Planet spirals in transition disks: a cautionary tale

Wladimir Lyra

California State University, Northridge

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Alex Richert (Penn State University)

Mario Flock (JPL),

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Aaron Boley (University of British Columbia)

Mordecai-Mark Mac Low (AMNH)

Satoshi Okuzumi (Tokyo Tech)

ExSoCal, Sep 19th, 2017

CSUN (pronounced “sea-sun”)
aka Starfleet Academy

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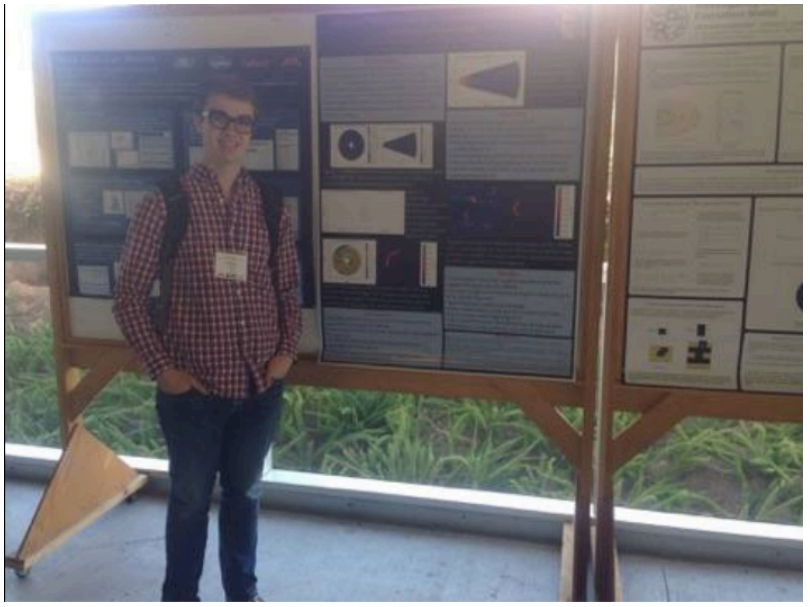
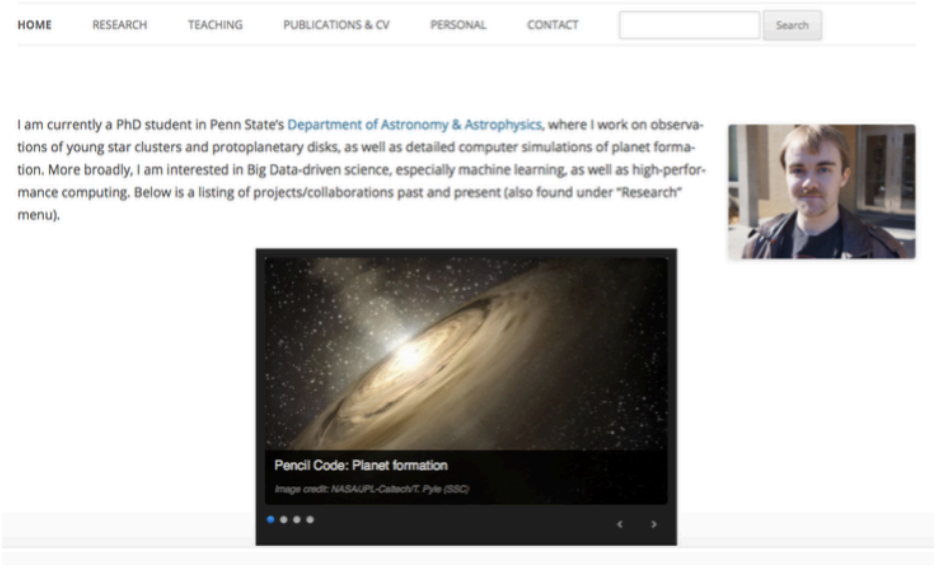
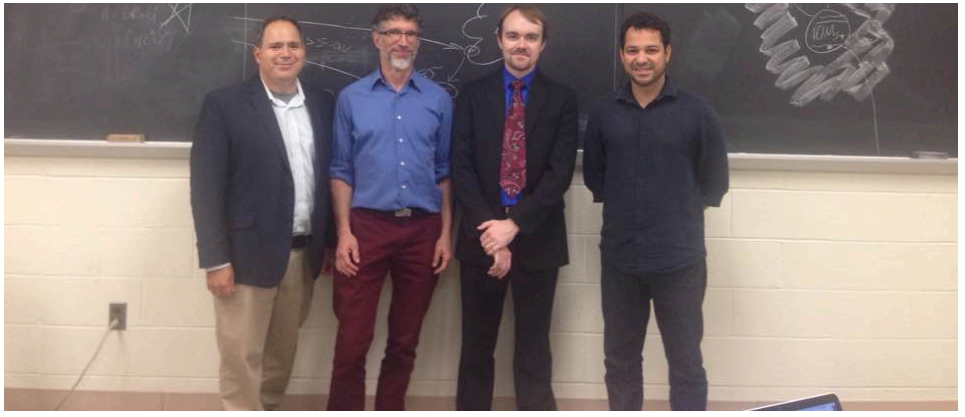
Blake Hord

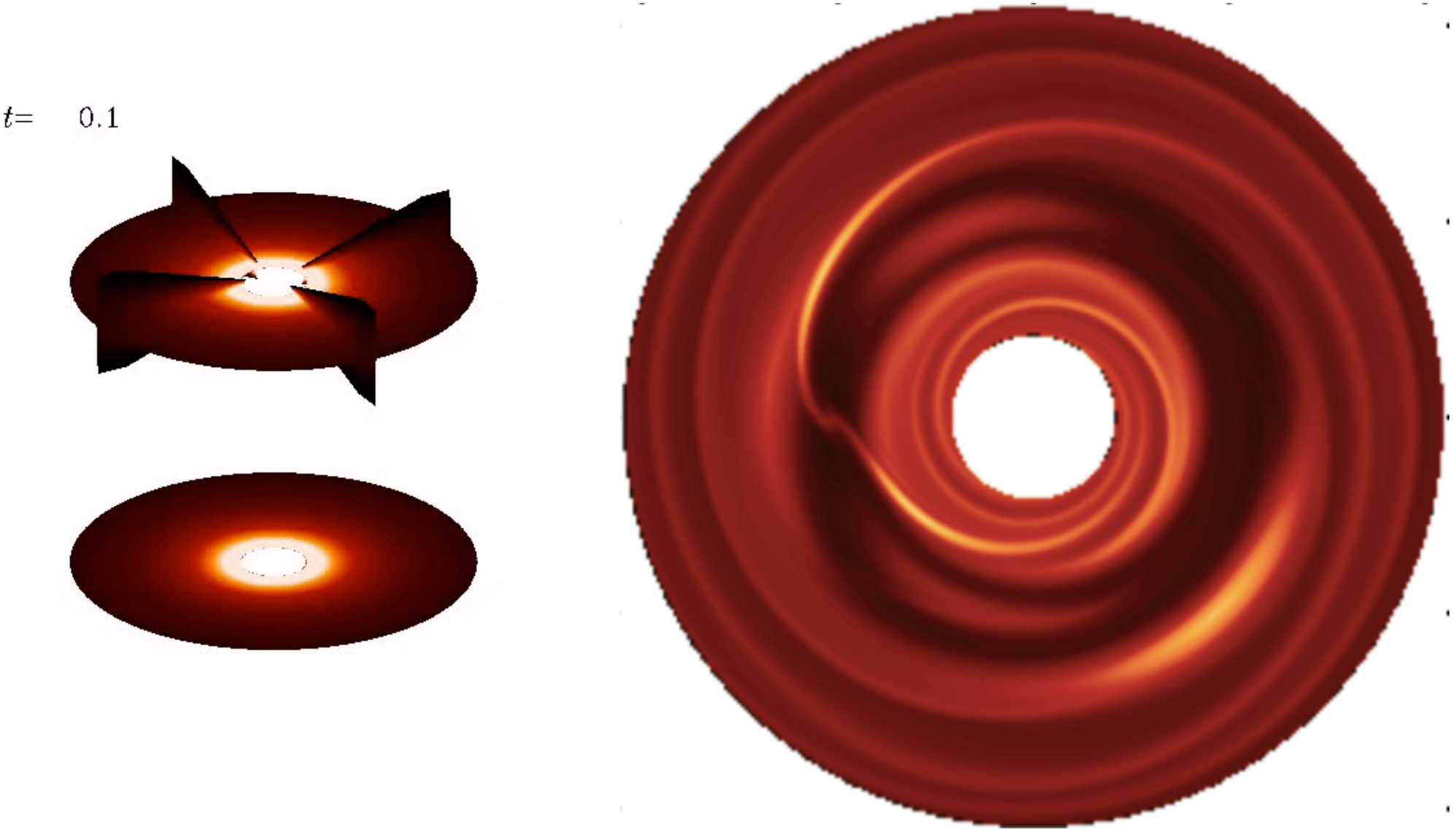


Alex Richert





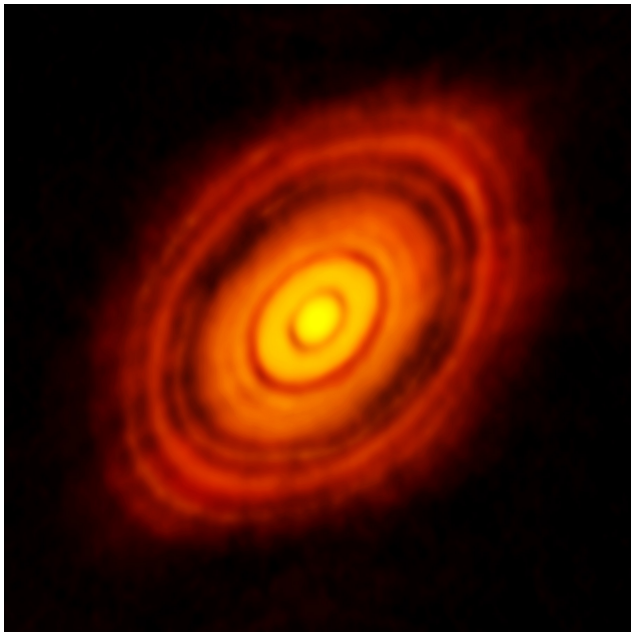
Planet-disk interaction model predictions: gaps, spirals, and vortices.



(Lyra et al. 2009b)

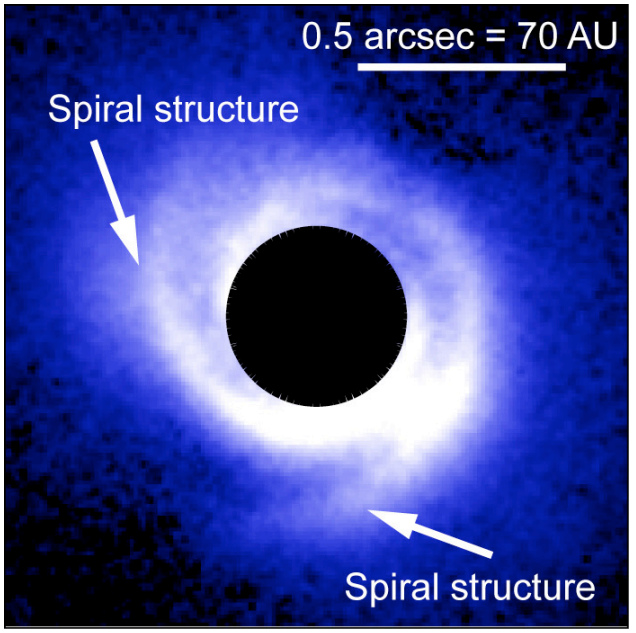
Observational evidence: gaps, spirals, and vortices

HL Tau



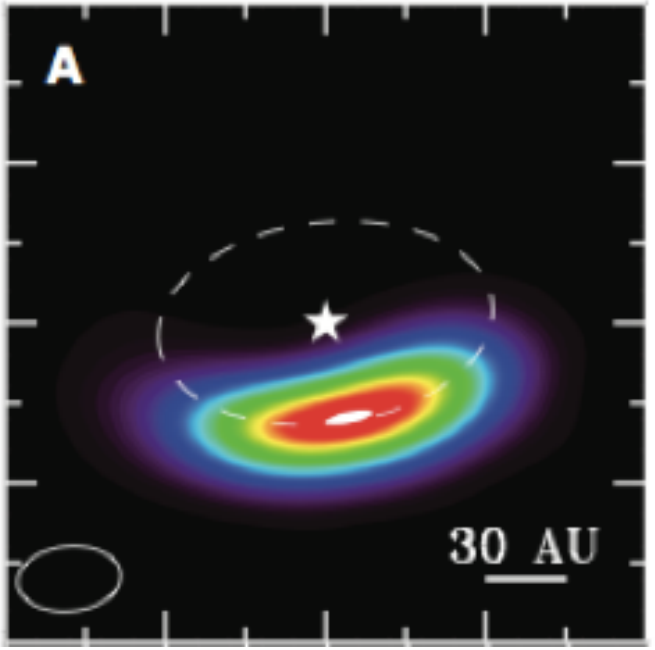
The ALMA Partnership et al. (2015)

SAO 206462



Muto et al. (2012)

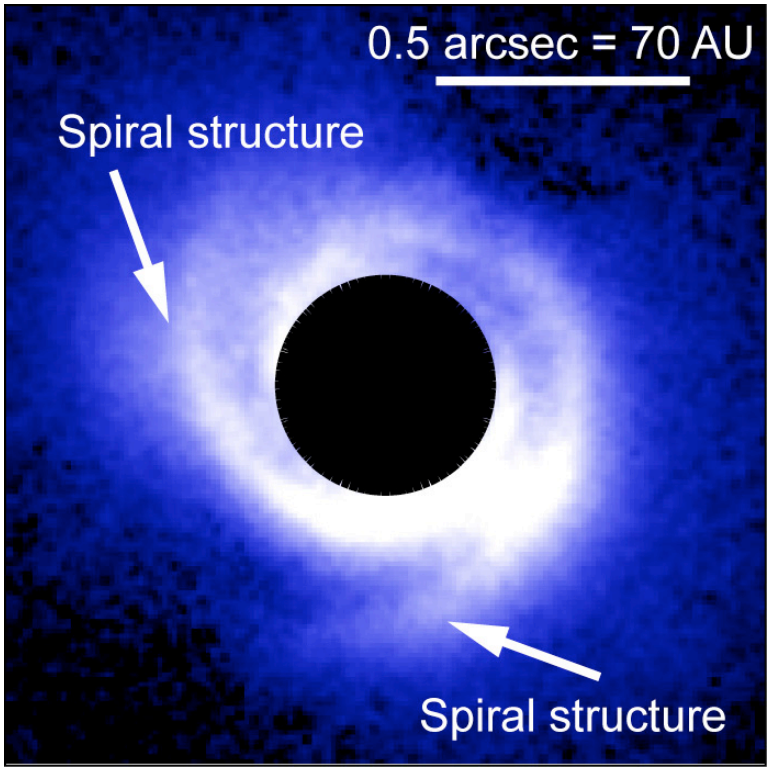
Oph IRS 48



van der Marel et al. (2013)

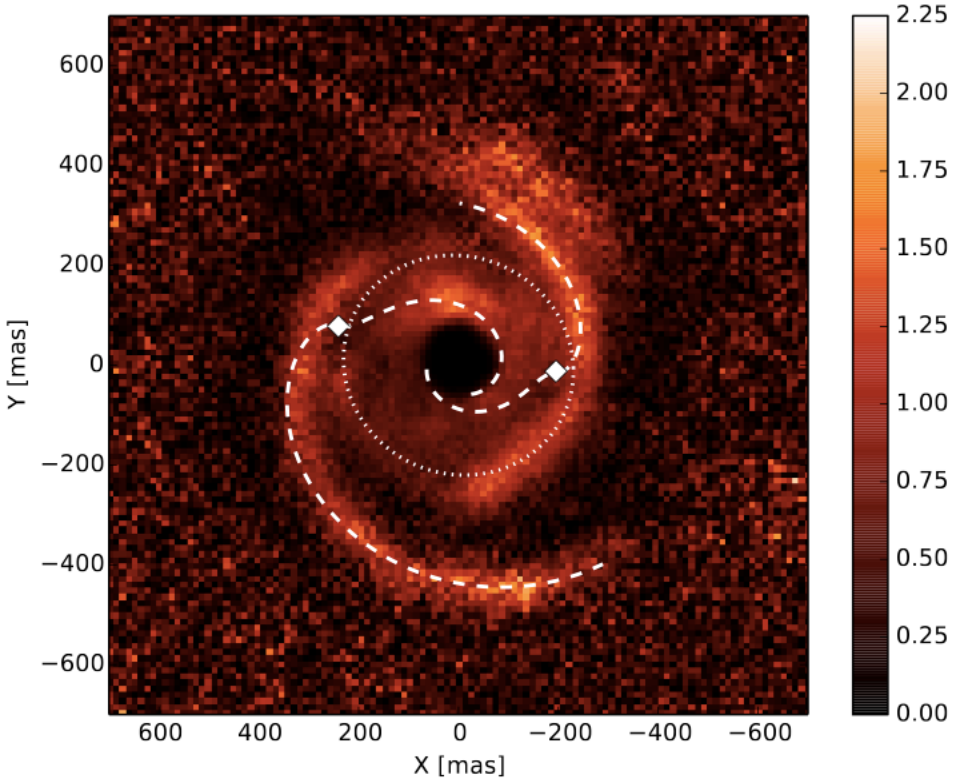
Observational Evidence: Spirals

SAO 206462



Muto et al. (2012)

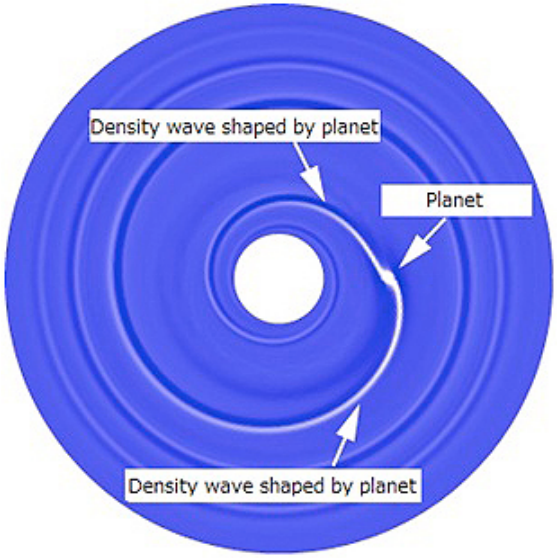
MWC 748



Benisty et al. (2015)

Spiral arm fitting leads to problems

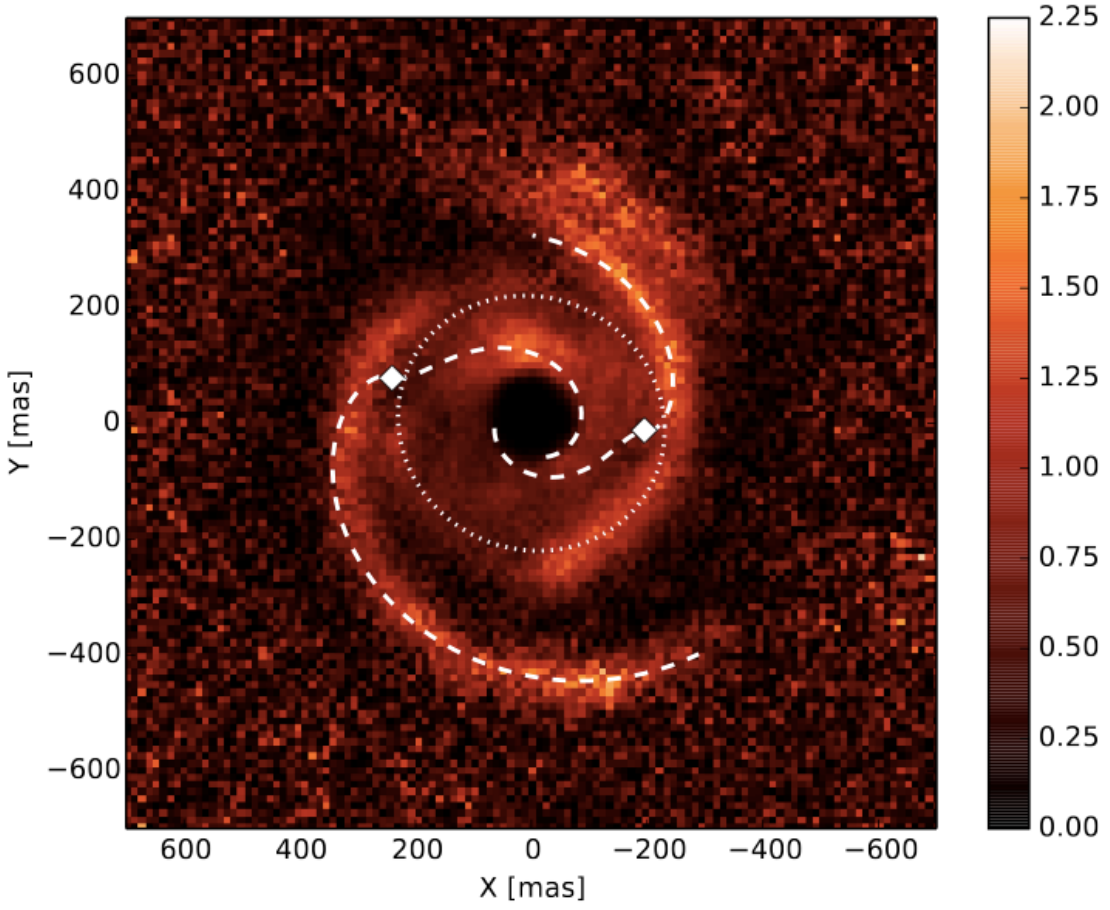
Analytical spiral fit



$$\theta(r) = \theta_c + \frac{\mathrm{sgn}(r - r_c)}{h_c} \times \left\{ \left(\frac{r}{r_c}\right)^{1+\beta} \left[\frac{1}{1+\beta} - \frac{1}{1-\alpha+\beta} \left(\frac{r}{r_c}\right)^{-\alpha} \right] - \left(\frac{1}{1+\beta} - \frac{1}{1-\alpha+\beta} \right) \right\},$$

Rafikov (2002)
Muto et al. (2012)

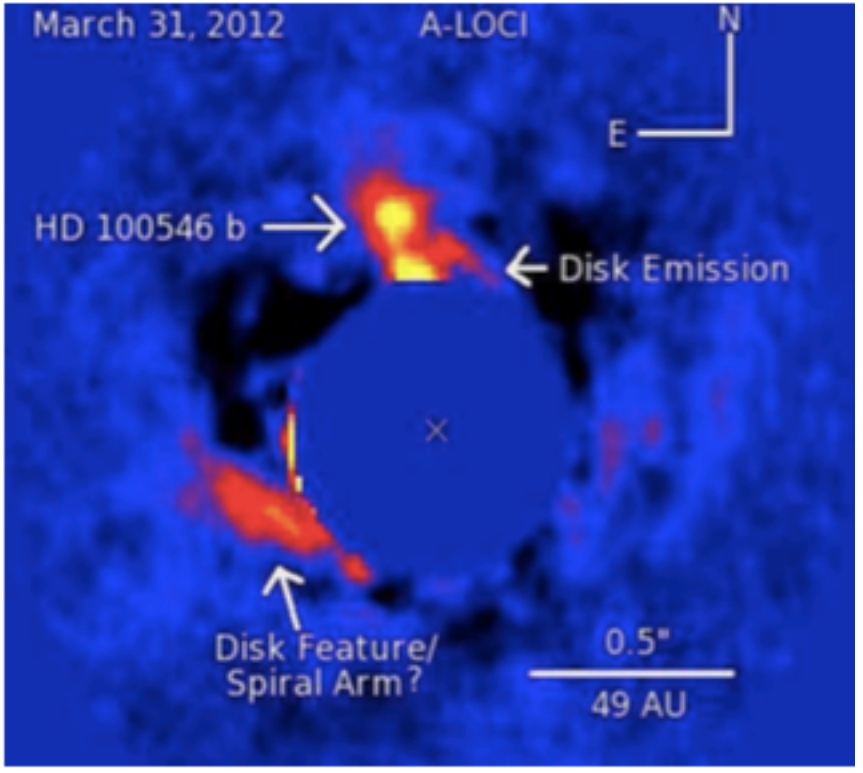
Spirals are **too wide**,
hotter (300K) than ambient gas (50K).



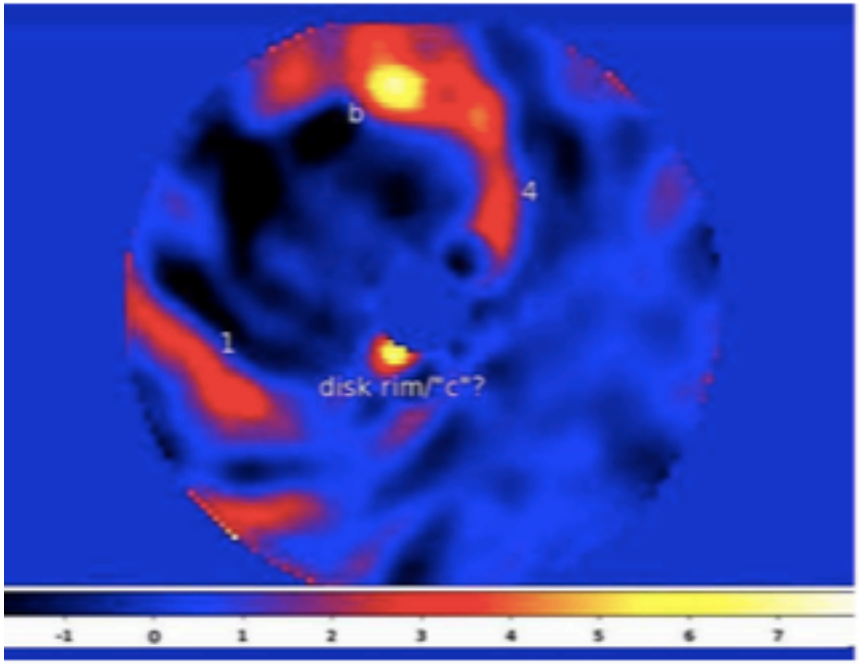
Benisty et al. (2015)

The strange case of thermal emission in HD 100546

L band (~3.5 μm)

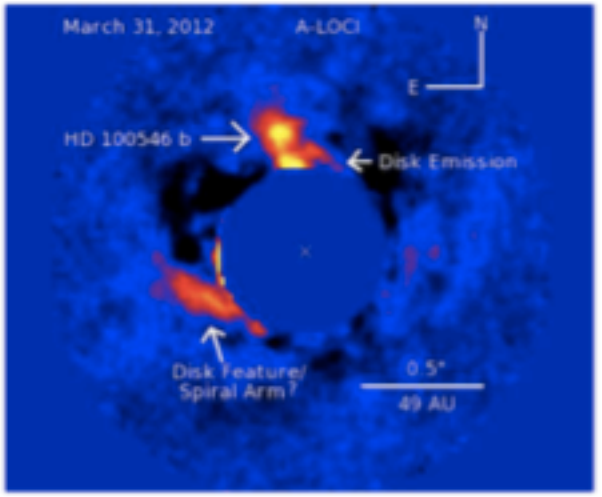


H band (~1.6 μm)

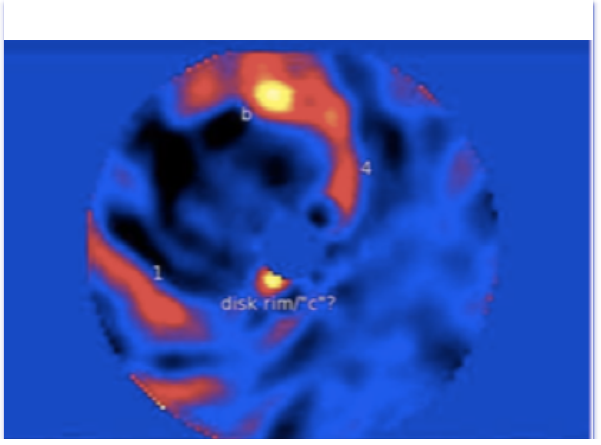


Currie et al. (2014), Currie et al. (2015)

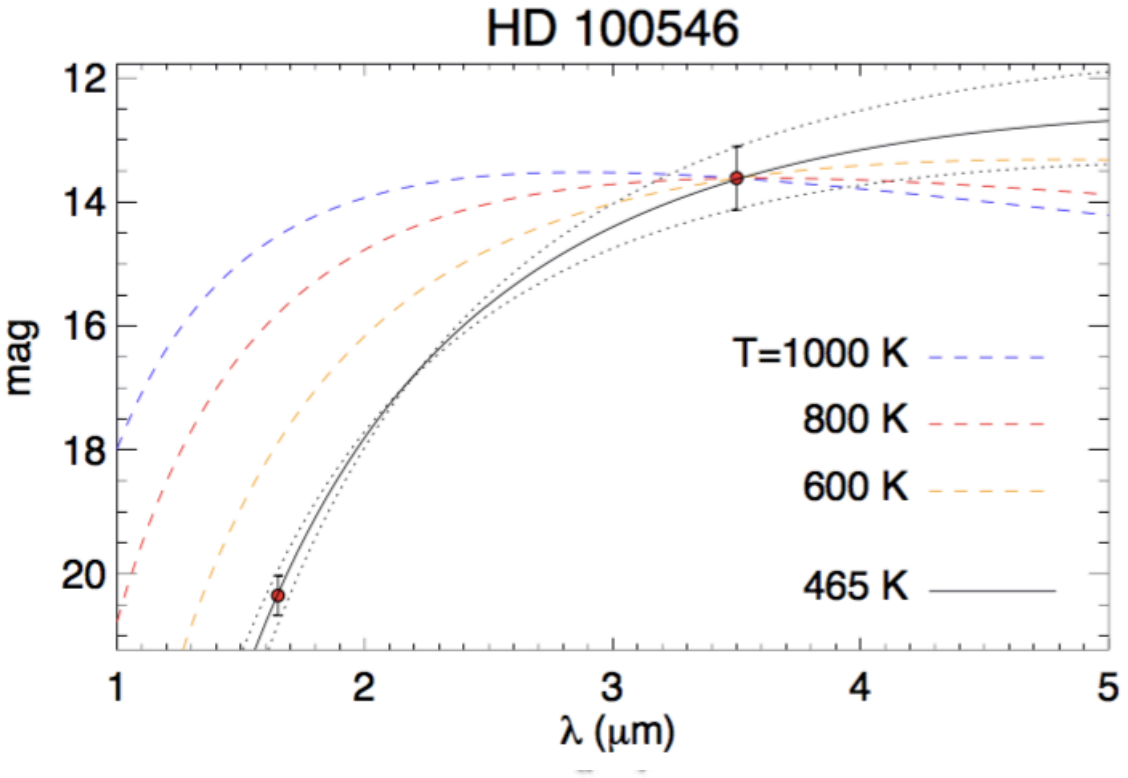
Pinning down the temperature



L band



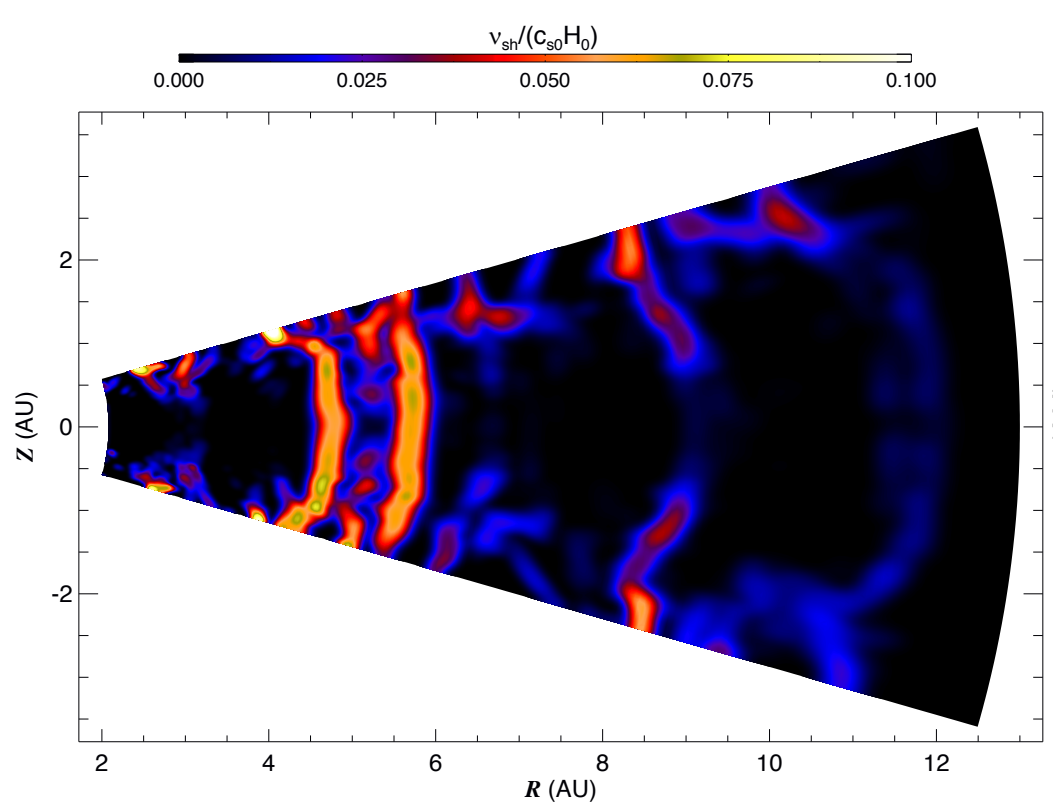
H band



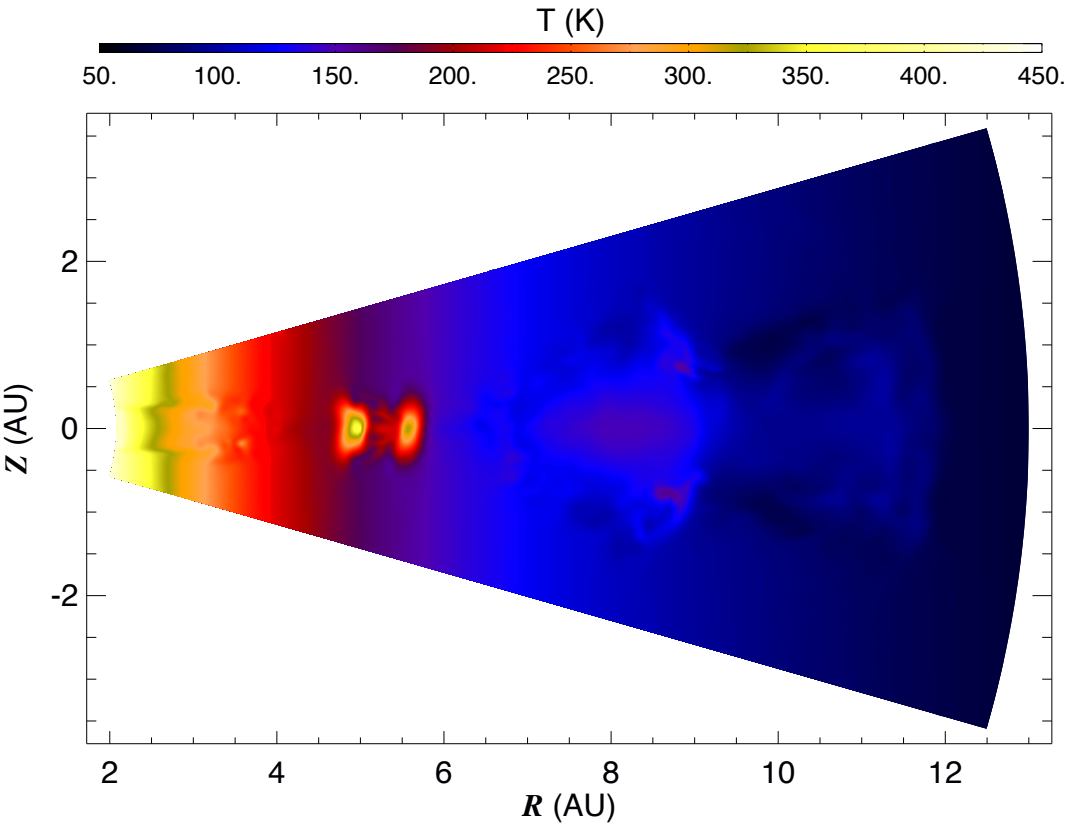
Lyra et al. (2016)

3D: Shock bores

Shocks (velocity convergence)



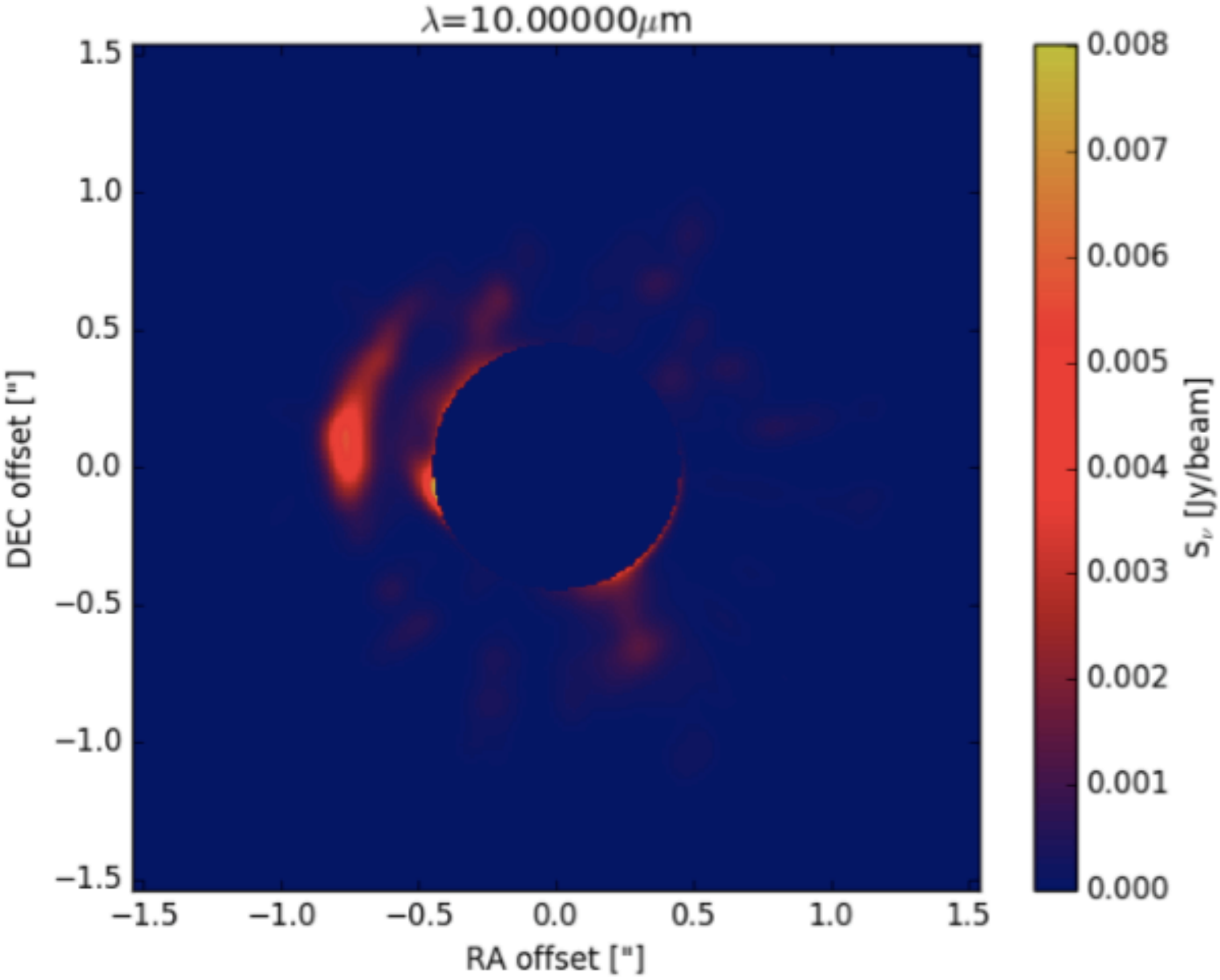
Temperature



Lyra et al. (2016)

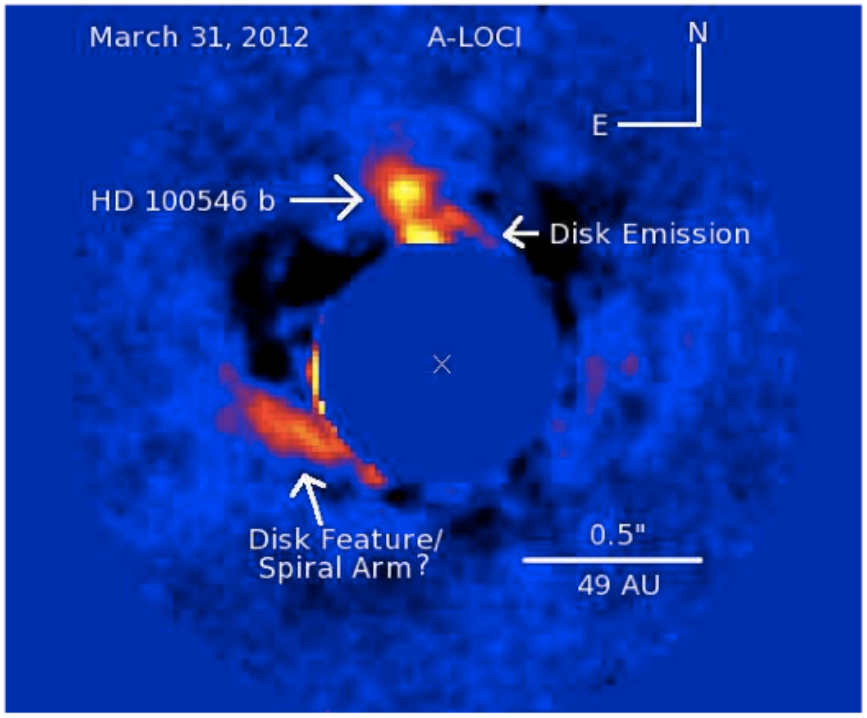
Your model doesn't look like my observation. Why should I care?

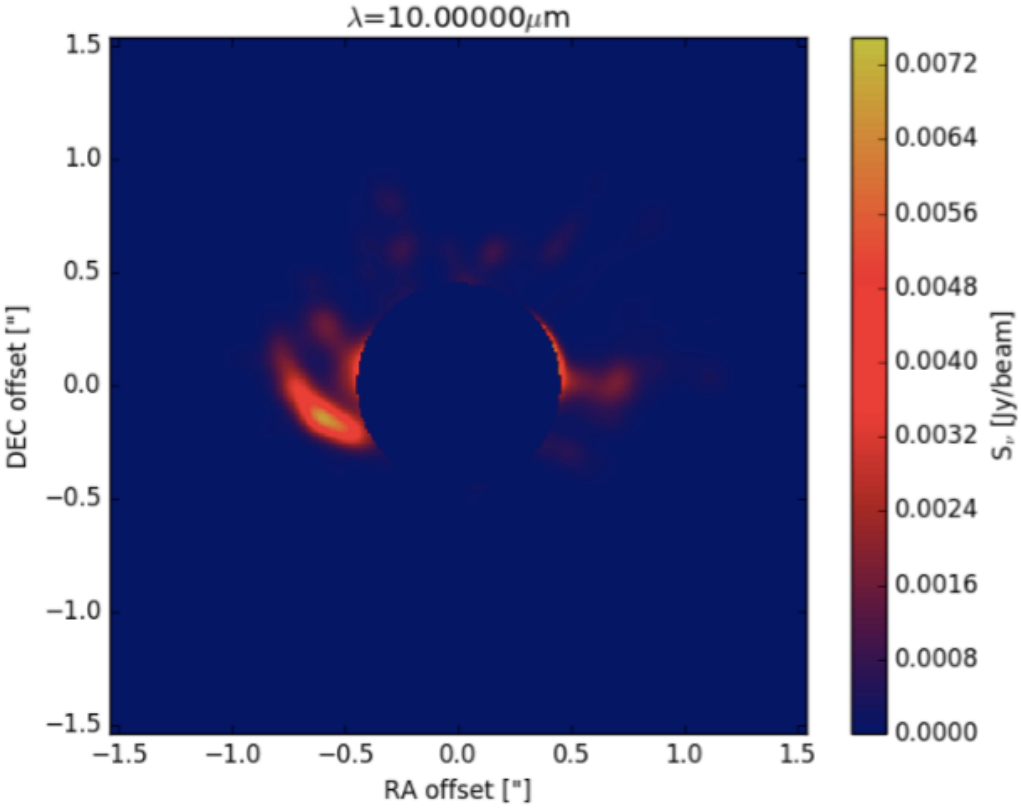
Synthetic image



Hord et al. (2017)

Observation vs Synthetic Image

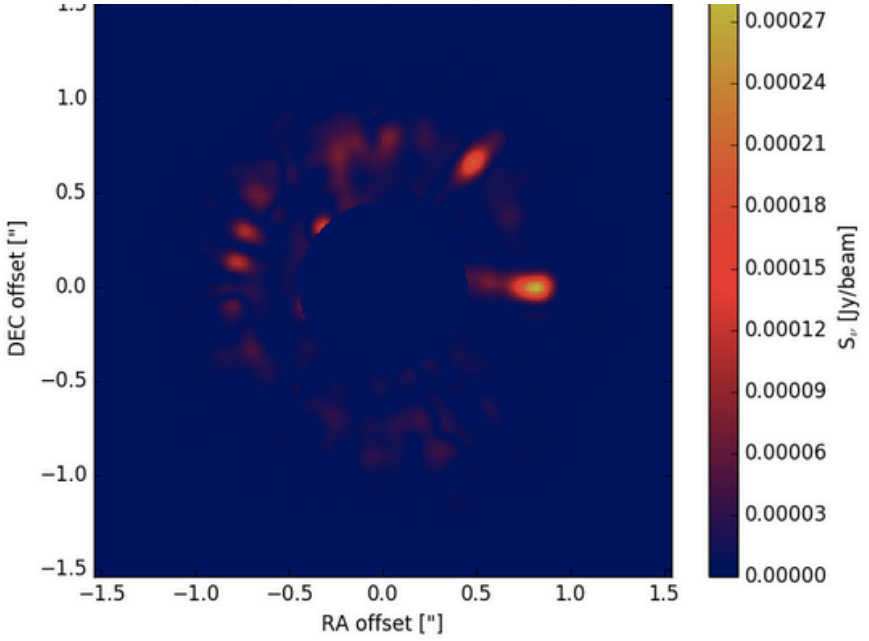




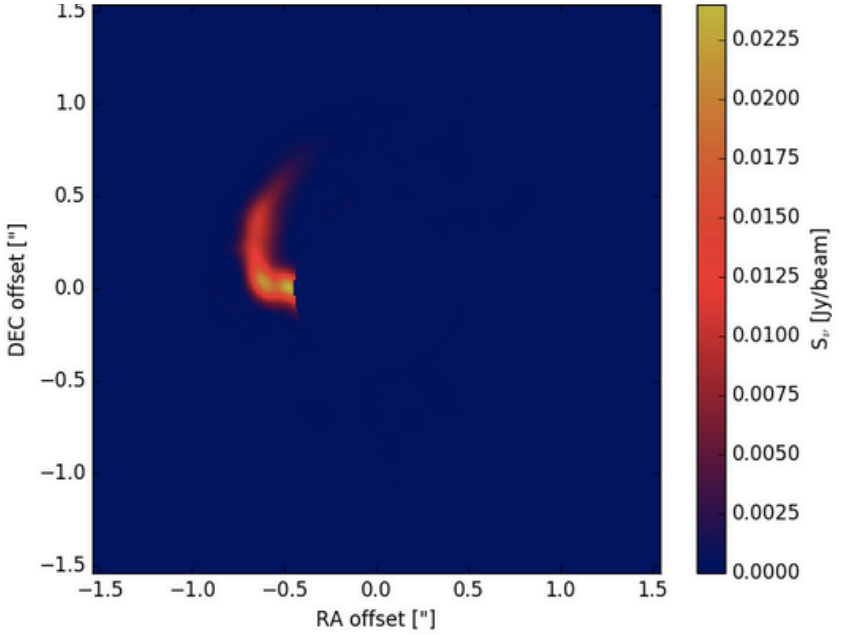
Hord et al. (2017)

Effect of shocks alone

1 μm

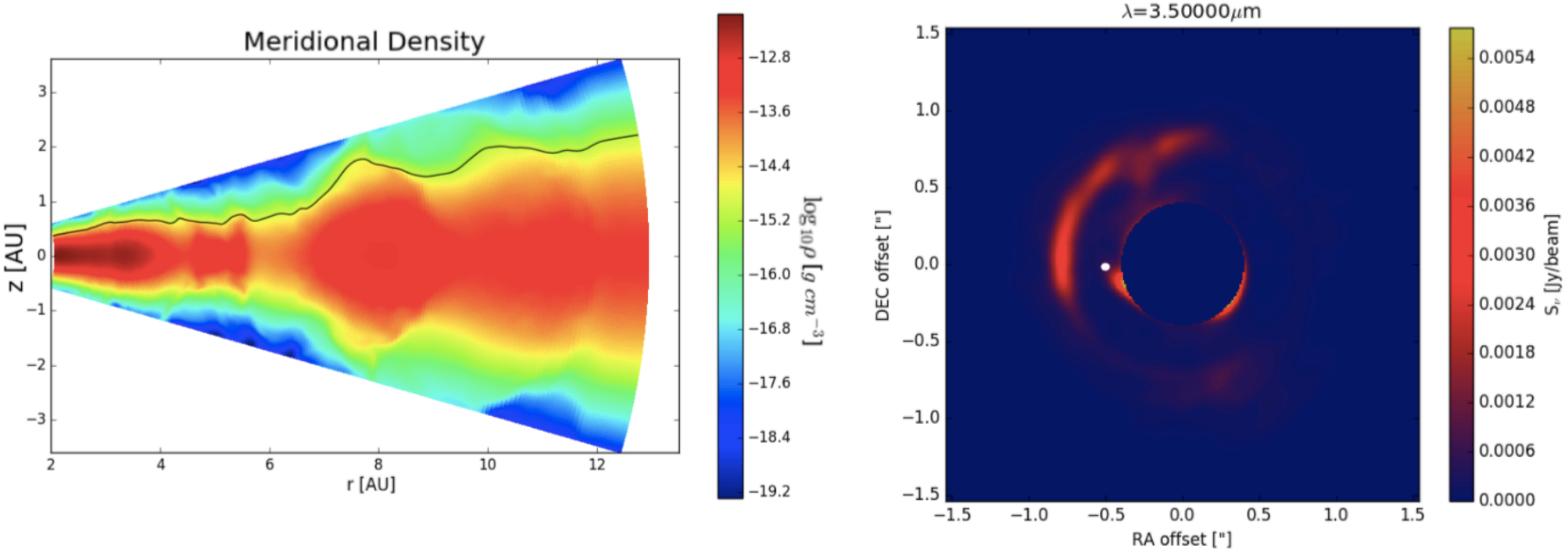


10 μm



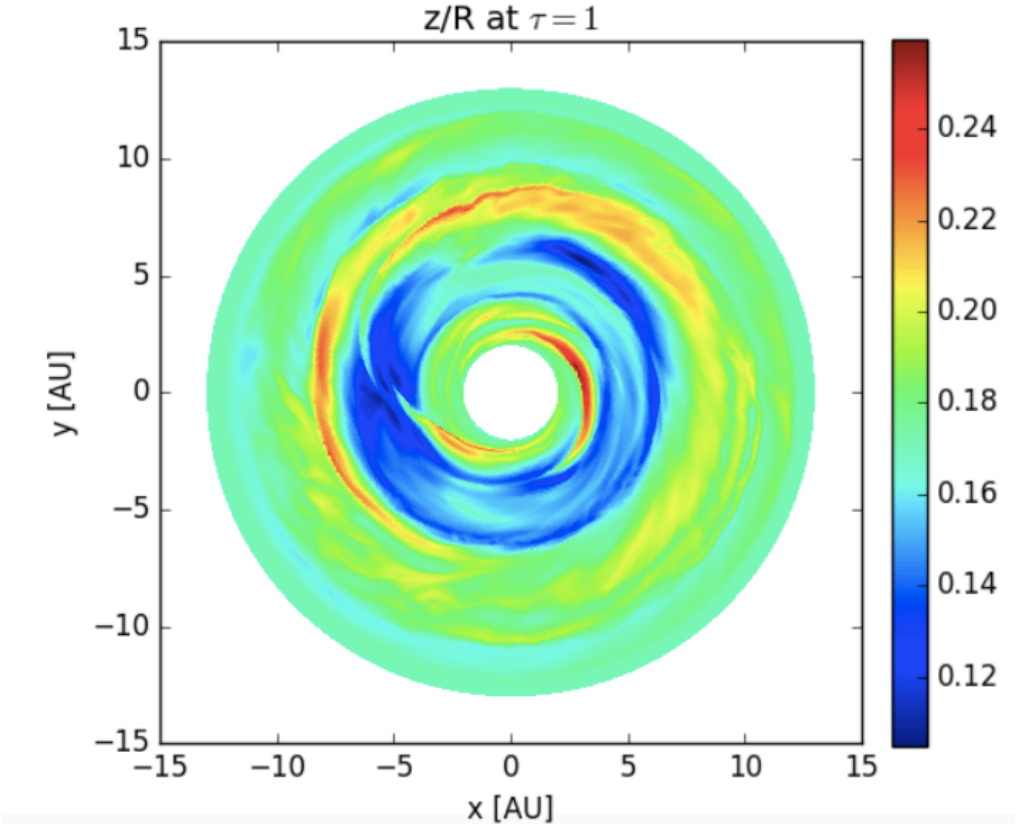
Hord et al. (2017)

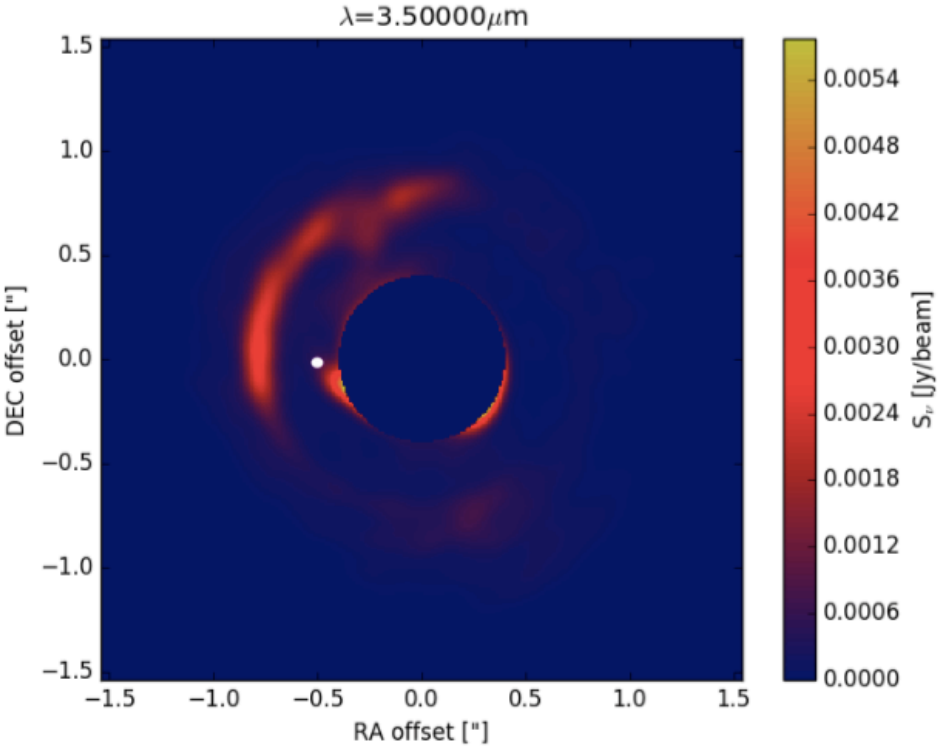
Scattering – A puffed up outer gap



Hord et al. (2017)

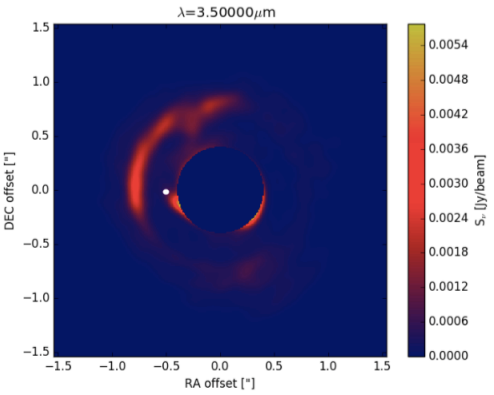
Scattering

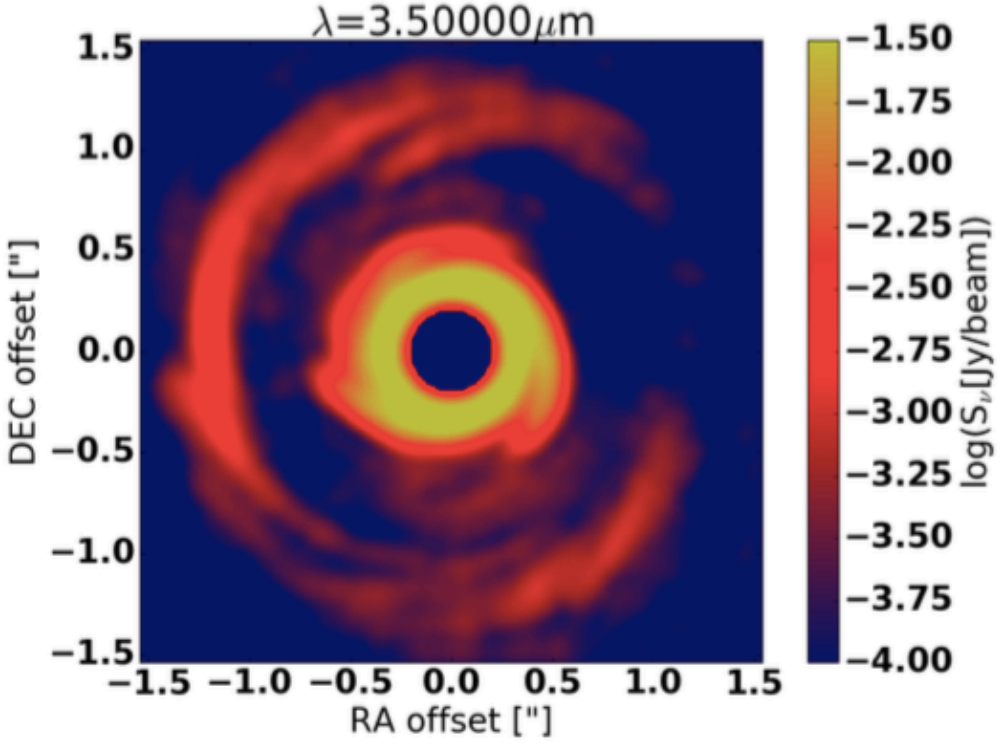


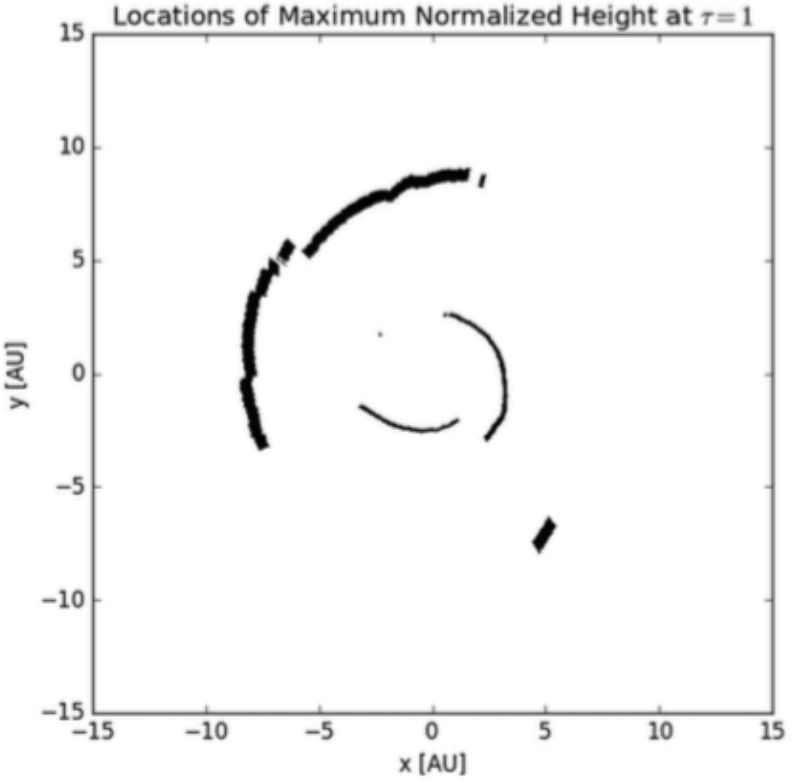


Hord et al. (2017)

We see what is not in the shadow of the inner disk spirals

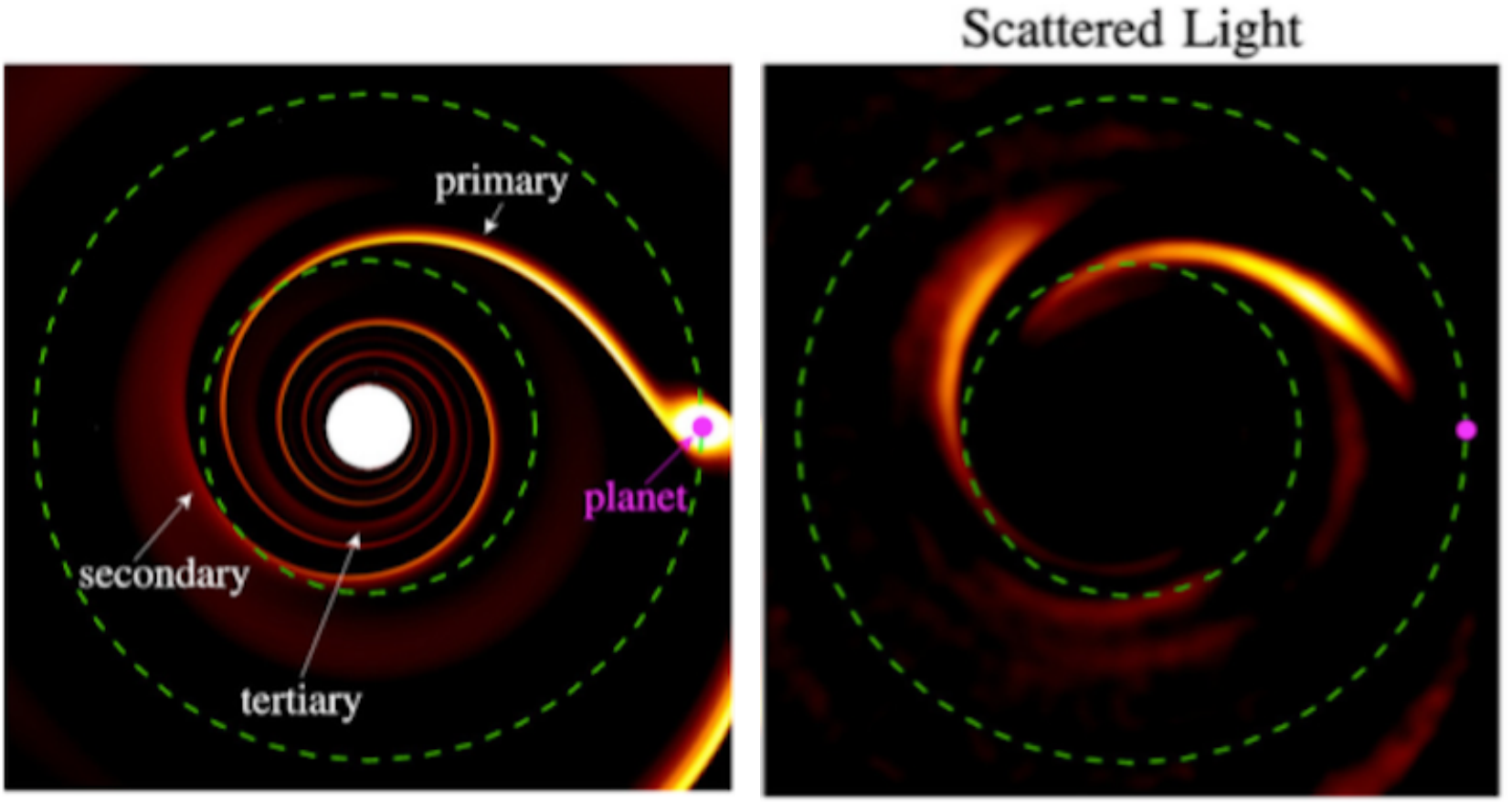






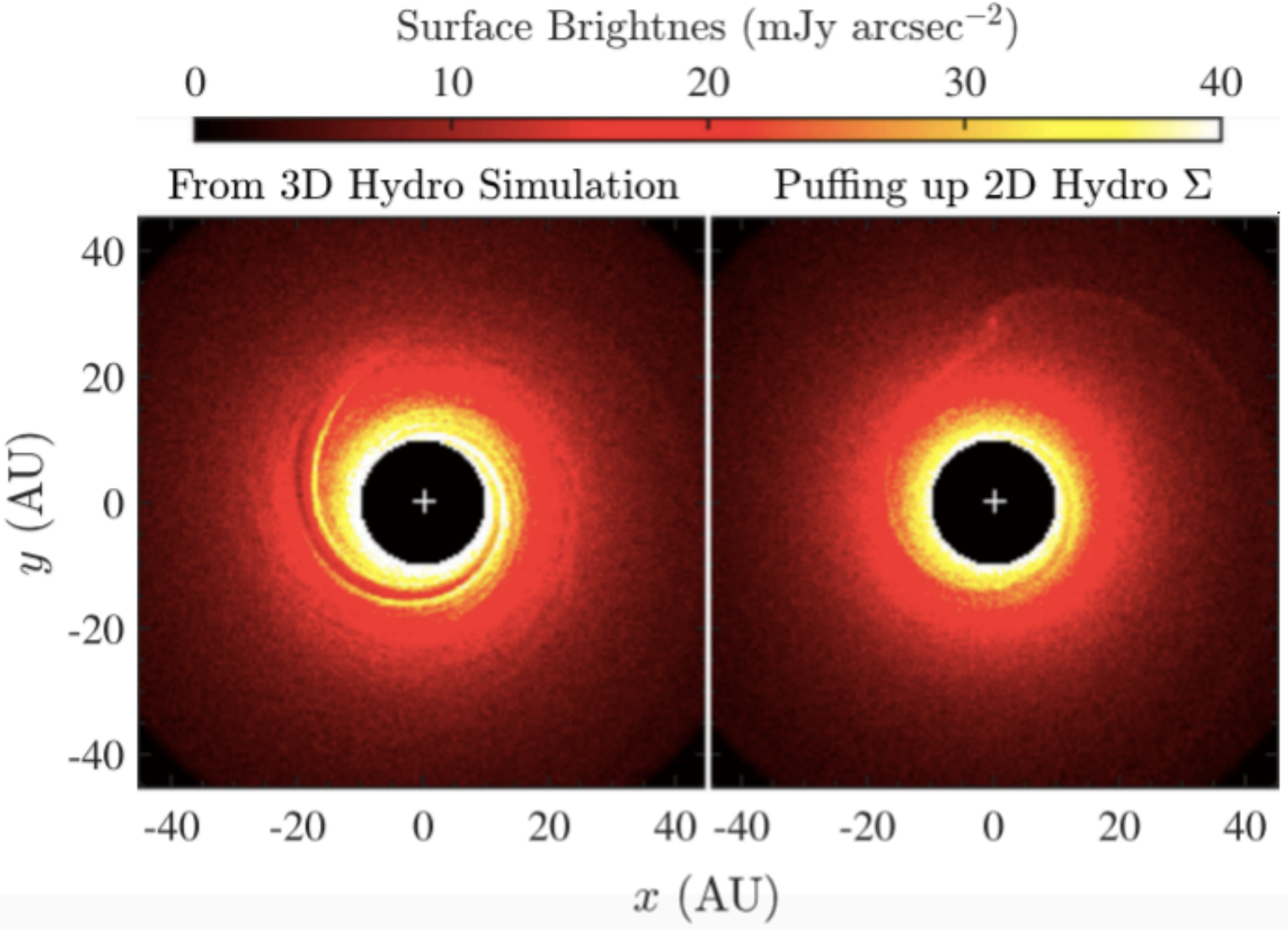
Hord et al. (2017)

Primary and Secondary spiral arms



Dong et al. (2015)

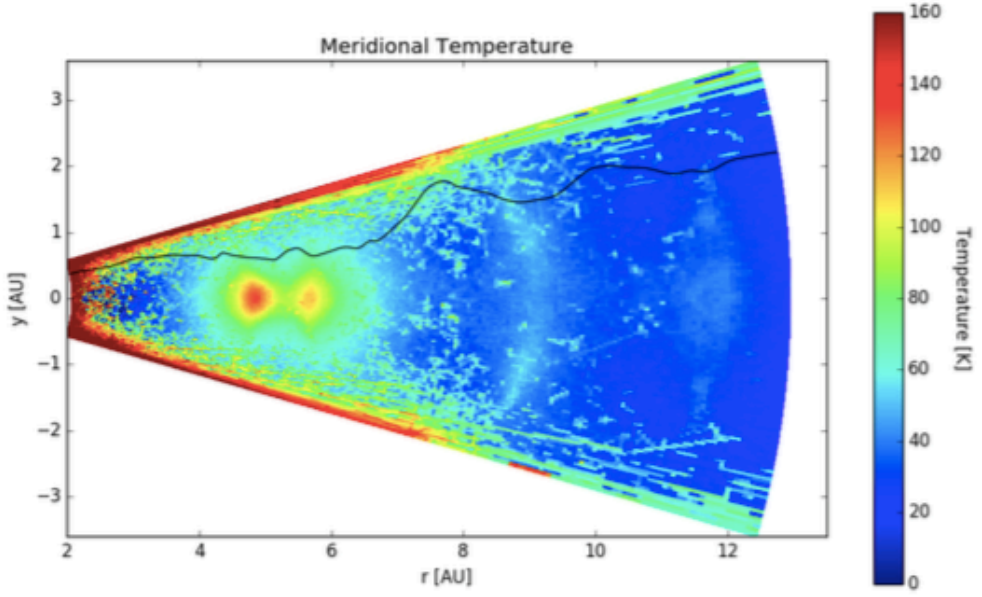
3D is needed

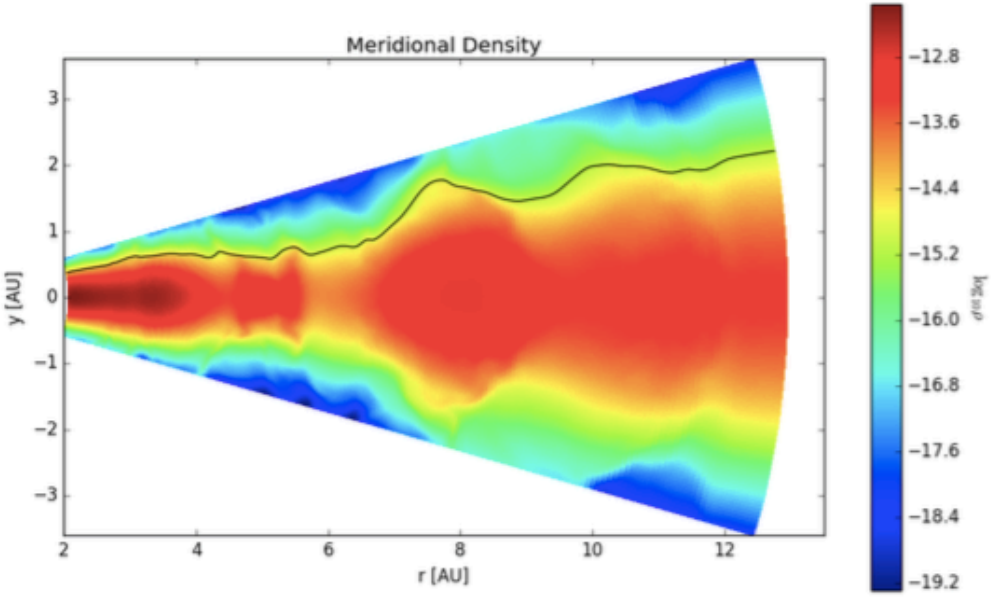


Dong & Fung (2017)

Conclusions

- 3D radiation-hydro models give results widely different than 2D isothermal
- Planet-induced shocks modify disk structure
- Hot lobes near high-mass planets in high resolution
- Planets puff up their outer gaps – visible in scattered light





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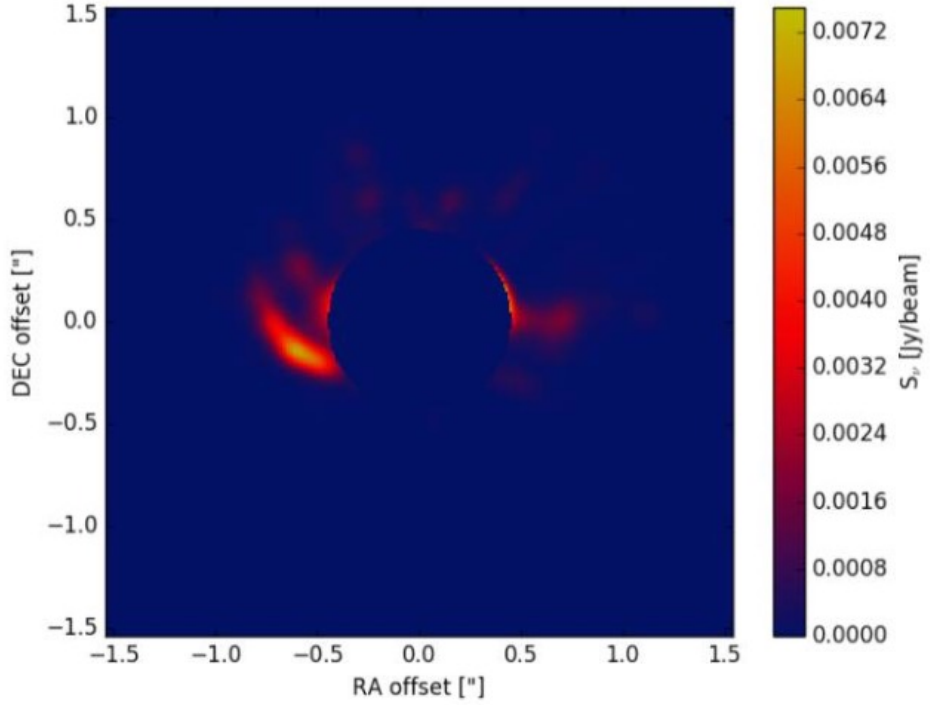

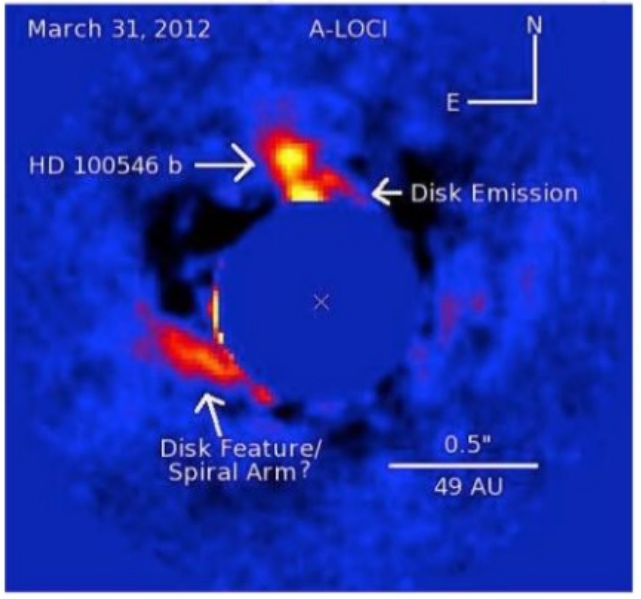

Scattering: “the light that never warms”

Hellish glare and in(ter)ference
The Queenly flux, eternal light
Or the light that never warms
Yes the light that never, never warms
Or the light that never
Never warms
Never warms
Never warms

Astronomy… a star

Astronomy
(Metallica, 1998)