Reading the DSHARP paper series

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DSHARP = Disk Substructures at High Angular Resolution Project

- one of the initial ALMA Large Programs

Link to the paper series:
http://adsabs.harvard.edu/cgi-bin/nph-abs_connect?title=**DSHARP**&start_entry_year=2018
Data (and scripts) publicly available:
https://almascience.org/alma-data/lp/**DSHARP**

1. Andrews et al.: Motivation, Sample, Calibration, and Overview
2. Huang et al.: Characteristics of Annular Substructures
3. Huang et al.: Spiral Structures in the Millimeter Continuum of the Elias 27, IM Lup, and WaOph 6 Disks
4. Kurtovic et al.: Characterizing substructures and interactions in disks around multiple star systems
5. Birnstiel et al.: Interpreting ALMA maps of protoplanetary disks in terms of a dust model
6. Dullemon et al.: Dust trapping in thin-ringed protoplanetary disks
7. Zhang et al.: The Planet-Disk Interactions Interpretation
8. Guzman et al.: The Rich Ringed Substructures in the AS 209 Disk
9. Isella et al.: A high definition study of the HD 163296 planet forming disk
10. Perez et al.: Multiple rings, a misaligned inner disk, and a bright arc in the disk around the T Tauri star HD 143006

Goal

- ❏ to find and characterize substructures in the spatial distributions of **solid particles** for a sample of **20 nearby** protoplanetary disks

Resolution

- ❏ ~0.035 arcsec, 5 au

Data

- ❏ 240 GHz continuum
- ❏ CO (2-1)

General features

- Rings
- Gaps
- Spirals
- Arcs

The papers

- Observational
    - Spiral
- Dust model
- Planet-disk interaction
- Rings, arcs
    - alignment

The big question

- ❑ Disk to planet
- ❑ Assembly of planetesimals

Observational facts

- ❑ Particle size variation with radius
- ❑ Solid-to-gas ratio variation with radius

⇒ Qualitative support of solid evolution models in the early stages of planetesimal assembly

The tension

- ❑ Smooth gas distribution?
  - ⇒ Pressure decreases with r
  - ⇒ Fast inward drift of solid particles
  - ⇒ Should not be smooth (monotonic)

Non-smooth (monotonic) distribution

- ❏ Gas, dust, magnetic field interaction
- ❏ Strong material property gradients

Prominence of substructure

⇒ Very efficient formation of planetary systems

⇒ "Second-generation" substructures

⇒ Affect the orbital architectures

Observations

- ❑ Molecular line
  - ❑ Difficult to get high S/N and high spatial resolution
- ❑ Dust continuum: easier

Survey design

- ❑ Spatial resolution ~ 5 au
- ❑ Contrast ~ 10% for r ~ 40 au

⇒ Optimal frequency: 240 GHz

⇒ Optimal sample region: Oph, Lup, Upper Sco, …

- ❑ Focus on Class II sources
- ❑ Exclude transition disks

Table 1. DSHARP Sample: Host Star Properties

Name	Region	2MASS designation	d (pc)	SpT	$\log T_{\rm eff}$ (K)	$\log L_*$ ($L_\odot$)	$\log M_*$ ($M_\odot$)	$\log t_*$ (yr)	$\log \dot{M}_*$ $M_\odot$ yr^{-1}	Refs.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
HT Lup [a]	Lup I	J15451286-3417305	154 ± 2	K2	3.69 ± 0.02	0.74 ± 0.20	$0.23^{+0.06}_{-0.13}$	5.9 ± 0.3	$<$ -8.4	1, 1, 1
GW Lup	Lup I	J15464473-3430354	155 ± 3	M1.5	3.56 ± 0.02	-0.48 ± 0.20	$-0.34^{+0.10}_{-0.17}$	6.3 ± 0.4	-9.0 ± 0.4	1, 1, 1
IM Lup	Lup II	J15560921-3756057	158 ± 3	K5	3.63 ± 0.03	0.41 ± 0.20	$-0.05^{+0.09}_{-0.13}$	5.7 ± 0.4	-7.9 ± 0.4	1, 1, 1
RU Lup	Lup II	J15564230-3749154	159 ± 3	K7	3.61 ± 0.02	0.16 ± 0.20	$-0.20^{+0.12}_{-0.11}$	5.7 ± 0.4	-7.1 ± 0.3	1, 1, 1
Sz 114	Lup III	J16090185-3905124	162 ± 3	M5	3.50 ± 0.01	-0.69 ± 0.20	$-0.76^{+0.08}_{-0.07}$	$6.0^{+0.1}_{-0.8}$	-9.1 ± 0.3	1, 1, 1
Sz 129	Lup IV	J15591647-4157102	161 ± 3	K7	3.61 ± 0.02	-0.36 ± 0.20	$-0.08^{+0.03}_{-0.15}$	6.6 ± 0.4	-8.3 ± 0.3	1, 1, 1
MY Lup [b]	Lup IV	J16004452-4155310	156 ± 3	K0	3.71 ± 0.02	-0.06 ± 0.20	$0.09^{+0.03}_{-0.13}$	$7.0^{+0.6}_{-0.3}$	$<$ -9.6	1, 1, 1
HD 142666	Upper Sco	J15564002-2201400	148 ± 2	A8	3.88 ± 0.02	0.96 ± 0.21	$0.20^{+0.04}_{-0.01}$	7.1 ± 0.3	$<$ -8.4	2, 2, 2
HD 143006	Upper Sco	J15583692-2257153	165 ± 5	G7	3.75 ± 0.02	0.58 ± 0.15	$0.25^{+0.05}_{-0.08}$	6.6 ± 0.3	-8.1 ± 0.4	3, 4, 5
AS 205 [a]	Upper Sco	J16113134-1838259	128 ± 2	K5	3.63 ± 0.03	0.33 ± 0.15	$-0.06^{+0.07}_{-0.05}$	5.8 ± 0.3	-7.4 ± 0.4	3, 4, 6
SR 4	Oph L1688	J16255615-2420481	134 ± 2	K7	3.61 ± 0.02	0.07 ± 0.20	$-0.17^{+0.11}_{-0.14}$	5.9 ± 0.4	-6.9 ± 0.5	7, 8, 9
Elias 20	Oph L1688	J16261886-2428196	138 ± 5	M0	3.59 ± 0.03	0.35 ± 0.20	$-0.32^{+0.12}_{-0.07}$	$<$ 5.9	-6.9 ± 0.5	9, 10, 9
DoAr 25	Oph L1688	J16262367-2443138	138 ± 3	K5	3.63 ± 0.03	-0.02 ± 0.20	$-0.02^{+0.04}_{-0.19}$	6.3 ± 0.4	-8.3 ± 0.5	11, 10, 12
Elias 24	Oph L1688	J16262407-2416134	136 ± 3	K5	3.63 ± 0.03	0.78 ± 0.20	$-0.11^{+0.16}_{-0.08}$	5.3 ± 0.4	-6.4 ± 0.5	11, 8, 9
Elias 27	Oph L1688	J16264502-2423077	116^{+19}_{-10}	M0	3.59 ± 0.03	-0.04 ± 0.23	$-0.31^{+0.15}_{-0.11}$	5.9 ± 0.5	-7.2 ± 0.5	7, 10, 9
DoAr 33	Oph L1688	J16273901-2358187	139 ± 2	K4	3.65 ± 0.03	0.18 ± 0.20	$0.04^{+0.05}_{-0.17}$	6.2 ± 0.4	···	13, 8
WSB 52	Oph L1688	J16273942-2439155	136 ± 3	M1	3.57 ± 0.03	-0.15 ± 0.20	$-0.32^{+0.13}_{-0.17}$	5.8 ± 0.5	-7.6 ± 0.5	7, 8, 9
WaOph 6	Oph N 3a	J16484562-1416359	123 ± 2	K6	3.62 ± 0.03	0.46 ± 0.20	$-0.17^{+0.17}_{-0.09}$	5.5 ± 0.5	-6.6 ± 0.5	14, 10, 14
AS 209	Oph N 3a	J16491530-1422087	121 ± 2	K5	3.63 ± 0.03	0.15 ± 0.20	$-0.08^{+0.11}_{-0.14}$	6.0 ± 0.4	-7.3 ± 0.5	15, 10, 6
HD 163296	isolated?	J17562128-2157218	101 ± 2	A1	3.97 ± 0.03	1.23 ± 0.30	$0.31^{+0.05}_{-0.03}$	7.1 ± 0.6	-7.4 ± 0.3	2, 2, 2

Note—Col. (1) Target name. Col. (2) Associated star-forming region. The Lup sub-cloud regions are as designated by Cambrésy (1999). Upper Sco memberships were made following Luhman et al. (2018). AS 209 and WaOph 6 are located well northeast of the main Oph region in the Oph N 3a complex. They are most closely associated with the L163 and L162 dark clouds, respectively. Col. (3) The 2MASS designations, to aid in catalog cross-referencing. Col. (4) Distance (computed from the *Gaia* DR2 parallaxes). Col. (5) Spectral type from the literature (first reference entries in Col. 11). Col. (6) Effective temperatures from the literature (second reference entries in Col. 11). Col. (7) Stellar luminosities from the literature, scaled according to the appropriate d in Col. (4) (second reference entries in Col. (11). Cols. (8)+(9) Stellar masses and ages. Col. (9) Accretion rates, inferred from (properly scaled) accretion luminosities (third reference entries in Col. 11). All quoted measurements correspond to the peak of the marginalized posterior distributions. Uncertainties reflect the 68.3% confidence interval; limits are taken at the 95.5% confidence level.

[a] HT Lup (Sz 68) and AS 205 (V866 Sco) are triple systems. See Kurtovic et al. (2018) for details.

[b] The MY Lup disk is inclined and flared enough that it likely extincts the host: the L_* and t_* estimates may be too faint and old, respectively.

SEDs

I $0.3 \leqslant \alpha$;
Flat $-0.3 \leqslant \alpha < 0.3$;
II $-1.6 \leqslant \alpha < -0.3$;
III $\alpha < -1.6$.

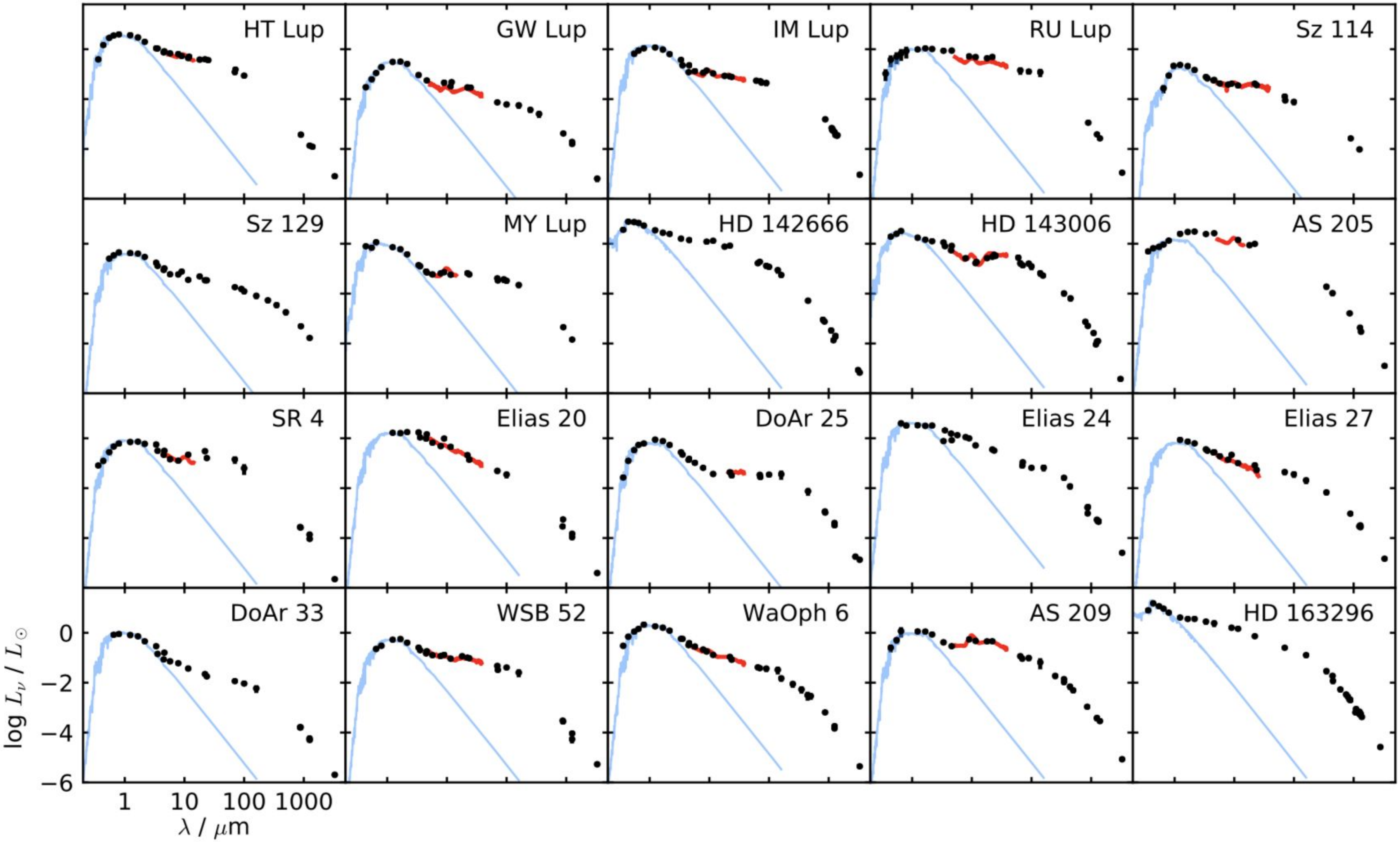
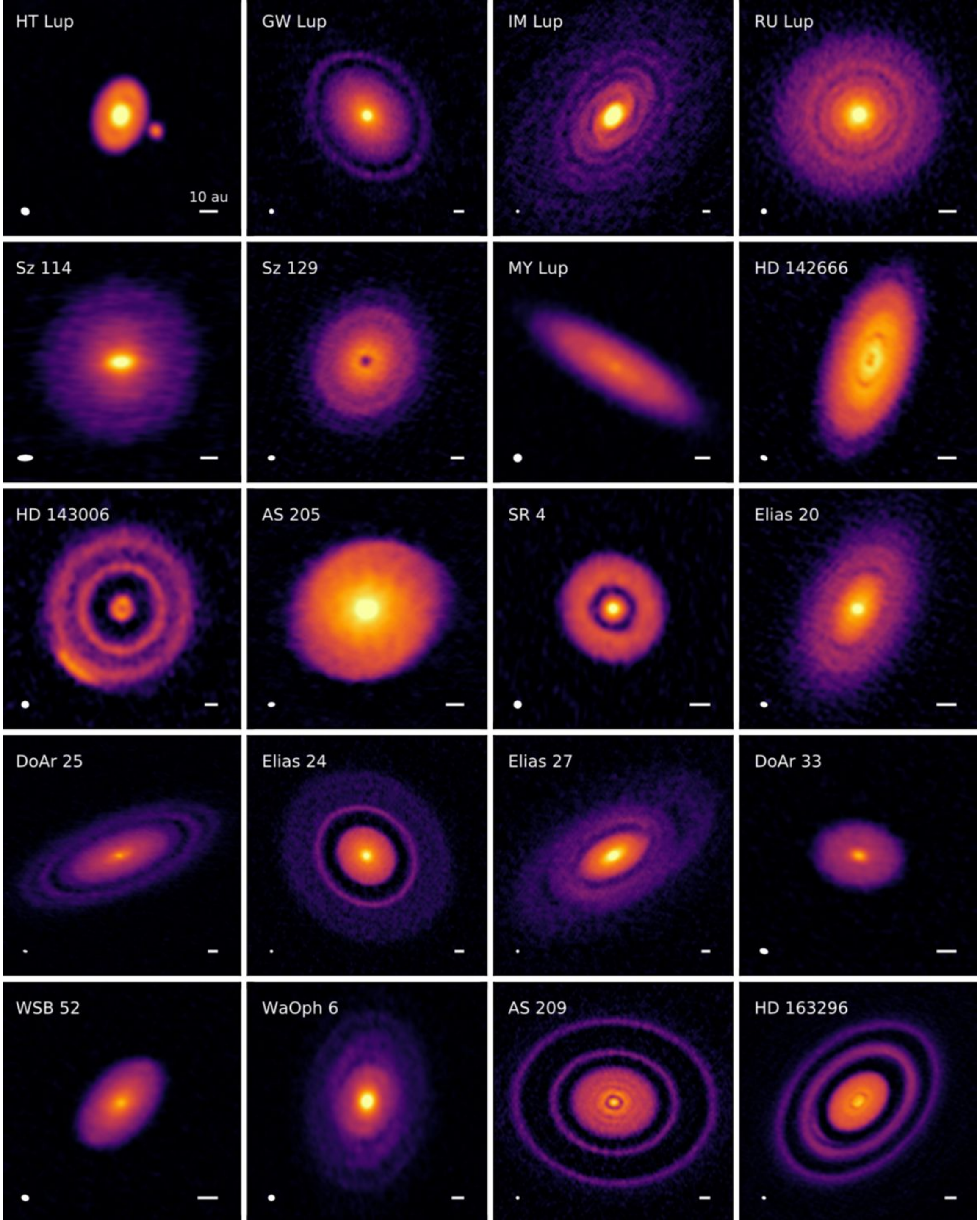
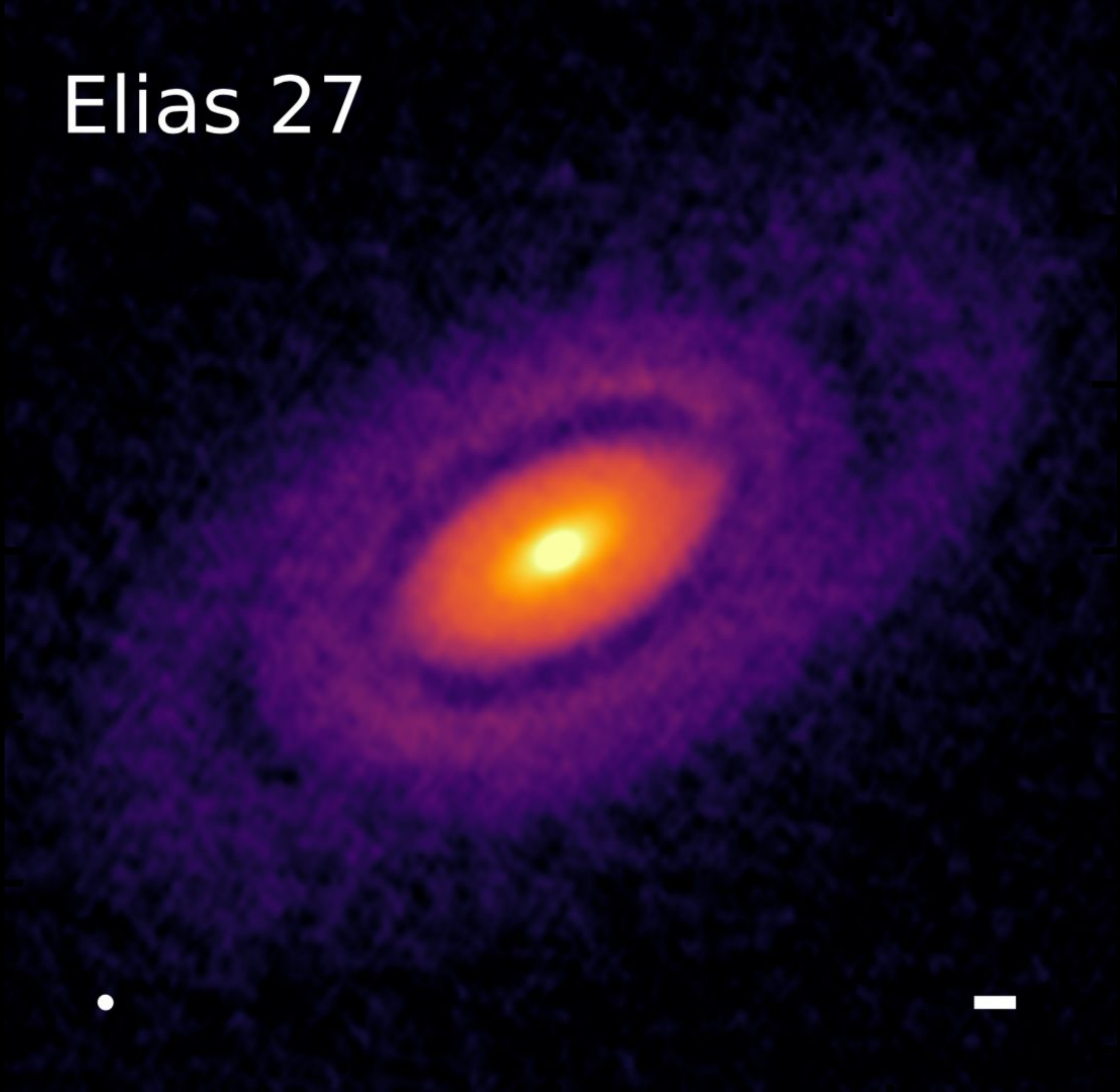
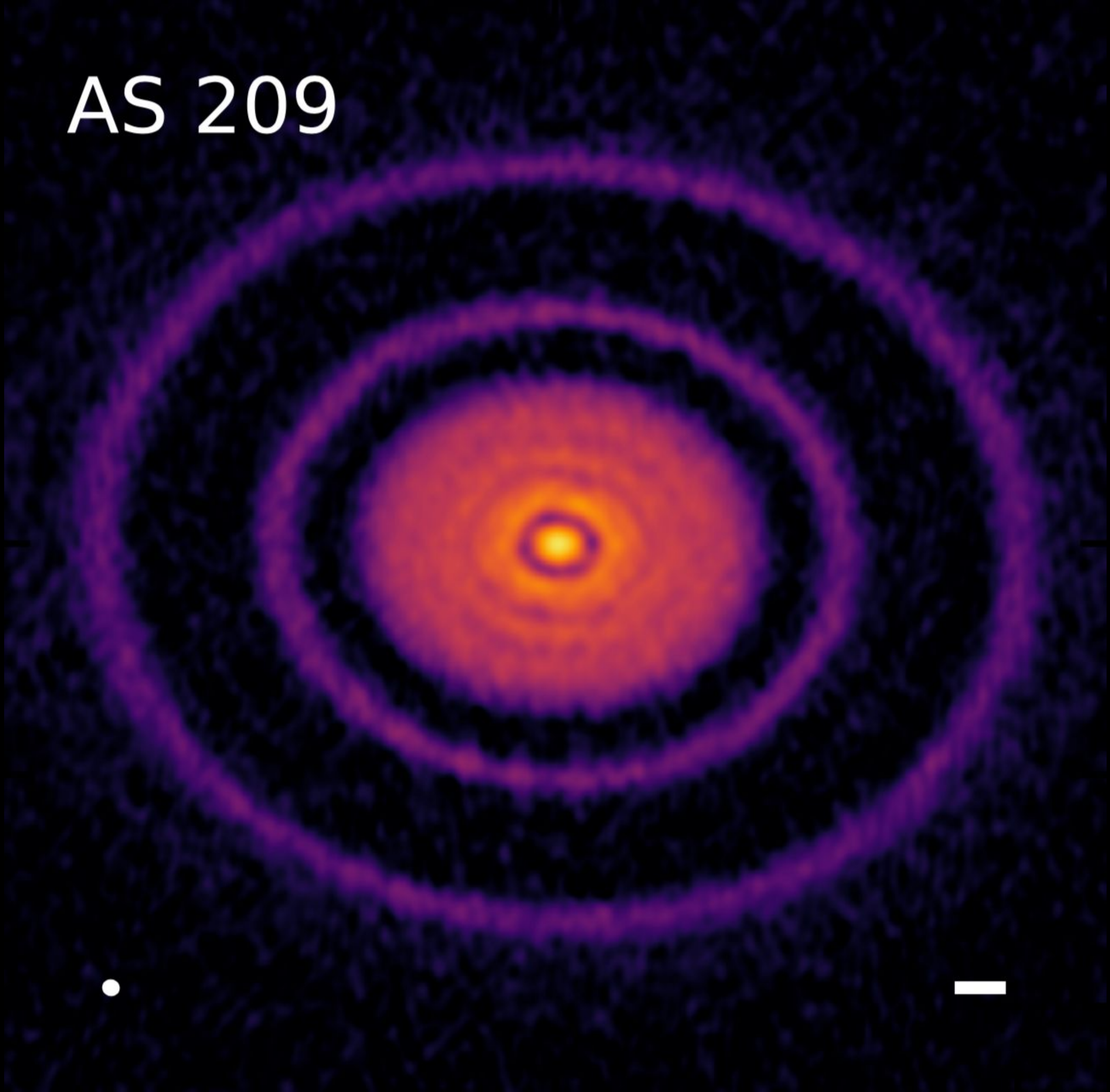


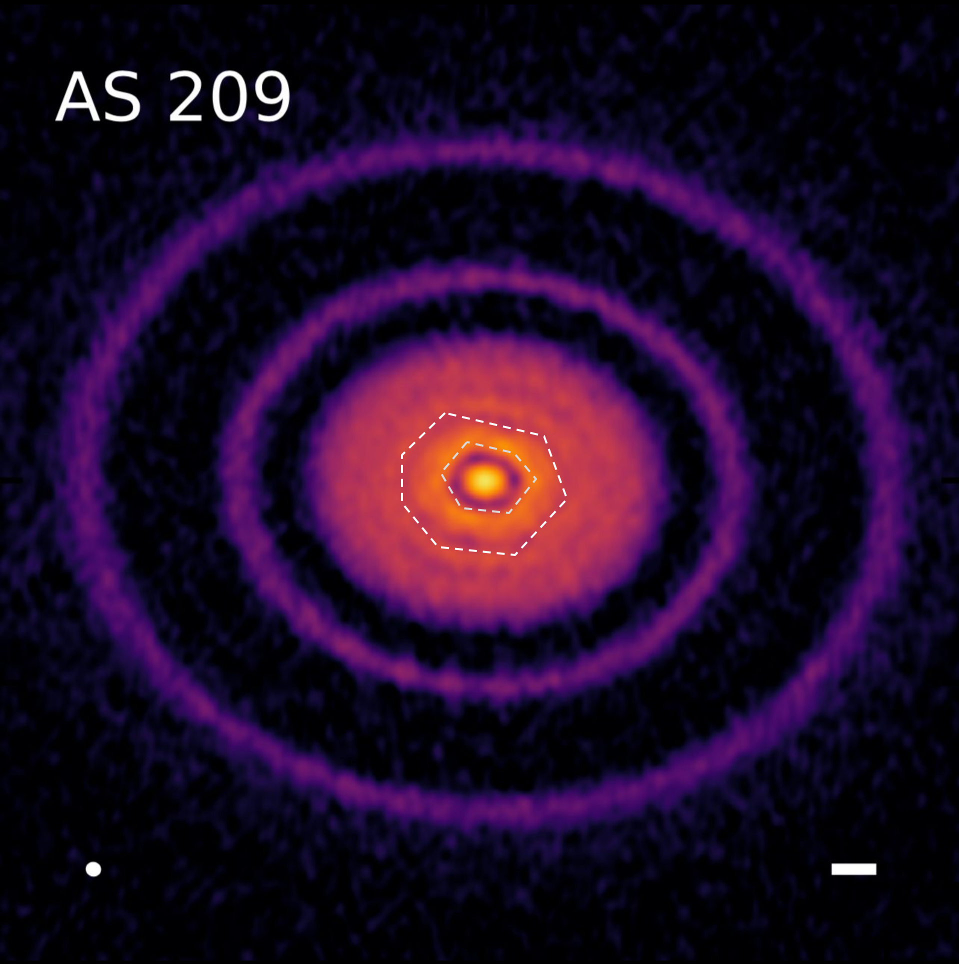
Figure 1. Broadband SEDs for the DSHARP targets. The ordinate is $L_\nu = 4\pi d^2 \nu F_\nu$ in $L_\odot$ units. These SEDs have been de-reddened

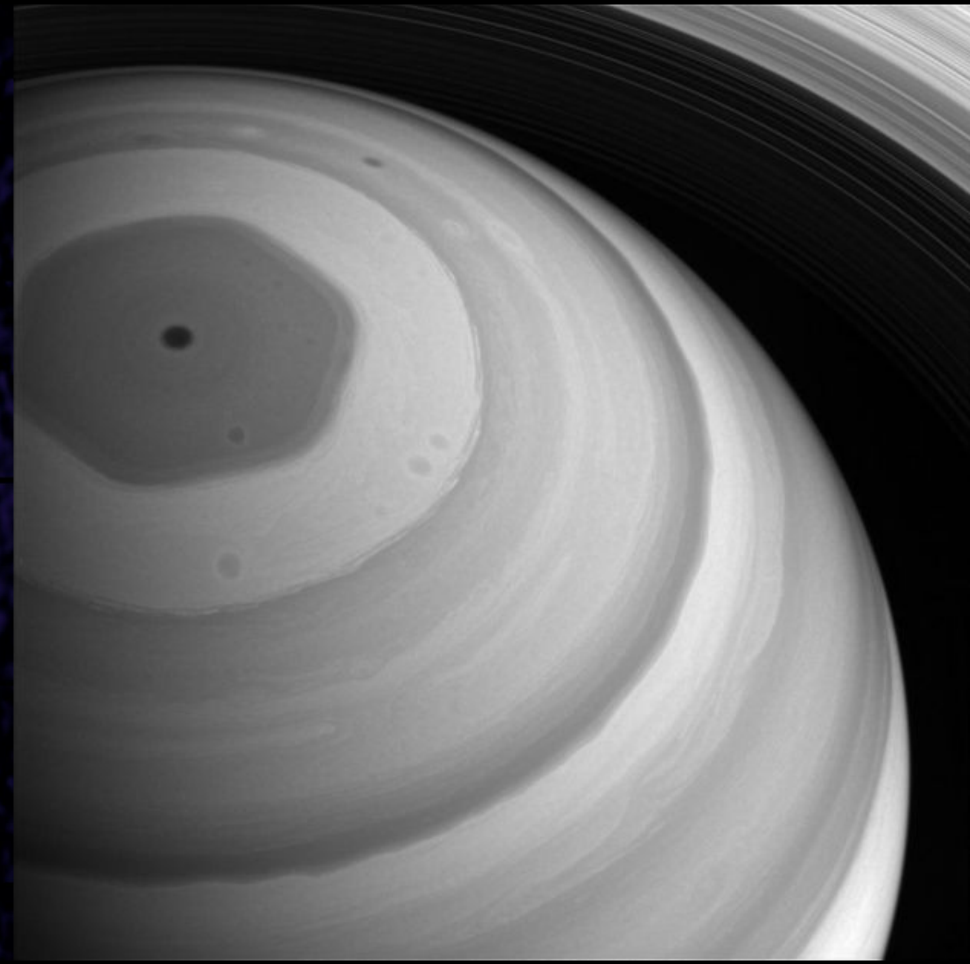

HT Lup
10 au
GW Lup
IM Lup
RU Lup
Sz 114
Sz 129
MY Lup
HD 142666
HD 143006
AS 205
SR 4
Elias 20
DoAr 25
Elias 24
Elias 27
DoAr 33
WSB 52
WaOph 6
AS 209
HD 163296


Elias 24

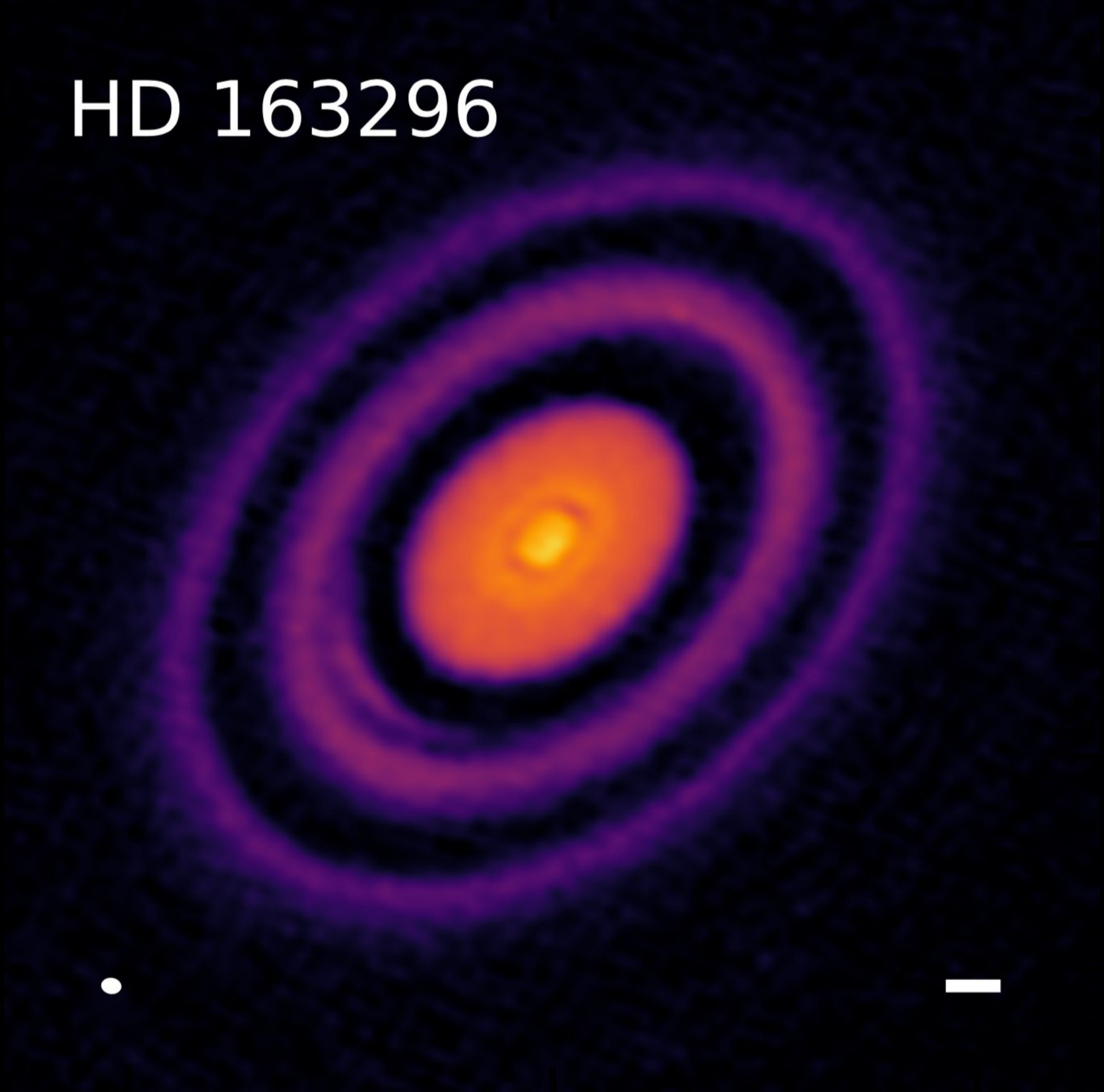

Elias 27


AS 209

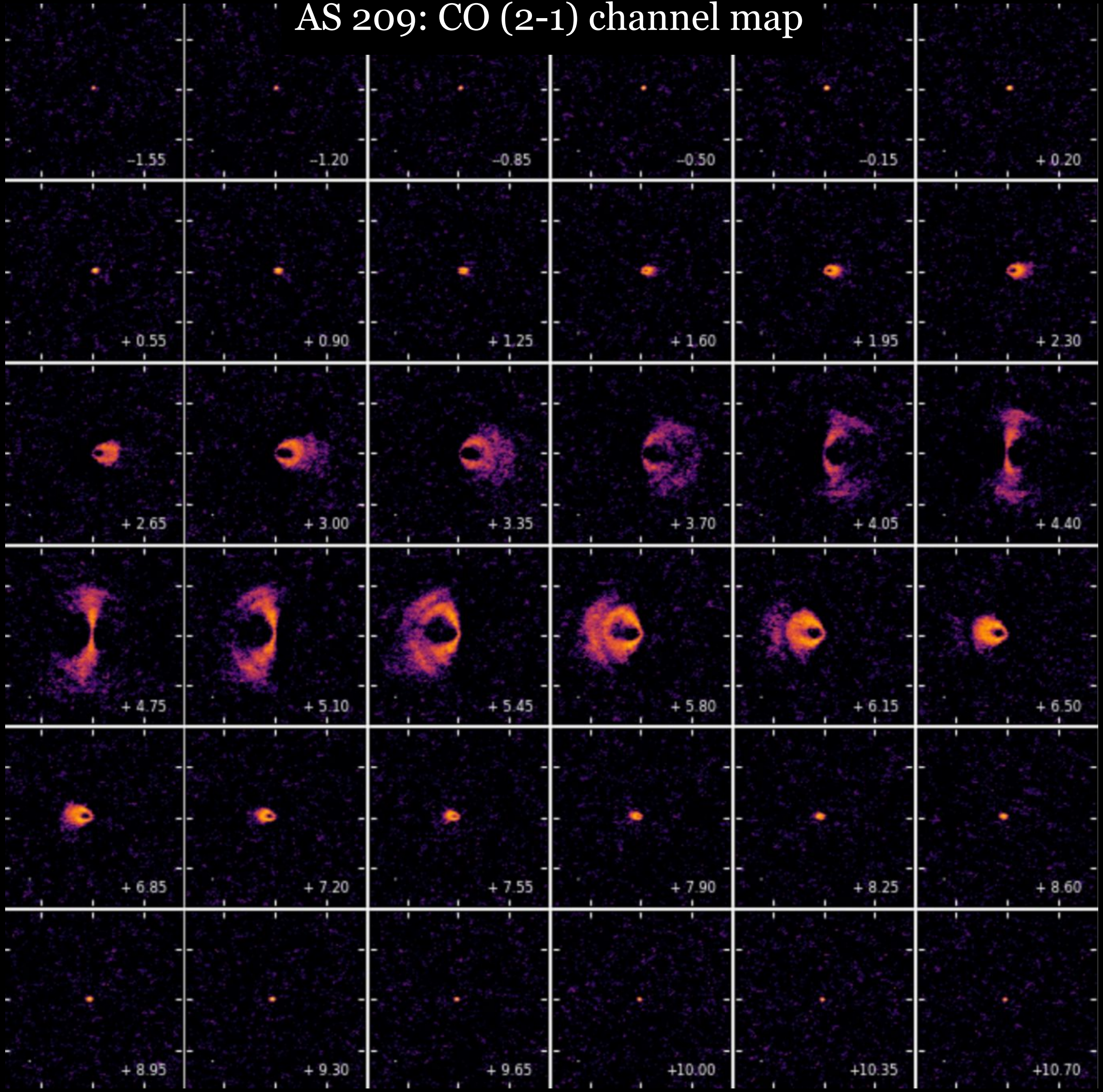




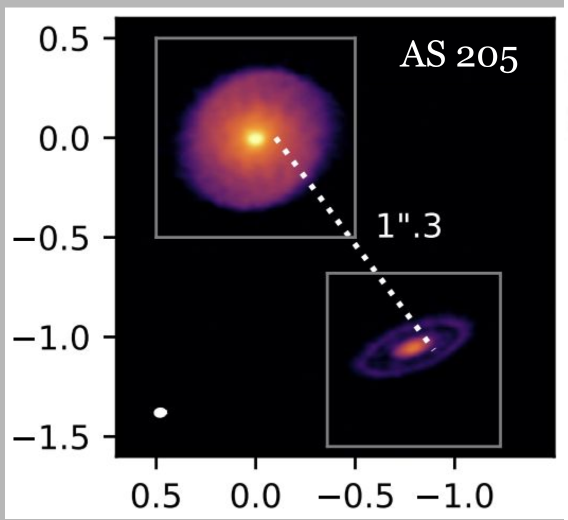
http://sci.esa.int/cassini-huygens/60593-greyscale-cassini-views-of-saturn-famous-hexagon/

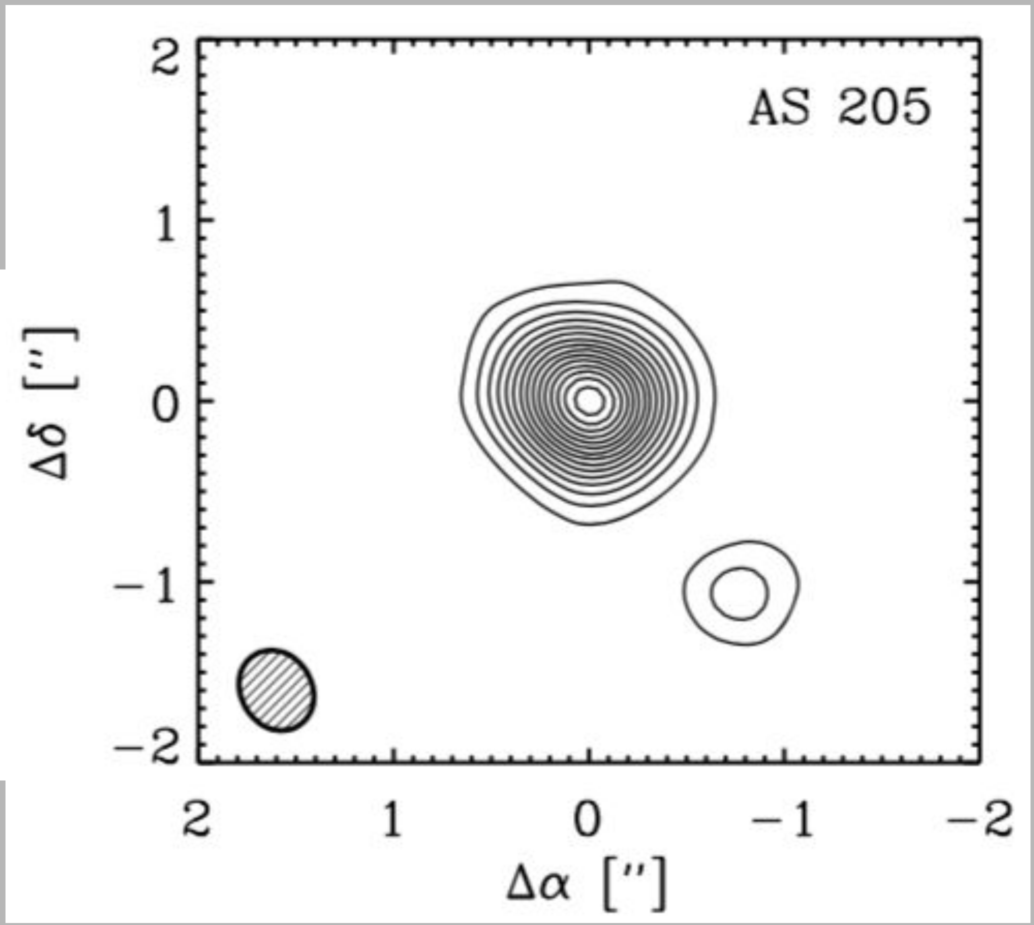

HD 163296

AS 209: CO (2-1) channel map



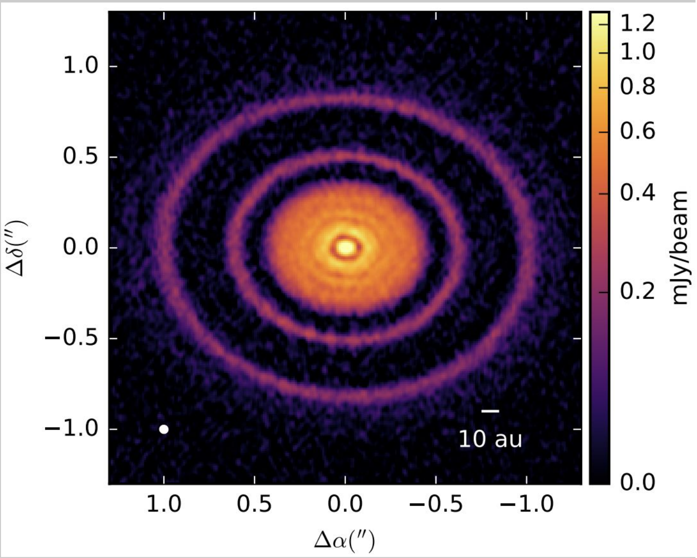
Compare with SMA (~2007) data

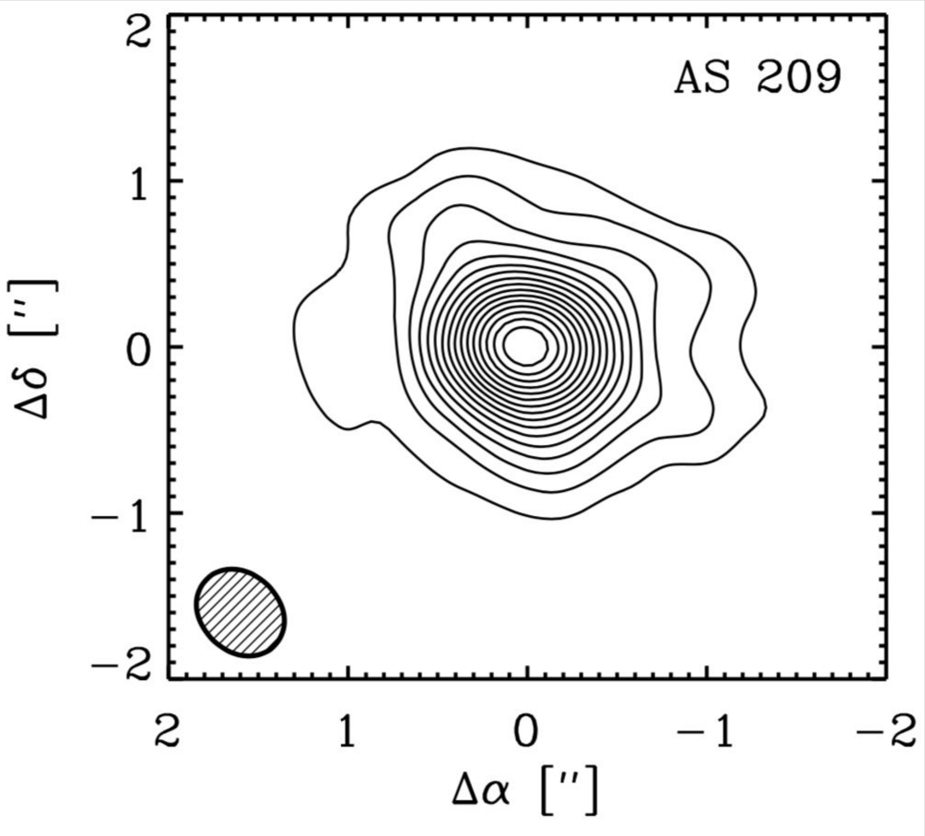




Andrews+2009

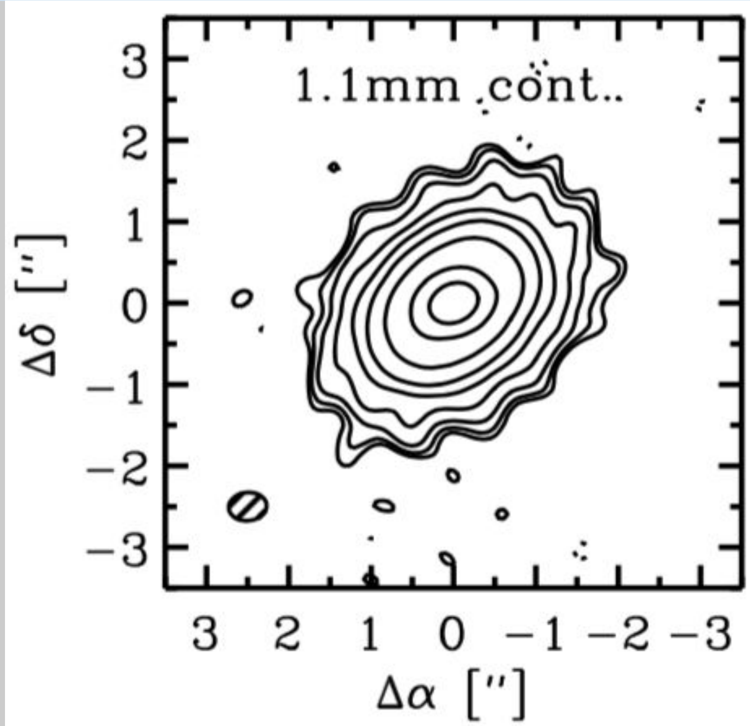
Compare with SMA (~2007) data



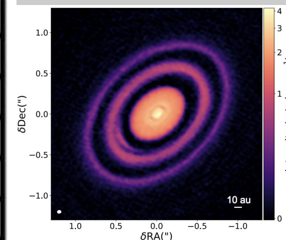


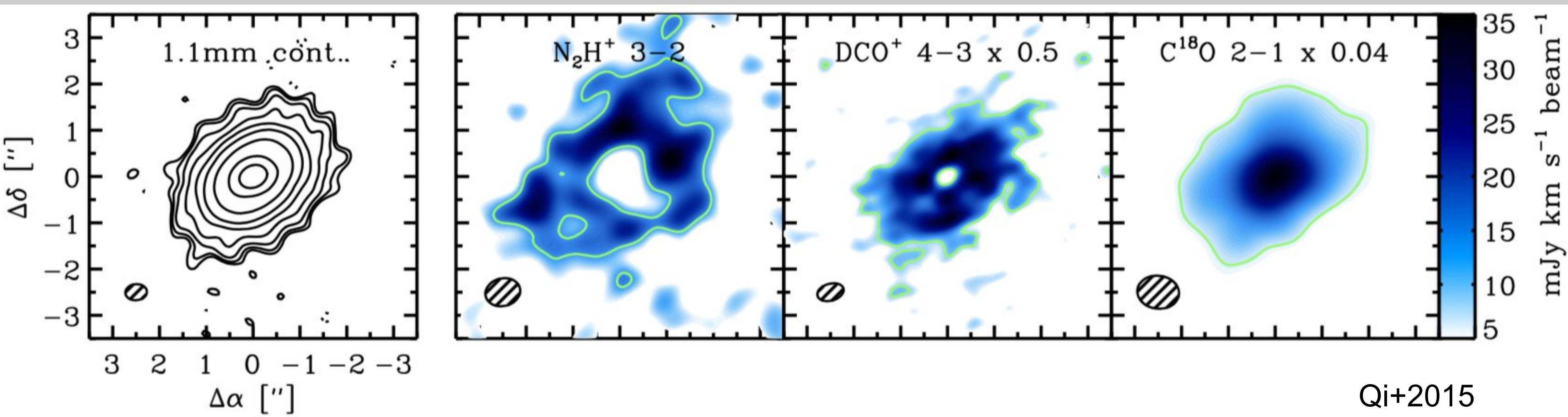
Andrews+2009

Compare with old ALMA (2014) data



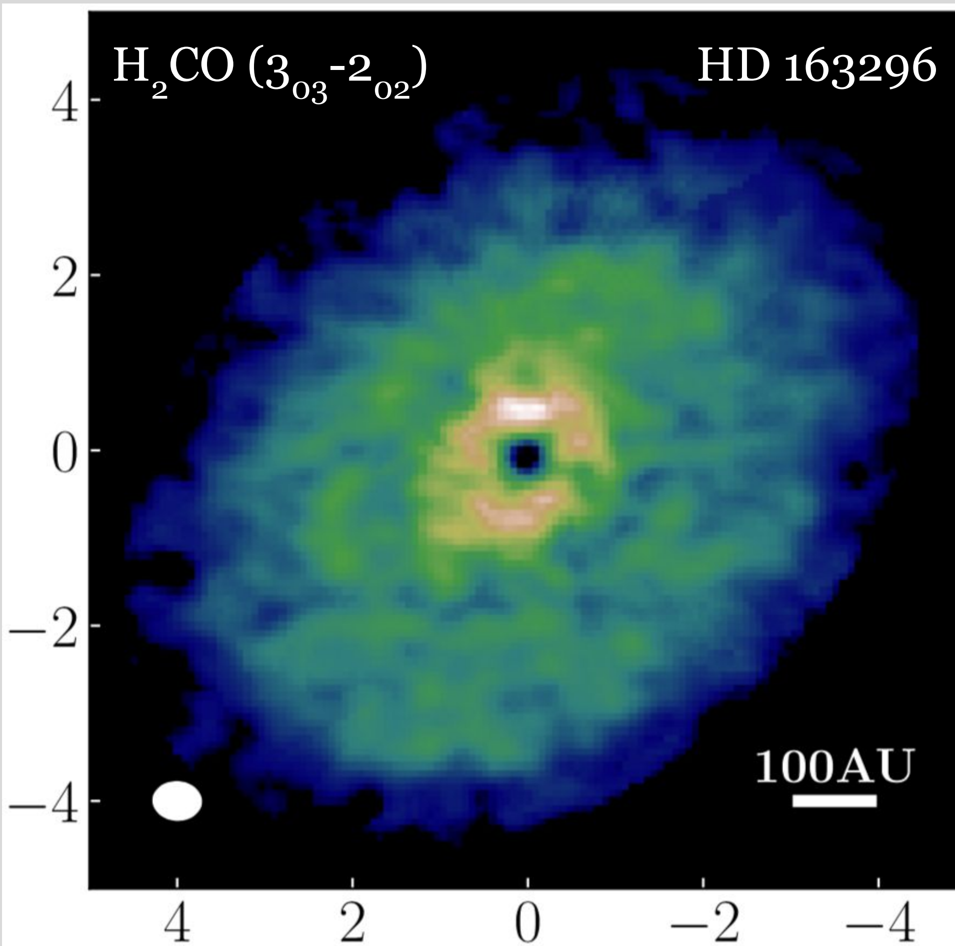
HD 163296

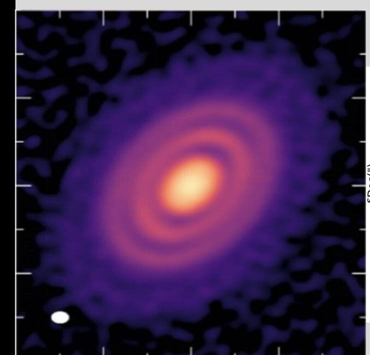




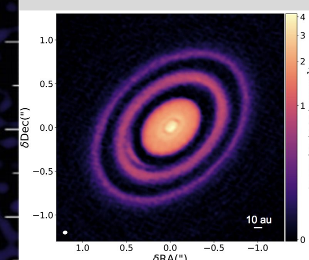
Qi+2015

Compare with other ALMA data





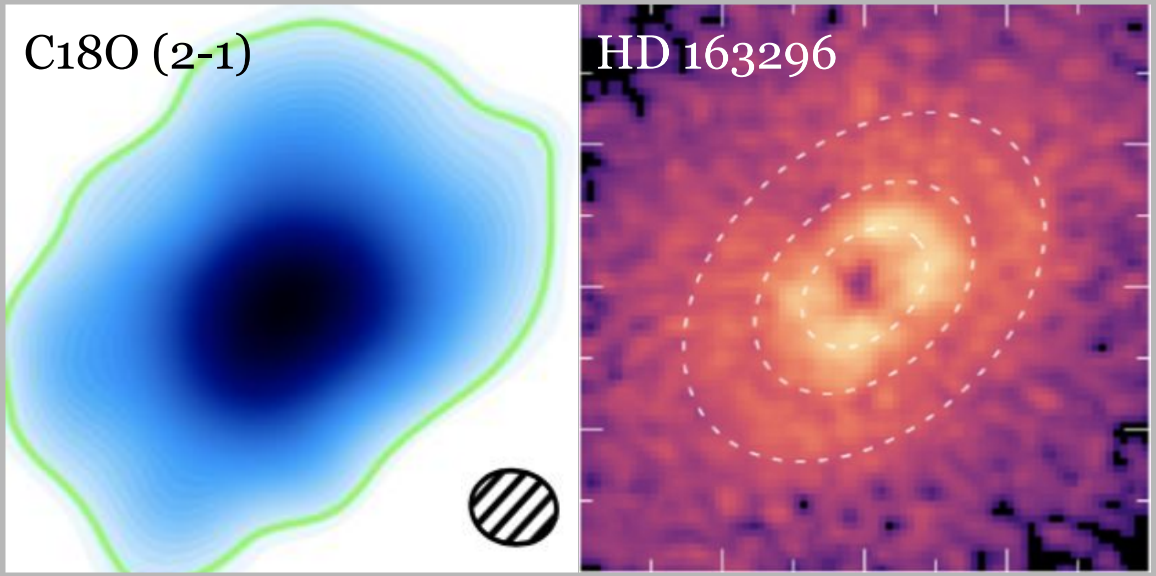
Isella+2016



Isella+2018

Carney+2017

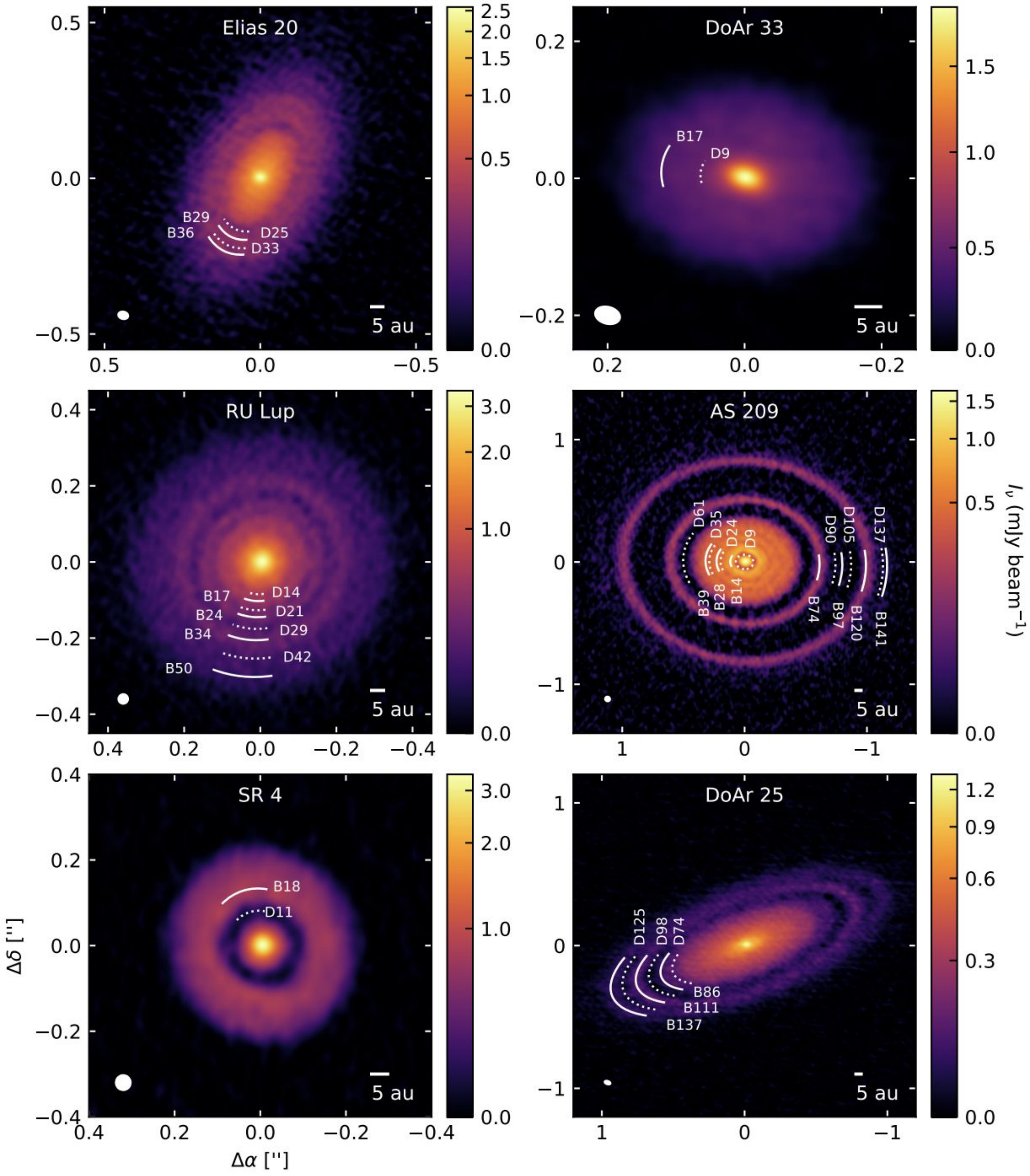
Compare with other ALMA data



Qi+2015 Isella+2016

Individual papers

Paper II. Huang et al.: Annular substructures



Dxx: gap with radius xx au

Bxx: ring with radius xx au

Paper II. Huang et al.: Annular substructures

No obvious corelation with stellar parameters

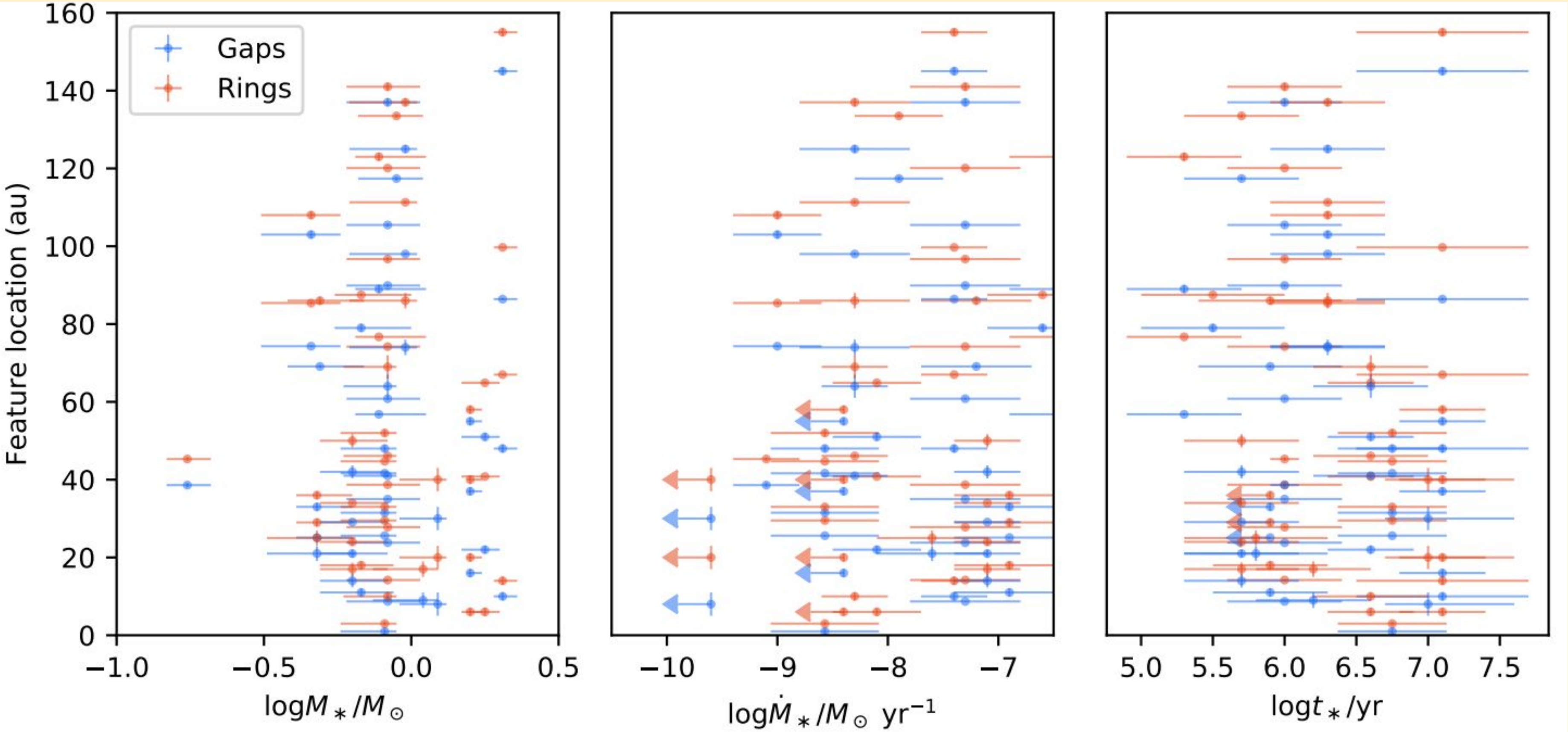
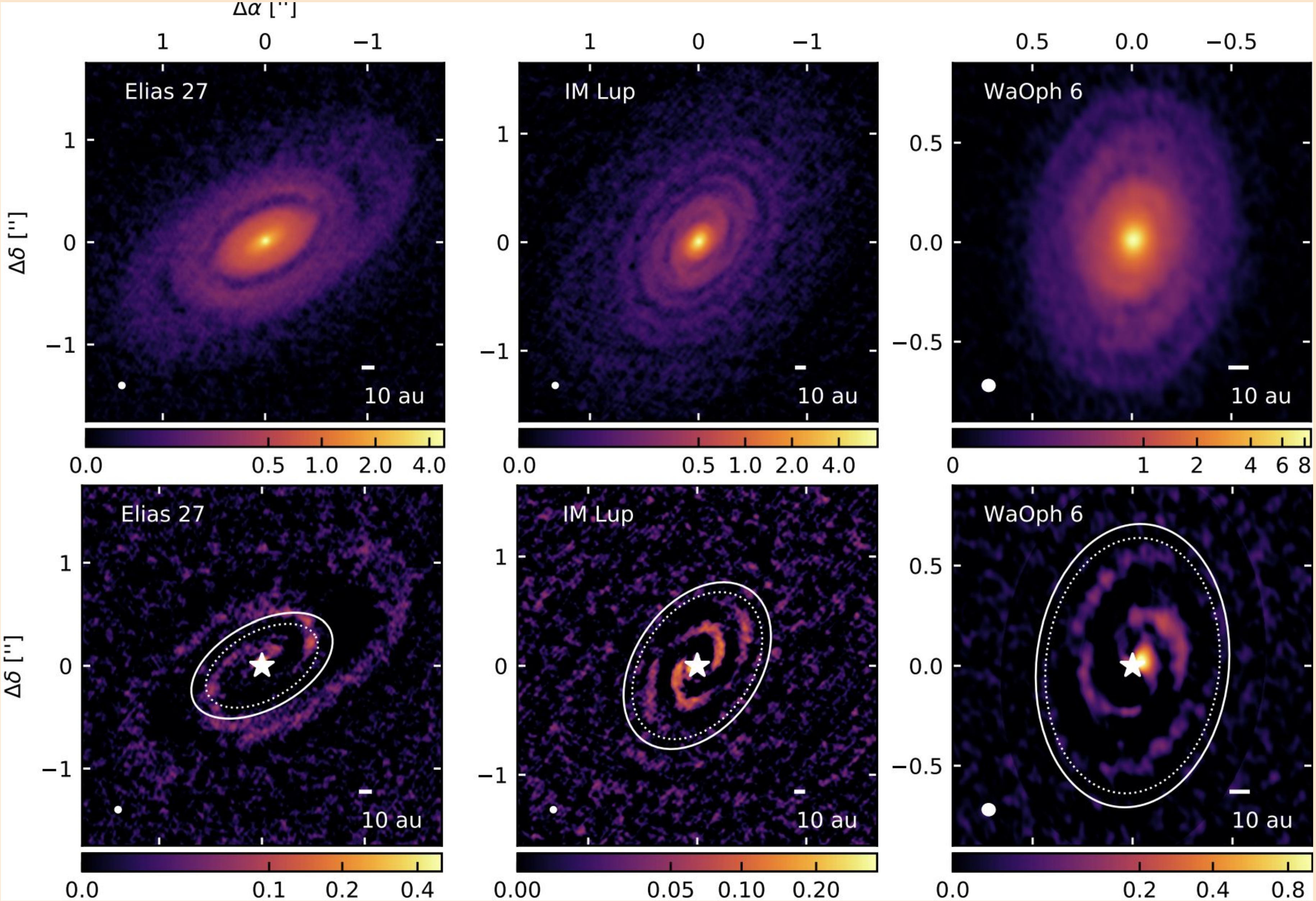
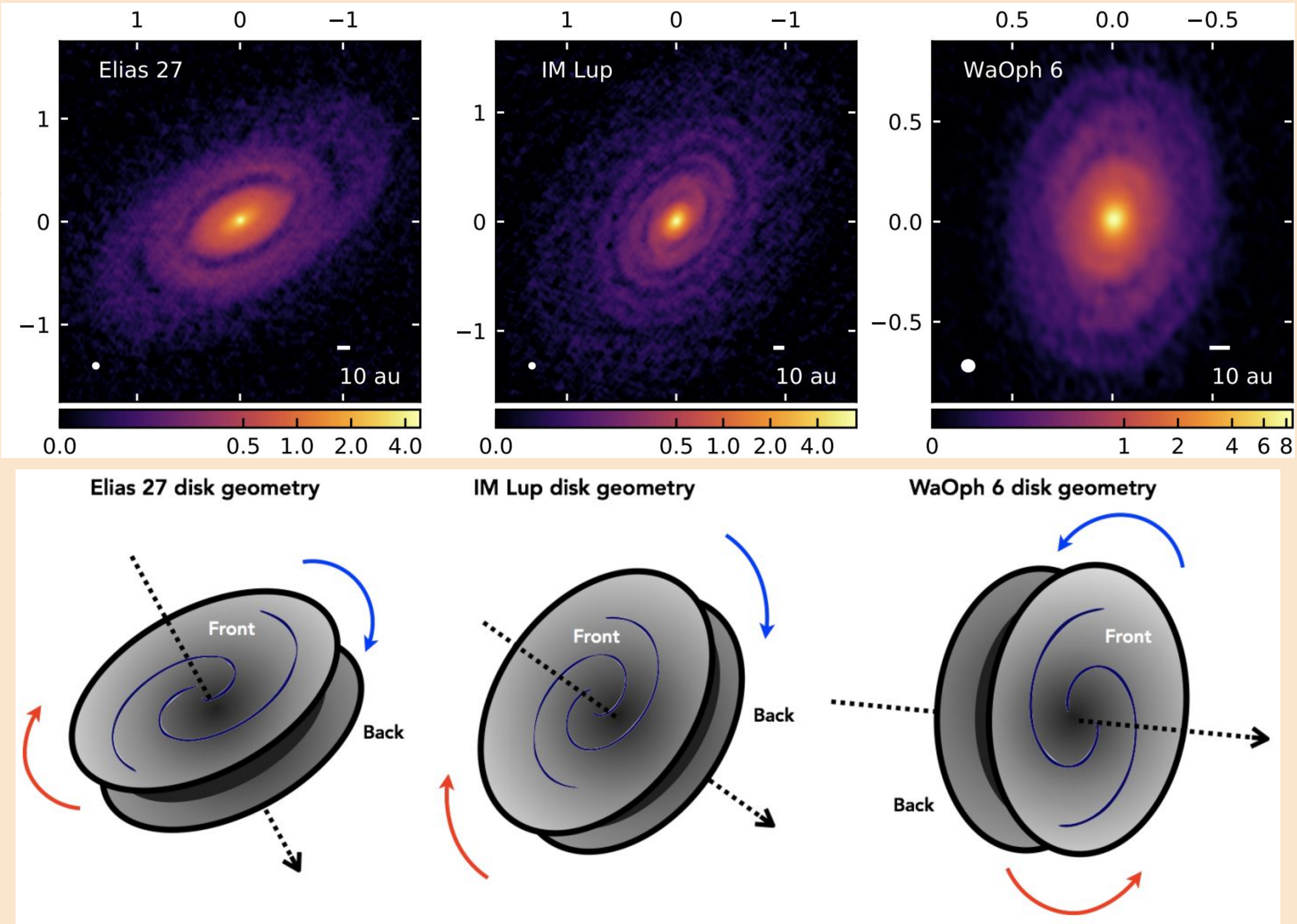


Figure 10. Scatterplots of the radial positions of substructures as a function of stellar mass (M_*), stellar age (t_*), and stellar mass accretion rate ($\dot{M}_*$), respectively. 1σ error bars are shown for the stellar parameters and for the feature locations in the disk. Upper limits are shown as arrows.

Paper III. Huang et al.: Elias 27, IM Lup, and WaOph 6

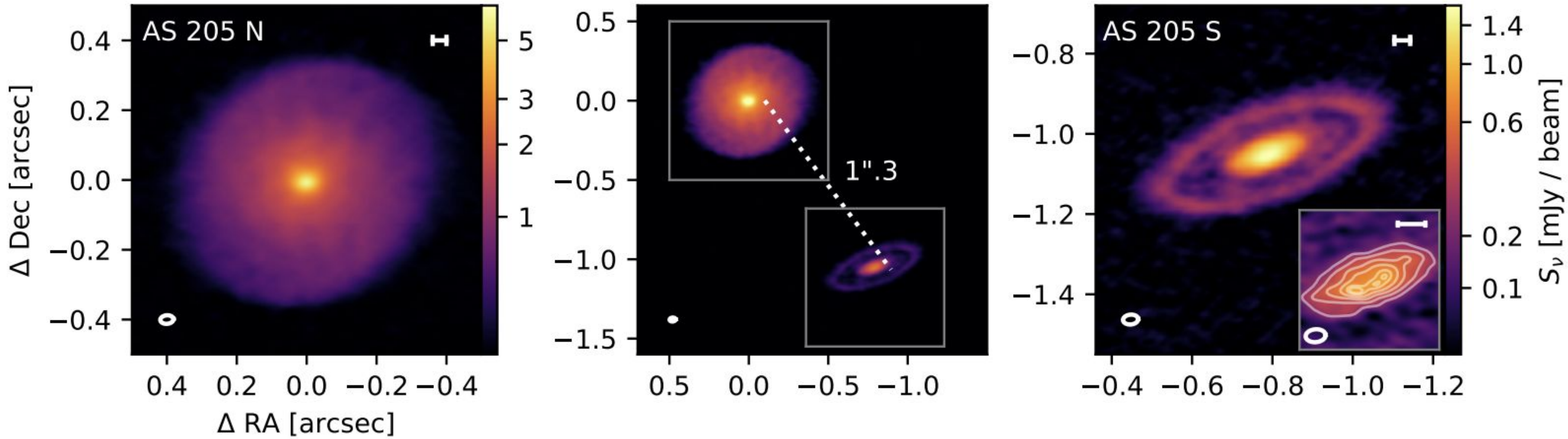


Paper III. Huang et al.: Elias 27, IM Lup, and WaOph 6

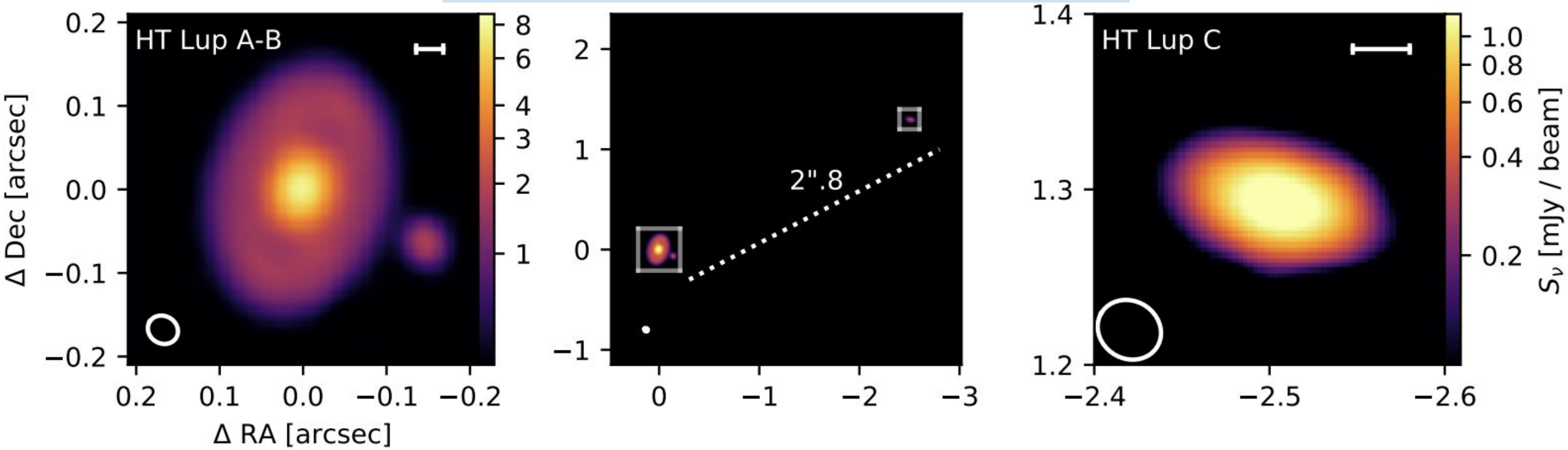


Paper IV. Kurtovic et al.: disks around multiple star systems

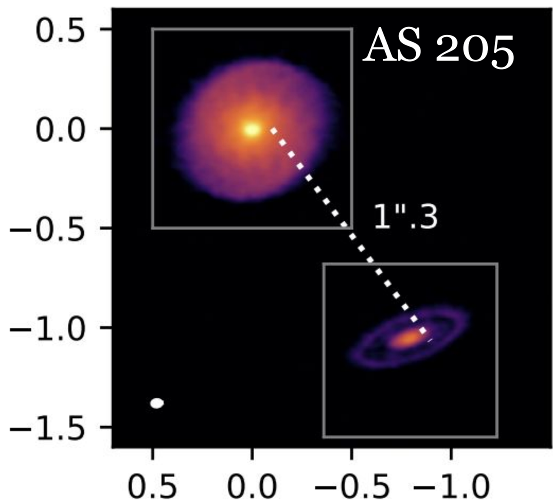
Two disks

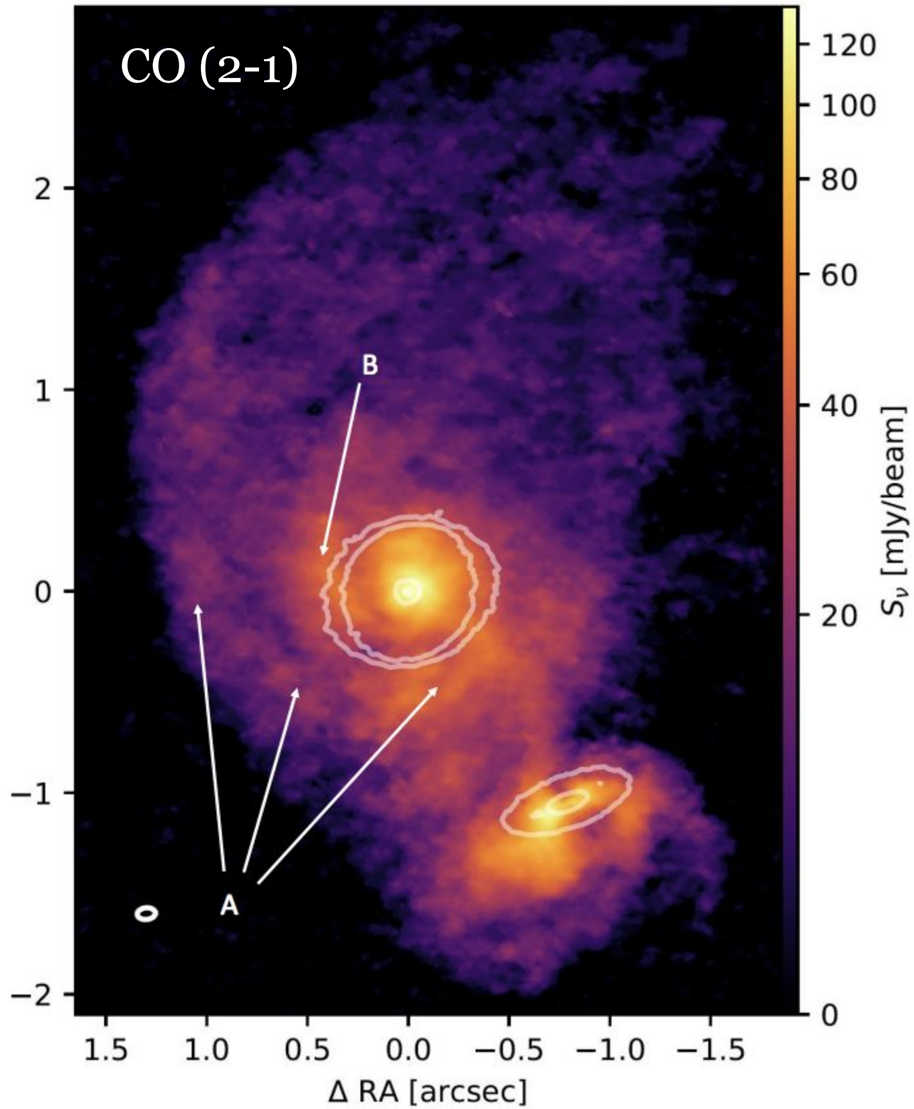


Three disks

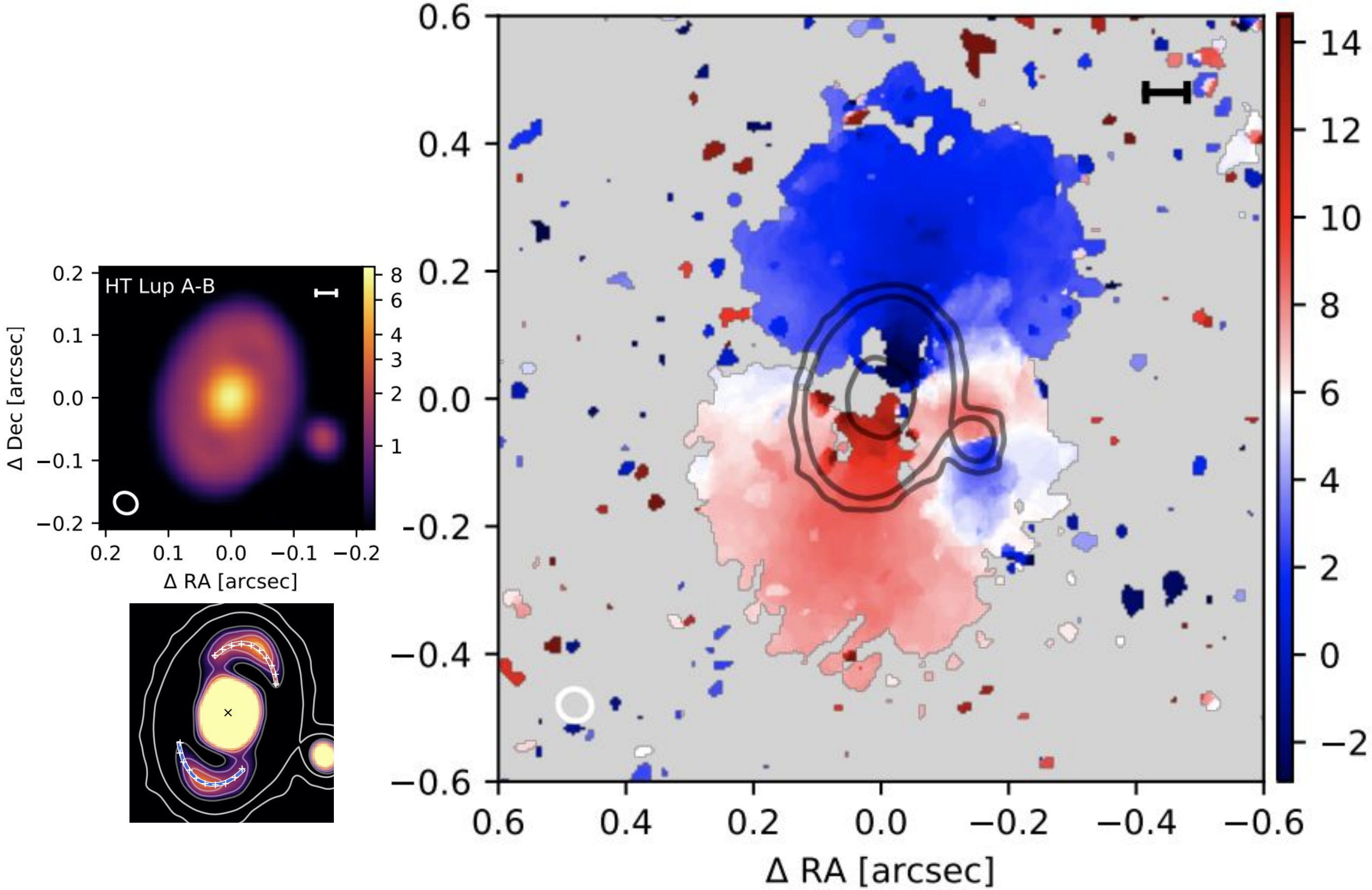


Dust vs gas: encounter



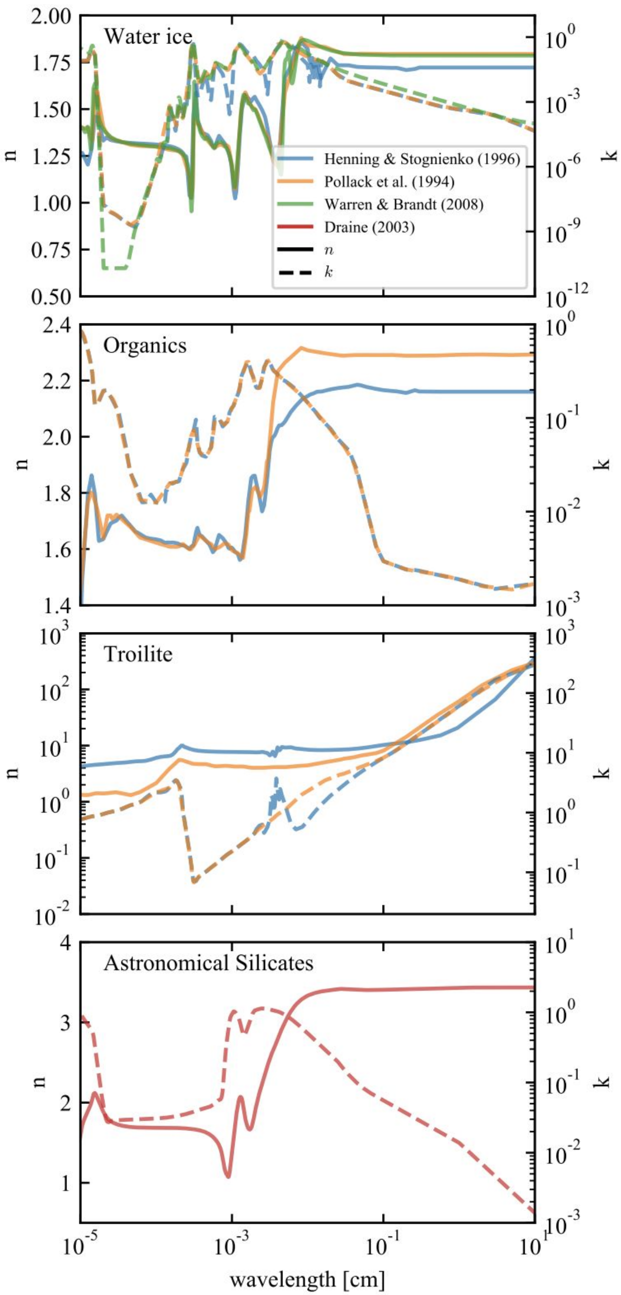


Dust vs gas: misalignment

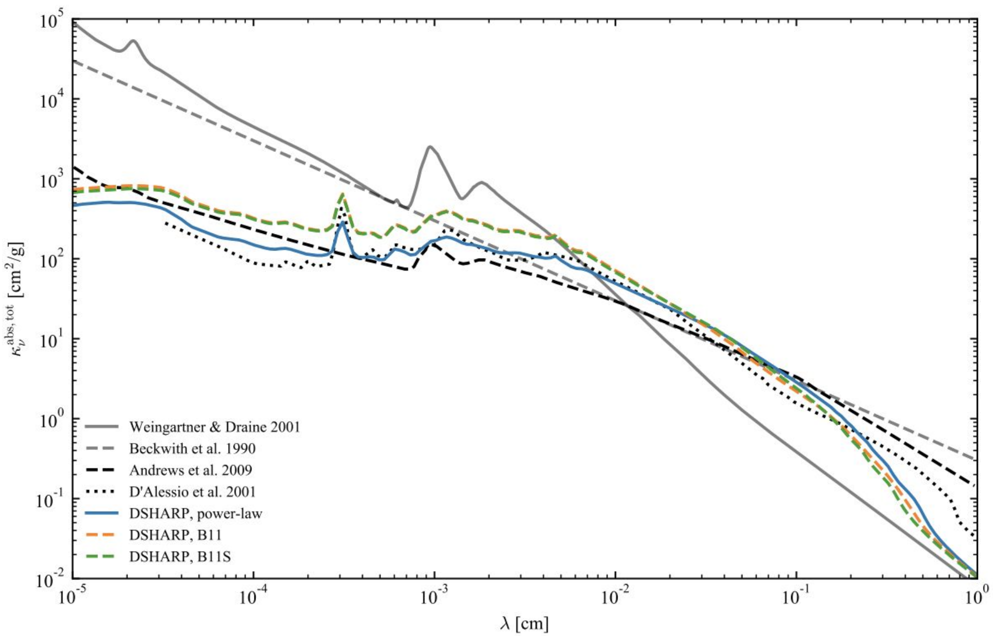


Paper V. Birnstiel et al.: dust model

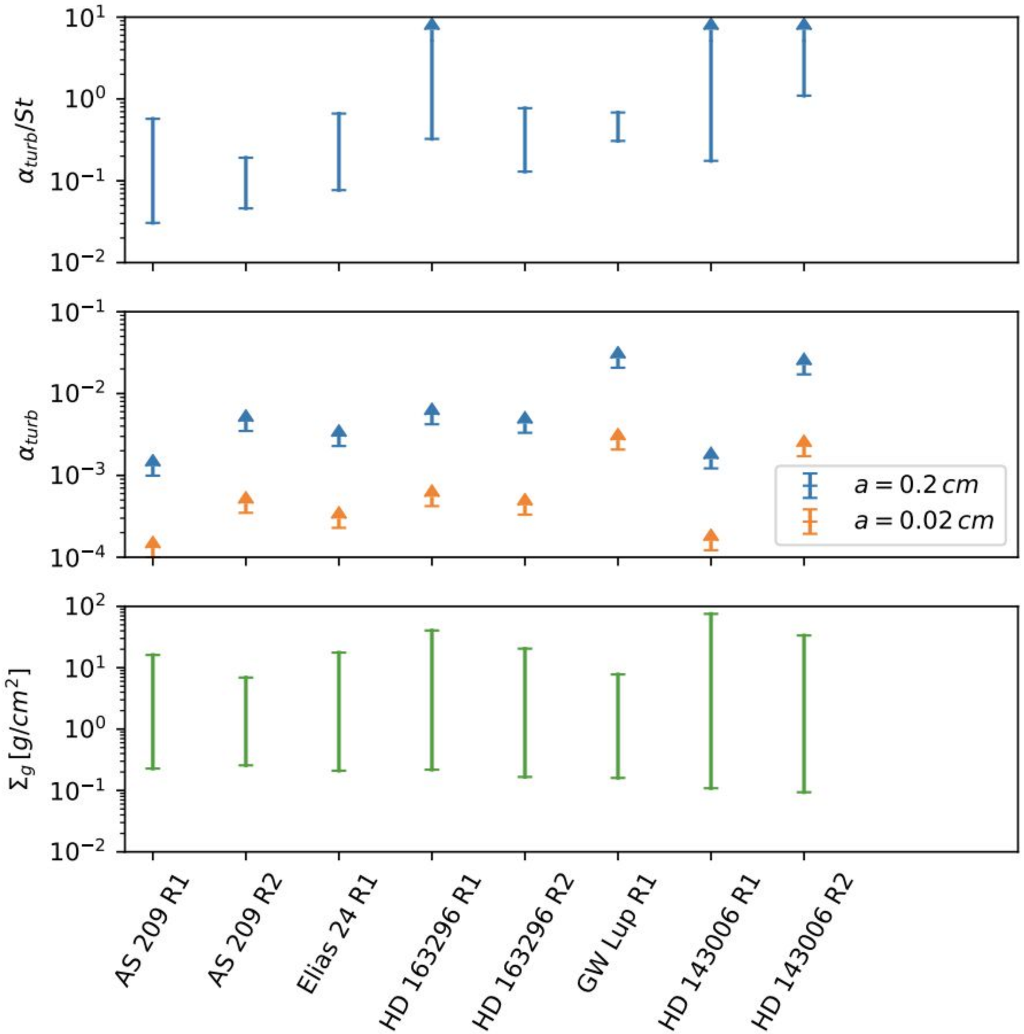
Optical constants



Absorption coefficients



Dust trapping in radial pressure bumps

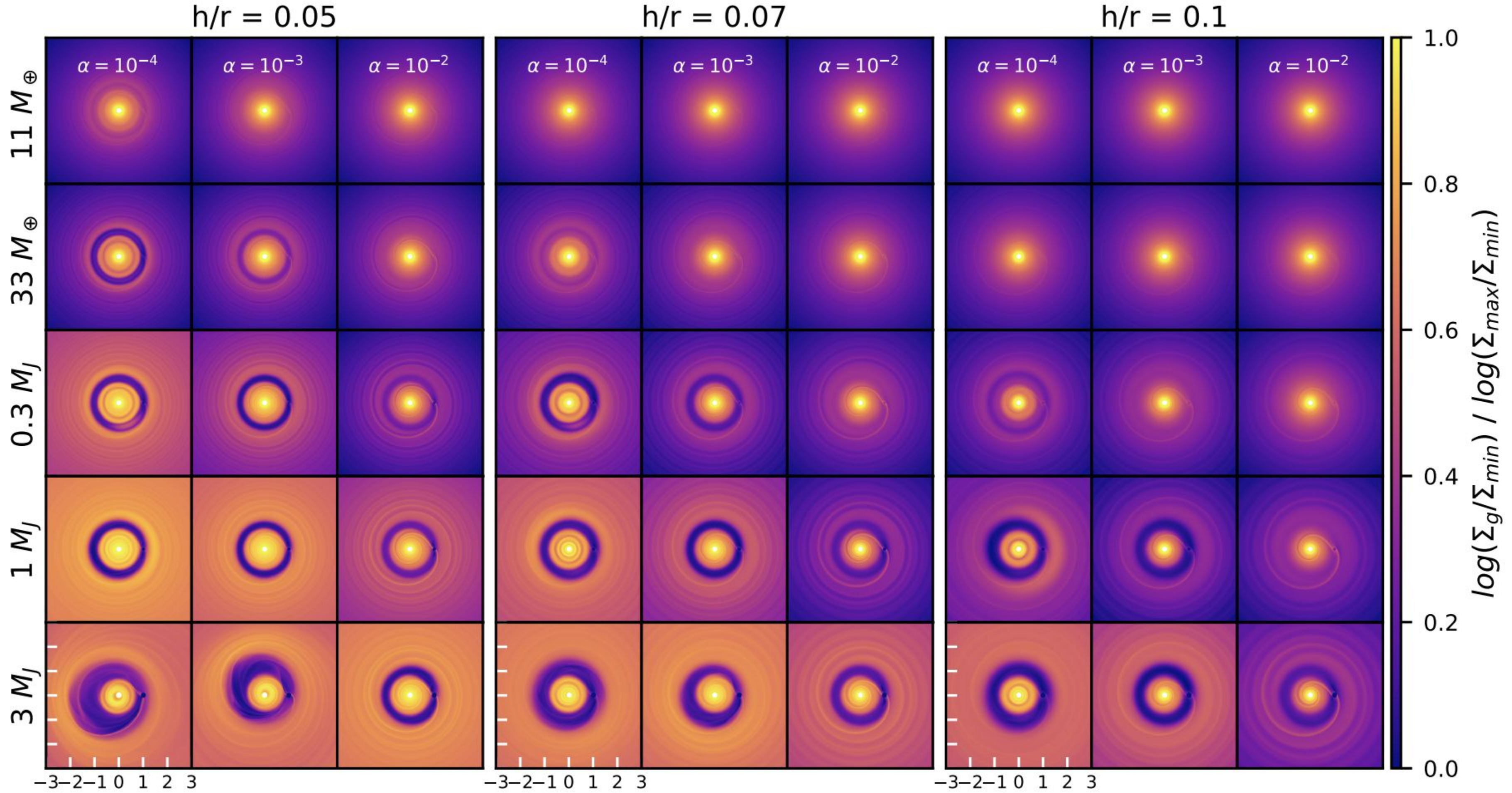


Paper VII. Zhang et al.: Planet-disk interaction

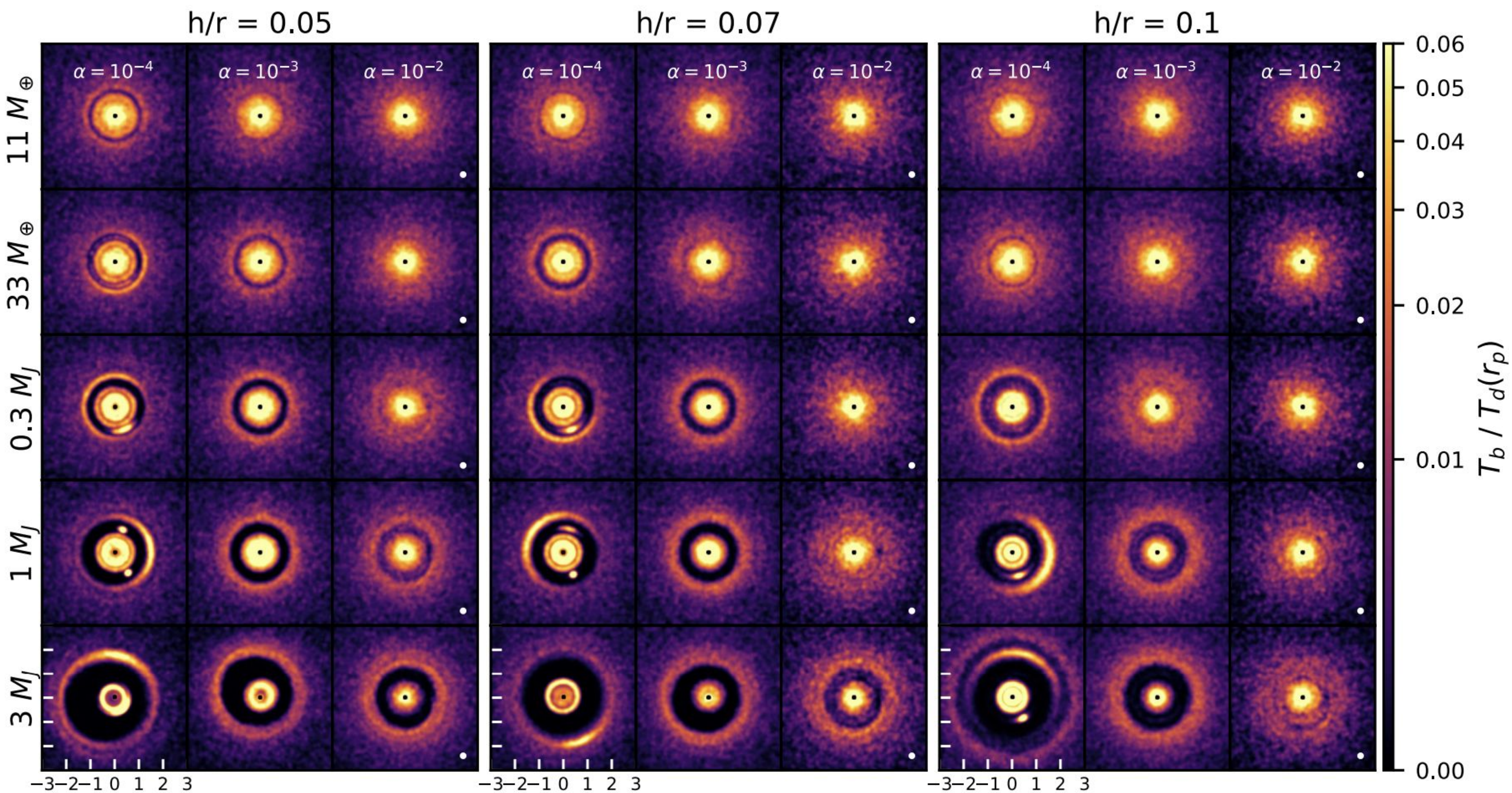
2D hydrodynamical simulation

- ❑ FARGO code
- ❑ No disk self-gravity
- ❑ No radiative cooling
- ❑ No dust feedback

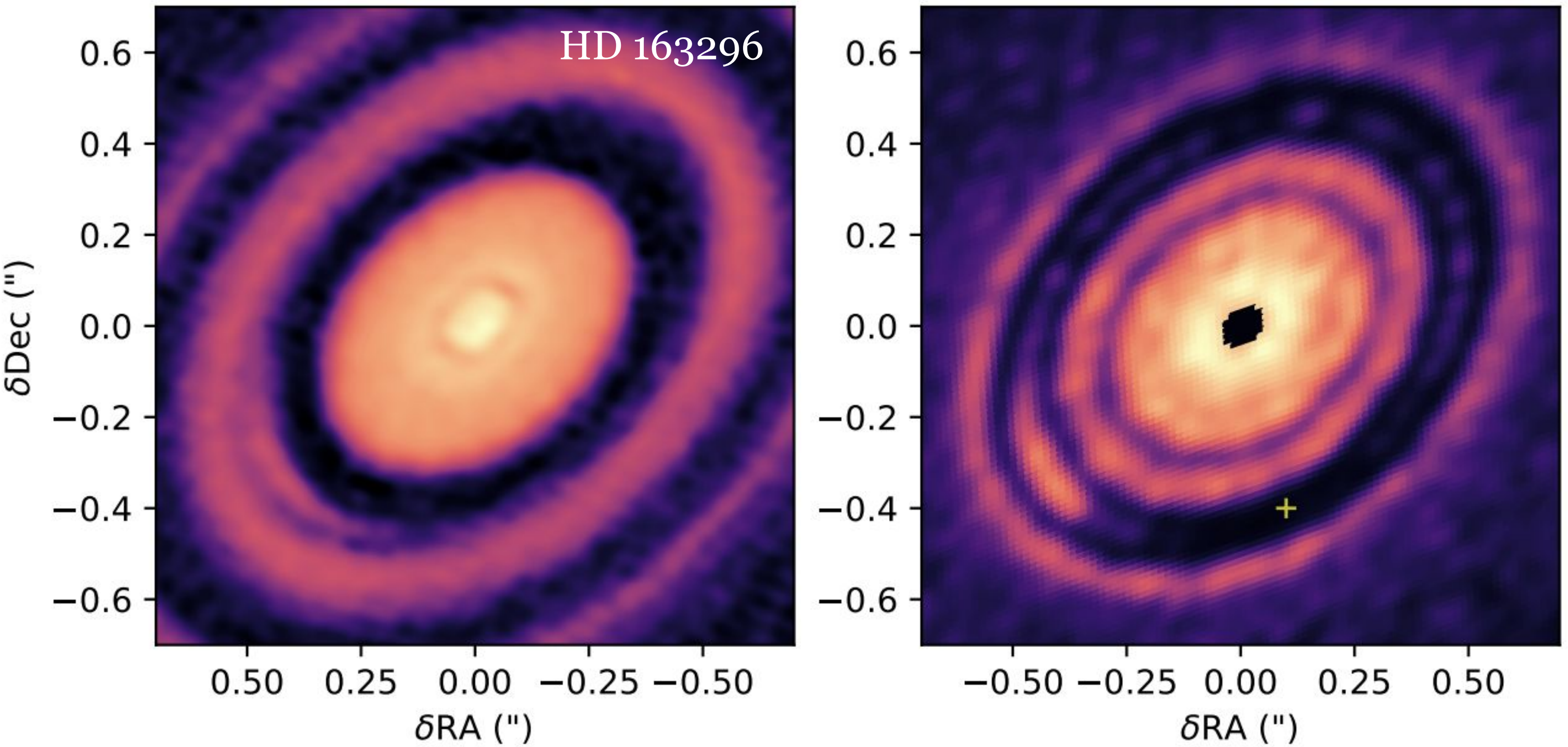
Simulations: gas surface density



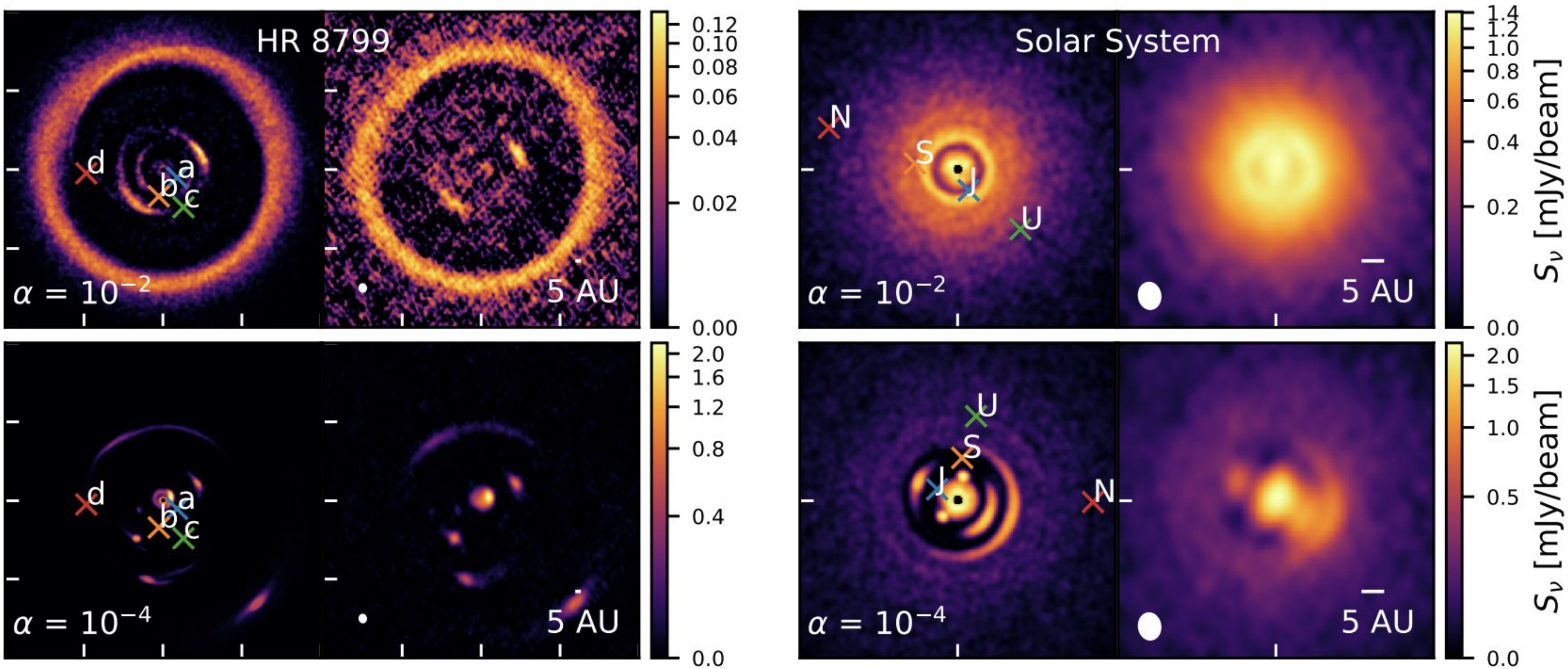
Simulations: dust emission



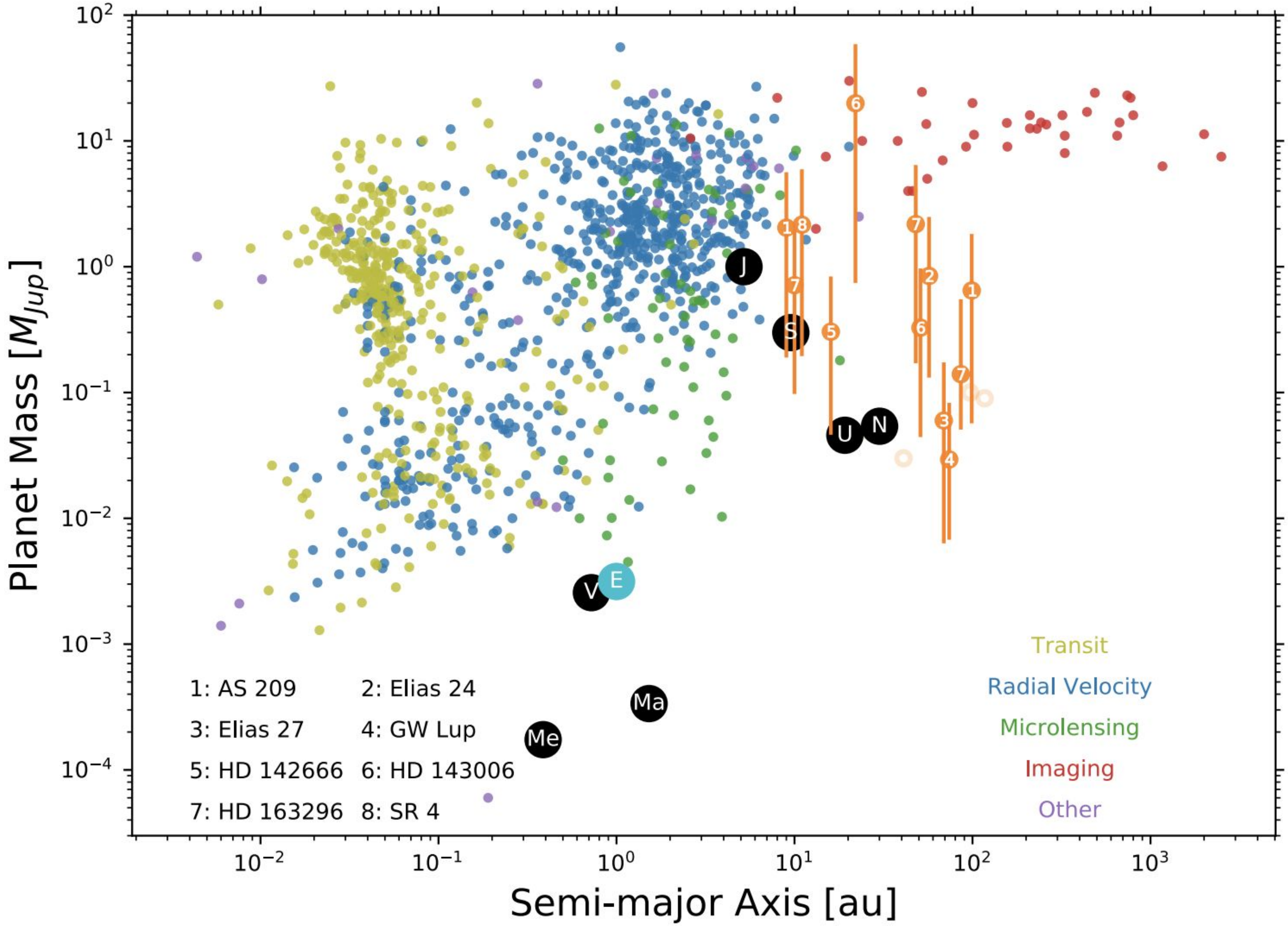
Data vs model



Solar system at 140 au



Planet mass vs. Planet semi-major axis

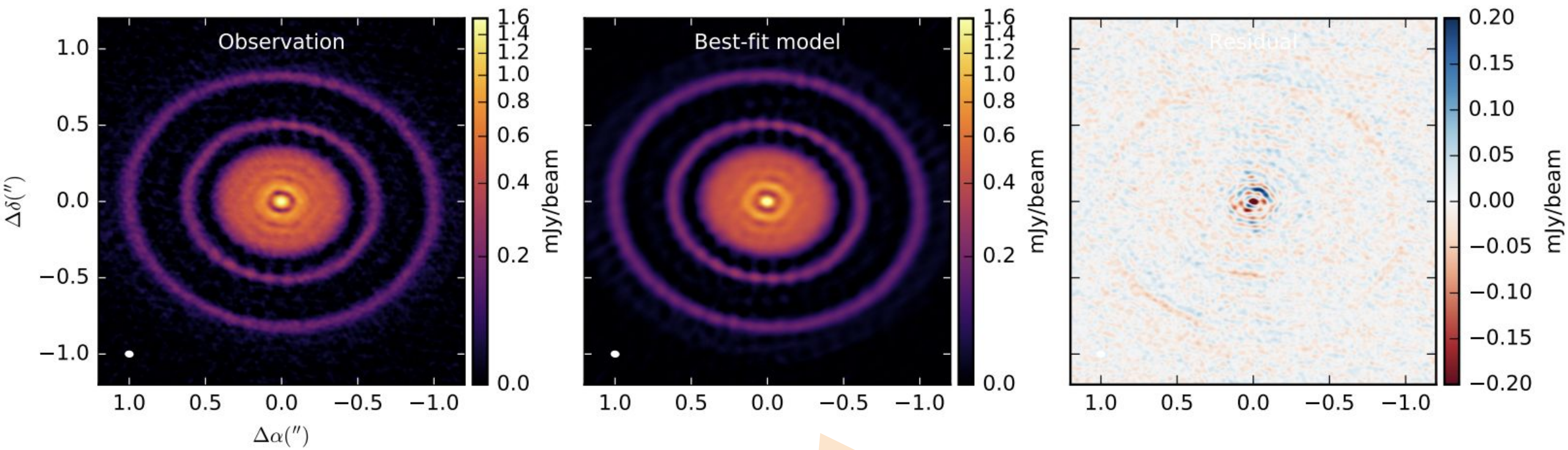


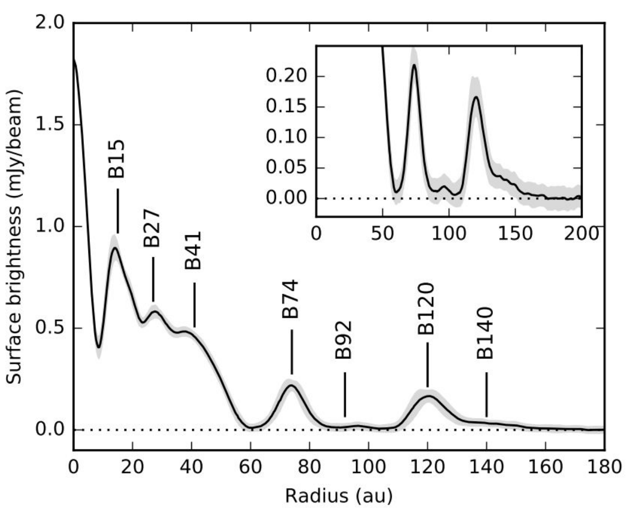
Paper VIII. Guzman et al.: AS 209 detailed analysis

Ring fitting

$$I(r) = \sum_{i=0}^{N} A_i \exp(-(r - r_i)^2 / 2\sigma_i^2).$$

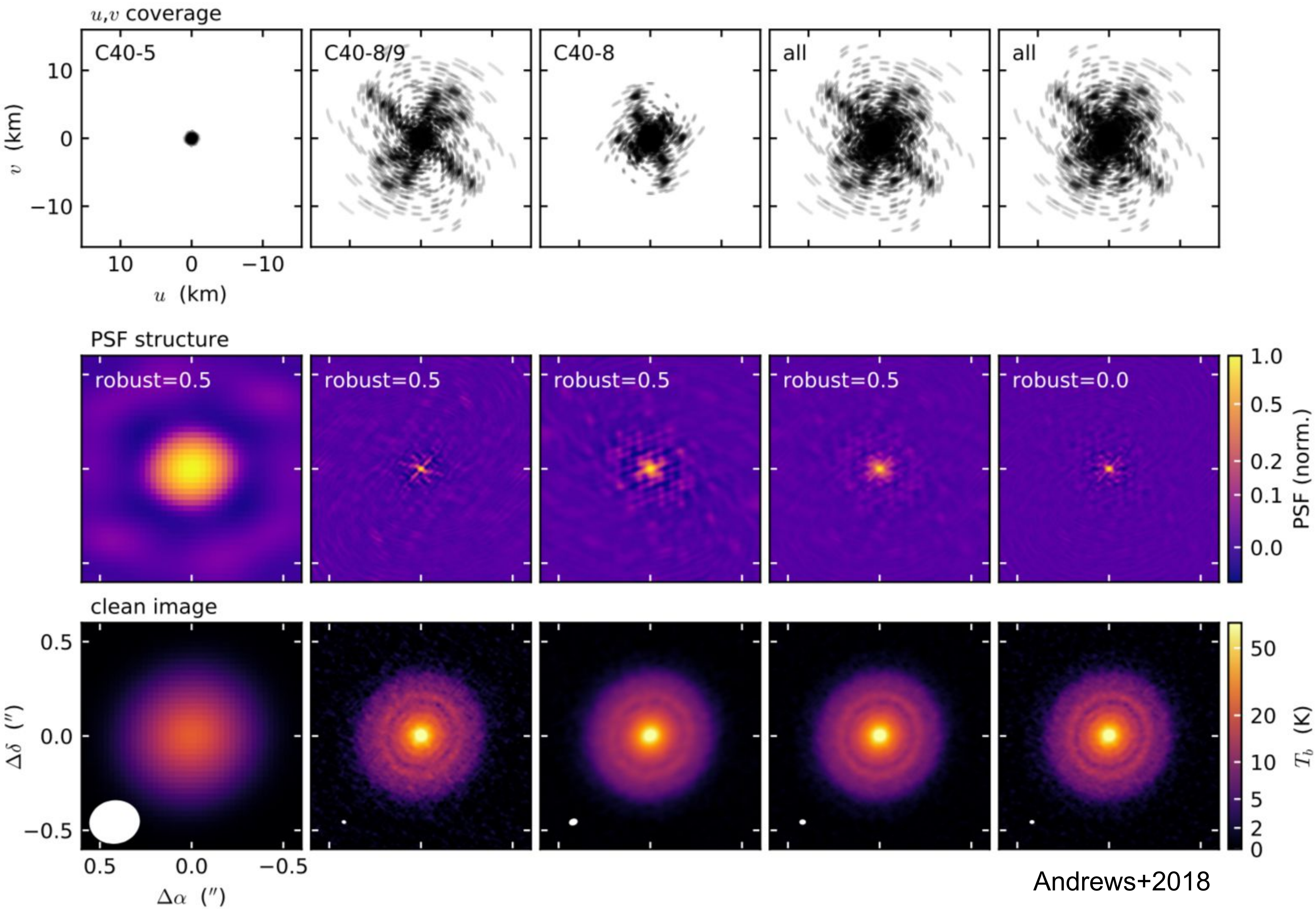
Result: 8 rings





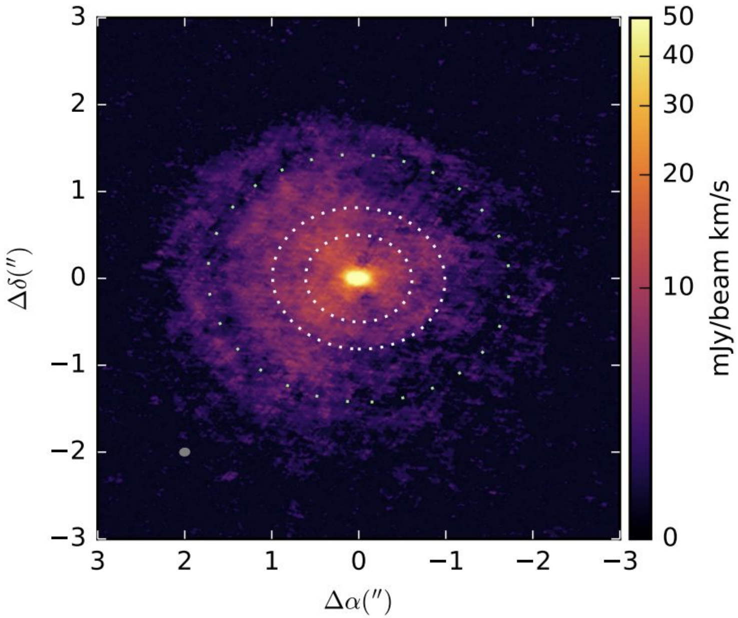
... A slightly **hexagonal** structure and bumpiness can be seen in the rings, which is also seen in the observations. This demonstrate these structures are **not real** but correspond to **PSF effects**...

The ALMA PSF

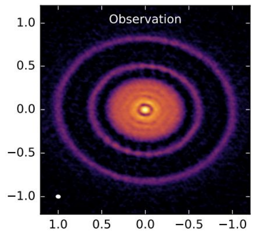


Andrews+2018

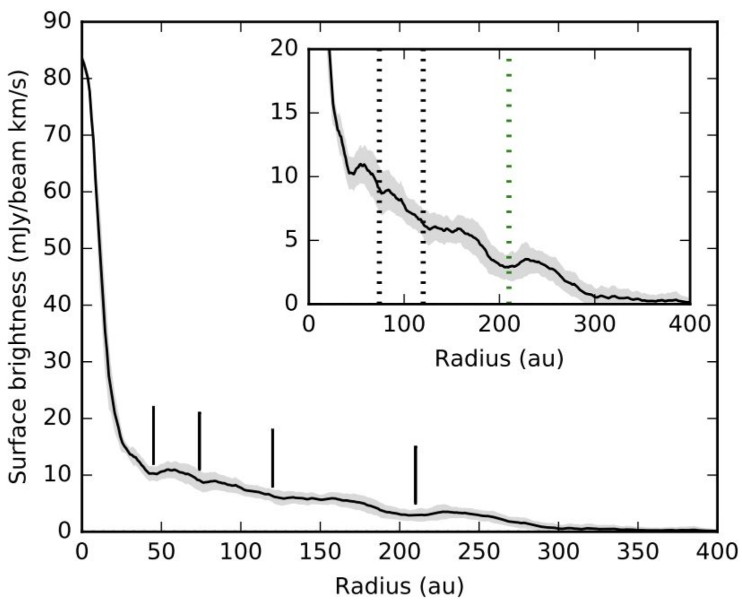
Paper VIII. Guzman et al.: AS 209 detailed analysis



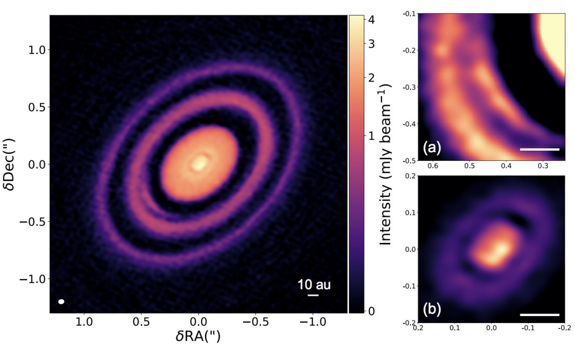
CO (2-1) moment zero

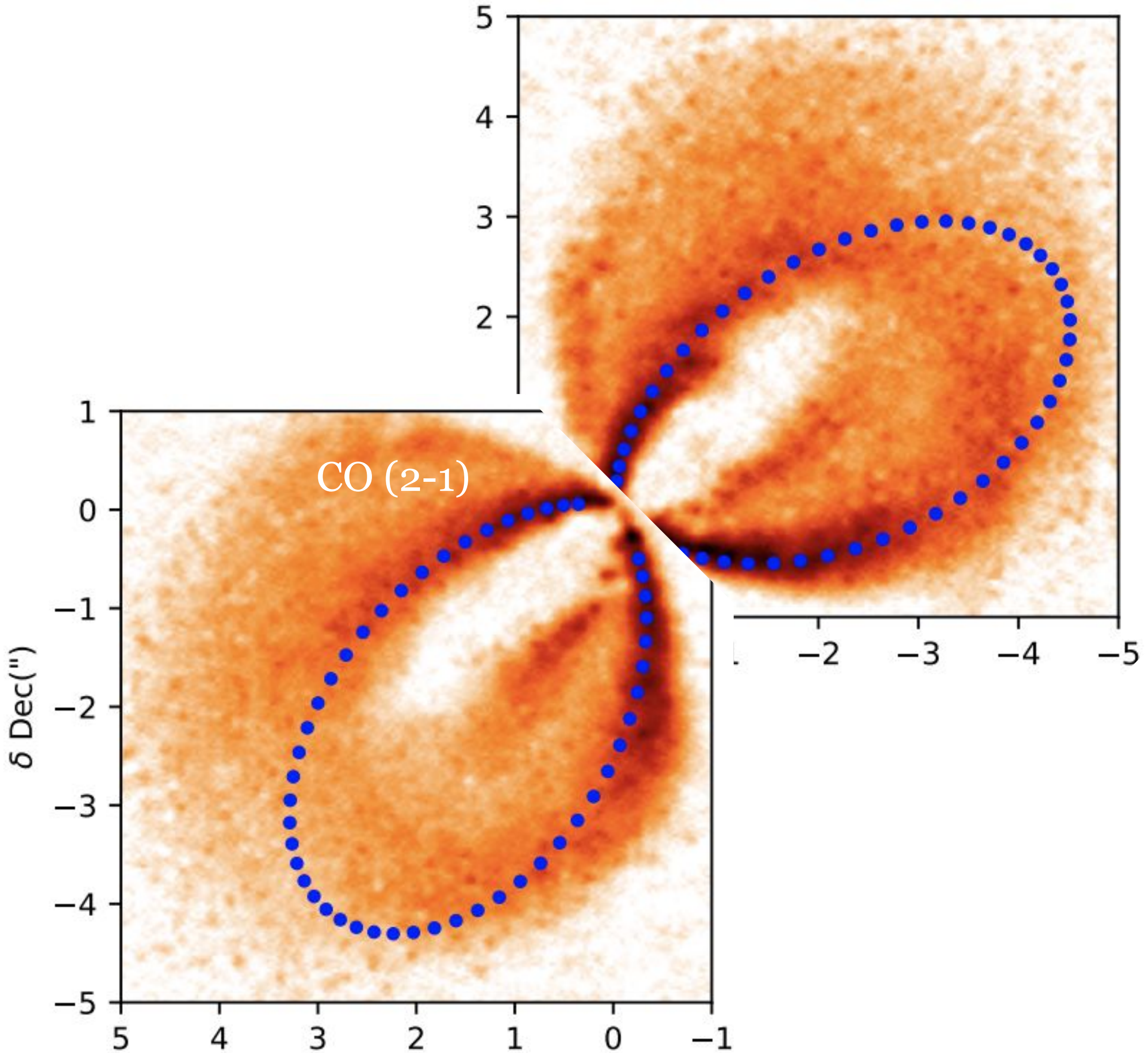


CO extends much larger than dust

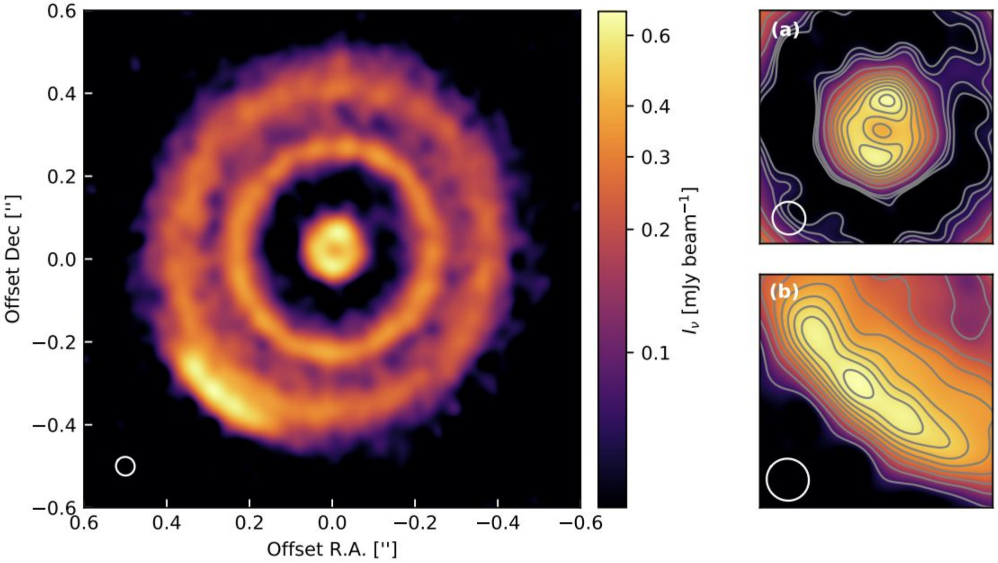


Paper IX. Isella et al.: HD 163296

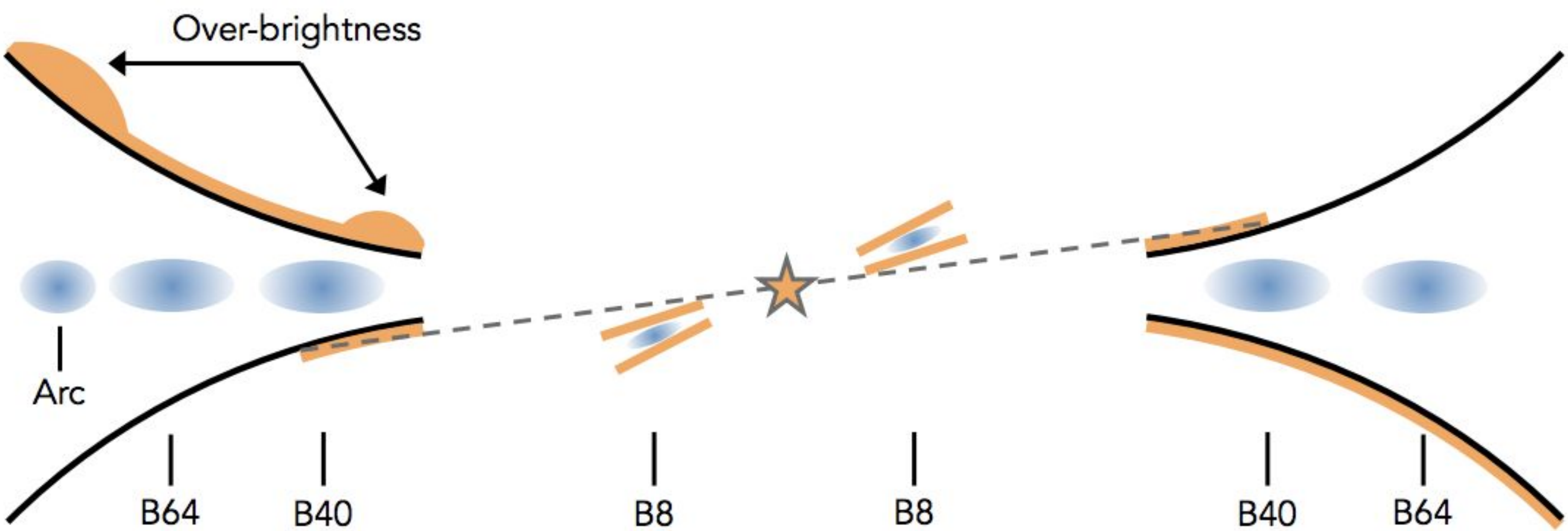


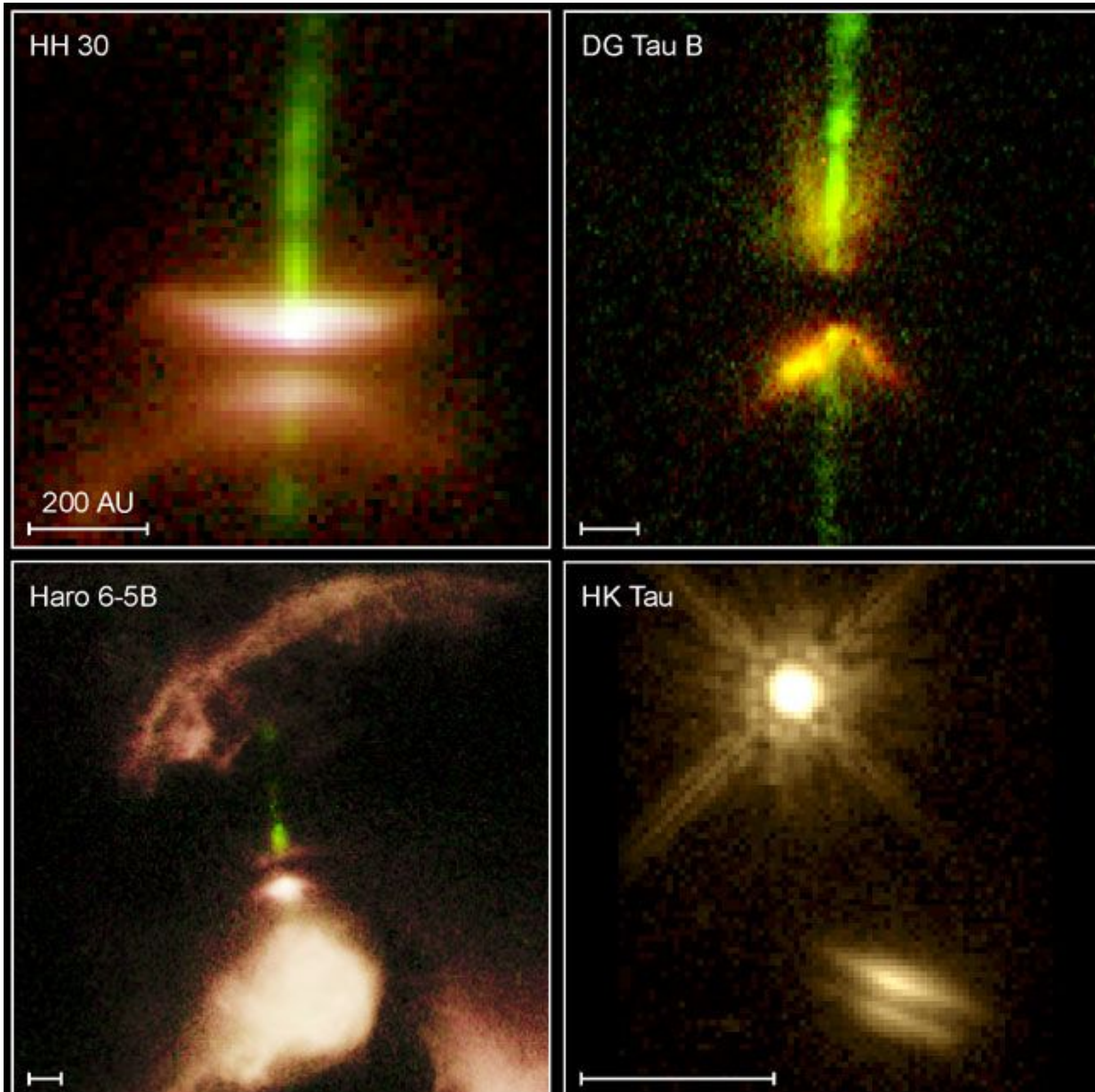


Paper X. Perez et al.: HD 143006



misalignment between inner and outer disk





Disks around Young Stars **HST • WFPC2**

PRC99-05b • STScI OPO

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