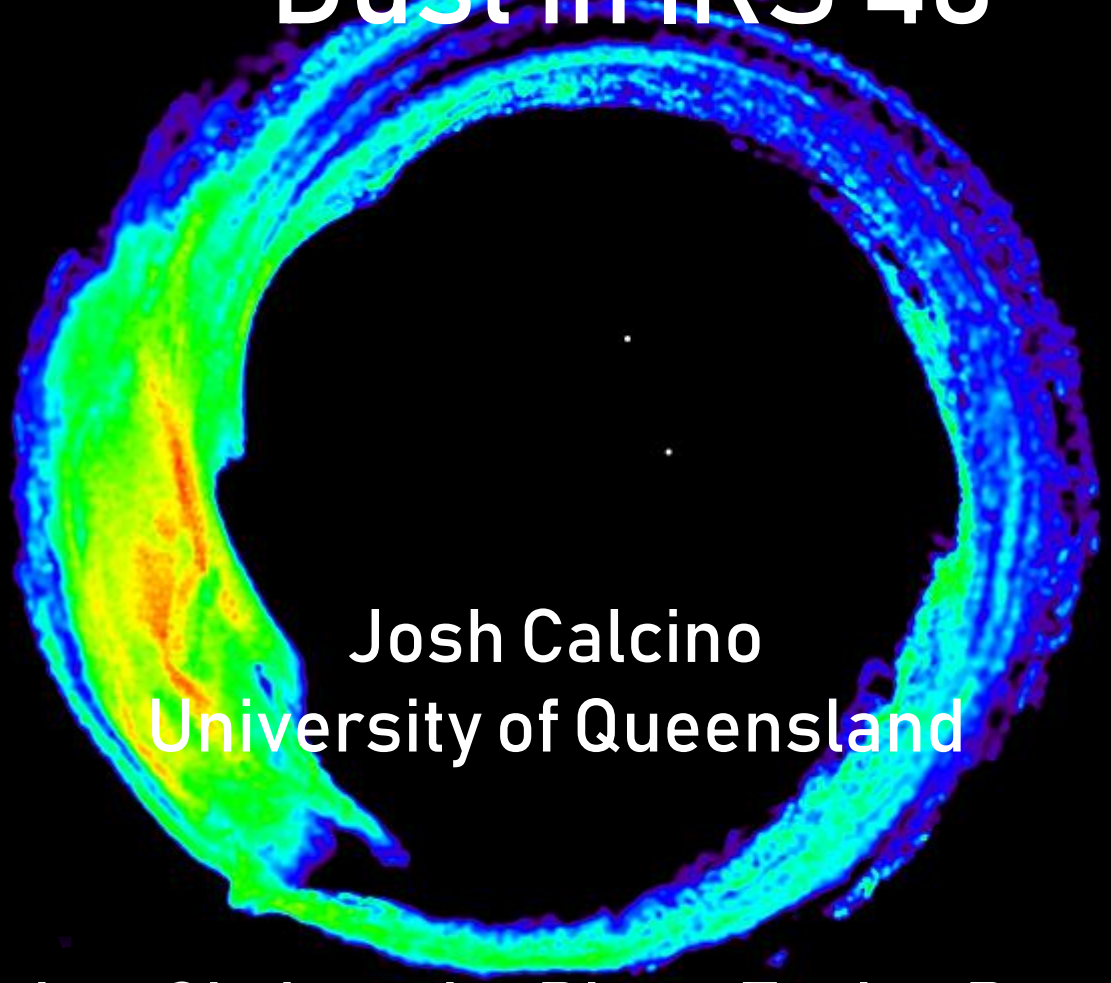
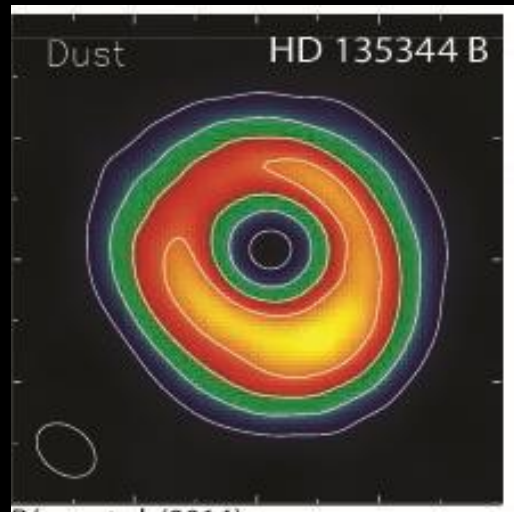
Signatures of an eccentric disk: Gas and Dust in IRS 48



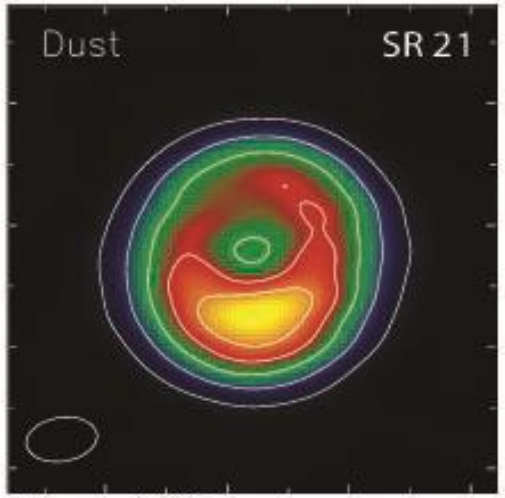
Josh Calcino
University of Queensland

With: Daniel Price, Christophe Pinte, Enrico Ragusa, Valentin Christiaens, Nicolas Cuello, Giovanni Dipierro

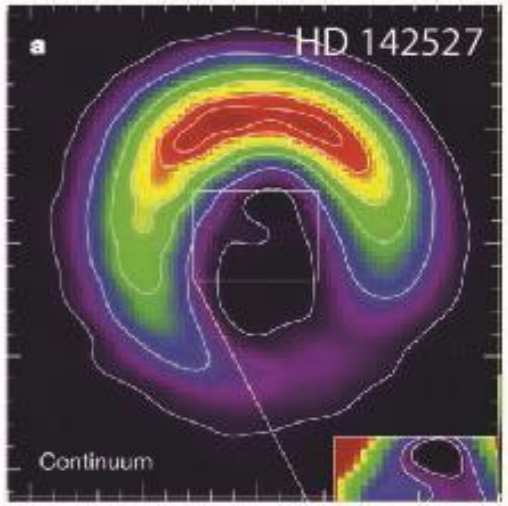
Observations of Transition Disks



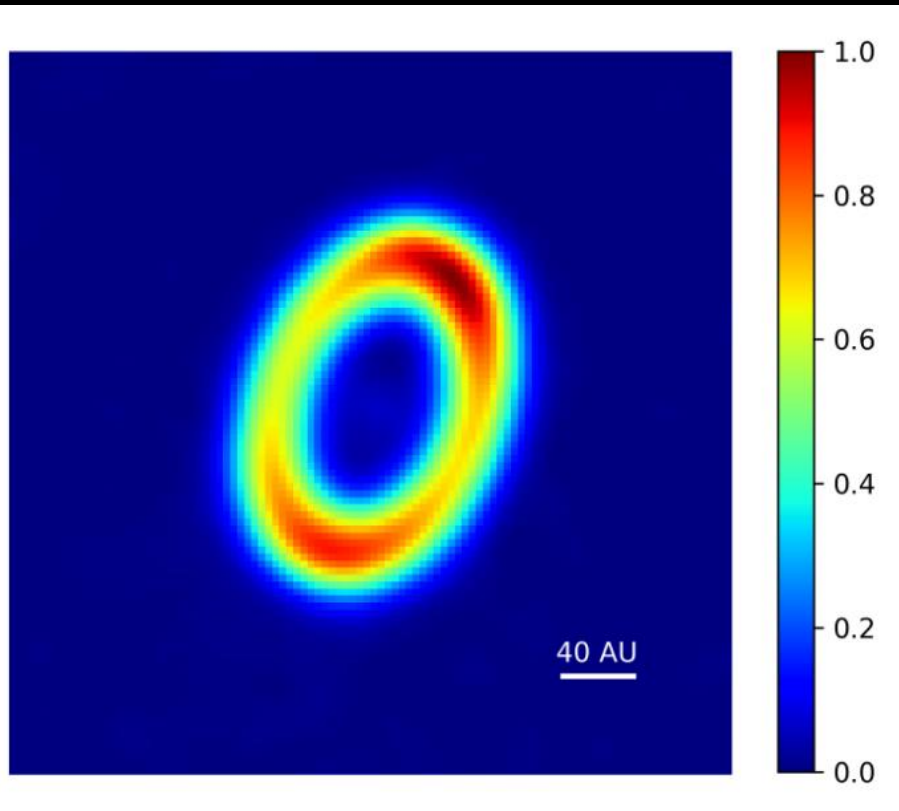
Pérez et al. (2014)

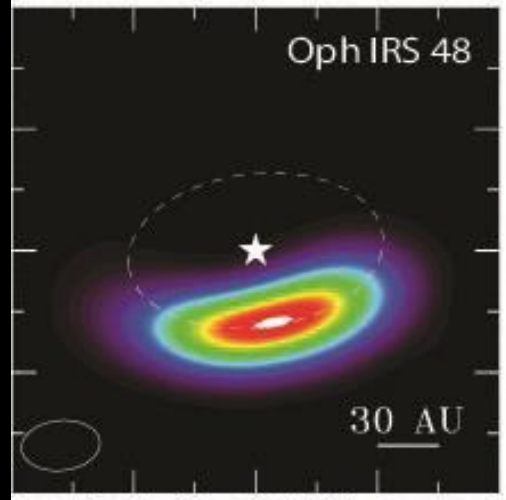


Pérez et al. (2014)

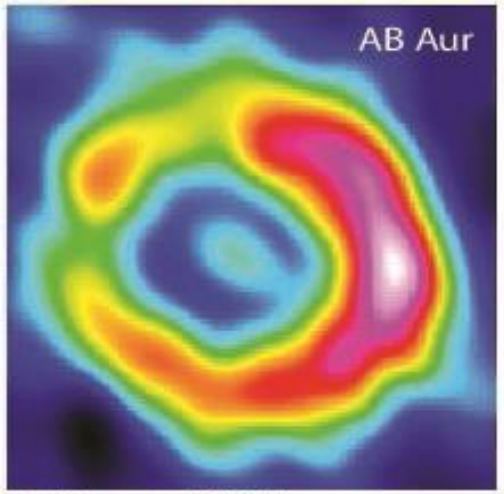


Casassus et al. (2013)

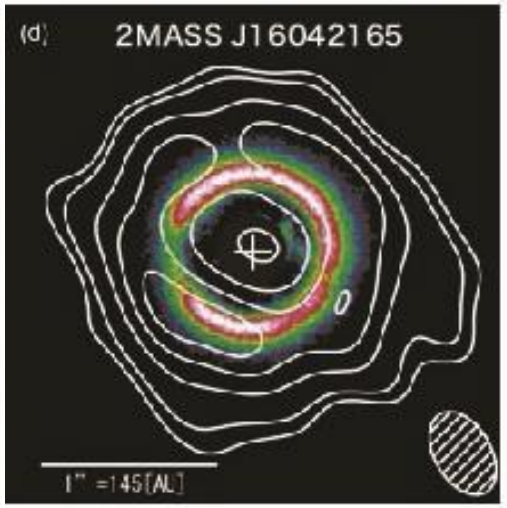




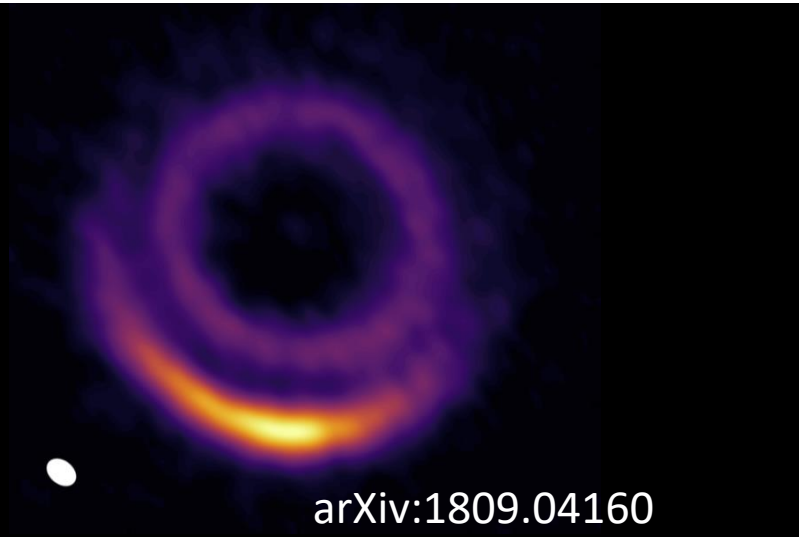
van der Marel et al. (2013)



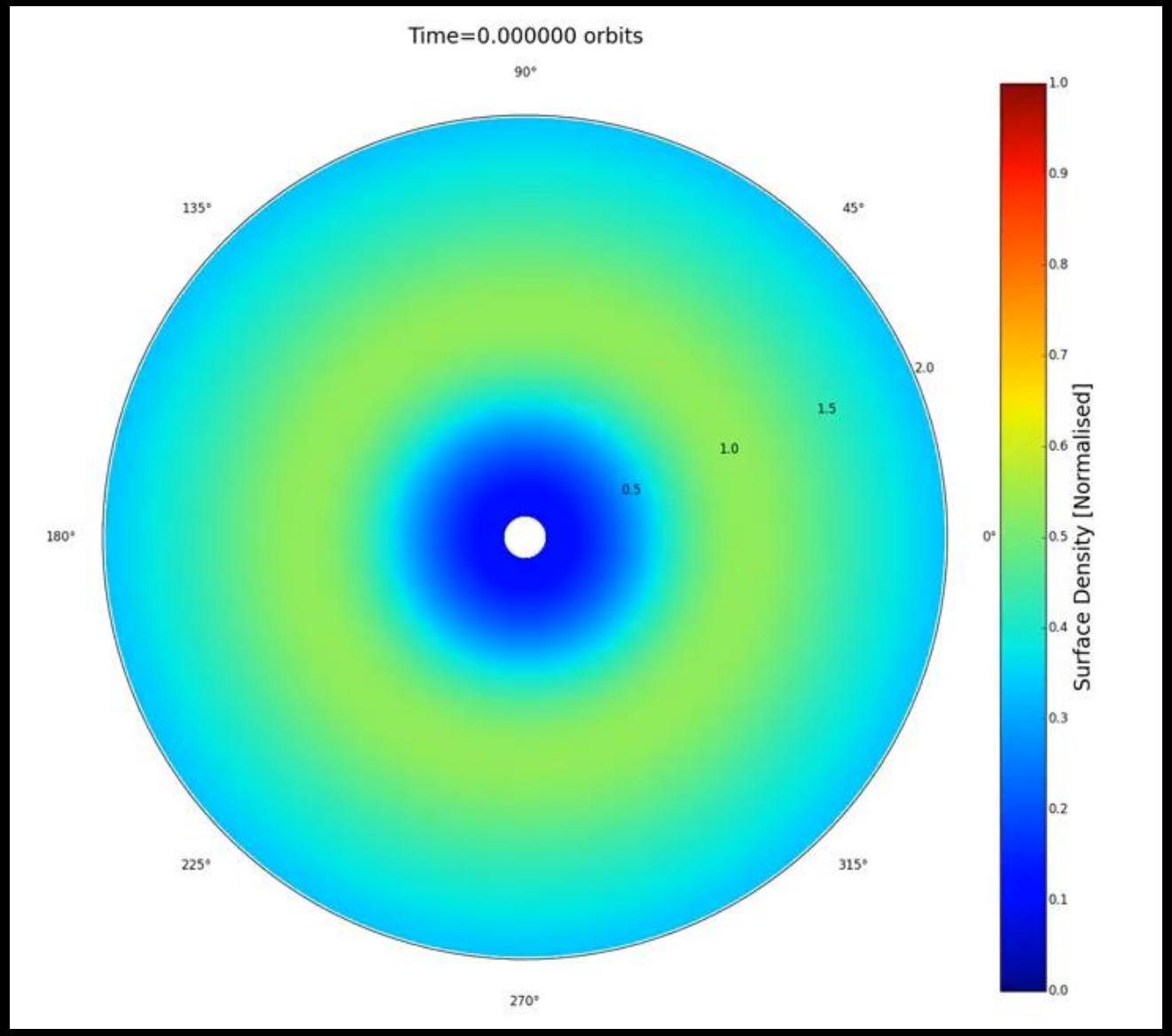
Rodriguez et al. (2014)



Mayama et al. (2012)


arXiv:1809.04160

Are Vortices Responsible?

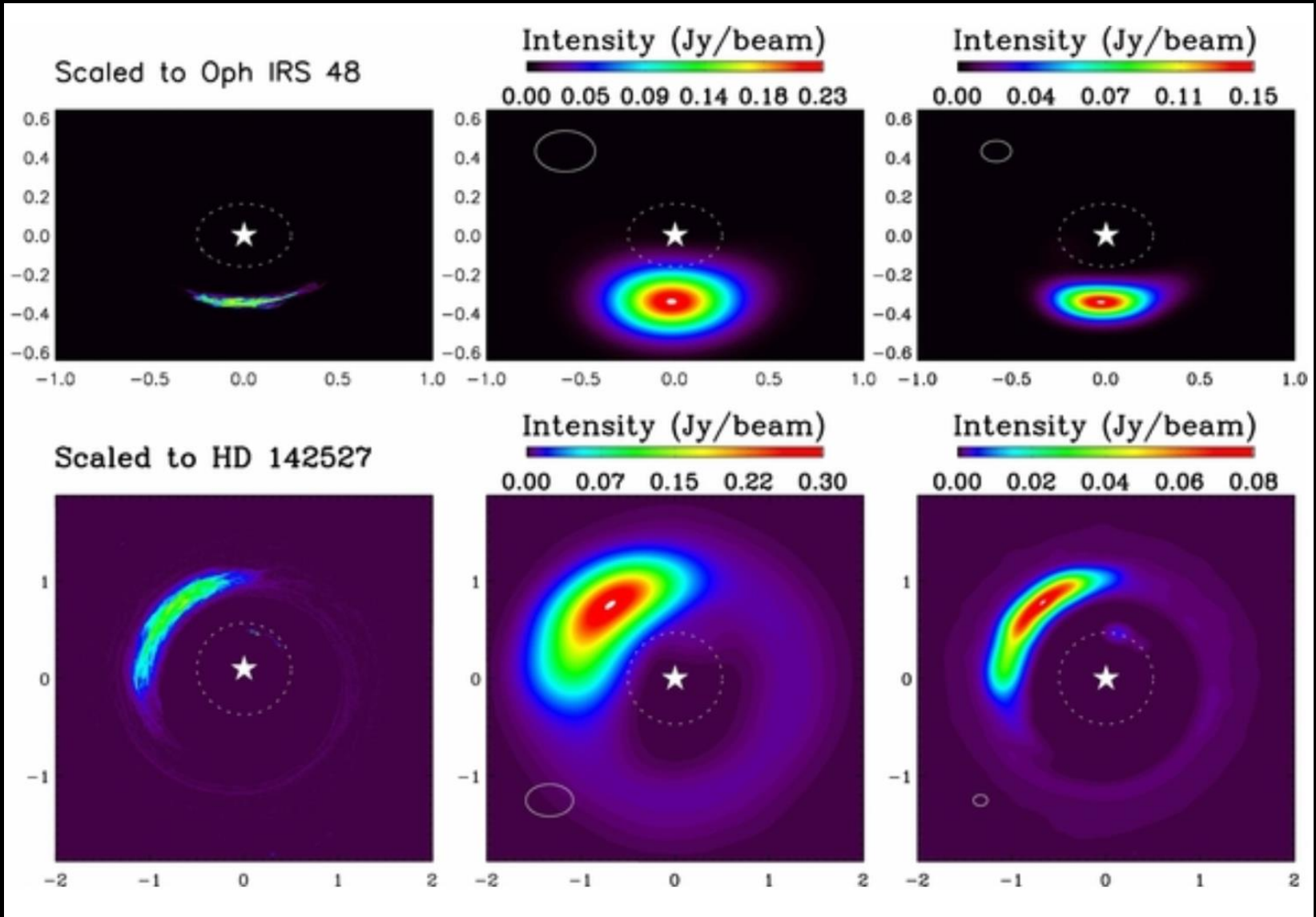


James Owen, arXiv:1607.08250

- Most popular explanation
- Requires low viscosity
- Created by various hydrodynamic instabilities
- Leads to large dust concentration
- Possible mechanism for planet formation

Caused by planetary mass objects!

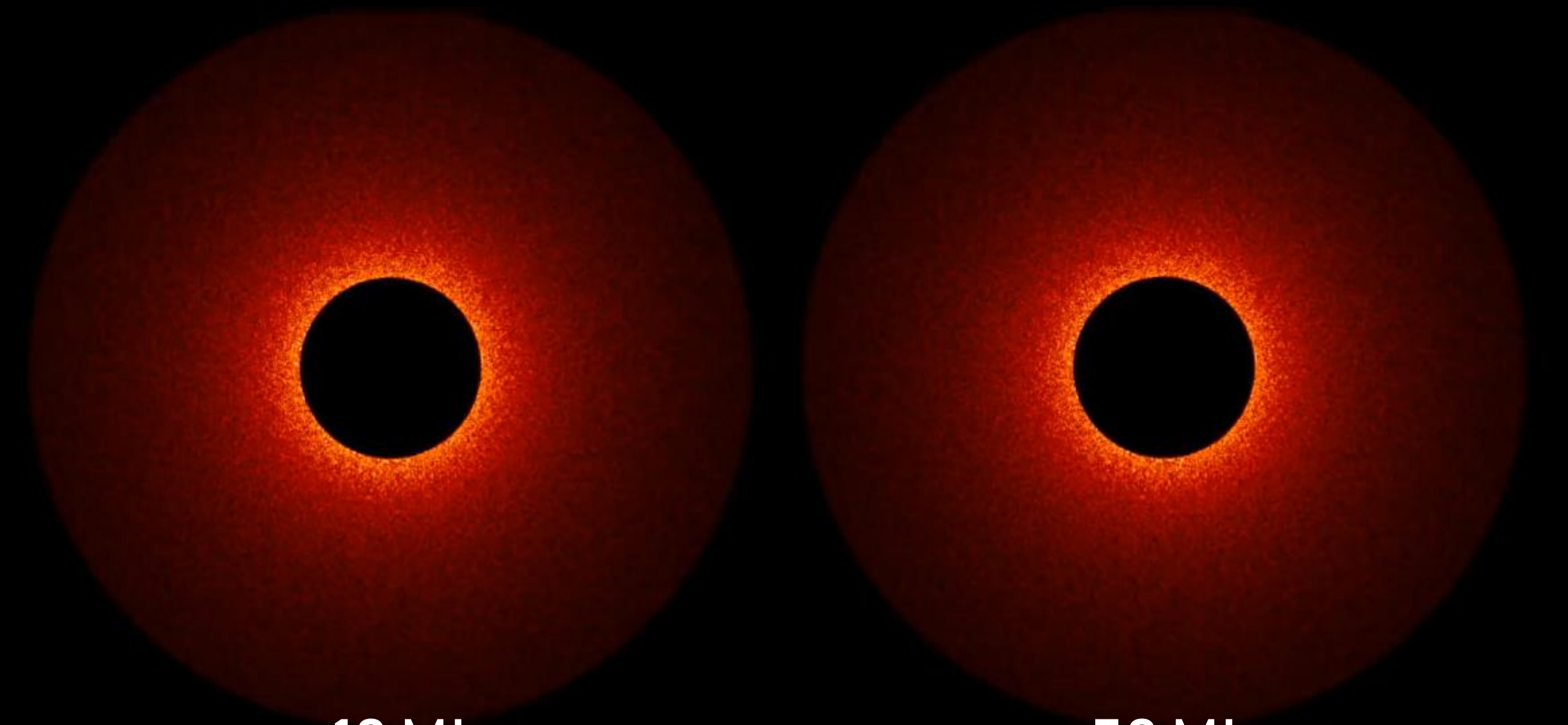
Vortices with Dust



- Dust concentrates in the pressure maximum
- Leads to large dust concentration
- Possible mechanism for planet formation

arXiv:1405.2790

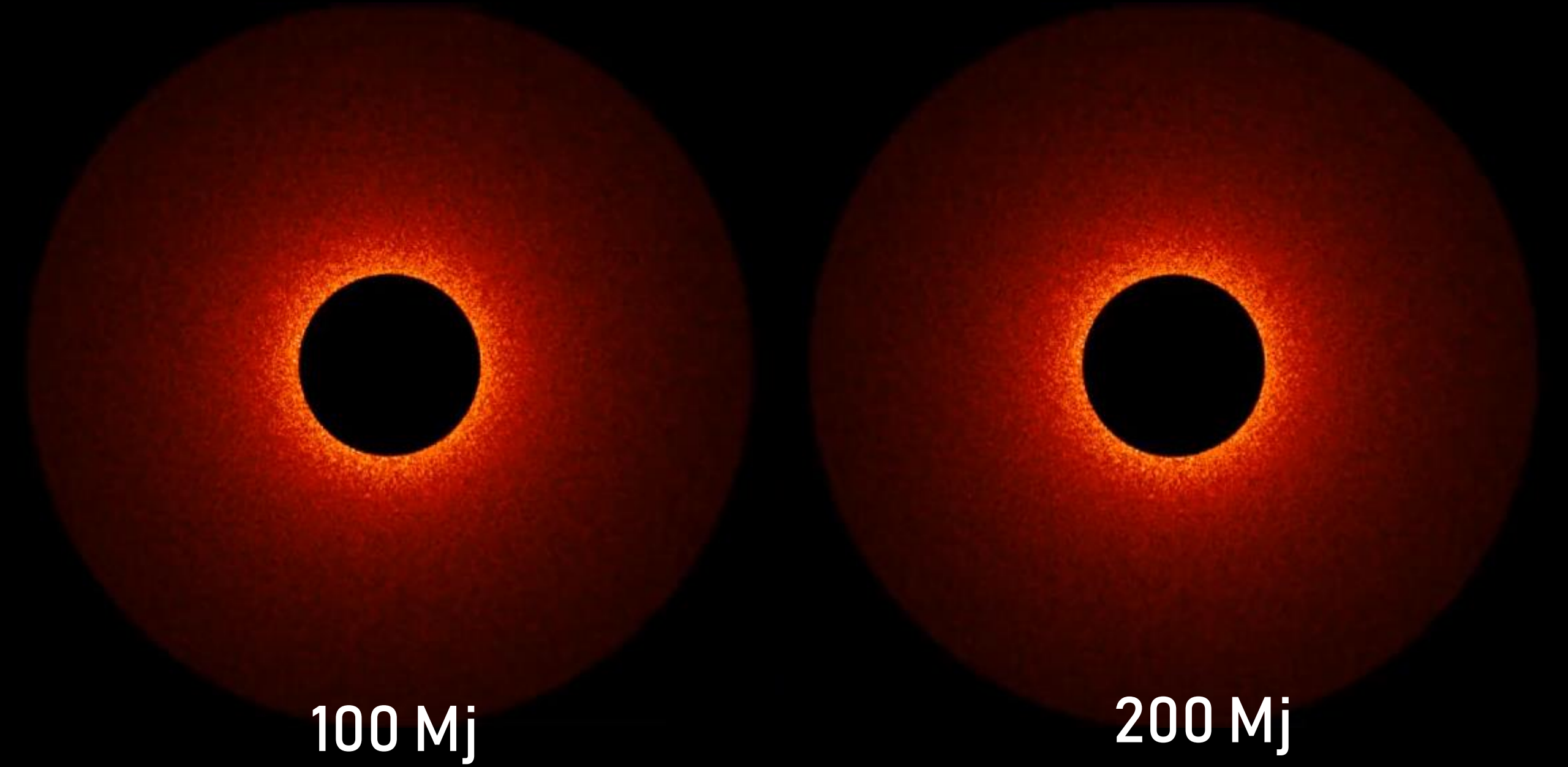
What about Companions?



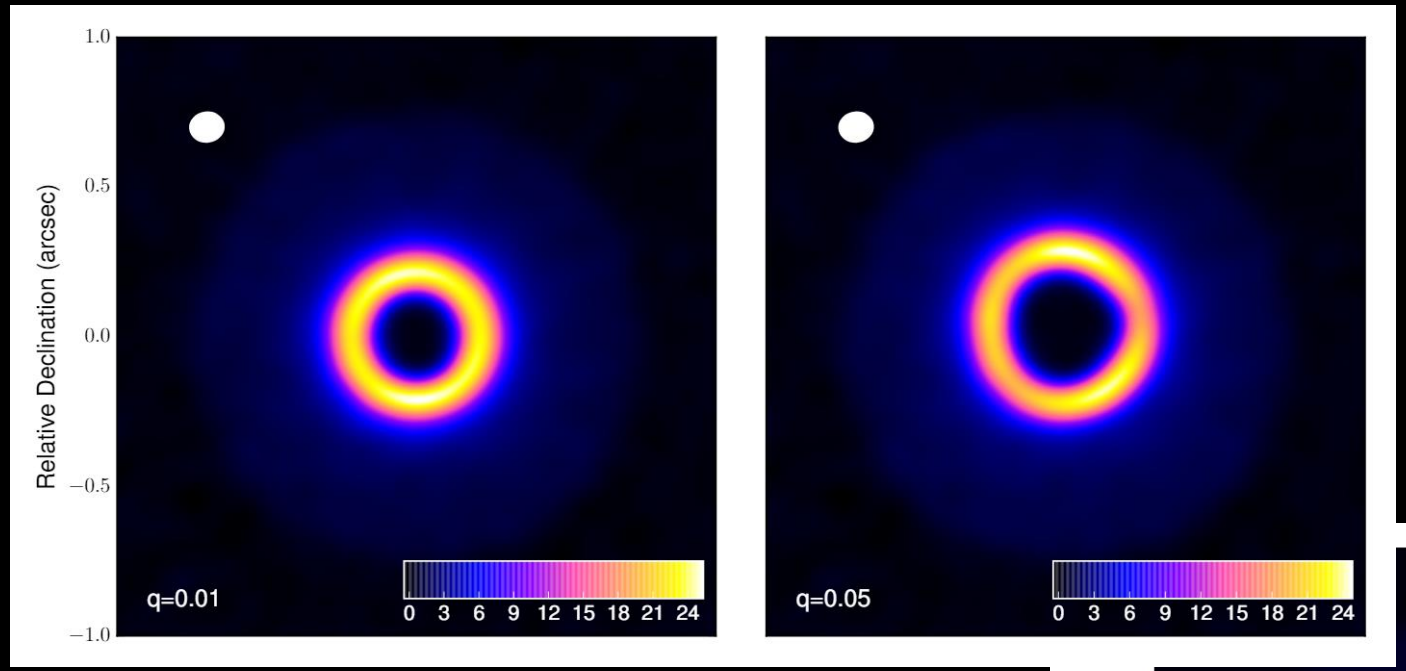
10 Mj

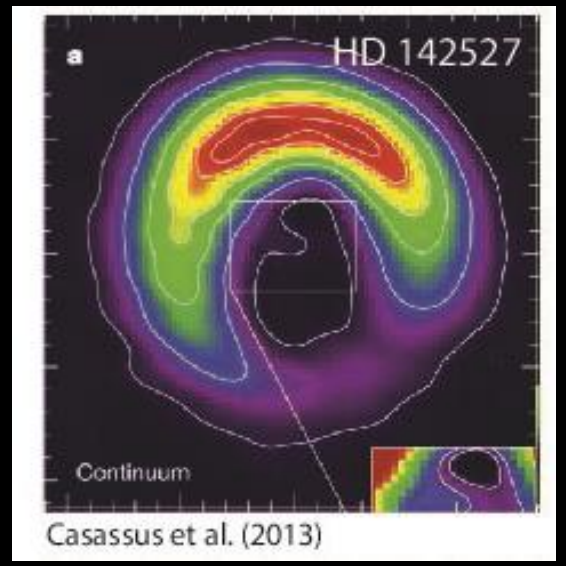
50 Mj

What about Companions?

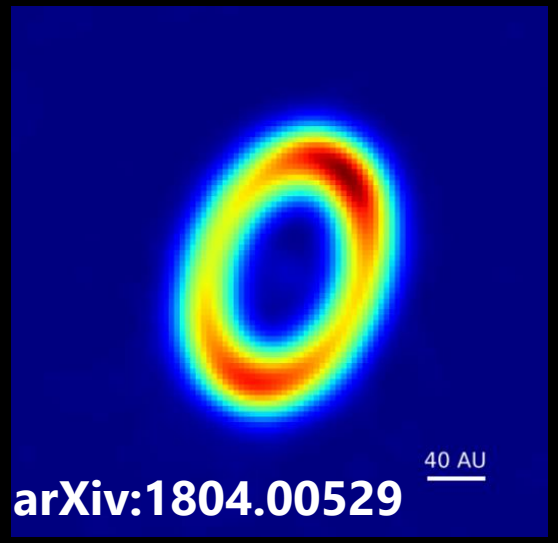


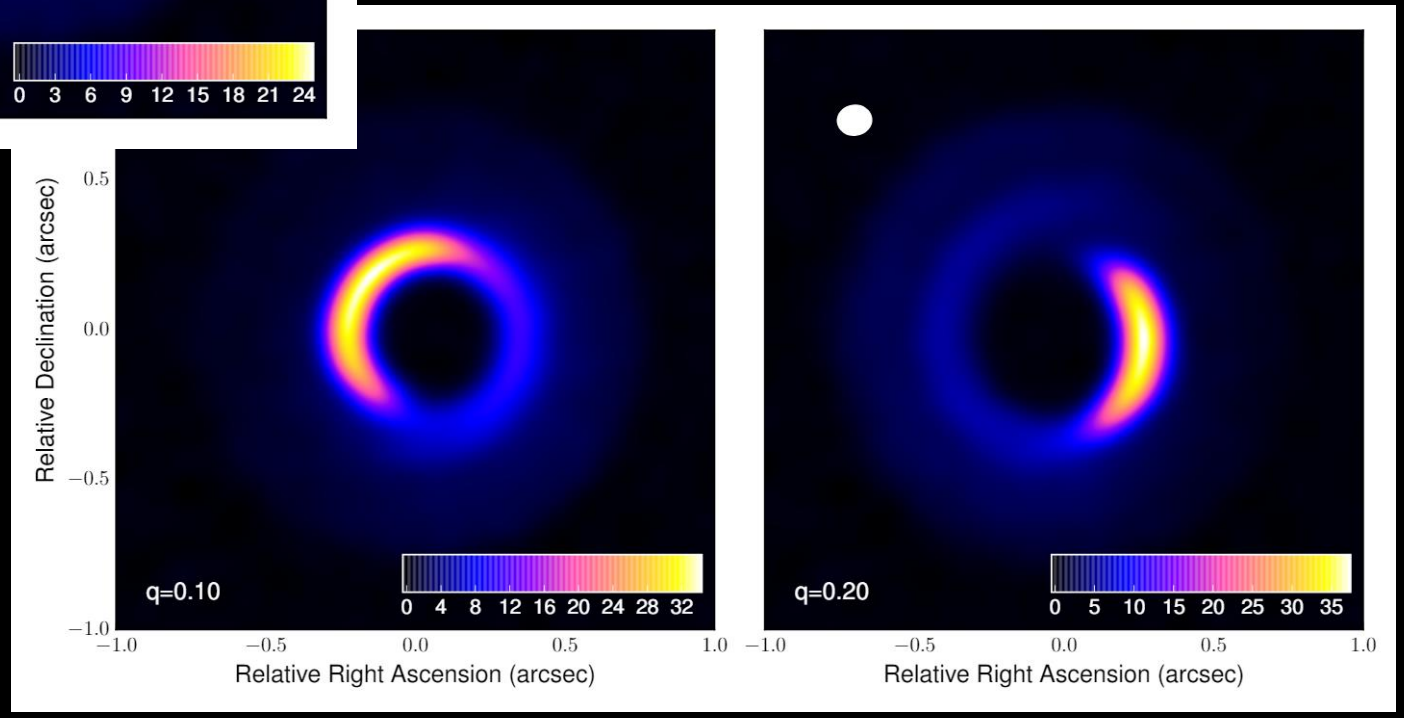
What about Dust Grains?





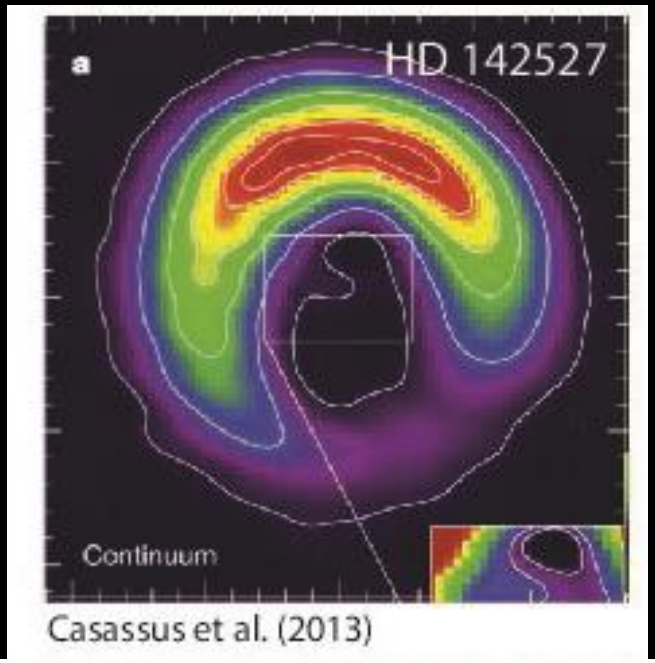
arXiv:1609.08159



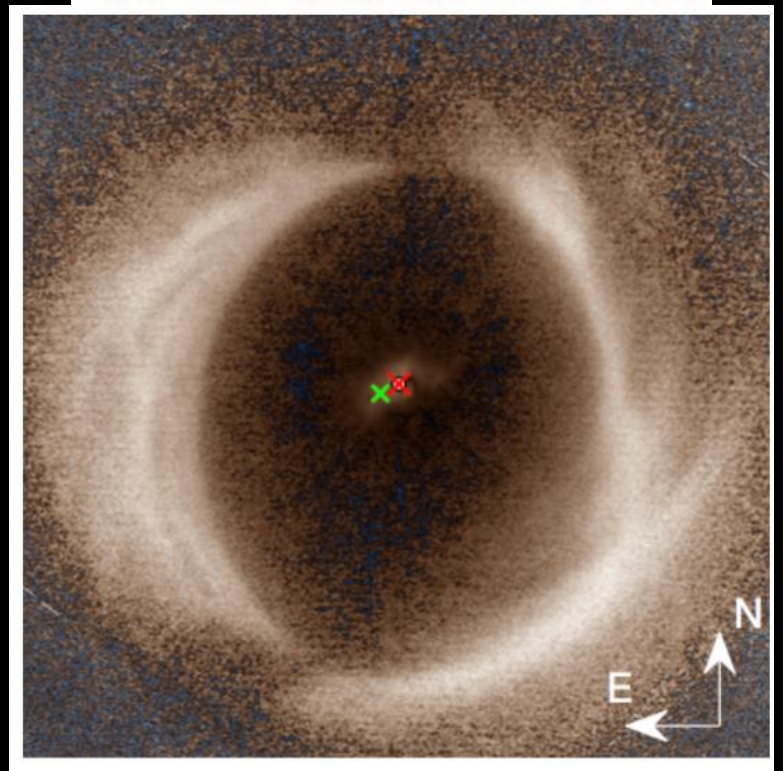


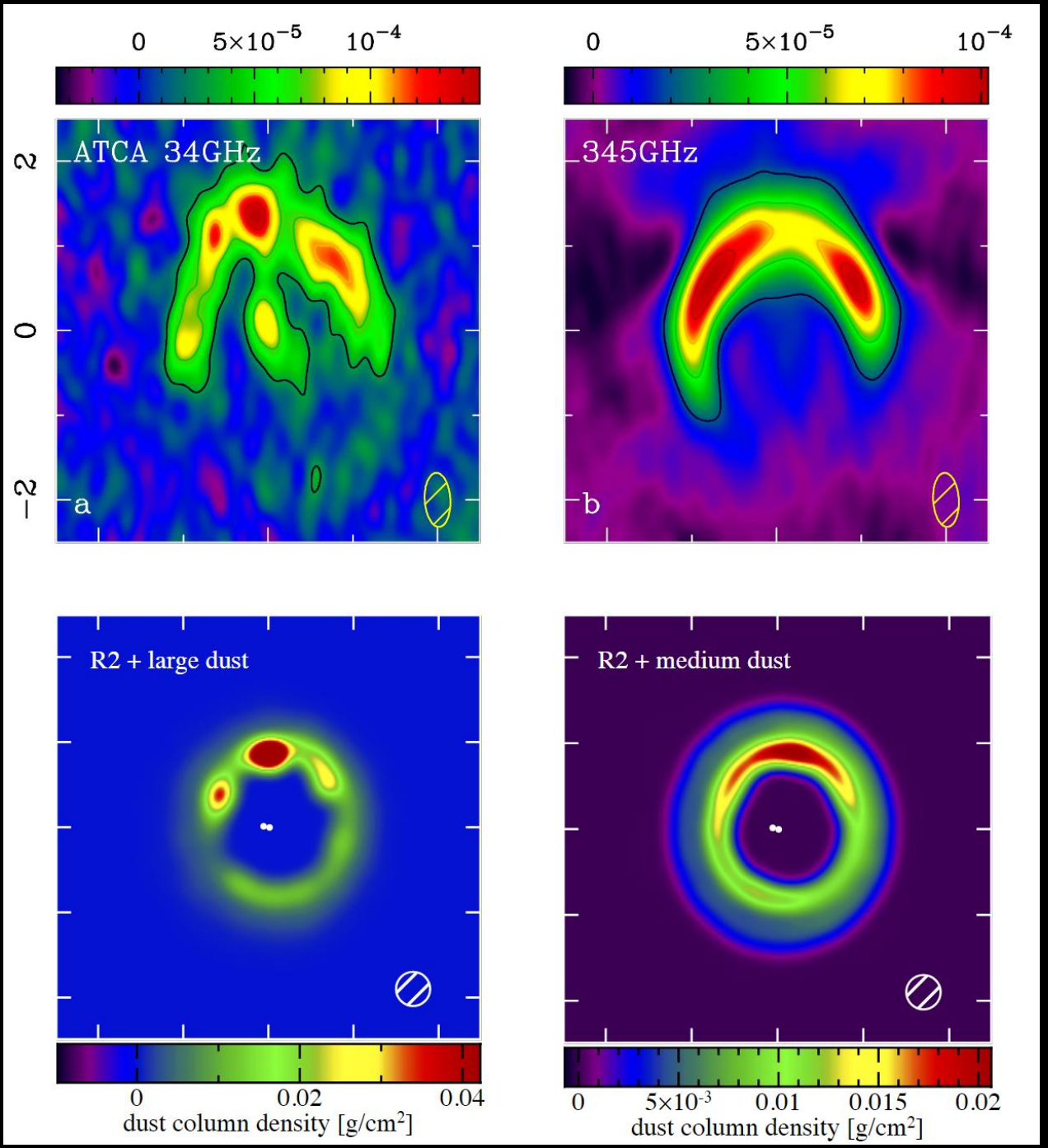
HD 142527

- Horseshoes in mm wavelengths
- Spiral arms in scattered light
- Shadow on the disk
- Stellar companion detected



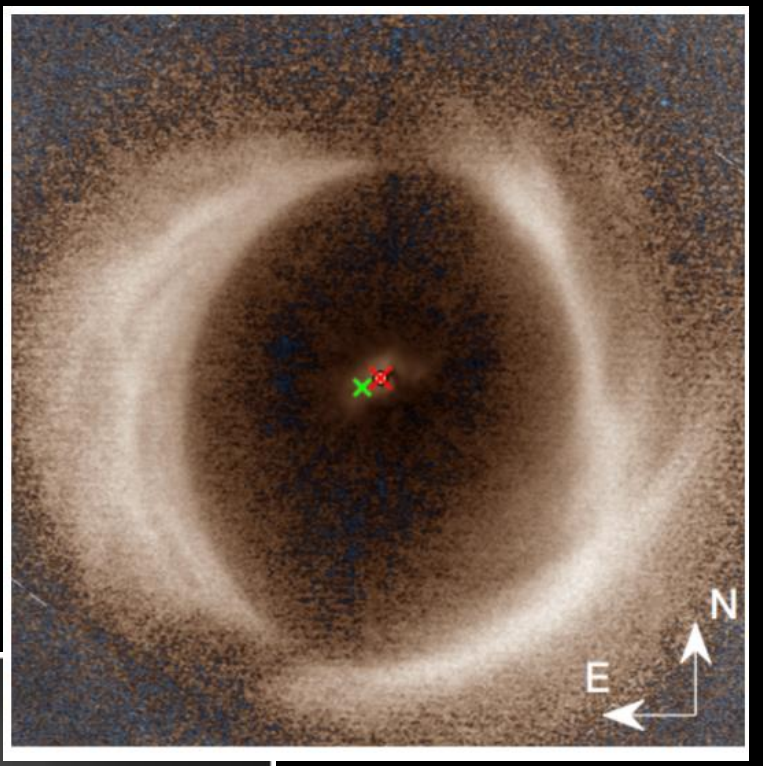
Casassus et al. (2013)

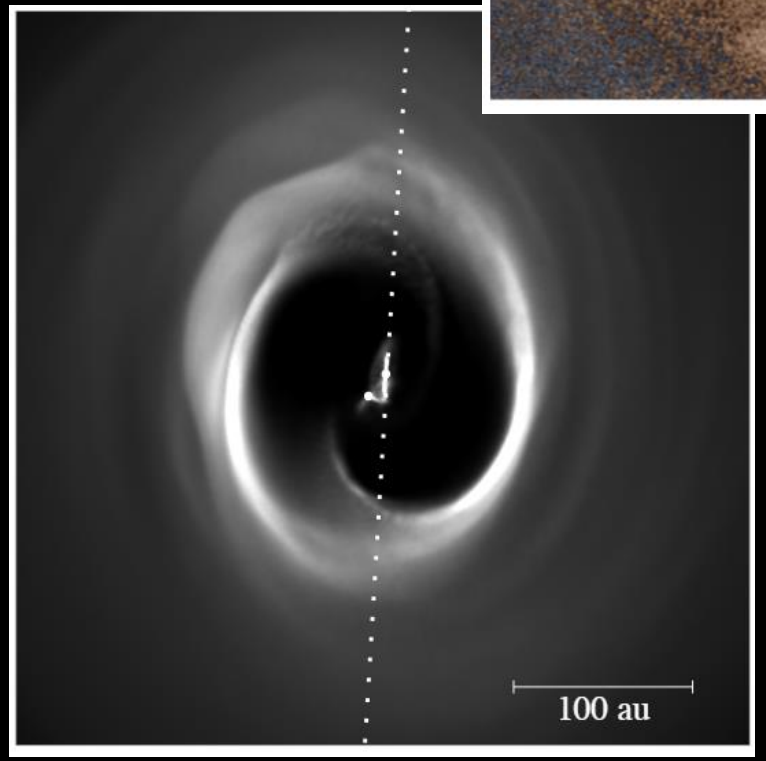




Star mass: 1.8 Msun

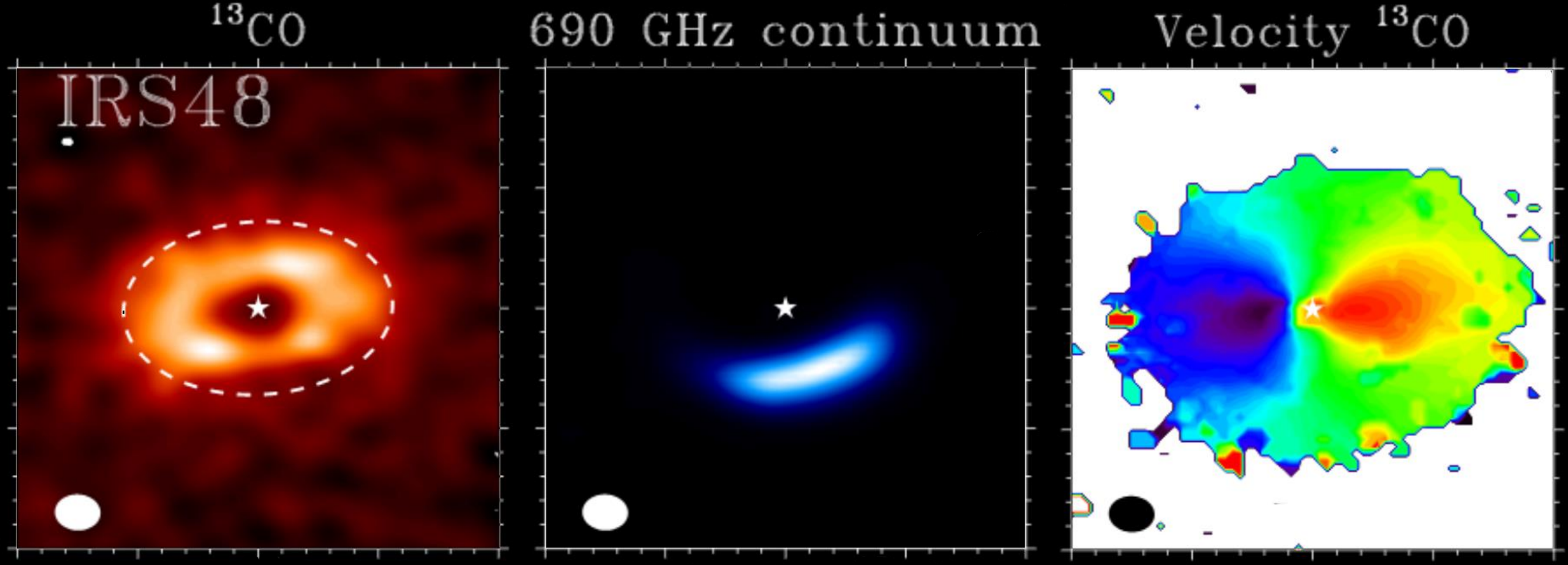
Com mass: 0.4 Msun





arXiv: 1803:02484

IRS48 is quite enigmatic



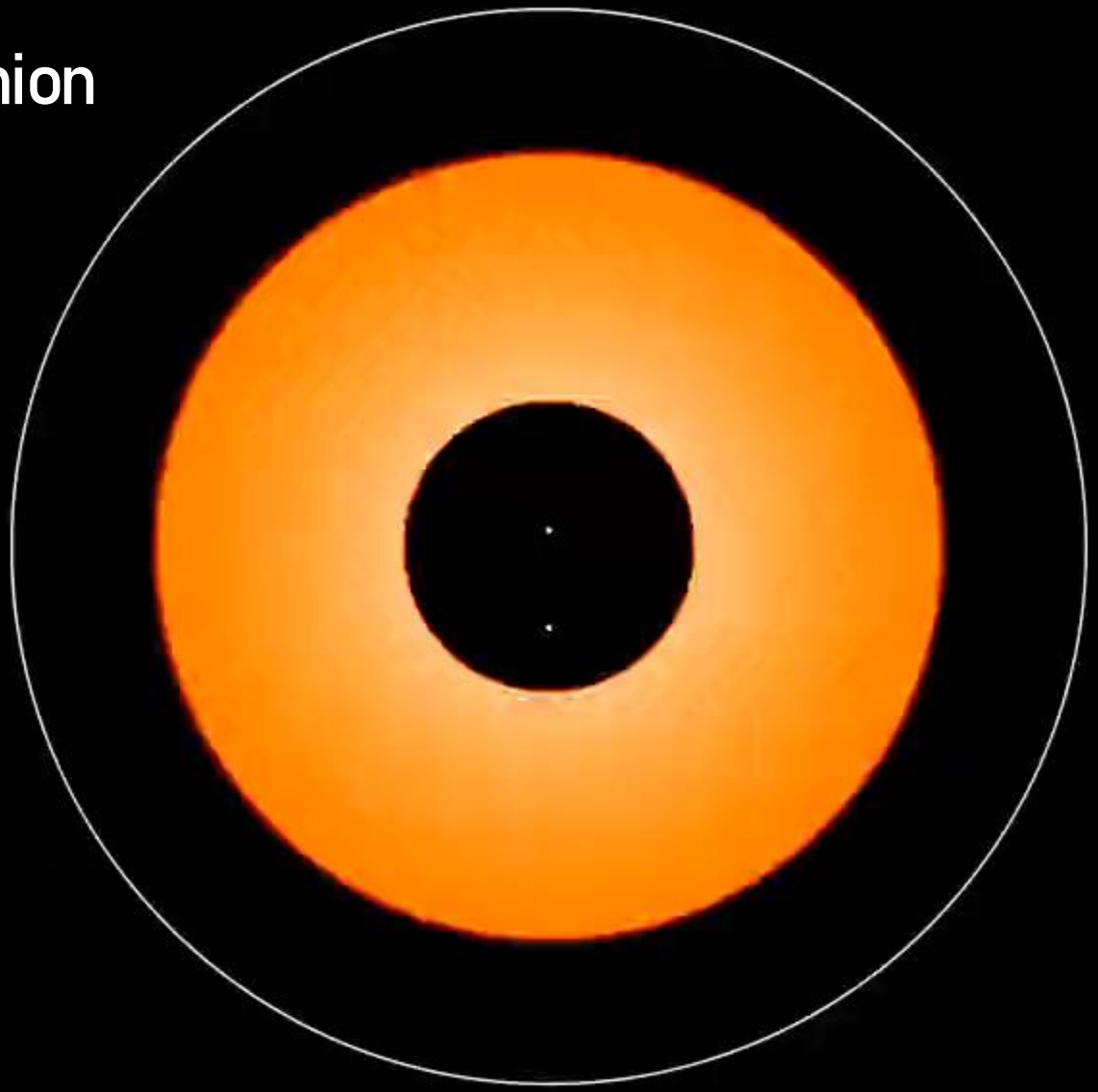
van der Marel et al., arXiv:1511.07149

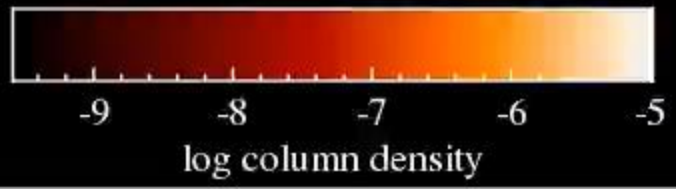
2 Solar Mass central mass

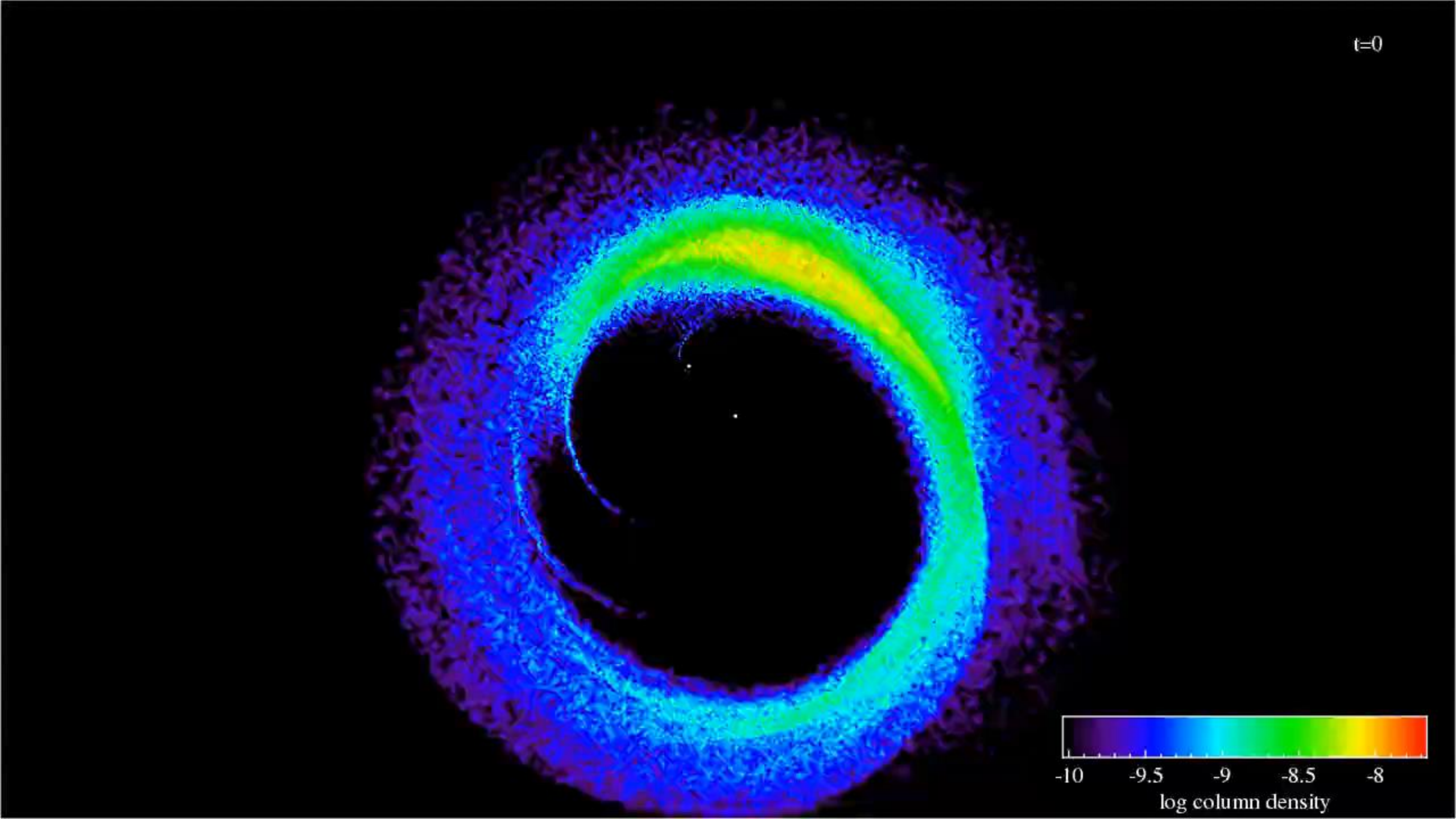
0.4 Solar Mass companion

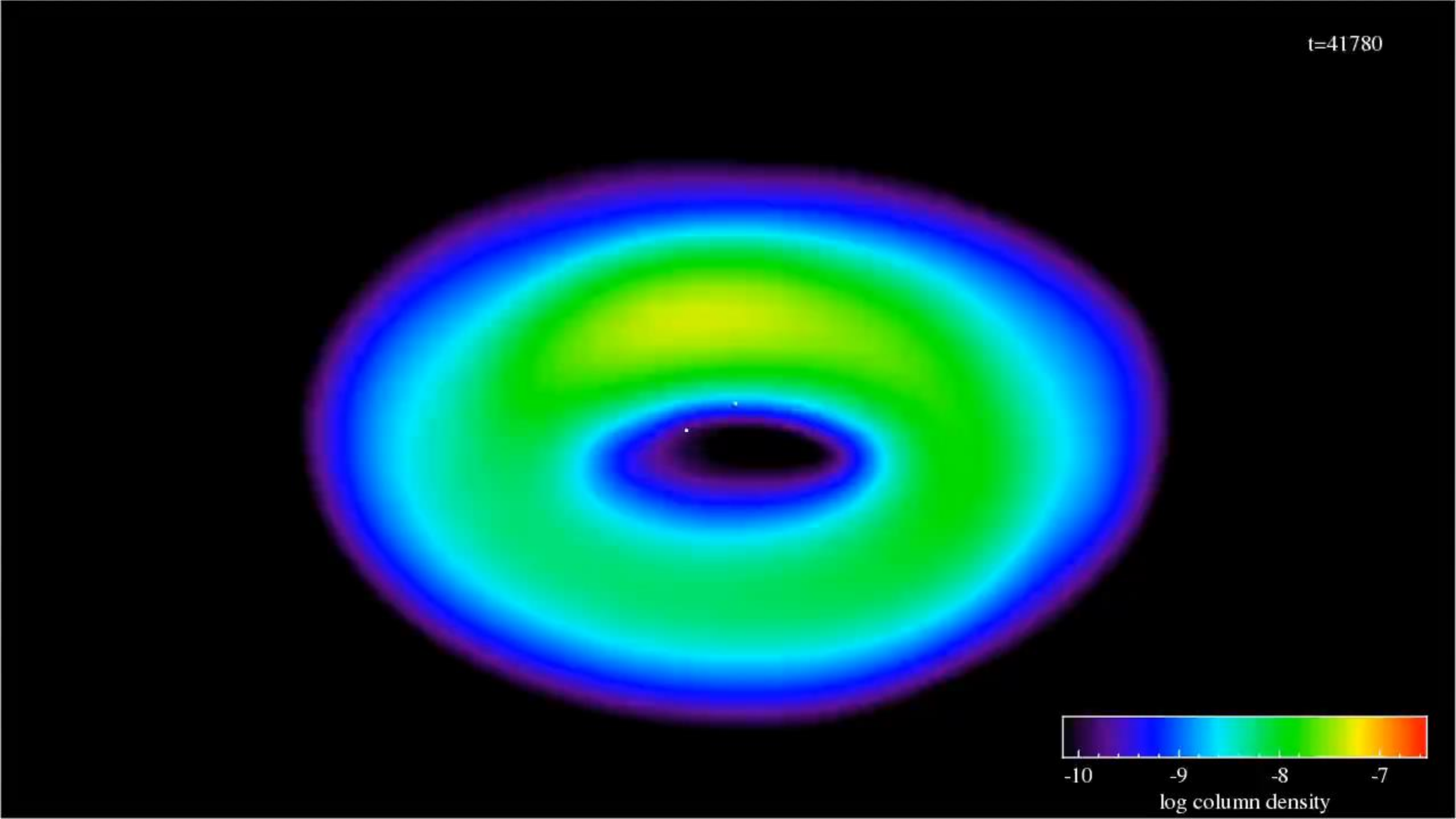
10 au separation

alpha_SS = 0.0015

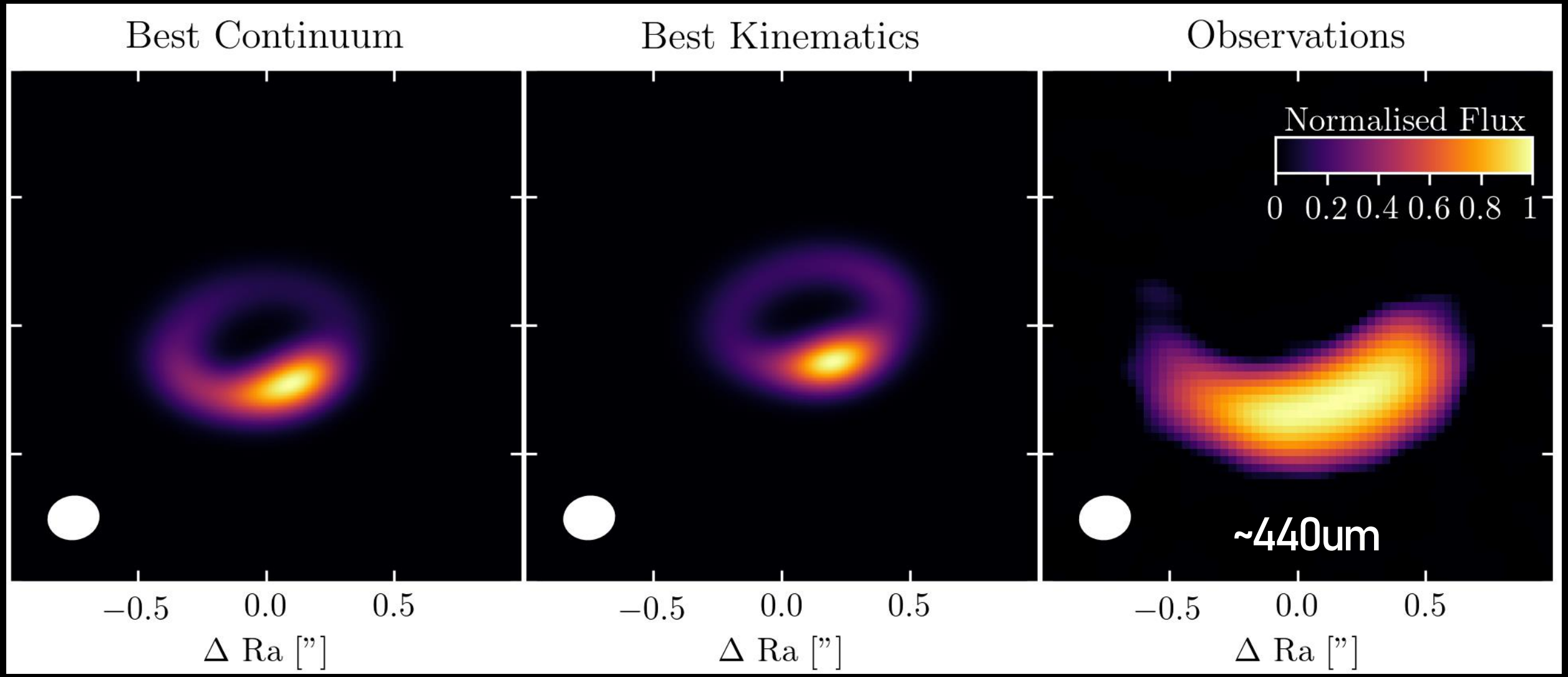





t=0
-10
-9.5
-9
-8.5
-8
log column density

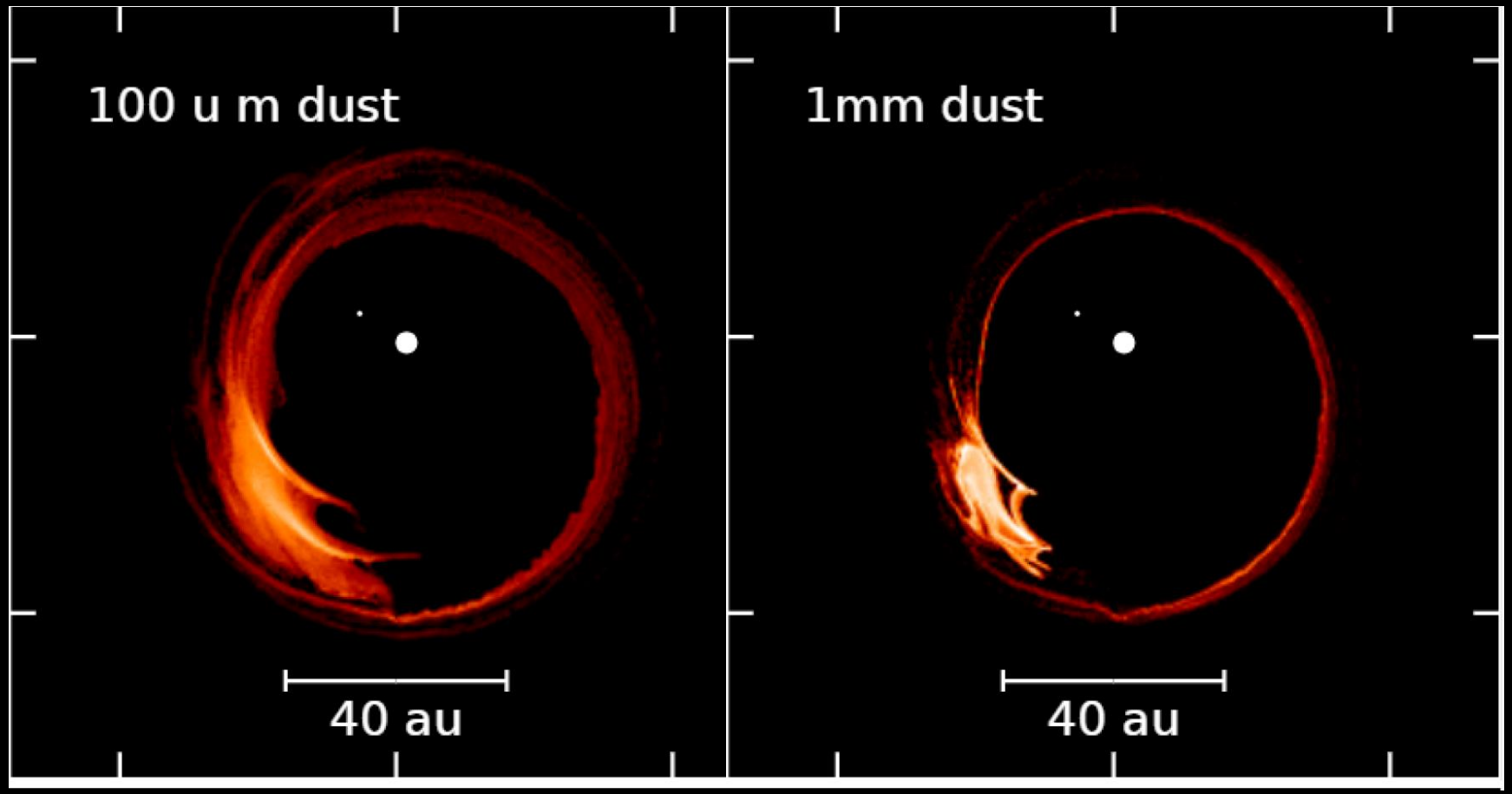

t=41780
-10
-9
-8
-7
log column density

A solution without Vortices



Contrast ratio depends strongly on the assumed dust grain size distribution

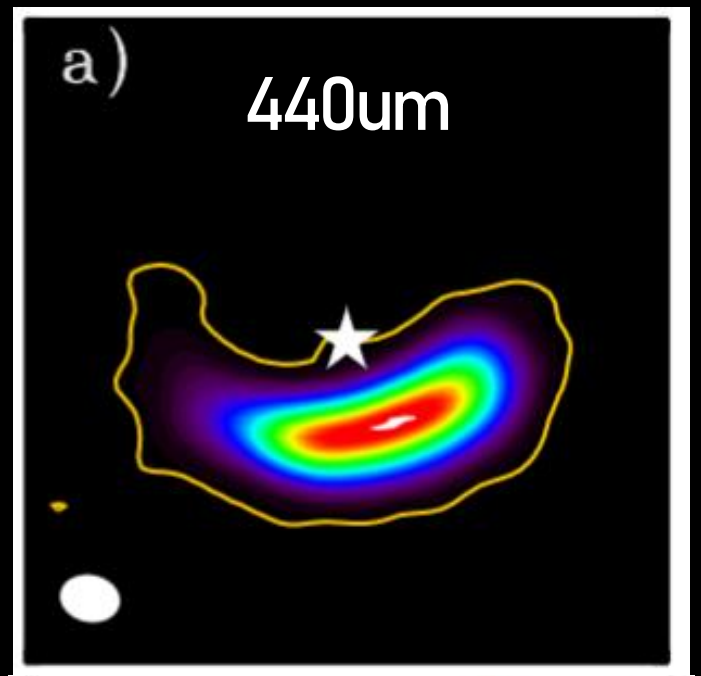
Changes with Grain Size

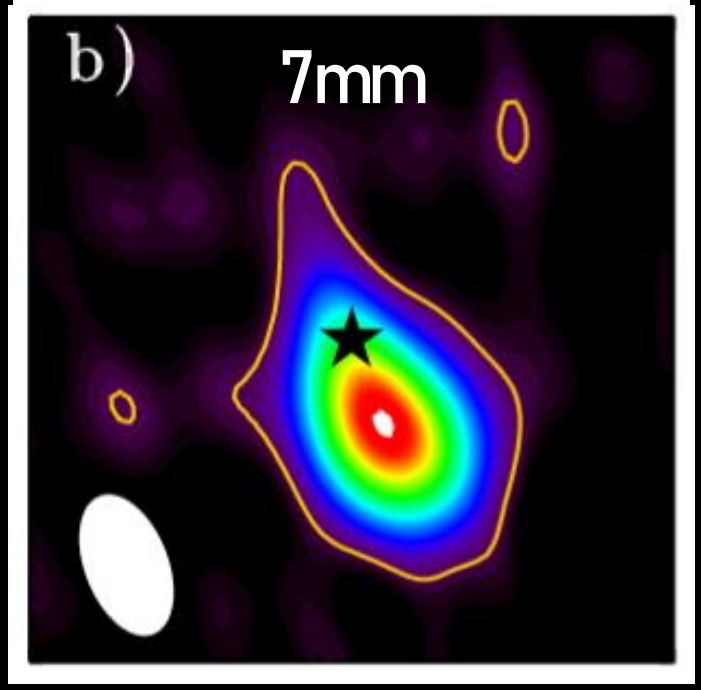


St = 0.01 – 0.1

St = 0.1 – 1

Larger grains are more azimuthally trapped



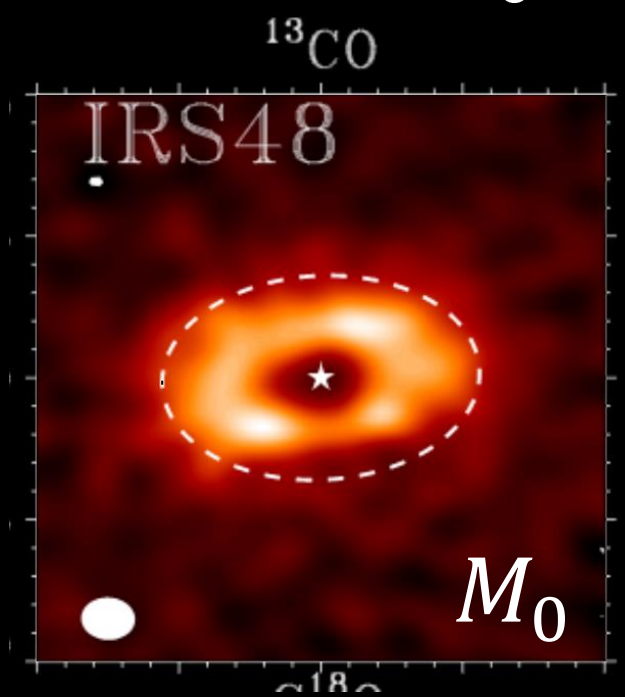


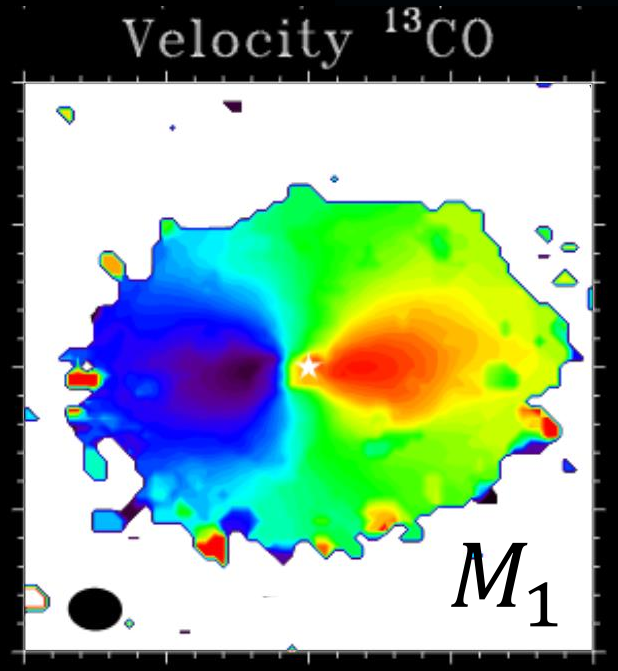
Arxiv:1508.01003

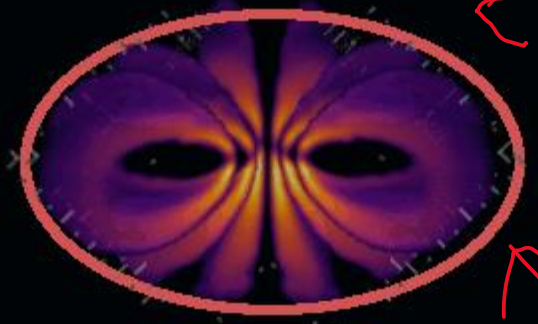
A quick note about kinematics..

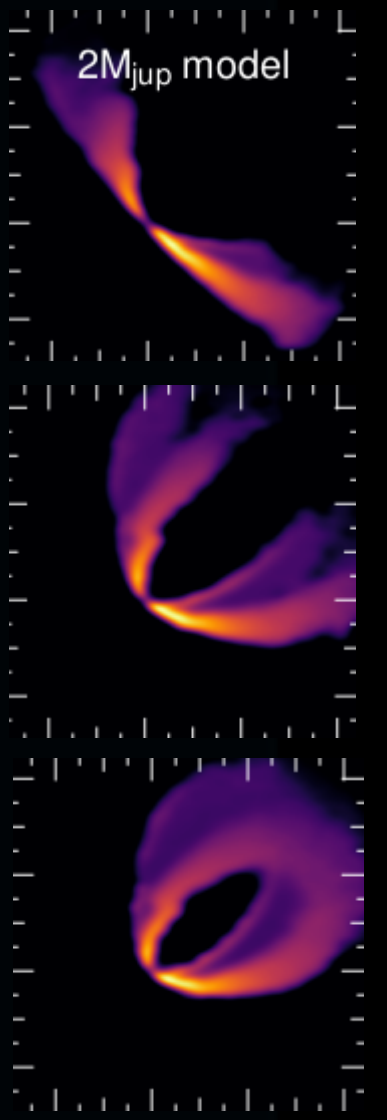
$$M_0 = \int I(x, y, v)\, dv$$

$$M_1 = \frac{1}{M_0} \int I(x, y, v)\, v\, dv$$



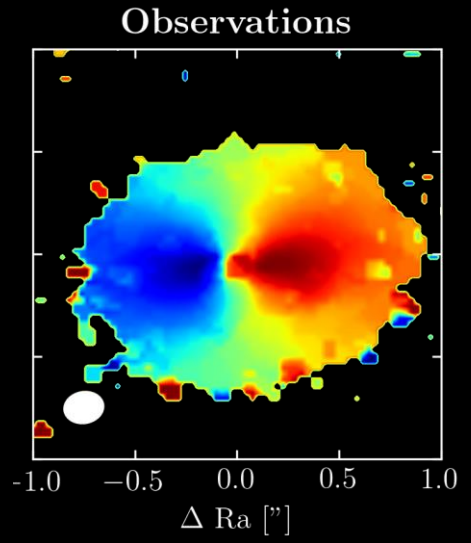




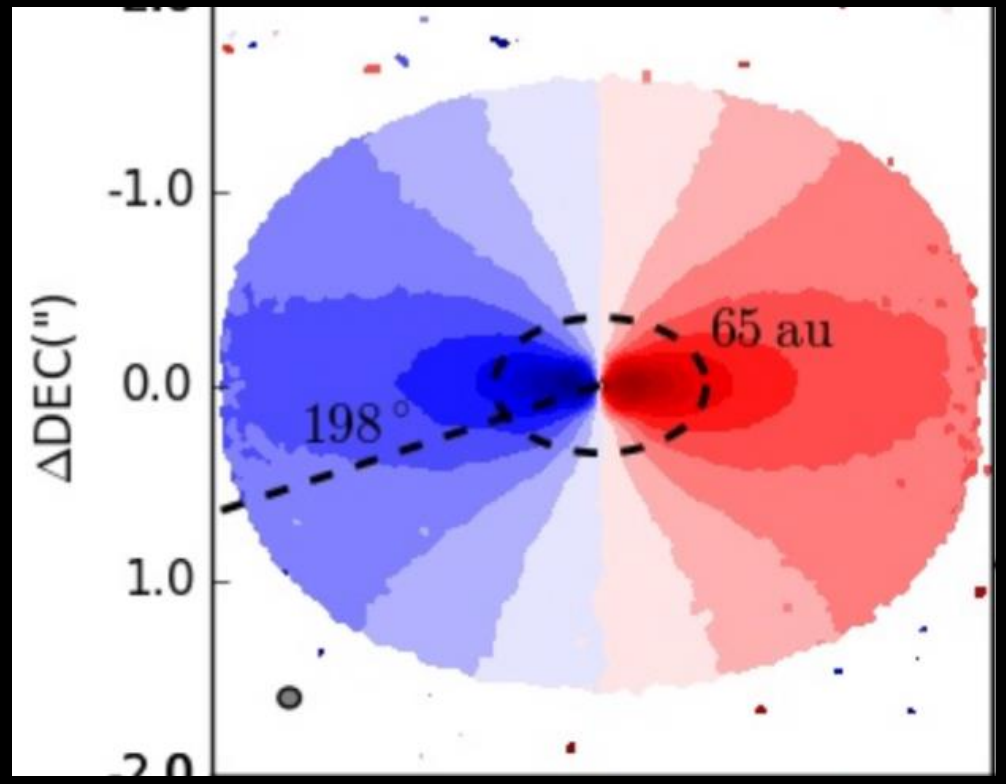


What are the Vortex Predictions?

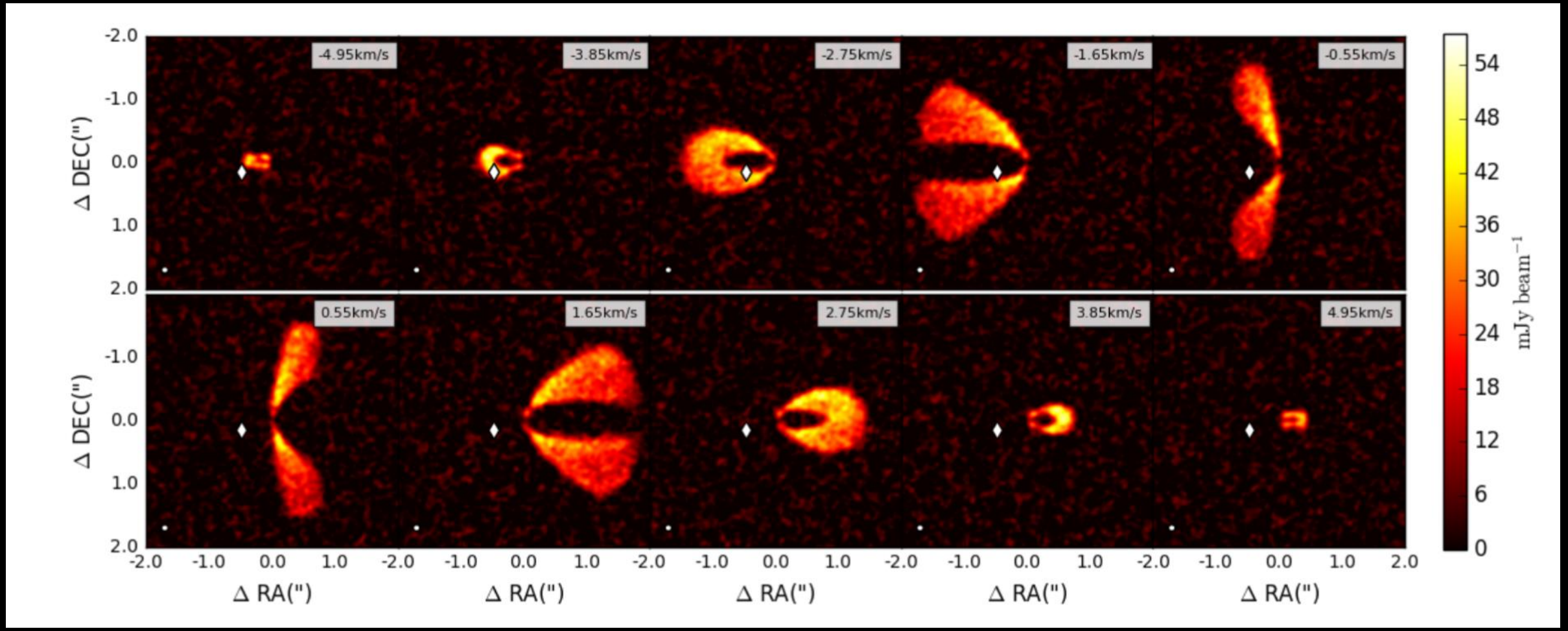
- Planetary mass companion (~Mj) somewhere, maybe internal to the vortex
- Symmetric velocity map
- No strong kinks in channel maps



arXiv:1809.07001

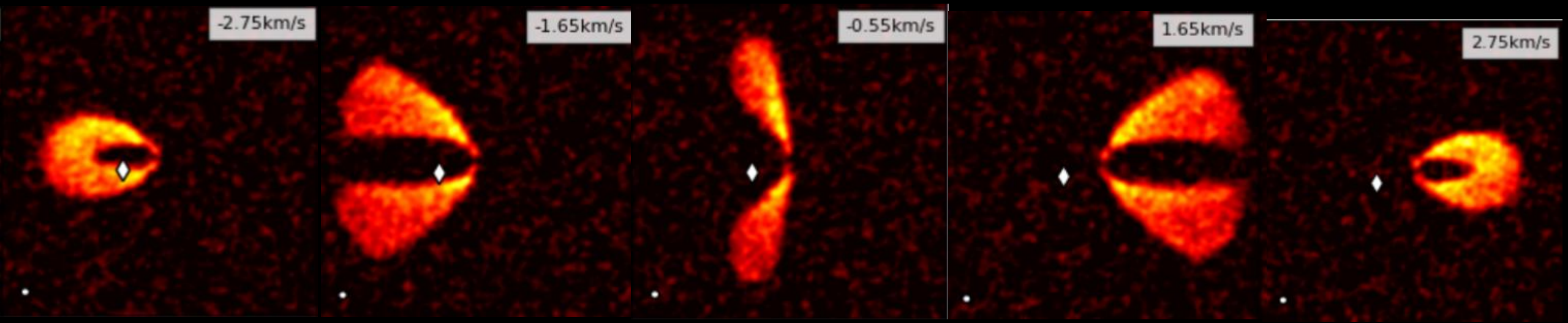


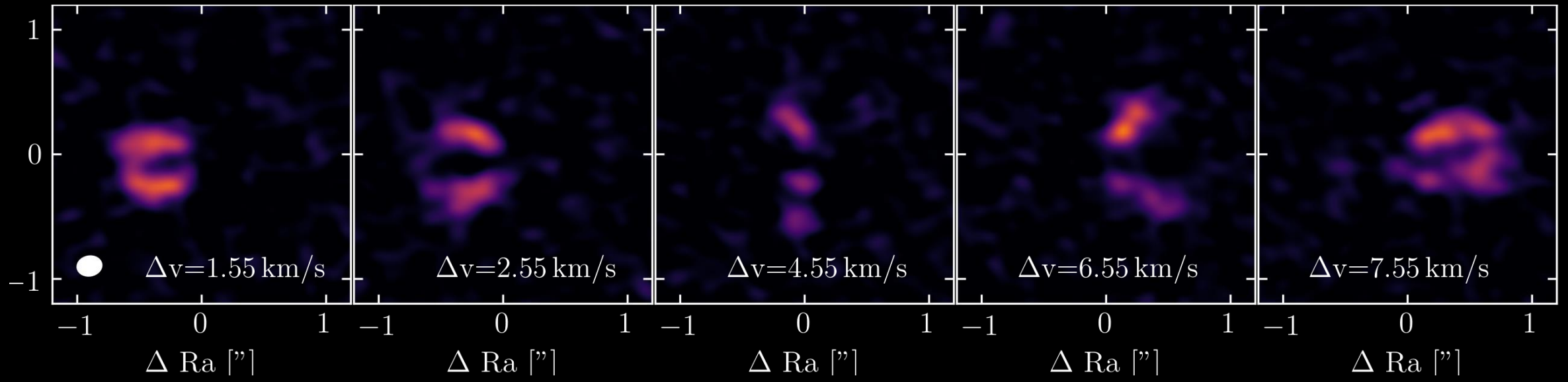
Vortex Channel Maps



arXiv:1809.07001

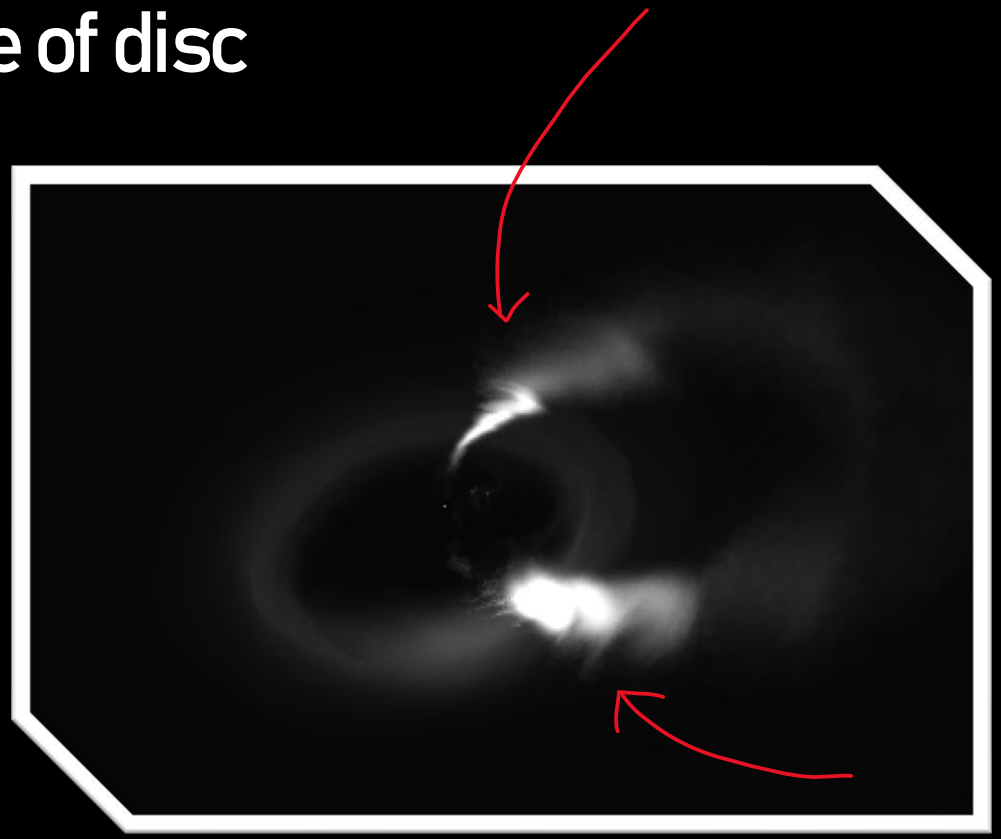
Vortex Channel Maps



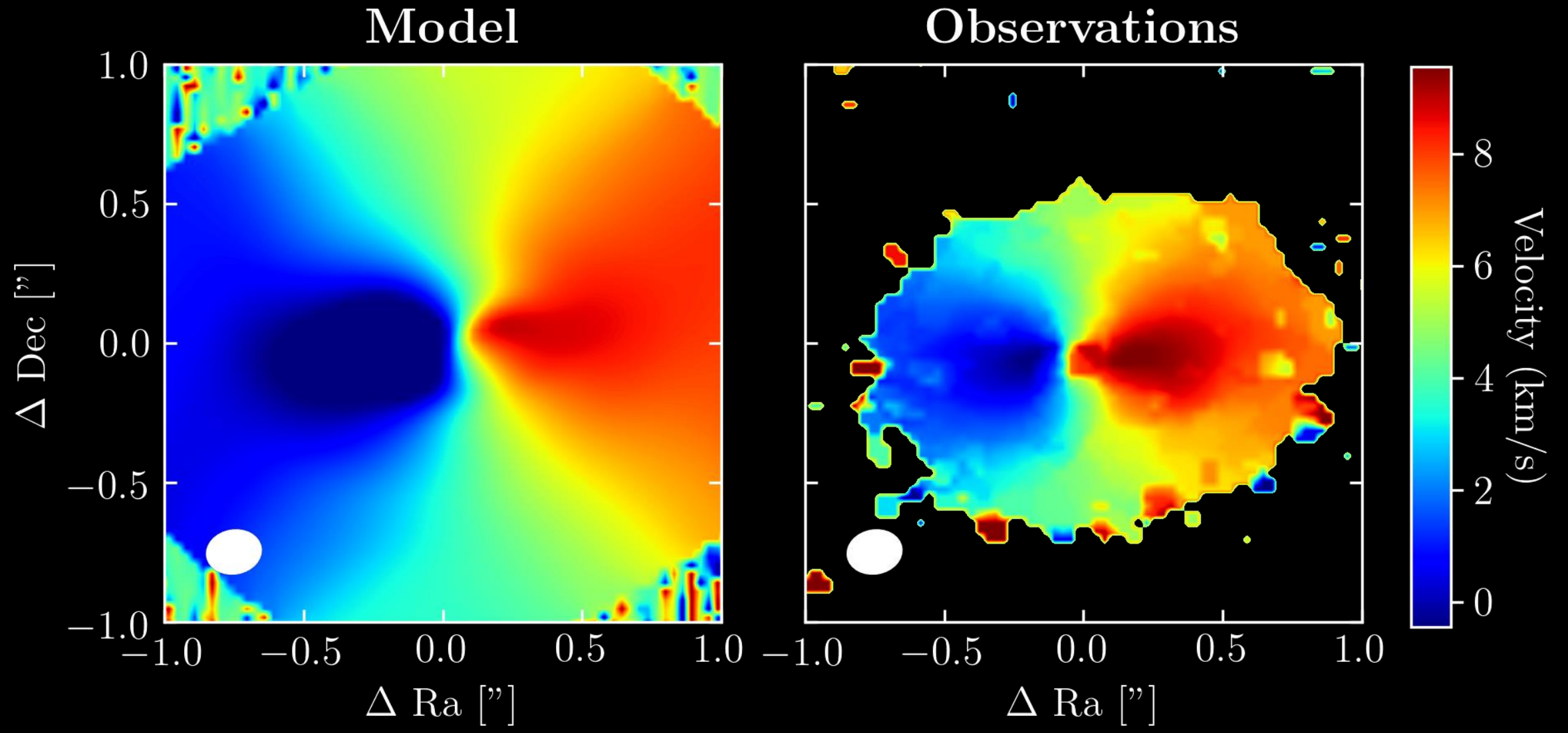


What are the Circumbinary Disk Predictions?

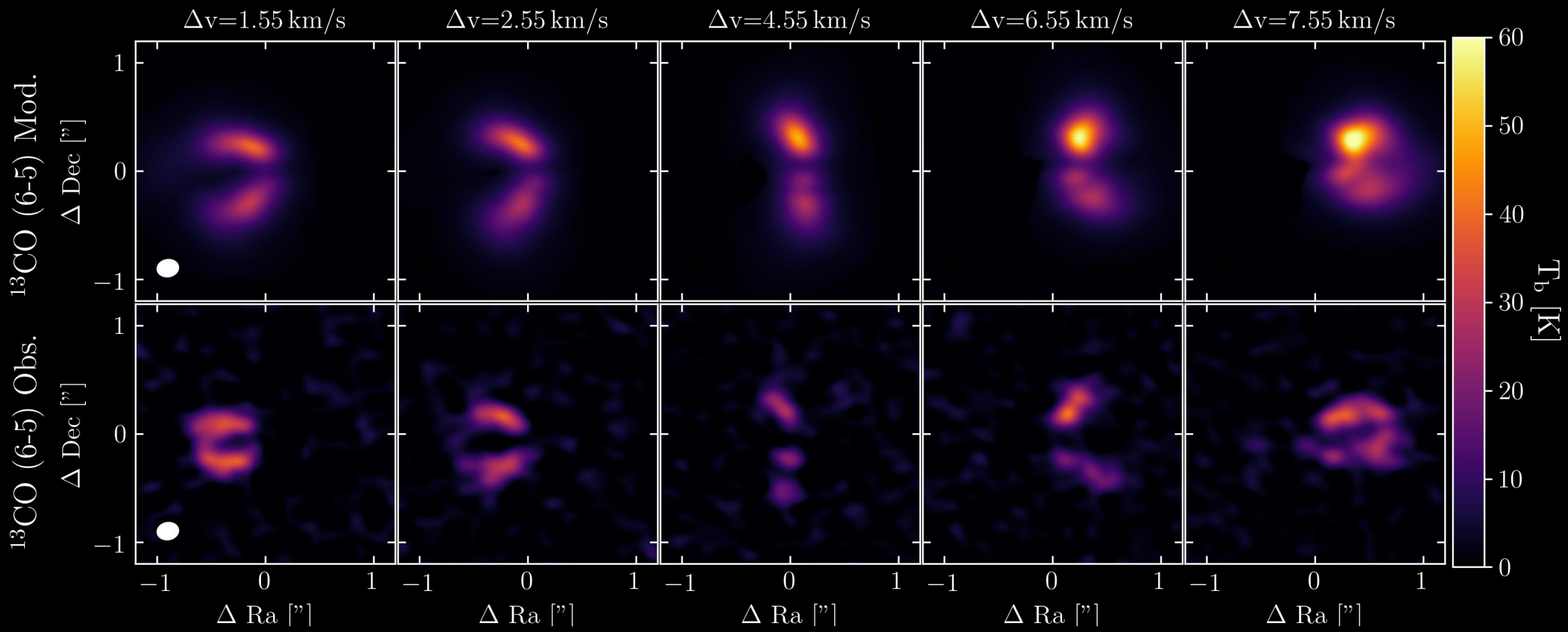
- Massive companion (~0.4 Msun) at ~10 au
- Eccentric disc, star offset from centre of disc
- Asymmetric velocity map
- Kinky channel maps



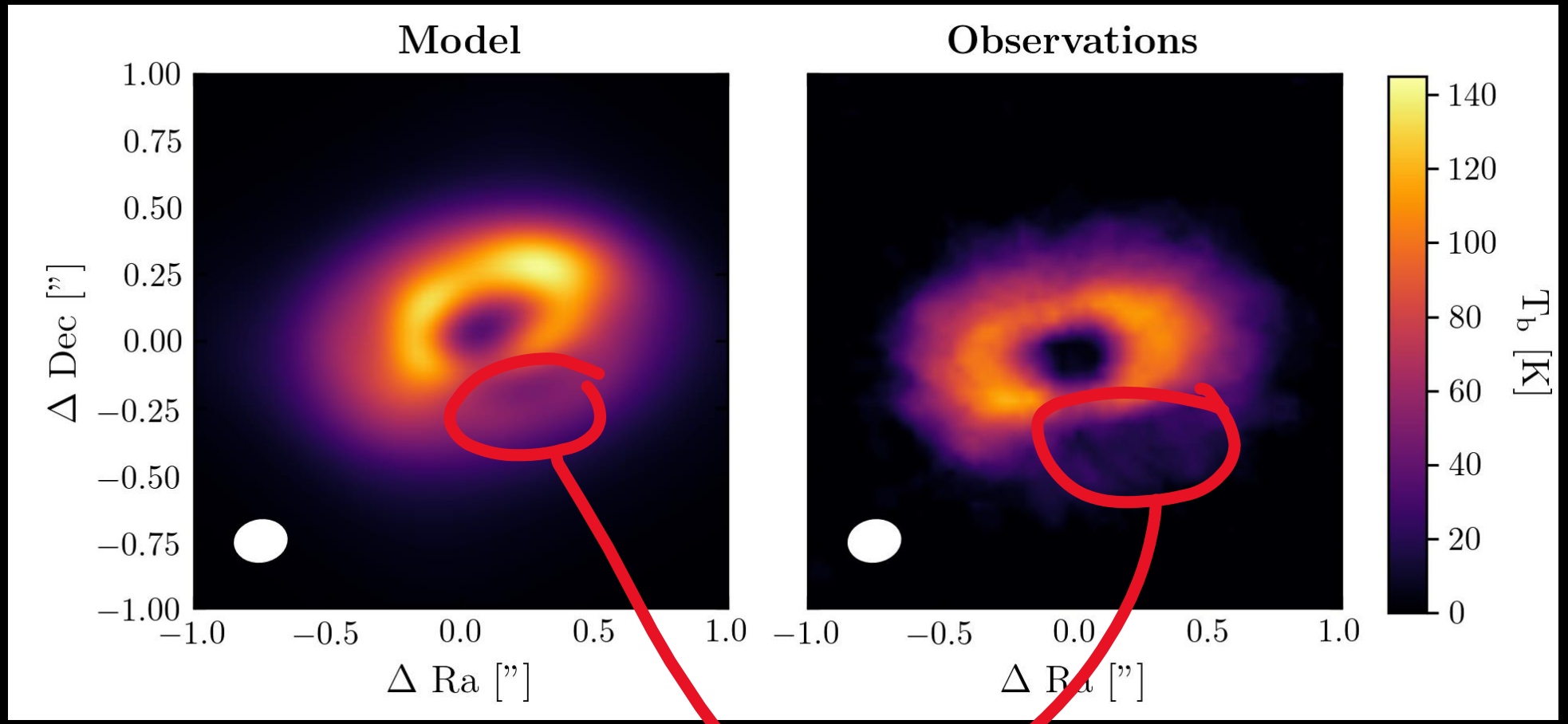
Velocity Map



The Kinematics look Kinky!



The CO Gap is smaller than the Dust Gap



Caveats

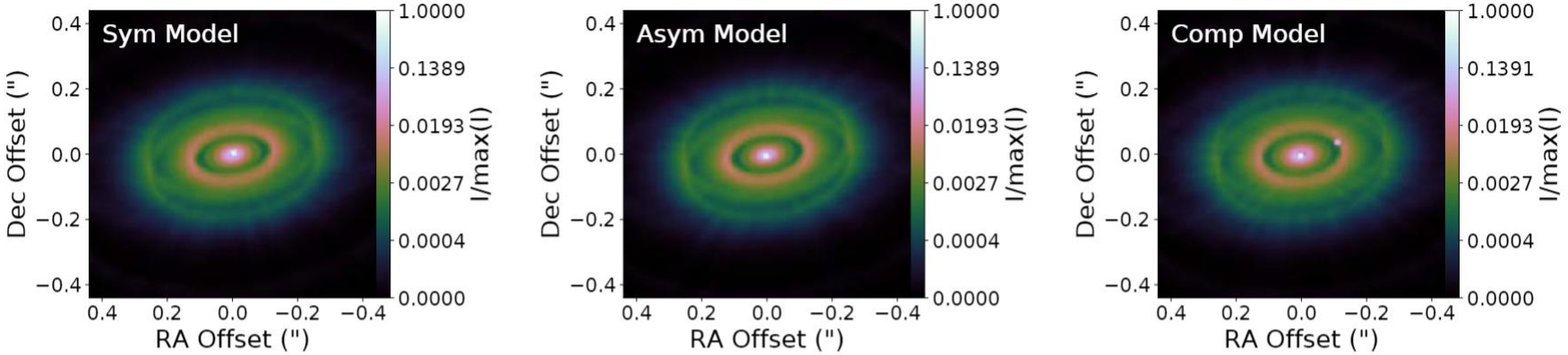
- Disc cavity smaller than observations
- Dust asymmetry not as large as observations
- No massive companion detected

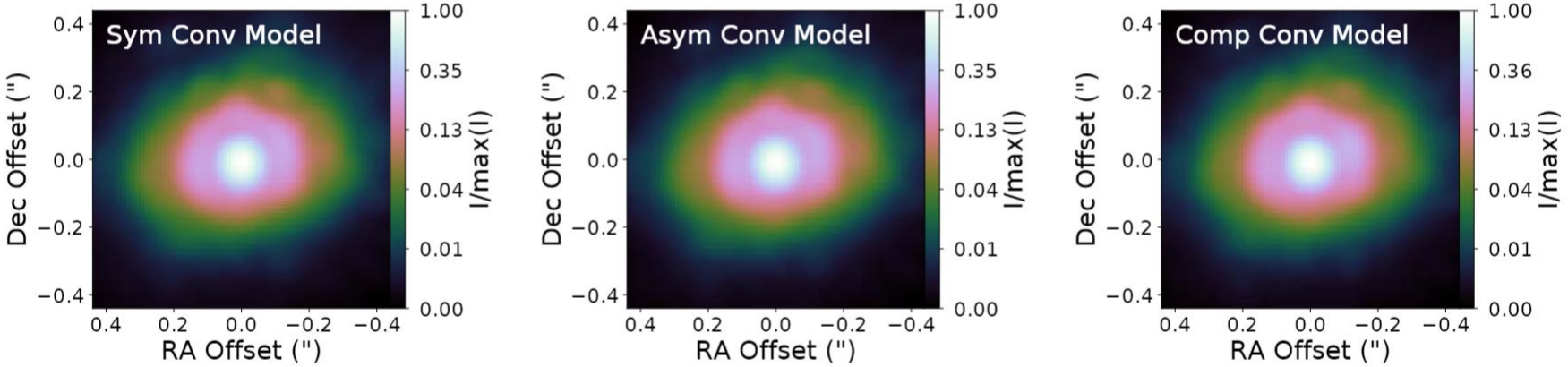
Solutions

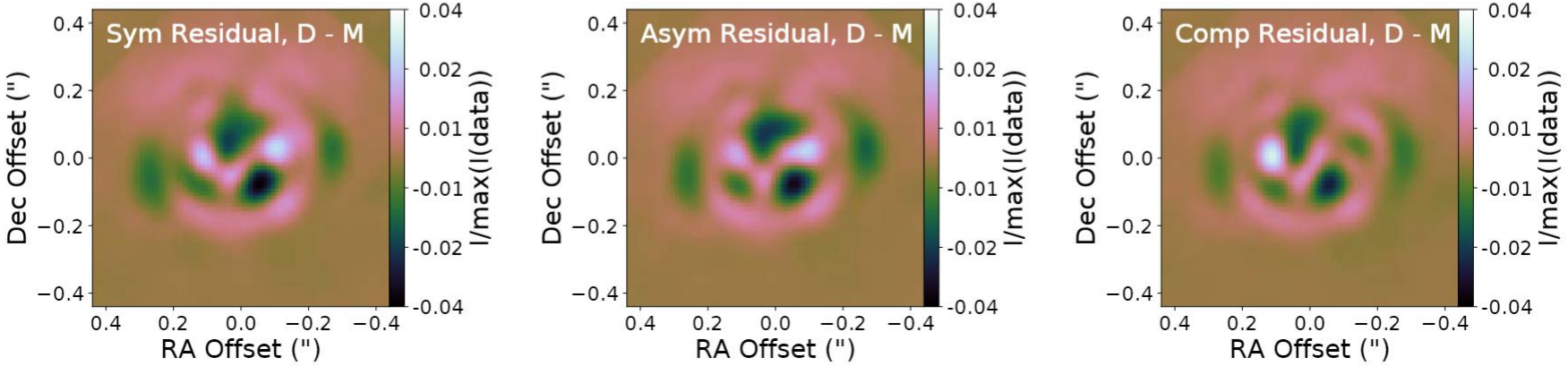
- Increase secondary/primary mass ratio, increase primary/secondary separation
- Run simulations longer, lower viscosity
- No massive companion detected yet

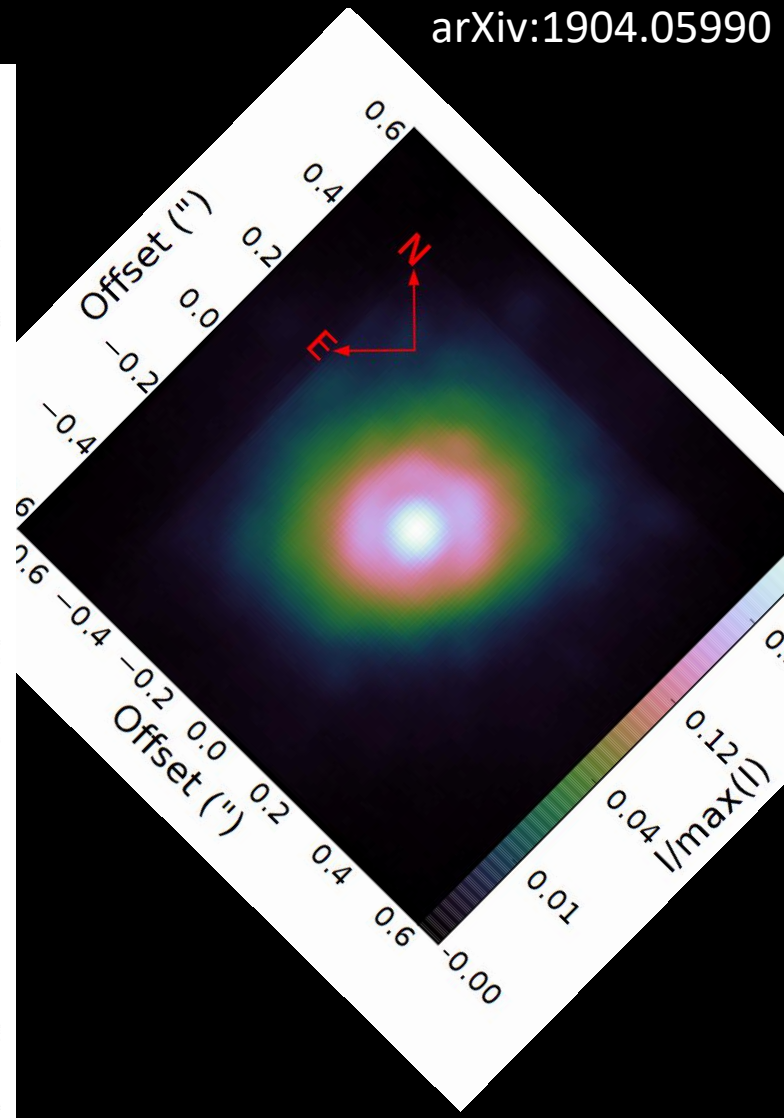
Is there a companion?

arXiv:1904.05990









Observations taken with Keck

Is there a companion?

Parameter	Oph IRS 48 Symmetric	Asymmetric	Companion
Dust to gas ratio	$3.10\pm0.66 \times 10^{-3}$	$3.20\pm0.26 \times 10^{-3}$	$2.06\pm0.09 \times 10^{-3}$
δ_d	$2.48\pm0.43 \times 10^{-4}$	$2.11\pm0.23 \times 10^{-4}$	$4.20\pm0.35 \times 10^{-4}$
δ_1	$1.01\pm0.10 \times 10^{-2}$	$9.40\pm0.61 \times 10^{-3}$	$1.24\pm0.06 \times 10^{-2}$
r_d (AU)	1.6±0.2	1.4±0.1	2.0±0.1
r_d (mas)	12±1	10±1	15±1
r_1 (AU)	15.0±0.3	14.6±0.1	15.2±0.2
r_1 (mas)	112±2	108±1	113±1
r_2 (AU)	32.1±0.9	31.0±0.3	31.3±0.3
r_2 (mas)	238±7	231±2	233±2
Inclination (°)	54.8±0.5	54.2±0.3	52.4±0.3
Position angle (°)	99.0±0.6	98.8±0.3	96.5±0.4
Star offset (mas)	-	5.0±0.4	5.3±0.3
Star offset position angle (°)	-	118.7±7.8	122.9±8.2
Companion offset (mas)	-	-	104±2
Companion position angle (°)	-	-	288.6±4.6
Companion contrast (mag)	-	-	3.97±0.05
Flux Ratio (7.8)	7.8	7.8	7.8
Reduced $\chi^2_{\rm shot}$	65.1	60.0	48.0
Reduced $\chi^2_{\rm shot}$ 2016 data	68.3	61.0	52.6

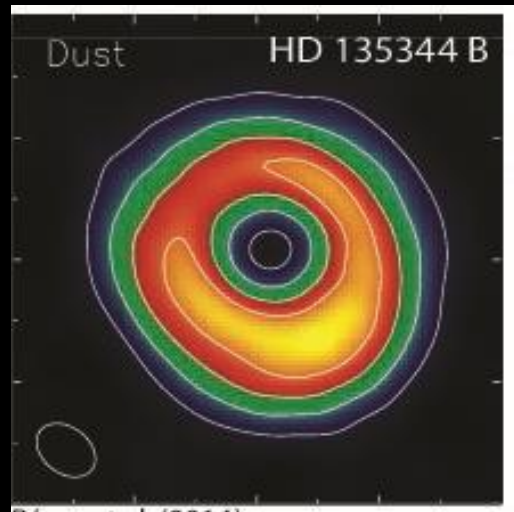
~10 au separation

Flux ratio some what consistent with the mass ratio

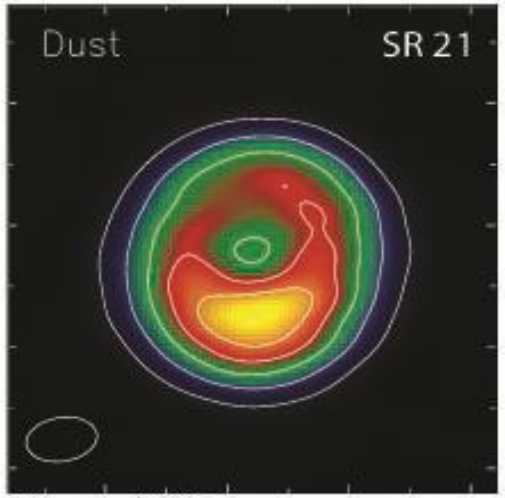
Circumbinary disk or a Vortex?

Feature	C	V
Dust asymmetry	✓	✓
Dust contrast Ratio	? ✓	✓
Velocity Map	✓	?
Channel Maps	✓	?
Disk asymmetry	✓	?
Offset Stellar Position	✓	?

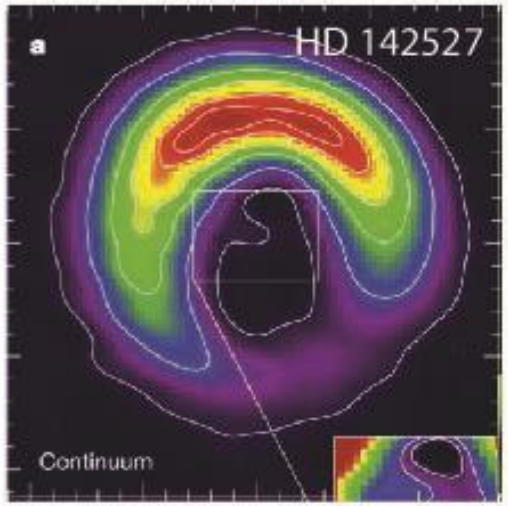
Observations of Transition Disks



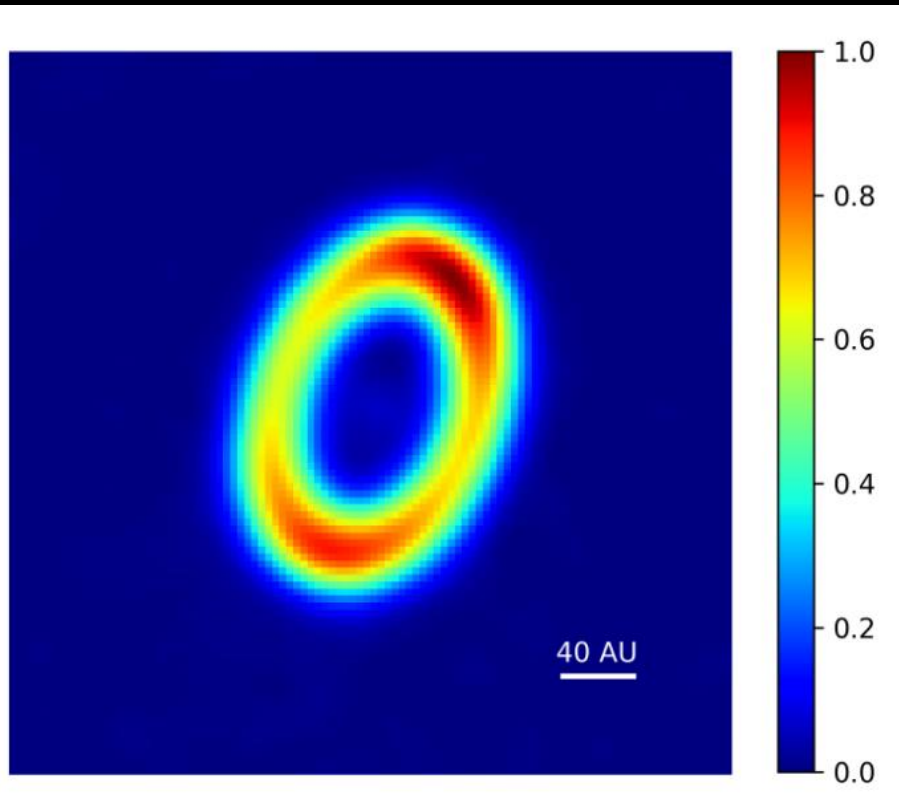
Pérez et al. (2014)

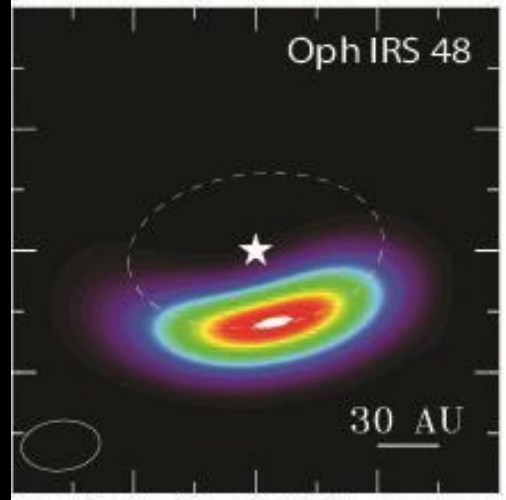


Pérez et al. (2014)

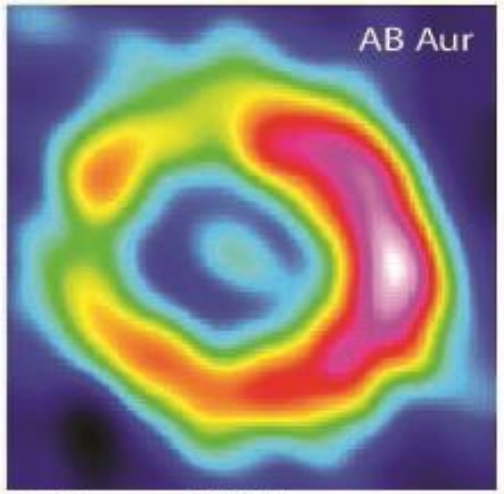


Casassus et al. (2013)

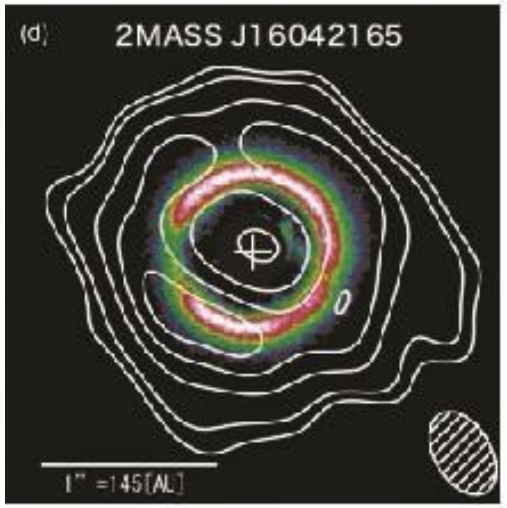




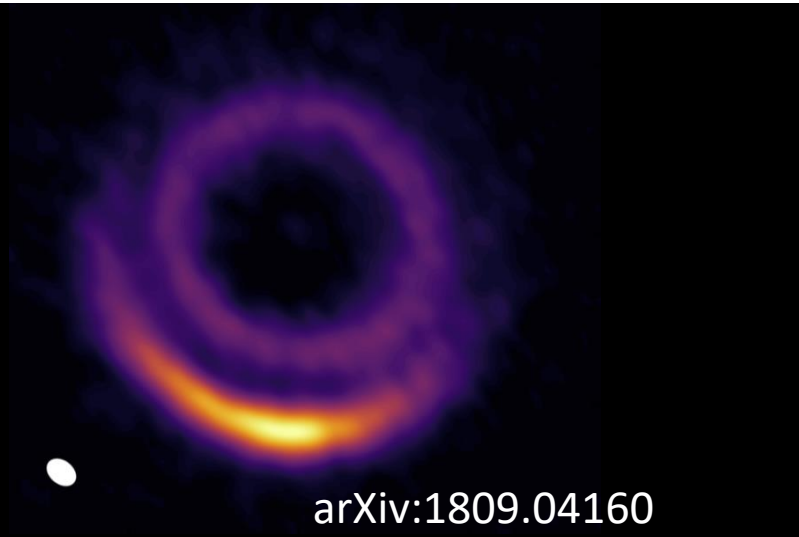
van der Marel et al. (2013)



Rodriguez et al. (2014)



Mayama et al. (2012)


arXiv:1809.04160