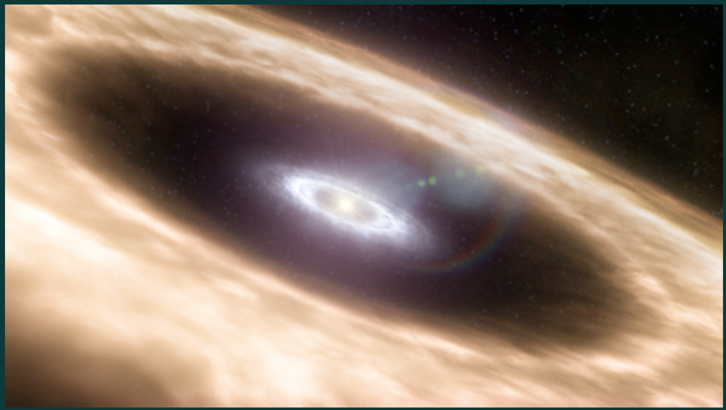
Probing the Origin of Planetary Systems

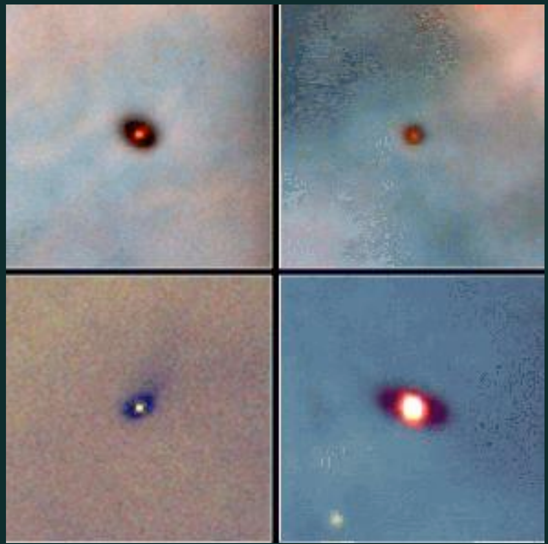
John Carpenter (Caltech)



Andrea Isella • Luca Ricci • Laura Perez

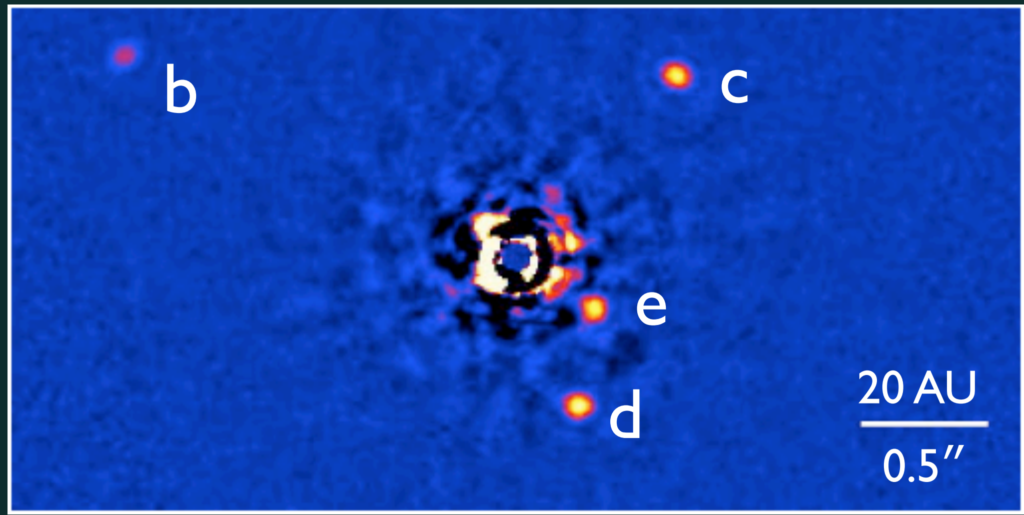
Disks to Planets

Silhouette disks in Orion



McCaughrean & O'Dell 1995

Planets around HR 8799



Marois et al. (2011)

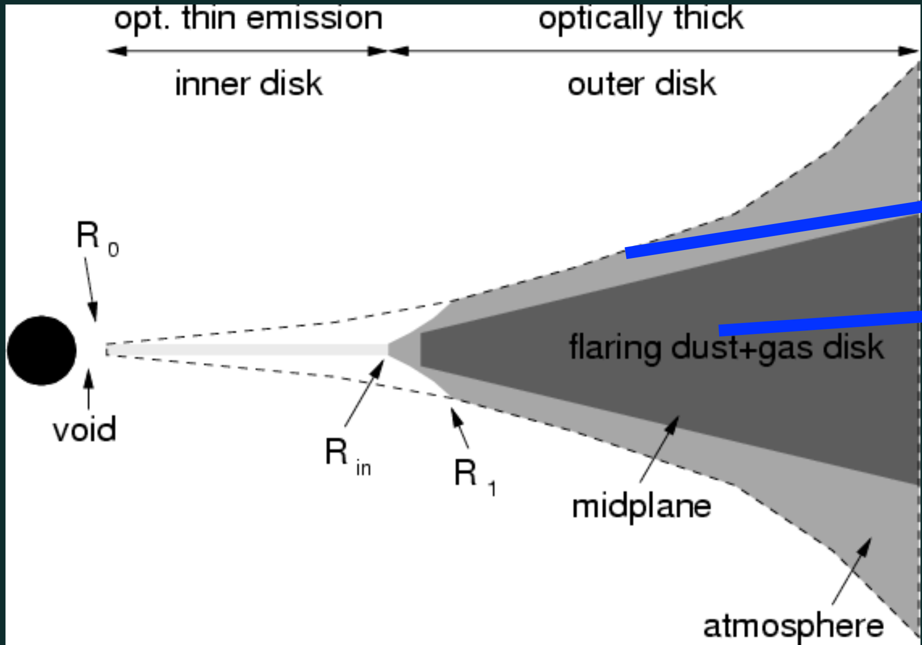
What is the mass distribution in the disk?

Where in the disk do planets form?

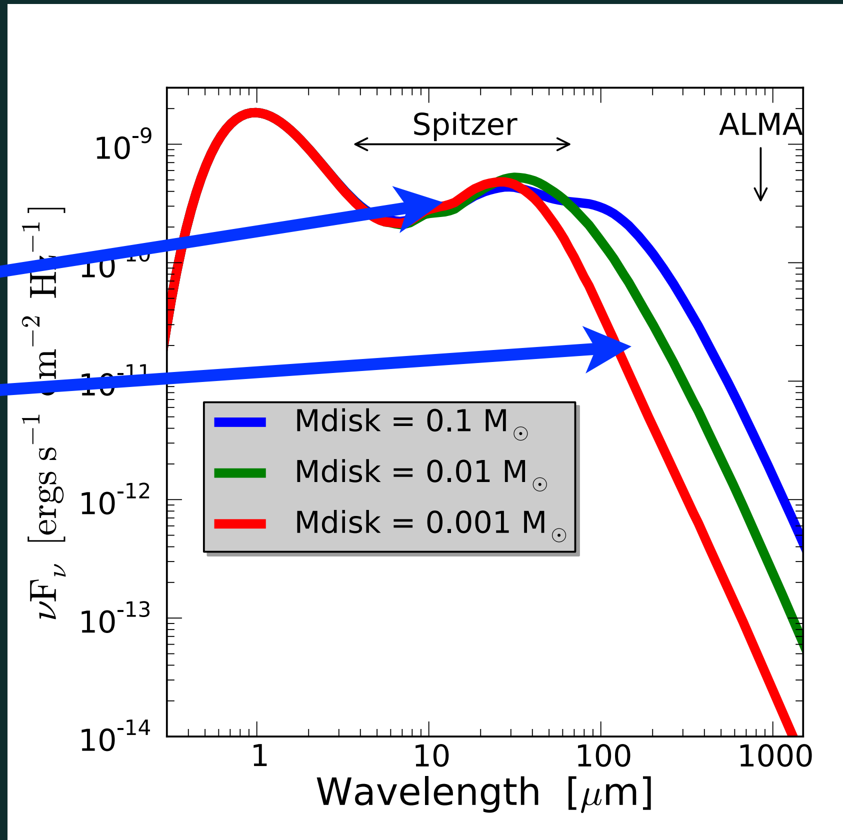
When do planets form?

➡ Observe the location of the gas and dust

Why (sub-)millimeter?

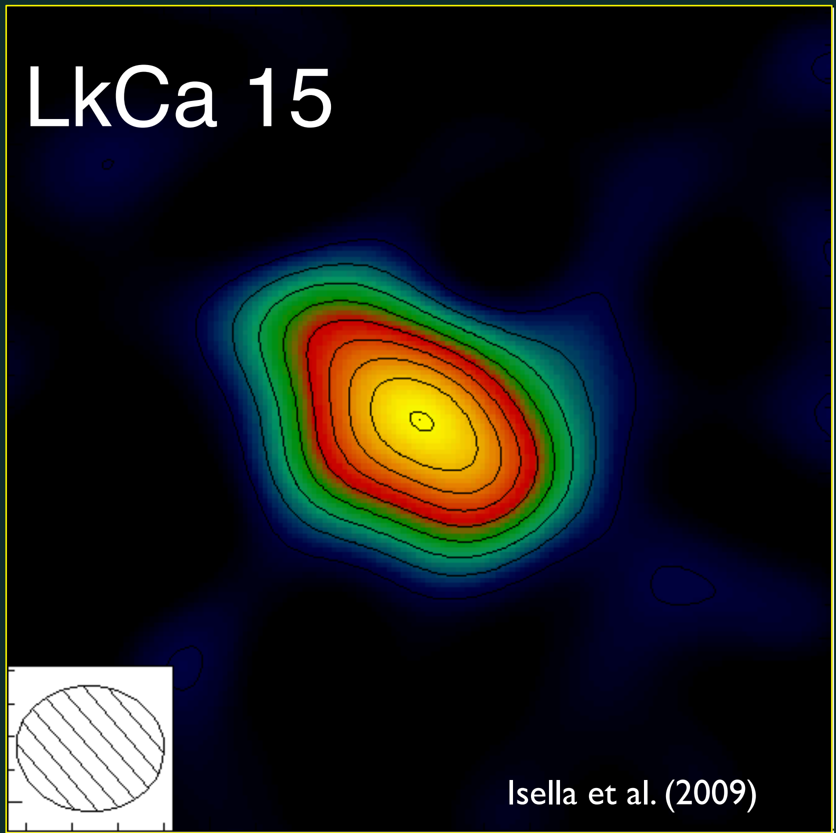


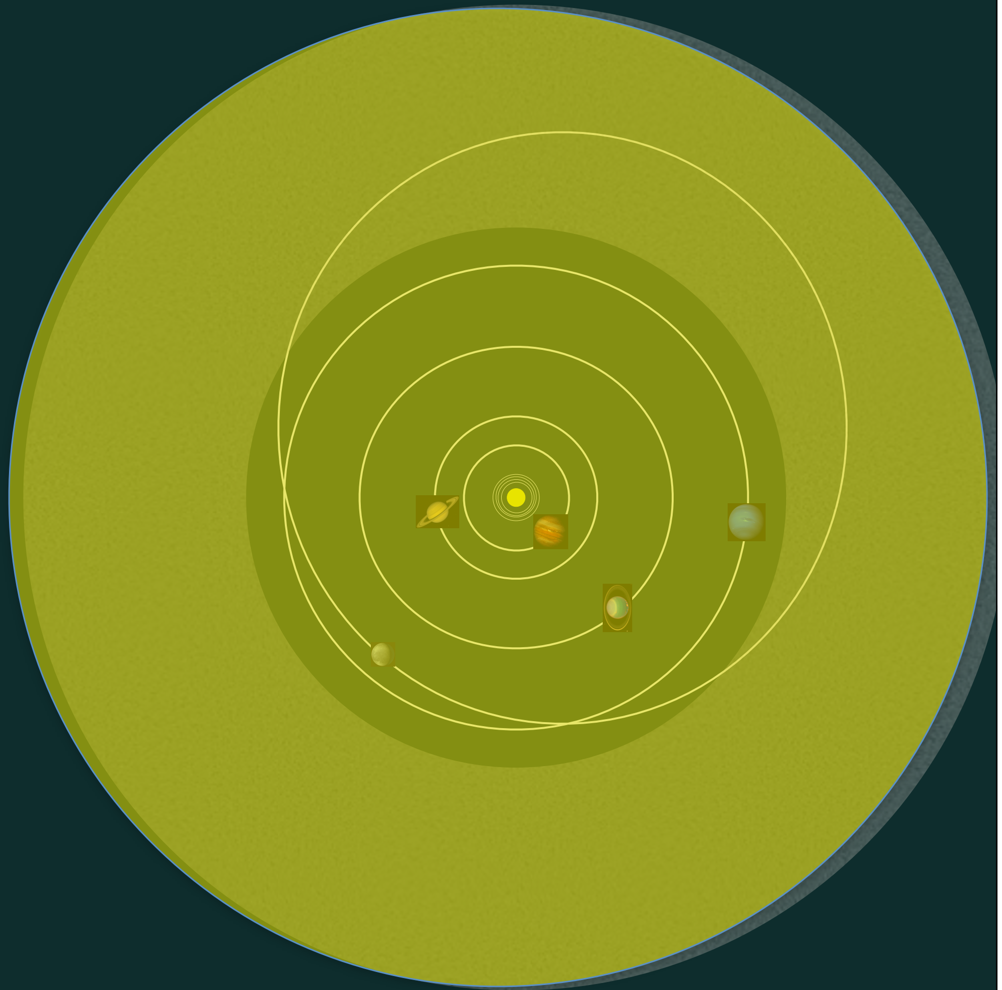
Ratzka et al. 2007



Why ALMA? Because resolution is Critical

CARMA observations @ 1.3 mm

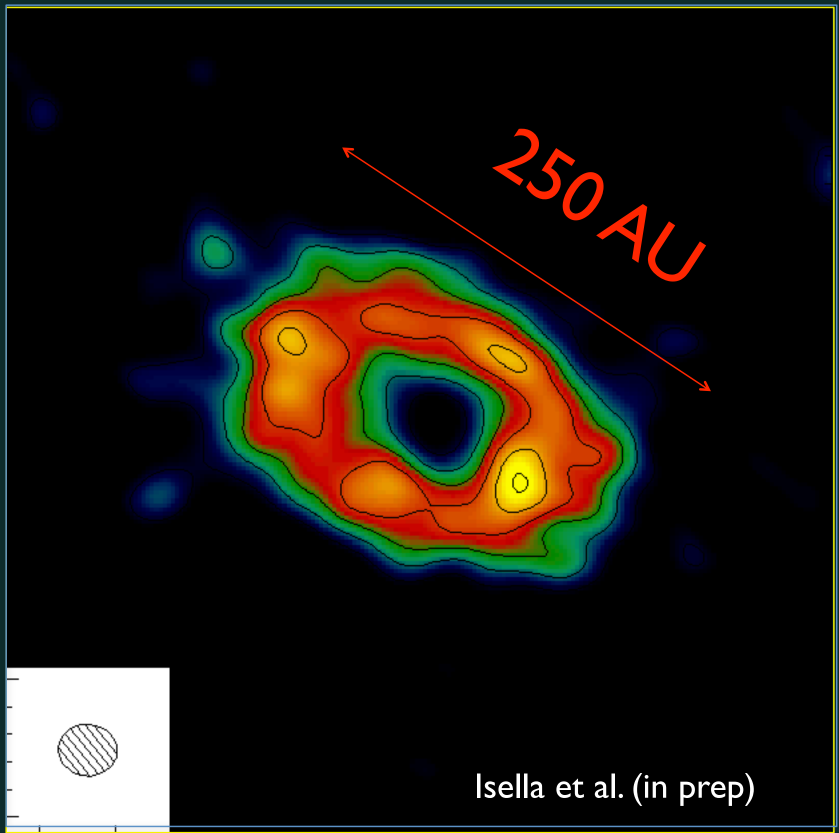


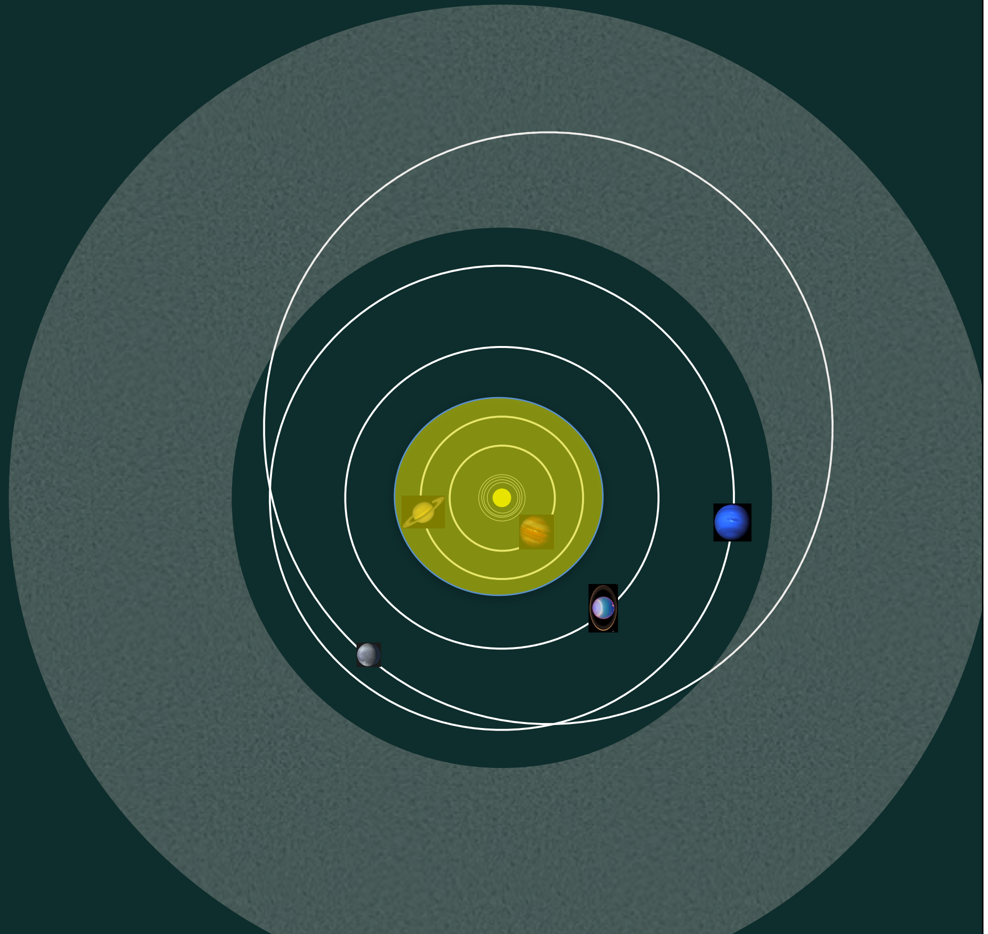


0.8″, or 110 AU at 140 pc

Why ALMA? Because resolution is critical

CARMA observations @ 1.3 mm

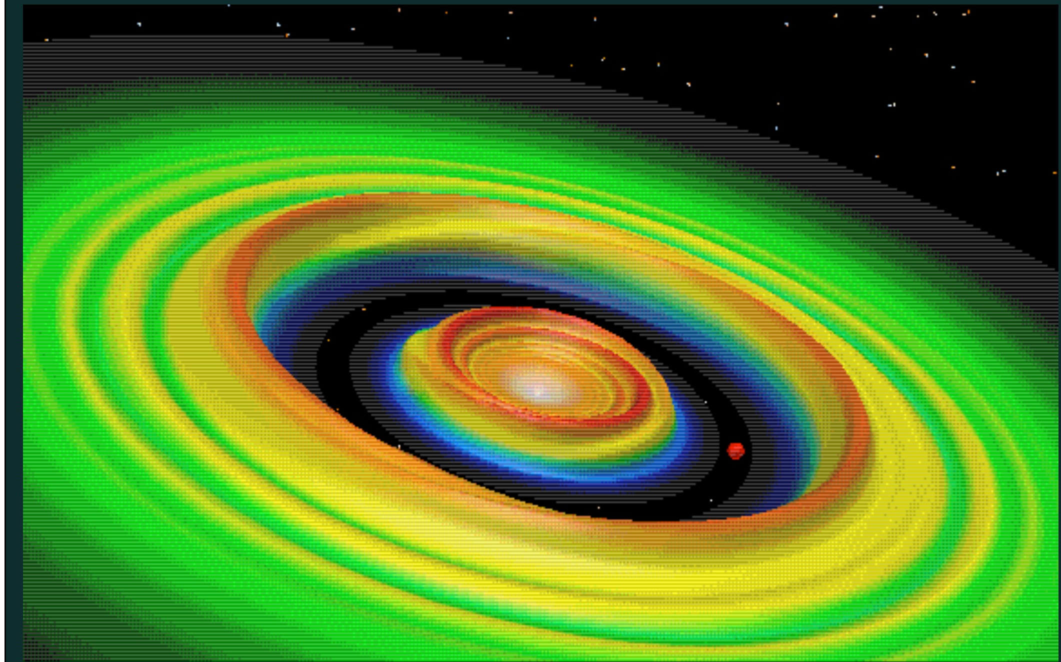




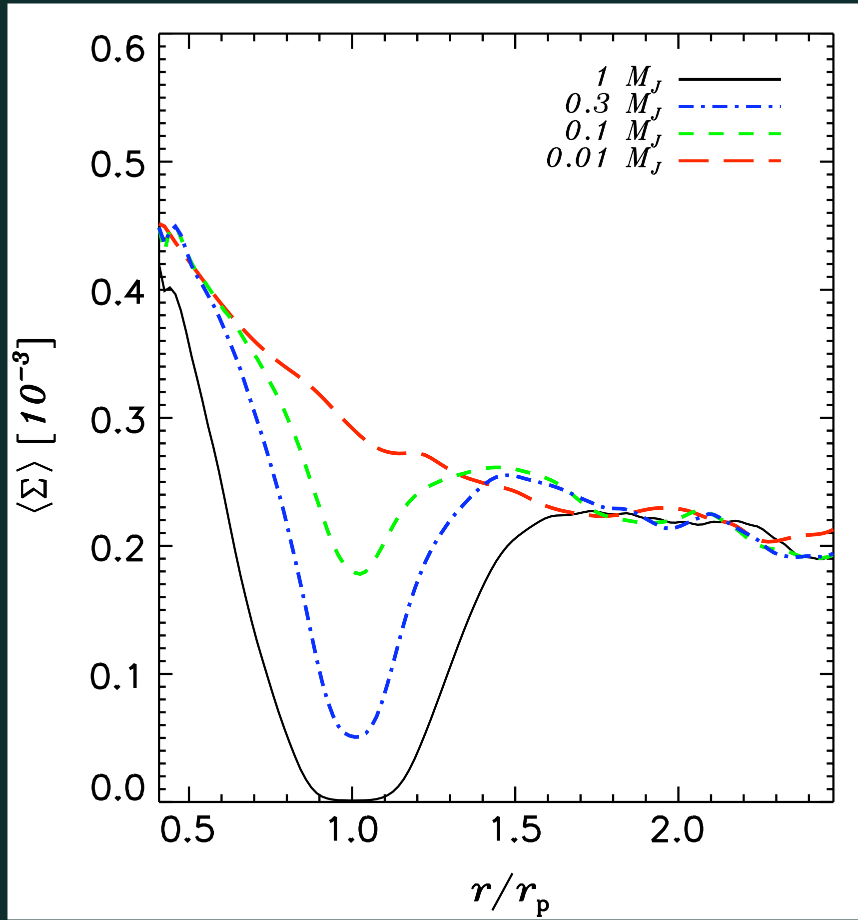
ALMA will provide angular resolution down to 0.01″, or 1.5 AU @ 140 pc

Dynamical Signatures of Planets

Embedded planets create gaps in disks



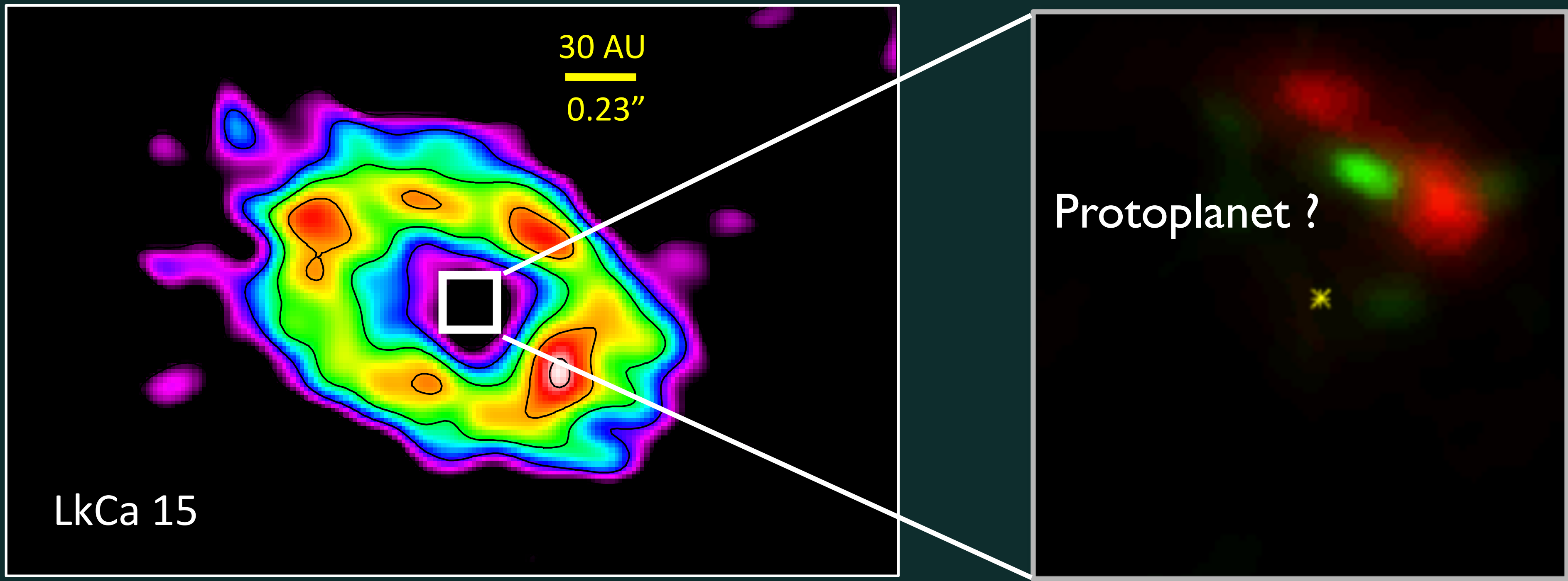
Simulation from Geoff Bryden



Wolf et al. (2007)

LkCa 15: “Transition” Disk

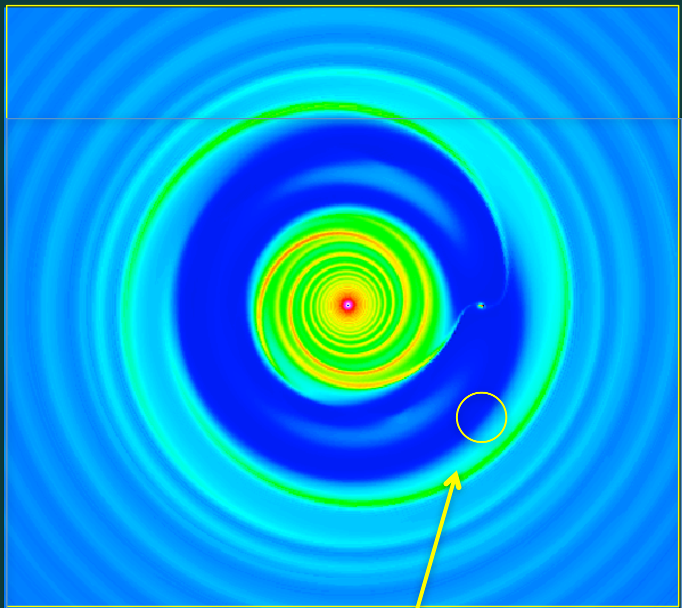
Keck 2.2/3.4μm image



Kraus & Ireland (2011)

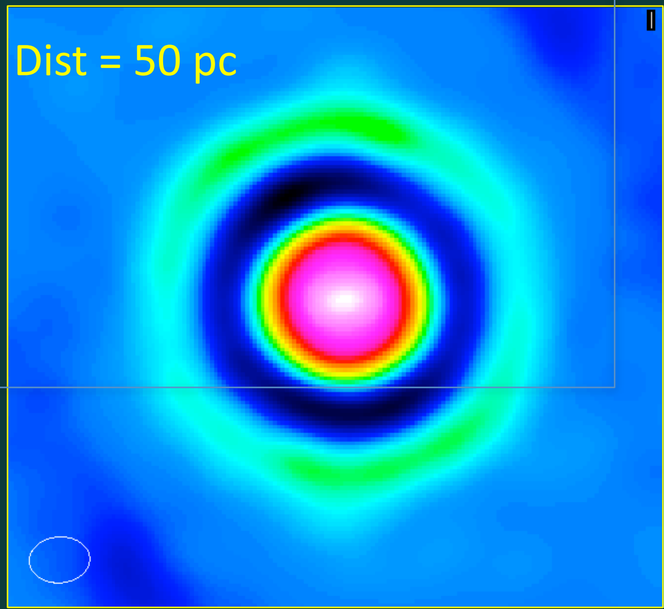
Signatures of planets in circumstellar disks

MODEL



1 M_J @ 10 AU
Mstar = 0.5 Msun

SIMULATED OBSERVATIONS



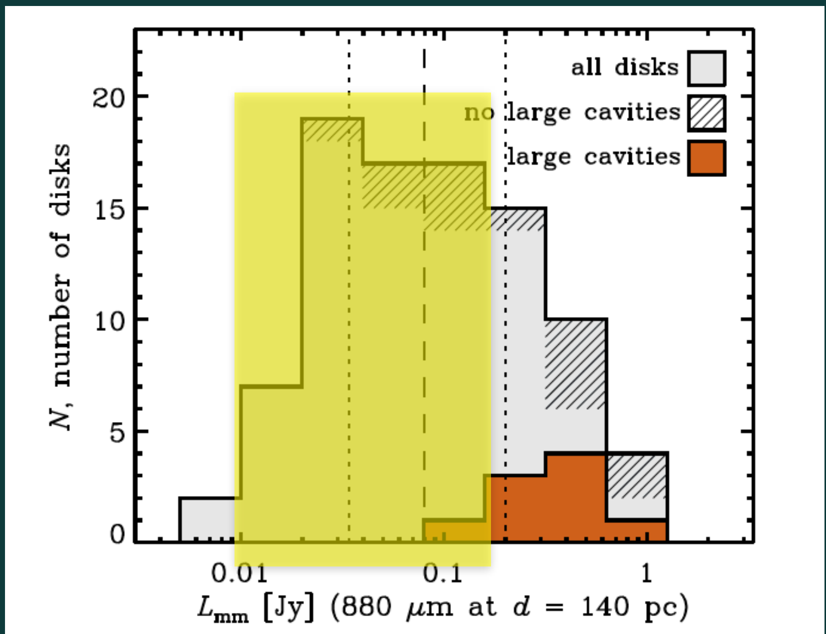
Freq = 680 GHz (Band 9)
Baseline = up to 500 m
# Ant = 16
Tint = 5 hr
noise = 0.2 mJy/beam
Beam size = 0.23″x0.17″
Weighting = natural

Detect Radial Gaps

Extending the observations to fainter disks

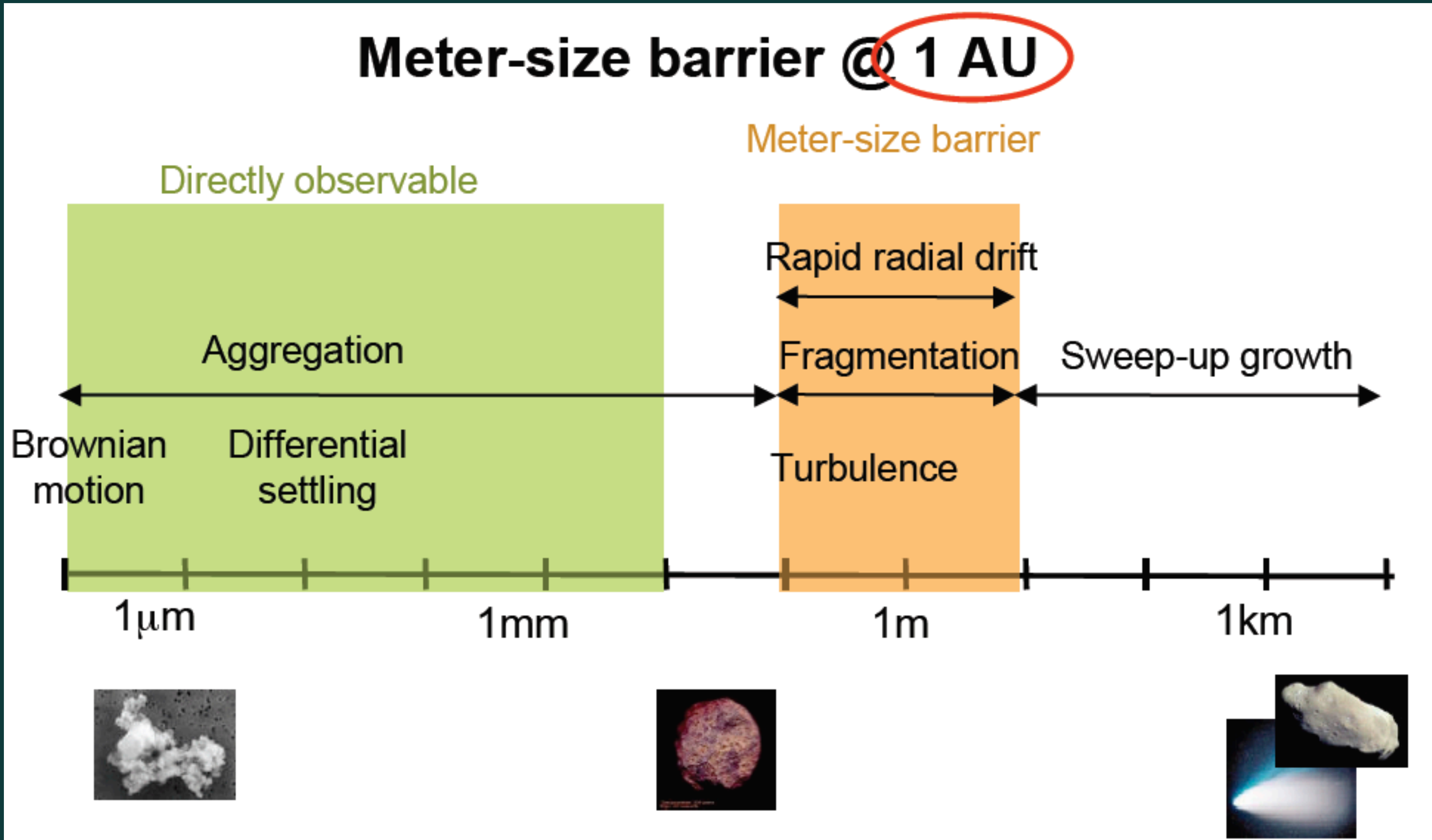
Array	Noise (mJy/beam) (1hr @ 230 GHz)
ALMA (30 antennas)	0.02
CARMA	0.8 (x40)
PdBI	0.4 (x20)
SMA	1.5 (x75)

Andrews et al. (2011)

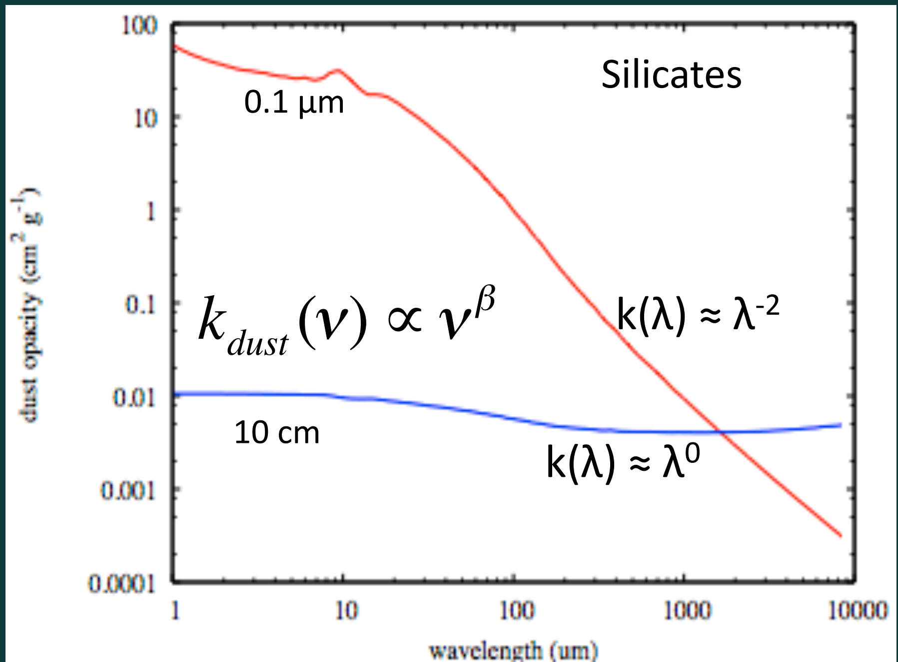


Large cavities (>15AU in radius) are quite common in mm bright disks but are rare/not observed in fainter disks. Is this result only an effect of the observational bias (i.e. limited sensitivity on the extended structures)?

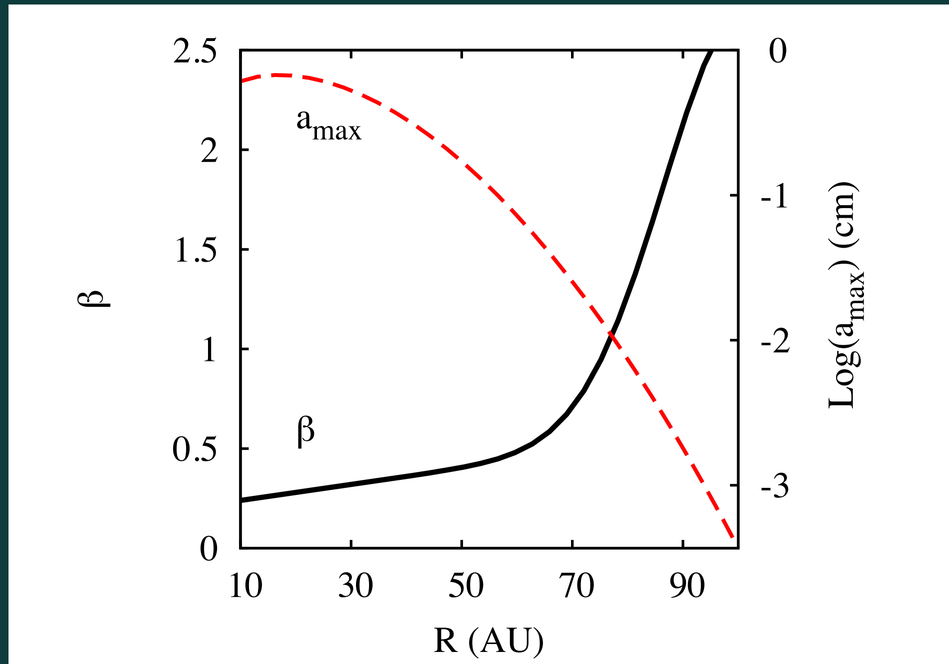
From sub-micron dust grains to planets



From sub-micron dust grains to planets



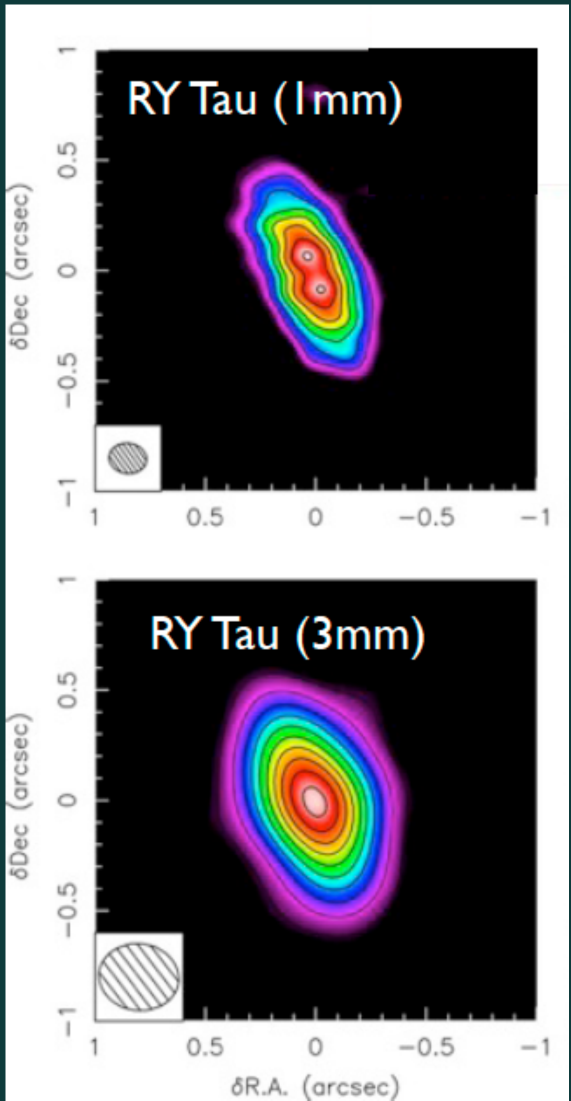
MODEL PREDICTION



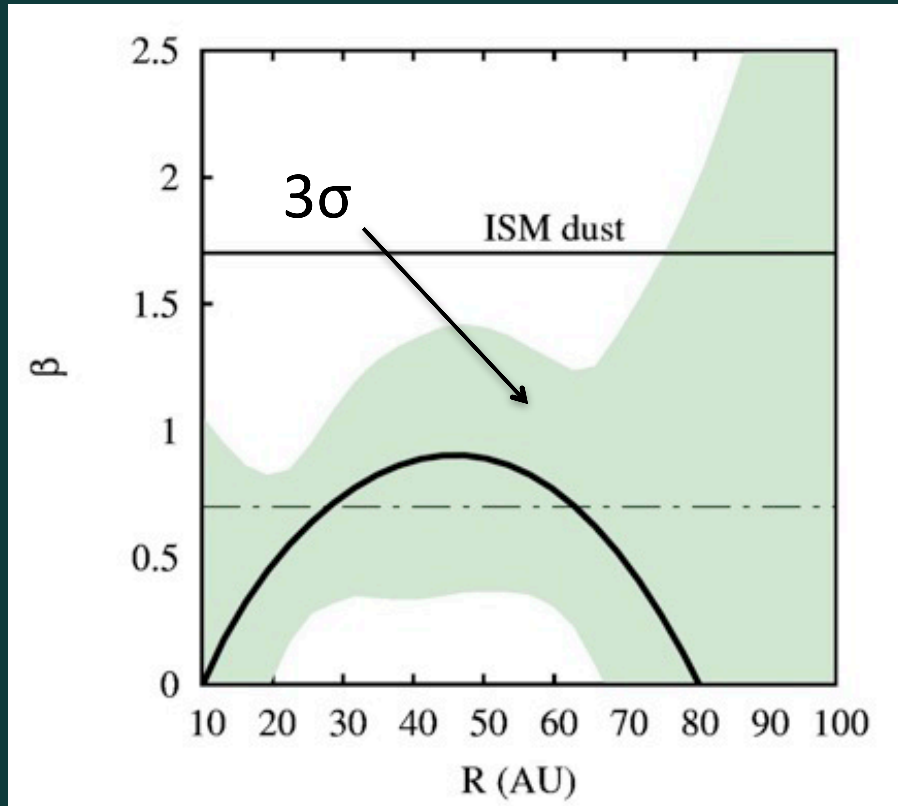
Birnstiel et al. (2010)

From sub-micron dust grains to planets

CARMA observations

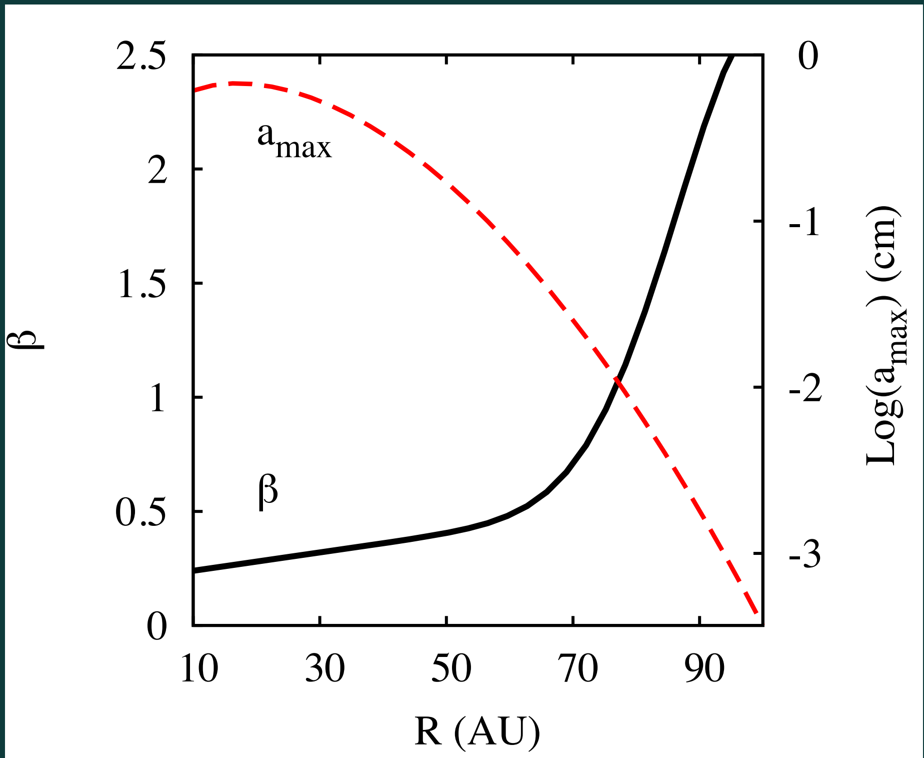


Isella et al. (2010a)

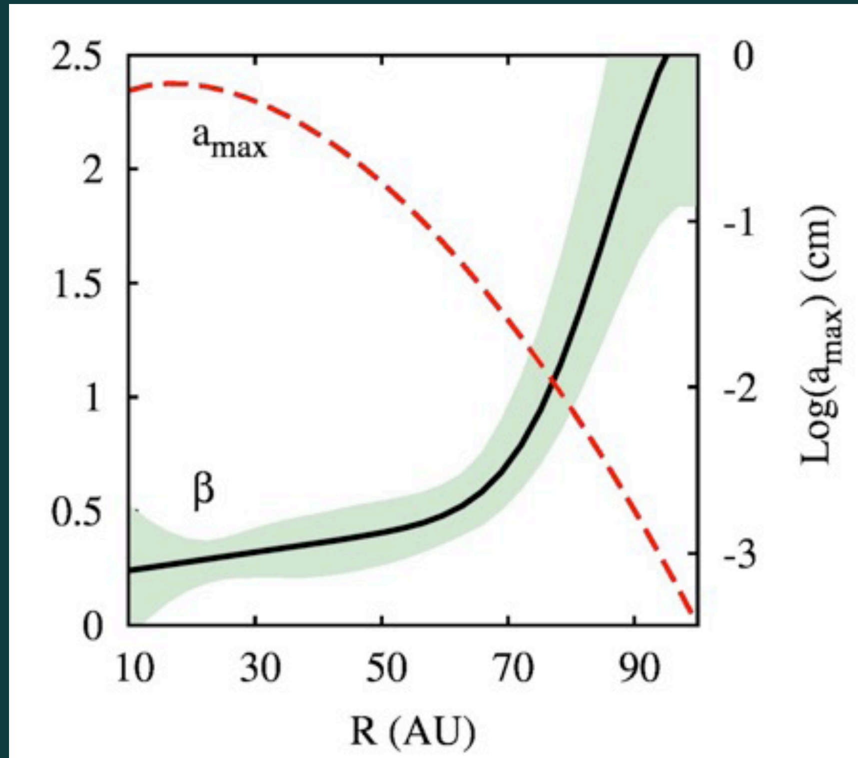


From sub-micron dust grains to planets

Model

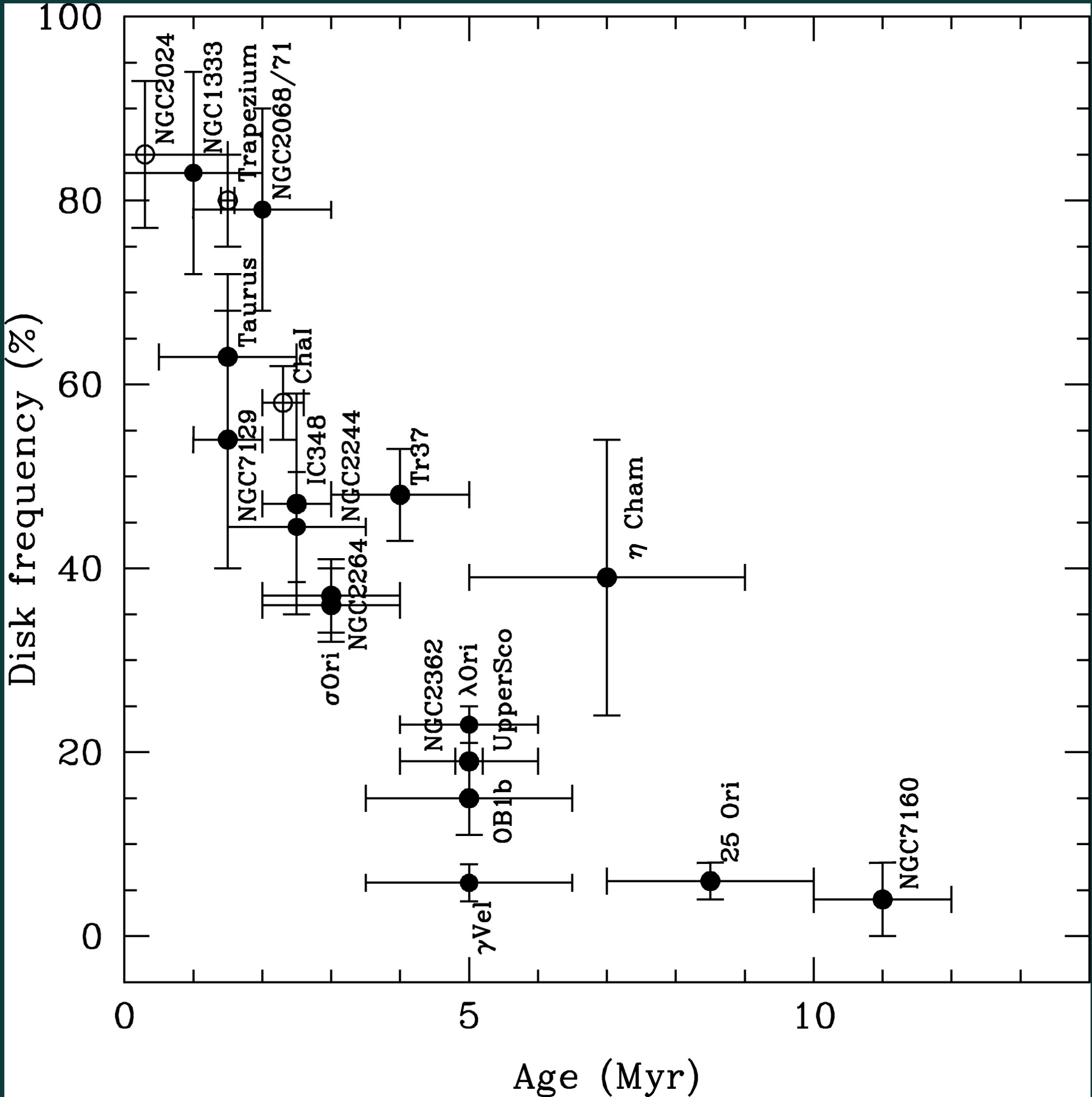


Anticipated



ALMA 3 mm and EVLA 7 mm

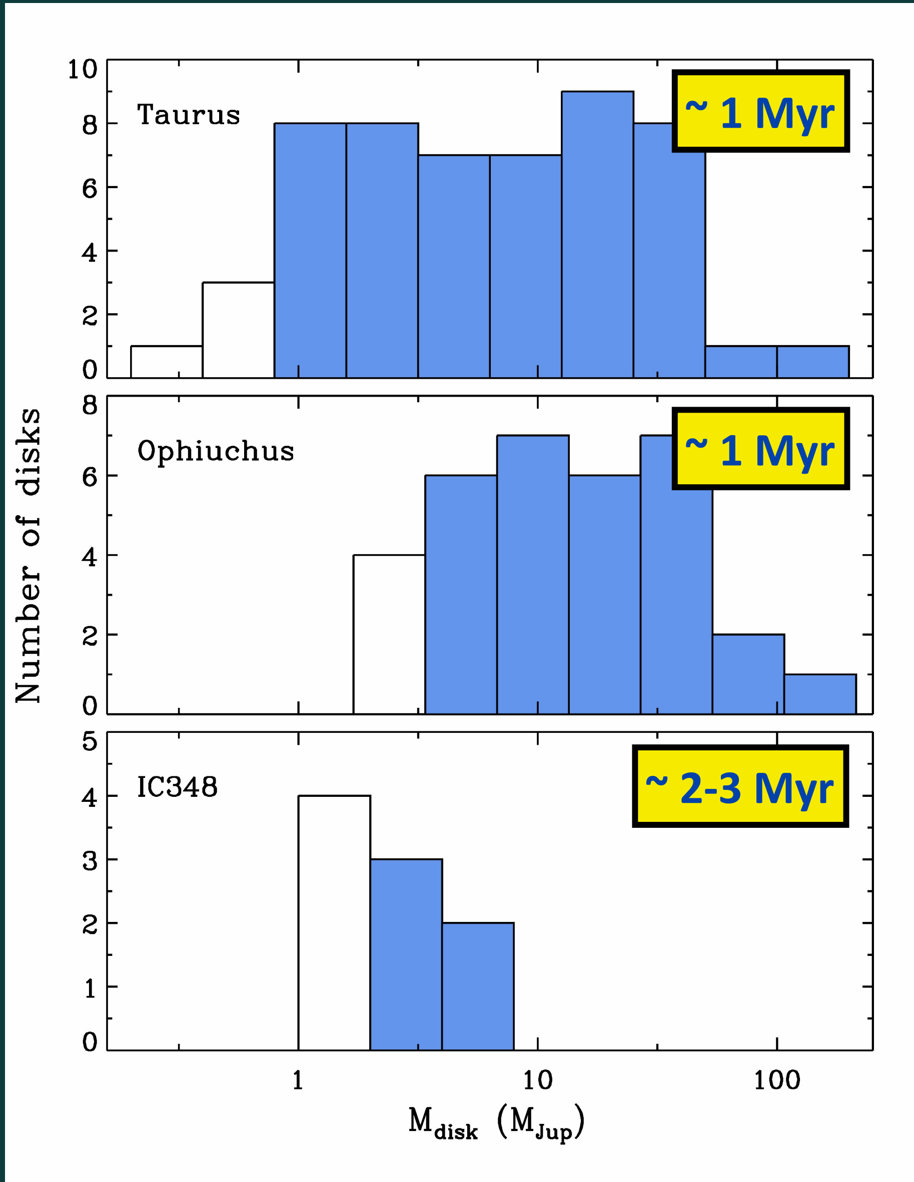
Evolution of Dust Mass



Hernandez et al. (2008)

- Based on infrared observations
- Infrared emission is optically thick
- Traces inner disk (< 1 AU)
- Submillimeter observations trace the dust mass

Evolution of Dust Mass



Lee et al. (2008)

- Lack of massive disks after ~ 2 Myr (?)
- ALMA
  - > 10x more sensitivity to dust continuum
  - Trace gas content with CO

Summay: Disks with ALMA

- Search for gaps/asymmetries in disks
- Trace evolution in grain growth and disk mass
- *many* other topics
  - disk chemistry
  - turbulence
  - disk mass vs stellar mass