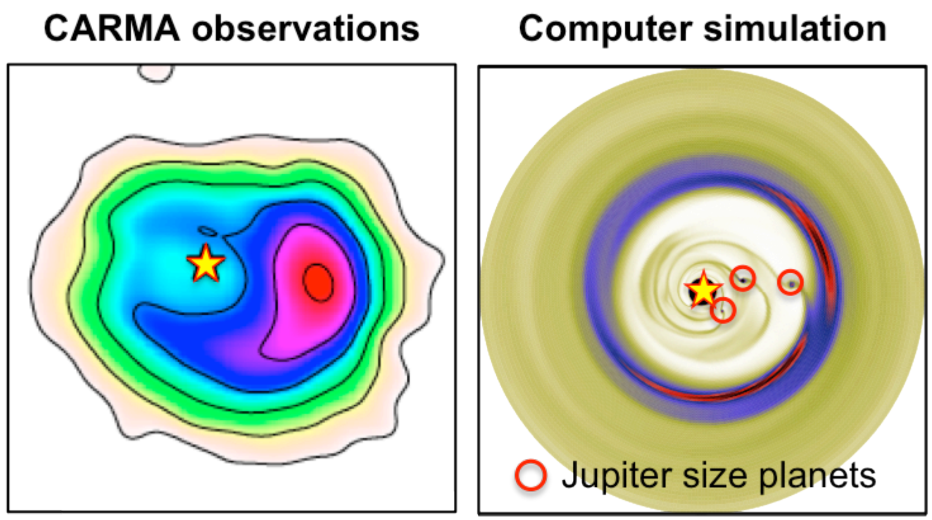


A possible origin of the asymmetry

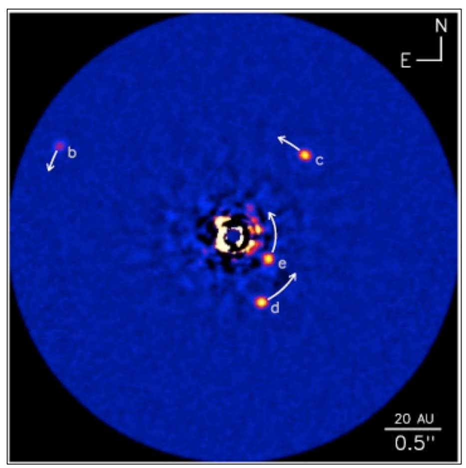
FARGO 2D Hydrodynamic (no magnetic field) simulations of the interaction between a multi-planet system and a viscous circumstellar disk



Giant planets make cavities and asymmetries

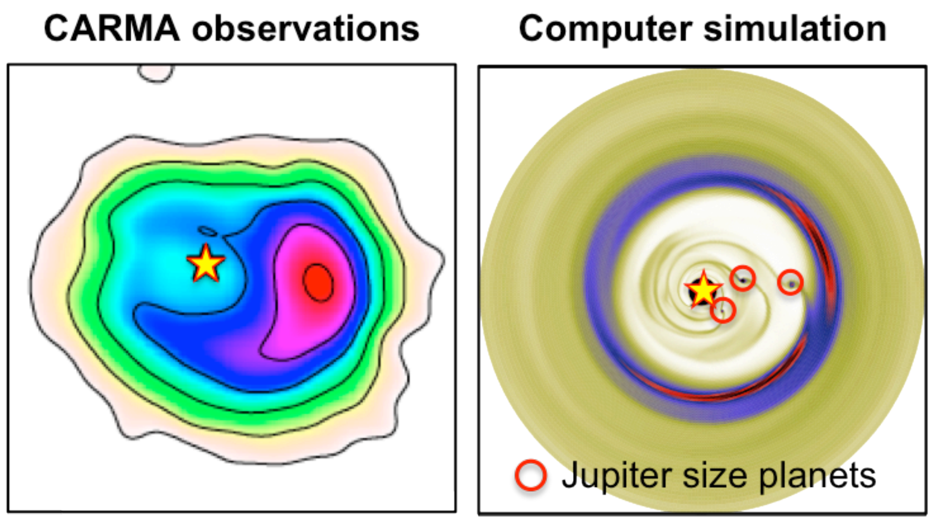


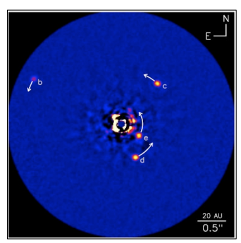
LkHα 330 – G3 - 3 Myr
(AI+ 2013)



HR 8799 – A5 - 30 Myr
(Marois et al. 2008)

Giant planets make cavities and asymmetries





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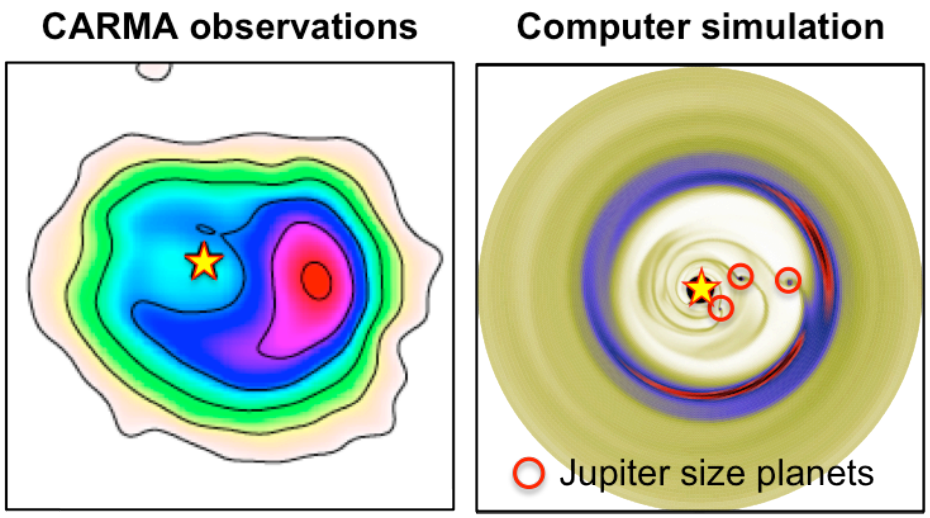


Dust emission

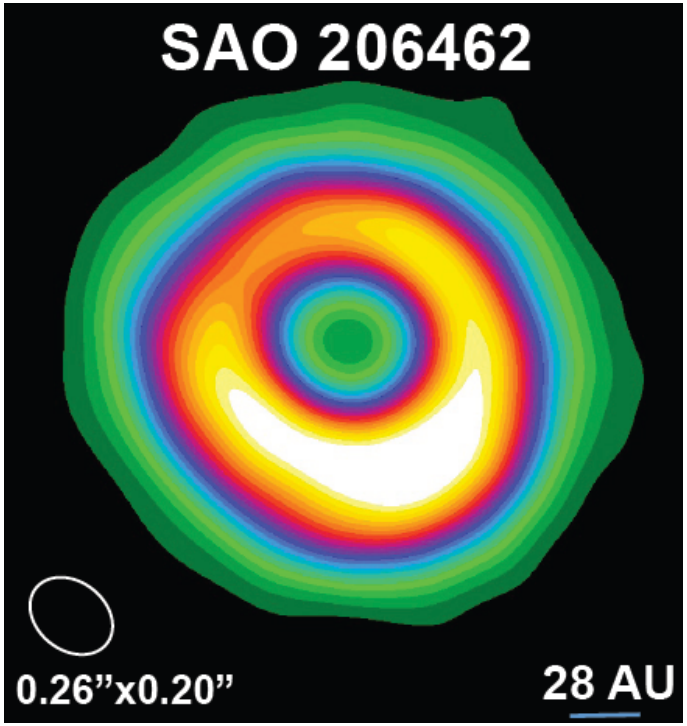
Gas density

$$F_\lambda(r,\theta) \propto \Sigma_g(r,\theta) \times T_d(r,\theta) \times \lambda^{-2} \times k_{d,\lambda}(r,\theta)$$

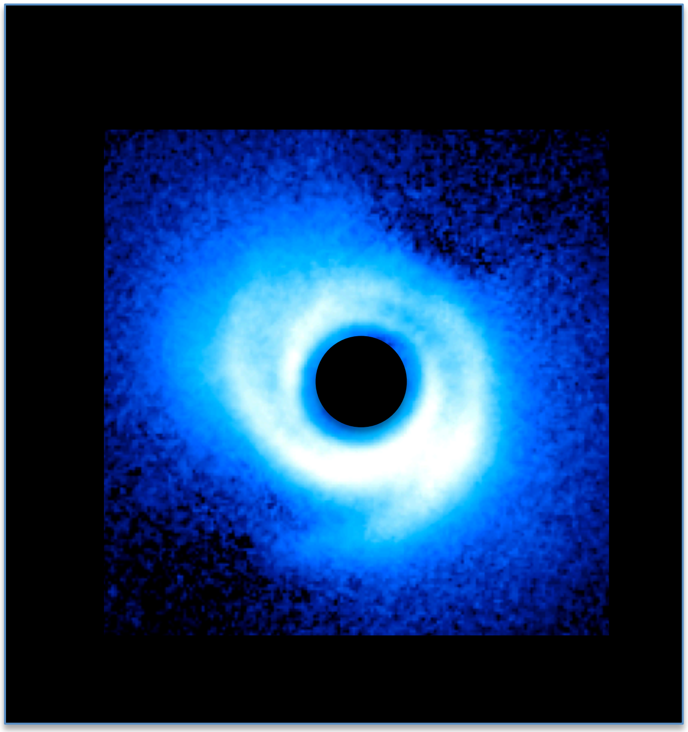
The effects of disk-planet interaction on the disk temperature and opacity needs to be quantified.

!

Disk Asymmetries seen by ALMA

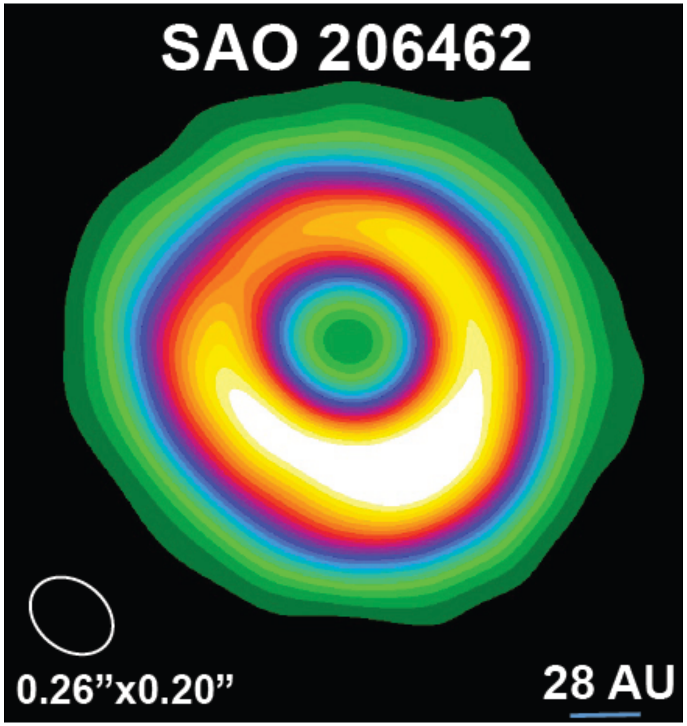


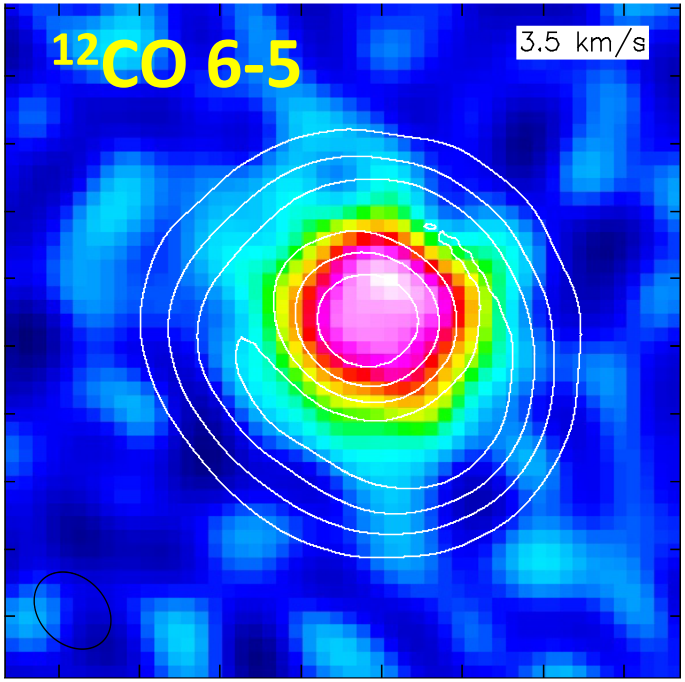
ALMA Cycle 0 observations of the dust thermal emission at 0.45 mm (Perez et al., in prep)



SUBARU 1.6 µm observations of the polarized disk scattered light (Muto et al. 2012)

Disk Asymmetries seen by ALMA



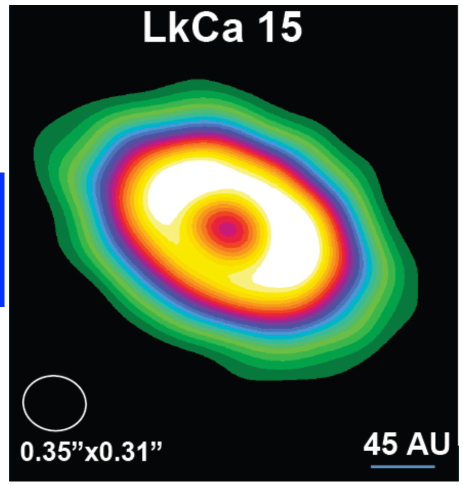


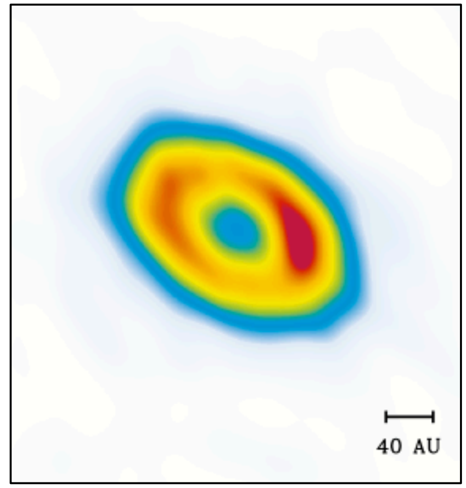
ALMA Cycle 0 observations of the dust thermal and ^{12}CO emission at 0.45 mm (Perez et al., in prep)

Multi-wavelengths observations of LkCa 15

$$F_\lambda(r,\theta) \propto \Sigma_g(r,\theta) \times T_d(r,\theta) \times \lambda^{-2} \times k_{d,\lambda}(r,\theta)$$

ALMA 0.45 mm
(Perez et al. in prep)

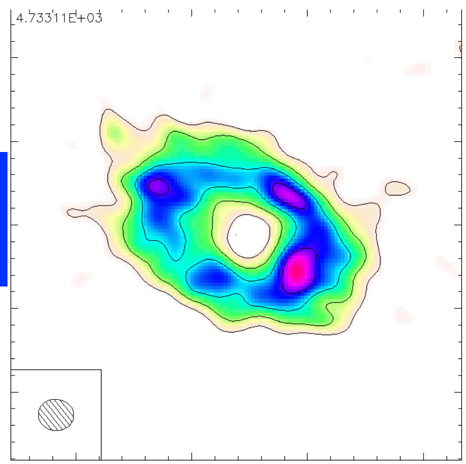




SMA/PdBI 0.87 mm
(Andrews et al. 2011)

ALMA Cycle 1 by the end of 2013

CARMA 1.3 mm
(Isella et al. 2012)

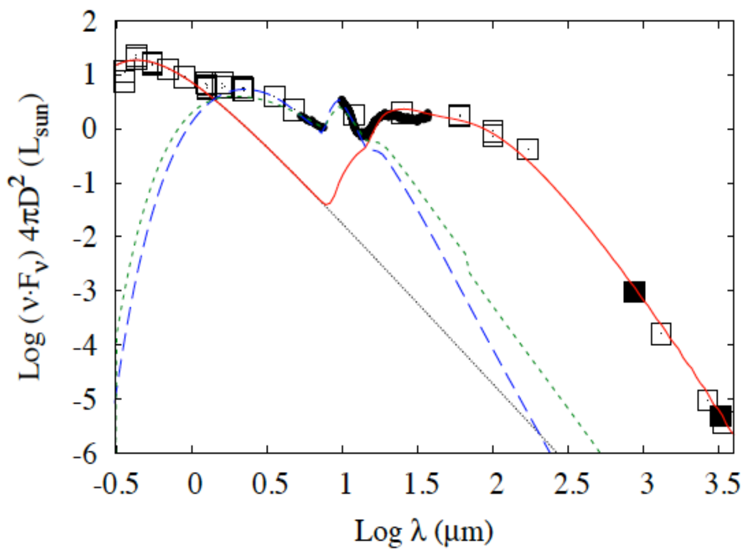


VLA 7mm
(Isella et al. in prep)

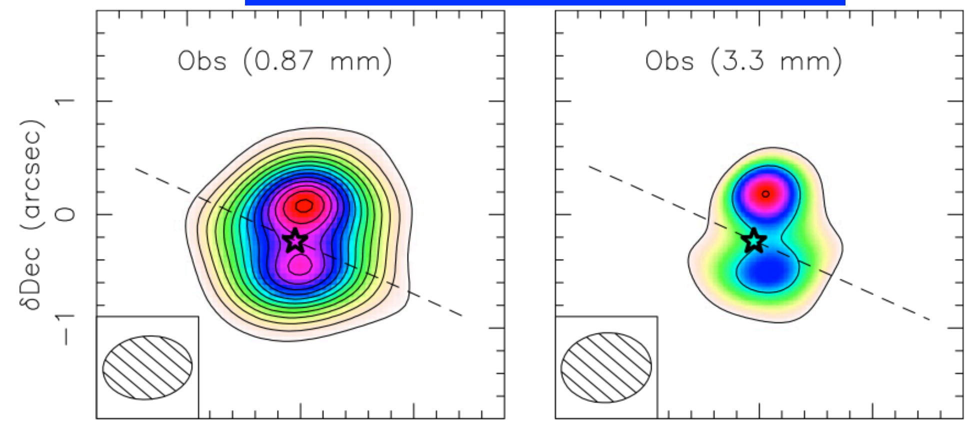
θ = 70 mas/9 AU
rms = 4 μJy

Disk asymmetries: the next step

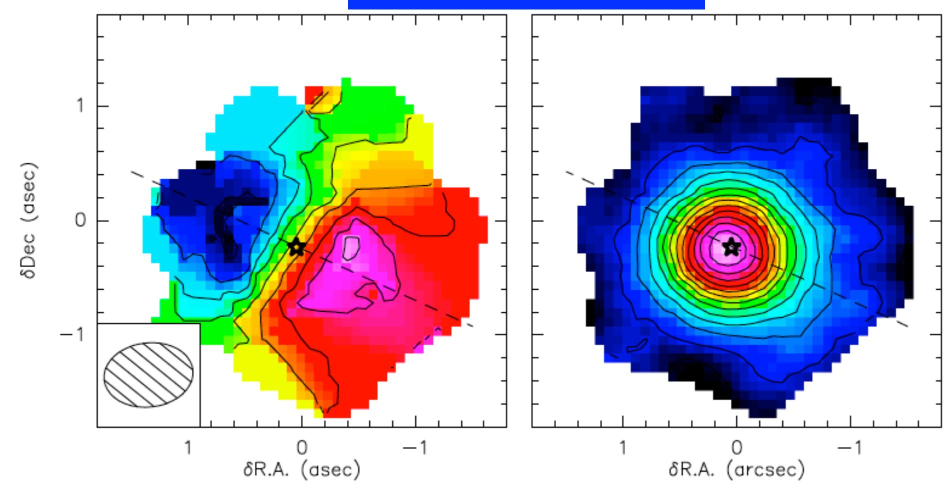
MWC 758 – 2.0 Msun – 3 Myr



Dust thermal emission



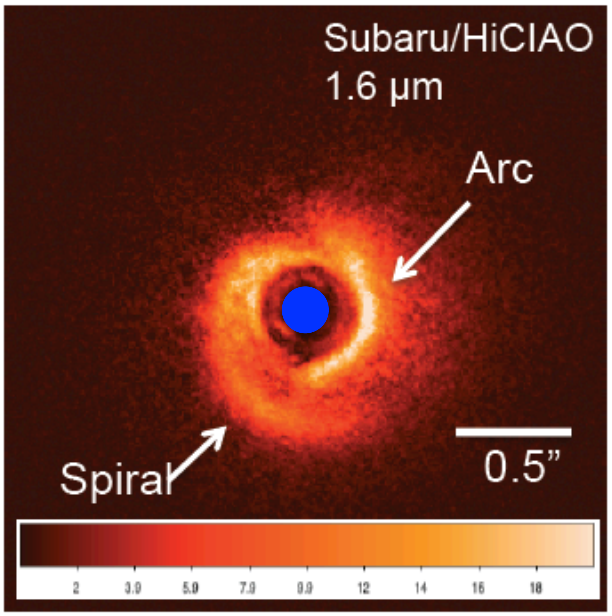
^{12}CO (3-2)



Isella et al. (2010)

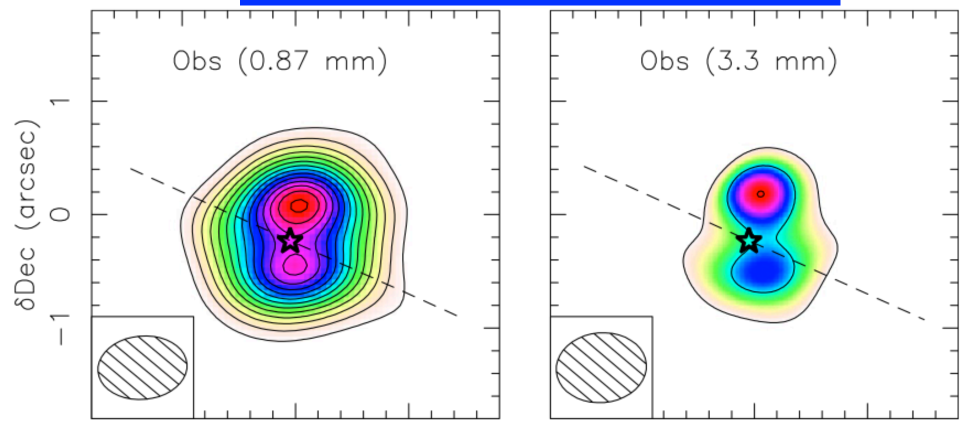
Disk asymmetries: the next step

Scattered light



Grady et al. (2013)

Dust thermal emission



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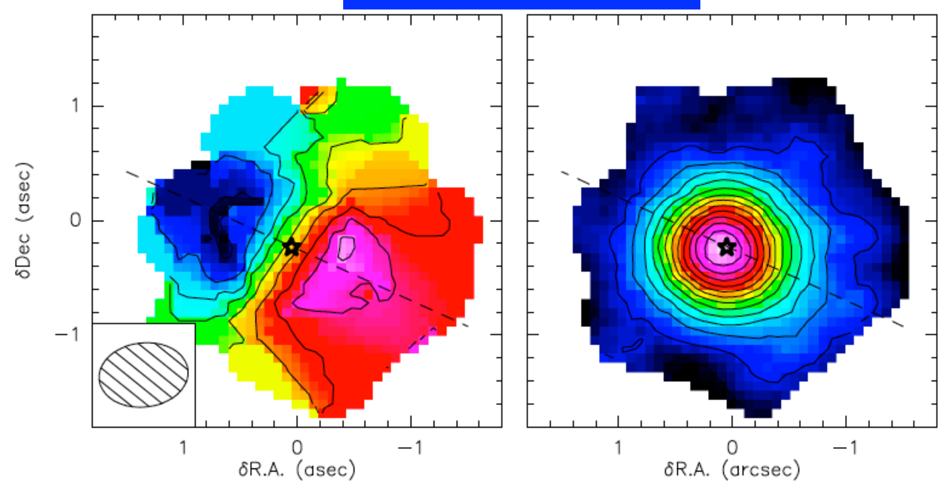

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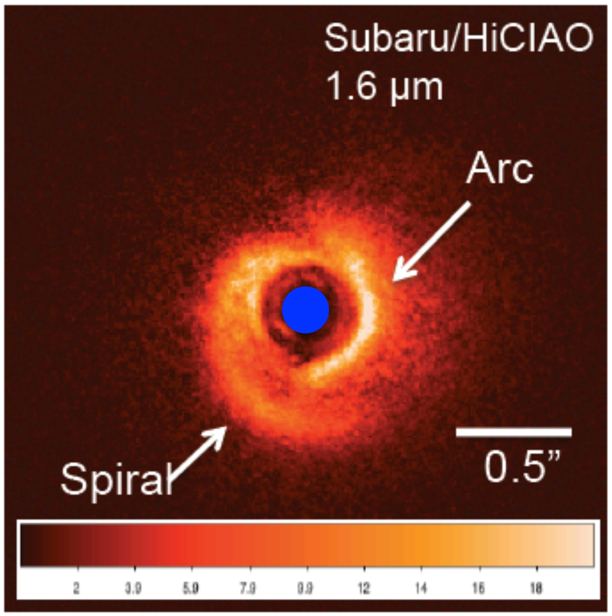
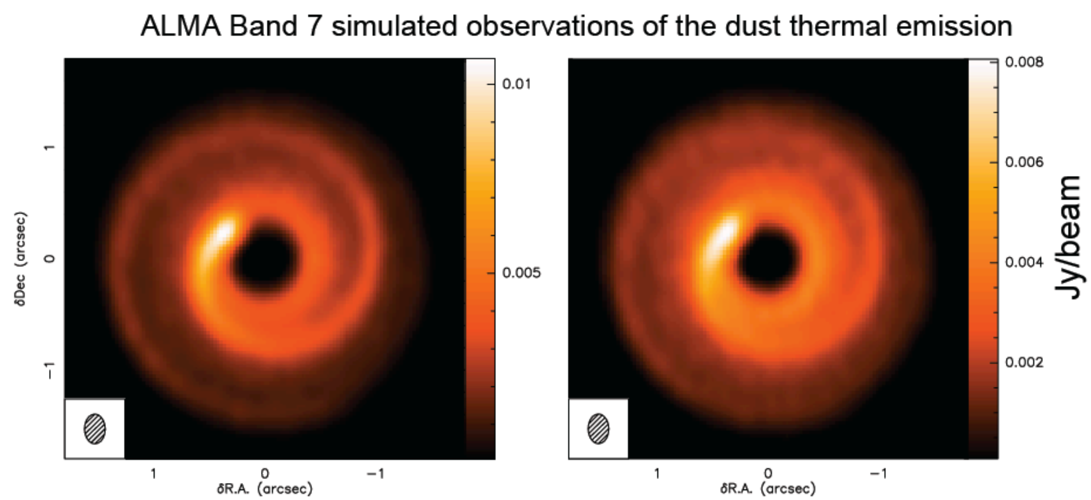


Grady et al. (2013)

ALMA Cycle 1 observations of the dust thermal emission, 13CO and C18O J=3-2



4 M_J planet @ 50 AU

1 M_J planet @ 50 AU

Constrain mass and radius of the perturbing object(s)

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