Inner walls or vortices?

Crescent-shaped asymmetries in ALMA observations of protoplanetary discs

Álvaro Ribas, Cathie Clarke, Francesco Zagaria

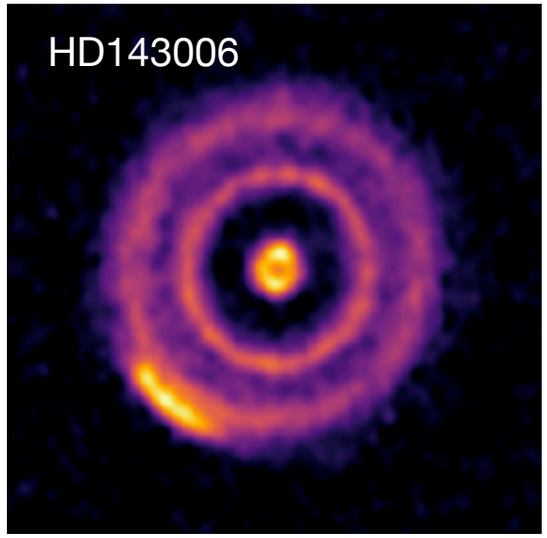
Institute of Astronomy, University of Cambridge

UK and Ireland Discs Meeting, 9-11 September 2024, University of Warwick

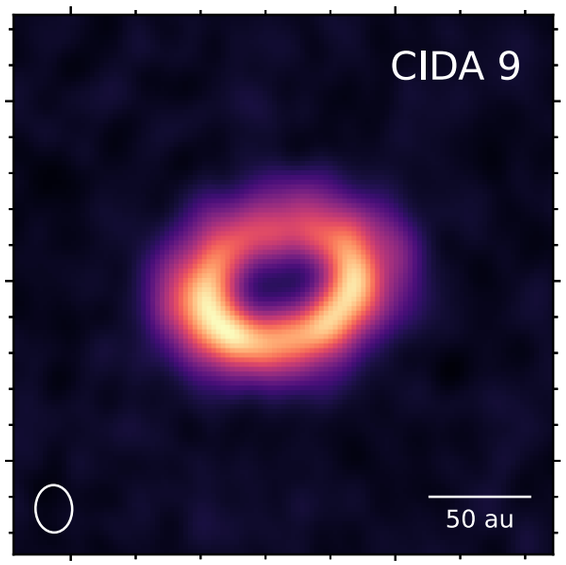
UNIVERSITY OF CAMBRIDGE

Azimuthal asymmetries are common in discs

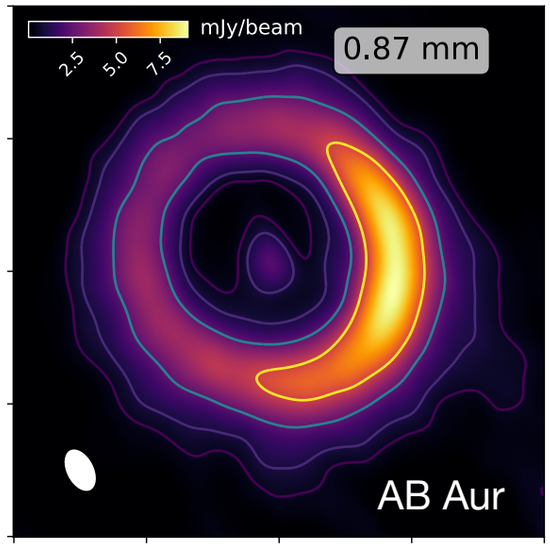
Usually interpreted as dust overdensities due to vortices or induced by companions.



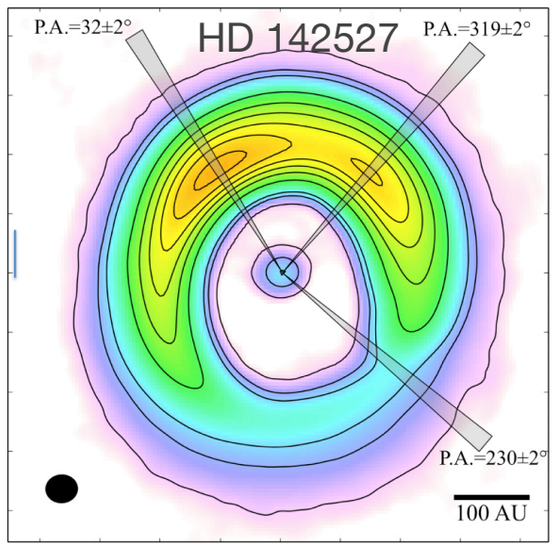
Andrews et al. 2018



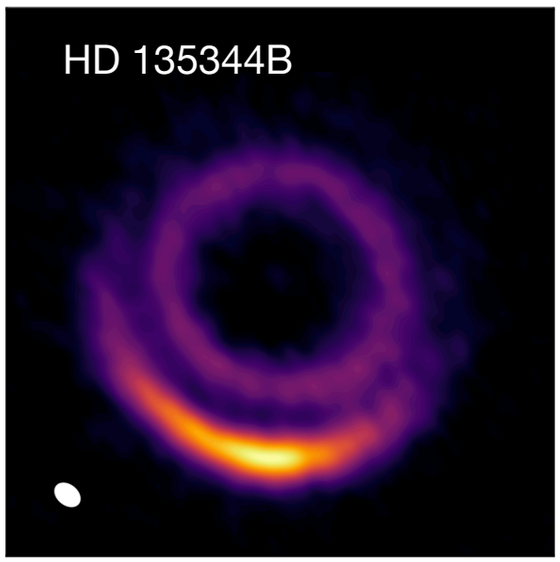
Ribas et al. 2024



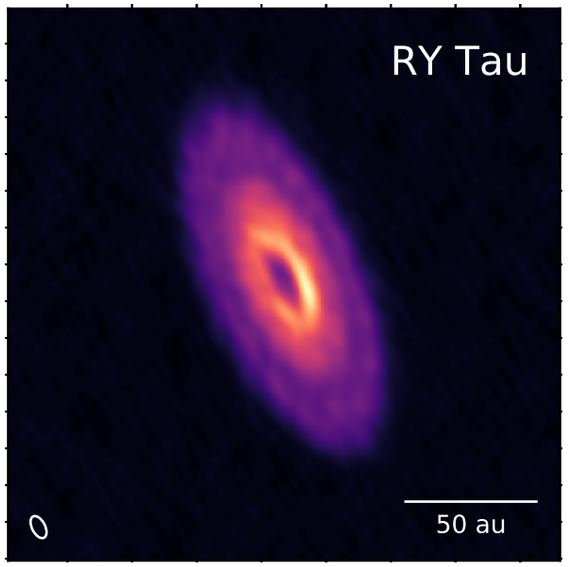
Riviere-Marichalar et al. 2024



Ohashi et al. 2018



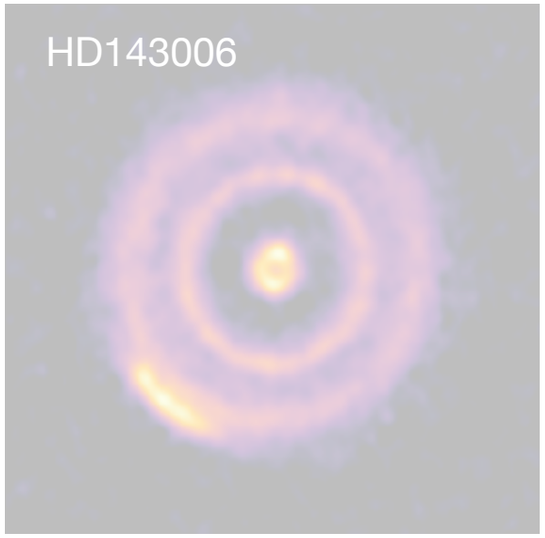
Cazzoletti et al. 2018



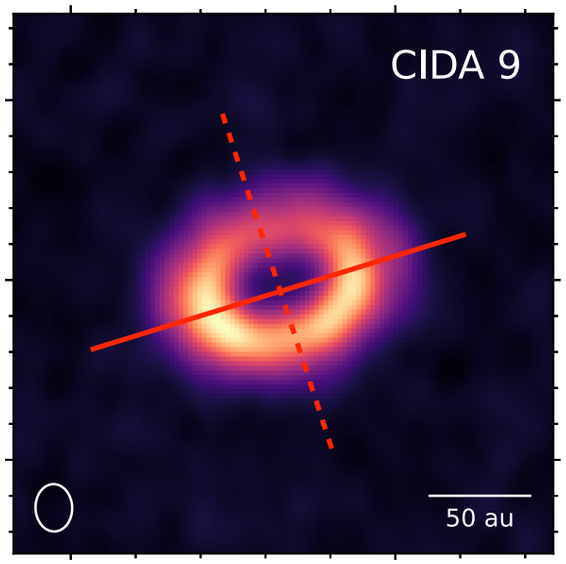
Ribas et al. 2024

Azimuthal asymmetries are common in discs

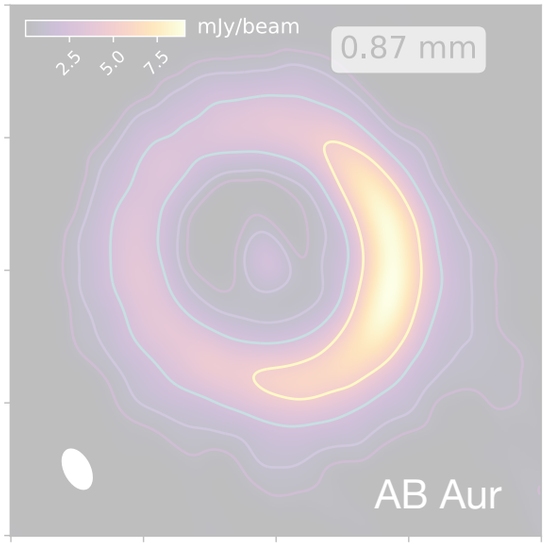
Usually interpreted as dust overdensities due to vortices or induced by companions.



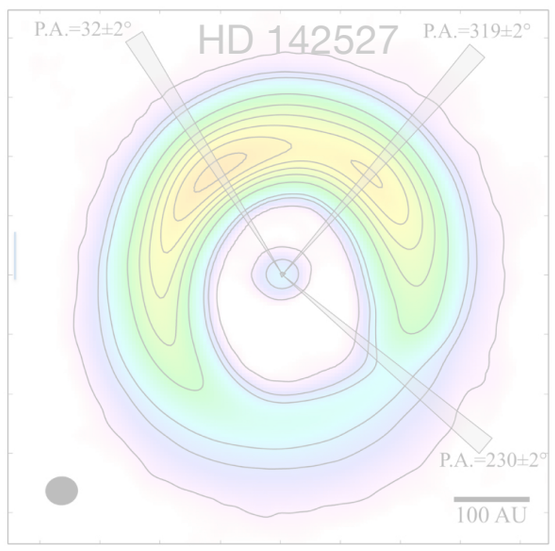
Andrews et al. 2018



Ribas et al. 2024

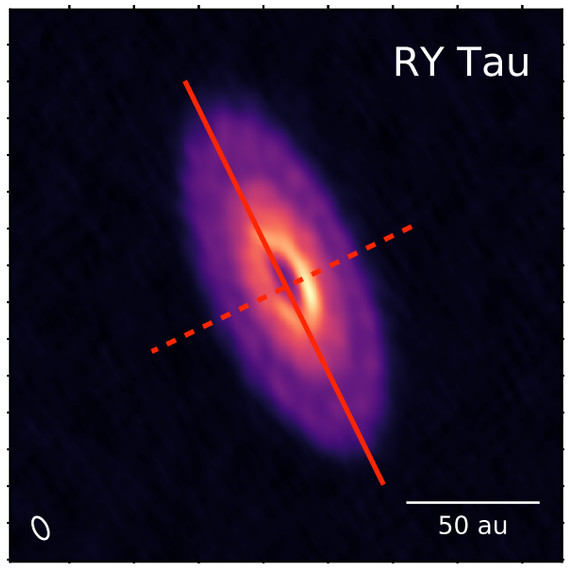


Riviere-Marichalar et al. 2024



Ohashi et al. 2018

Cazzoletti et al. 2018



Ribas et al. 2024

Are some crescent-shaped asymmetries geometric? Can we use them to constrain the disc vertical structure?

Monthly Notices
of the
ROYAL ASTRONOMICAL SOCIETY

Royal Astronomical Society

MNRAS **532,** 1752–1764 (2024)
Advance Access publication 2024 June 26

https://doi.org/10.1093/mnras/stae1534

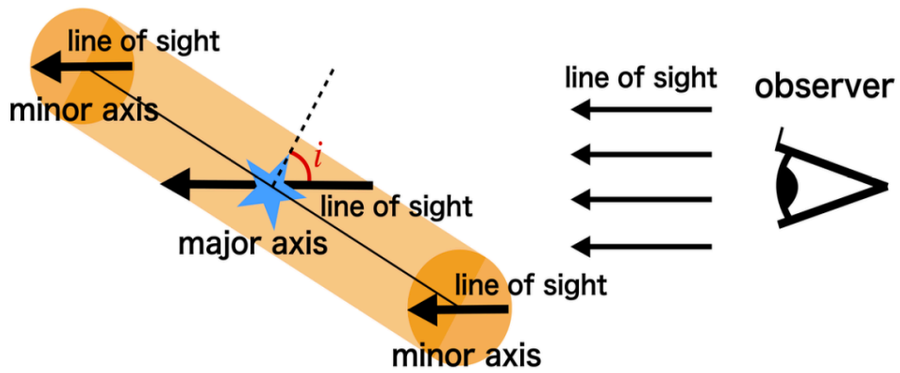
Inner walls or vortices? Crescent-shaped asymmetries in ALMA observations of protoplanetary discs

Á Ribas ,★ Cathie J. Clarke and Francesco Zagaria
Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK

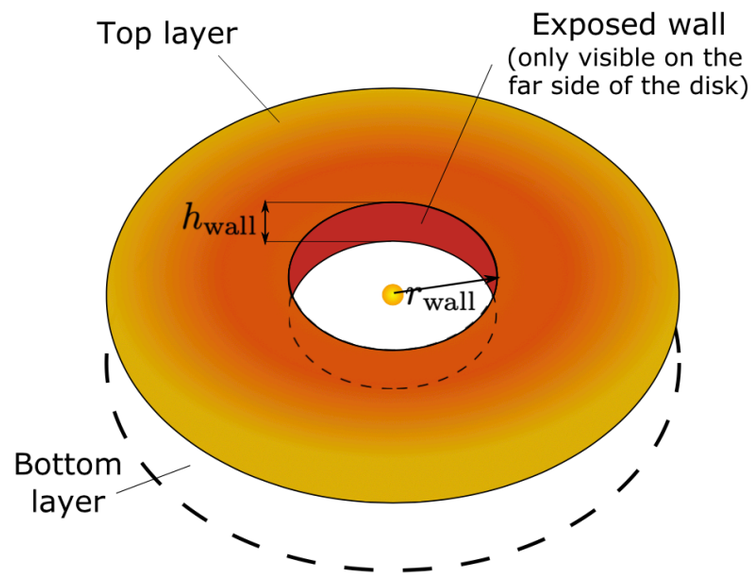
Accepted 2024 June 17. Received 2024 June 10; in original form 2024 March 20

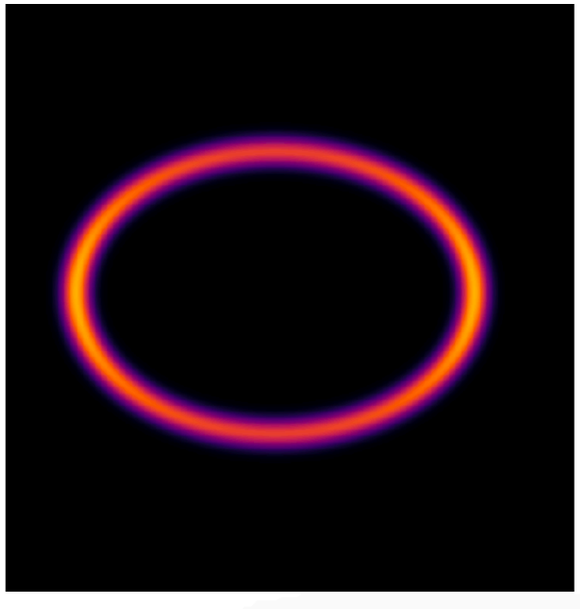
Inclination can induce azimuthal asymmetries in discs. These are purely geometric – no overdensities needed

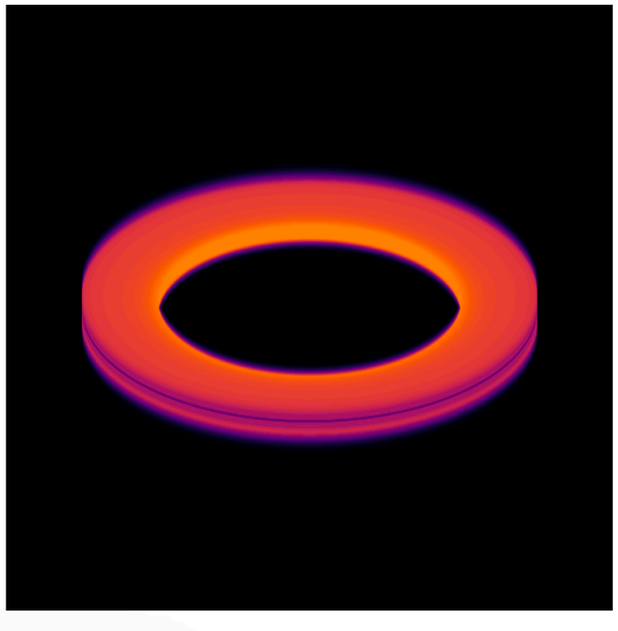
OPTICALLY THIN, GEOMETRICALLY THICK RING



OPTICALLY THICK INNER WALL





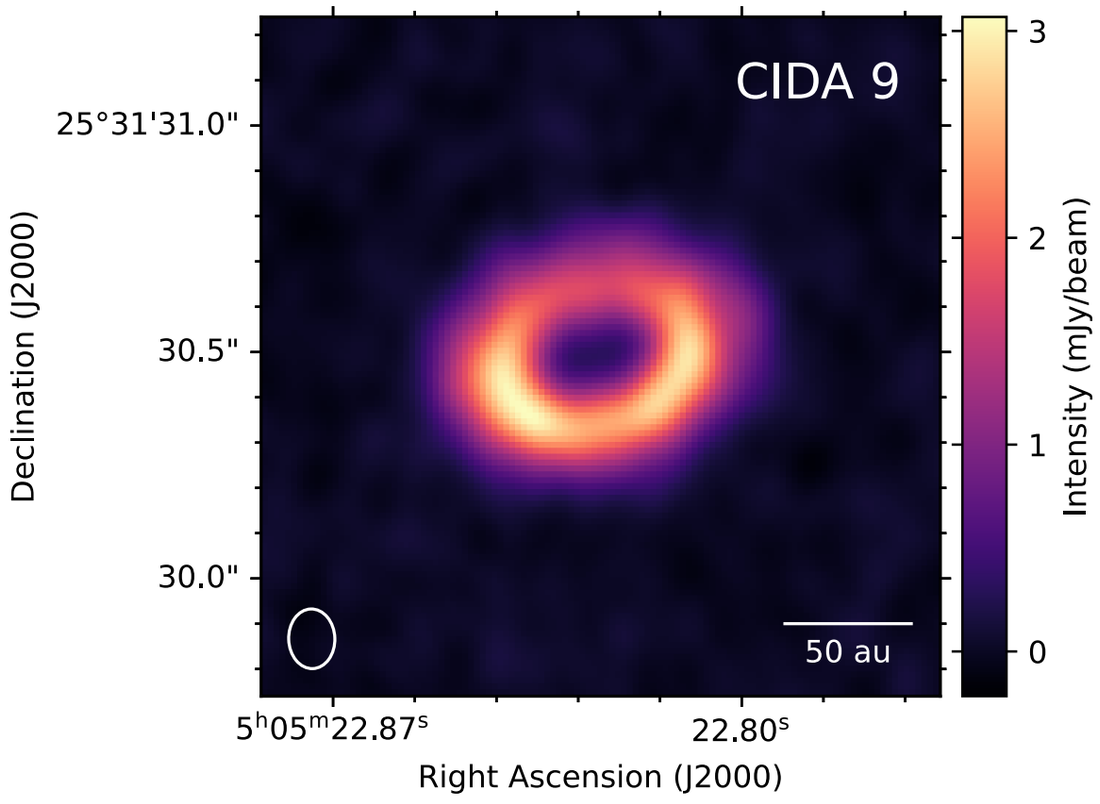


Doi & Kataoka 2021

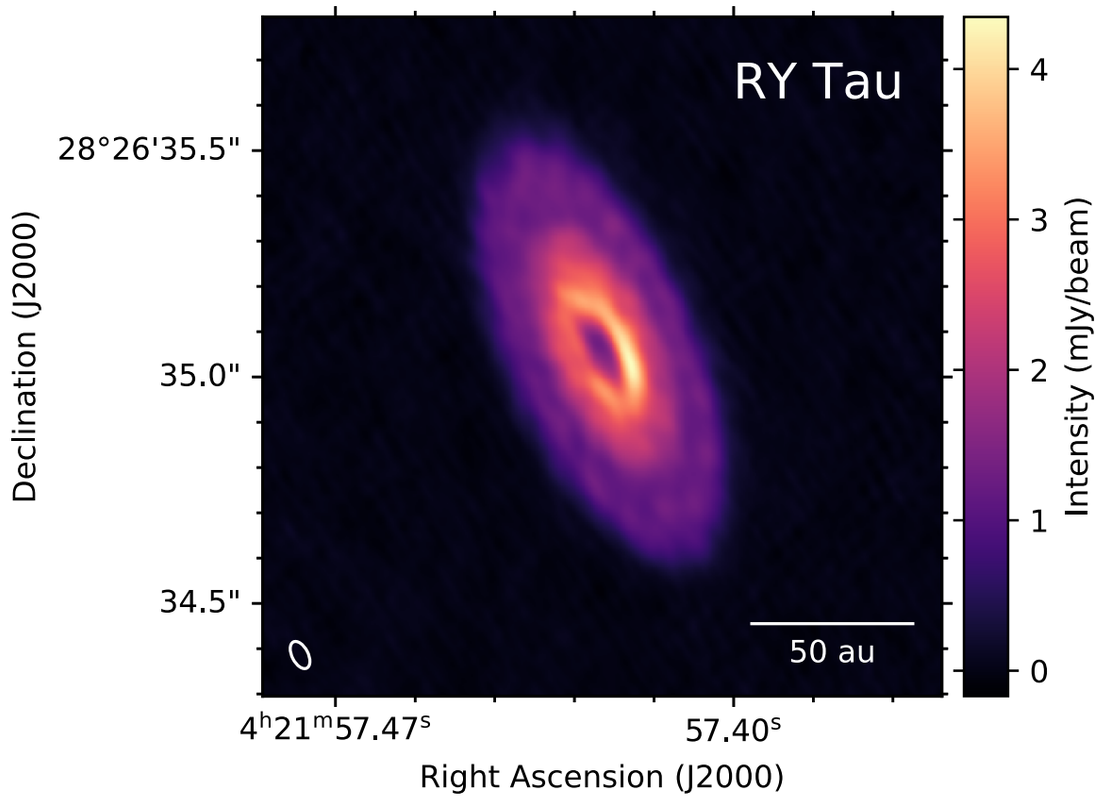
Ribas et al. 2024

We explore these questions in CIDA 9A and RY Tau

Both sources in Taurus-Auriga, observed with ALMA at 1.3 mm.



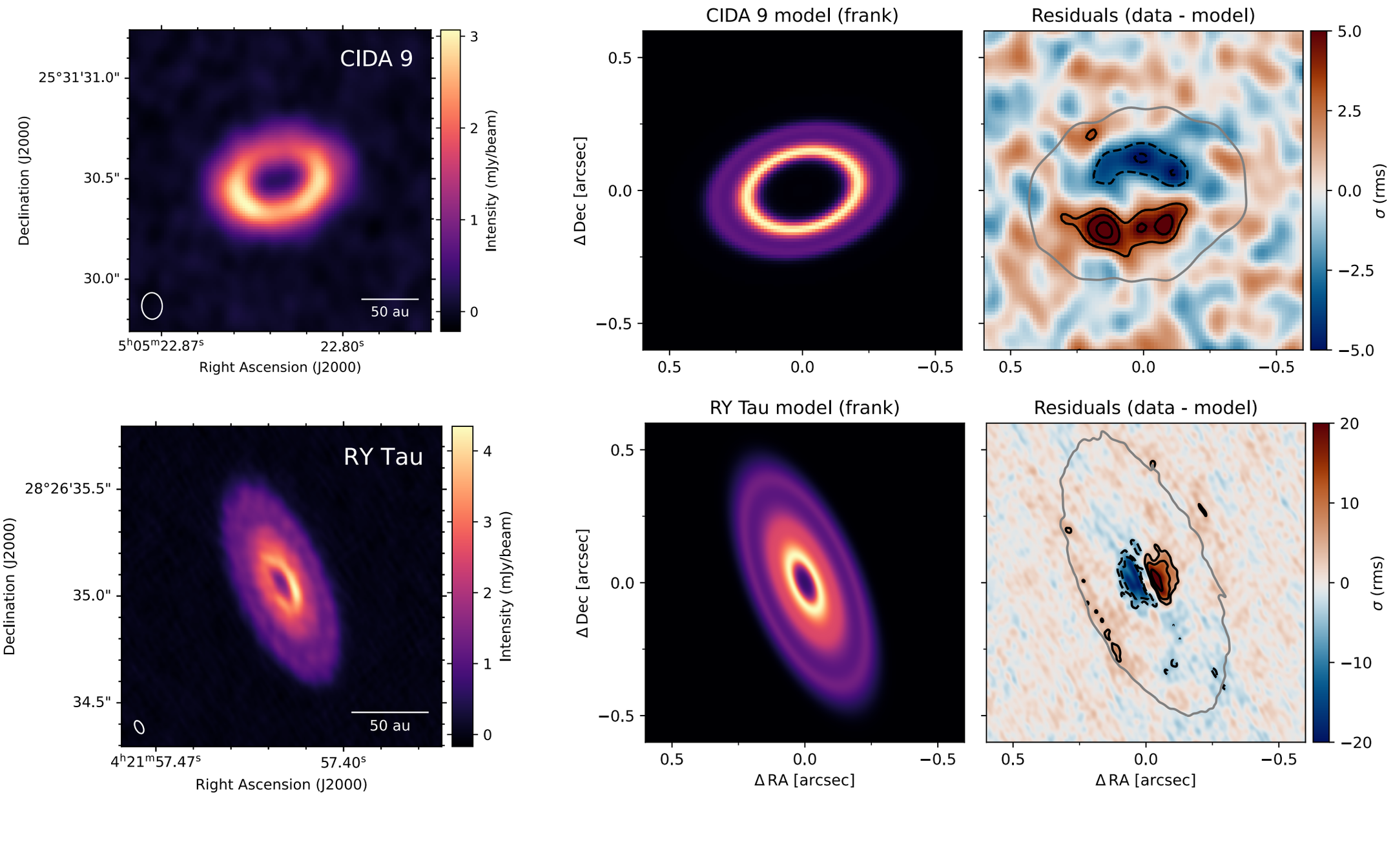
175 pc
M2, $T_{\rm eff}$~3600 K
Beam: 0.1” (~17 au)
Binary system (disc around primary)



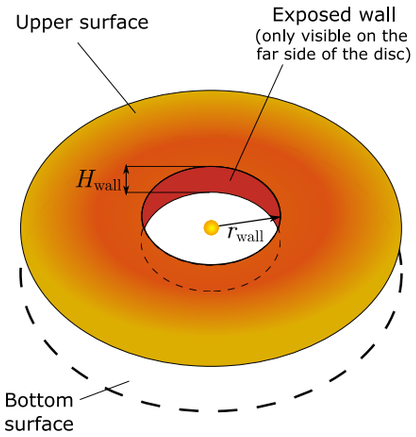
138 pc
F7-G1, $T_{\rm eff}$~6000 K
Beam: 0.04” (~6 au)

The asymmetries are clear in the residuals after subtracting axisymmetric models

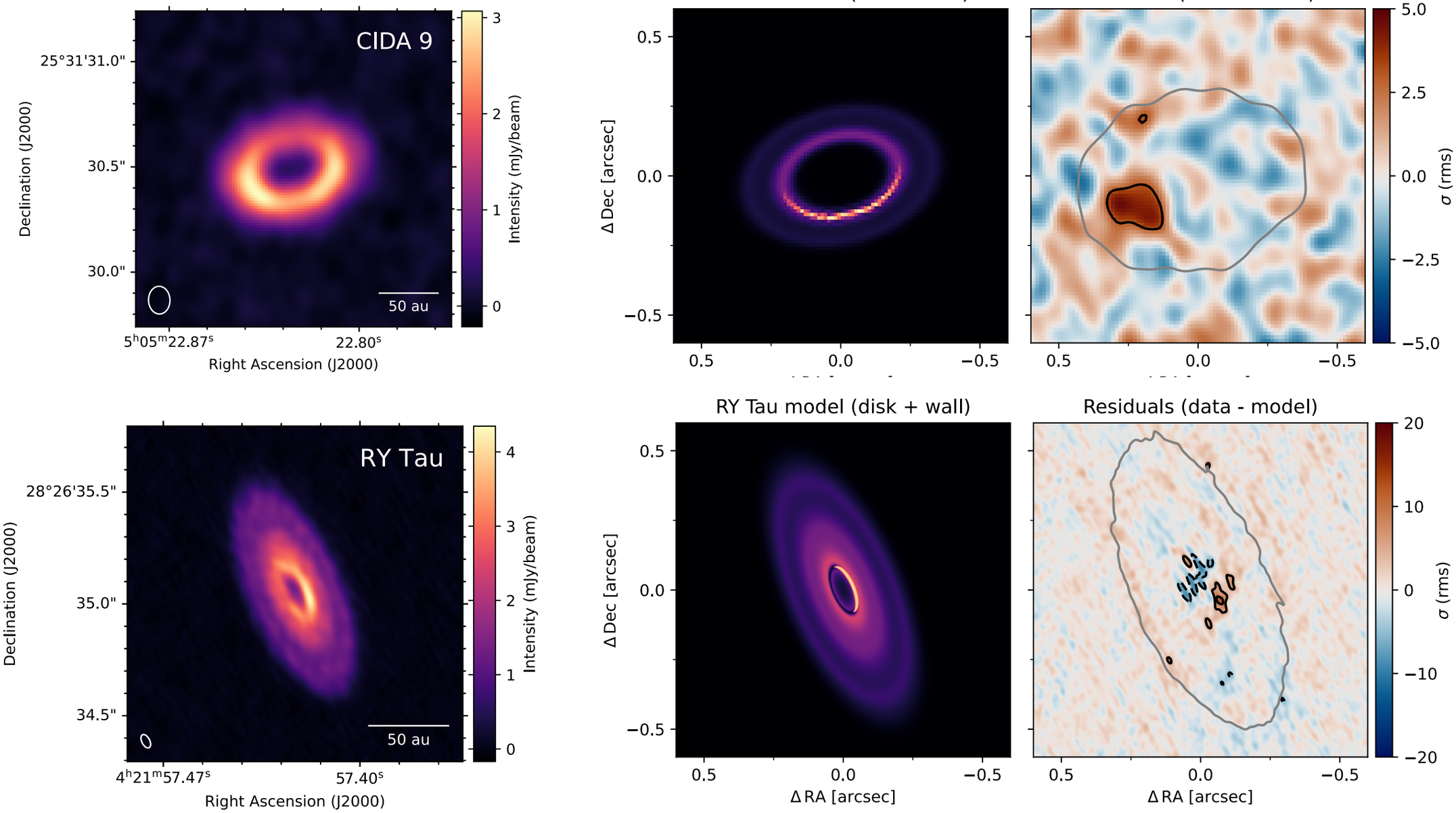
Radial profiles extracted from visibilities using `frank` (Jennings et al. 2020)



We include a geometric wall model on top of the axisymmetric model

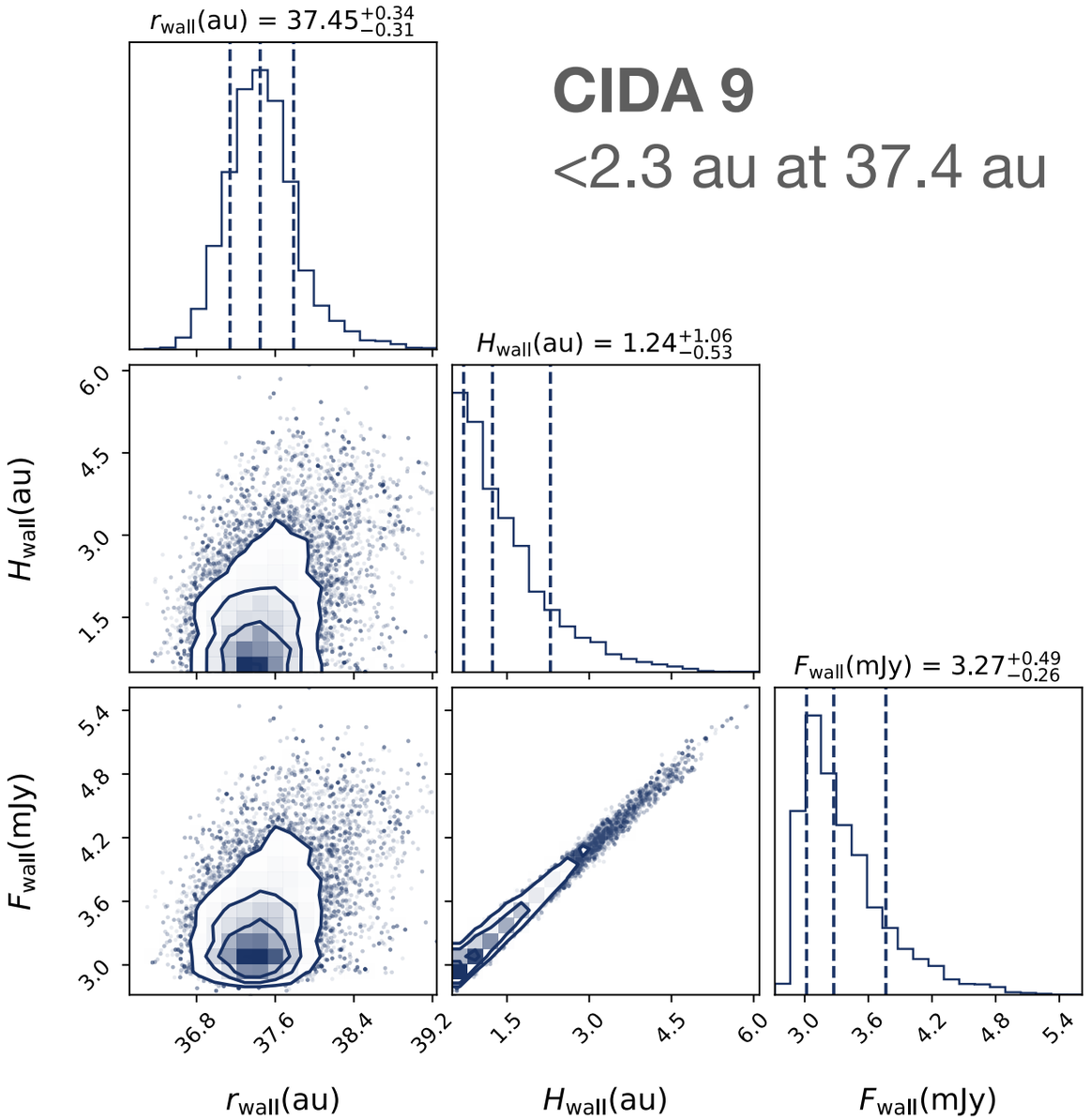


The modeling is performed in visibility space with `galario` (Tazzari et al. 2018)



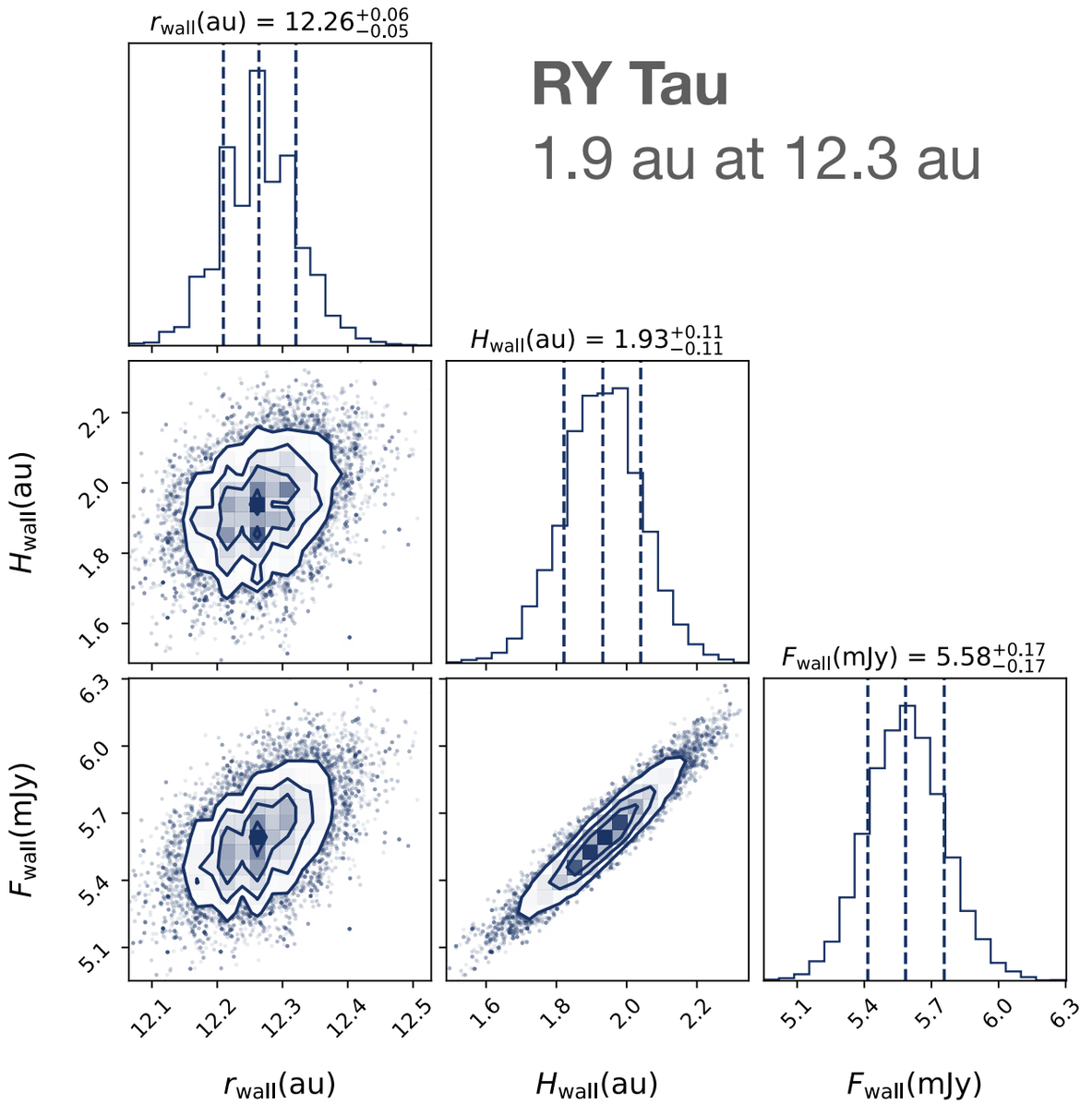
The geometric models place constraints on the vertical thickness of the inner walls

These are **not** scale heights!



CIDA 9

<2.3 au at 37.4 au

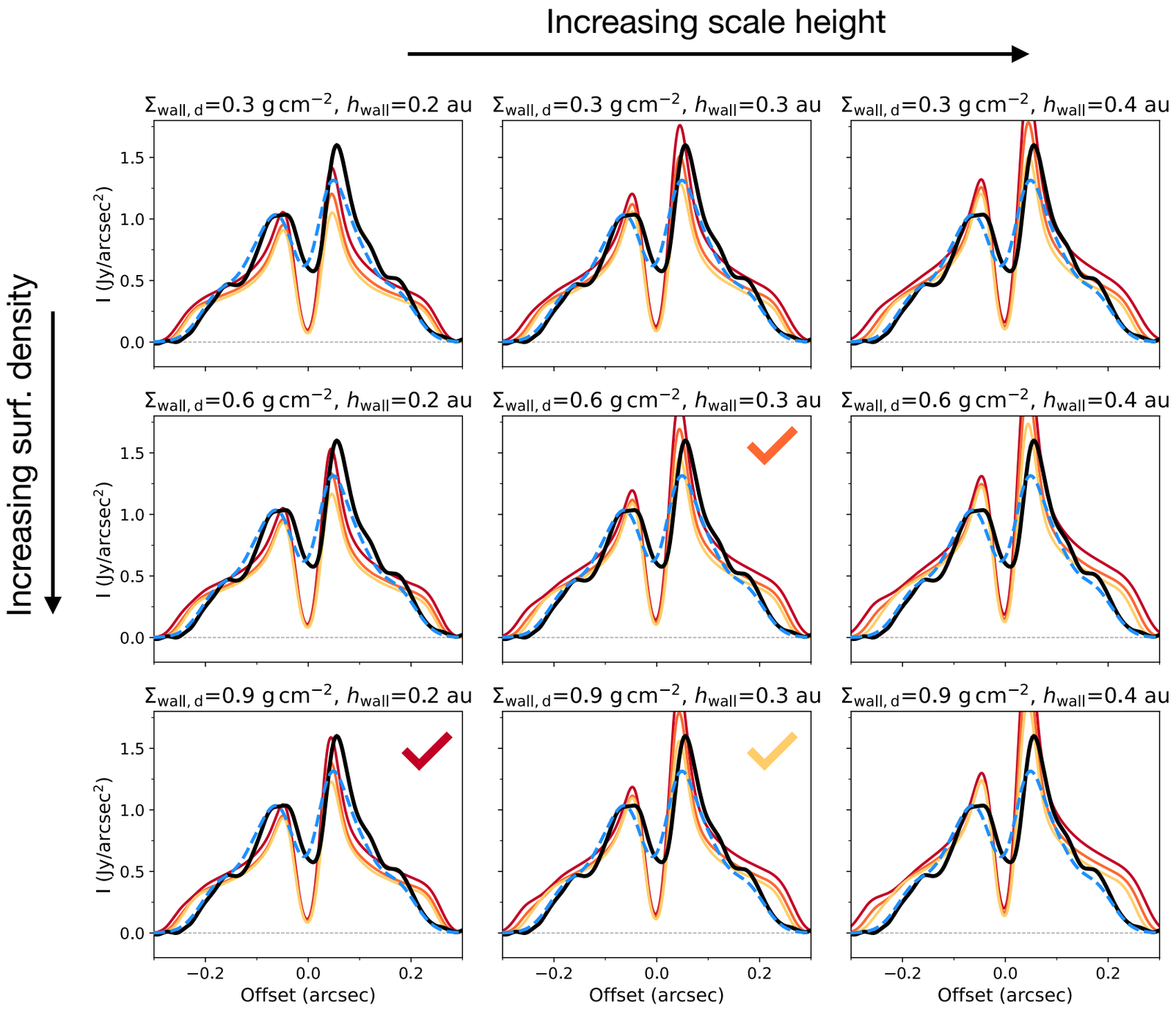


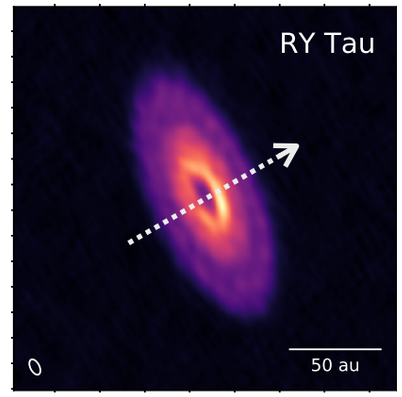
RY Tau

1.9 au at 12.3 au

To estimate the scale height we use a cut along the minor axis of radiative transfer models (MCFOST)

We modify the disc surface density, scale height, and settling.





RY Tau

$$h_{\rm wall} = 0.2 - 0.3\,{\rm au}$$

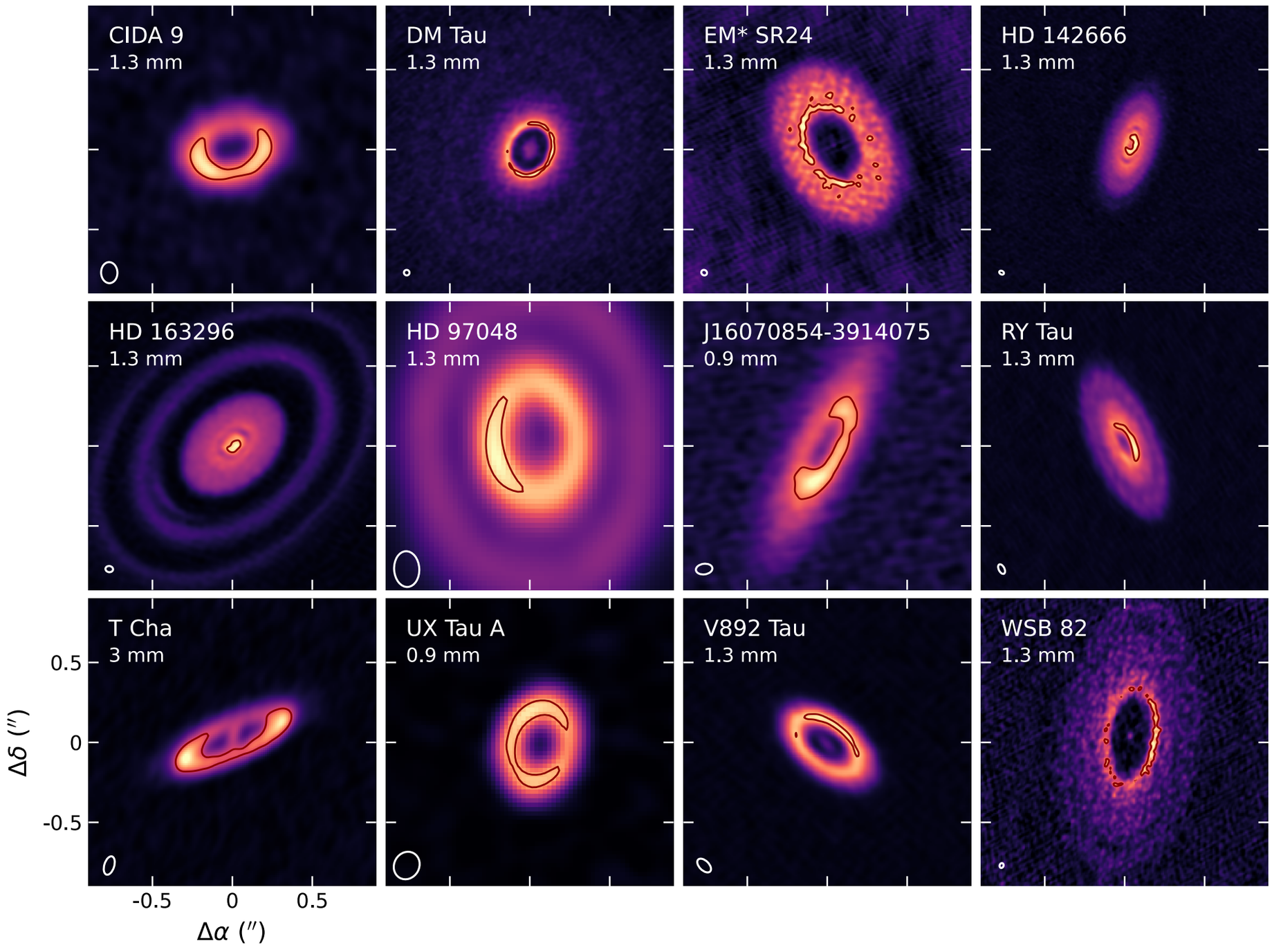
CIDA 9

$$h_{\rm wall} = 0.4 - 0.5\,{\rm au}$$

Observation
Geometric best-fit
No settling
Settling (α=10^{-4})
Settling (α=10^{-5})

If this effect is geometric, then it should be common

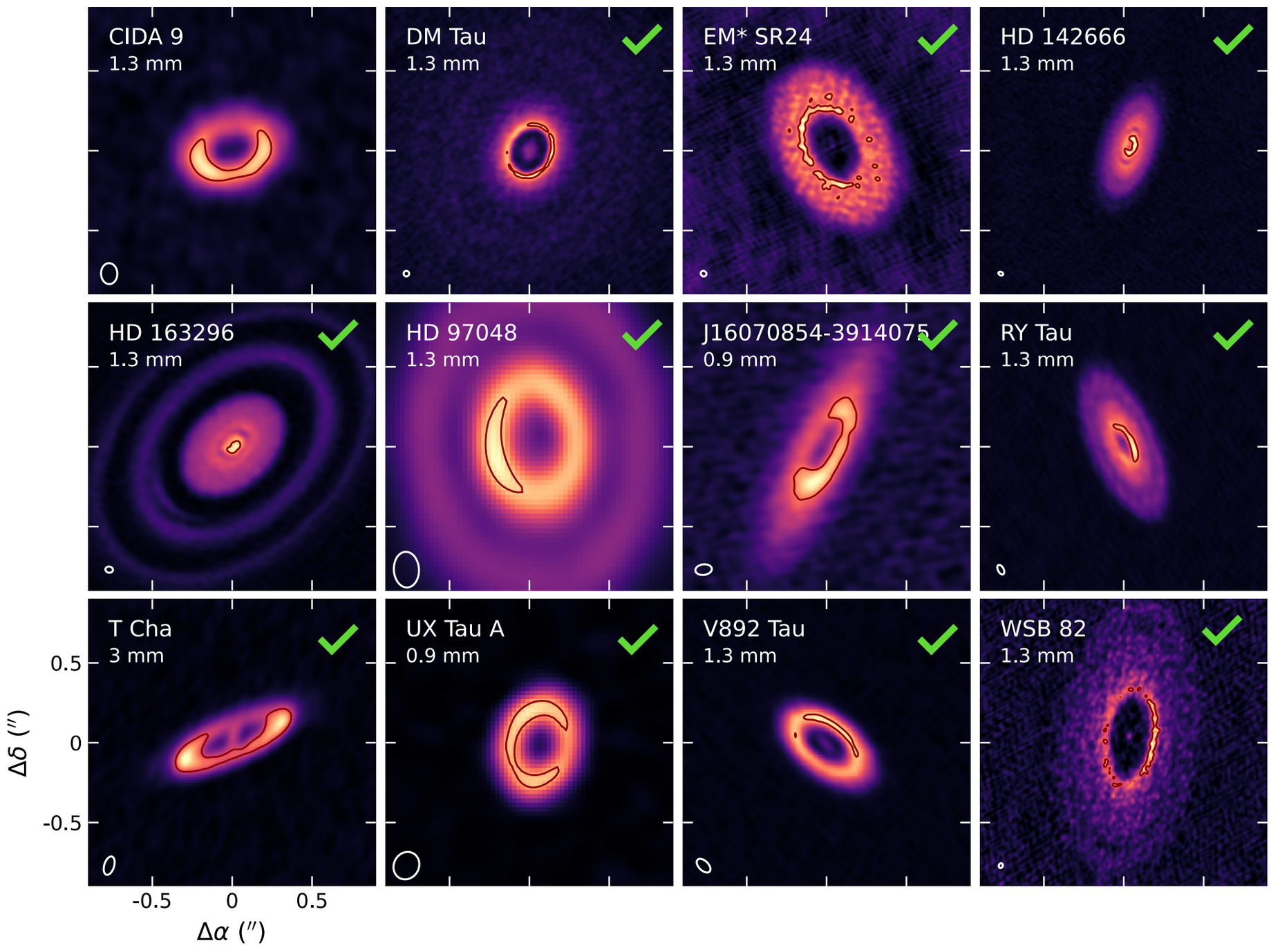
Based on a quick visual inspection of published images, we identified **12 cases with similar asymmetries**.



And it should appear on the far side of discs

Orientation information exists for 11 of these objects (scattered light, CO)

The asymmetry is on the far side 100% of the times (<0.05% random chance).



Some additional things to consider

- This effect appears if emission is optically thick: **contrast between the near and far sides of the disc should decrease at longer wavelengths**.

- This effect is symmetric about the minor axis and appears on one side of the disc only. **Some azimuthal asymmetries are definitely not walls.**

- **Walls and vortices can co-exist**: both can be present at the same time.

Take away messages

- Optically thick emission + inclination can create crescent-shaped asymmetries.
- We can use this to constrain the vertical structure of discs.
- Strong statistical evidence in favor of a geometric origin in multiple examples.

Thank you!