An unbiased high-resolution ALMA survey of disk substructures in Taurus

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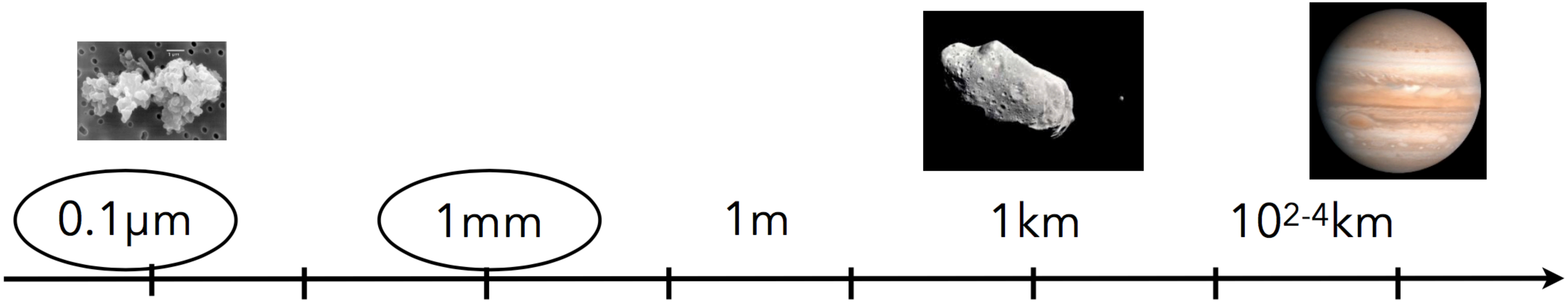
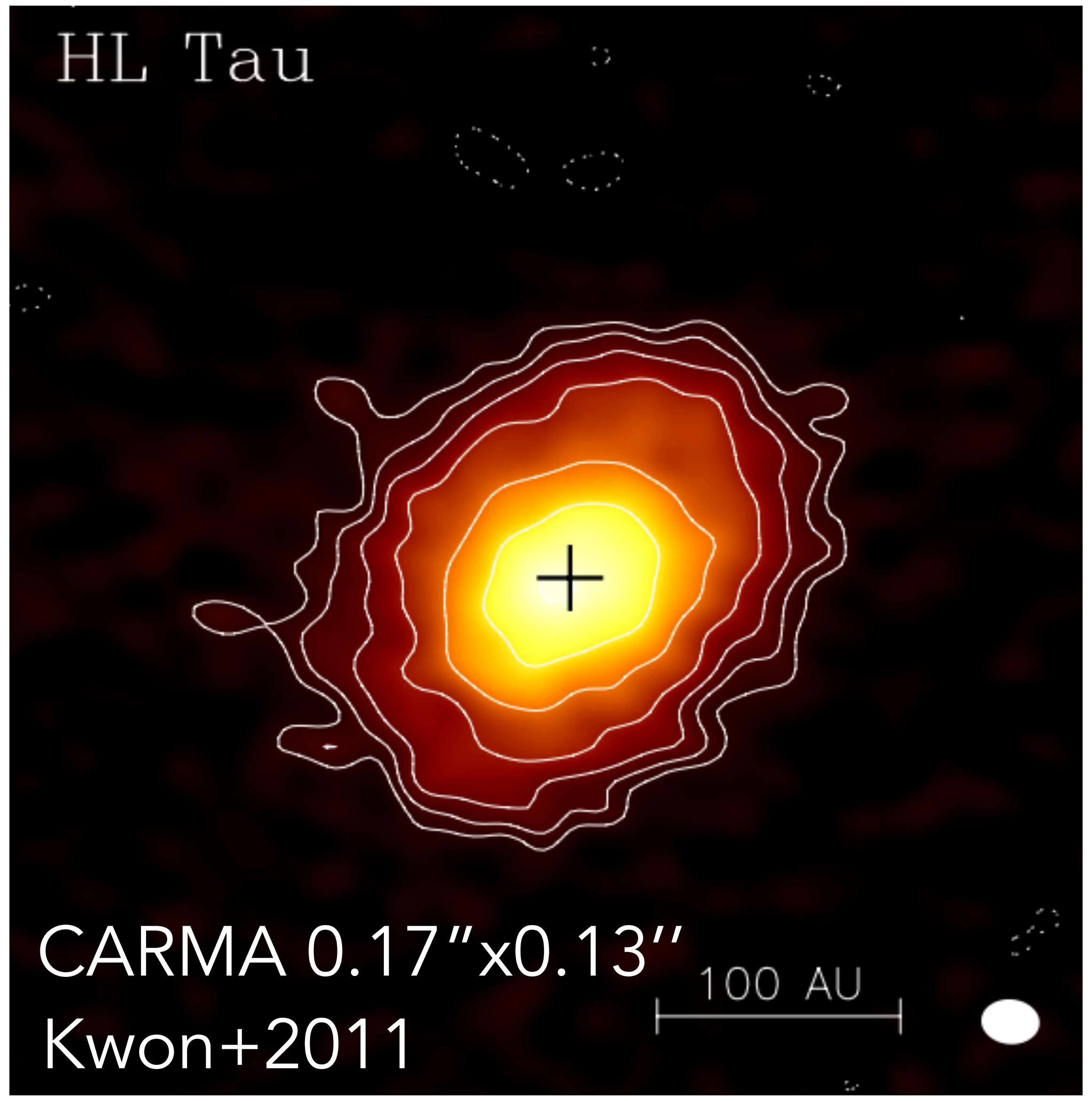
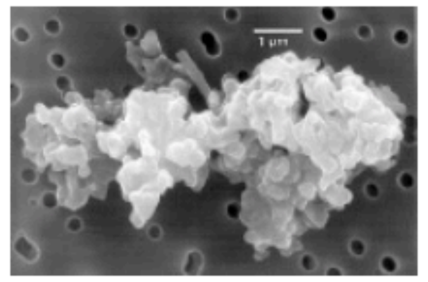
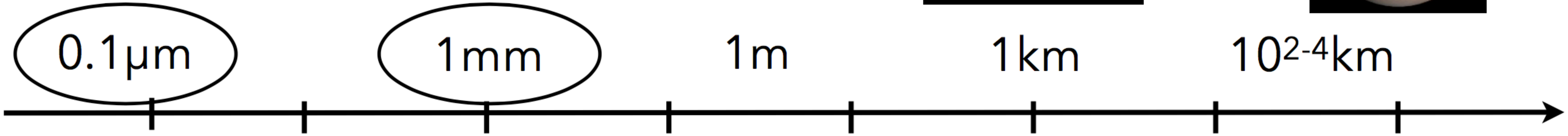
dust radial drift

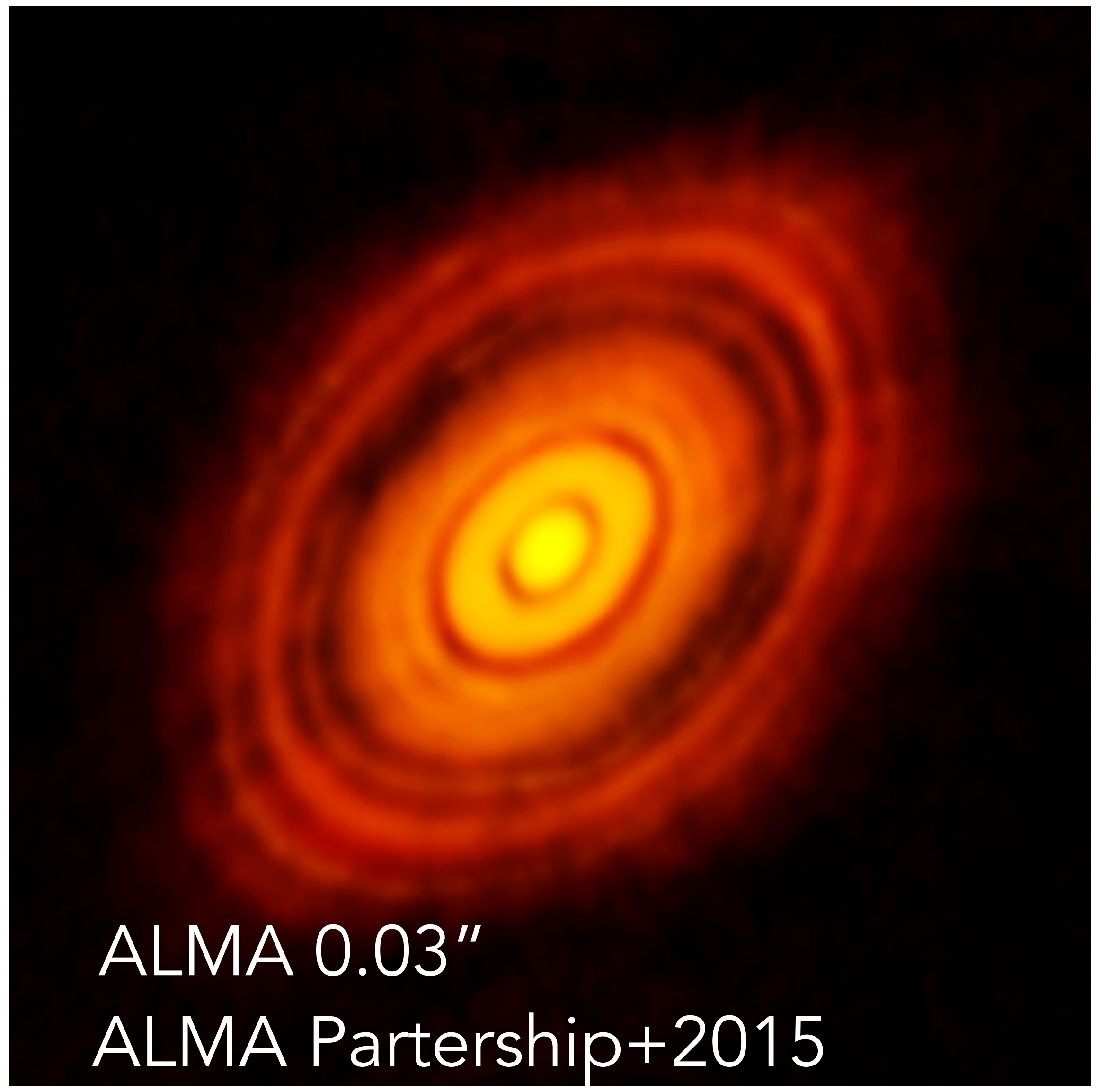




disk substructures: prevent inward radial drift





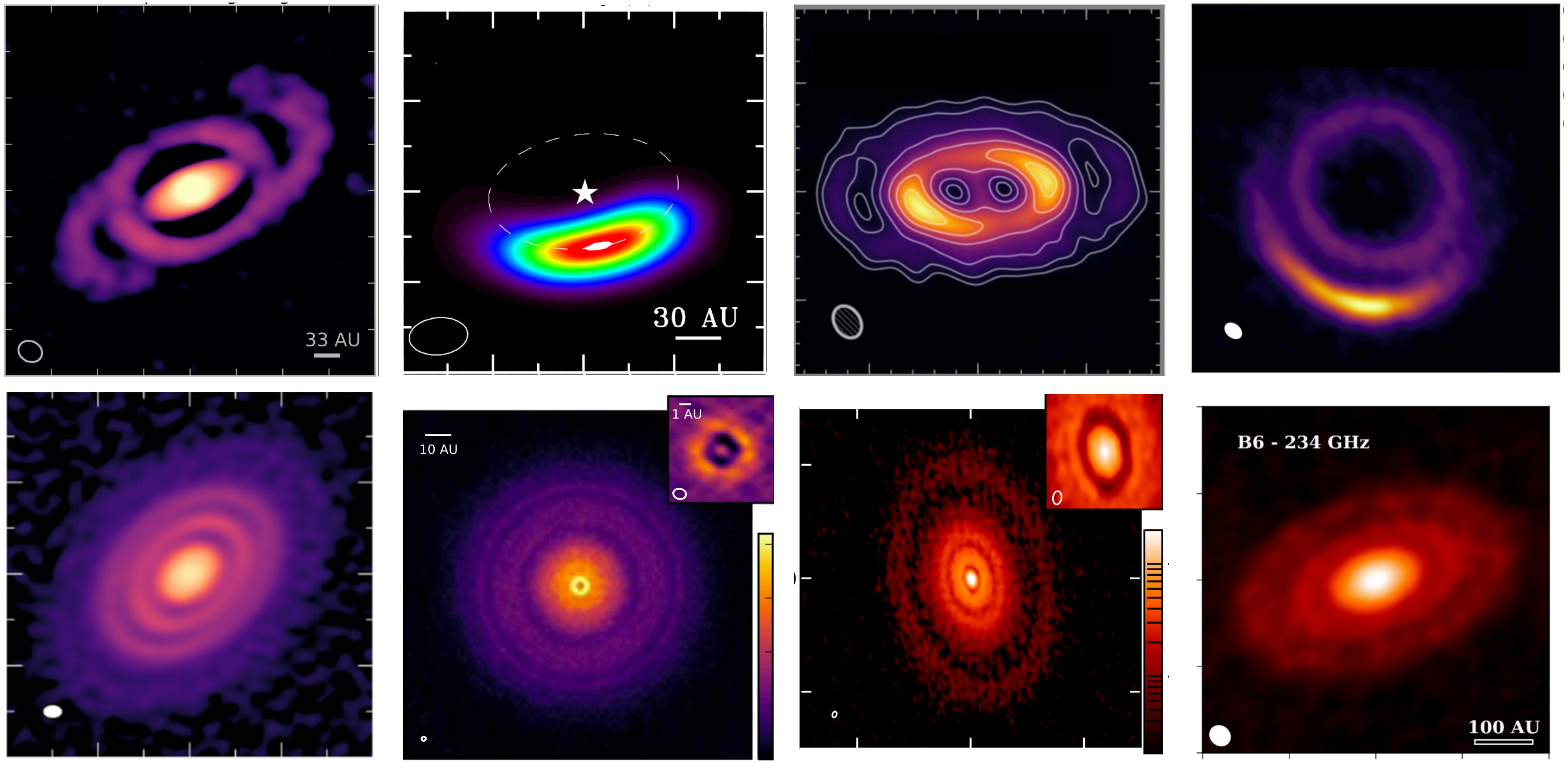


ALMA 0.03″
ALMA Partership+2015

disk substructures with ALMA

- *azimuthal asymmetry*
- *concentric gaps and rings*

one prominent bias: targeting bright disks

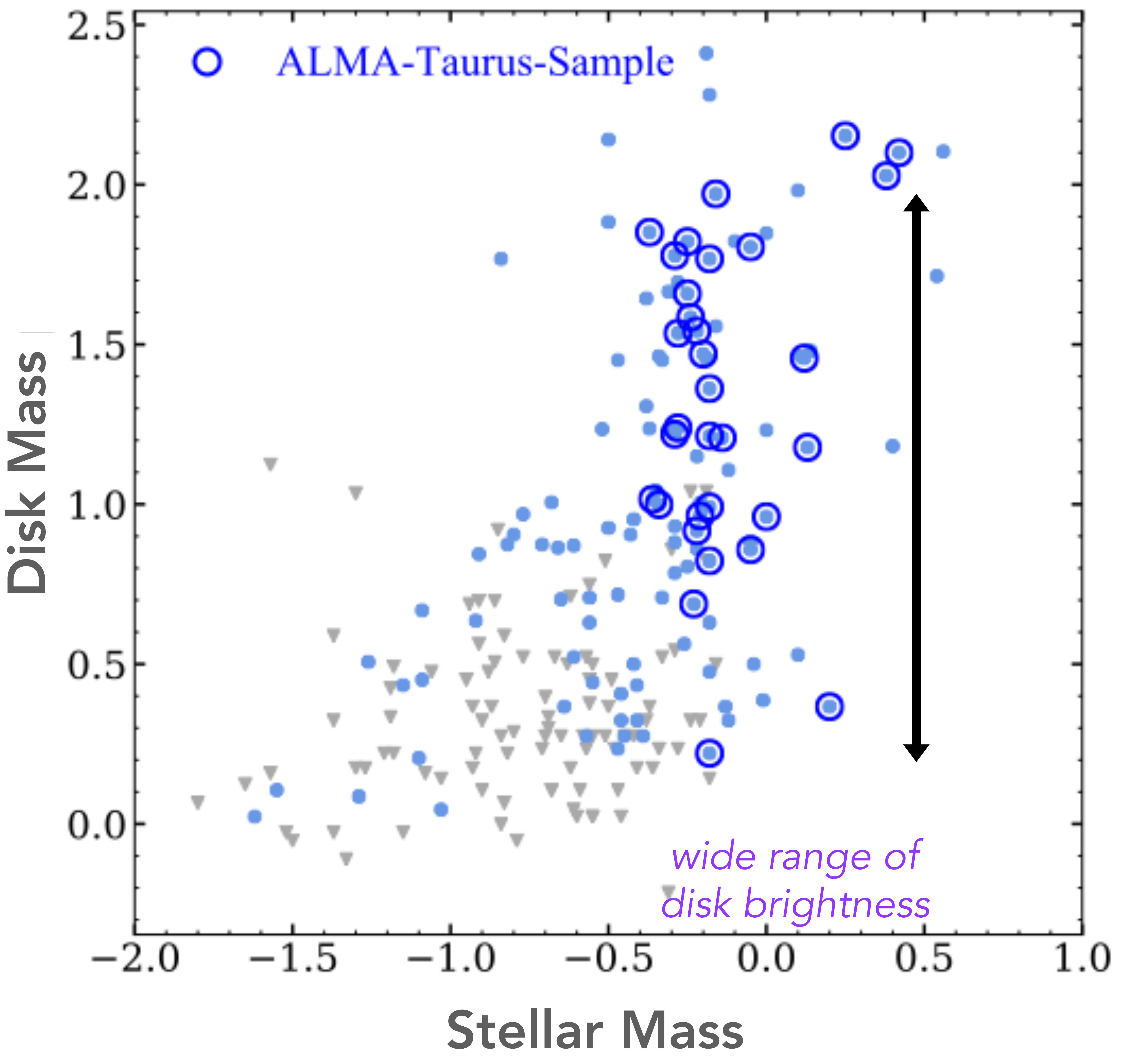


see, e.g., Perez+2015; van der Marel+2013; Loomis+2017; Cazzoletti+2018
Isella+2016; Andrews+2016; Clark+2018; van Terwisga+2018; [DSHARP]()

A ~~unbiased(-ish)~~ representative ALMA Disk Structure Survey in Taurus

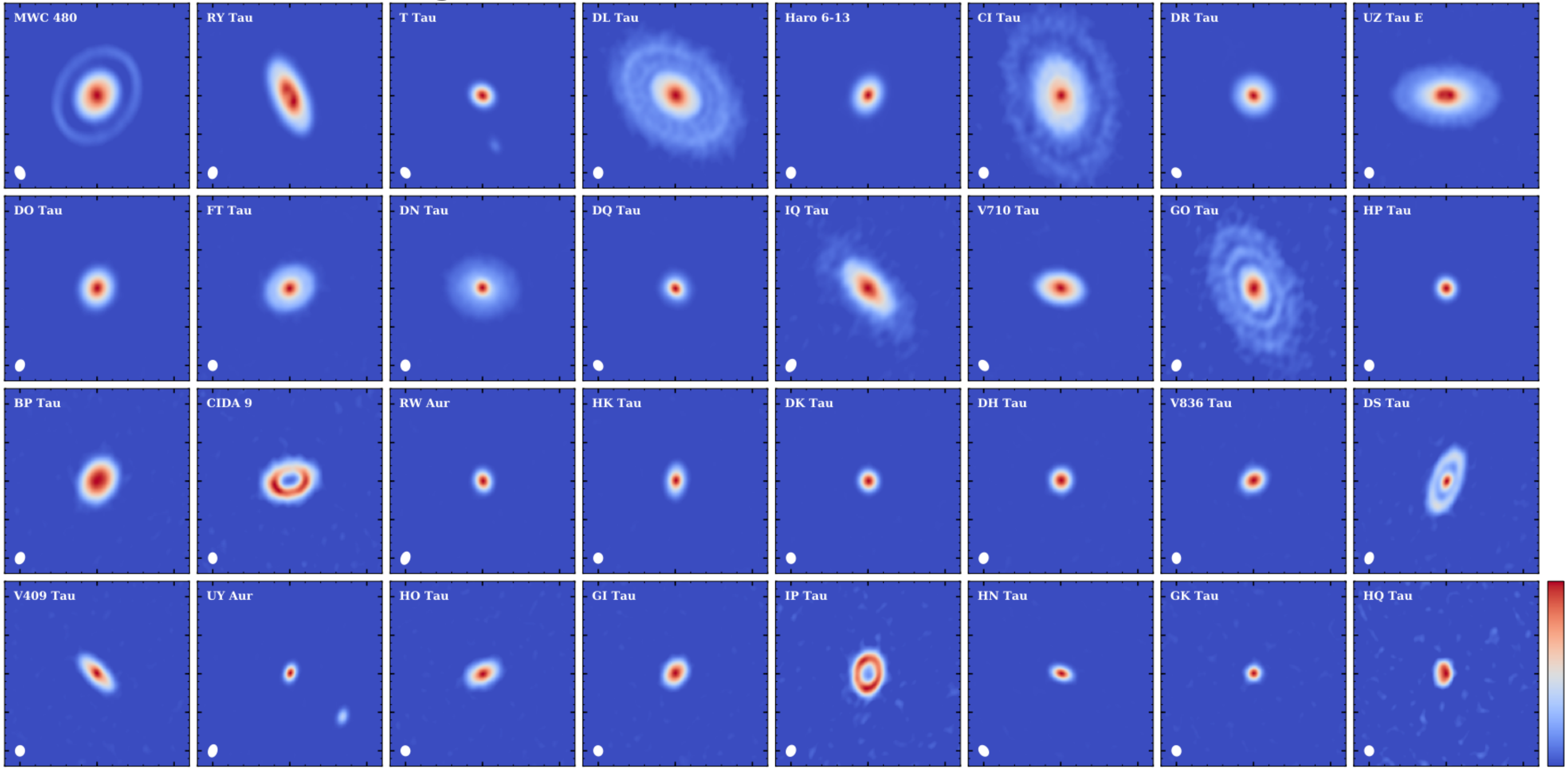
Sample Selection:
- spectral type earlier than M3
- excluding binaries of 0.1″-0.5″
- low extinction (Av<3)
- no archival high-resolution (<0.2″) observations

Snapshots of 32 disks:
- 1.3 mm + 13CO + C18O
- 4-10 min on-source time
- beam of 0.12″ (~15 au)



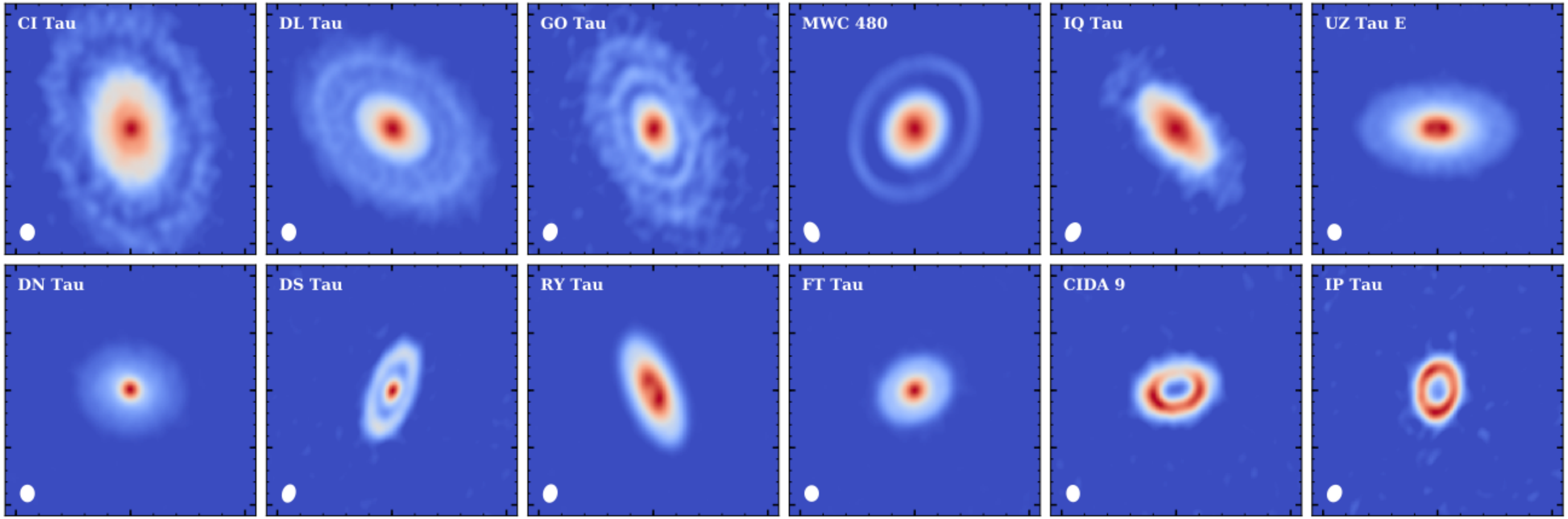
mm continuum images for 32 disks at ~15 au resolution

in order of decreasing mm flux



2.4″ in each side

12/32 disks with substructures (rings, gaps, inner cavities)

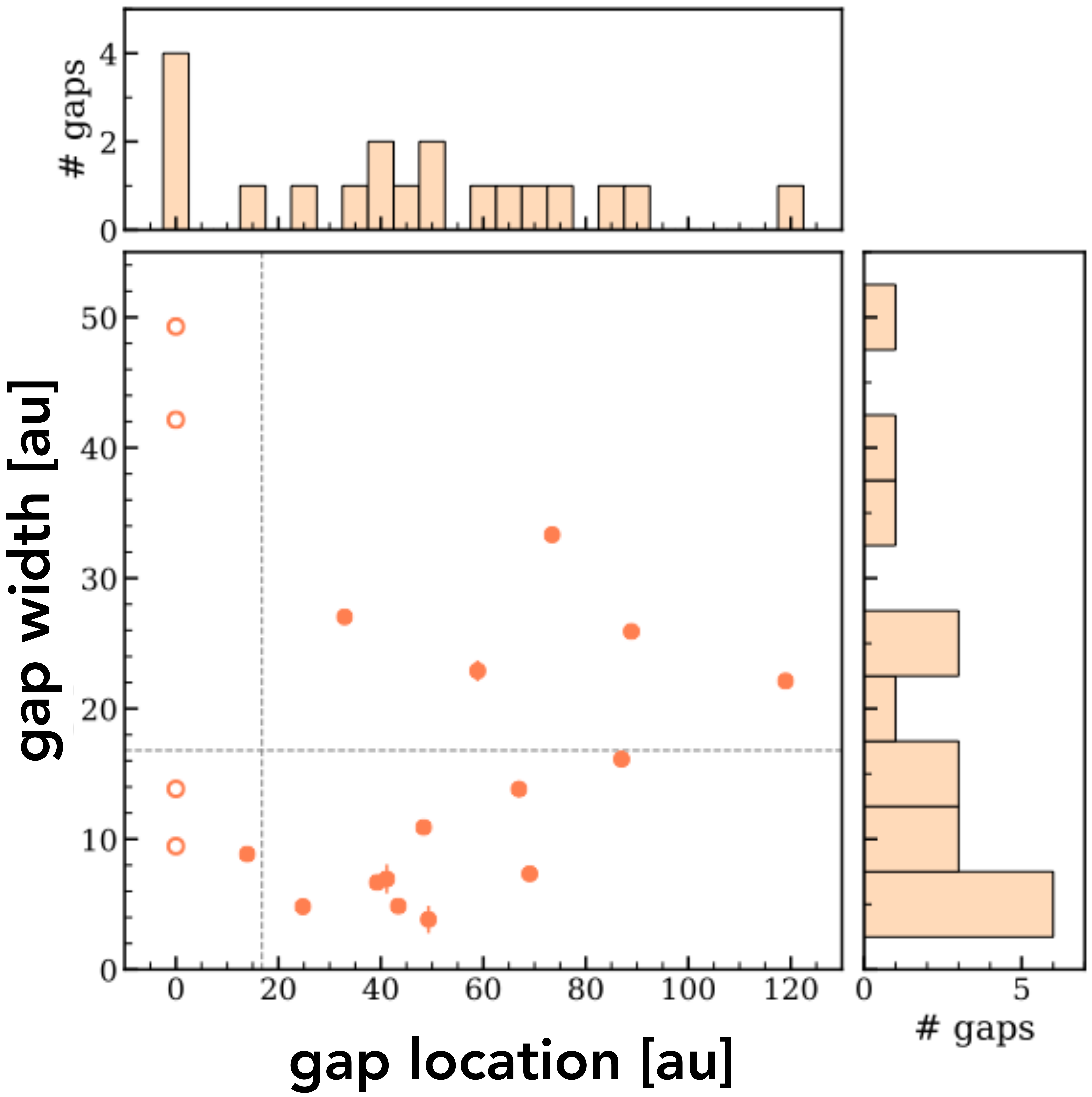


single ring / multiple rings / inner cavities

Long, Pinilla, Herczeg et al. 2018

- *Axisymmetric rings are the most common type of substructures*
- *Spirals and high-contrast azimuthal variations are rare, not seen in our data*

gap/ring properties



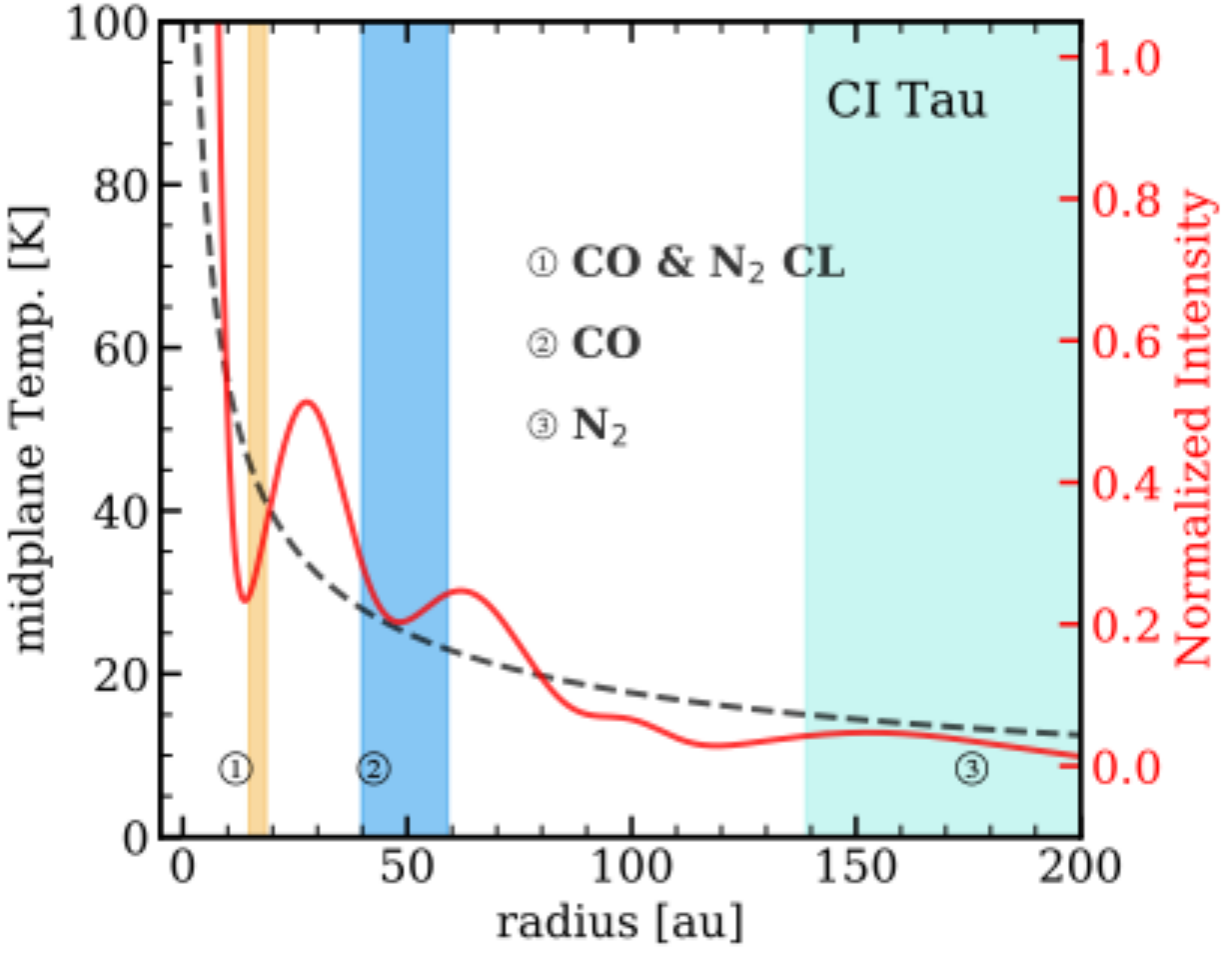
disk morphology fitting in the visibility plane with *Galario* (Tazzari+2018)

- gaps are distributed from 20 —120 au
- many narrow gaps, marginally resolved
- gap location & gap width weakly correlated

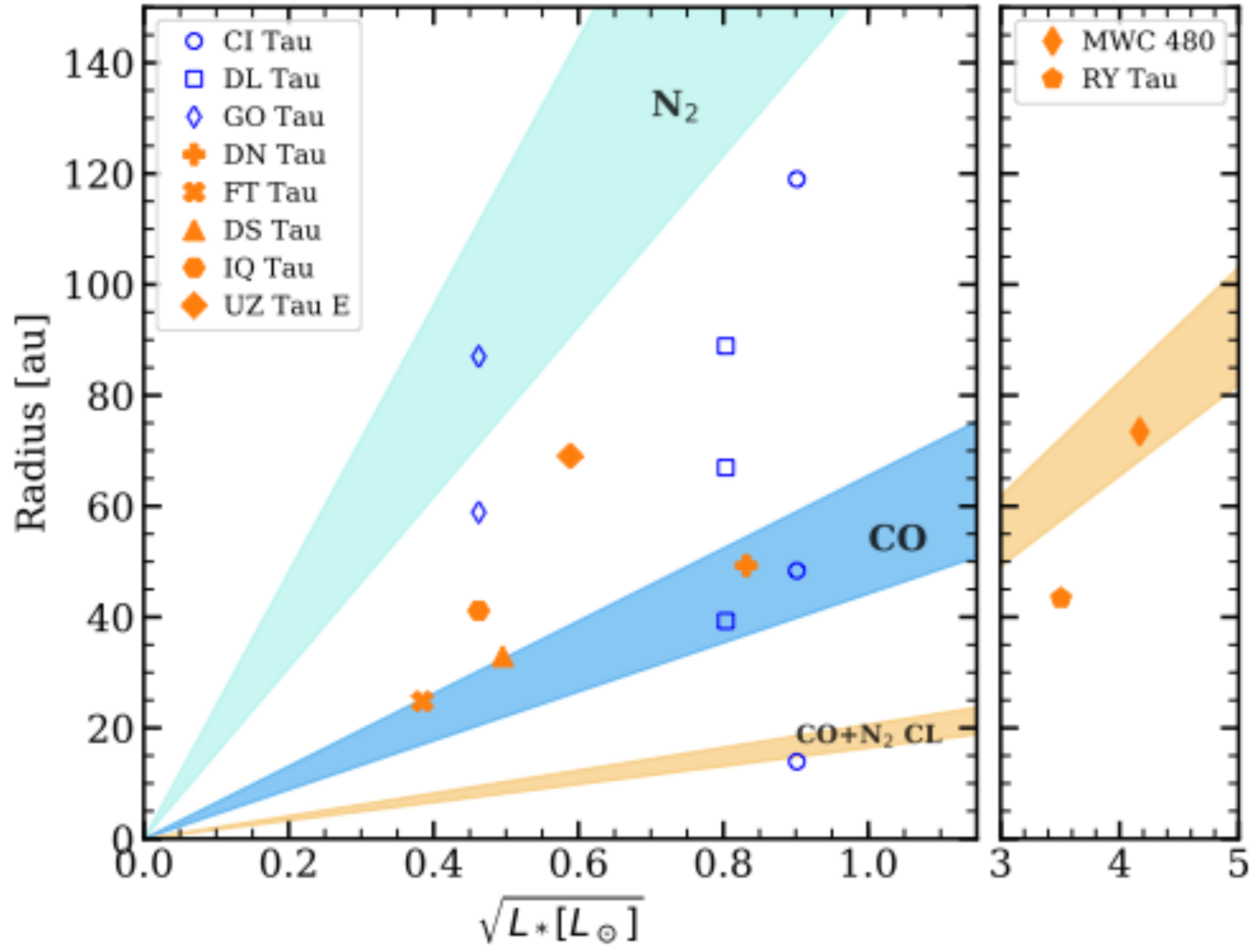
Long et al. 2018

Are these substructures related to ice lines?

dashed line: temperature profile
red line: intensity profile



shaded regions: expected ice line locations
symbols: gap locations

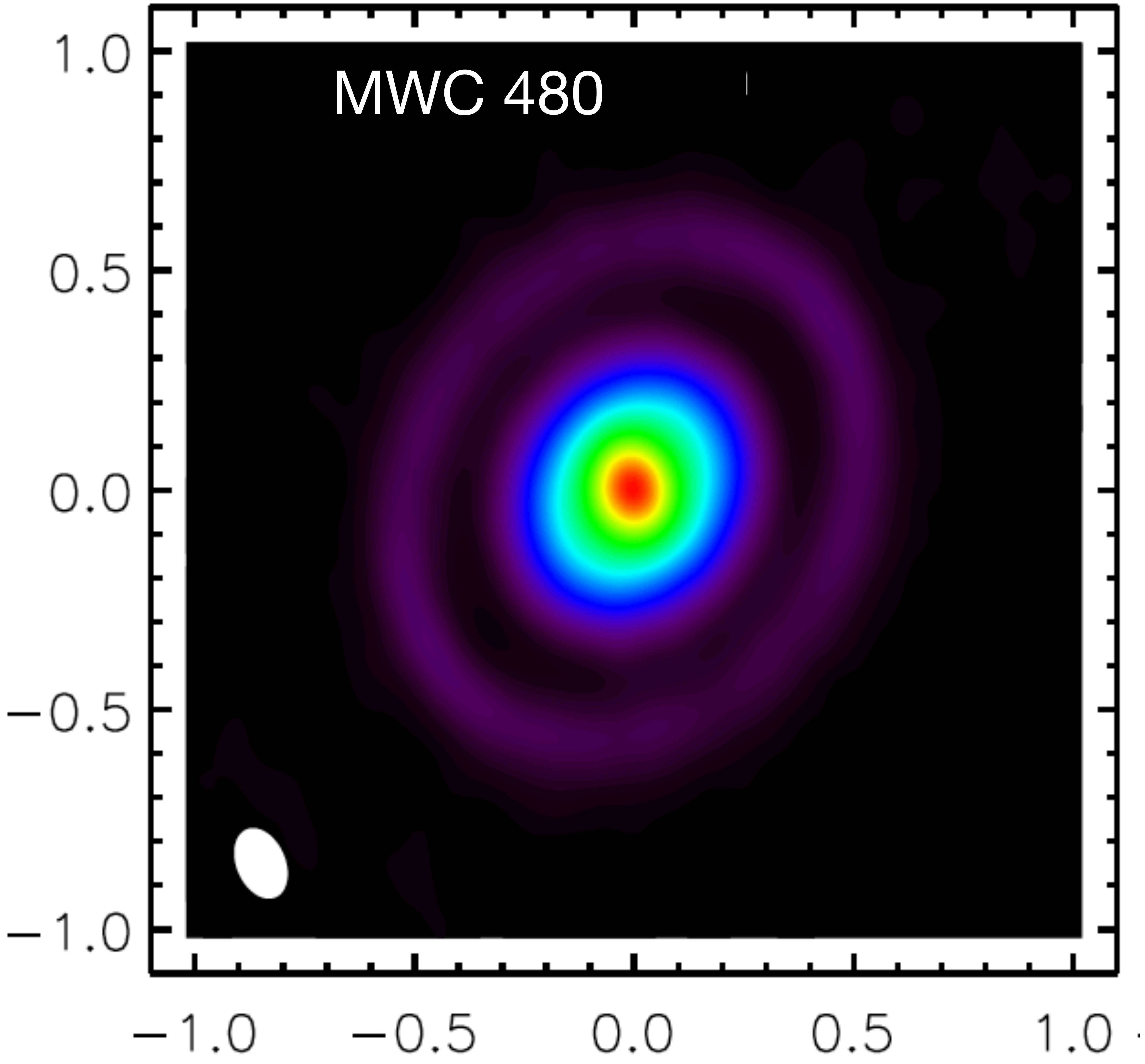


Long et al. 2018

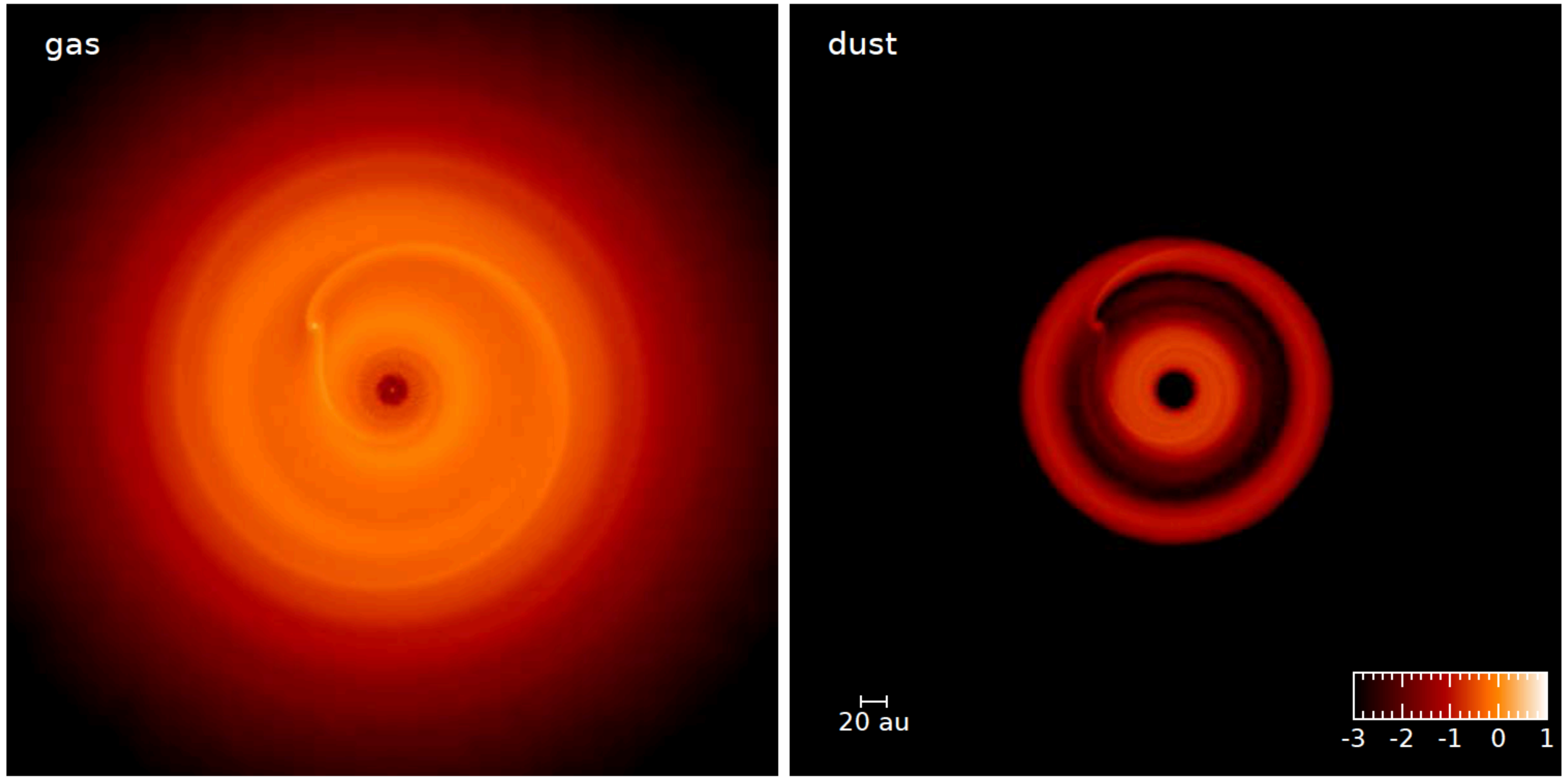
Not all gaps have their matched ice lines;
ice lines are *unlikely* to be a universal mechanism in creating gaps and rings

(see also Huang+2018, van der Marel+2019)

What if the gaps are carved by young planets?
(Liu, Dipierro, Ragusa et al. 2019)



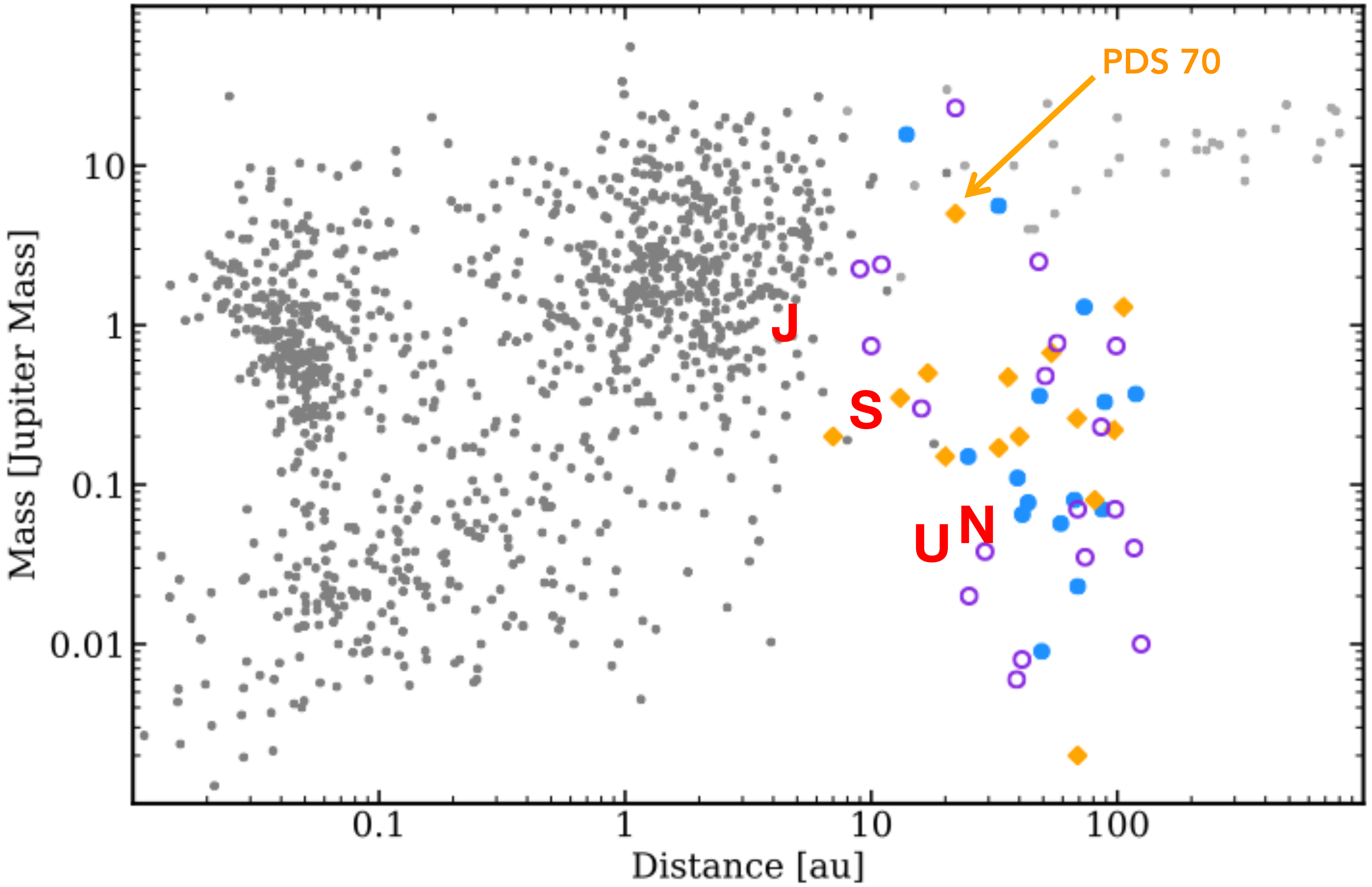
model structure with hydro, RT



Deep gap (contrast of a factor of ~30) consistent with a 2 MJ planet

What if the gaps are carved by young planets?
(Lodato et al. 2019)

gap-inferred planet population



assuming gap width corresponds to 4-7 times planet Hill radius

- If gaps are carved by planets, these planets are most likely to be low mass planets (e.g., Neptunes)
- Gap-inferred young planet population has no discrepancy with current exoplanet statistics
- May migrate inward from present location?

Zhang et al. 2018: DSHARP

Bae et al. 2018: compilation from archival gaps

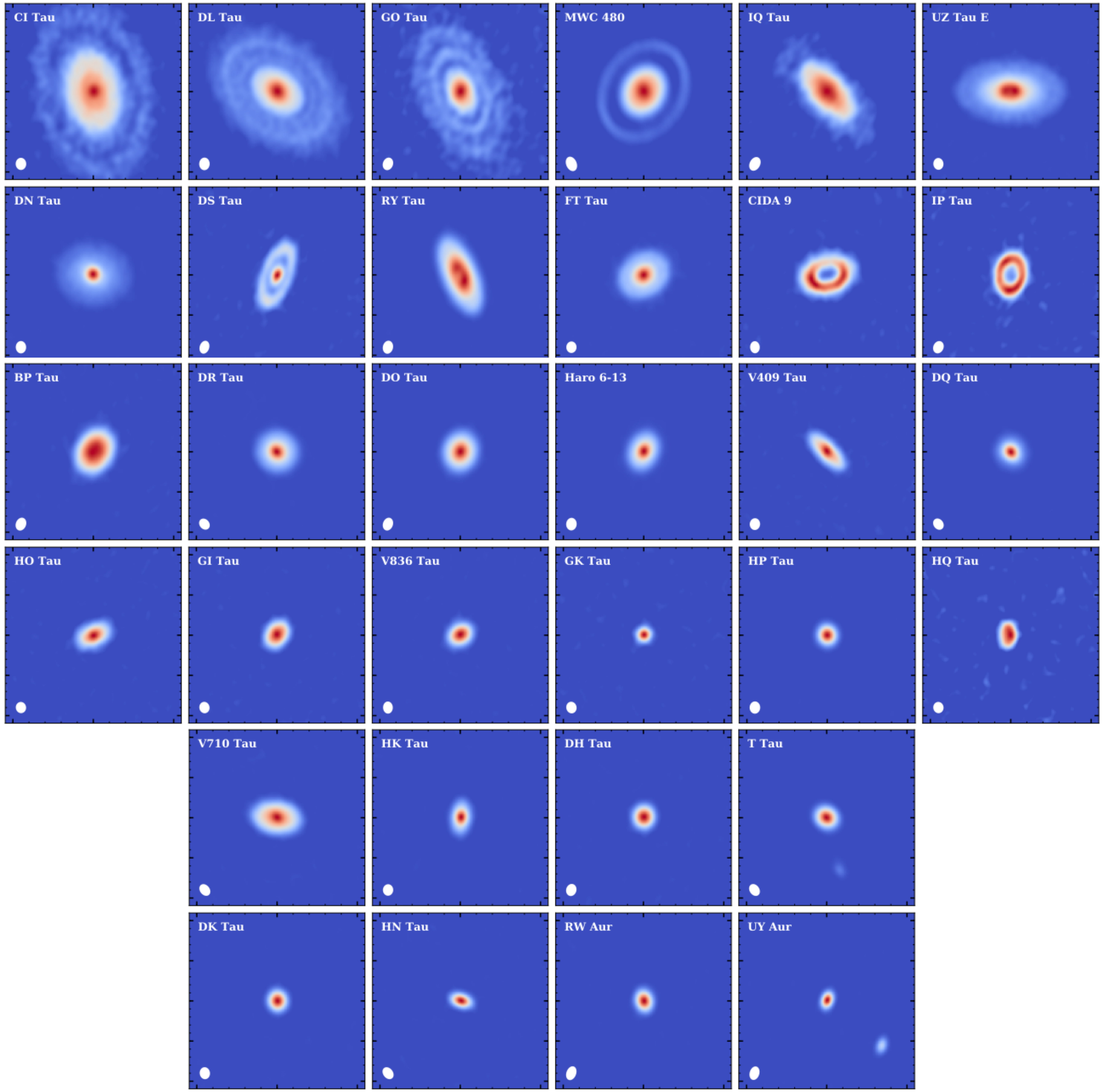
ring disks vs. smooth disks

12 disks with substructures

12 <u>smooth</u> disks in single stars

(well described by a tapered power-law)

8 <u>smooth</u> disks in binaries (0.7'' — 4'')



ring disks vs. smooth disks

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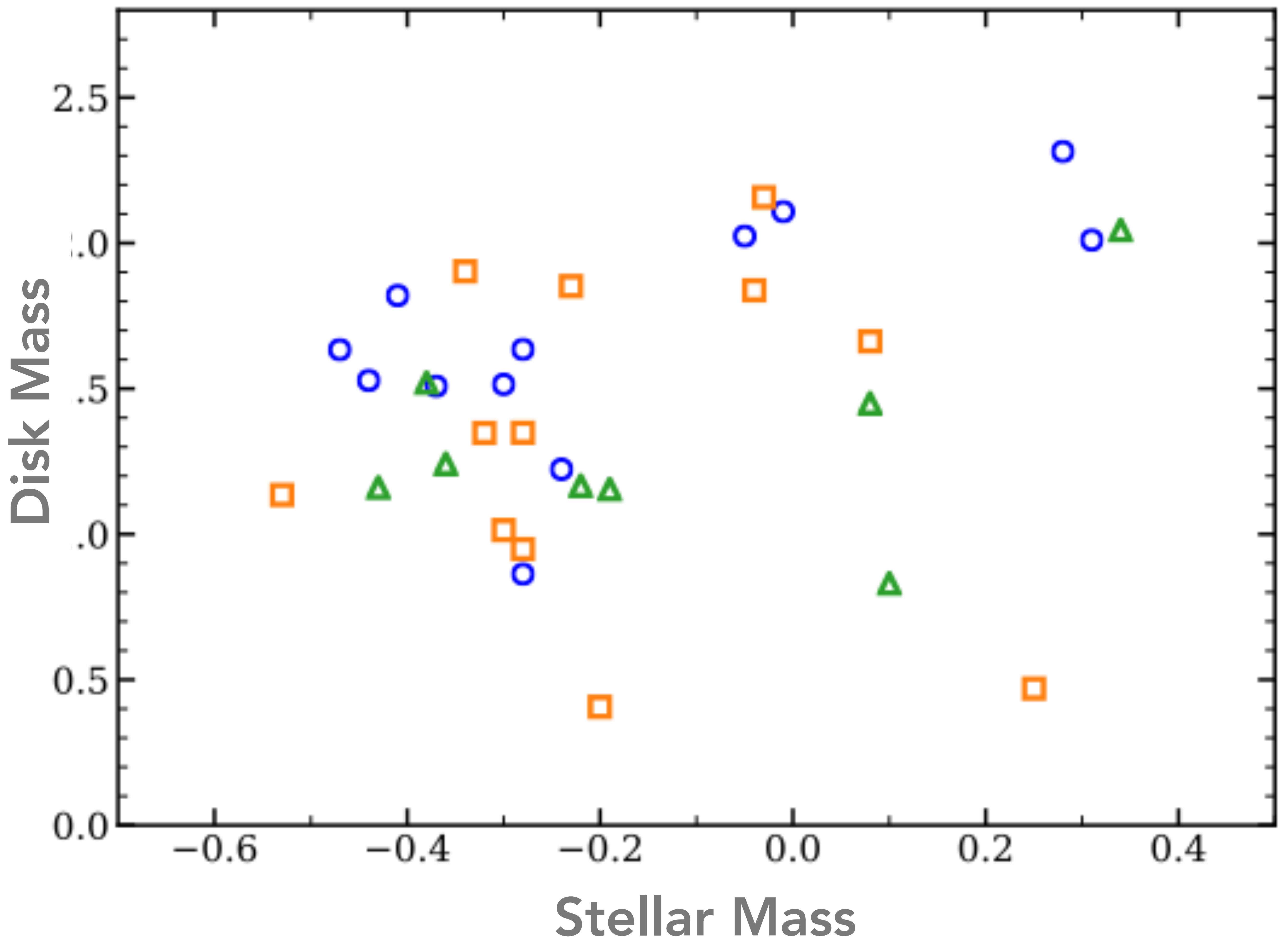
rings smooth singles smooth binaries



Long et al. 2019

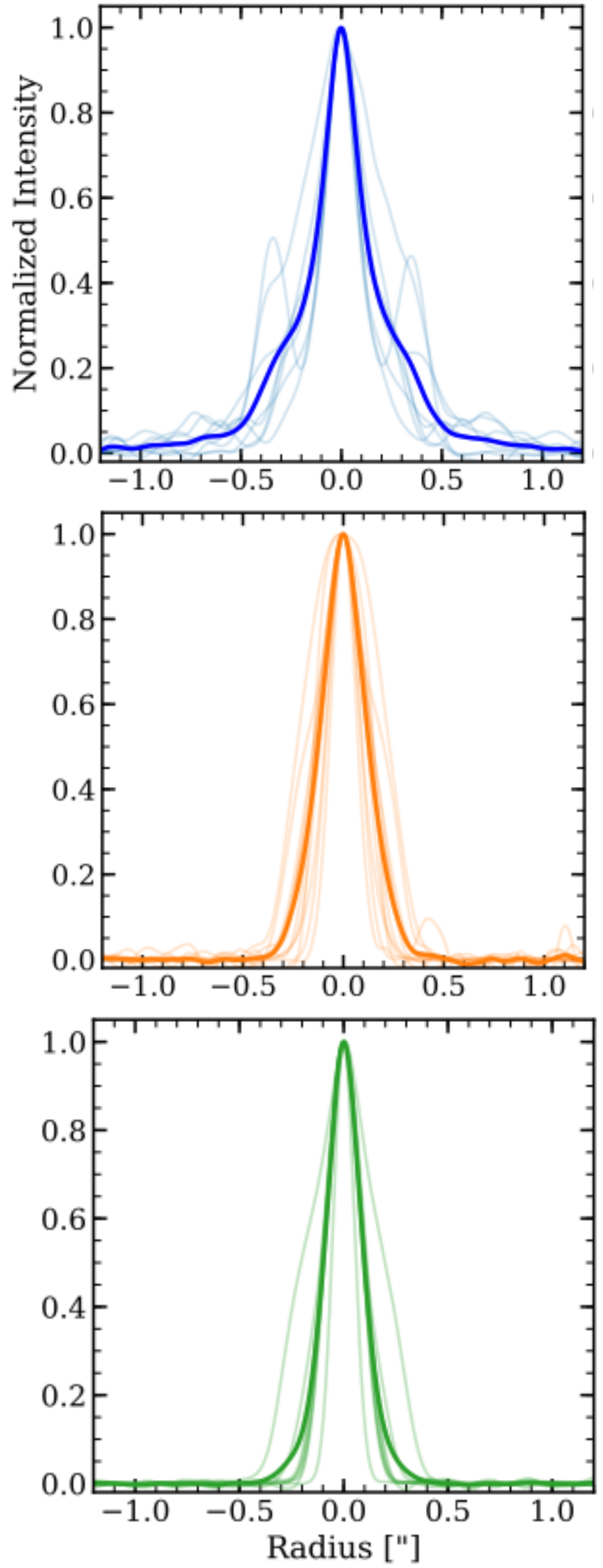
disk radial profile comparison

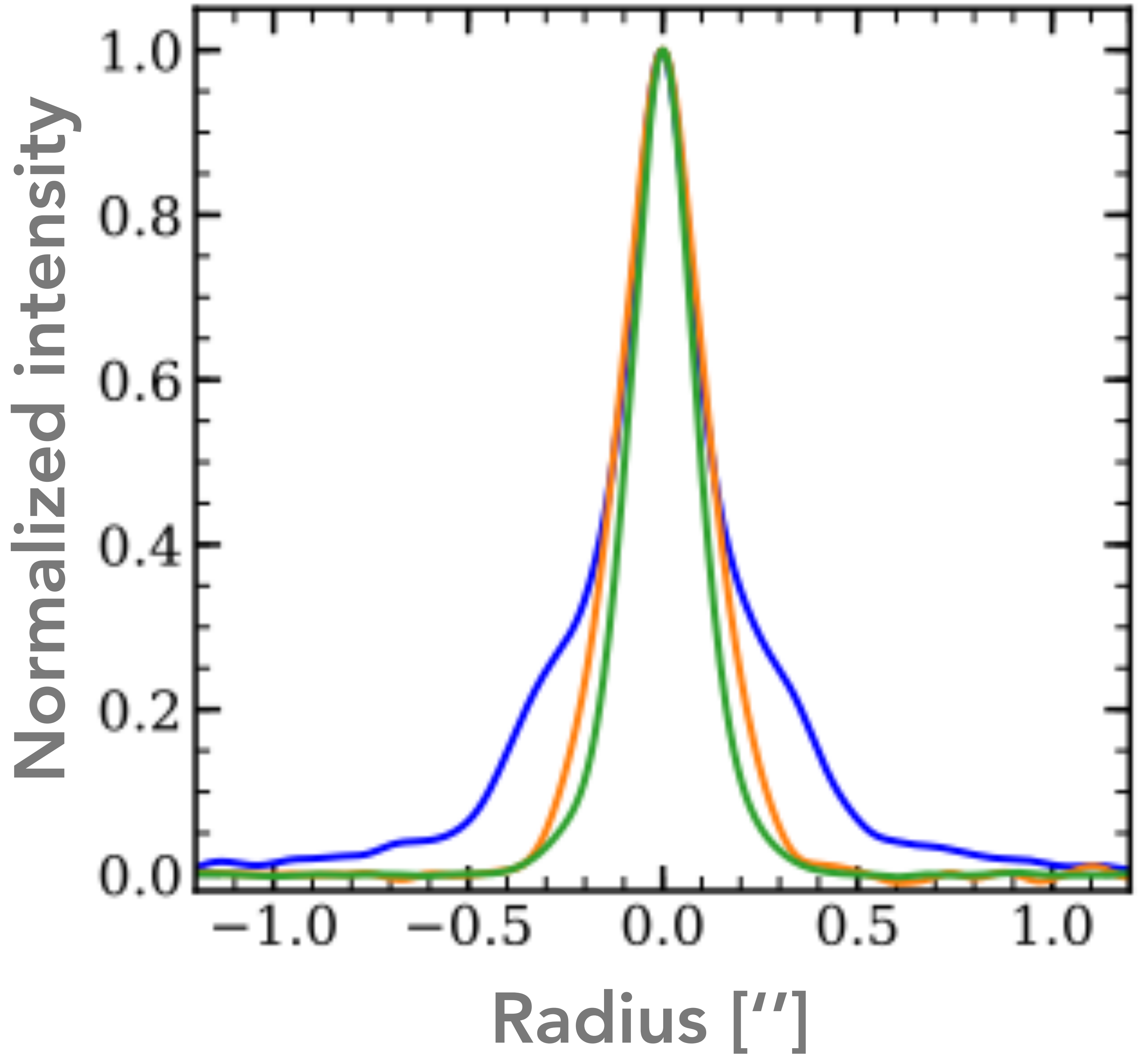
12 disks with substructures

12 smooth disks in single stars

(well described by a tapered power-law)

8 smooth disks in binaries (0.7'' — 4'')



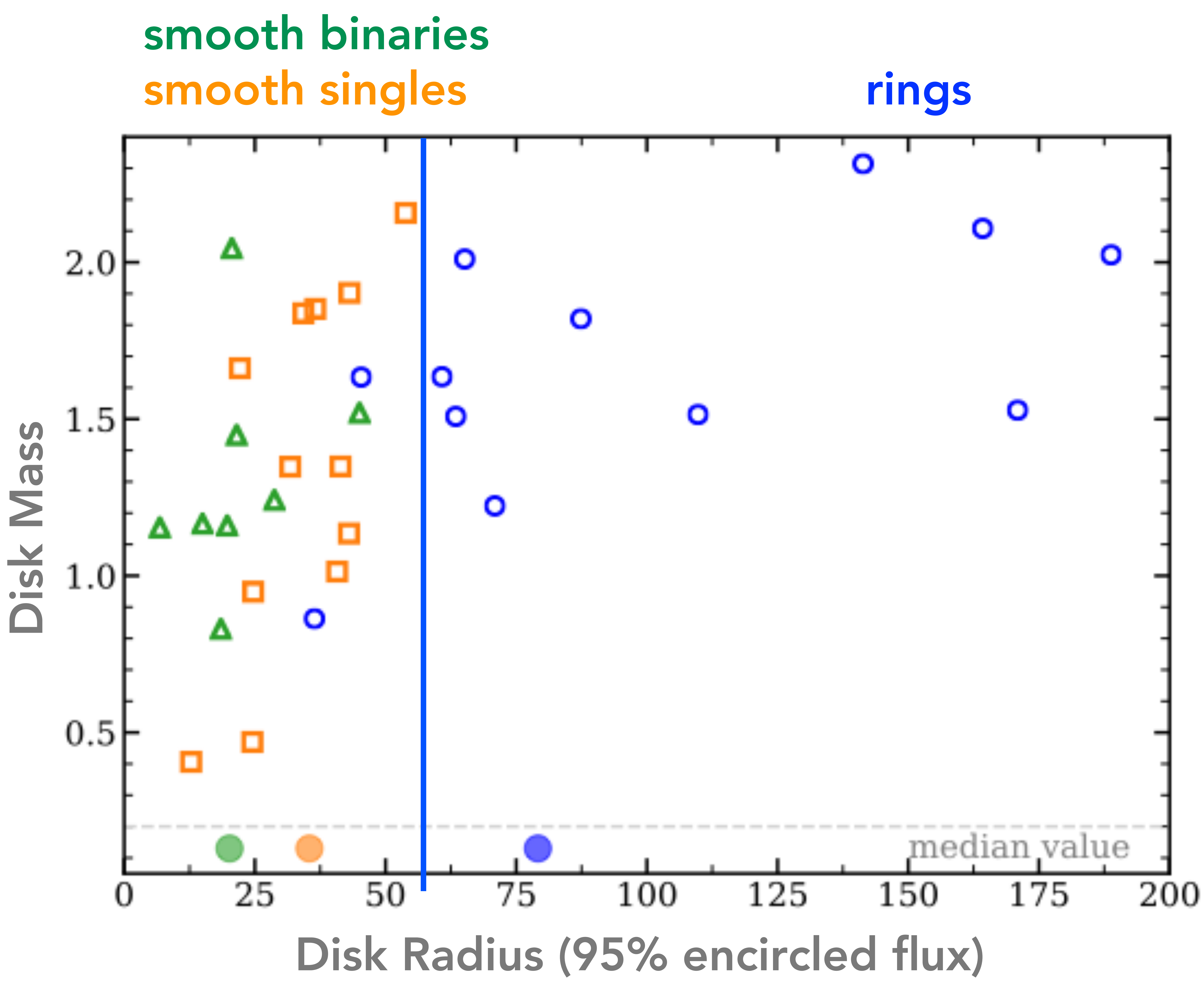


disks with substructures are more extended

(not a brightness difference)

Long et al. 2019

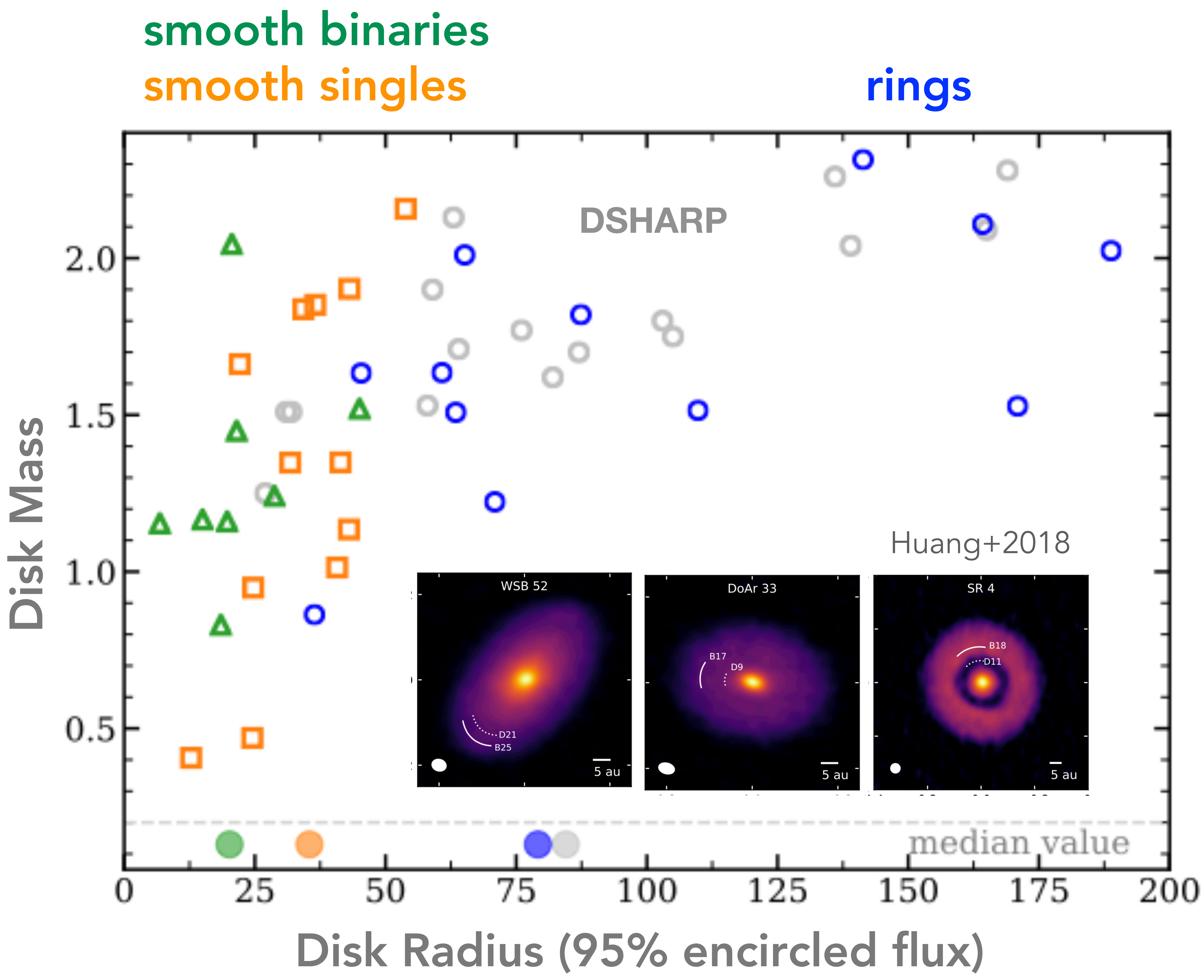
dust disk size comparison



- *disks in our sample with spatial extents larger than 55 au all show detectable substructures*
- *Initial conditions or radial drift/ dust evolution?*
  (see also Facchini, Rosotti talks)

Long et al. 2019

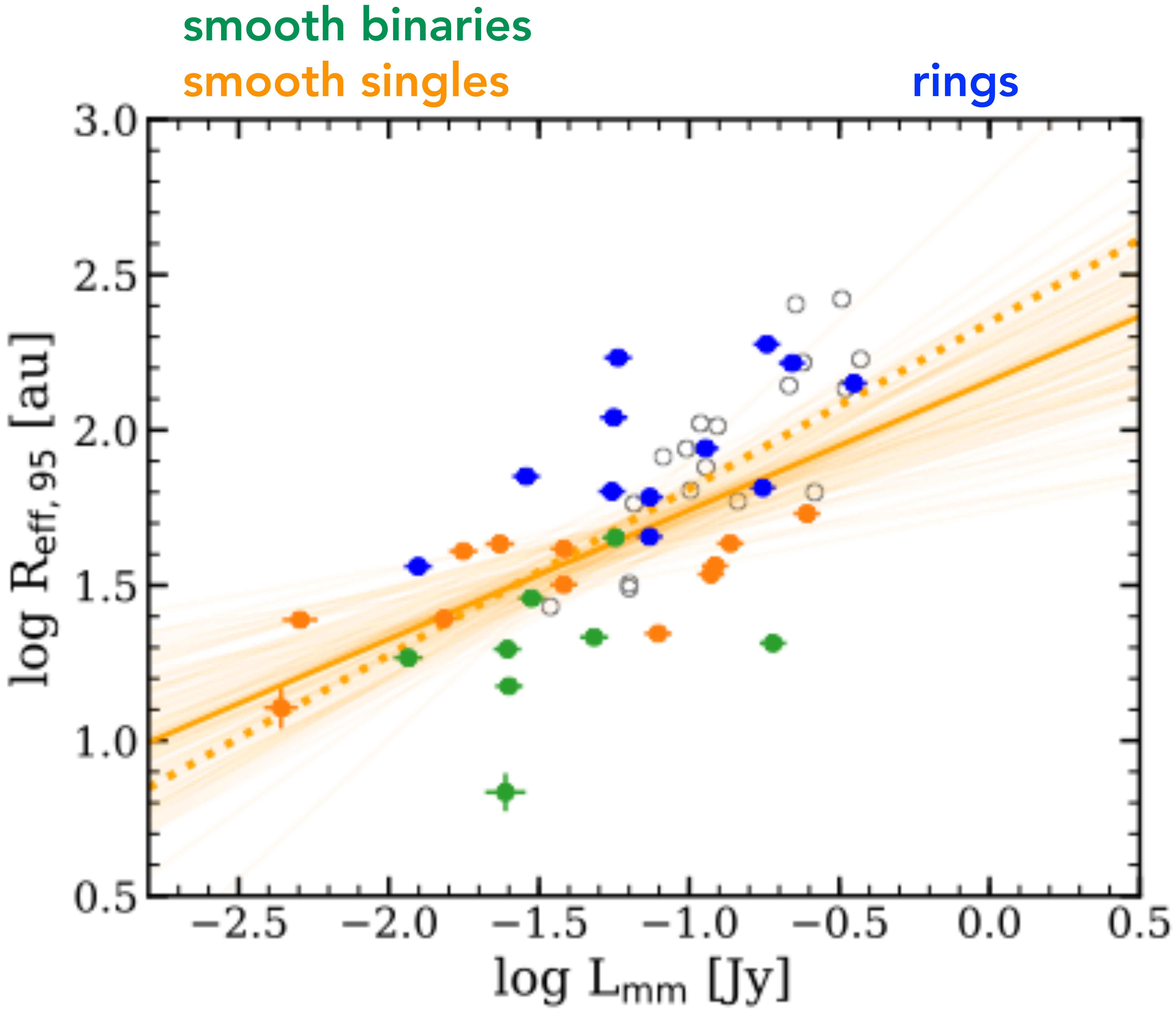
dust disk size comparison



- *any hidden substructures in the inner disks should be low-contrast or very narrow (requires very high-spatial resolution)*

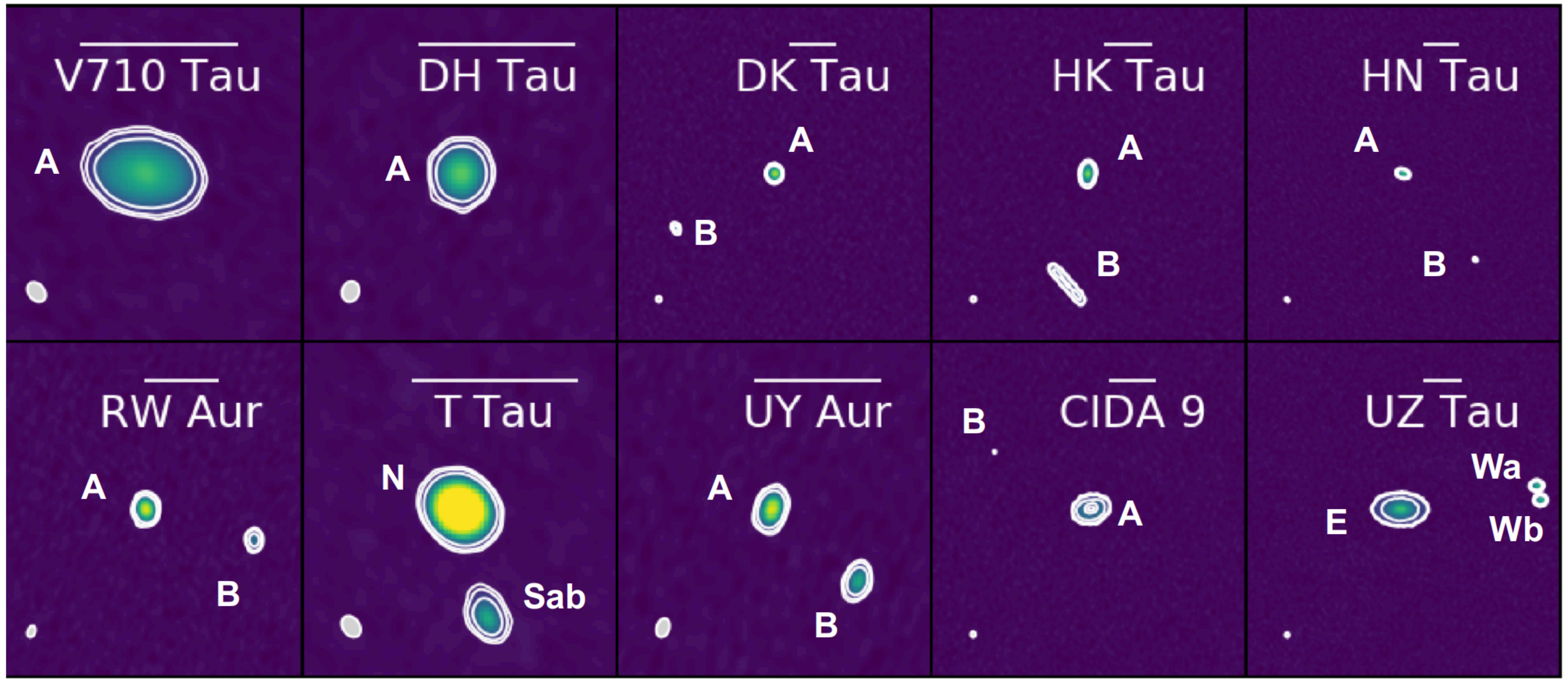
Long et al. 2019

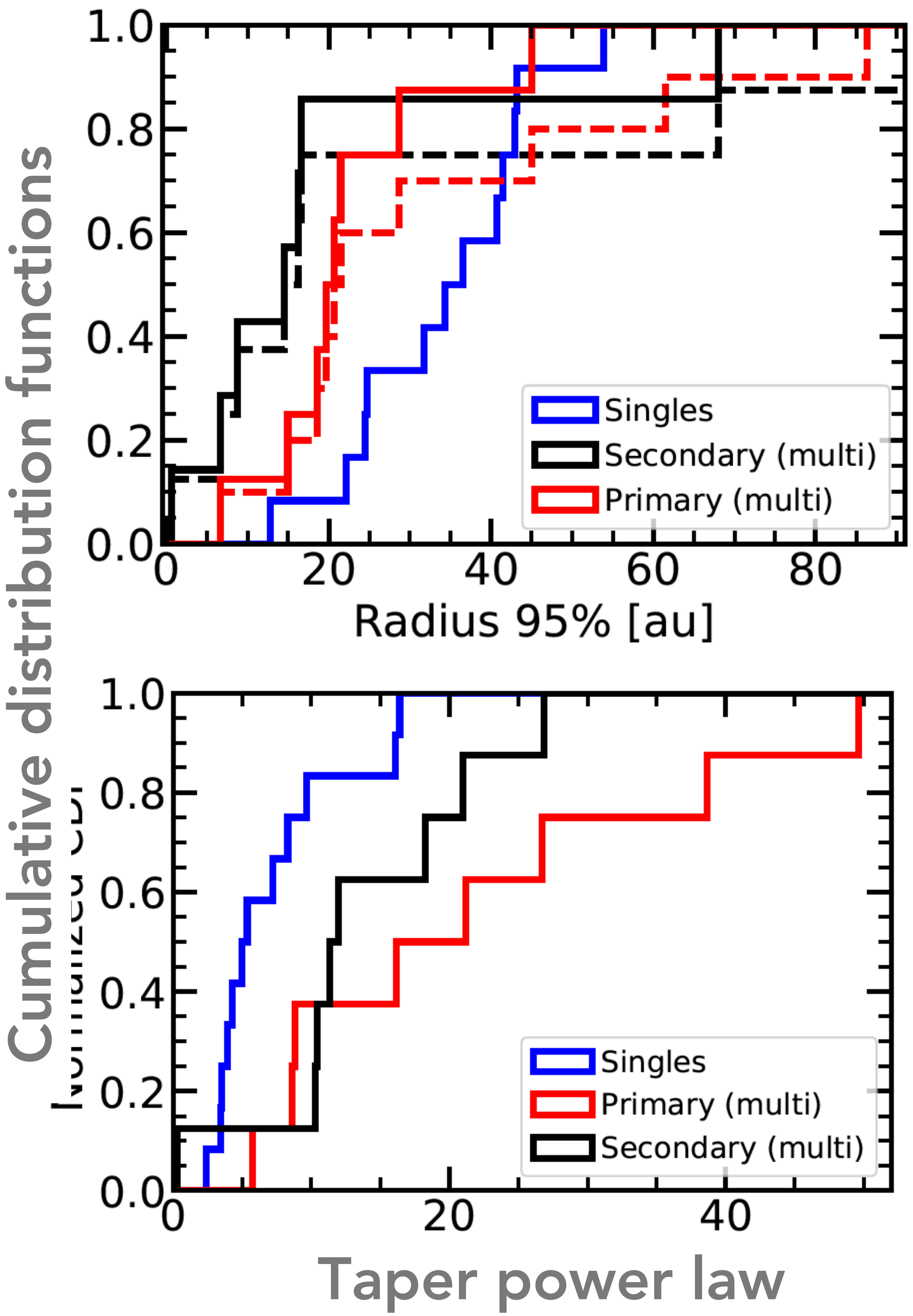
dust disk size - luminosity relation



- *disk luminosity roughly scales with the disk surface area (Tripathi +2017, Andrews+2018)*
- *optically thick disks with various filling factors?*

truncation of disks by companions





- *dust disks in multiple systems are smaller*
- *outer edge sharper (radial drift, Birnstiel & Andrews 2014)*
- *consistent with tidal truncation only if orbital eccentricities are high (>0.5)*
- *caveat: looking at dust, not gas*

Manara et al. 2019

Take-home Messages

- disk substructures are common, especially in large disks (seen in more than 1/3 of our sample)
- the most common type of substructures are axisymmetric rings and gaps
- very narrow substructures may present in the compact smooth disks
- compact smooth disks are likely optically thick
- Compact disks: lack ring at large radius, not a brightness effect