Planet Formation Beyond ALMA

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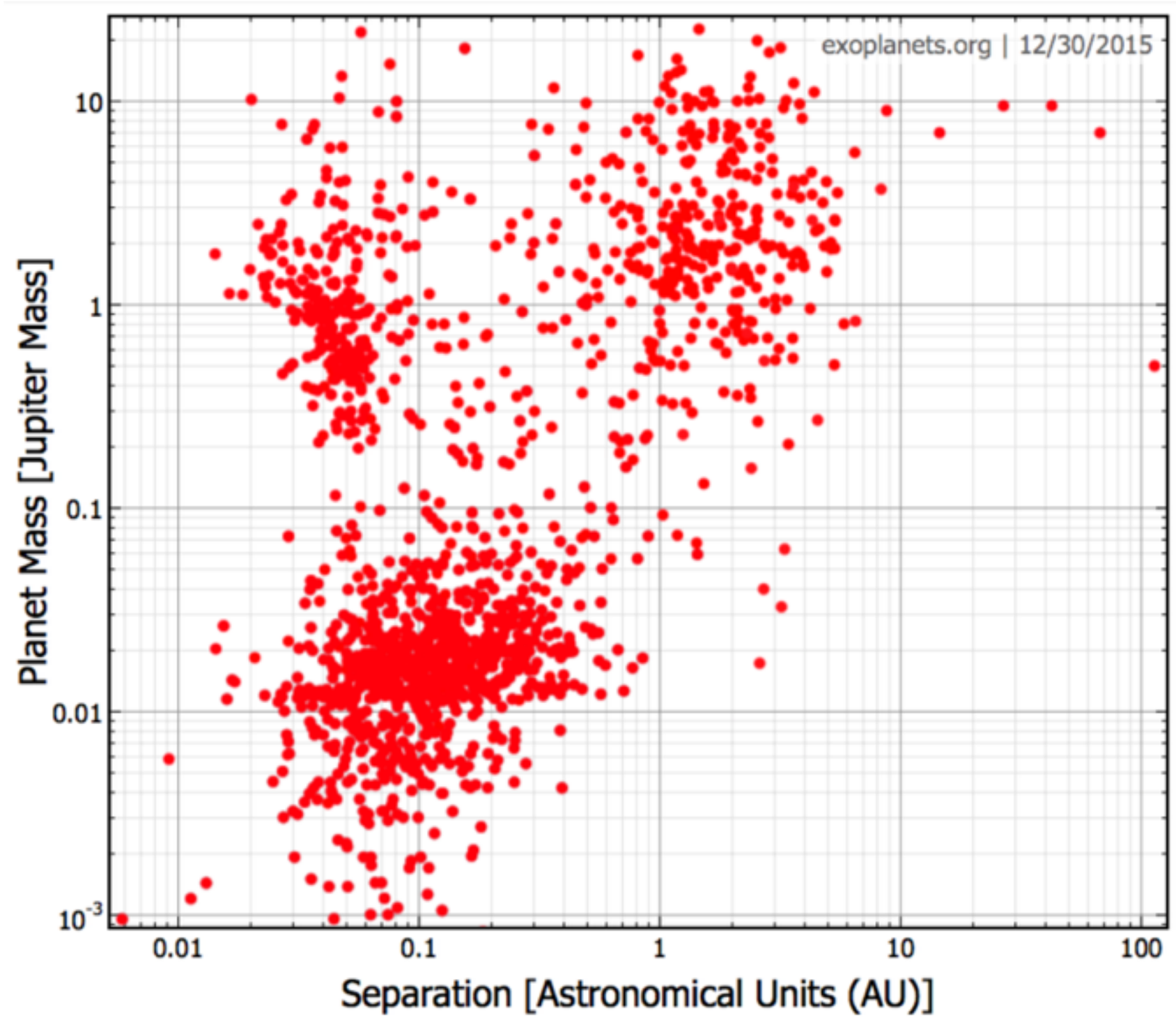
Talk Outline

1. Planet formation revealed by ALMA

2. How can the ngVLA contribute?

Demographics of extrasolar planets

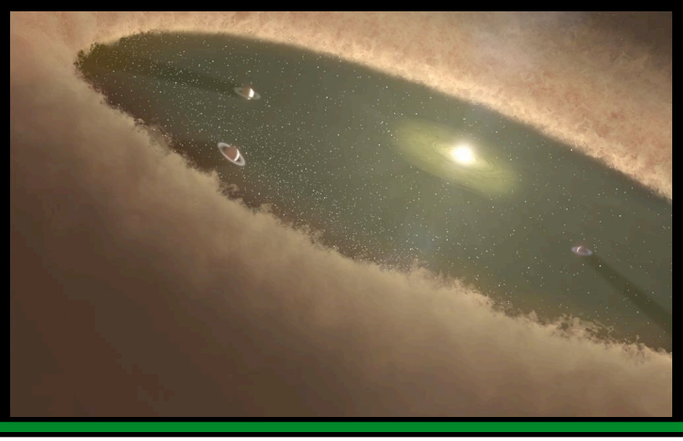


Three stage evolution

Formation stage
Birth - Infancy - Childhood

age < 10 Myr

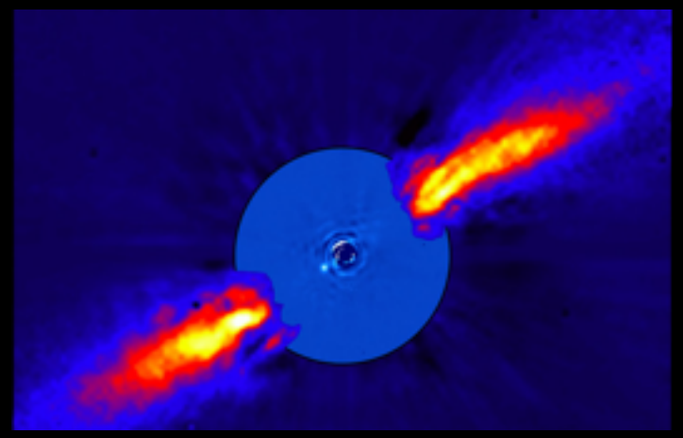
Interaction between planets and the gaseous disk



Early evolution
Adolescence

10 Myr < age < 1 Gyr

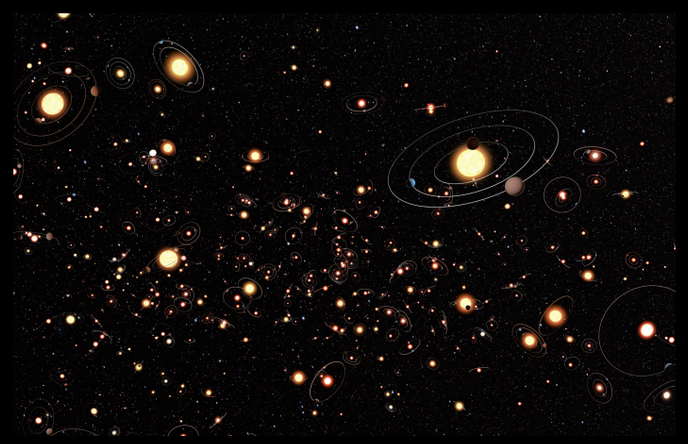
Debris disk planet-planet interaction

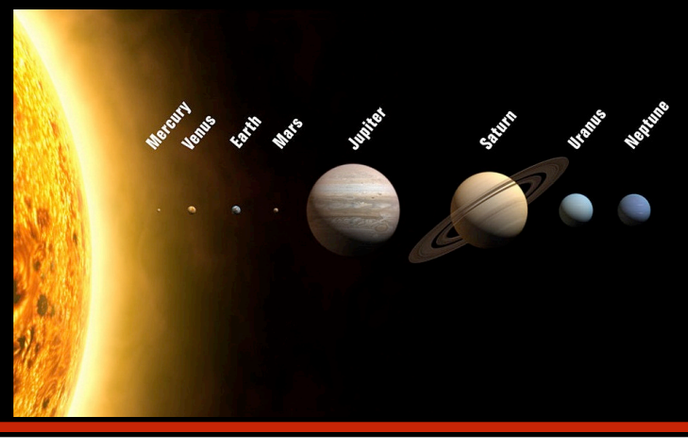


Late evolution
Adulthood

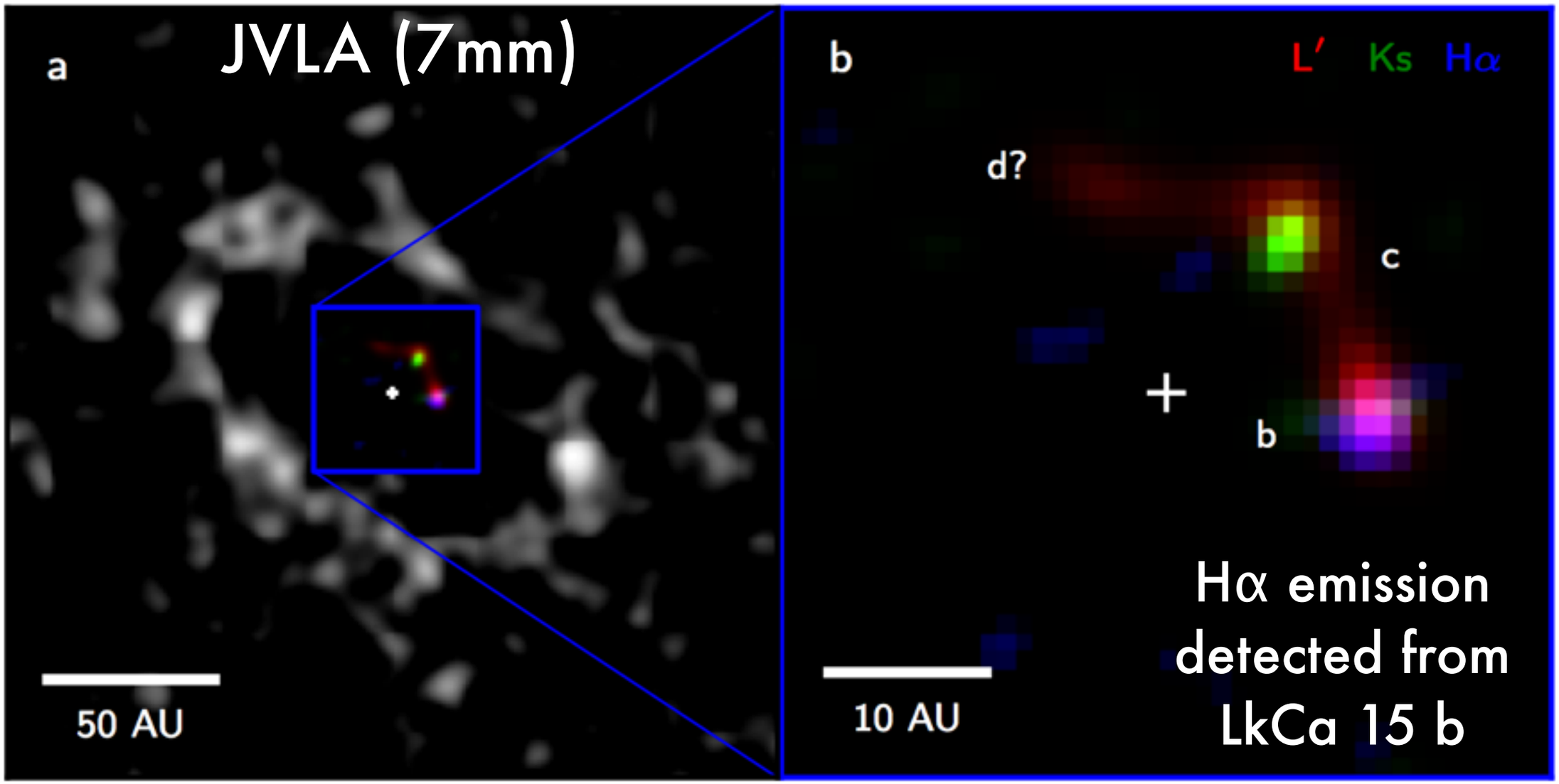
age > 1 Gyr

Debris disk planet-planet interaction





A newborn planetary system

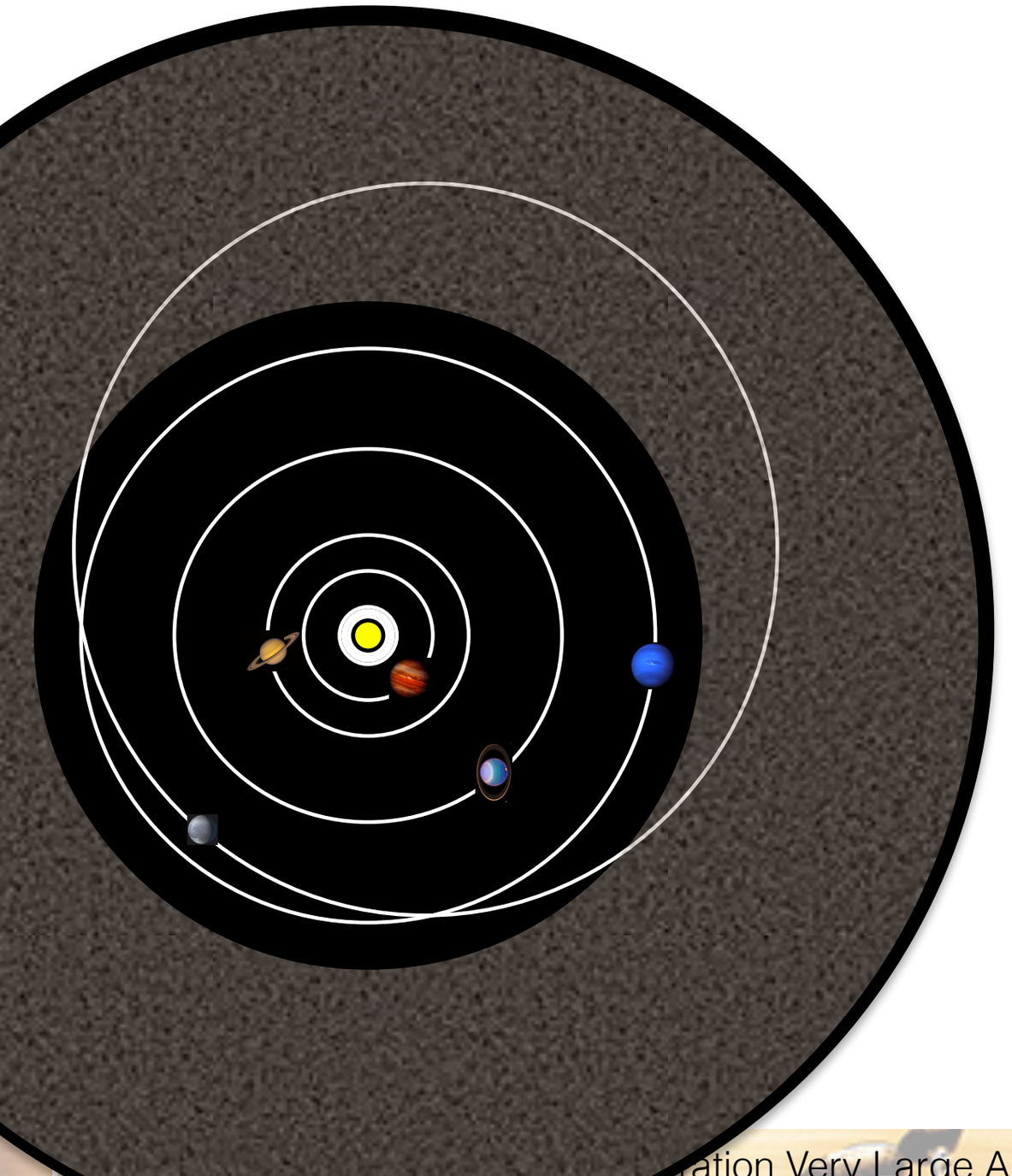


Isella et al. (2014)
Sallum et al. (2015)

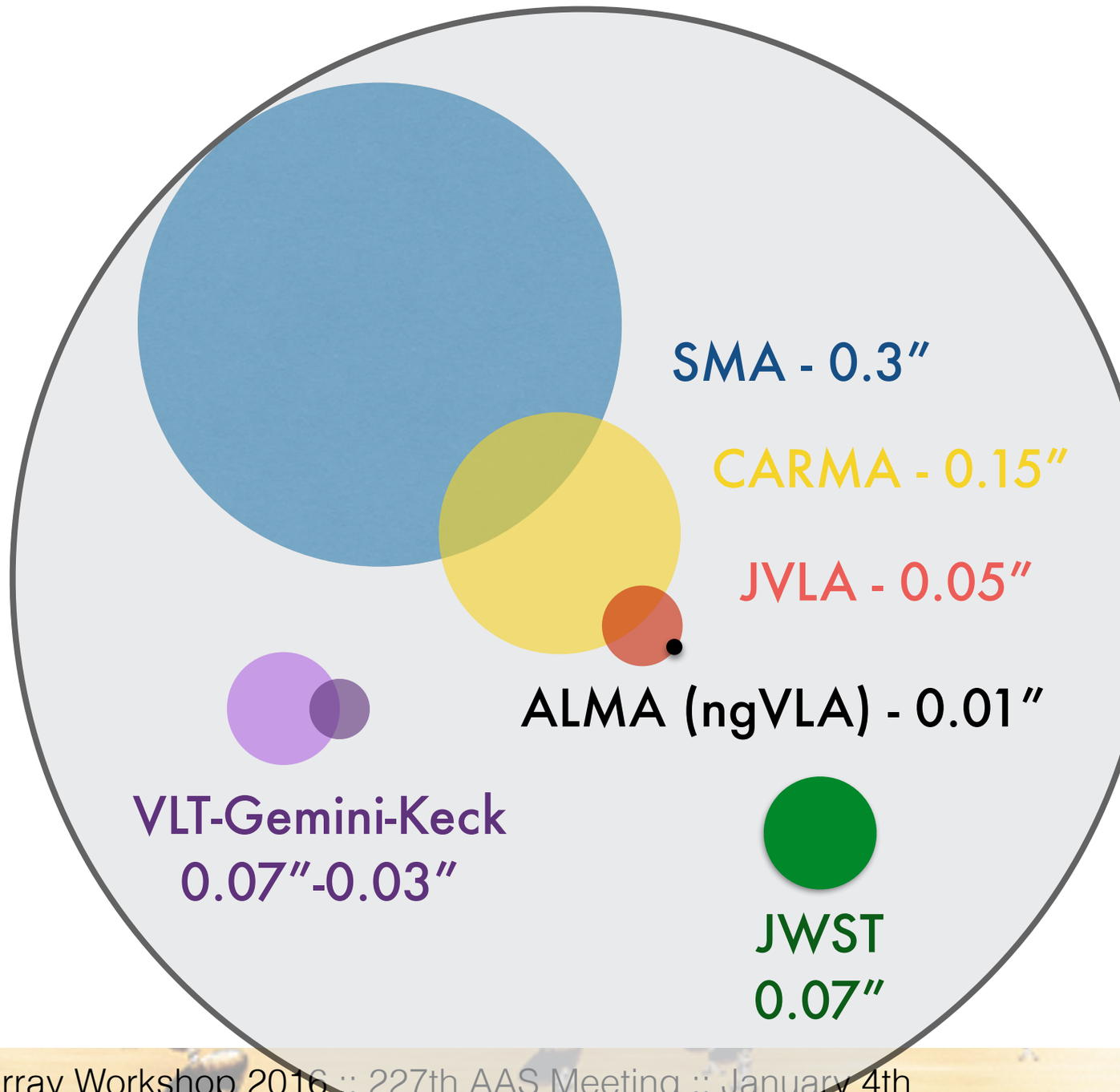
LkCa 15 system
age < 5 Myr

The Angular Resolution is Critical

100 AU

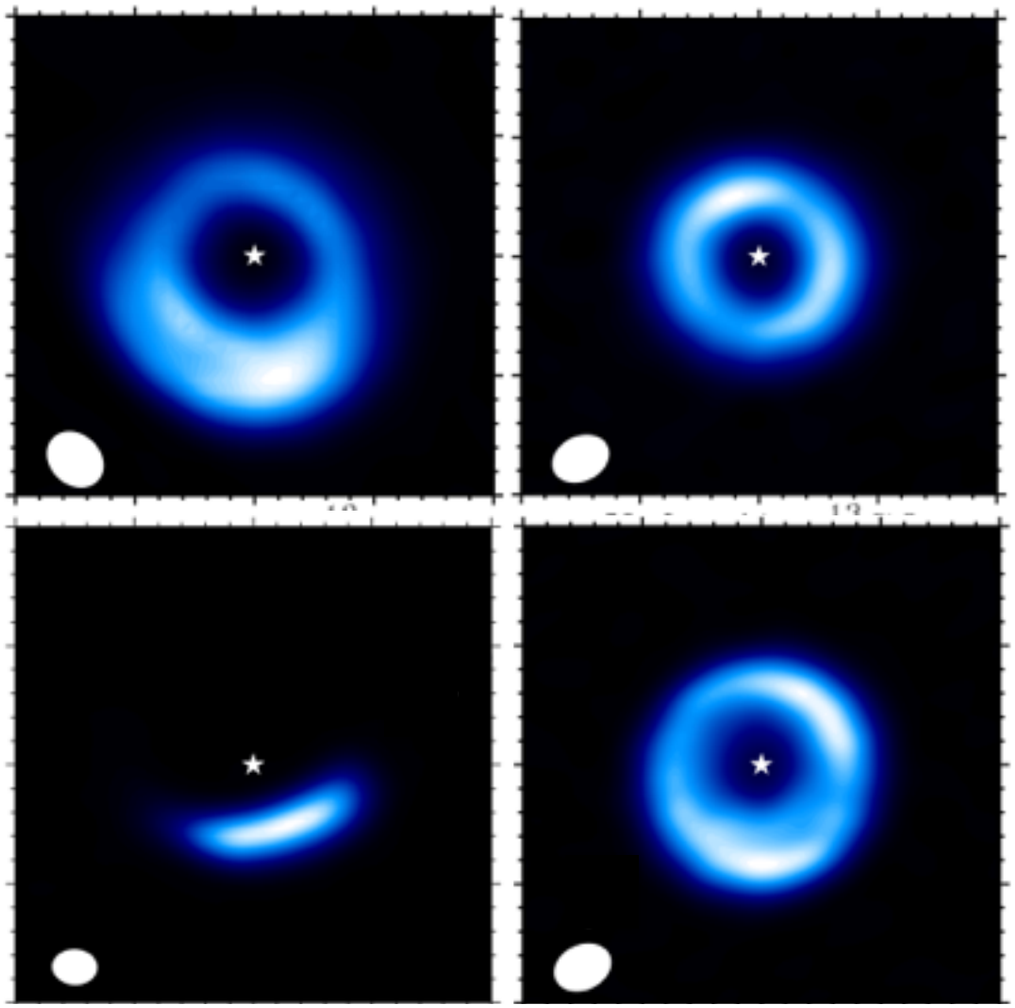


0.7″ @150 pc

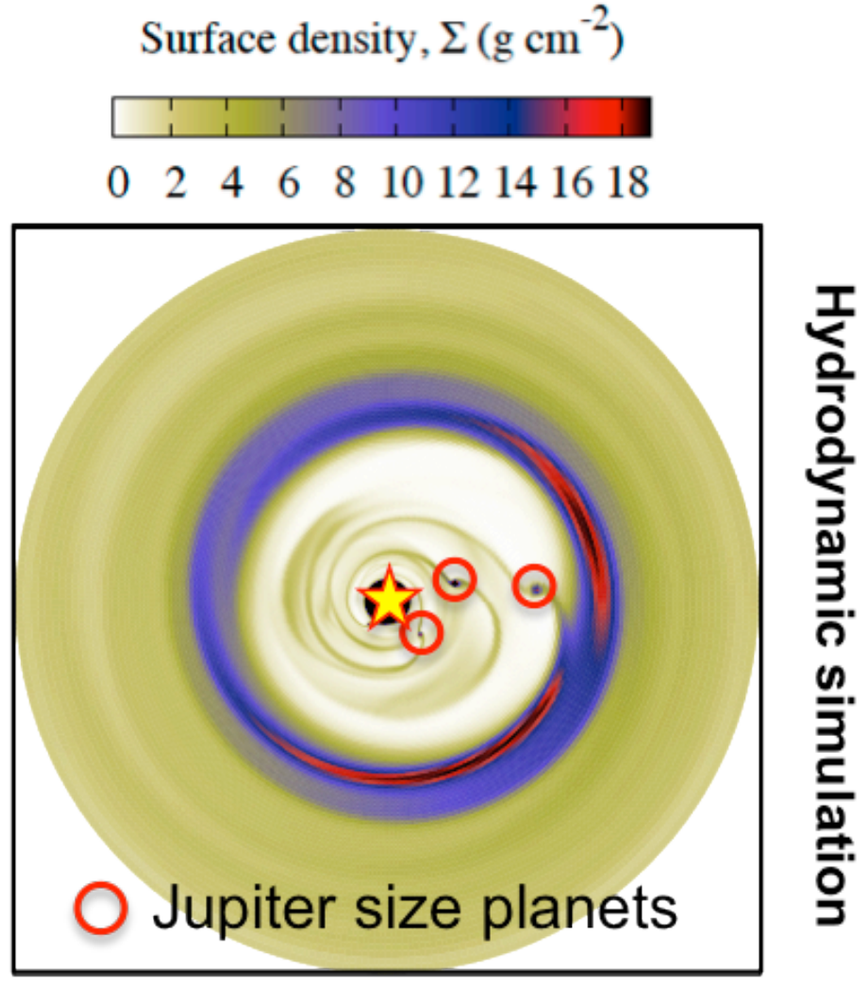


Newborn planetary systems revealed by ALMA

Reveal large scale perturbations on the disk structure possibly caused by the tidal interaction between young planets and the circumstellar material



Dust continuum emission between 345-690 GHz
Resolution of 0.2", corresponding to 30 AU



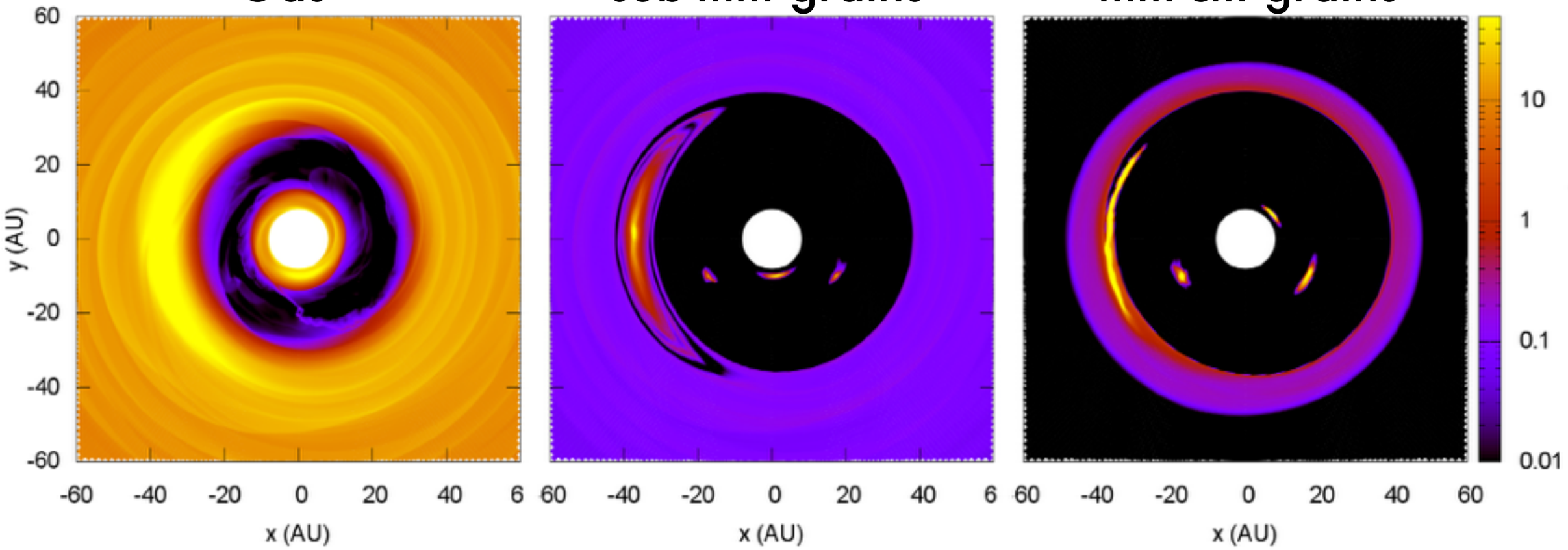
Isella et al. (2013)
Perez et al. (2014)
Van der Marel et al. (2015)

Dust Traps

(ALMA)
Gas

(ALMA)
sub-mm grains

(JVLA)
(ngVLA)
mm-cm grains

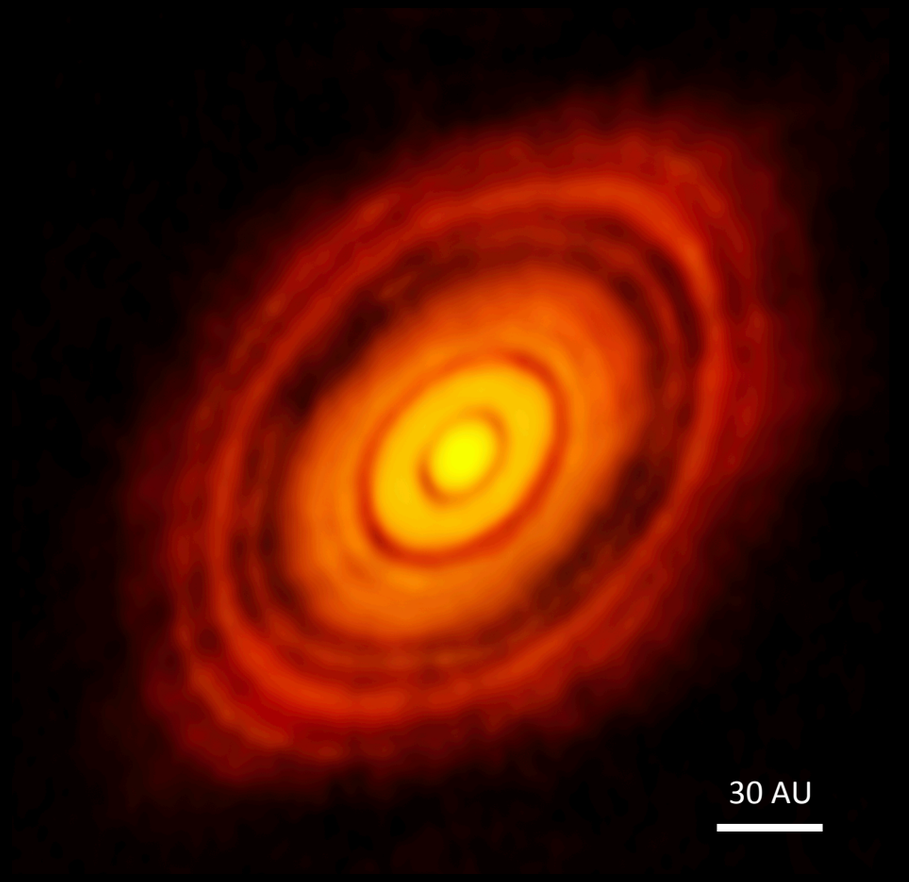


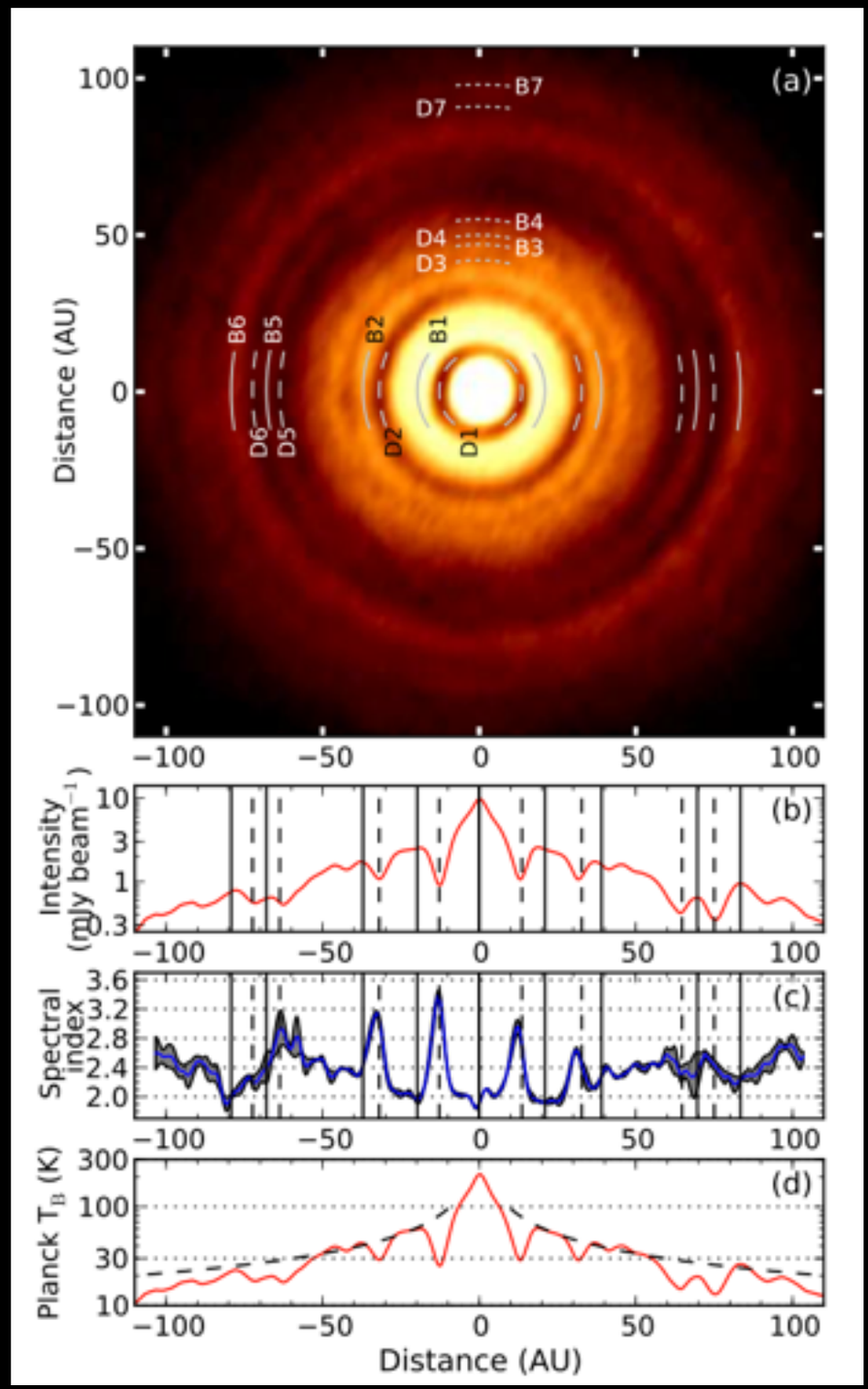
Dust traps might be crucial in forming planetesimals (aka, asteroids and comets) far from the central star.

Isella et al. (2015)
Fu et al. (2014)

HL Tau

(ALMA commissioning data - dust continuum at 1mm)

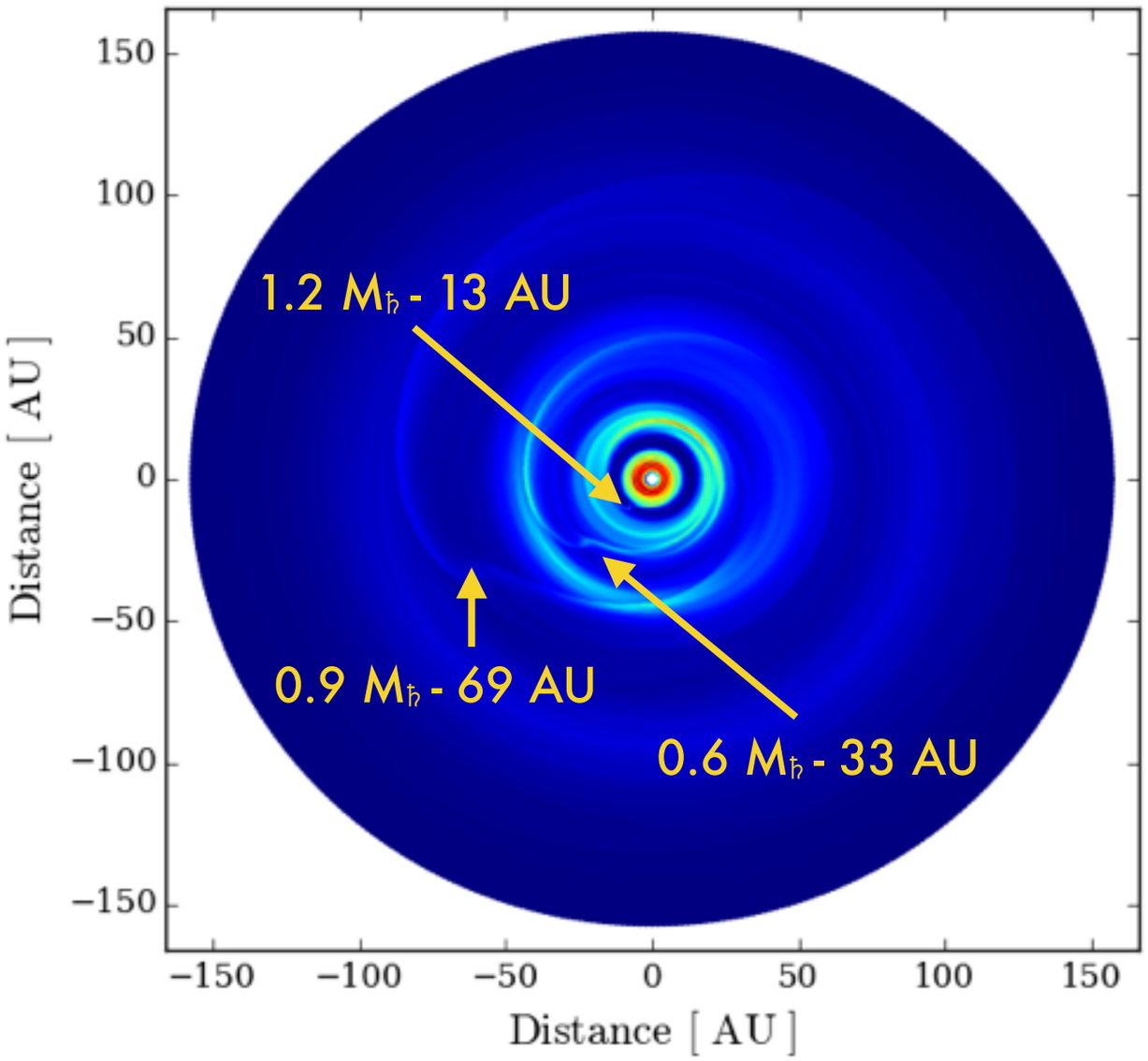


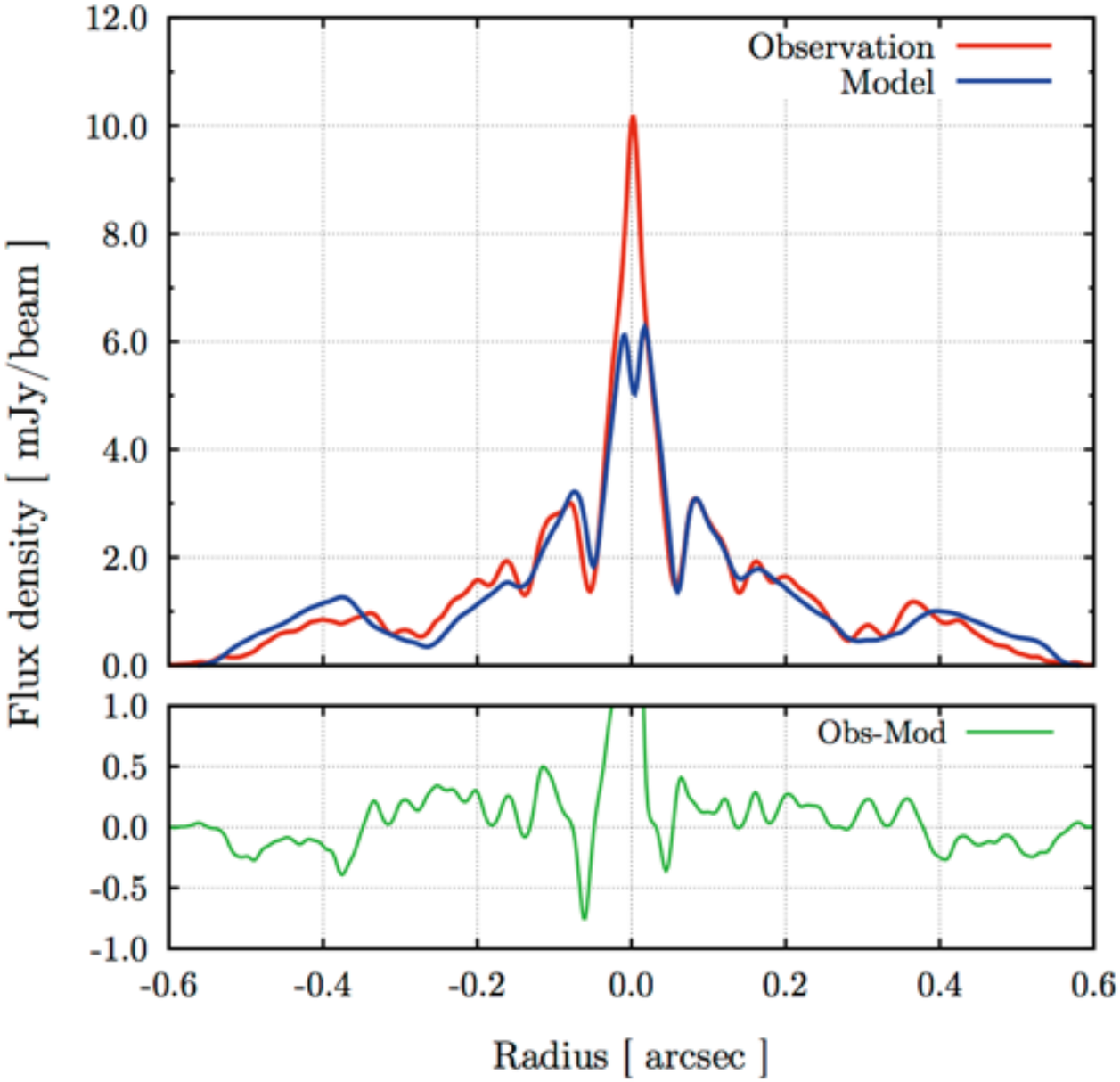


Alma partnership (2015)

HL Tau disk shaped by the planet-disk interaction

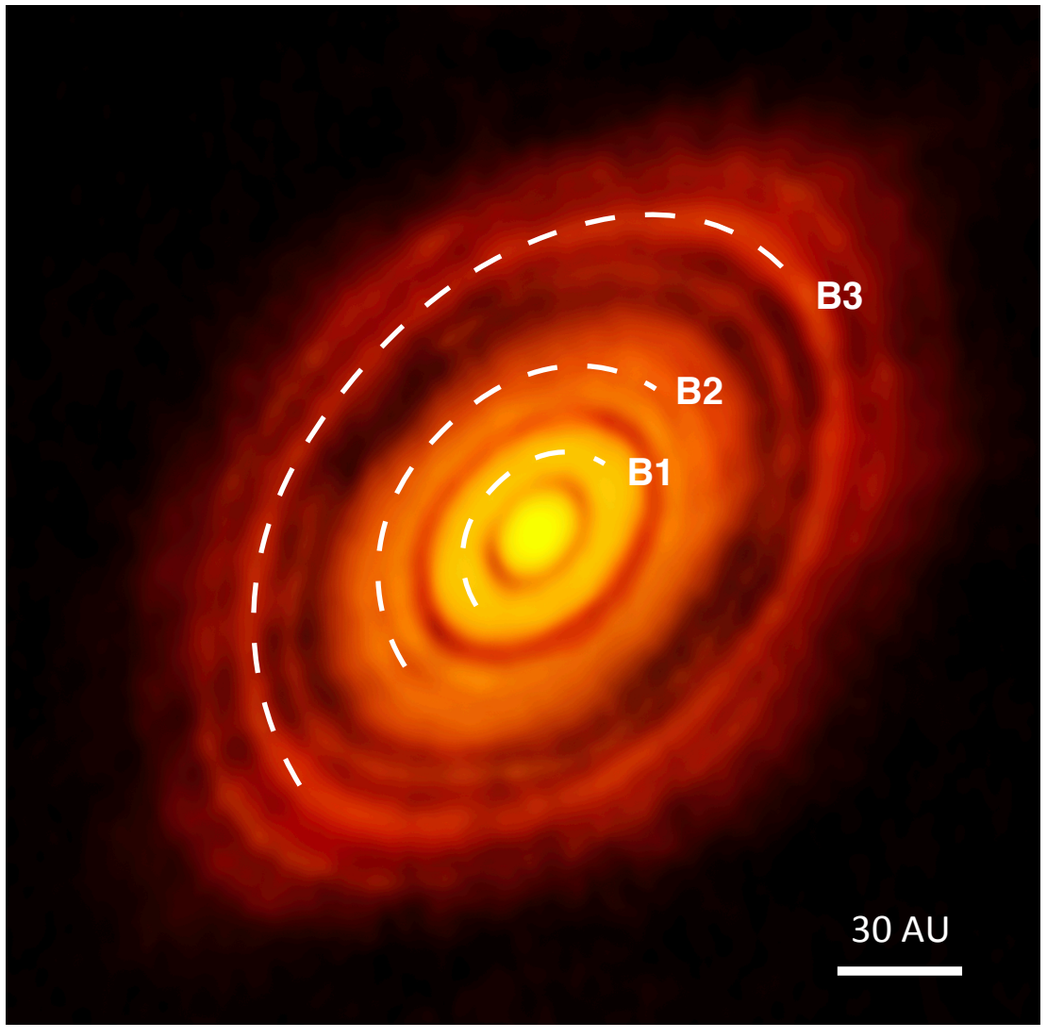
Li S. et al (2016, ApJ, in press)





The optical depth problem

ALMA partnership (2015)



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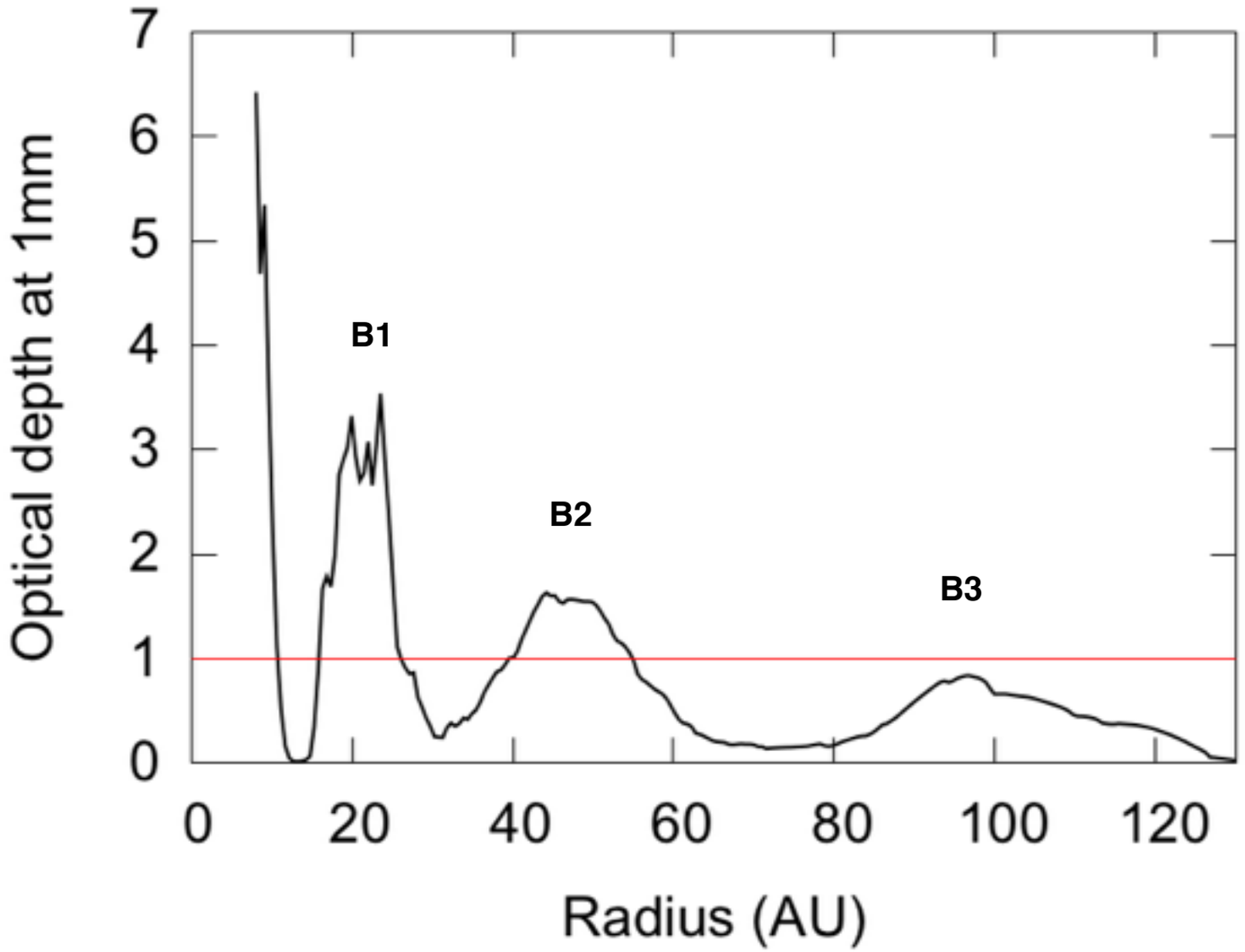
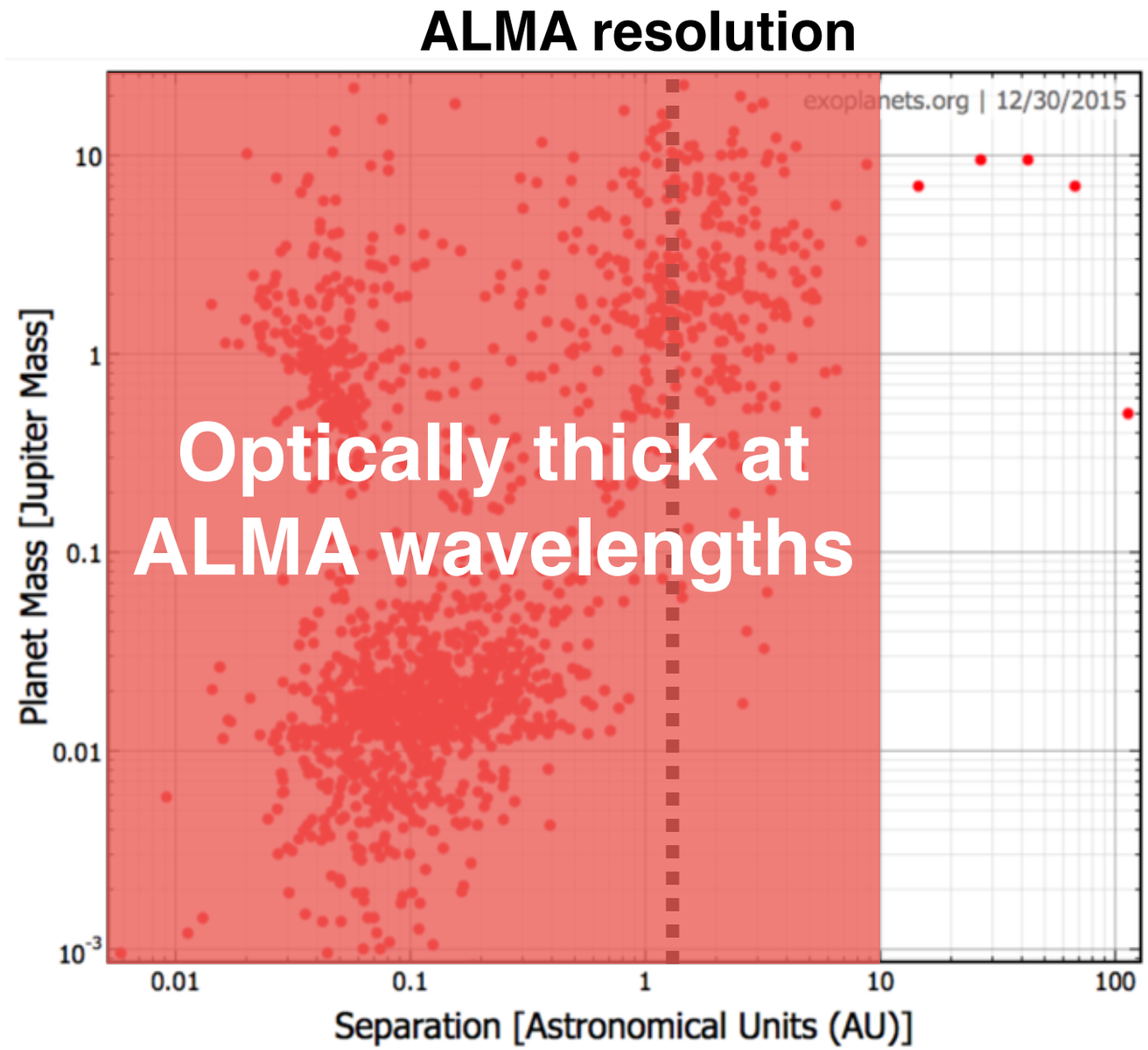


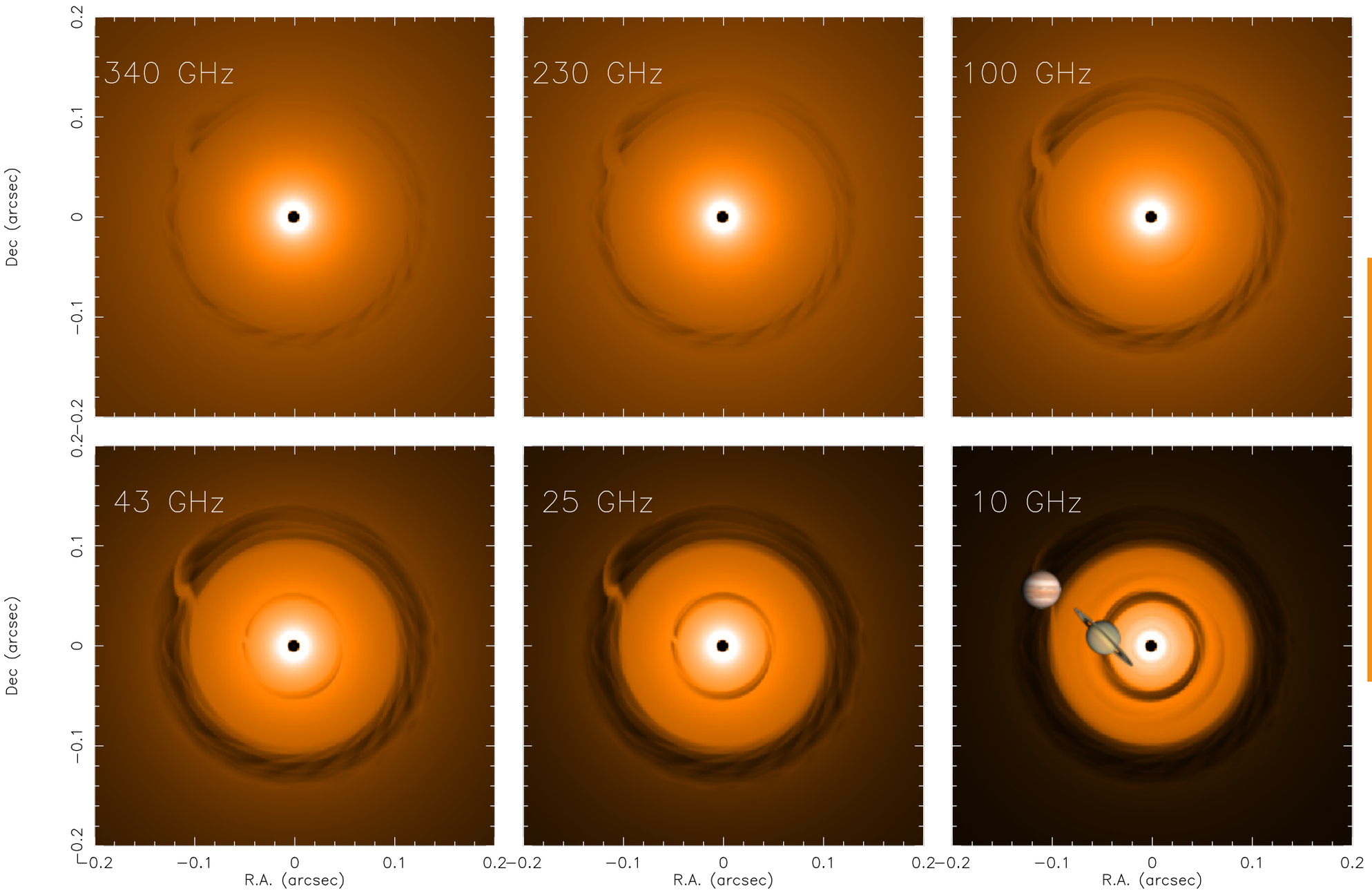
The optical depth problem

The regions where most of the planets form
are optically thick at the wavelengths covered by ALMA.



ngVLA view of the planet-disk interaction

Longer wavelength observations mitigate the optical depth problem



The ngVLA will allow to follow the temporal evolution of forming planetary systems

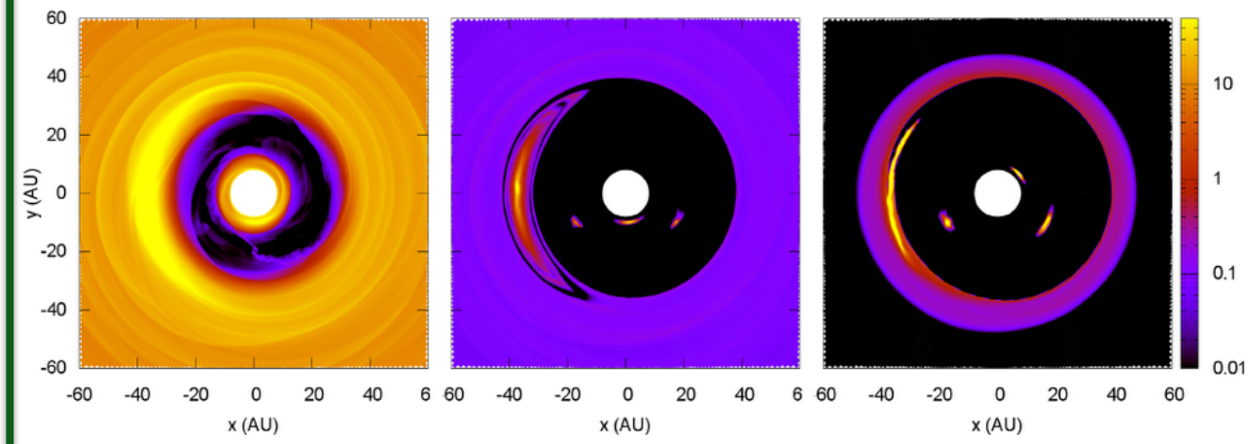
Isella et al. (2015, ngVLA white paper)

Conclusions

(ALMA)
Gas

(ALMA)
sub-mm grains

(JVLA)
(ngVLA)
mm-cm grains

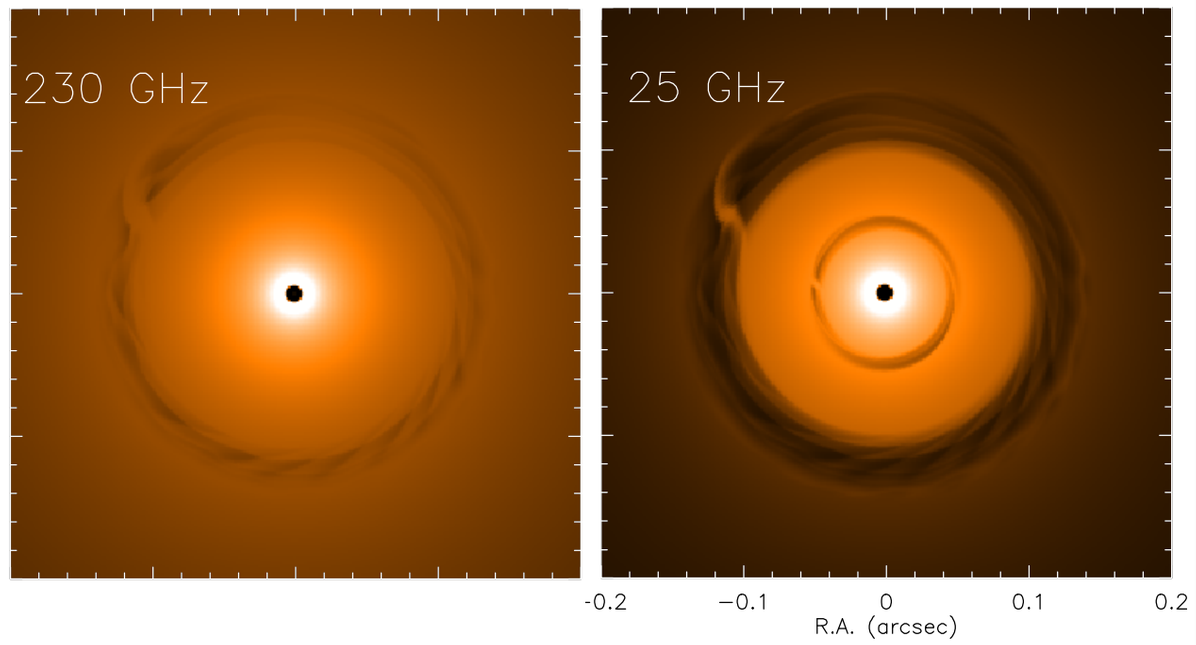


Study the distribution of pebbles (mm-cm). Complementary to ALMA observations, which probe the distribution of dust (sub-mm).

Map the disk-planet interaction in the terrestrial planet forming region, which is not accessible by ALMA due to the large optical depth

(ALMA)

(ngVLA)



Personal Considerations

1. the ngVLA is not alternative to or in competition with ALMA nor SKA.
   We need the ngVLA to make the best use of ALMA and SKA.
   We want the ngVLA because we have ALMA!

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2. What is the main problem in building the ngVLA? Money!

   ALMA: $0.5 B over 11 years + $34 M yearly (NSF contribution only)
   $0.3 per US tax payer PER YEAR over a period of 15 years

   ngVLA: ~ 5x ALMA (?) = $1.5 per US tax payer PER YEAR over a period of 15 years
   (most of these money will stay in the US!)

   JWST: $5.2 per US tax payer per year over a period of 7 years

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3. How can we train the next generation of (US) radio astronomers without facilities accessible to students?
   We should think about the role that the Universities might play in the construction of the next generation radio facilities. Is the "optical-infrared model" applicable to the microwave and radio domain?