Finanziato dall'Unione europea
NextGenerationEU

Ministero dell'Università e della Ricerca

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

INAF
ISTITUTO NAZIONALE DI ASTROFISICA



ONE STEP CLOSER TO PLANET FORMATION

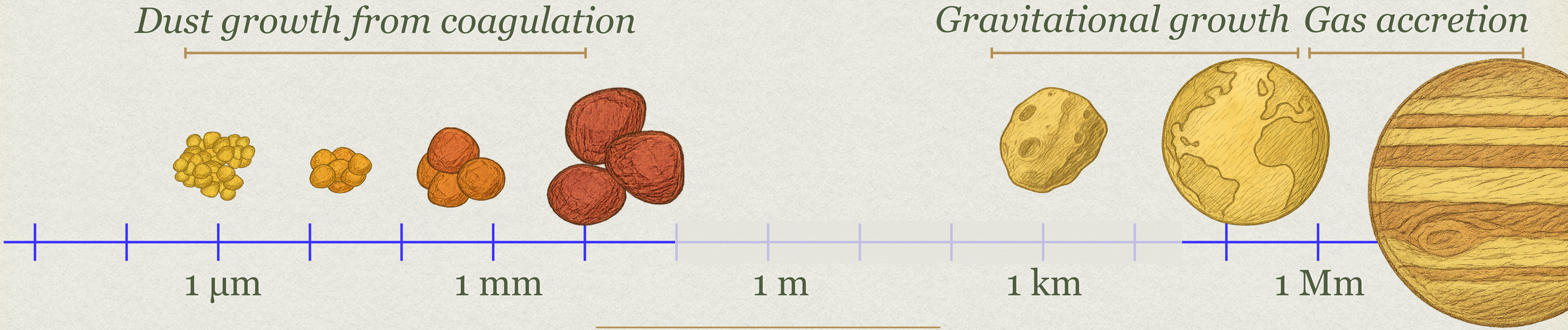
Antonio Garufi - *INAF, Istituto di Radioastronomia (IRA), Italy*

S. Pérez, J.D. Ilee, P. Pinilla, D. Price, M. Villenave,
and *"Cradle of Life"* working group

PNRR Missione 4 • Componente 2 • Investimento 3.1 • STILES • IR0000034 • CUP C33C22000640006

PLANET FORMATION IN (AND FROM) A NUTSHELL

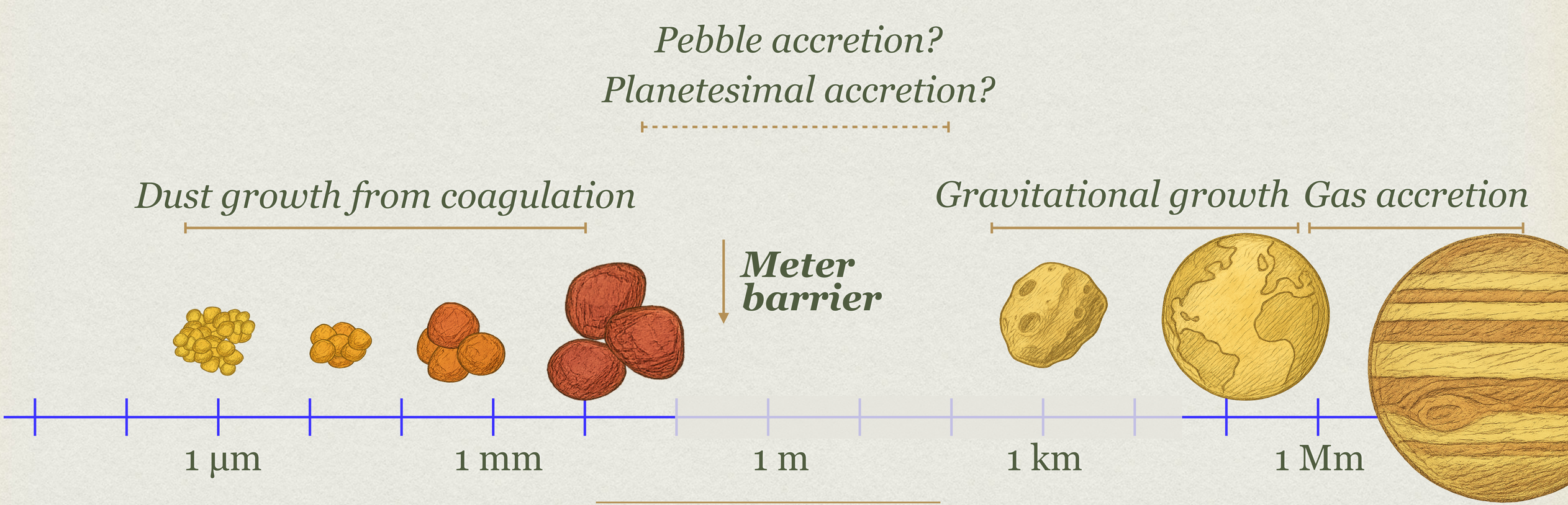
The growth of **ISM dust** grains to **planets** involves 14 orders of magnitude.



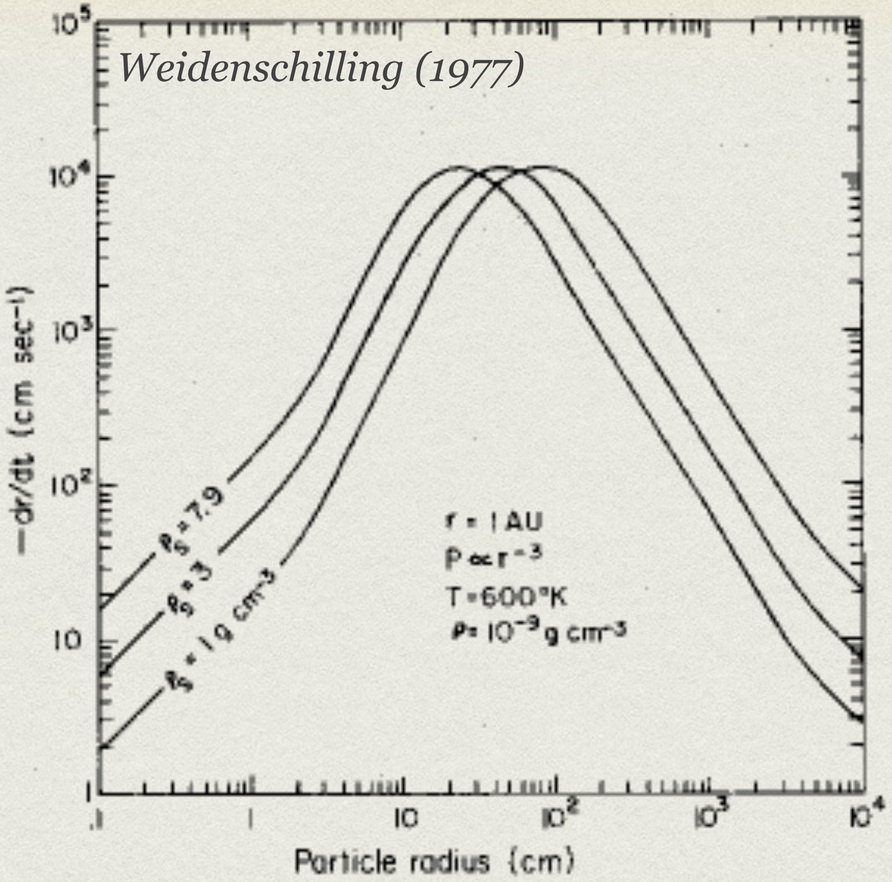
PLANET FORMATION IN (AND FROM) A NUTSHELL

The growth of **ISM dust** grains to **planets** involves 14 orders of magnitude.

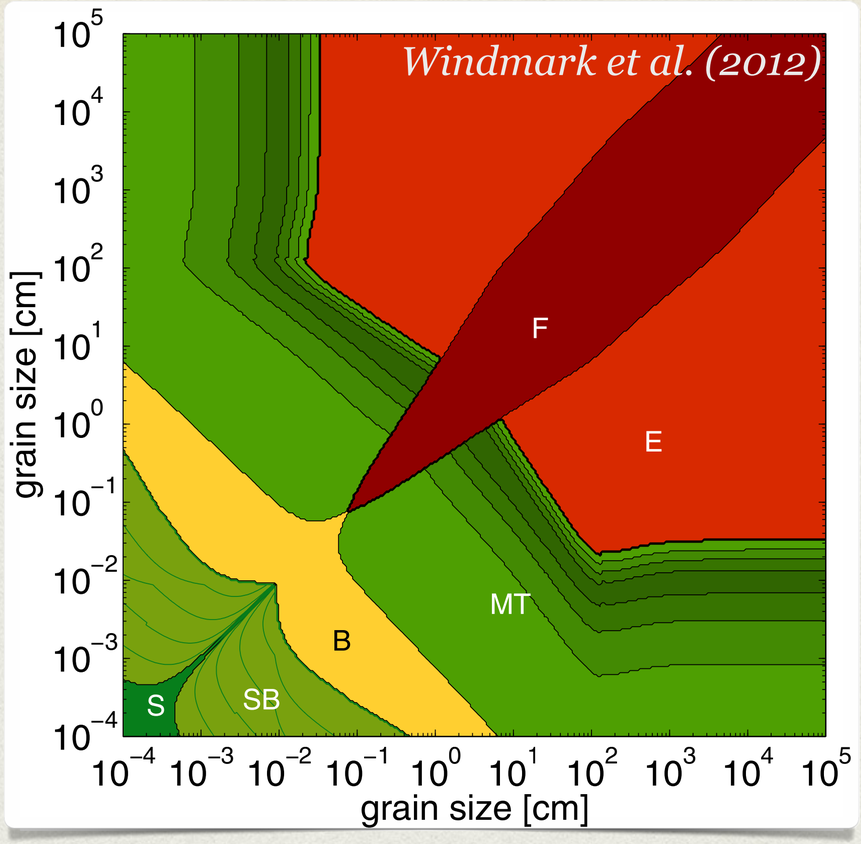
The most critical range is currently **not observable**.



PLANET FORMATION IN (AND FROM) A NUTSHELL



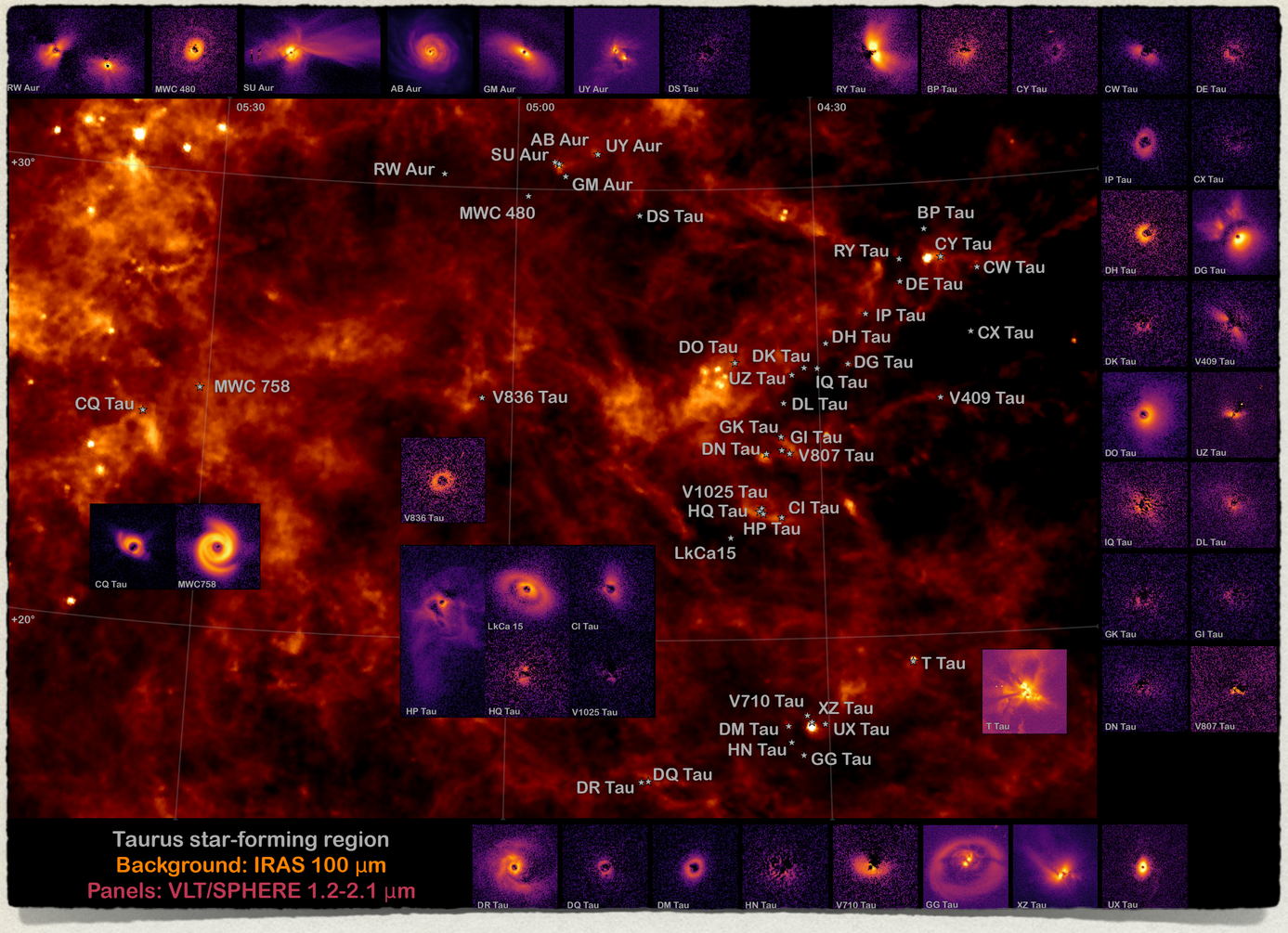




Rapid drift and inefficient collisions concur to define the **meter barrier**, over which particles should not grow.

Observations of **pebbles** in planet-forming disks are pivotal.

OBSERVATIONS OF PLANET-FORMING DISKS



The full census of disks in Taurus with VLT/SPHERE
Garufi et al. (2024)

Key-features of planet-forming disks to consider here:

Short-living ⇒ Rare

(mostly in star-forming regions at ≥ **150 pc**)

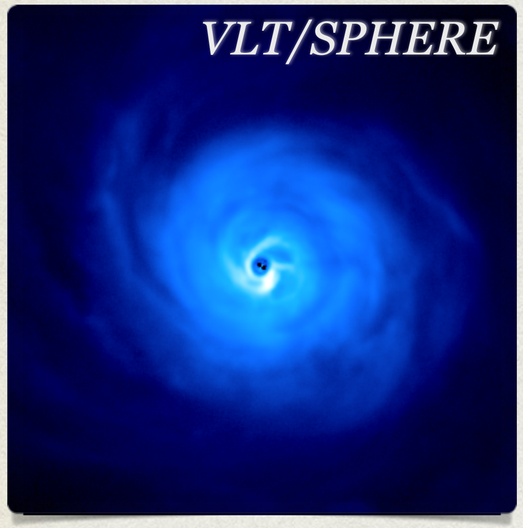
Small

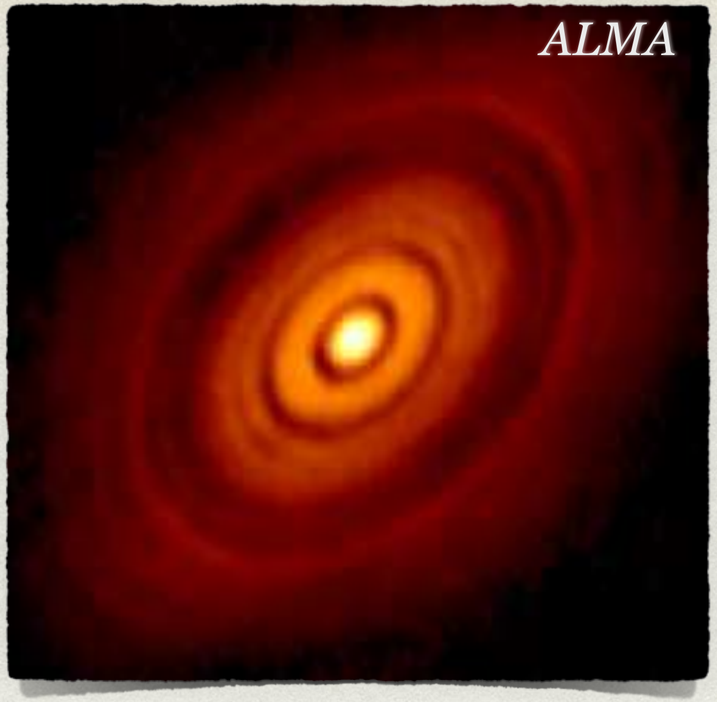
(**15—150 au** in radius)

Resolved maps require a resolution ≤ 0.1″

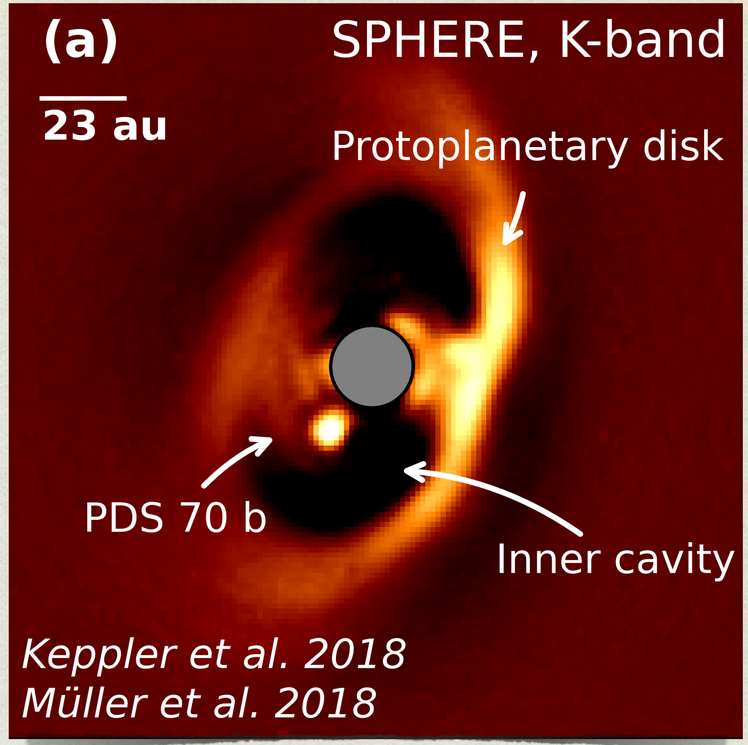
OBSERVATIONS OF PLANET-FORMING DISKS

Boccaletti et al. 2020

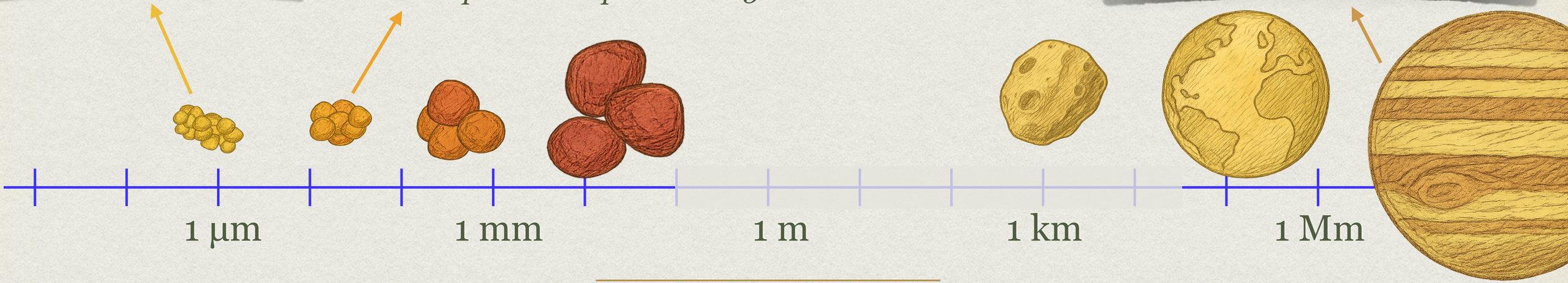




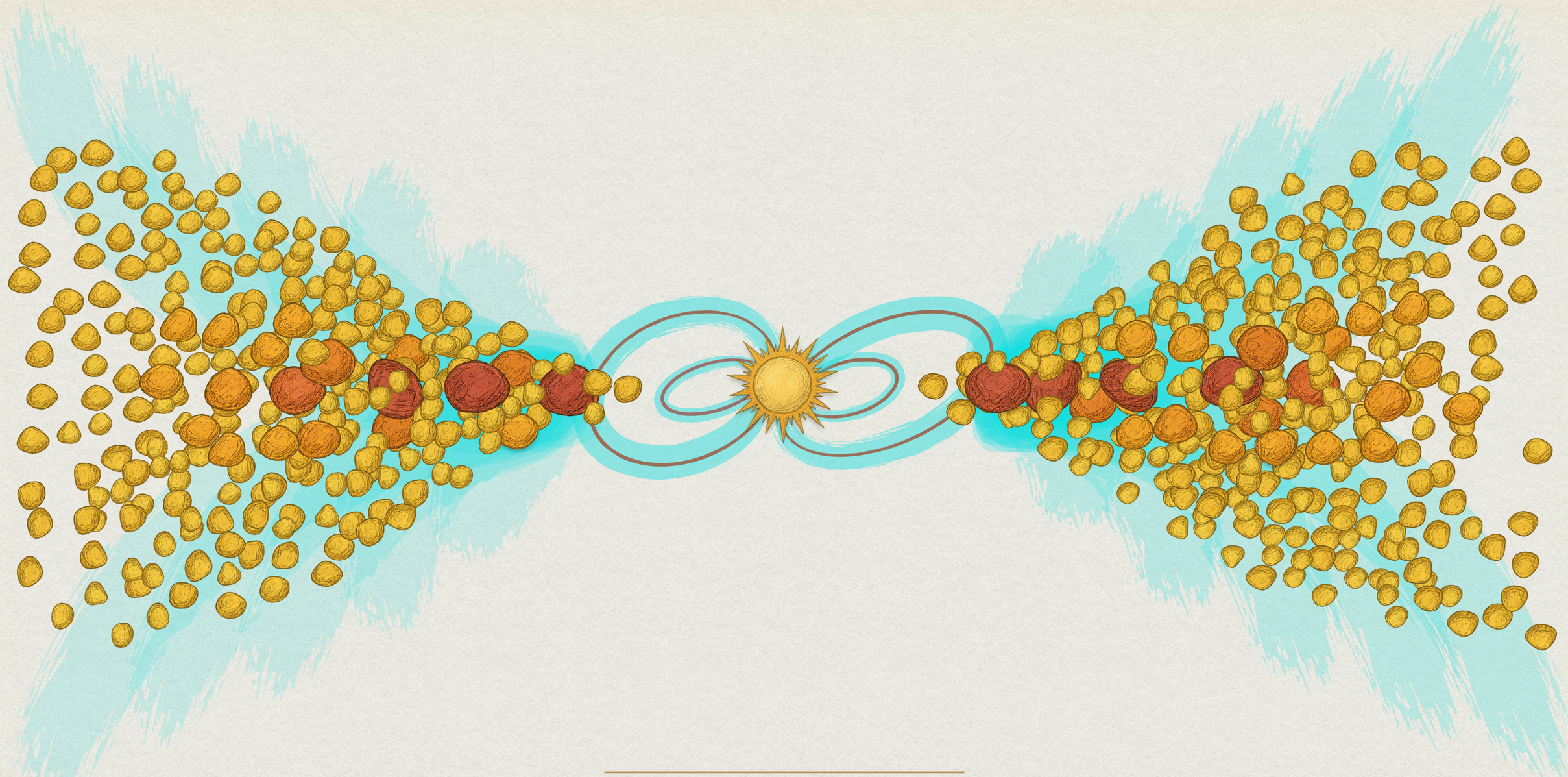
ALMA partnership et al. 2015



Keppler et al. 2018
Müller et al. 2018

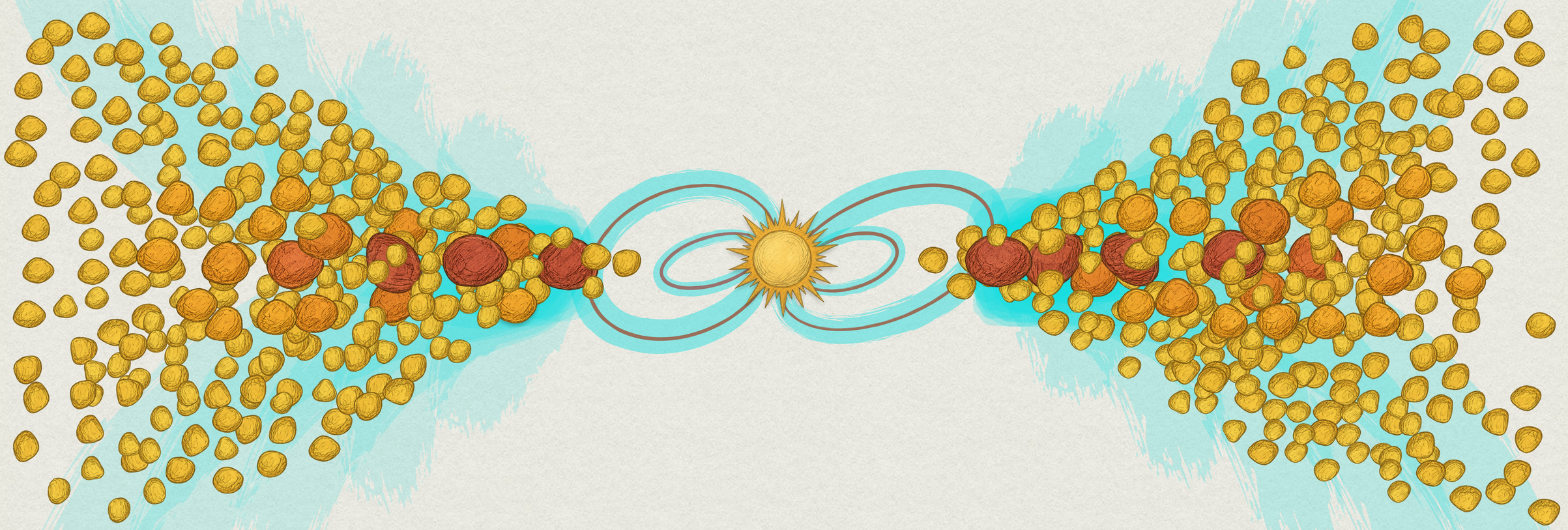


OBSERVATIONS OF PLANET-FORMING DISKS



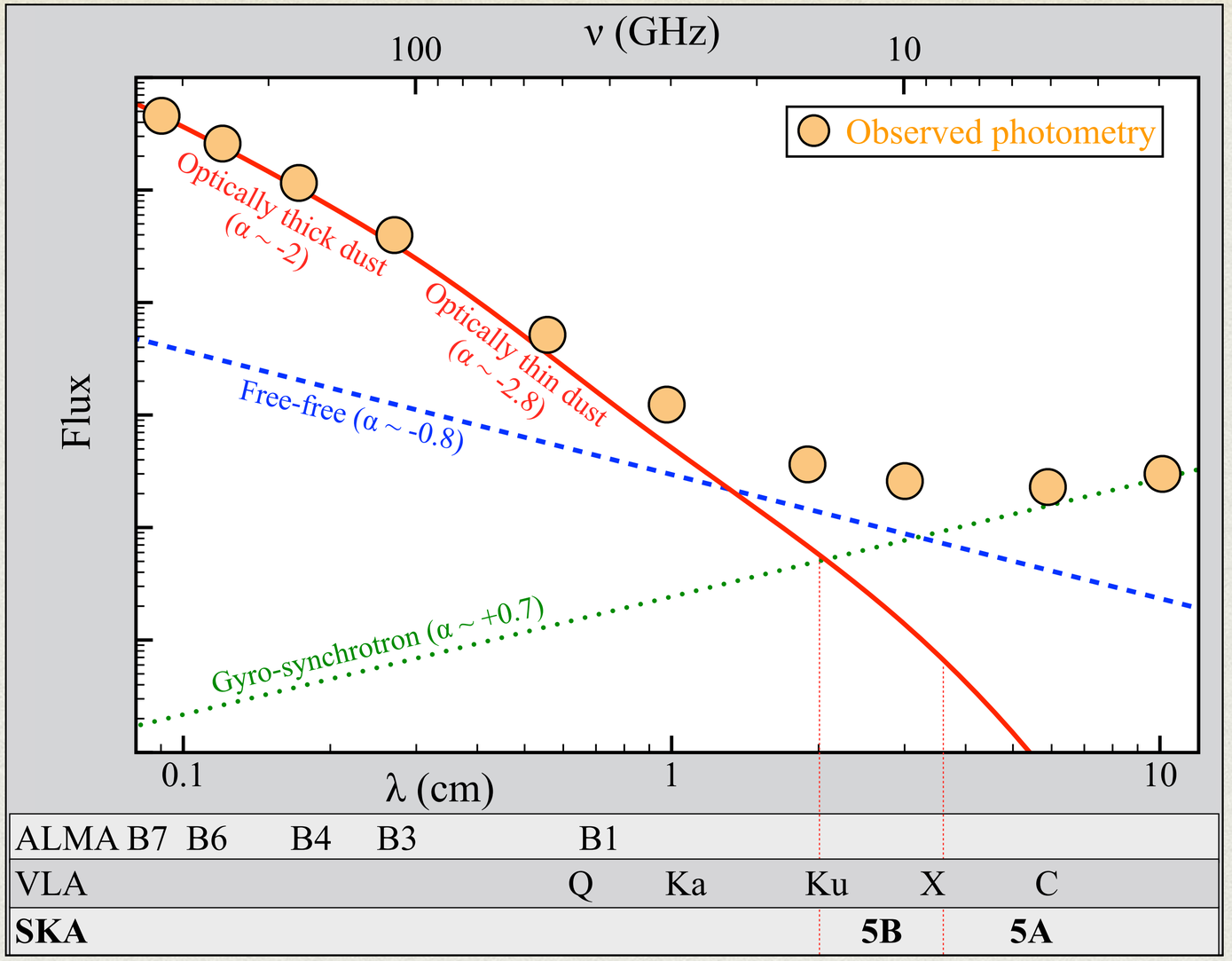
OBSERVATIONS OF PLANET-FORMING DISKS

Larger grains are **vertically** and **radially** concentrated.
Pebbles are deep in the disk and close to the star.



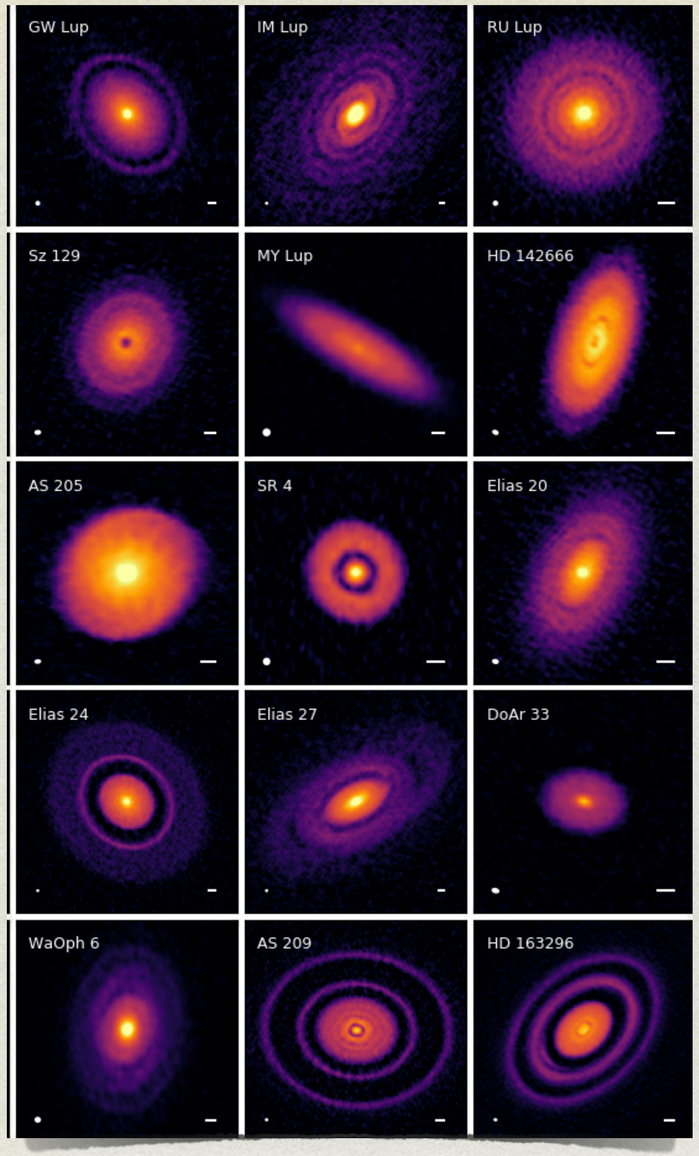
Pebbles and **ionized gas** both contribute to the cm emission.

OBSERVATIONS OF PLANET-FORMING DISKS



Pebbles and **ionized gas** both contribute to the cm emission.

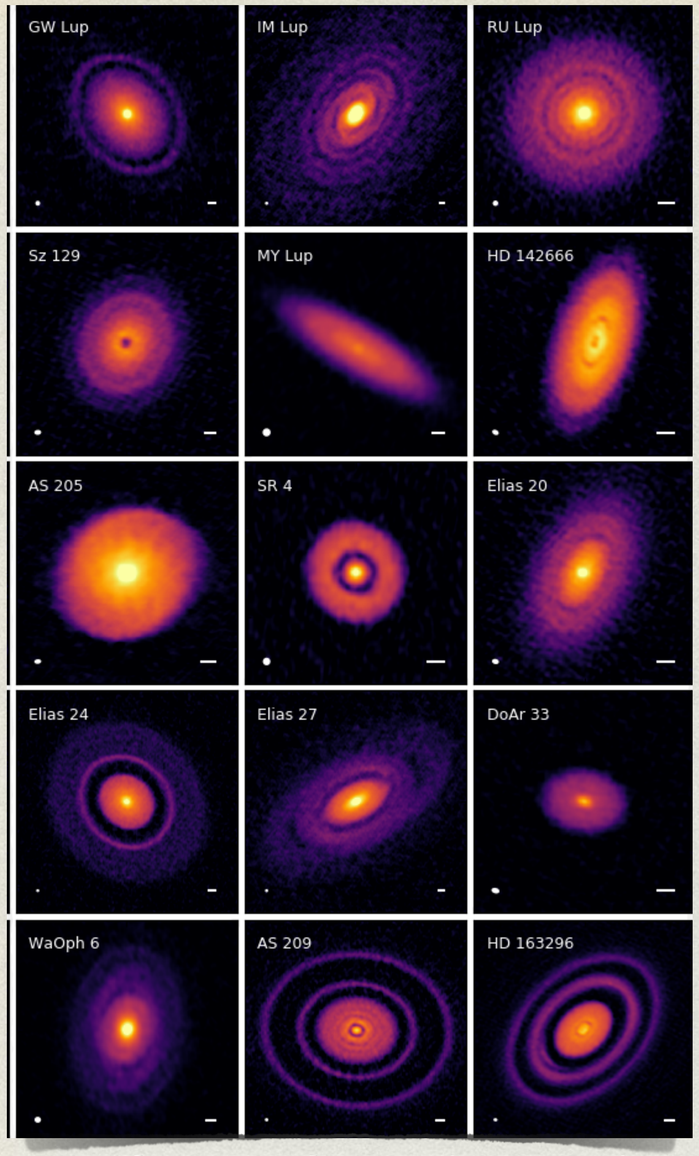
OBSERVATIONS OF PLANET-FORMING DISKS



Andrews et al. 2018 (DSHARP)

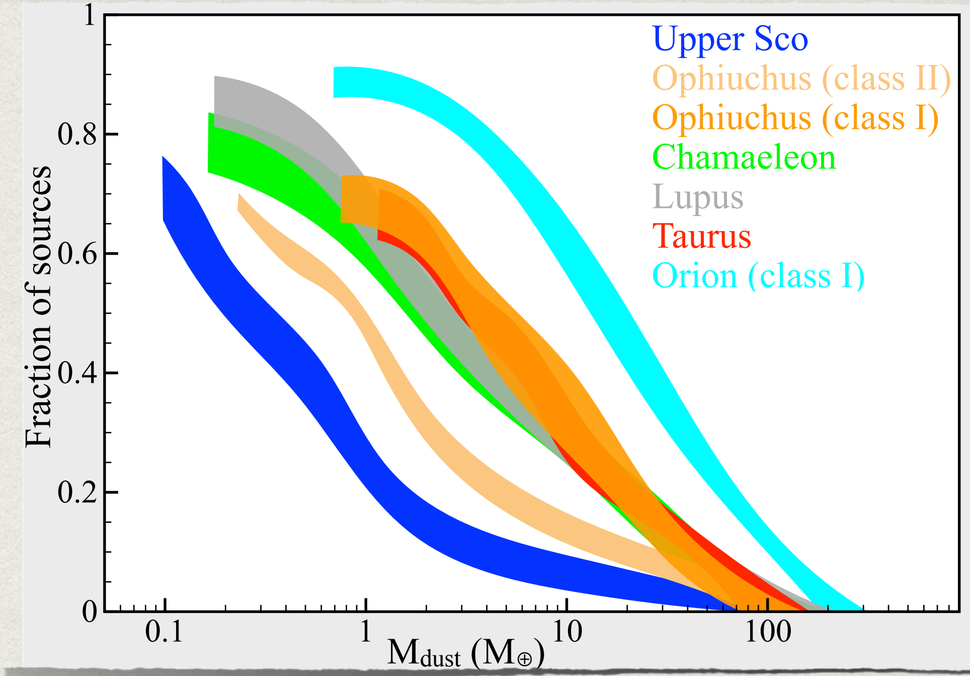
First ALMA images reveal the high occurrence of disk **substructures** (cavities, rings, spirals, arcs…).

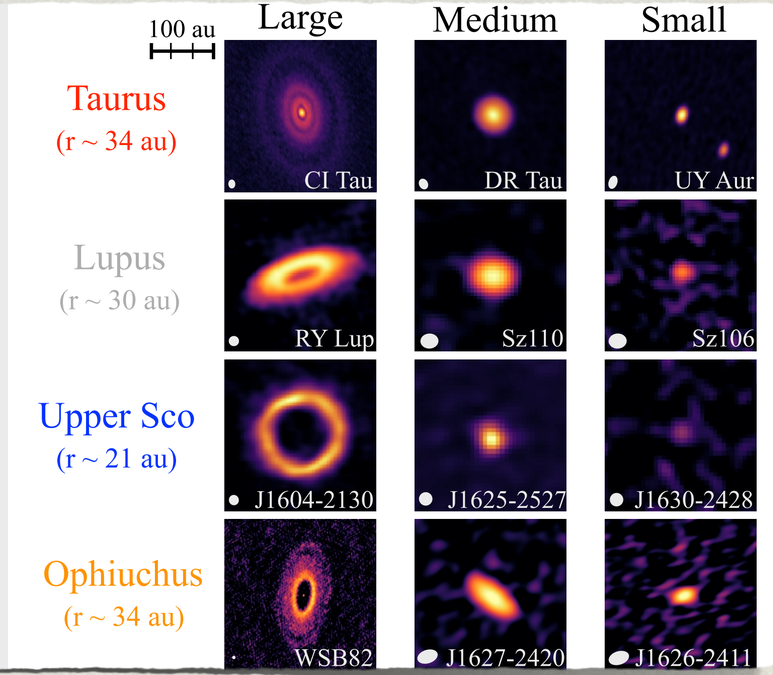
OBSERVATIONS OF PLANET-FORMING DISKS



Andrews et al. 2018 (DSHARP)

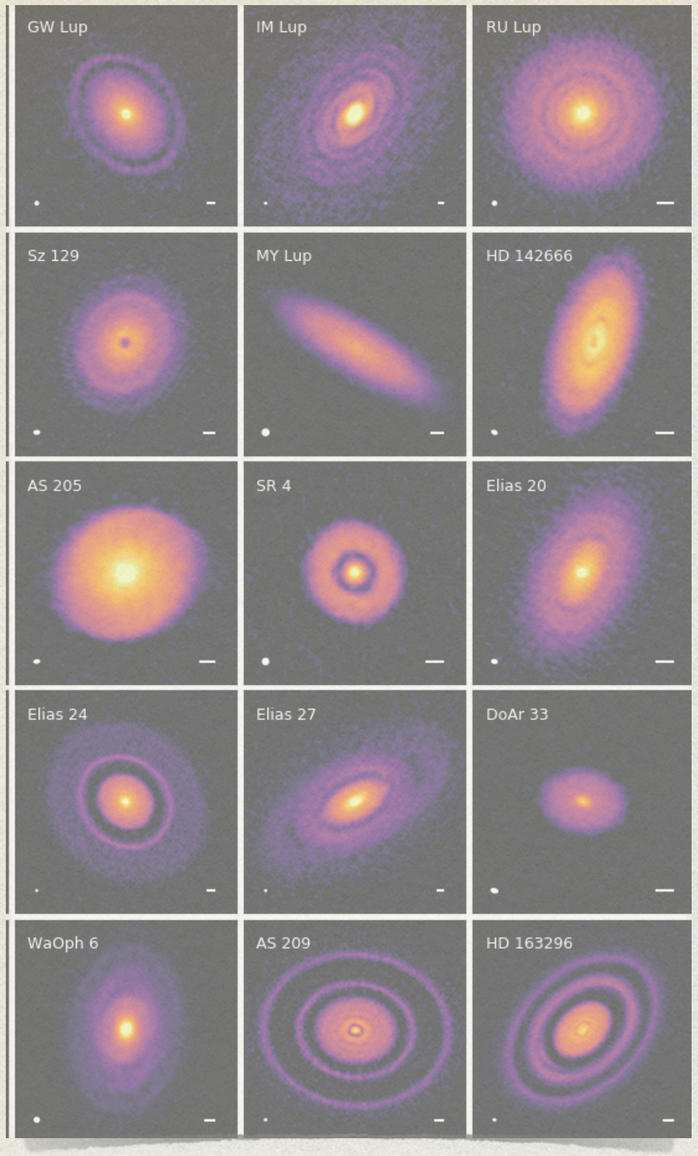
First ALMA images reveal the high occurrence of disk **substructures** (cavities, rings, spirals, arcs…).





Unbiased surveys of star-forming regions disclosed the variety of disk properties, and their evolution in time.

OBSERVATIONS OF PLANET-FORMING DISKS



!

The mm emission is severely **optically thick:** dust mass, and grain properties are uncertain.

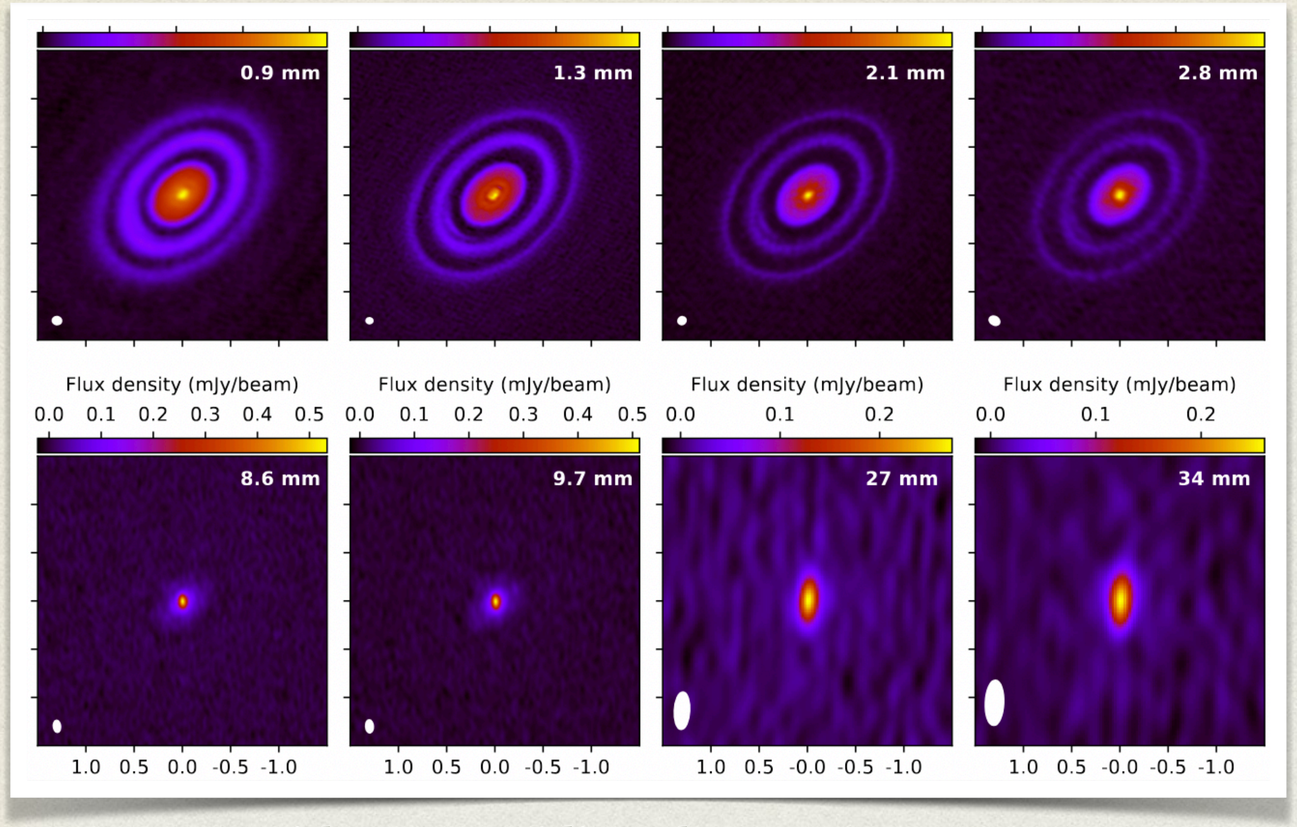
!

ONE STEP CLOSER TO PLANET FORMATION

ALMA

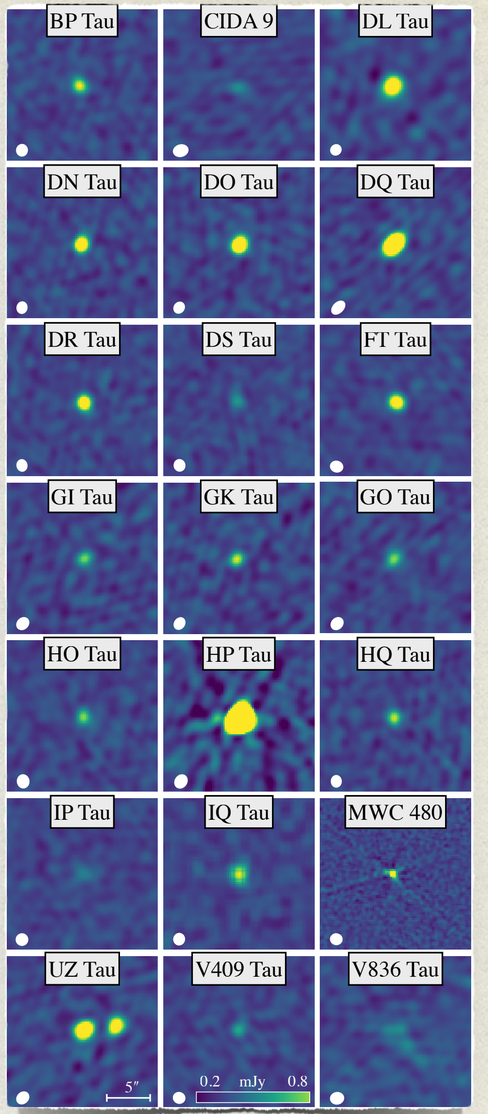
The cm-emission enables the characterization of **pebbles** from optically **thin** emission.

ONE STEP CLOSER TO PLANET FORMATION



HD163296 with VLA, Guidi et al. 2022

VLA and **ATCA** characterized mostly unresolved emission from exceptionally bright disks.



Taurus with VLA
Garufi et al. 2025

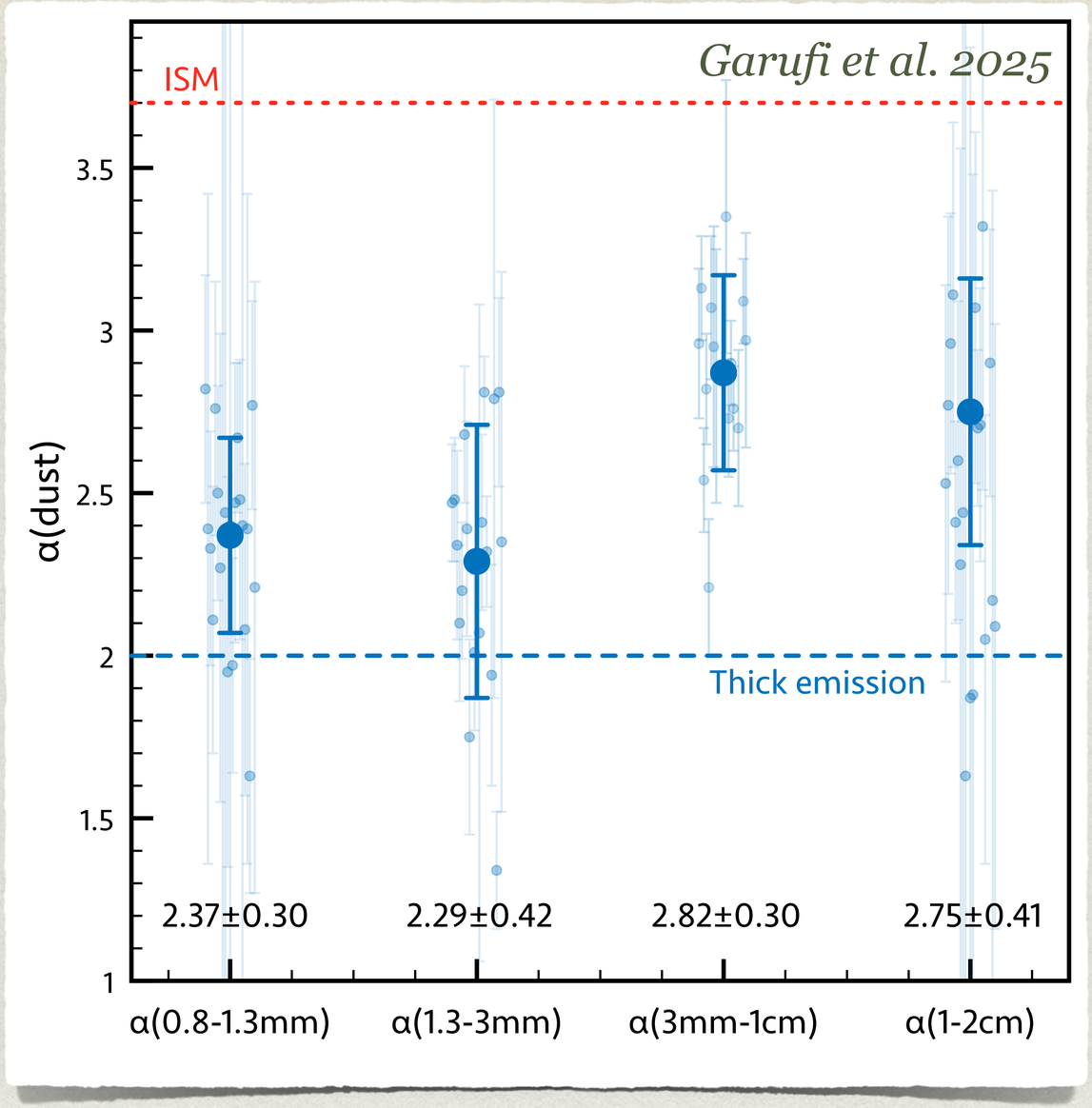
Limited resolution and sensitivity hinder pebble characterization and separation from emission of ionized gas.

DEMOGRAPHICS OF DISKS WITH SKAO

ALMA

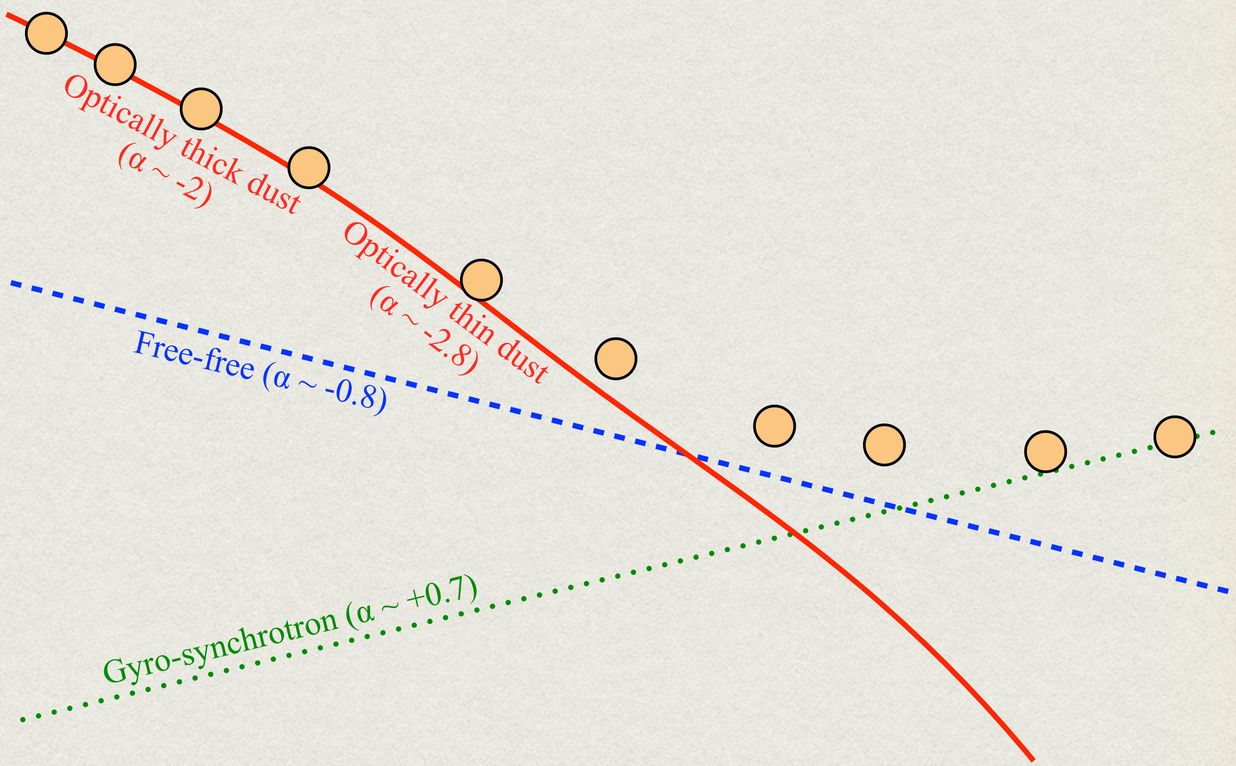
Let us predict observability based on ALMA samples and VLA (*unresolved*) spectral indices…

DEMOGRAPHICS OF DISKS WITH SKAO

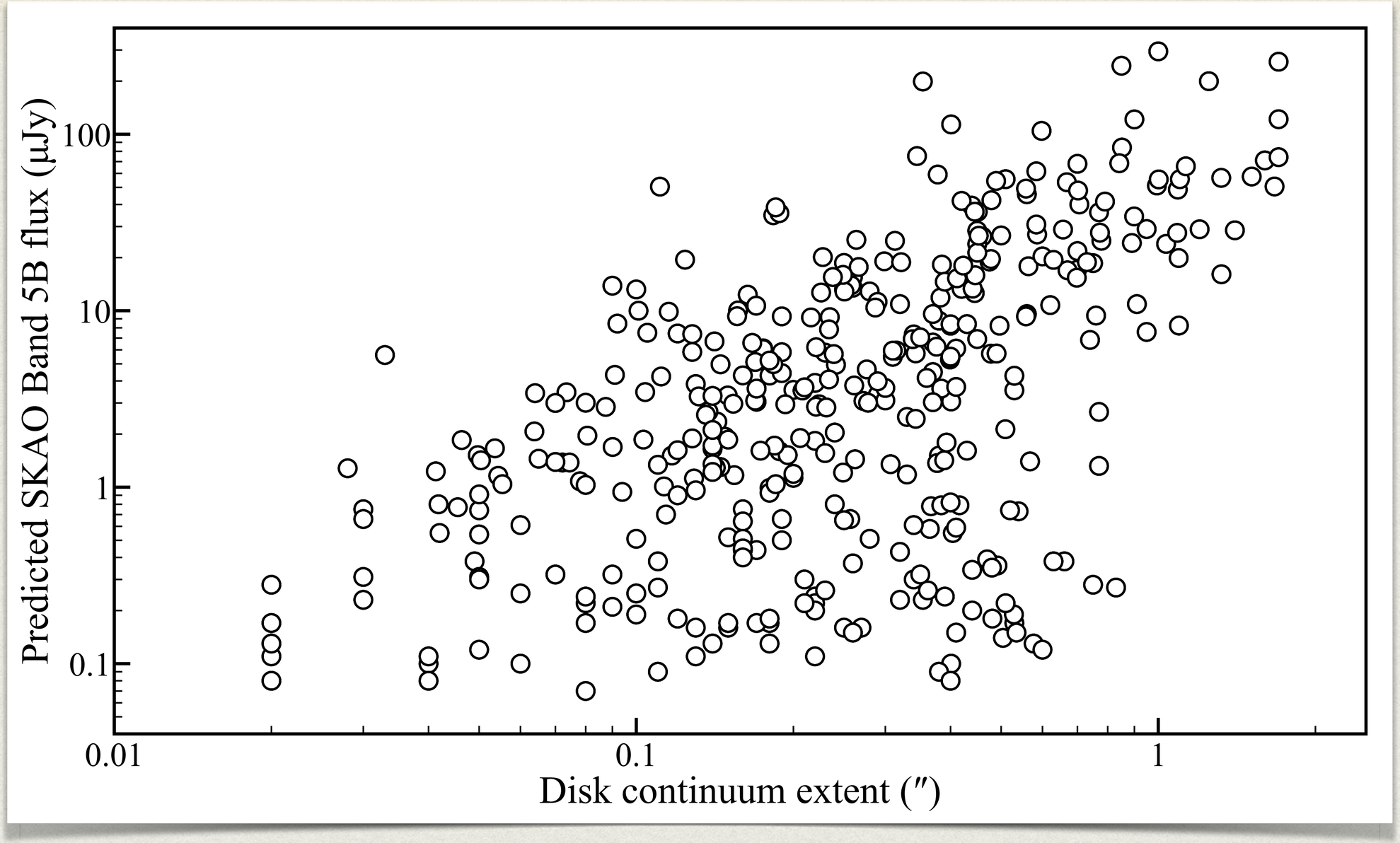


We assume that the dust spectral **indices** constrained for Taurus hold for all regions.

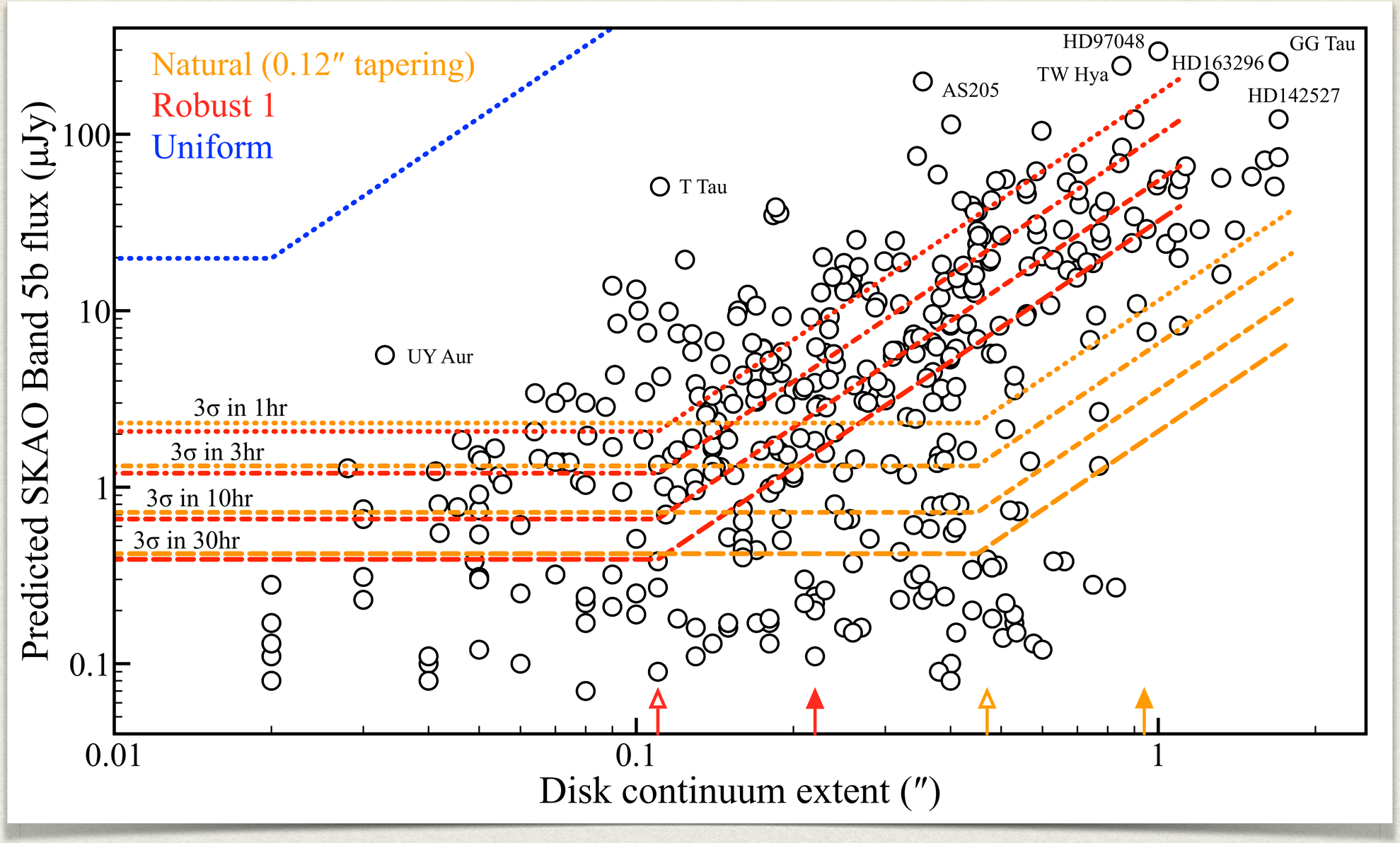
We translate ALMA fluxes into SKAO **fluxes**.



DEMOGRAPHICS OF DISKS WITH SKAO



DEMOGRAPHICS OF DISKS WITH SKAO

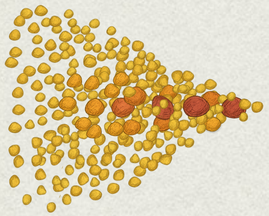


FINAL MESSAGES

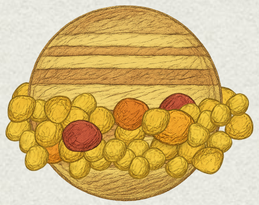
Our main **science cases** are:



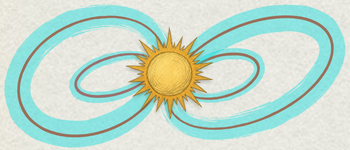
1. Pebbles in disks:
   spatially (settling, drift), spectrally (dust properties), regionally (evolution).



2. Dust opacity and disk mass:
   fluxes from optically thin emission compared with alternative methods.



3. Circumplanetary disks:
   intense dust growth and ionized gas emission in moon-forming disks..?



4. Ionized gas:
   free-free and non-thermal emission close to the star.