HD142527: A CRIME SCENE INVESTIGATION

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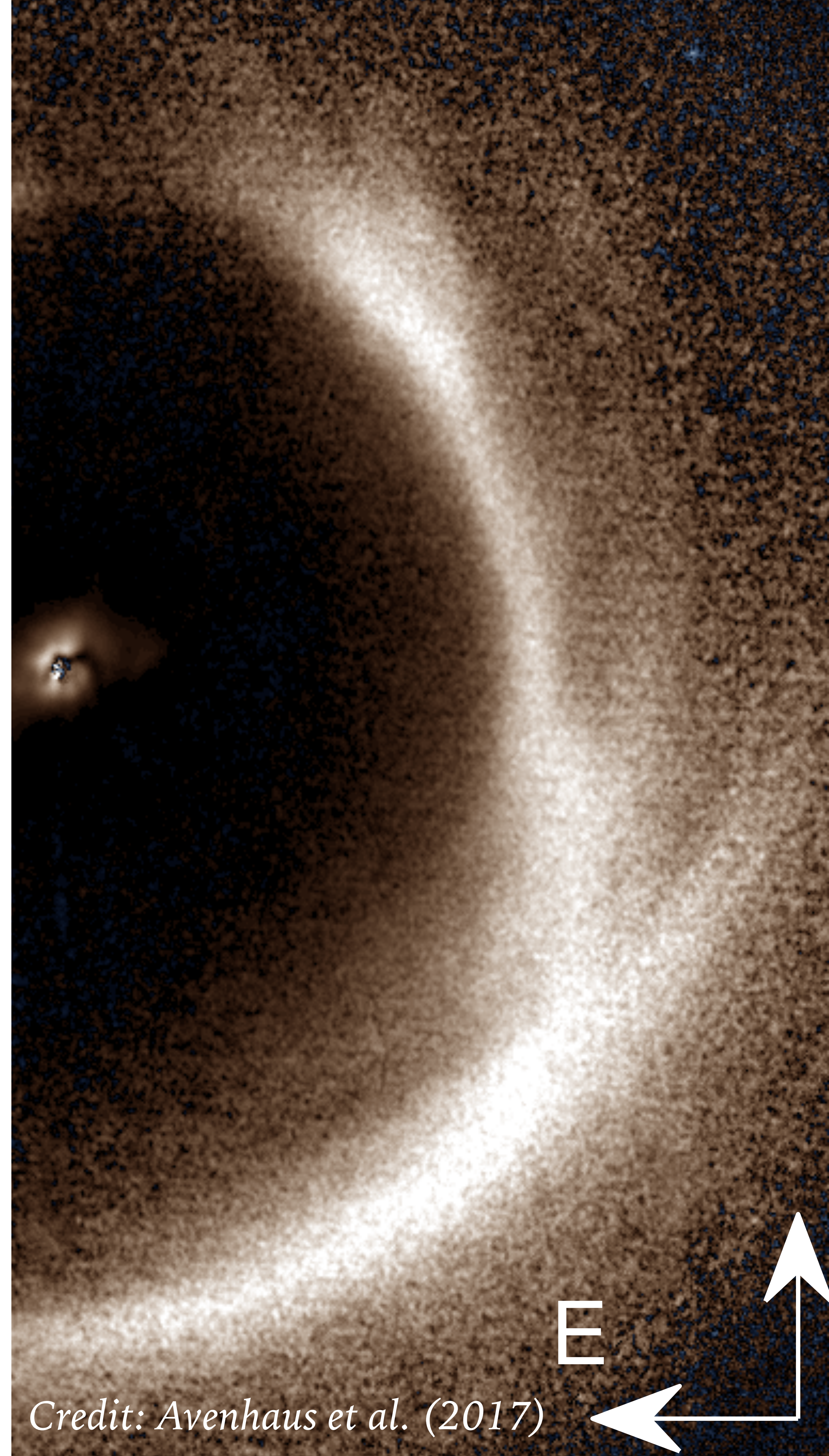
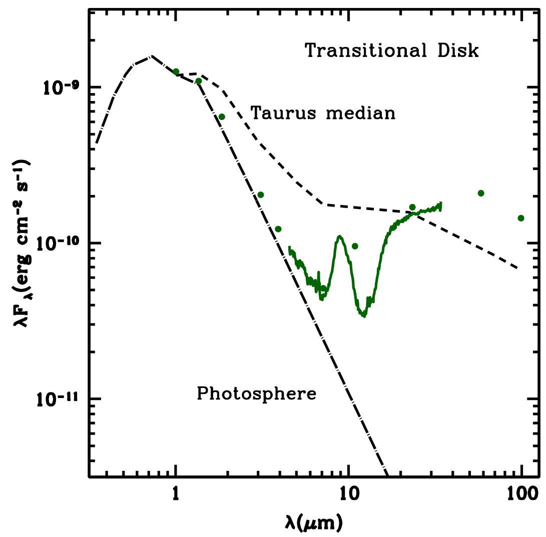
The Accreting Universe, TDLI Institute, Shanghai, 13th July 2017

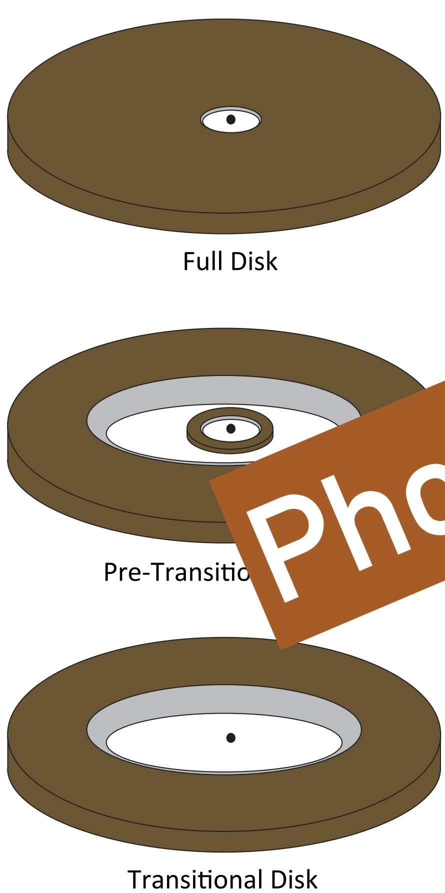


Credit: Avenhaus et al. (2017)

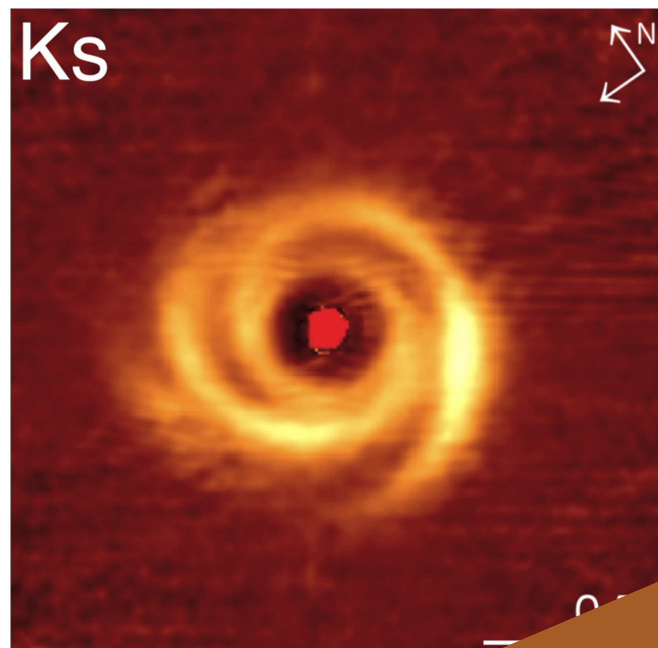
TRANSITION DISCS

Strom et al. (1989), Calvet et al. (2005), Espaillat et al. (2014), Casassus (2016), Owen (2016)



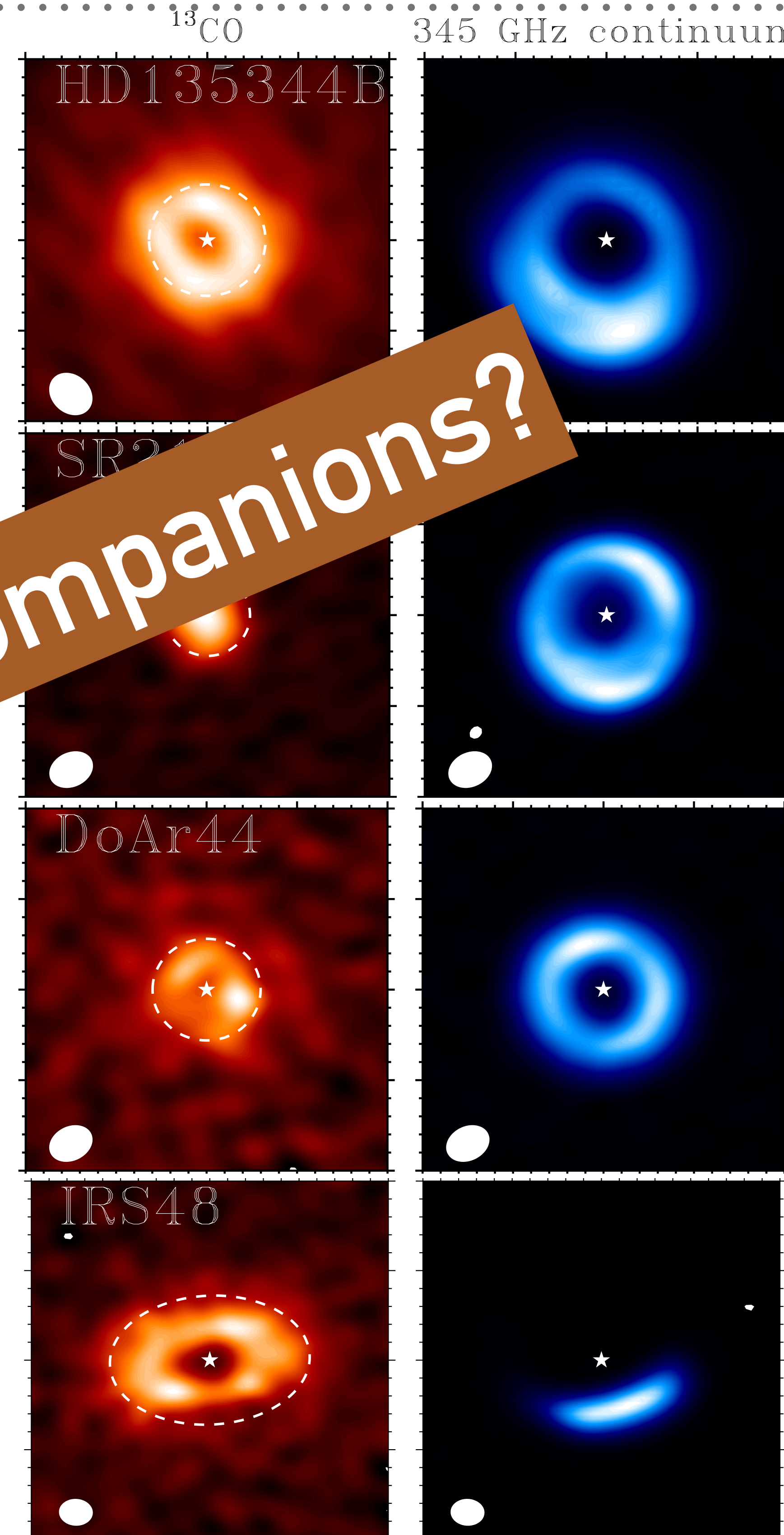


Espaillat et al. (2014)



Garufi et al

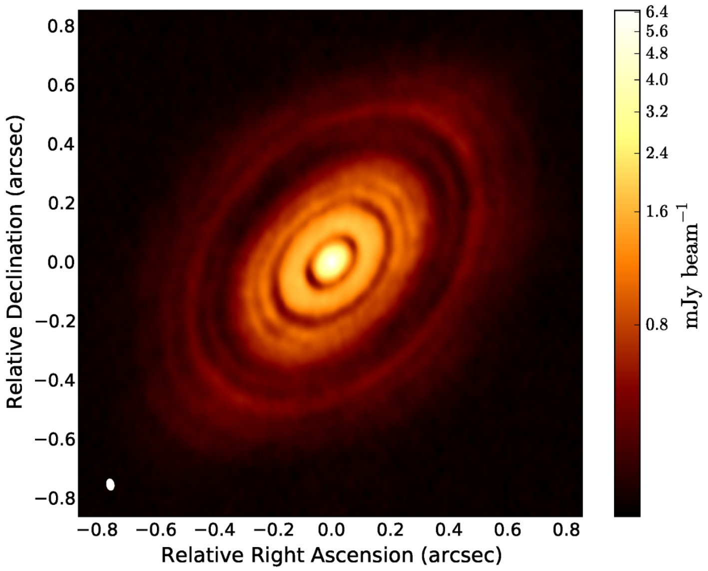
Benisty et al. (2016)



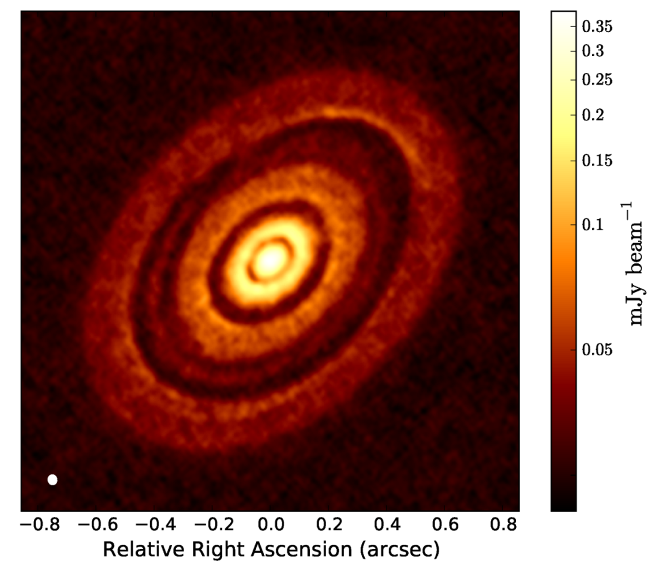
Van-der-Marel et al. (2016)

Photoevaporation or companions?

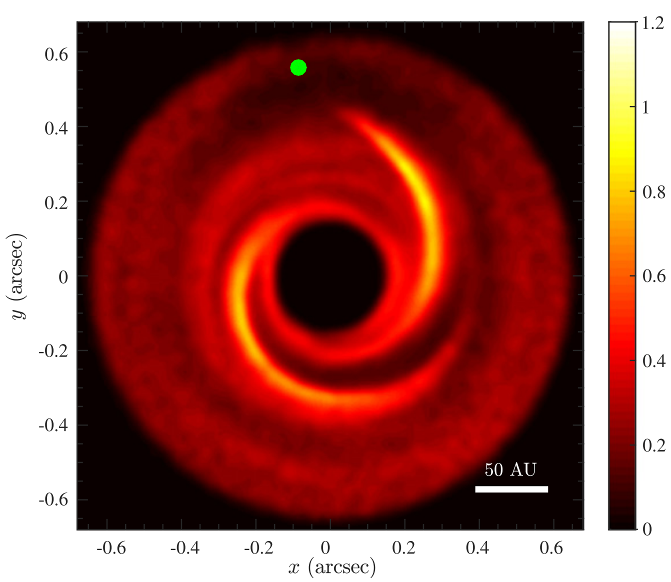
DISCS IN THE ERA OF ALMA + EXTREME ADAPTIVE OPTICS



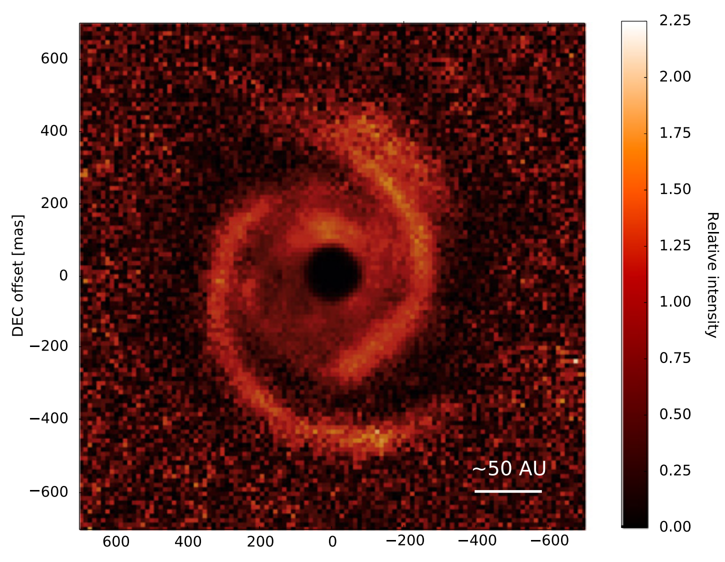
ALMA et al. (2015)



Dipierro et al. (2015)



Dong, Zhu, Rafikov & Stone (2015)



Benisty et al. (2015)

Companions or other physics?

e.g.

- *Lyra & Kuchner (2012)*
- *Pinilla (2012)*
- *Takahashi & Inutsuka (2012)*
- *Zhu & Stone (2014)*
- *Dipierro et al. (2014)*
- *Zhang, Blake & Bergin (2015)*
- *Loren-Aguilar & Bate (2015)*
- *Flock et al. (2015)*
- *Dong (2015)*
- *Meru et al. (2017)*

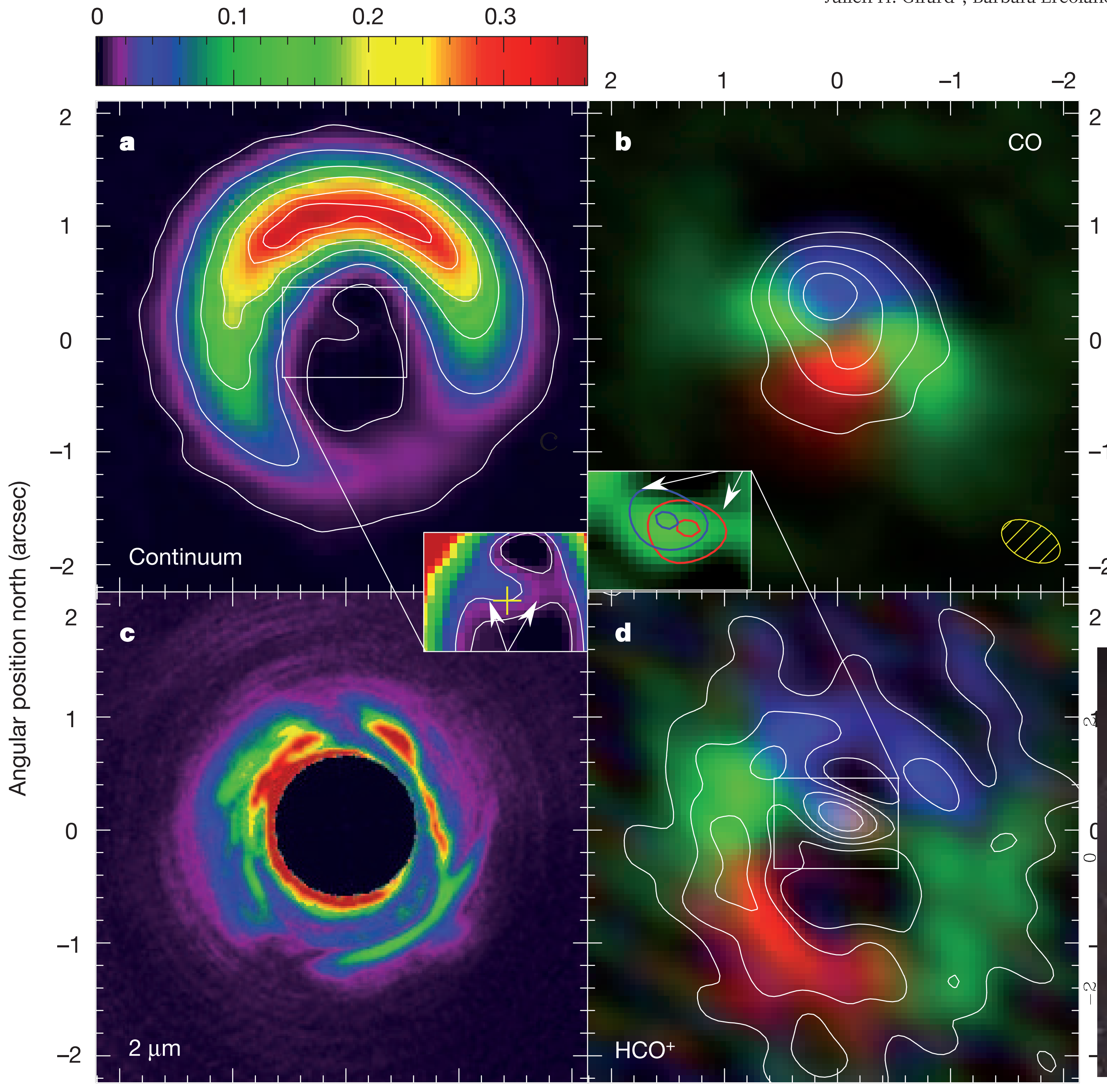
HD142527: CRIME SCENE

LETTER

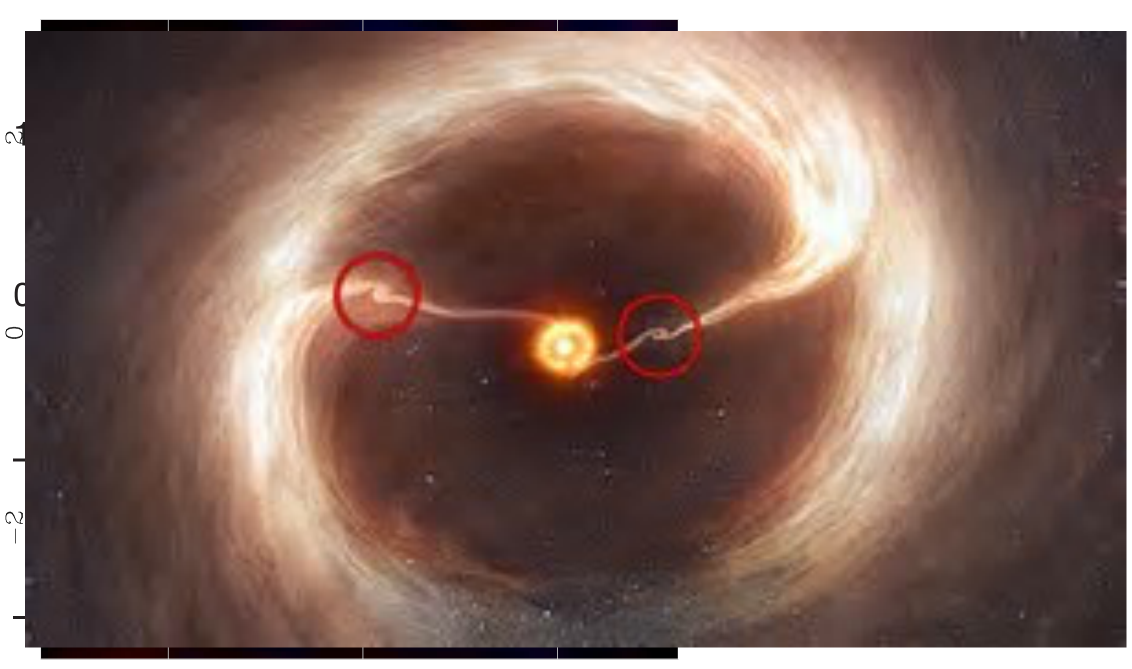
doi:10.1038/nature11769

Flows of gas through a protoplanetary gap

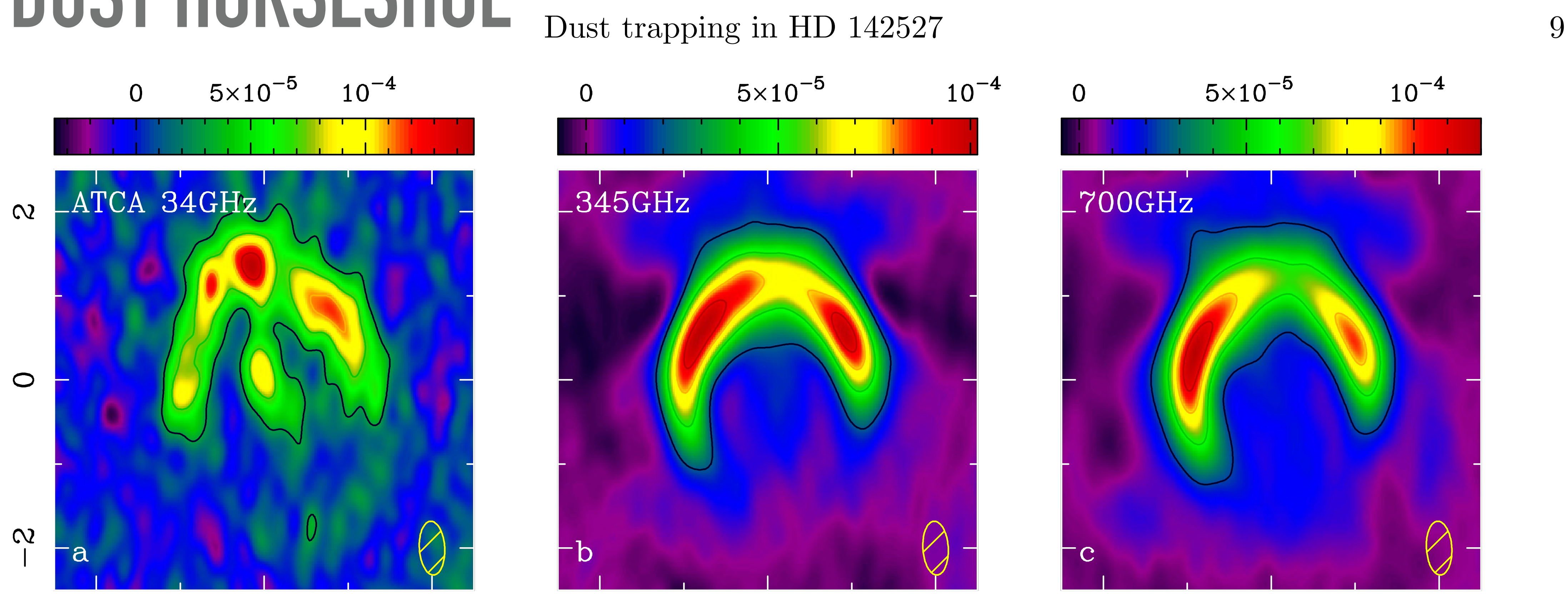
Simon Casassus[1], Gerrit van der Plas[1], Sebastian Perez M[1], William R. F. Dent[2,3], Ed Fomalont[4], Janis Hagelberg[5], Antonio Hales[2,4], Andrés Jordán[6], Dimitri Mawet[3], Francois Ménard[7,8], Al Wootten[4], David Wilner[9], A. Meredith Hughes[10], Matthias R. Schreiber[11], Julien H. Girard[3], Barbara Ercolano[12], Hector Canovas[11], Pablo E. Román[13] & Vachail Salinas[1]

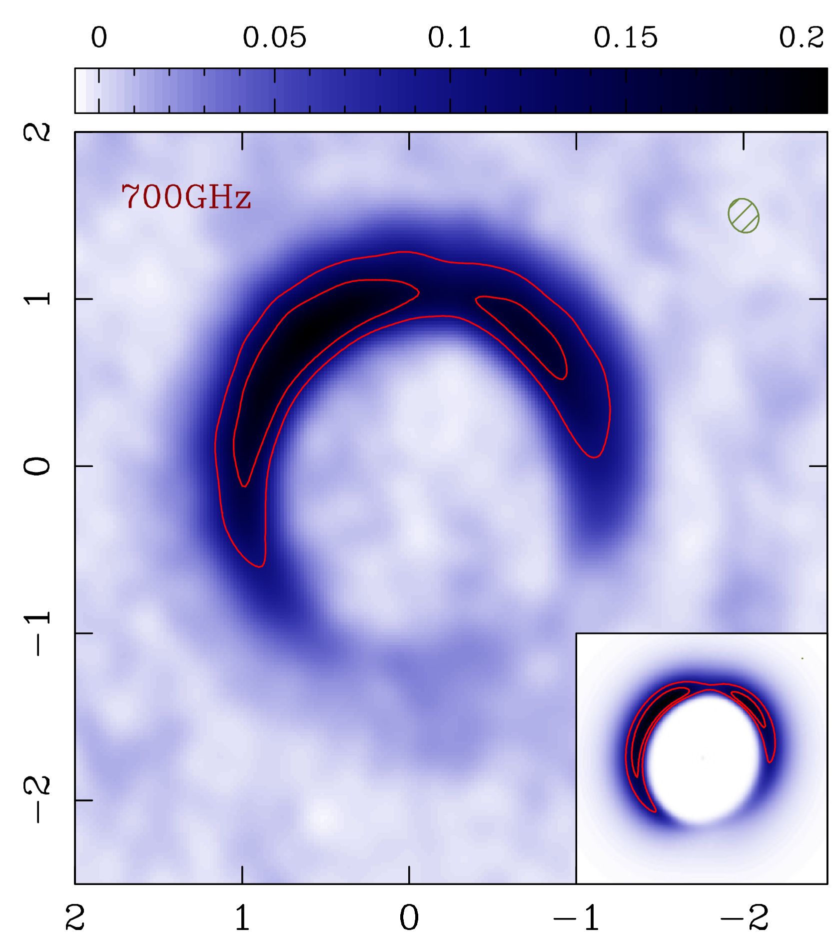


- Large ~100 au cavity
- Horseshoe in mm emission
- Gap-crossing filaments?



THE DUST HORSESHOE





“the large sub-mm crescent mostly reflects the gas background, with relatively inefficient trapping, so that the observed contrast ratio of ∼30 is accounted for with a contrast of 20 in the gas”

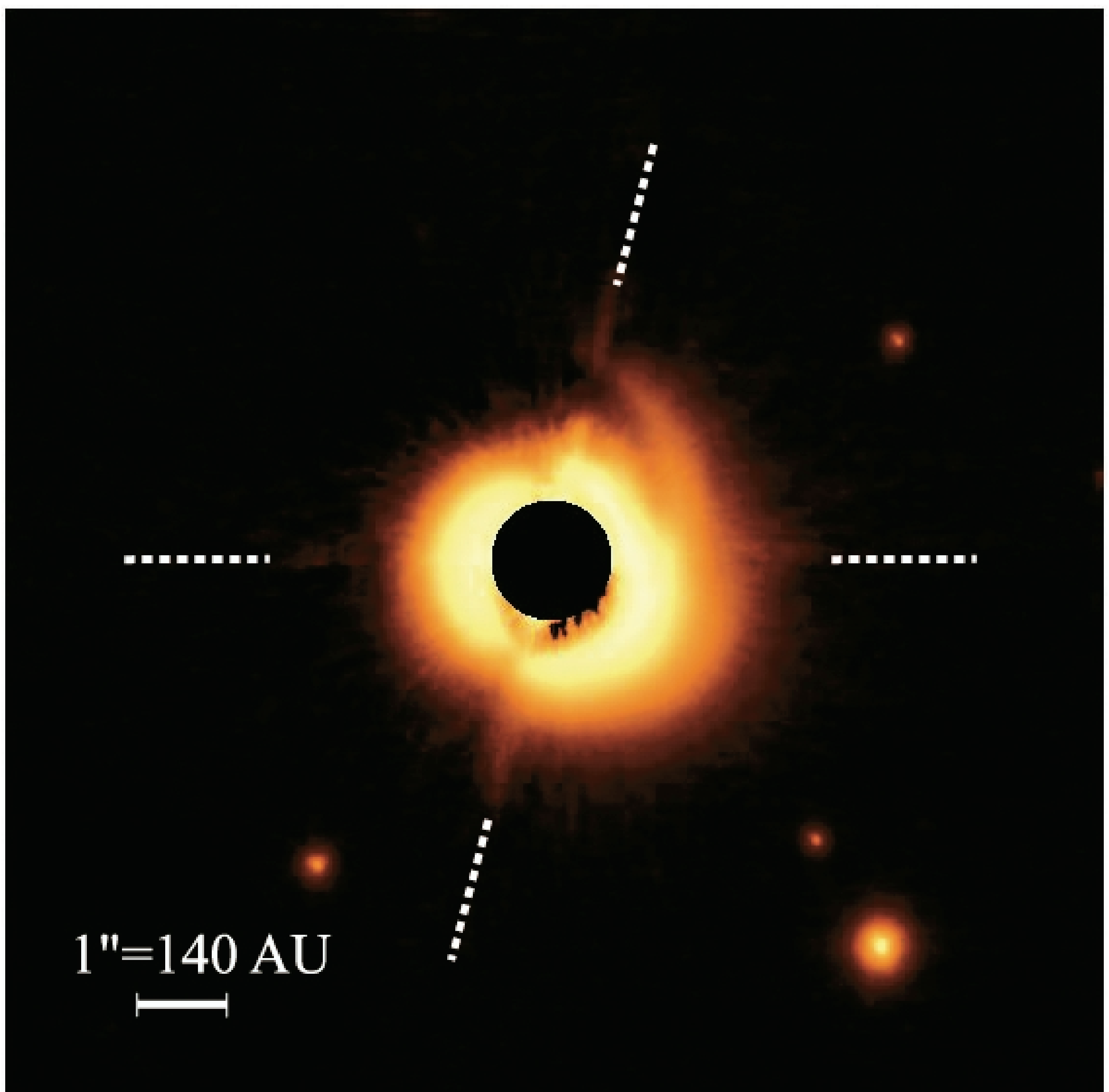
Casassus et al. 2015b

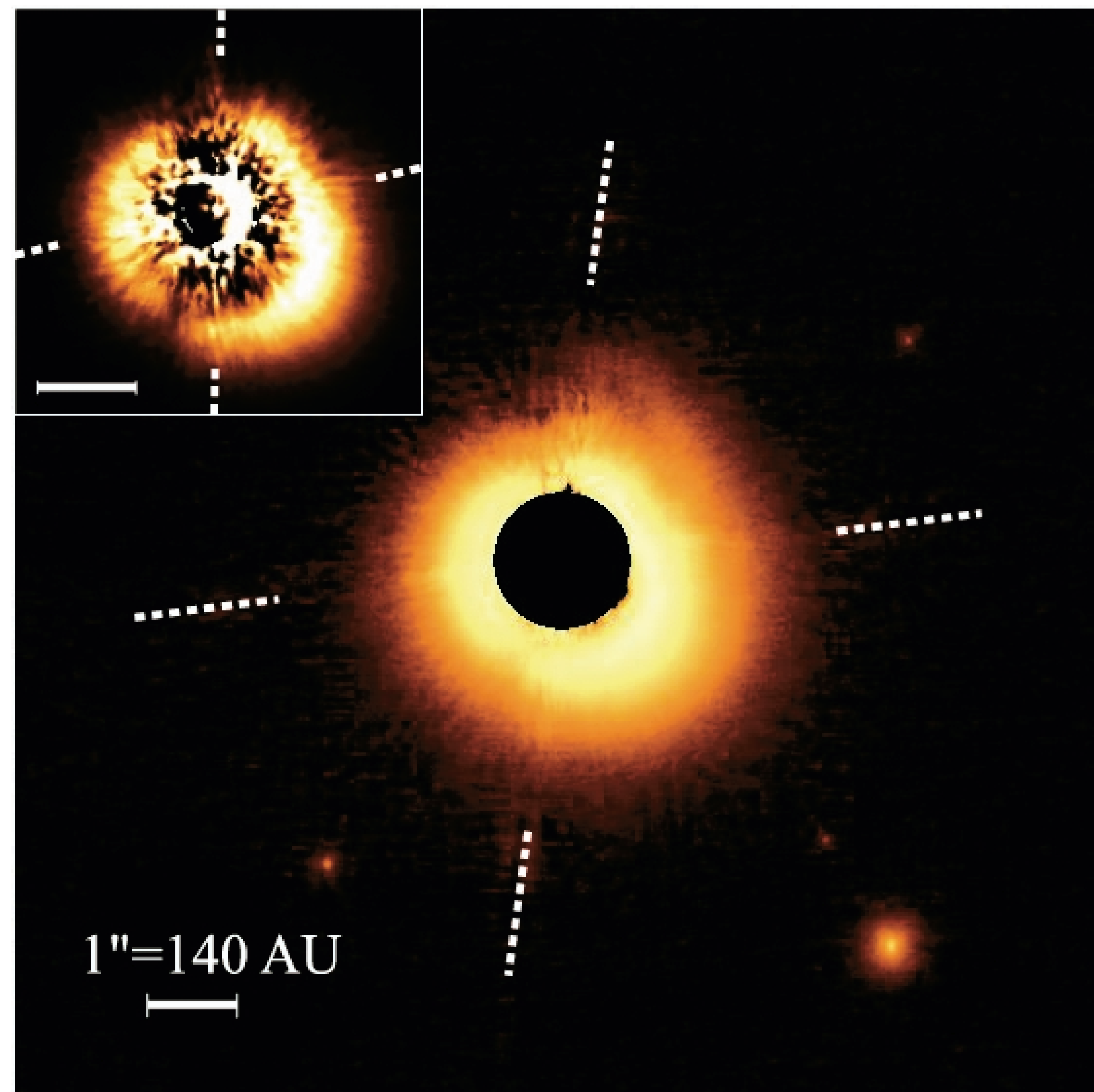
SPIRAL ARMS

THE ASTROPHYSICAL JOURNAL, 636:L153–L156, 2006 January 10

NEAR-INFRARED IMAGES OF PROTOPLANETARY DISK SURROUNDING HD 142527[1]

MISATO FUKAGAWA,[2,3] MOTOHIDE TAMURA,[4,5] YOICHI ITOH,[6] TOMOYUKI KUDO,[5] YUSUKE IMAEDA,[6] YUMIKO OASA,[6]
SAEKO S. HAYASHI,[5,7] AND MASAHIKO HAYASHI[5,7]
Received 2005 August 28; accepted 2005 November 30; published 2006 January 3





The Astrophysical Journal Letters, 785:L12 (5pp), 2014 April 10 doi:10.1088/2041-8205/785/1/L12

SPIRAL ARMS IN THE DISK OF HD 142527 FROM CO EMISSION LINES WITH ALMA

V. Christiaens[1], S. Casassus[1], S. Perez[1], G. van der Plas[1], and F. Ménard[2]
[1] Departamento de Astronomía, Universidad de Chile, Casilla 36-D, Santiago, Chile; valchris@das.uchile.cl
[2] UMI-FCA, CNRS/INSU, France (UMI 3386) and Departamento de Astronomía, Universidad de Chile, Santiago, Chile
Received 2014 January 24; accepted 2014 March 5; published 2014 March 28

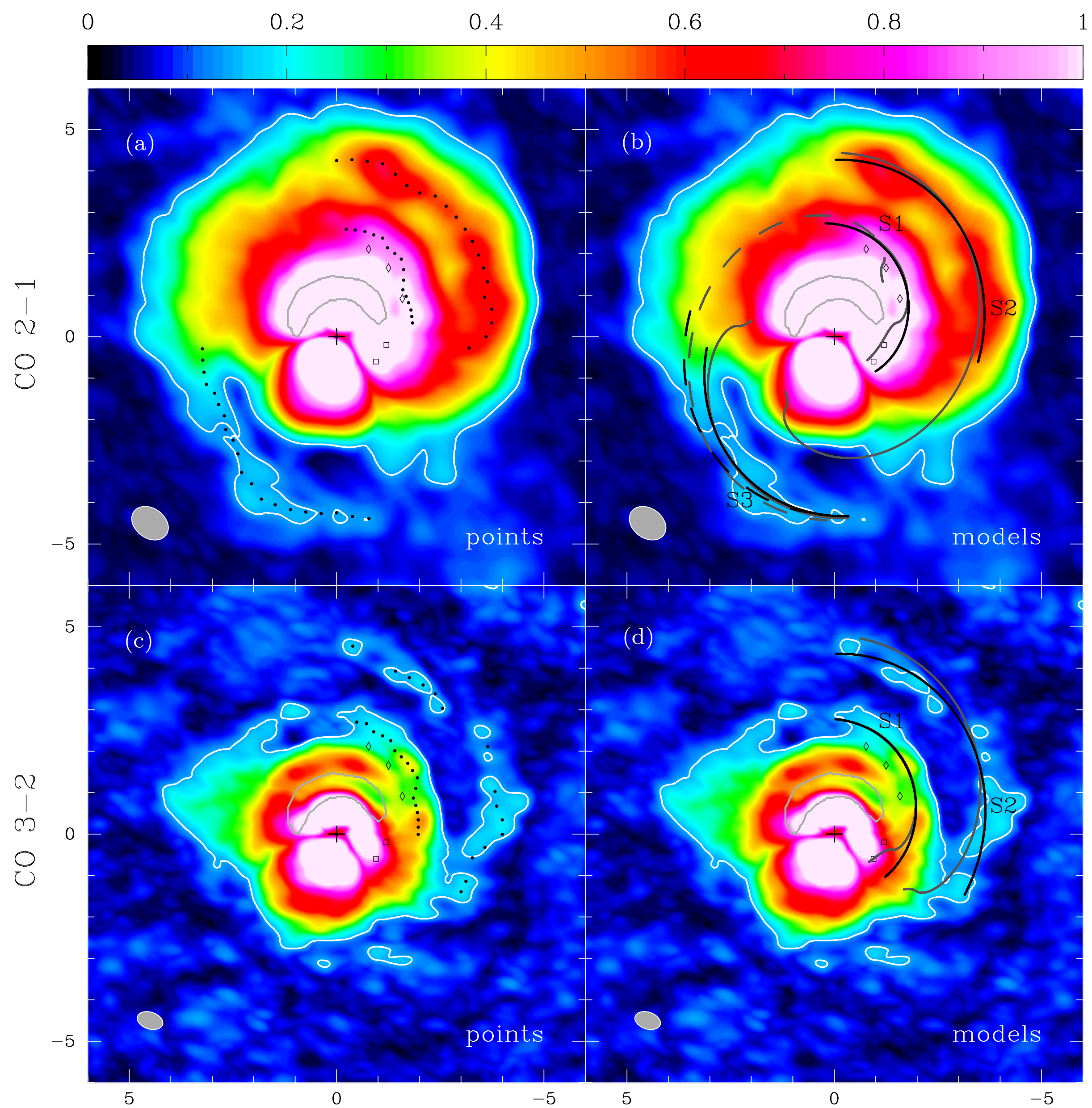


Figure 3. Modeling of the spirals observed in the CO 2–1 and CO 3–2 I_{peak} maps. Legends follow from Figures 1(b) and (f). For comparison, we indicate the position of the *H*-band spiral arm from Fukagawa et al. (2006; diamonds) and the Ks-band spiral root from Casassus et al. (2012; squares). (a) Points tracing the spirals used for modeling. (b) Modeling of the spiral arms as in Muto et al. (2012; solid dark gray lines) and Kim (2011; solid black lines). The dashed dark gray and dashed black spirals represent the point-symmetric location of S2 models with respect to the star. (c) and (d) Identical to (a) and (b) with the CO 3–2 I_{peak} map.

(A color version of this figure is available in the online journal.)

Near-infrared imaging polarimetry of HD 142527⋆,⋆⋆

H. Canovas[1,9], F. Ménard[2,9], A. Hales[3,4,9], A. Jordán[5,9], M. R. Schreiber[1,9], S. Casassus[6,9],
T. M. Gledhill[7], and C. Pinte[8]

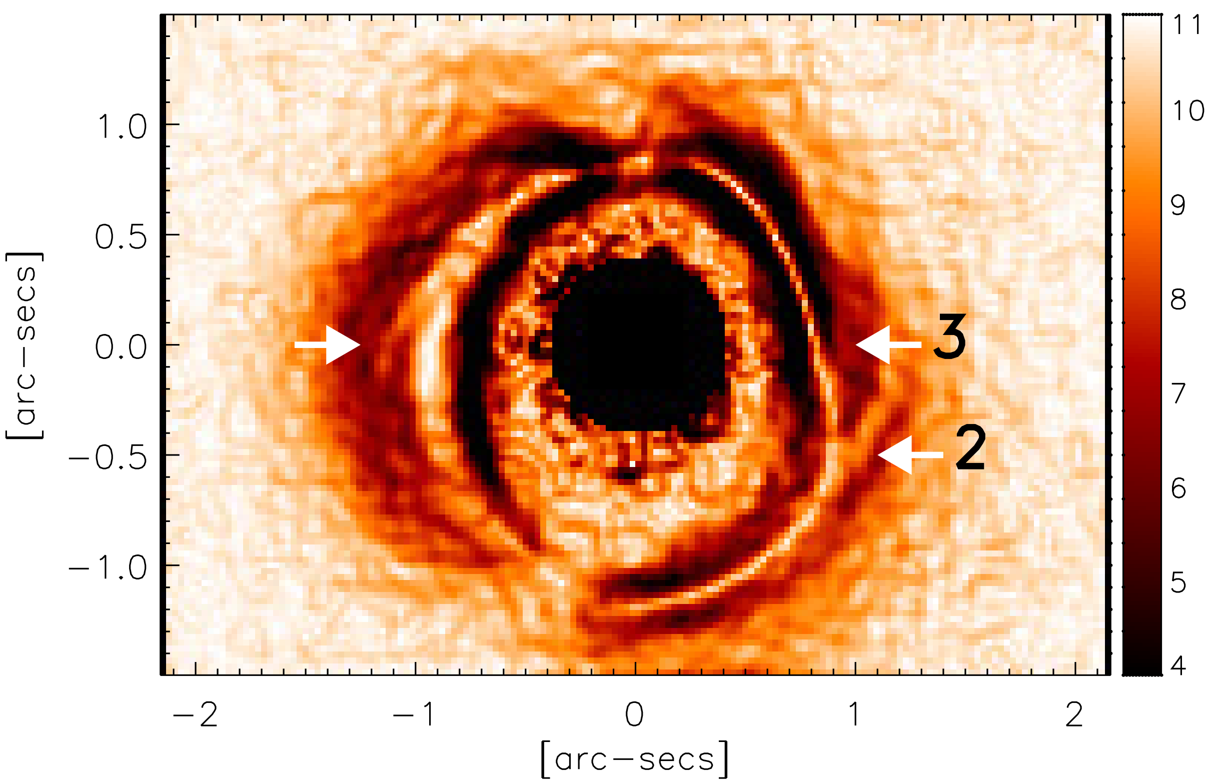


Fig. 6. P_I images at H band after applying a Sobel filter to highlight the regions of the image with edges. The three arrows indicate spiral arms on the disk. For comparison, we used the same notation as in Casassus et al. (2012) (see also Rameau et al. 2012) to label the spiral arms. The spiral arm labeled "2" perfectly matches its equivalent in Casassus et al. (2012). The spiral arm labeled "3" is barely visible in our images. The spiral arm on the east side is detected for the first time. Color bar is in arbitrary units.

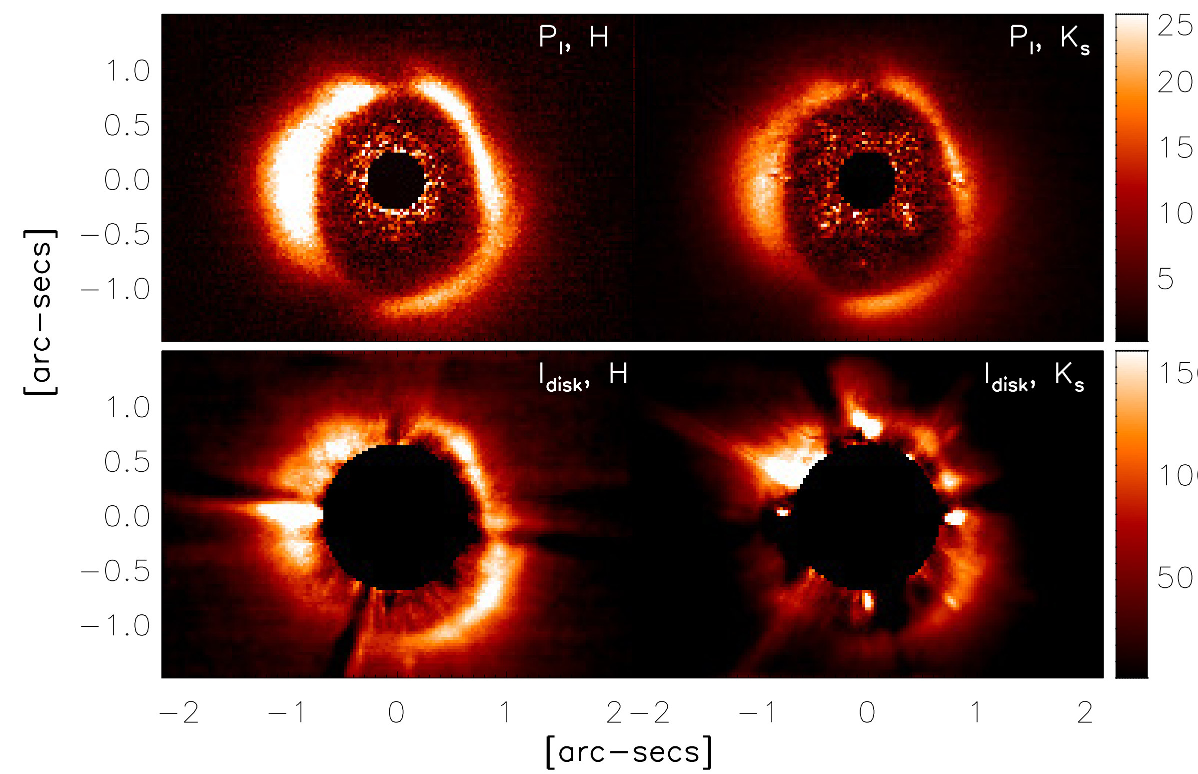


Fig. 3. P_I (*top row*) and I_{disk} (*bottom row*) images at H (*left column*) and K_s band (*right column*) of HD 142527. Masked area in the P_I images cover the saturate region, while in the PSF-subtracted images cover the artifact-dominated regions. The P_I are plotted with the same scale to enhance differences/similarities. The same is done with the I_{disk} images. The bright patch in the I_{disk} image at north-east direction in K_s band is an artifact due to the PSF-subtraction (as it is the bright path on the east direction in the I_{disk} image at H band, see also the caption in Fig. 2). Color bar units are given in counts.

SHADOWS

THE ASTROPHYSICAL JOURNAL LETTERS, 798:L44 (4pp), 2015 January 10 MARINO, PEREZ, & CASASSUS

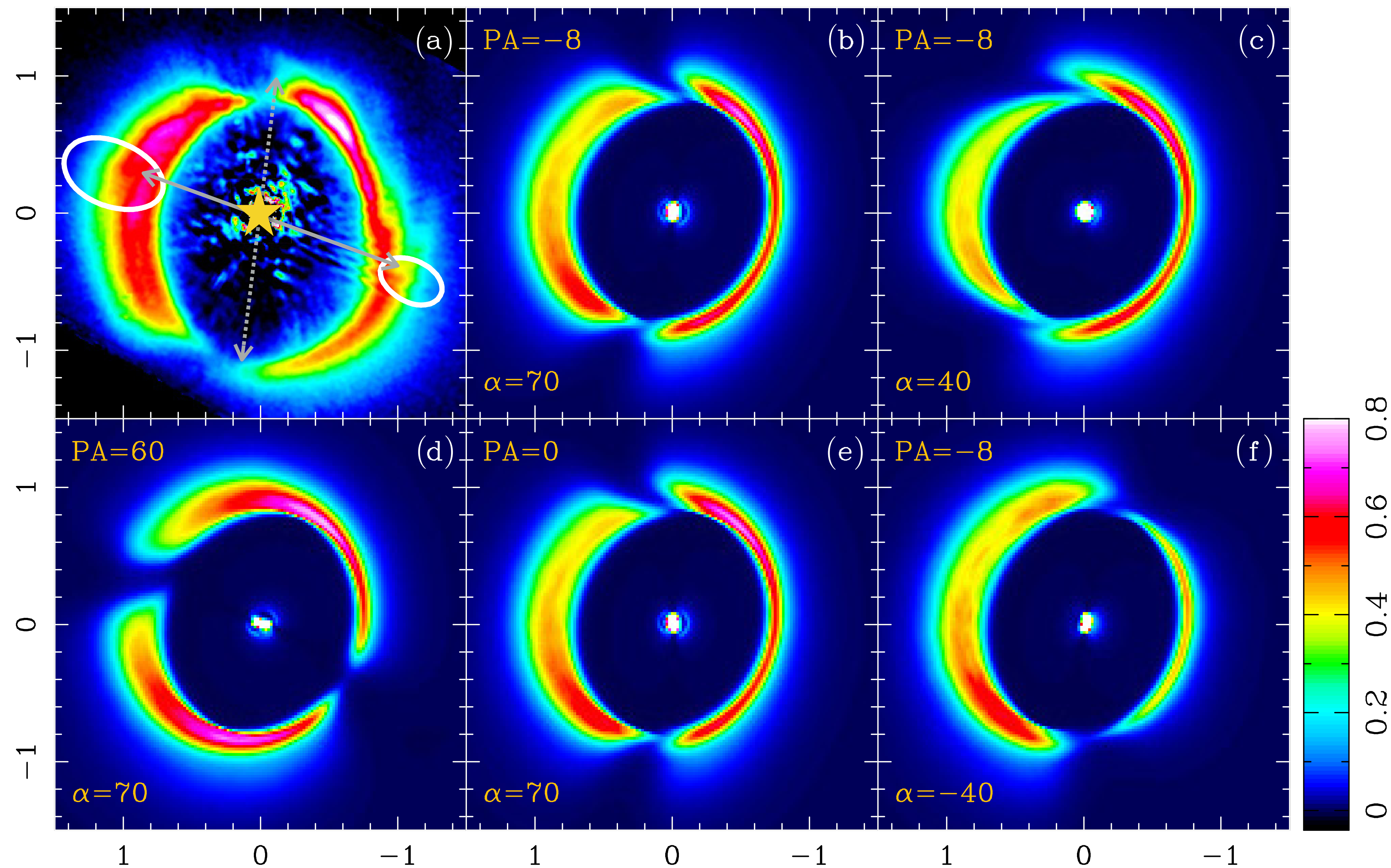
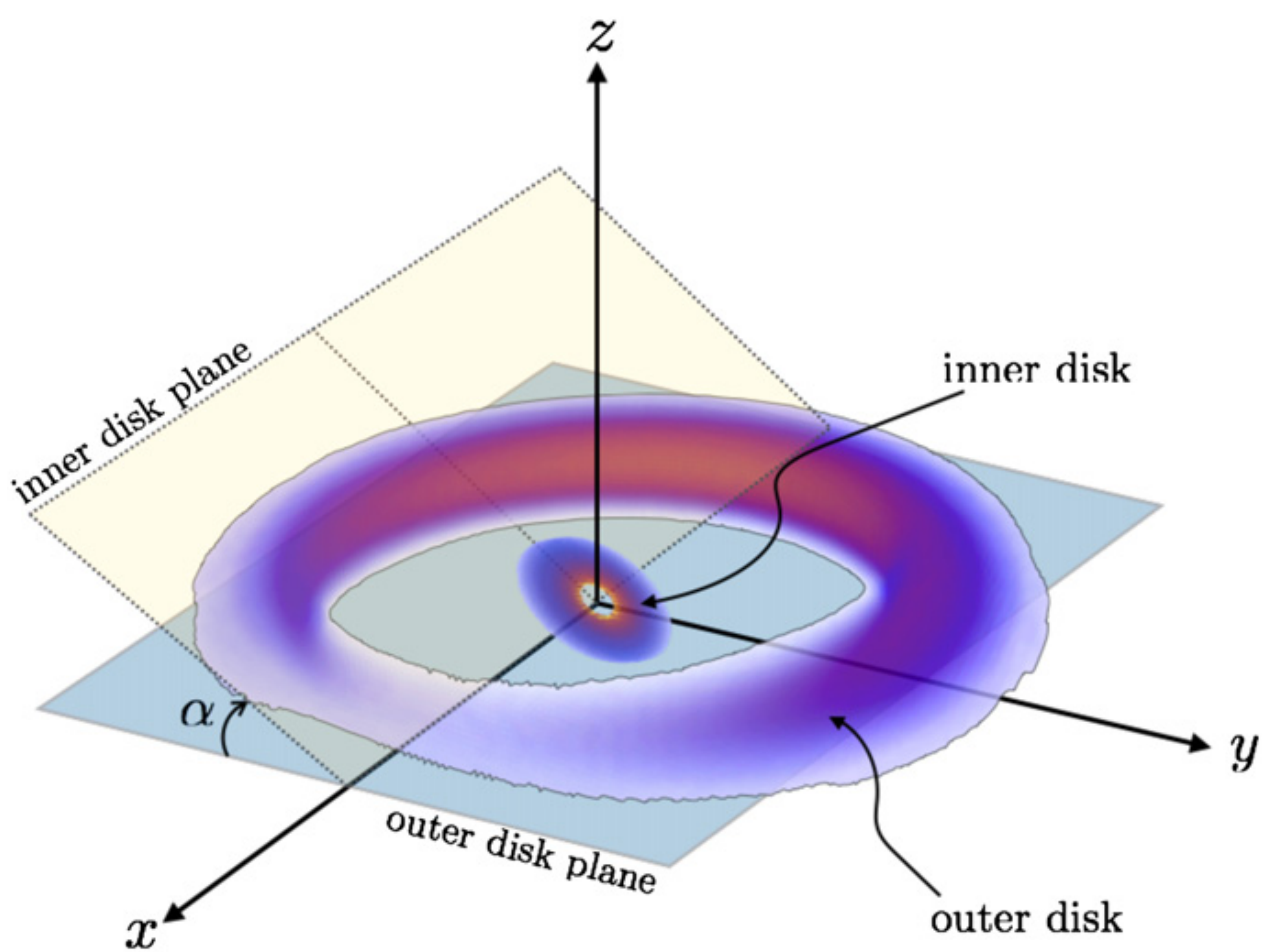


Figure 2. Impact of the inner disk orientation on the *H*-band light scattered off the outer disk. (a) NACO-PDI *H*-band image from Avenhaus et al. (2014) compared with the $C^{18}O$(2–1) emission at systemic velocity from Perez et al. (2014). The $C^{18}O$(2–1) emission, represented here as one white contour at 0.75 maximum, shows that the position angle (P.A.) of the outer disk is at $-20°$ east of north, and perpendicular to the solid gray double arrow, while the position angle of the intensity nulls is indicated by the dashed double arrow ($-8°$). (b)–(f) Radiative transfer prediction for polarized intensity in the *H* band for different inner disk P.A.s (indicated in degrees on the plots) and for different relative inclinations α between the inner and the outer disks. The $x-$ and $y-$axes indicate offset along R.A. and decl., in arcsec.

SHADOWS = INCLINED INNER DISC?

THE ASTROPHYSICAL JOURNAL LETTERS, 798:L44 (4pp), 2015 January 10



Marino, Perez & Casassus (2015)

“FAST RADIAL FLOWS” = DISC TEARING?

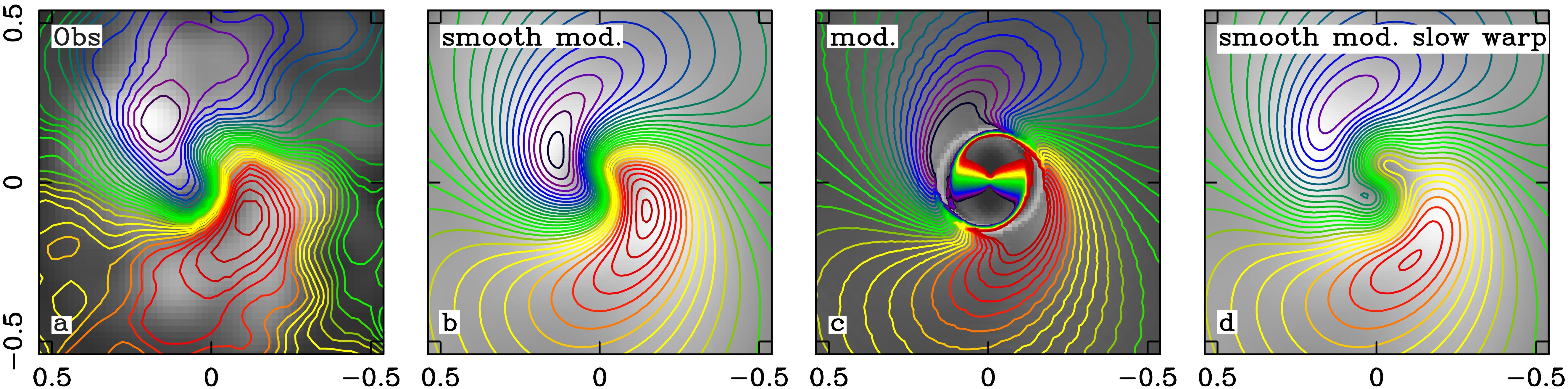
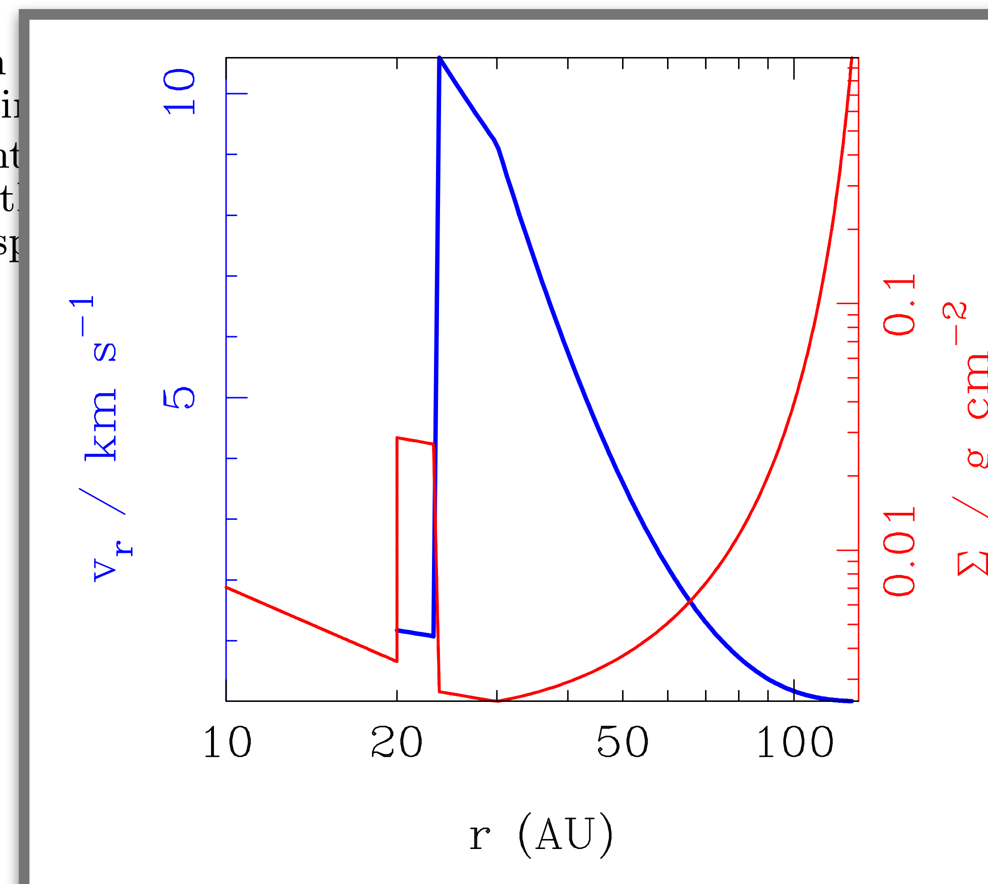


Figure 7. Comparison of observed and model CO(6-5) kinematics in … rdinates is set to
the stellar position. Velocity-integrated intensity in CO(6-5) is shown i… tant interval and
are spread over [0.21, 7.87] km s^{-1} (as in Fig. 1). **a)**: Observed moment… ents extracted on
the radiative transfer prediction, after smoothing to the resolution of t… odel resolutions,
without smoothing. Regions without contours near the origin corresp… a slow velocity
component perpendicular to the disk plane ($v_{\rm warp}$ in the text).

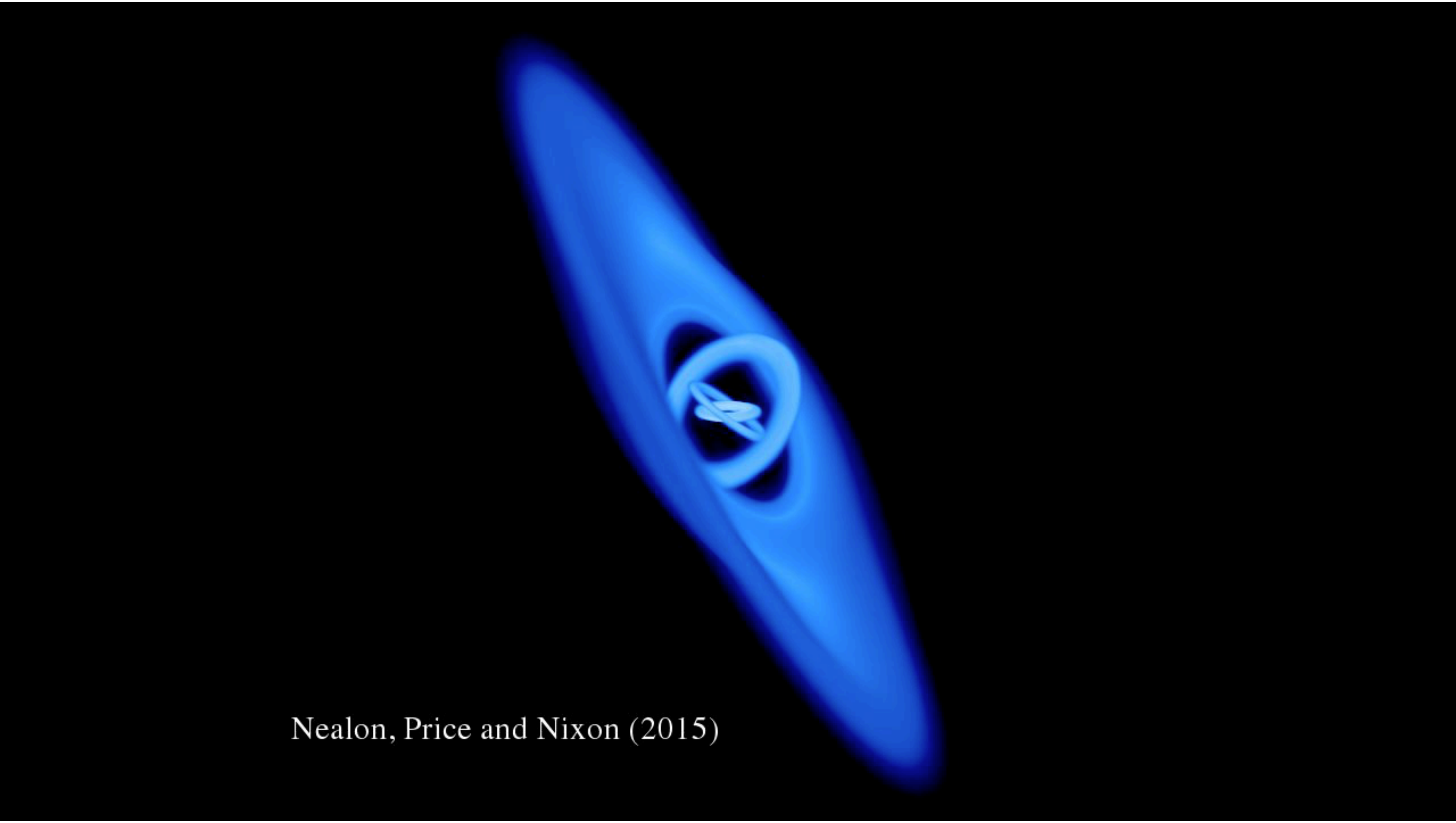
dubbed disk tearing (Nixon et al. 2013; Nealon et al. 2015; Doğan et al. 2015), where nodal precession torques induced by the binary produce a warp at the inner edge … companion on … 100 AU scale … cavity. It is



Require infall motions from cavity edge at the free-fall velocity!

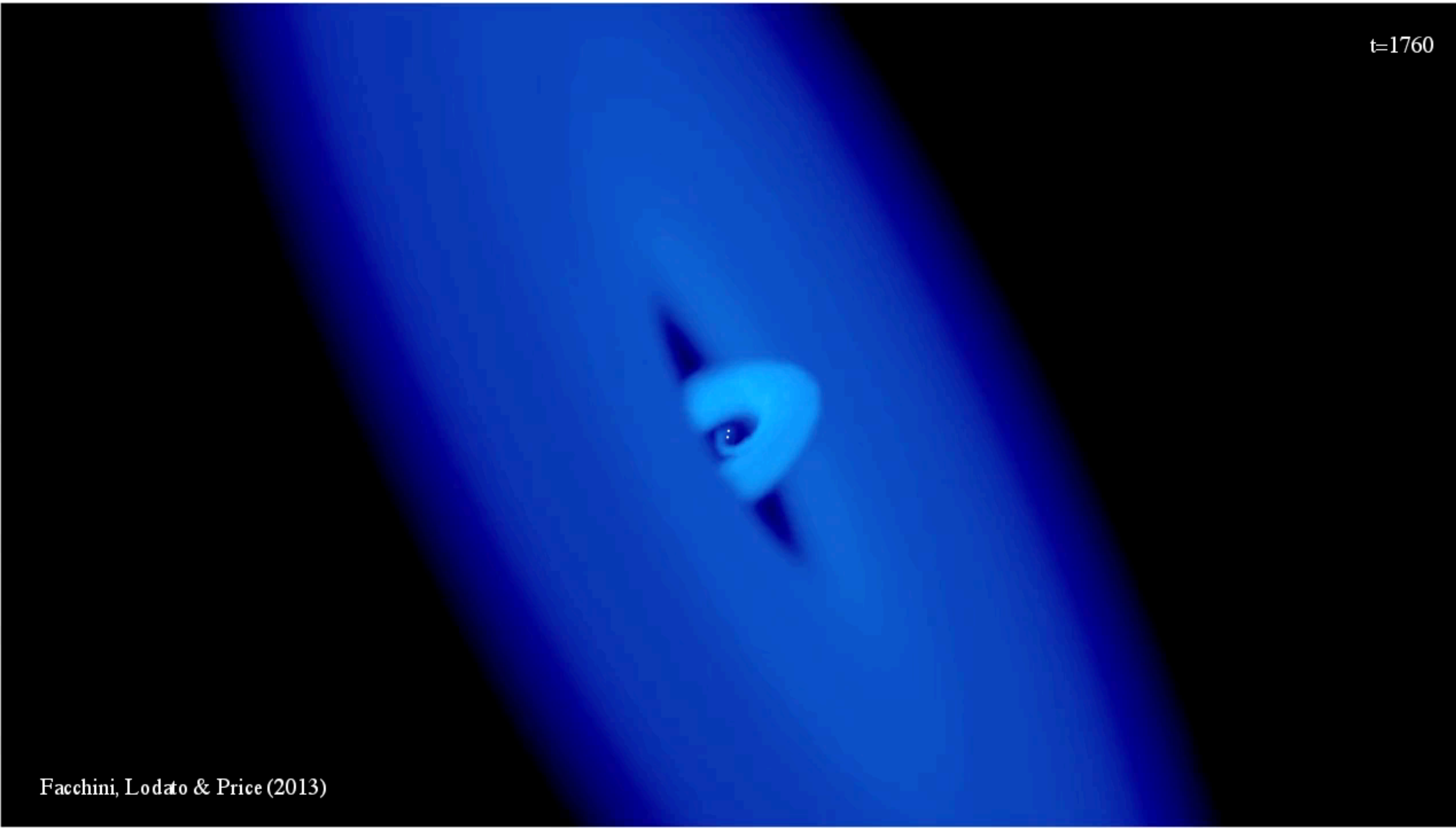
DISC TEARING?

Nixon et al. (2012, 2013), Nealon et al. (2015), Dogan et al. (2015)



TEARING IN PROTOSTELLAR DISCS?

Nixon et al. (2013), Facchini et al. (2013)
Martin et al. (2014), Martin & Lubow (2017)



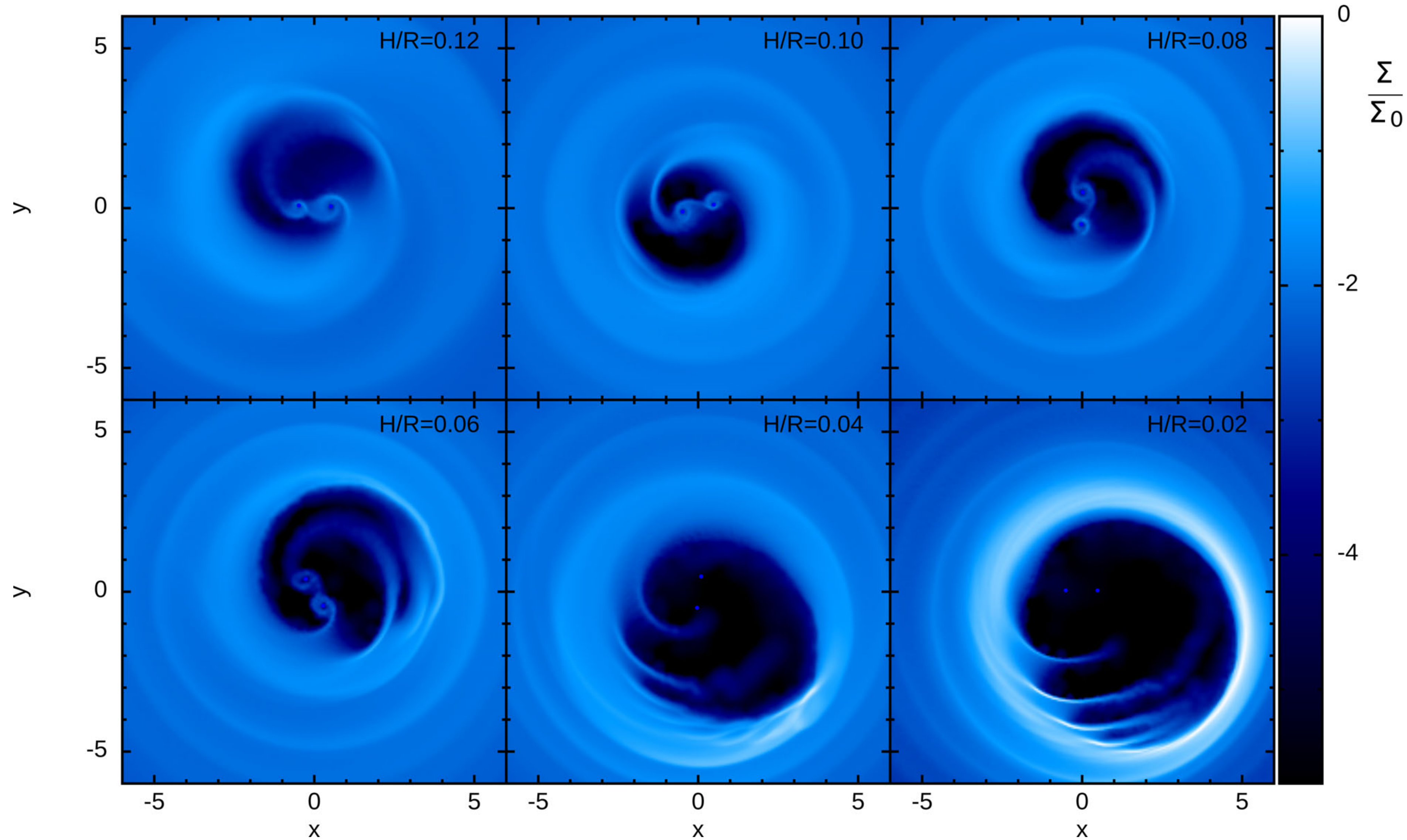
Tend to break rather than tear…

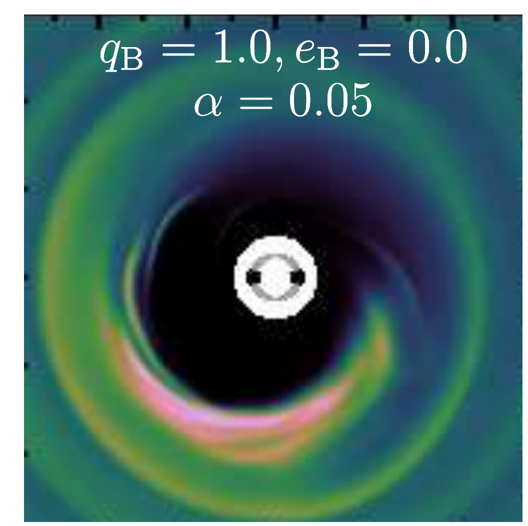
CIRCUMBINARY DISCS = ECCENTRIC CAVITIES

Ragusa et al. (2016)

See also: MacFadyen & Milosavljevic (2008), D'Orazio+ (2013), Farris+ (2014), Miranda+ (2016)

1248 *E. Ragusa, G. Lodato and D. J. Price*

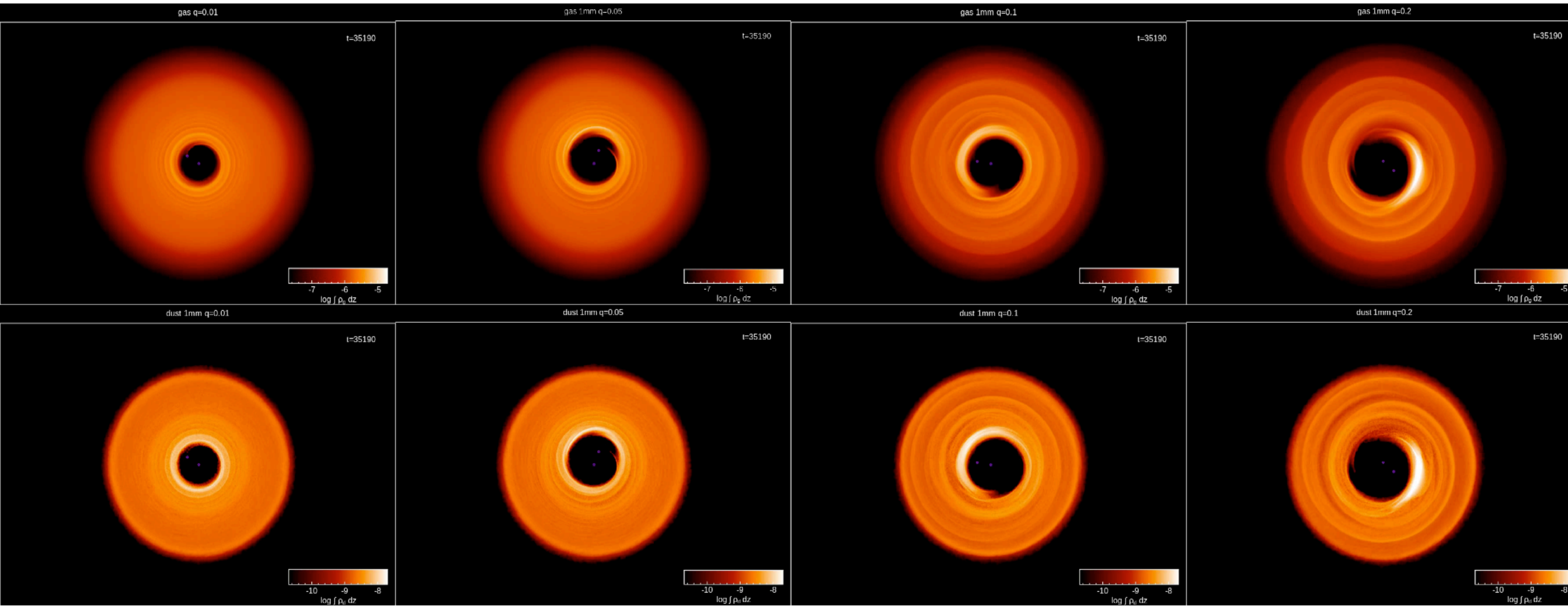




Miranda+2016

ON THE ORIGIN OF HORSESHOES IN TRANSITIONAL DISCS

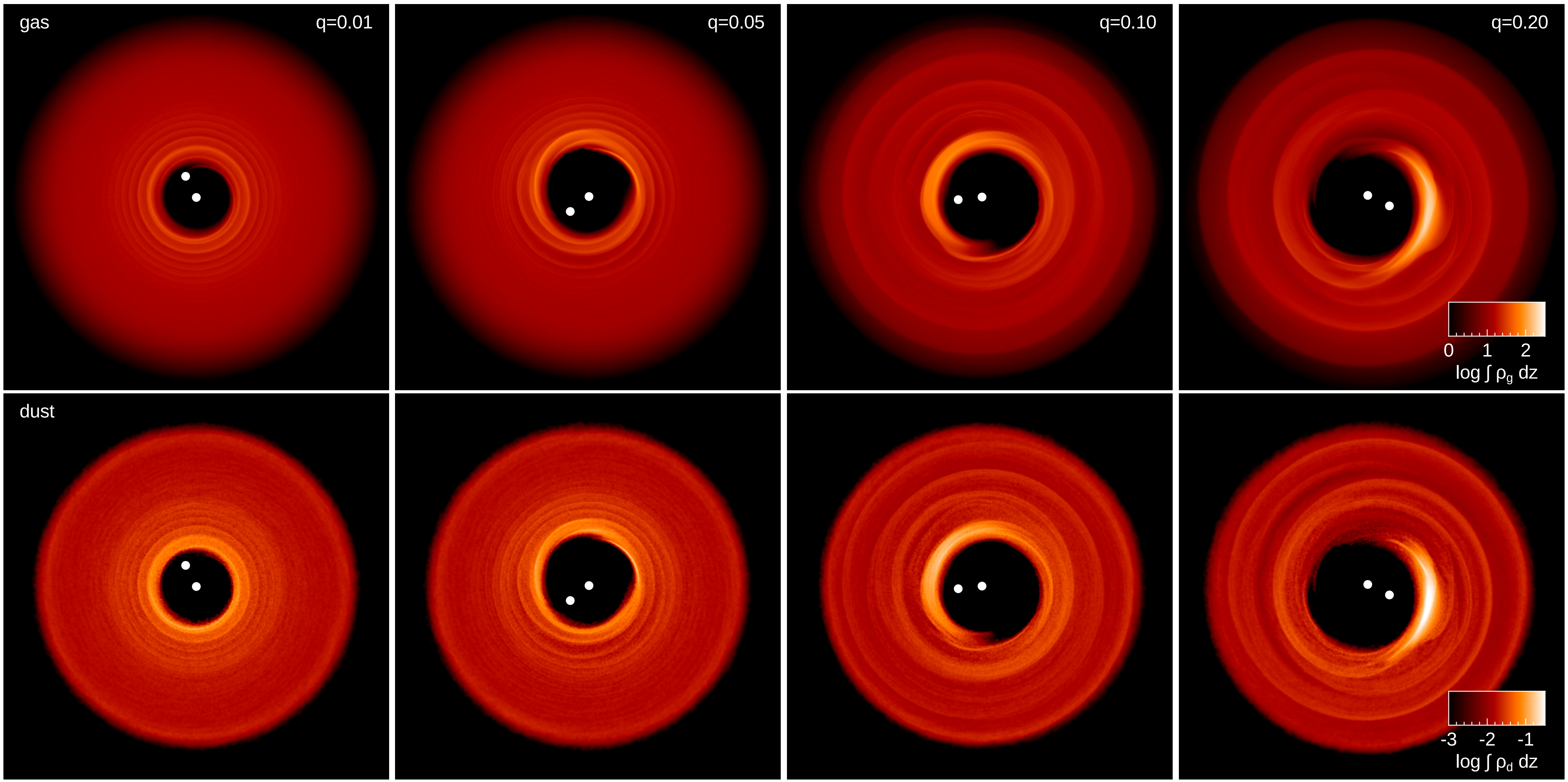
Ragusa et al. (2017), MNRAS 464, 1449



- Predict horseshoes and rings at cavity edge
- Horseshoes require massive companion q > 0.04
- Does not require low disc viscosity

HORSESHOES IN TRANSITIONAL DISCS

Ragusa+ (2017)



See also Lyra & Lin (2013), Zhu & Stone (2014), Mittal & Chiang (2015), Zhu & Baruteau (2016), Baruteau & Zhu (2016)

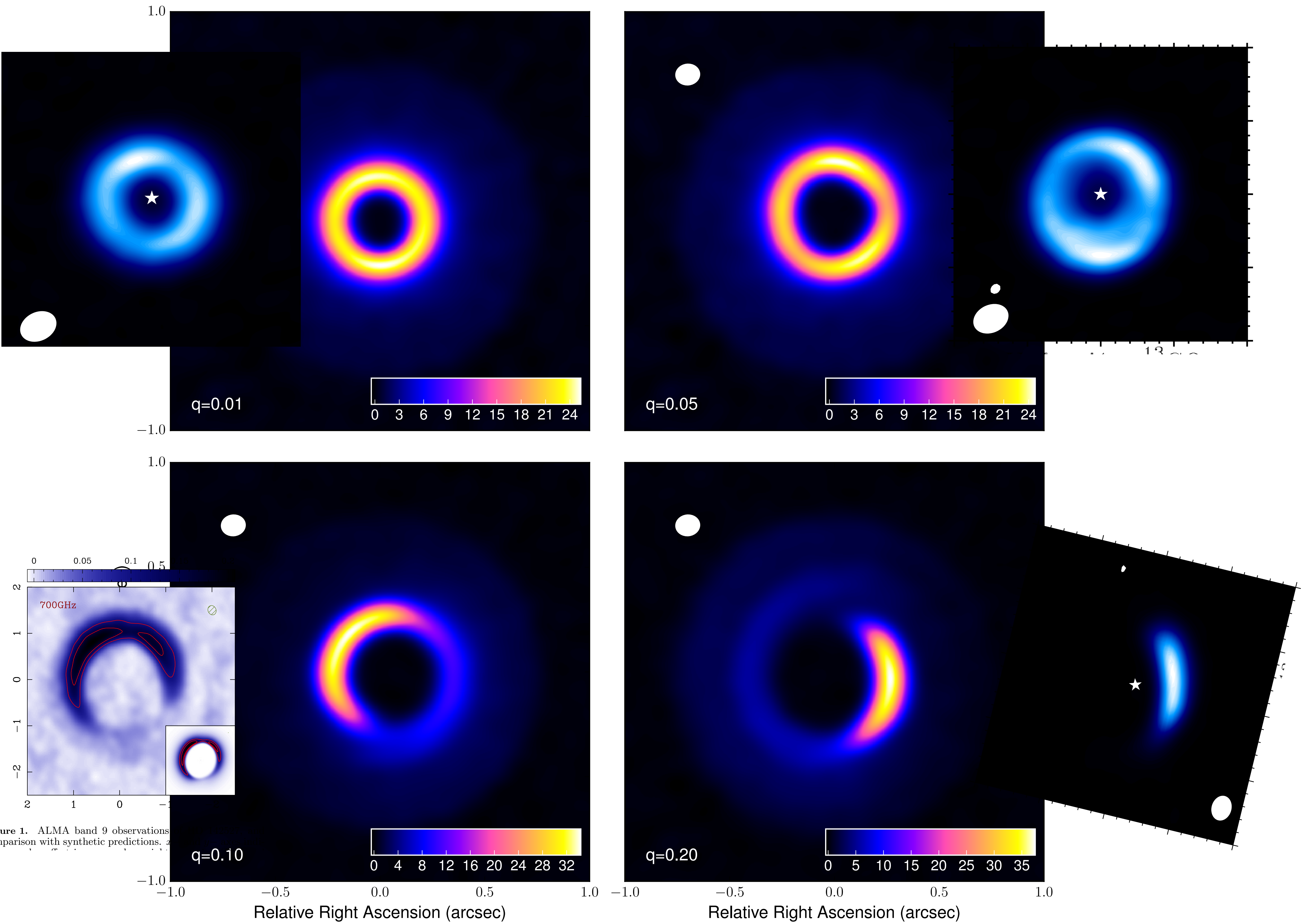
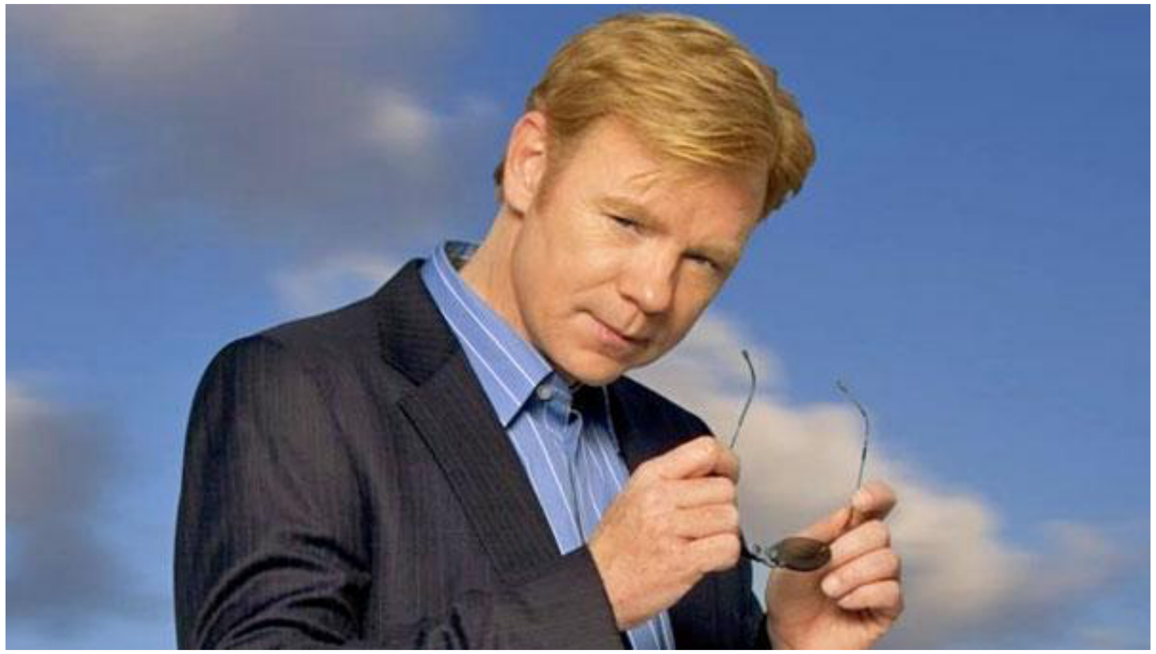


Figure 2. Comparison of ALMA simulated observations at 345 GHz of disc models with a mass ratio $q = 0.01$ (upper left), $q = 0.05$ (upper right), $q = 0.1$ (bottom left) and $q = 0.2$ (bottom right). Intensities are in mJy beam^{-1}. The white colour in the filled ellipse in the upper left corner indicates the size of the half-power contour of the synthesized beam: 0.12×0.1 arcsec ($\sim 16 \times 13$ au at 130 pc.).

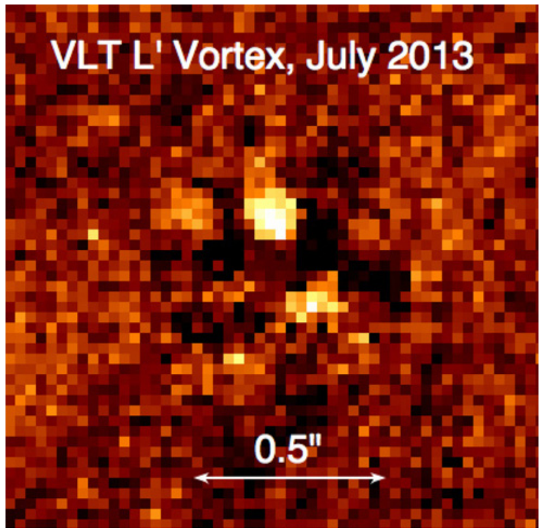
SUMMARY OF THINGS THAT NEED EXPLAINING IN HD142527



- Shadows
- Fast radial flows
- Spiral arms
- Central cavity
- Dust horseshoe
- Gap-crossing filaments
- Accretion of gas at “normal rates” through cavity
- Warp/inclined inner disc?
- Highly variable accretion rate

Understanding HD142527 could help to understand all the various features seen in transition discs!

IS THERE A BINARY?



A LIKELY CLOSE-IN LOW-MASS STELLAR COMPANION TO THE TRANSITIONAL DISK STAR HD 142527

BETH BILLER[1], SYLVESTRE LACOUR[2], ATTILA JUHÁSZ[3], MYRIAM BENISTY[1], GAEL CHAUVIN[1,4], JOHAN OLOFSSON[1], JÖRG-UWE POTT[1], ANDRÉ MÜLLER[1], AURORA SICILIA-AGUILAR[5], MICKAËL BONNEFOY[1], PETER TUTHILL[6], PHILIPPE THEBAULT[2], THOMAS HENNING[1], AND AURELIEN CRIDA[7]

DISCOVERY OF Hα EMISSION FROM THE CLOSE COMPANION INSIDE THE GAP OF TRANSITIONAL DISK HD 142527*

L. M. CLOSE[1], K. B. FOLLETTE[1], J. R. MALES[1,6], A. PUGLISI[2], M. XOMPERO[2], D. APAI[1,3], J. NAJITA[4], A. J. WEINBERGER[5], K. MORZINSKI[1,6], T. J. RODIGAS[1], P. HINZ[1], V. BAILEY[1], AND R. BRIGUGLIO[2]

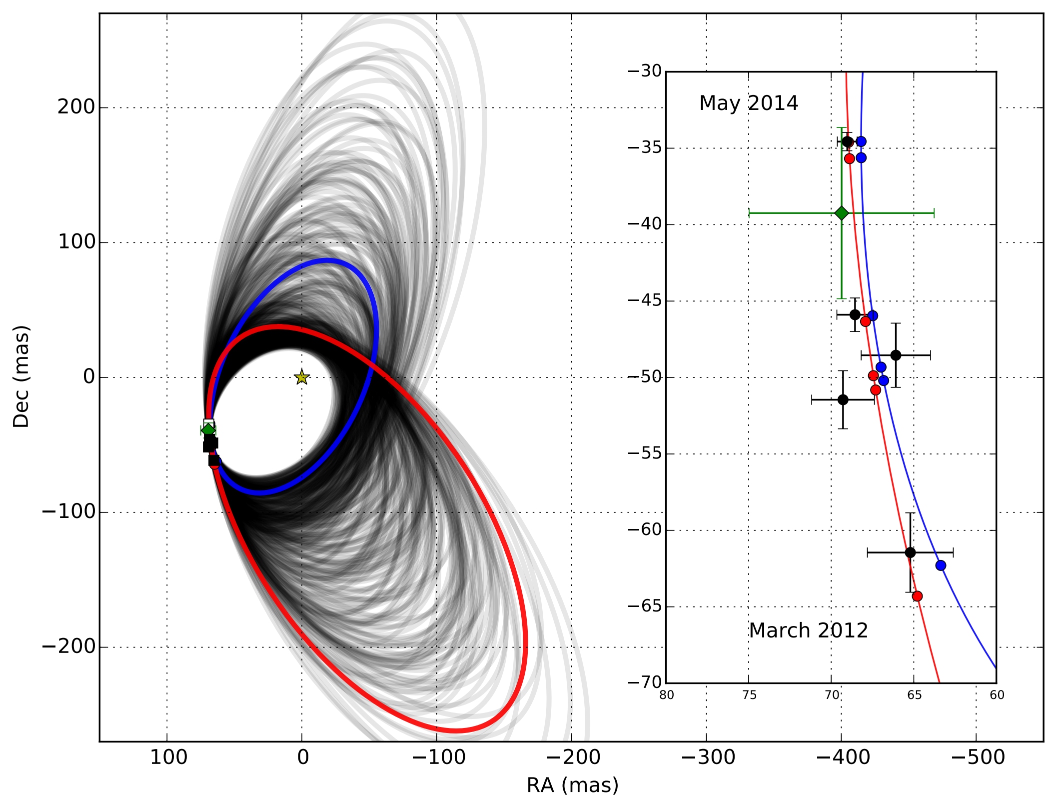
[1] Steward Observatory, University of Arizona, Tucson, AZ 85721, USA; lclose@as.arizona.edu
[2] INAF-Osservatorio Astrofisico di Arcetri, I-50125, Firenze, Italy
[3] Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, USA
[4] NOAO, 950 N Cherry Ave. Tucson, AZ 85719, USA
[5] Carnegie Institution DTM, 5241 Broad Branch Rd, Washington, DC 20015, USA

Received 2013 October 10; accepted 2013 December 16; published 2014 January 10

But how can a binary with a projected separation of ~13 au explain a 100 au cavity?

MODELLING HD142527

Price et al. (2017), in prep.



Lacour et al. (2016)

	a	e	i	Ω	ω	f
Orbit B1	26.5	0.24	119.9	349.7	218.0	25.93
Orbit B2	28.8	0.40	120.4	340.3	201.5	33.78
Orbit B3	34.3	0.50	119.3	159.2	19.98	35.04
Orbit R1	31.4	0.74	131.3	44.95	27.88	249.3
Orbit R2	38.9	0.61	120.3	19.25	354.0	268.3
Orbit R3	51.3	0.70	119.3	201.4	173.3	270.4

Orbital arc fits using IMORBEL (Pearce, Kennedy & Wyatt 2015)

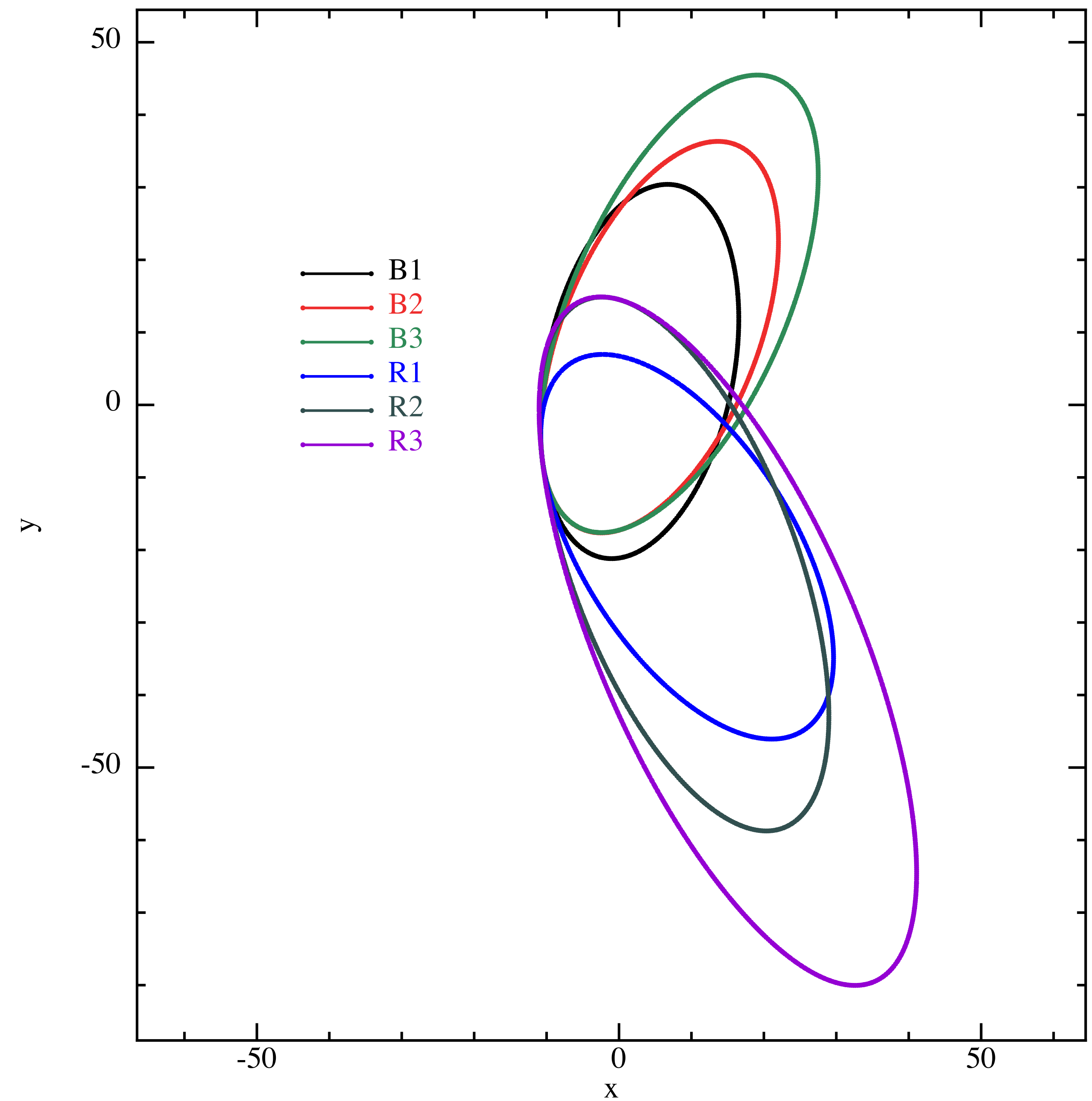
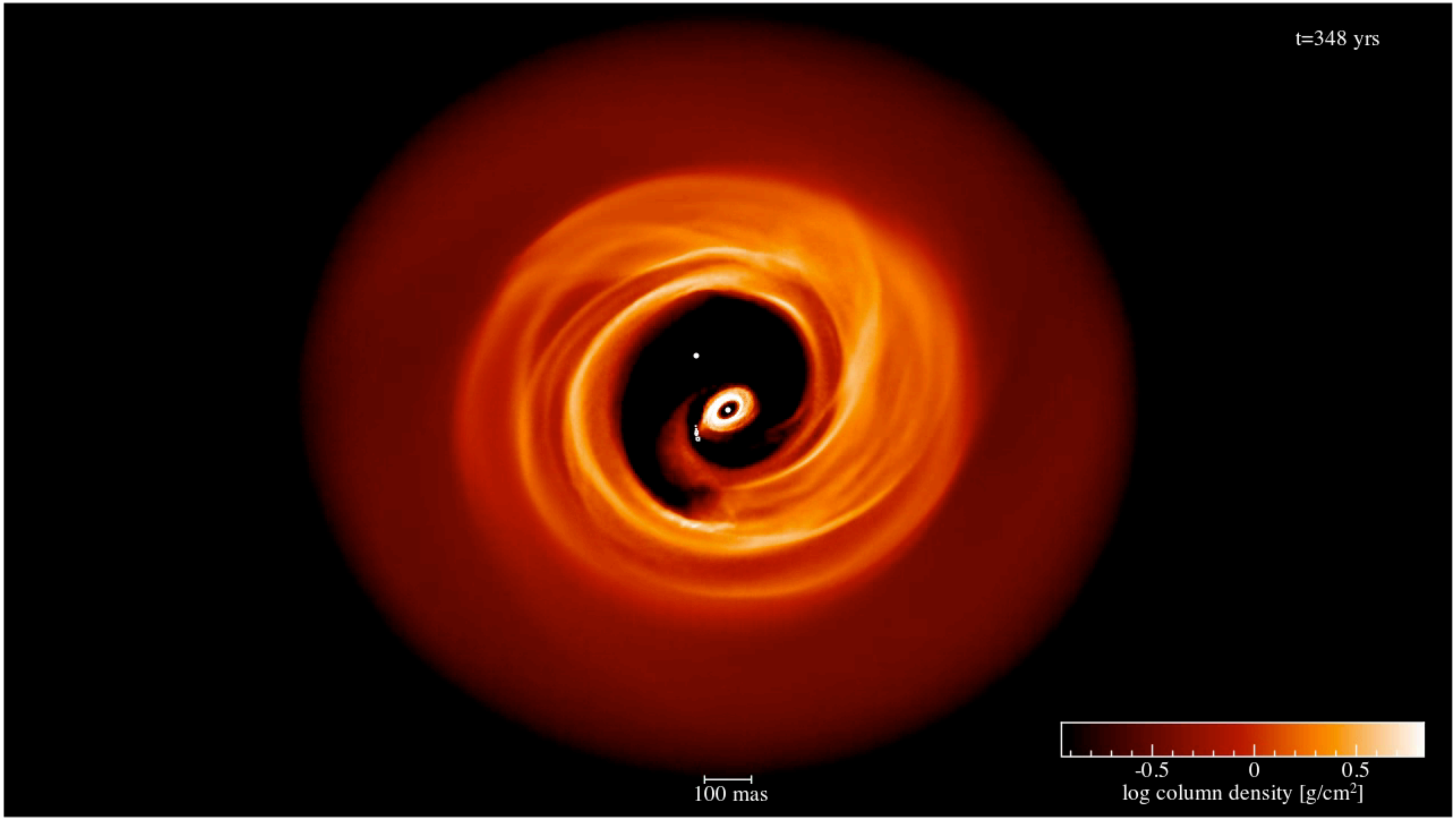


Figure 1. Selected trial orbits for HD142527B used in this paper, corresponding to the orbital elements listed in Table 1. Motion is clockwise.

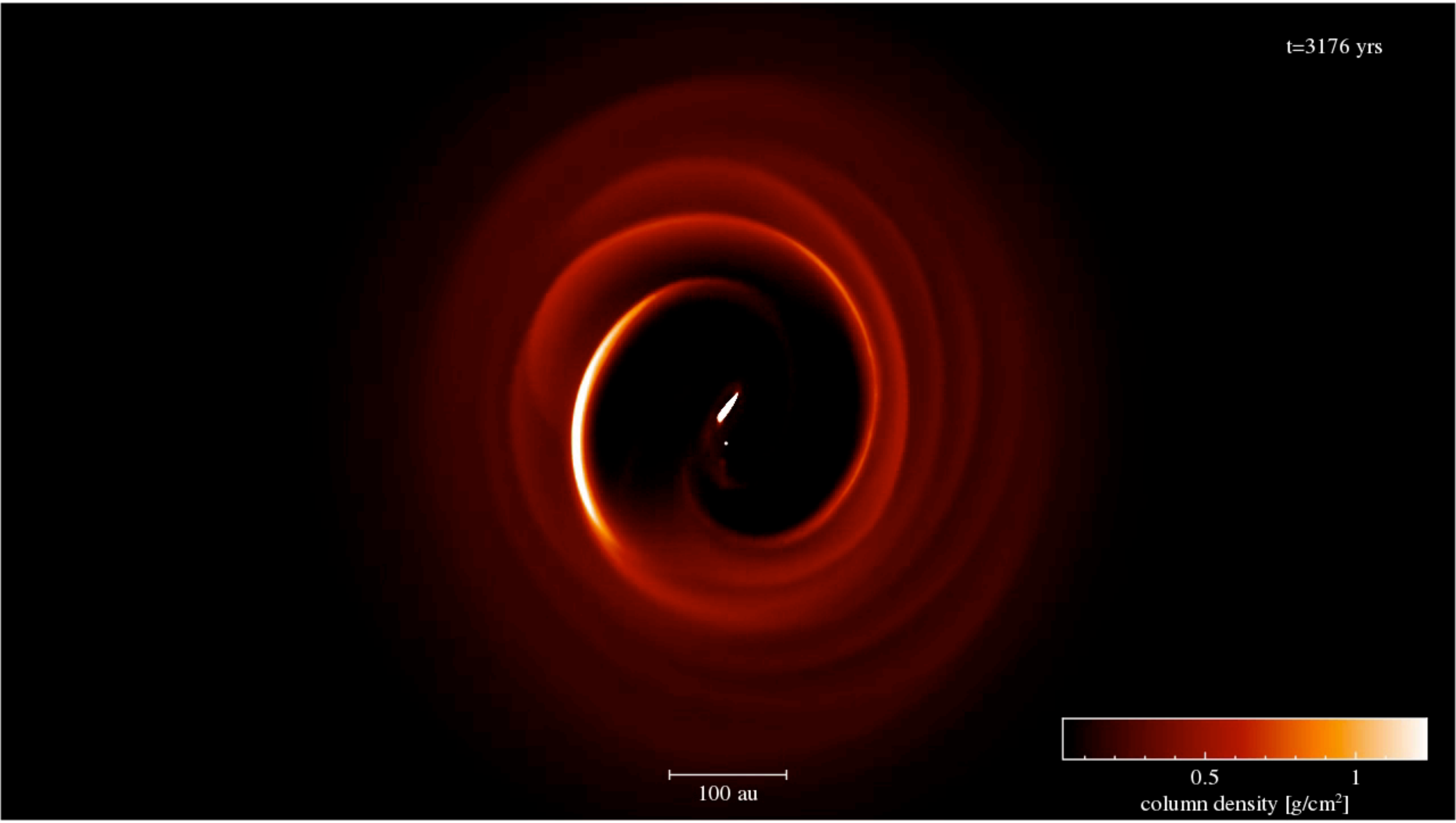
BLUE ORBIT

Price et al. (2017), in prep.

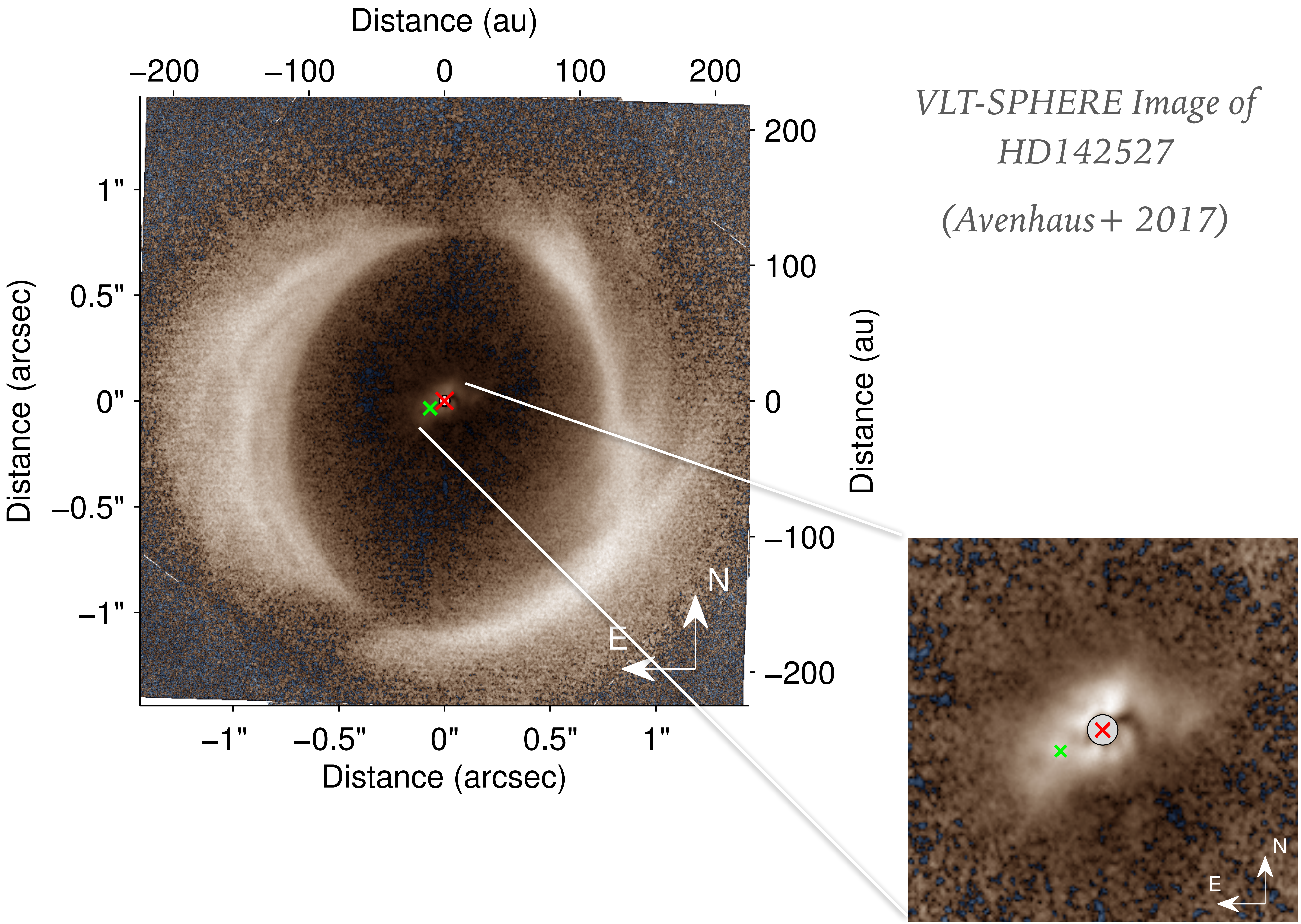


RED ORBIT

Price et al. (2017), in prep.



See almost polar alignment - see Rebecca Martin's talk, also work of Lai group



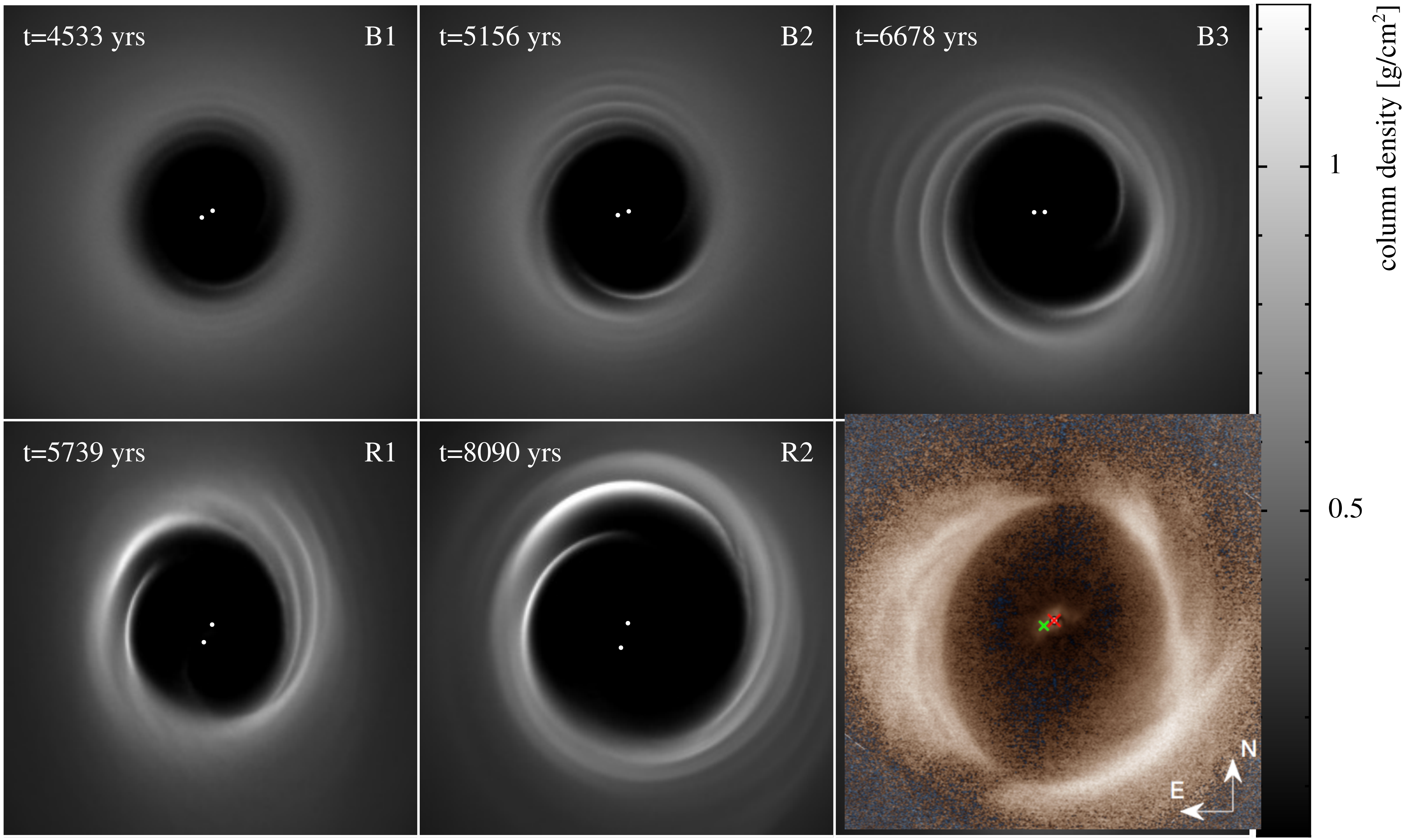
VLT-SPHERE Image of HD142527

(Avenhaus+ 2017)

SPIRALS

See also Ogilvie & Lubow (2002), Rafikov (2002), Fung & Dong (2015)

4 *Price et al.*



Price et al. (2017), in prep.

Binary must be on RED orbit!

SHADOWS

Price et al. (2017), in prep.

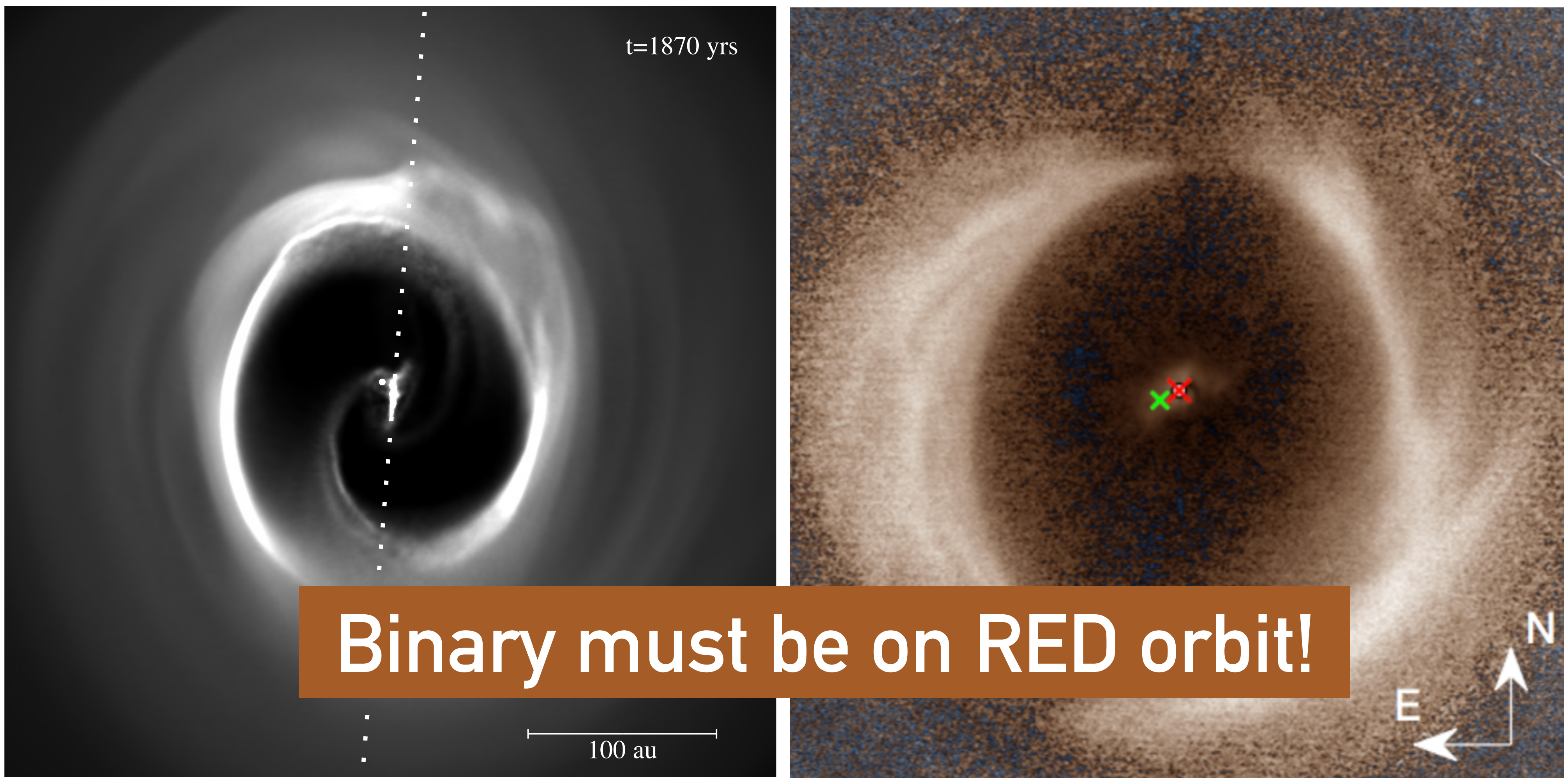
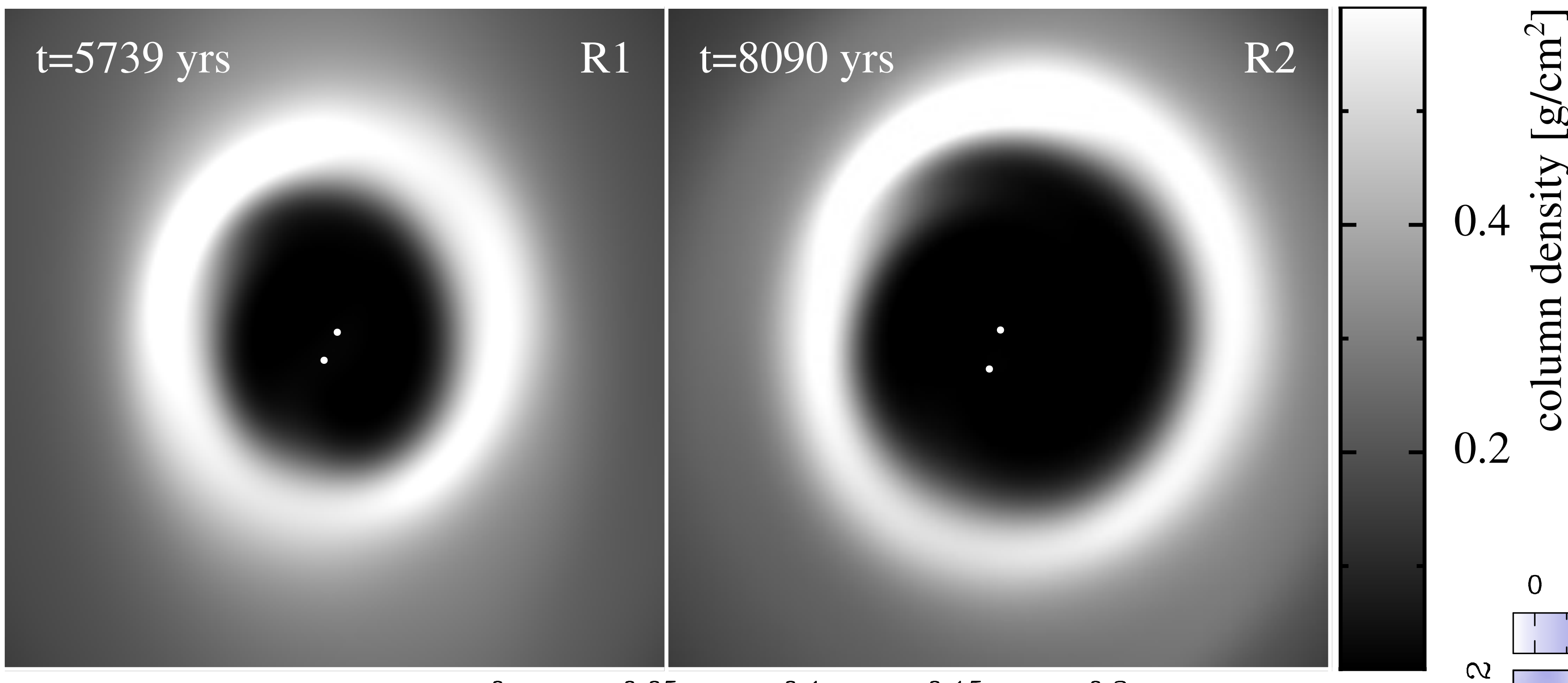
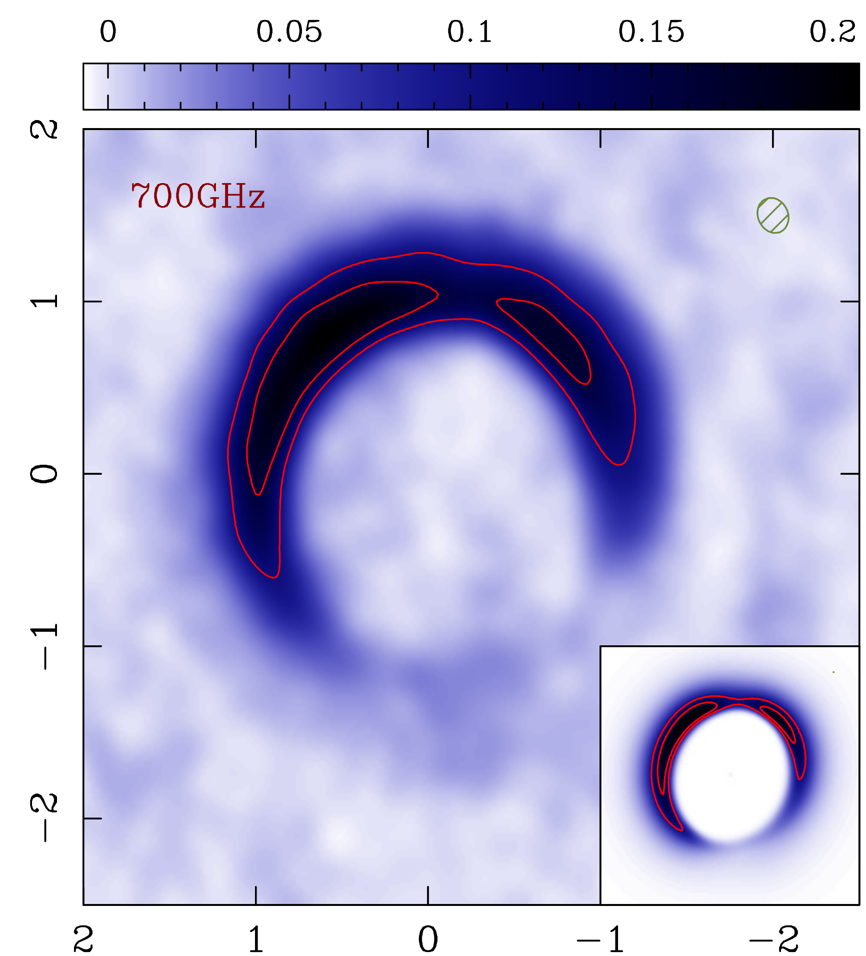


Figure 3. High resolution simulation of the R1 orbit (left) compared to the scattered light image from Avenhaus et al. (2017) (right), showing the formation of the circumprimary disc. Dotted line indicates the expected shadow from our simulated inner disc (left), which already lie close to the orientation of the observed shadows (right) despite the orbital uncertainty.

HORSESHOE?

Price et al. (2017), in prep.

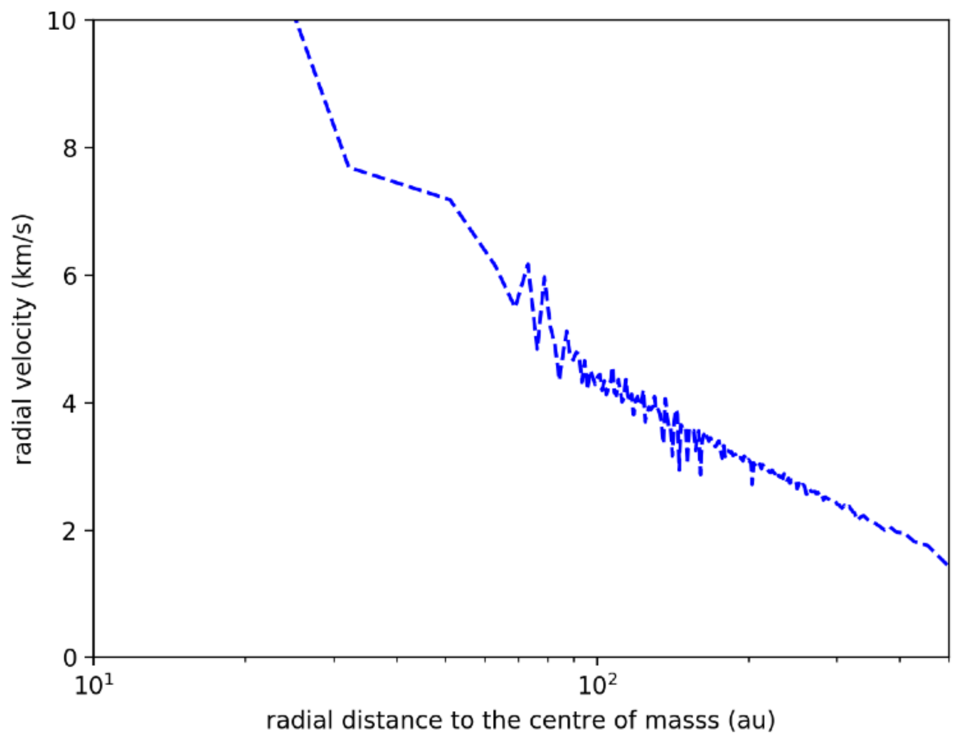


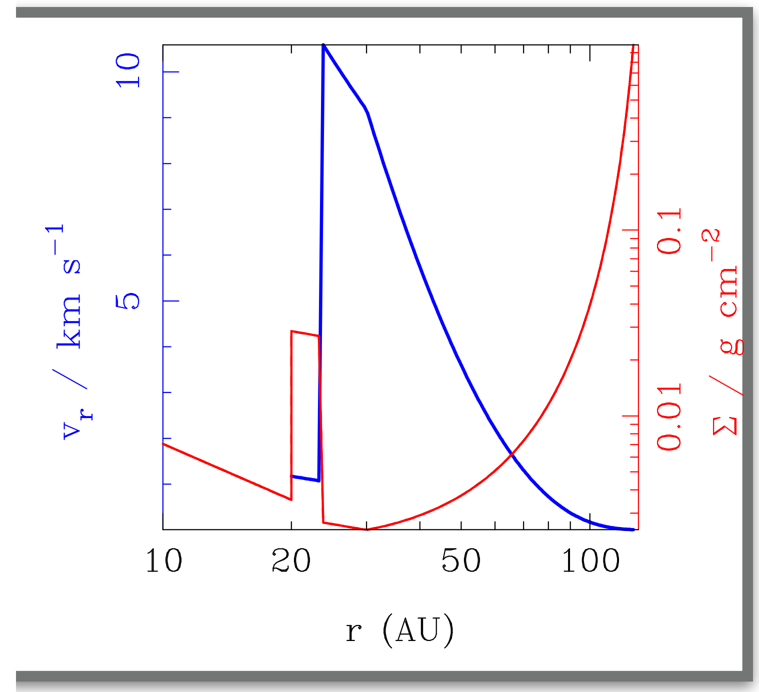


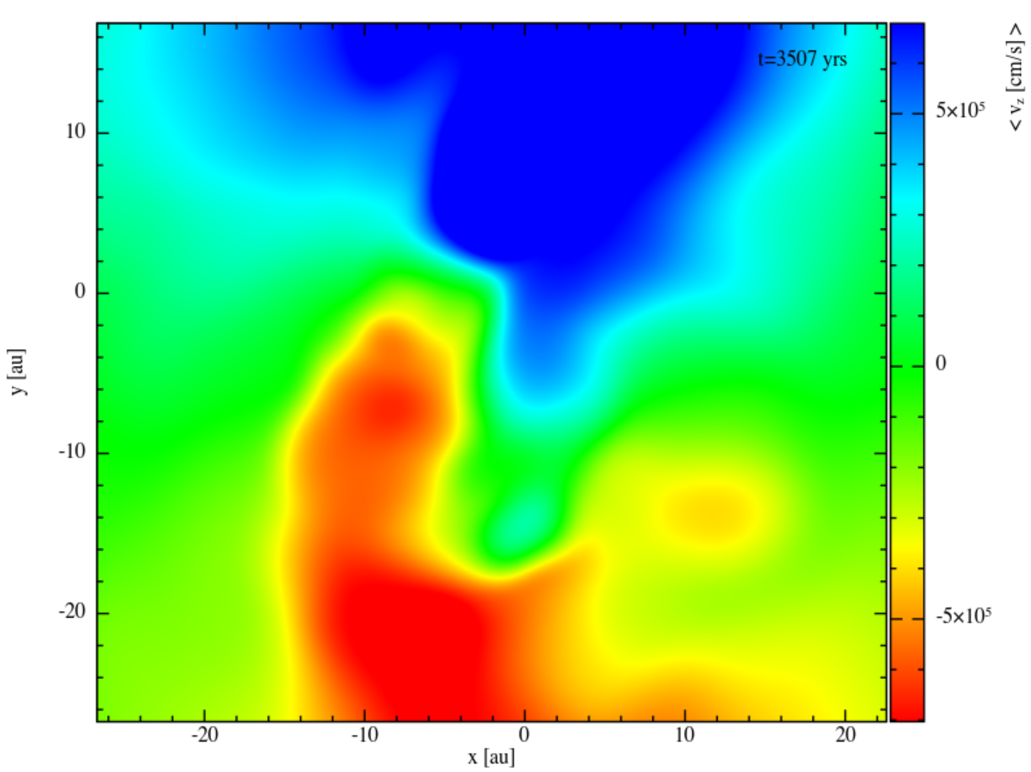
- ➤ Gas-only simulations at present
- ➤ Evidence for precession of horseshoe in simulations (e.g. Barker & Ogilvie 2016)

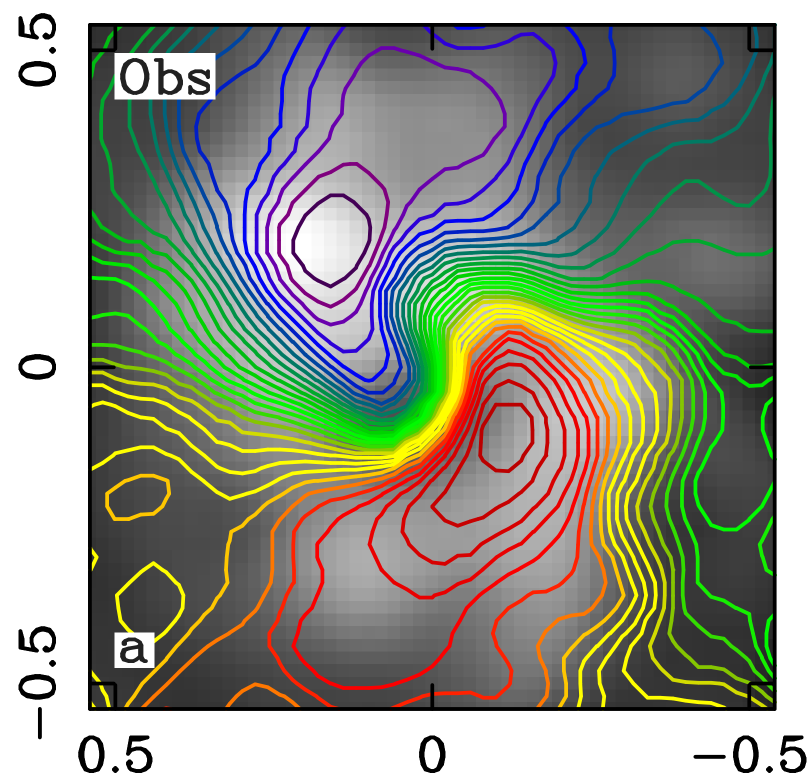
FAST RADIAL FLOWS

Price et al. (2017), in prep.

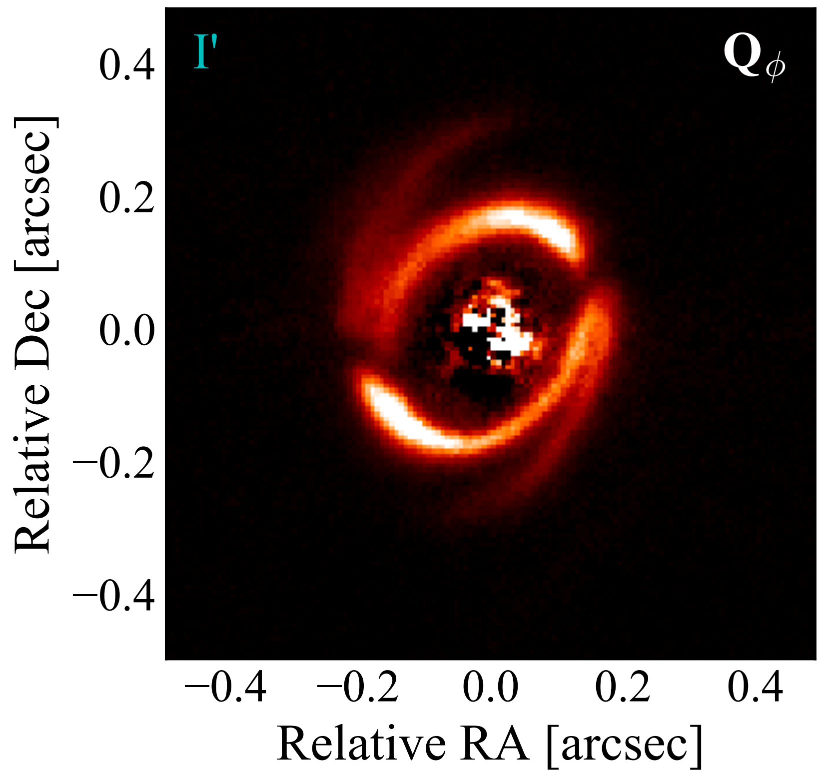








SPECIFIC OR GENERAL? HD100453



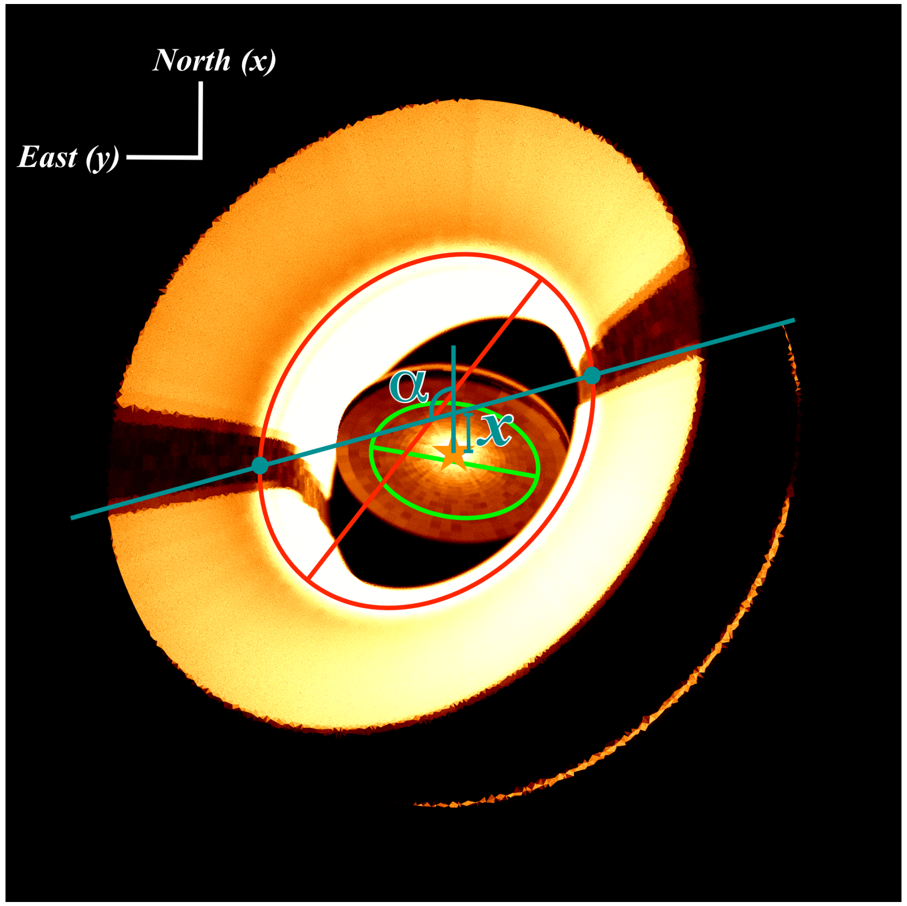
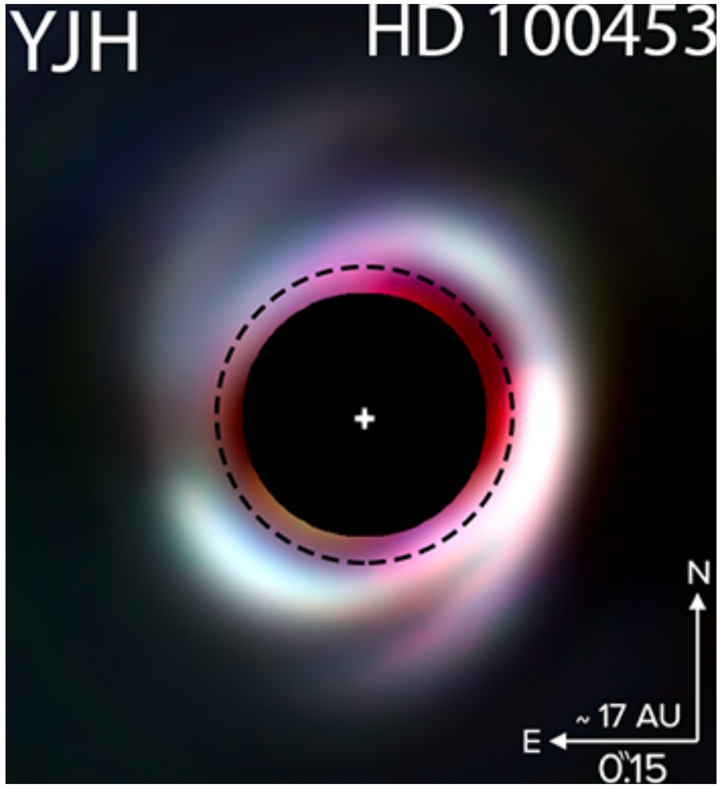


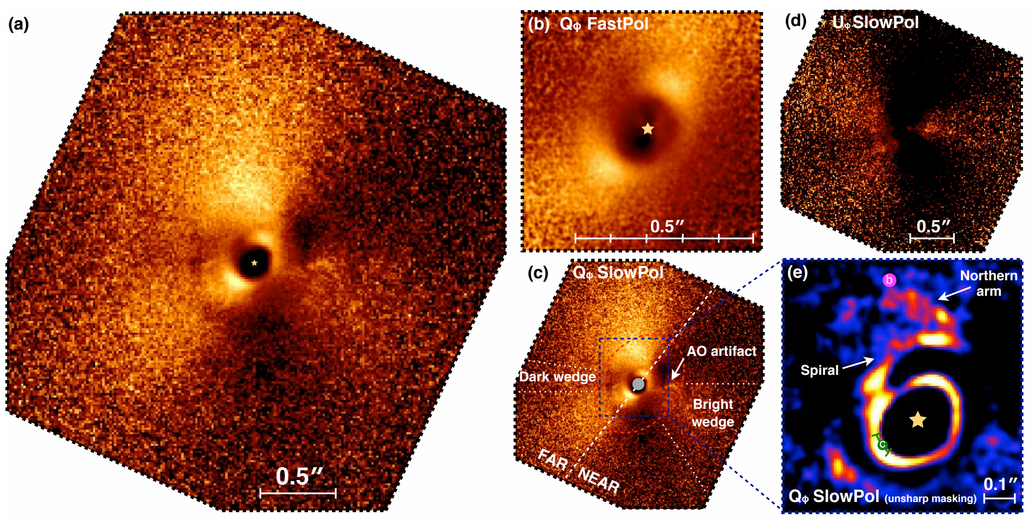
Fig. 1. Cartoon representation of the shadows cast on the outer disk of a transitional disk by a misaligned inner disk. For the purpose of clarity the inner disk is blown up significantly to be able to better visualise the geometry. Indicated are the ellipses of the inner and outer disks showing their position angles. Also indicated by the blue line is the connecting line between the shadows.

Min et al. (2017)



Wagner et al. (2015)

HD100546



5. CONCLUSION

The data presented in this paper clearly resolve the circumstellar environment of HD100546 close to the star at high S/N. The inner hole is detected with a radius of 14 ± 2 AU and an inclination of less than ∼50°. Some of the other disk features are puzzling. The general structure of the disk is well explained

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Astronomy & Astrophysics

Multiple spiral patterns in the transitional disk of HD 100546★

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NIR SPECTROSCOPY OF THE HAeBe STAR HD 100546. III. FURTHER EVIDENCE OF AN ORBITING COMPANION?

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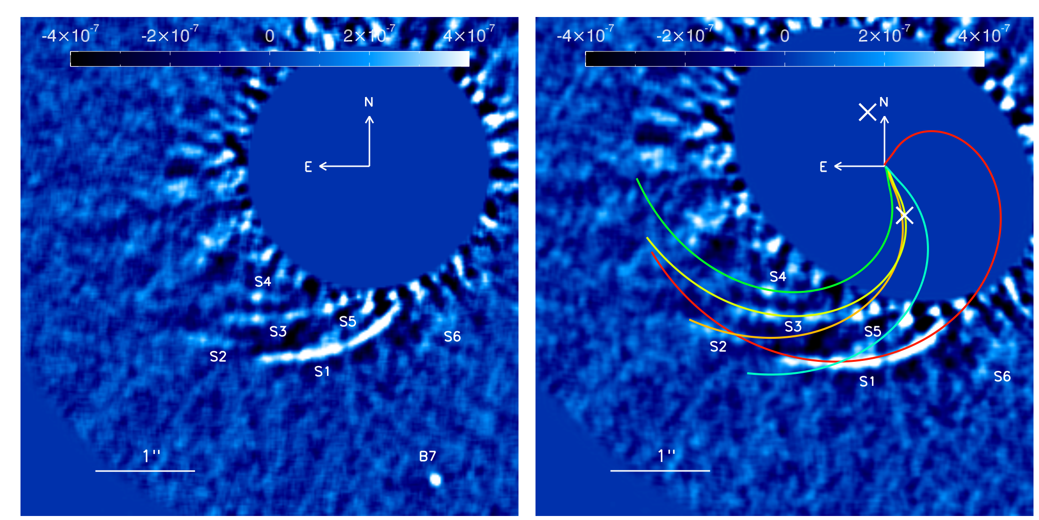

“A plausible scenario is a warped geometry in the inner disc casting a partial shadow on the outer disc”

SUMMARY

- All the main observational features in HD142527 can be explained by the presence of the binary companion
- Suggests circumbinarity may be the origin of many features seen in transitional discs (c.f. LkCa15; Sallum et al. 2015)
- Are all transitional discs circumbinary?