

Planet spirals in transition disks: a cautionary tale



Wladimir Lyra

California State University, Northridge
Jet Propulsion Laboratory



Blake Hord (Dobbs Ferry High School, Stanford University),

Alex Richert (Penn State University)

Mario Flock (JPL),

Neal Turner (JPL),

Aaron Boley (University of British Columbia)

Mordecai-Mark Mac Low (AMNH)

Satoshi Okuzumi (Tokyo Tech)

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



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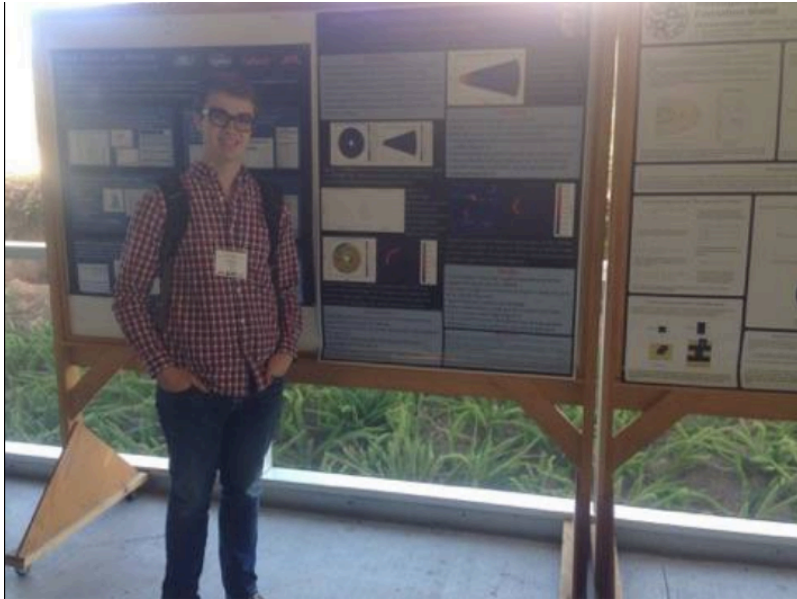
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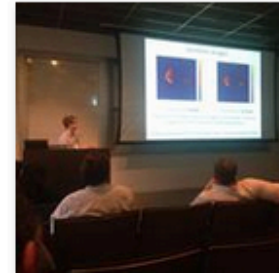
Blake Hord



Wladimir Lyra

September 22 at 12:32pm · Twitter · 🌐 ▼

Blake Hord, my high-school intern, presenting the summer research he did at #csun. #ExSoCal 2016. <https://t.co/JypTSoiSte>



Wladimir Lyra (@wladlyra) posted a photo on Twitter

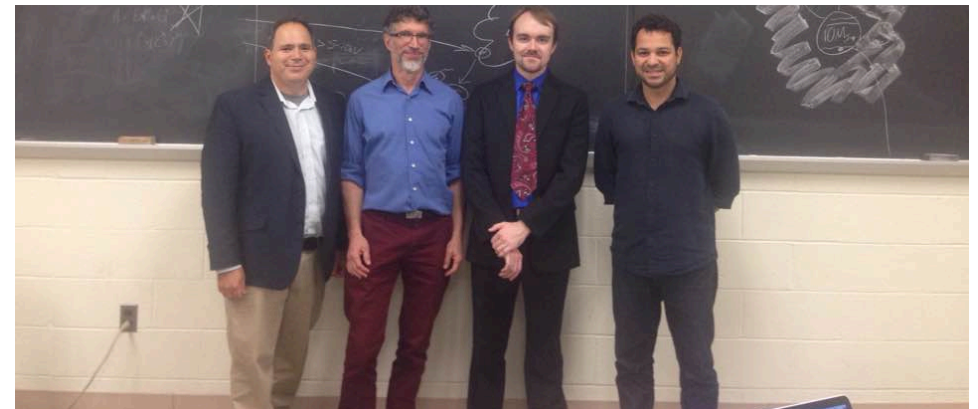
Get the whole picture - and other photos from Wladimir Lyra

[PIC.TWITTER.COM/JYPTSOISTE](https://pic.twitter.com/JyPTSoiSte) | BY WLADIMIR LYRA

Alex Richert

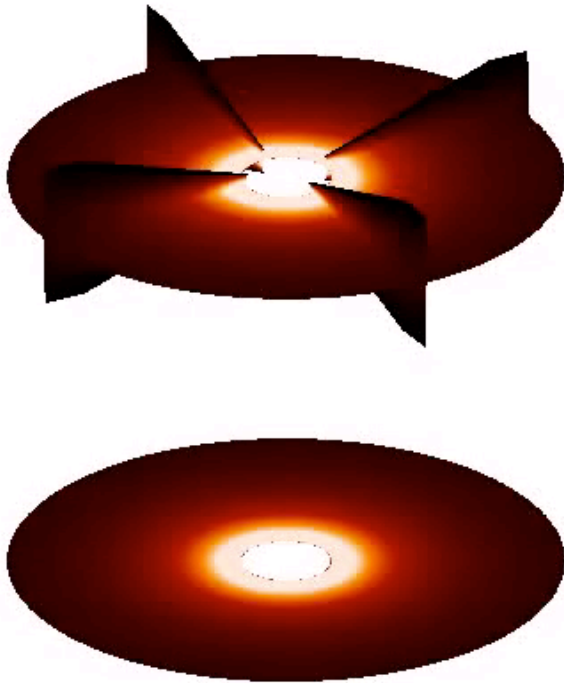
HOME RESEARCH TEACHING PUBLICATIONS & CV PERSONAL CONTACT Search

I am currently a PhD student in Penn State's Department of Astronomy & Astrophysics, where I work on observations of young star clusters and protoplanetary disks, as well as detailed computer simulations of planet formation. More broadly, I am interested in Big Data-driven science, especially machine learning, as well as high-performance computing. Below is a listing of projects/collaborations past and present (also found under "Research" menu).



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

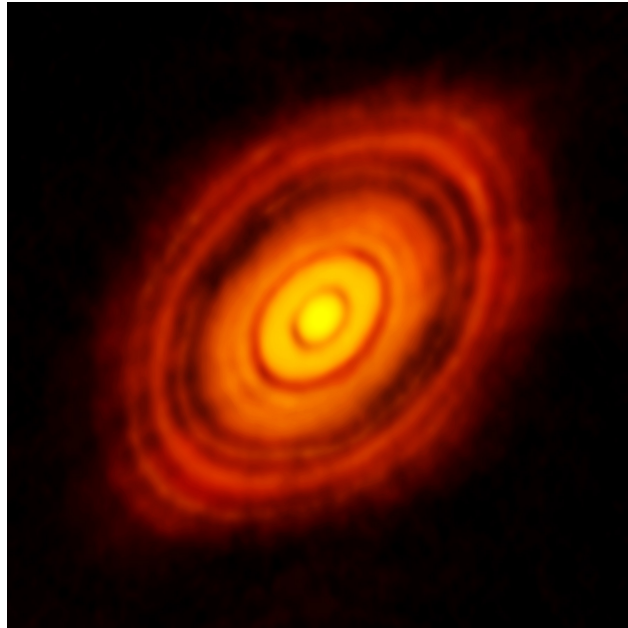
$t = 0.1$



(Lyra et al. 2009b)

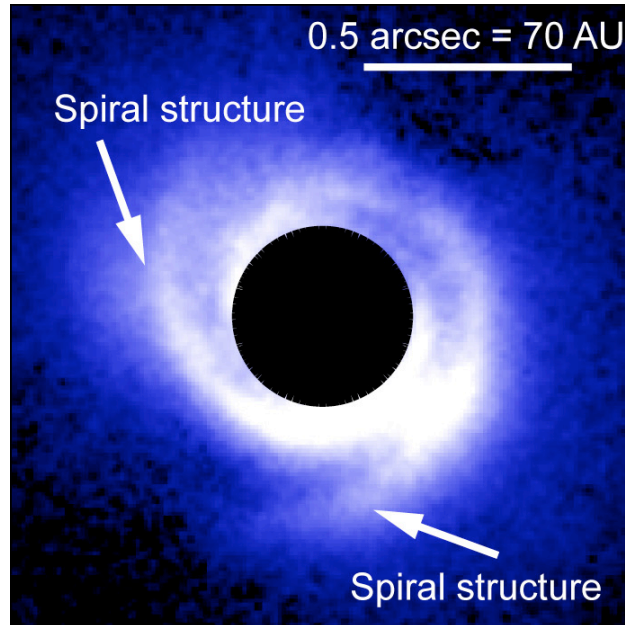
Observational evidence: gaps, spirals, and vortices

HL Tau



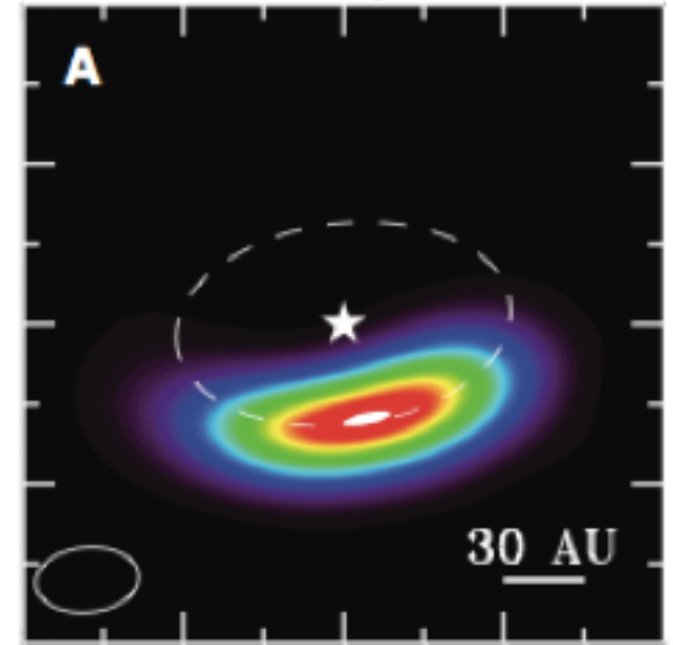
The ALMA Partnership et al. (2015)

SAO 206462



Muto et al. (2012)

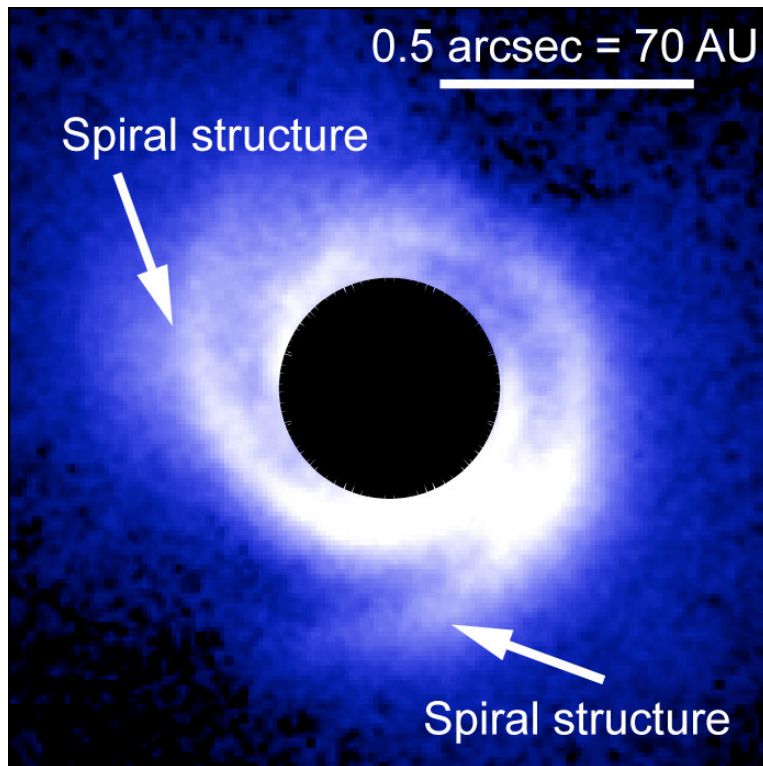
Oph IRS 48



van der Marel et al. (2013)

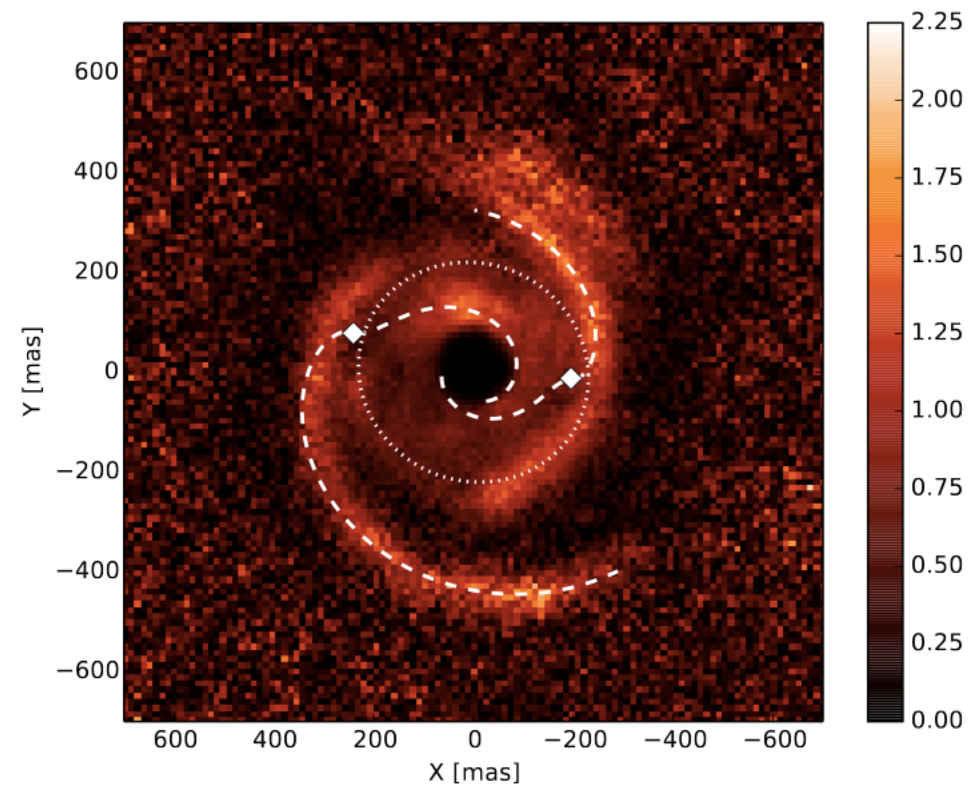
Observational Evidence: Spirals

SAO 206462



Muto et al. (2012)

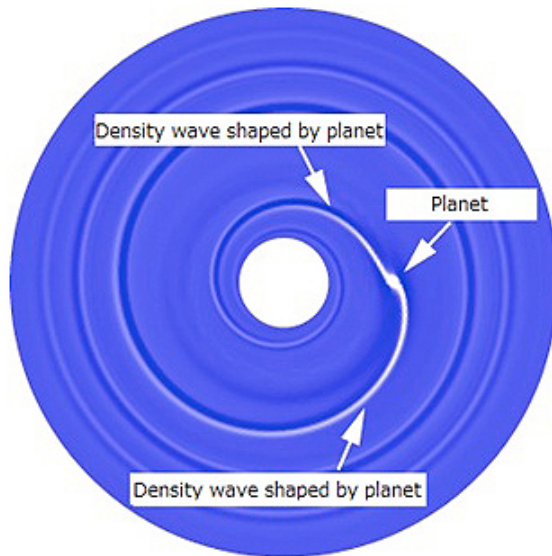
MWC 748



Benisty et al. (2015)

Spiral arm fitting leads to problems

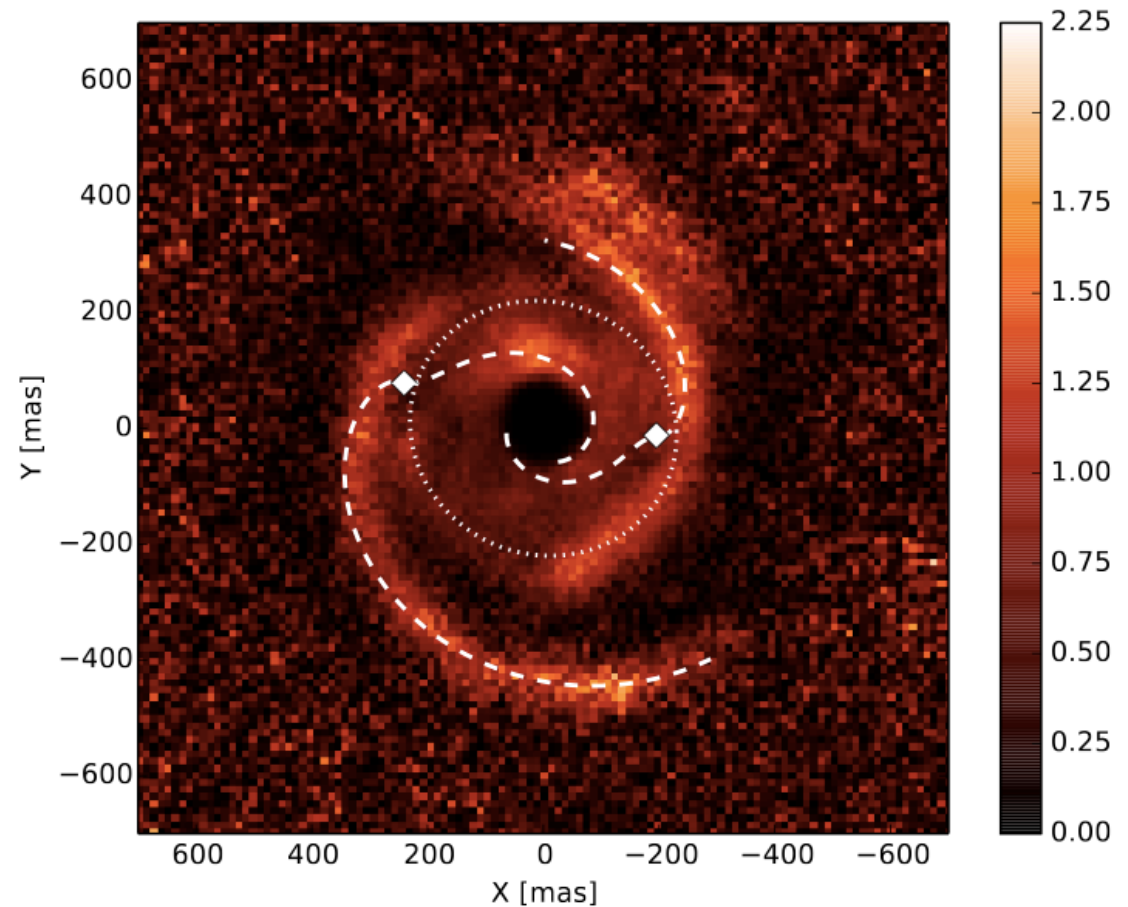
Analytical spiral fit



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

Rafikov (2002)
Muto et al. (2012)

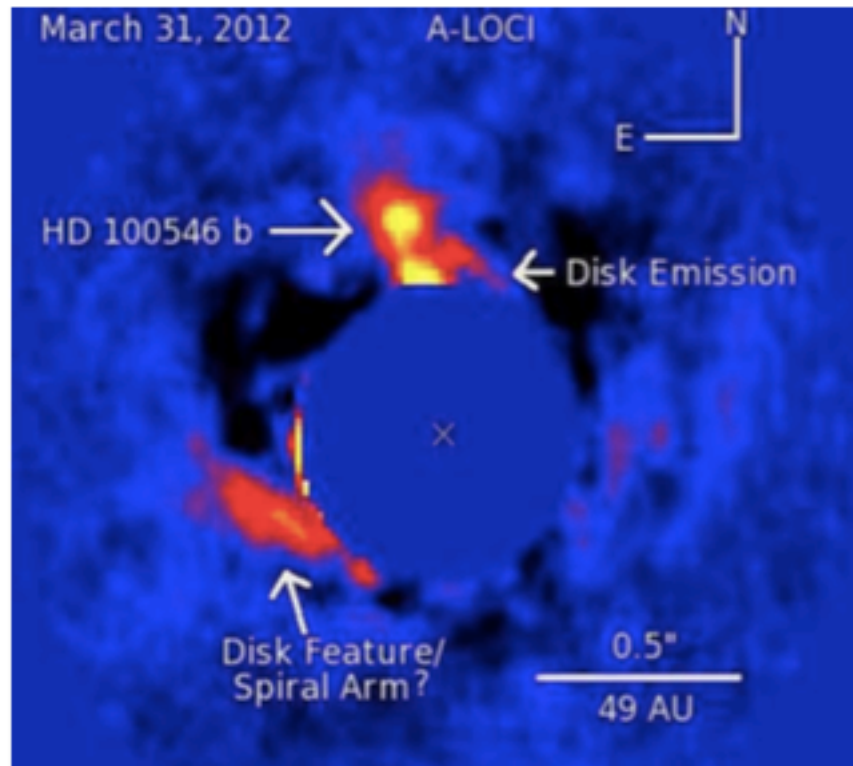
Spirals are **too wide**,
hotter (300K) than ambient gas (50K).



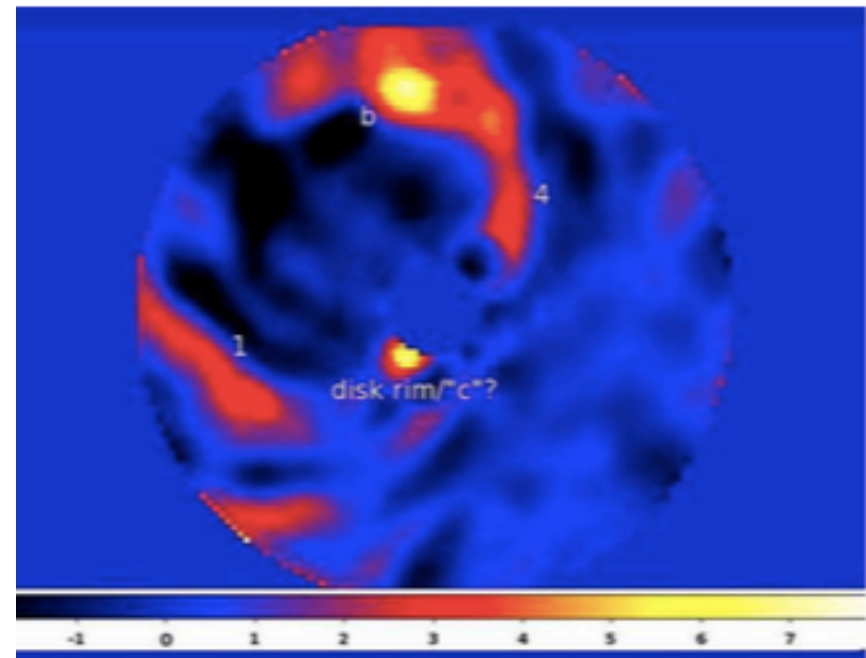
Benisty et al. (2015)

The strange case of thermal emission in HD 100546

L band ($\sim 3.5 \mu\text{m}$)

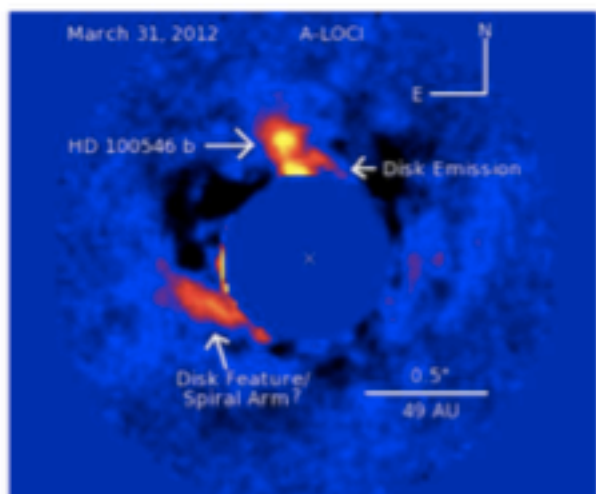


H band ($\sim 1.6 \mu\text{m}$)

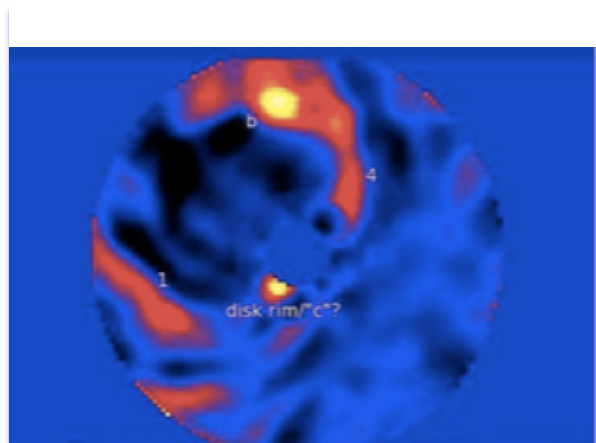


Currie et al. (2014), Currie et al. (2015)

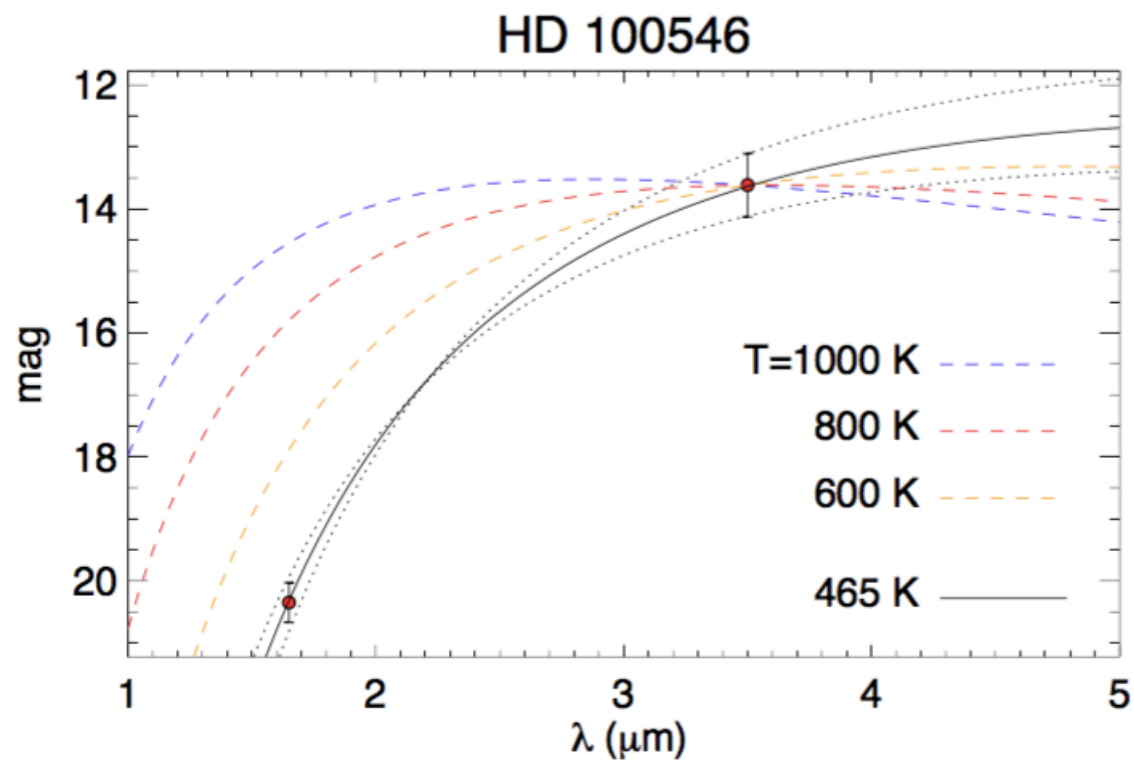
Pinning down the temperature



L band



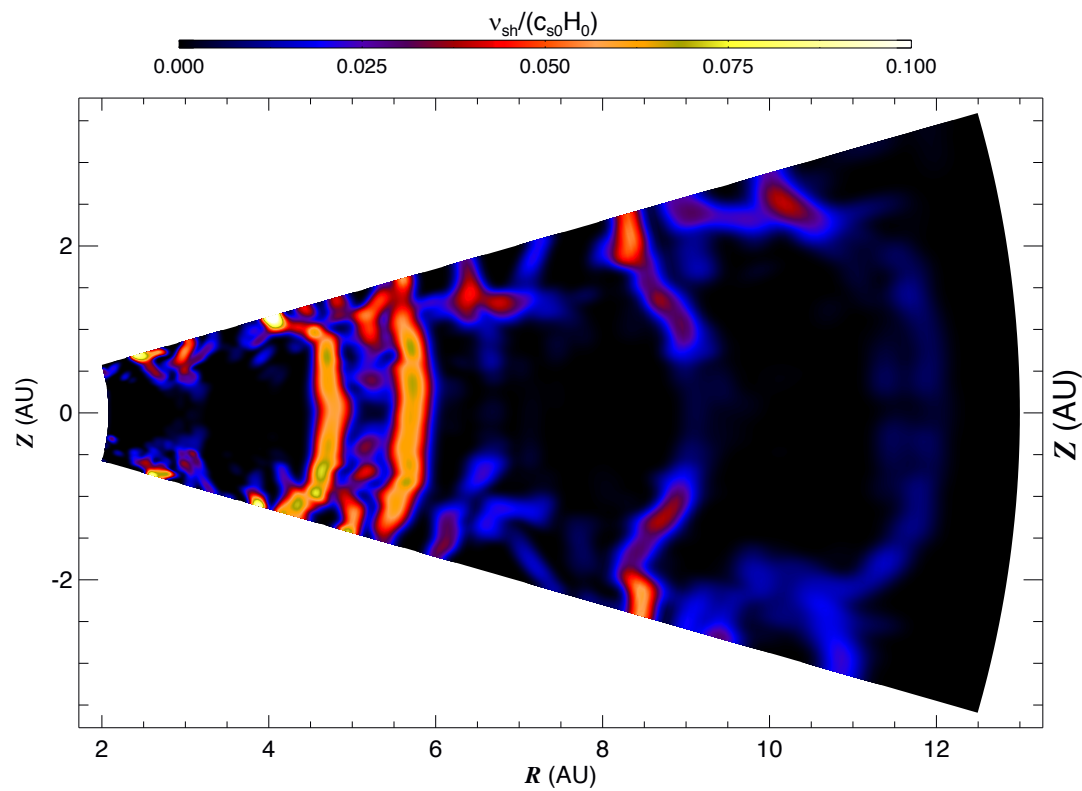
H band



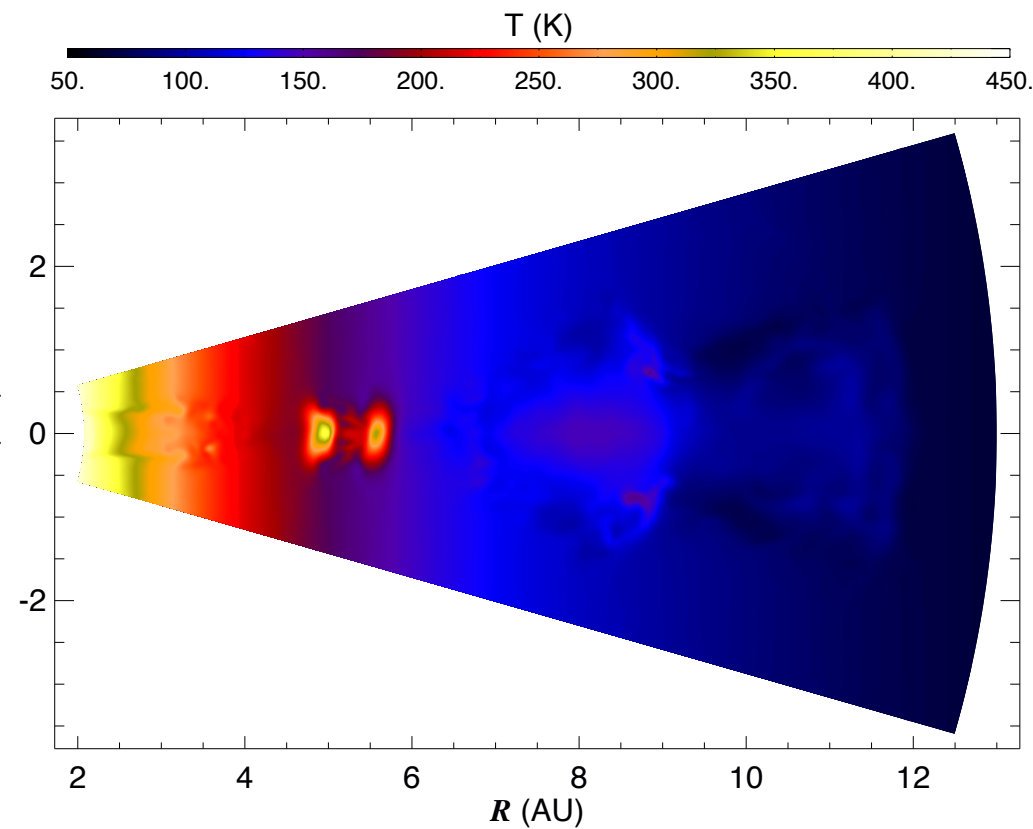
Lyra et al. (2016)

3D: Shock bores

Shocks (velocity convergence)



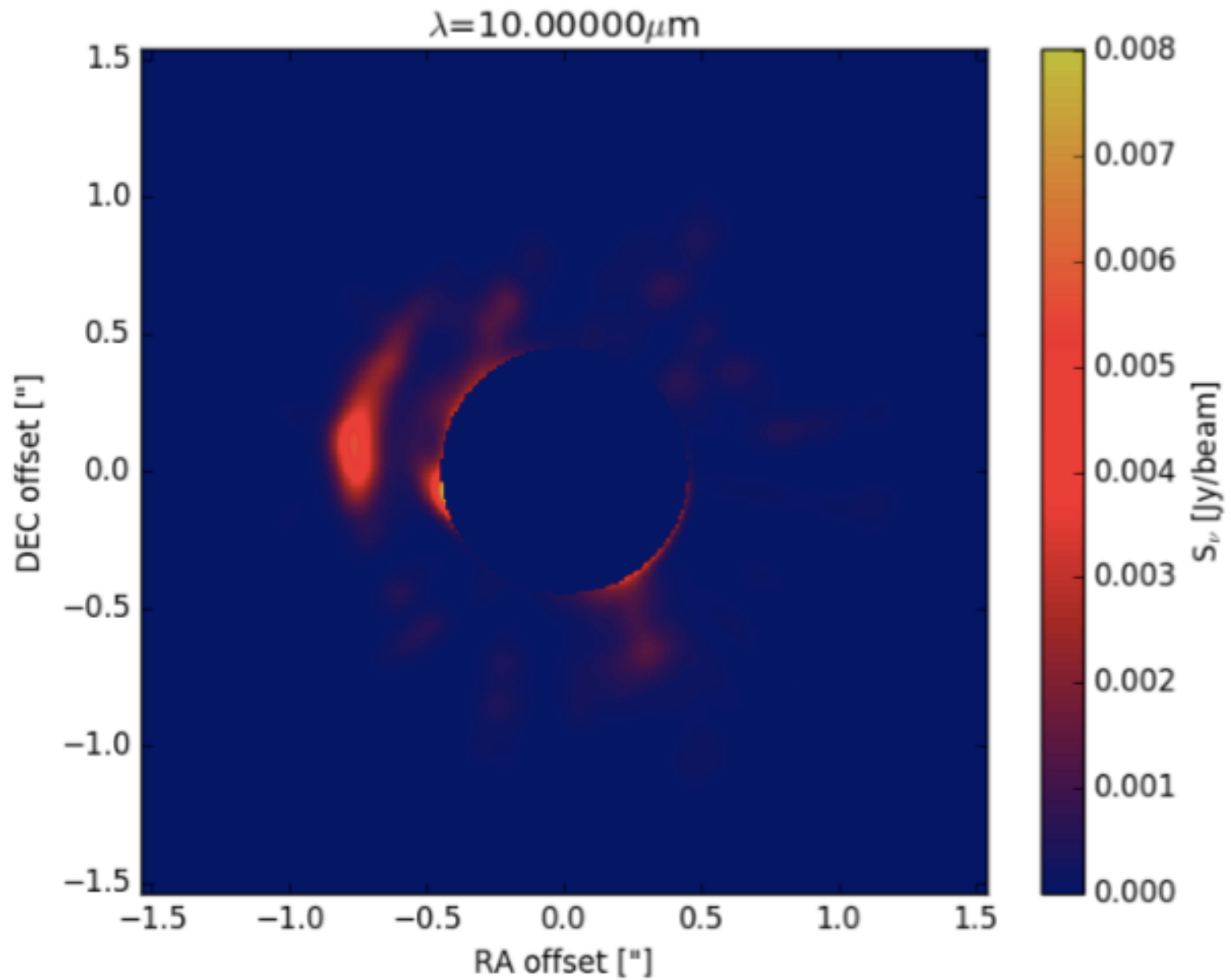
Temperature



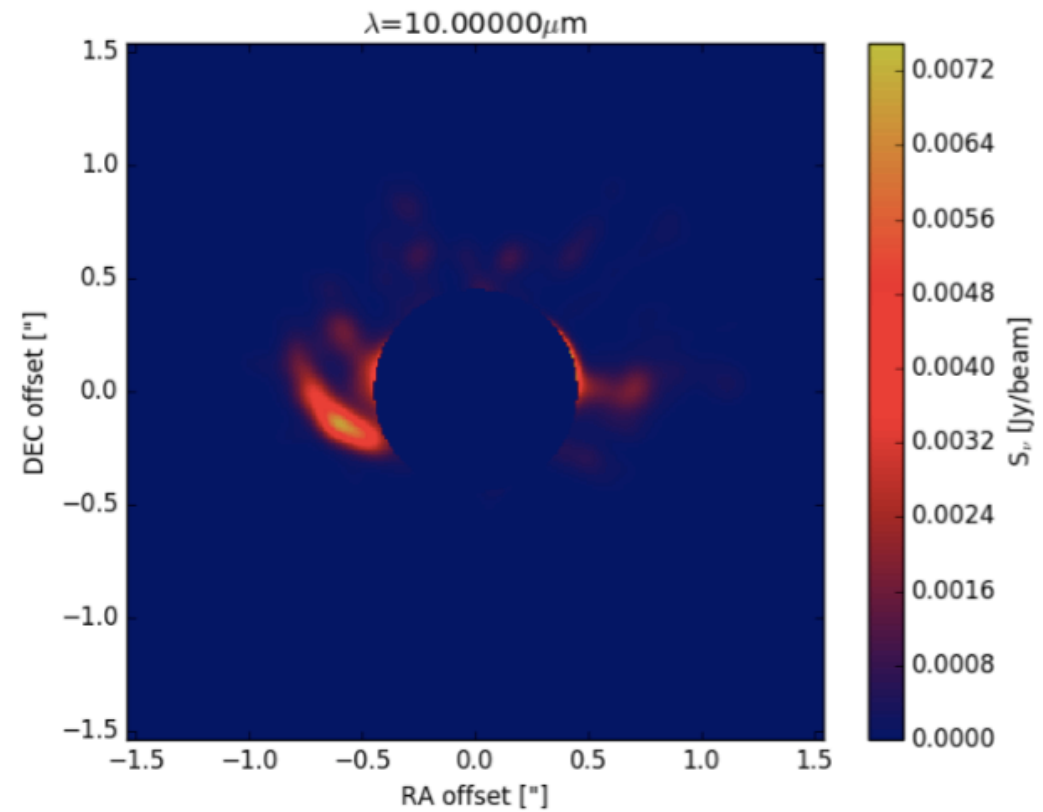
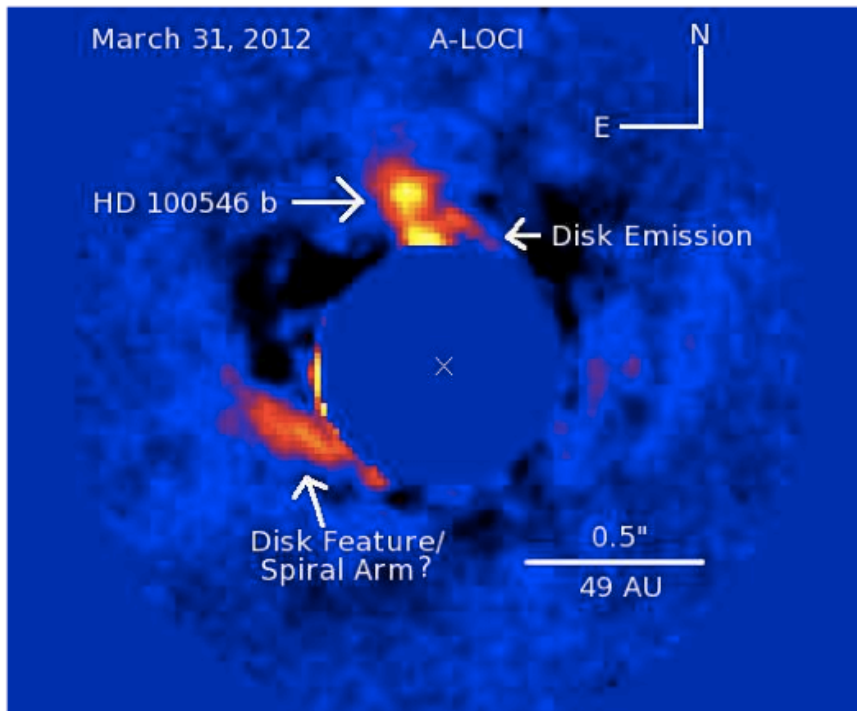
*Your model doesn't look
like my observation.
Why should I care?*



Synthetic image

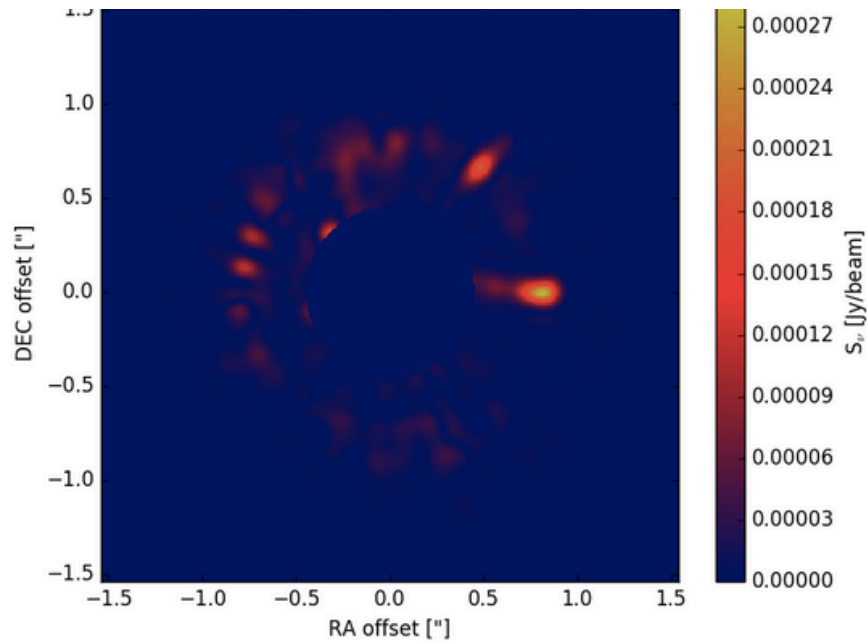


Observation vs Synthetic Image

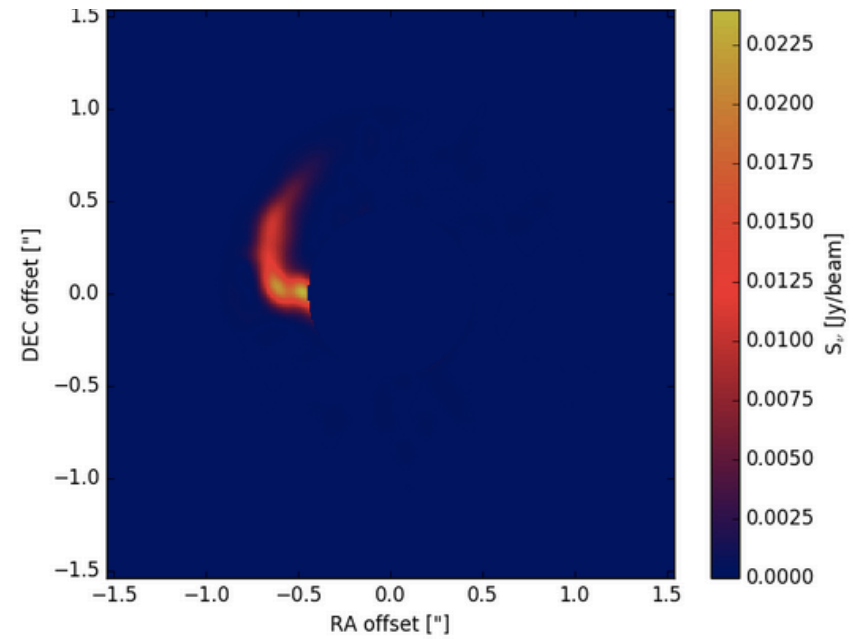


Effect of shocks alone

1 μm

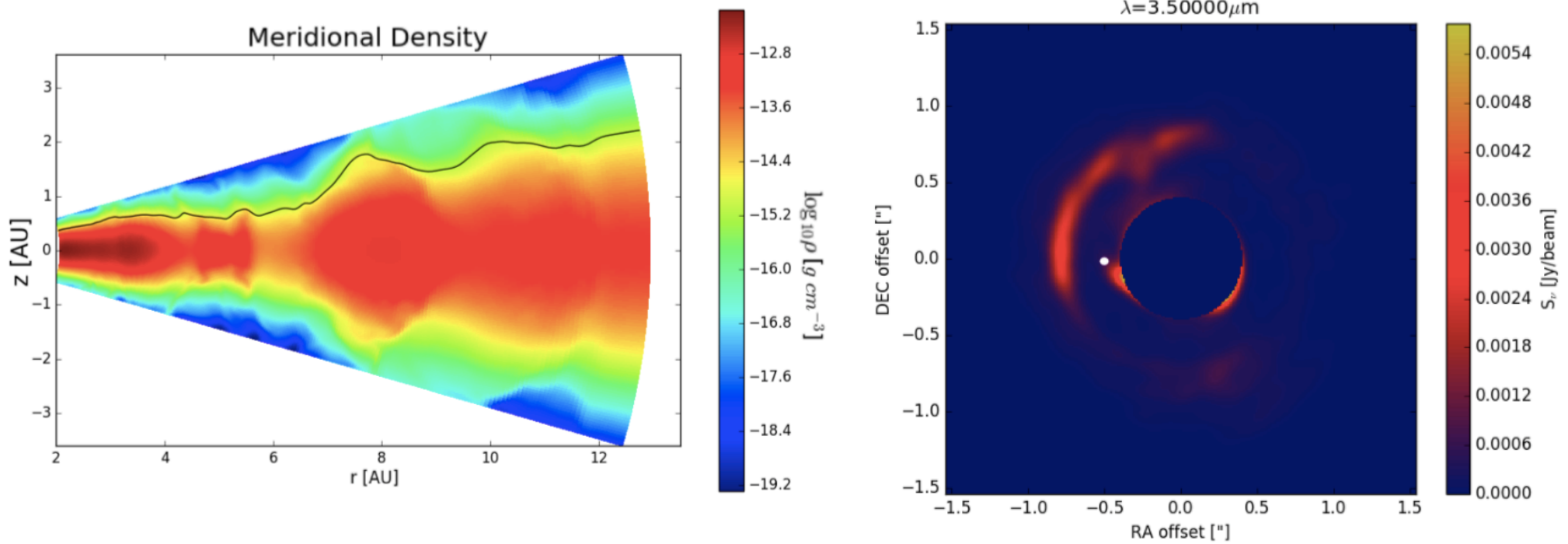


10 μm



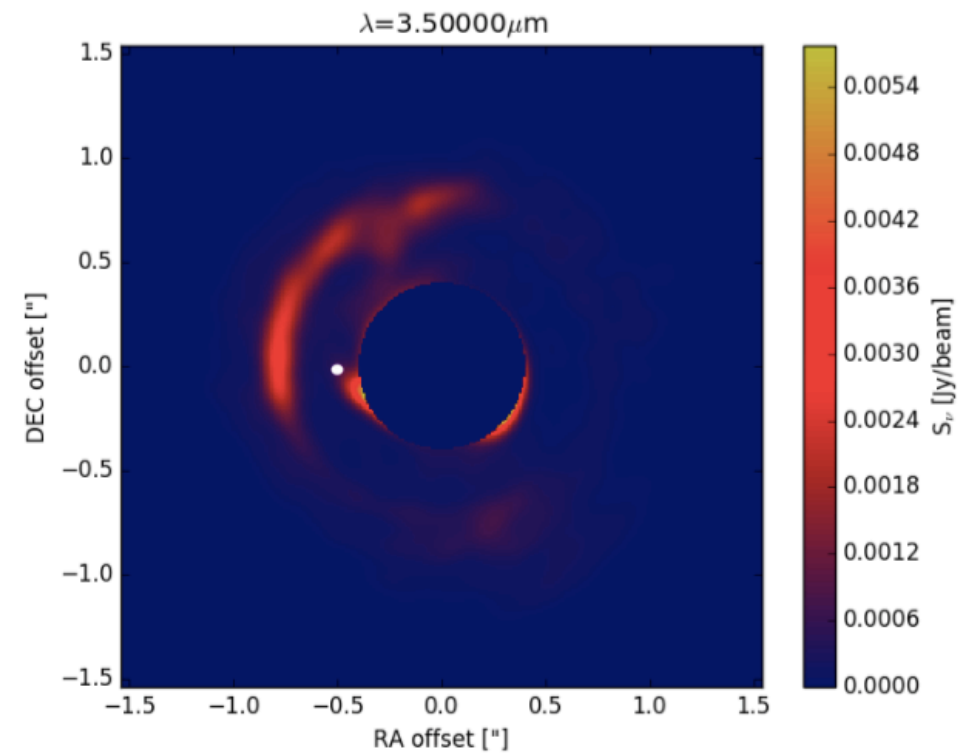
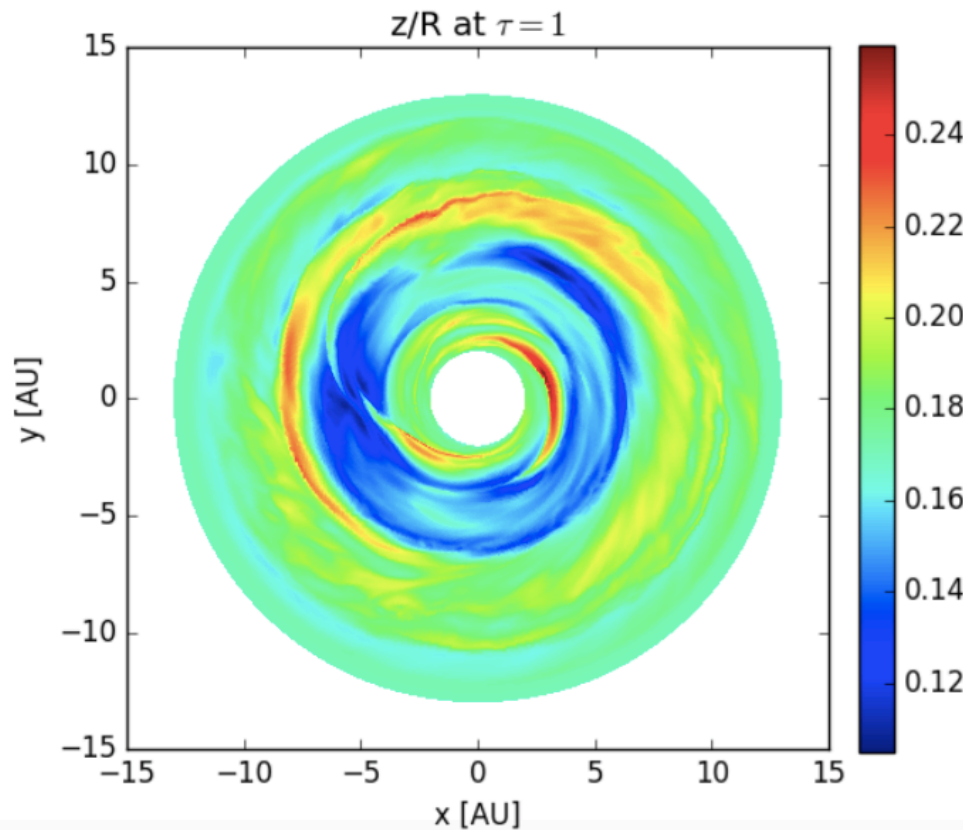
Hord et al. (2017)

Scattering – A puffed up outer gap



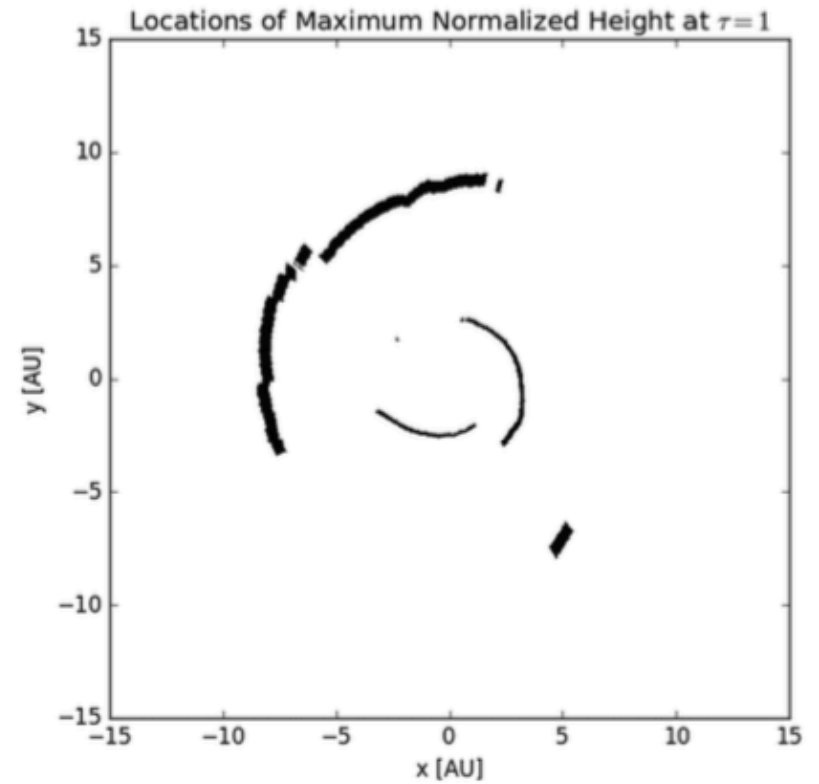
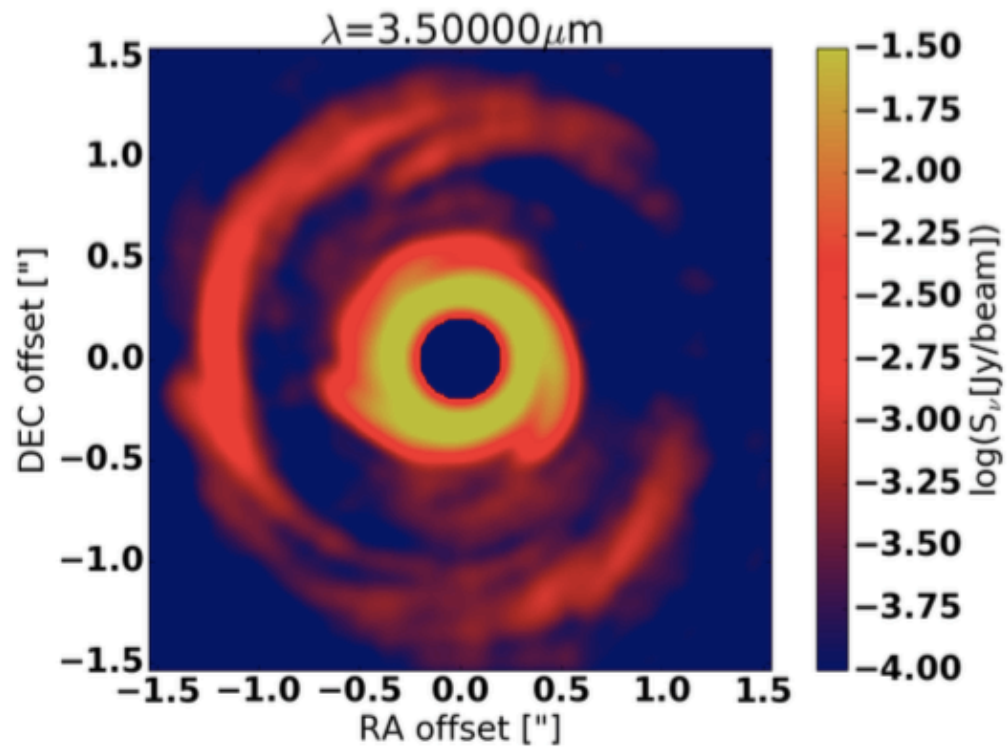
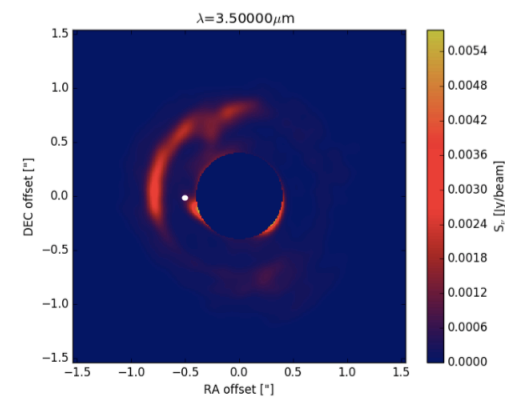
Hord et al. (2017)

Scattering



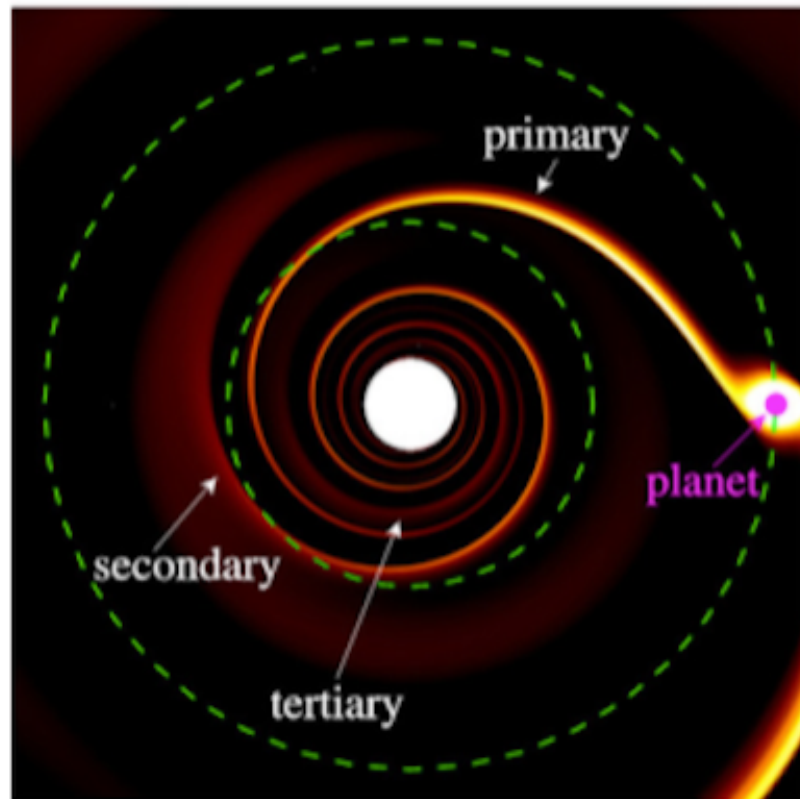
Hord et al. (2017)

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

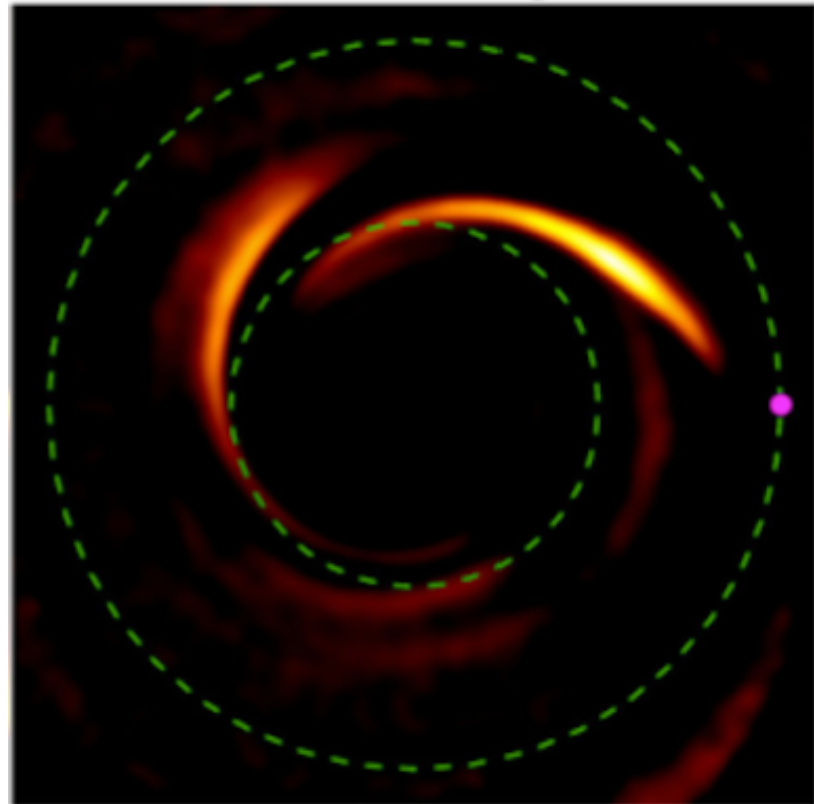


Hord et al. (2017)

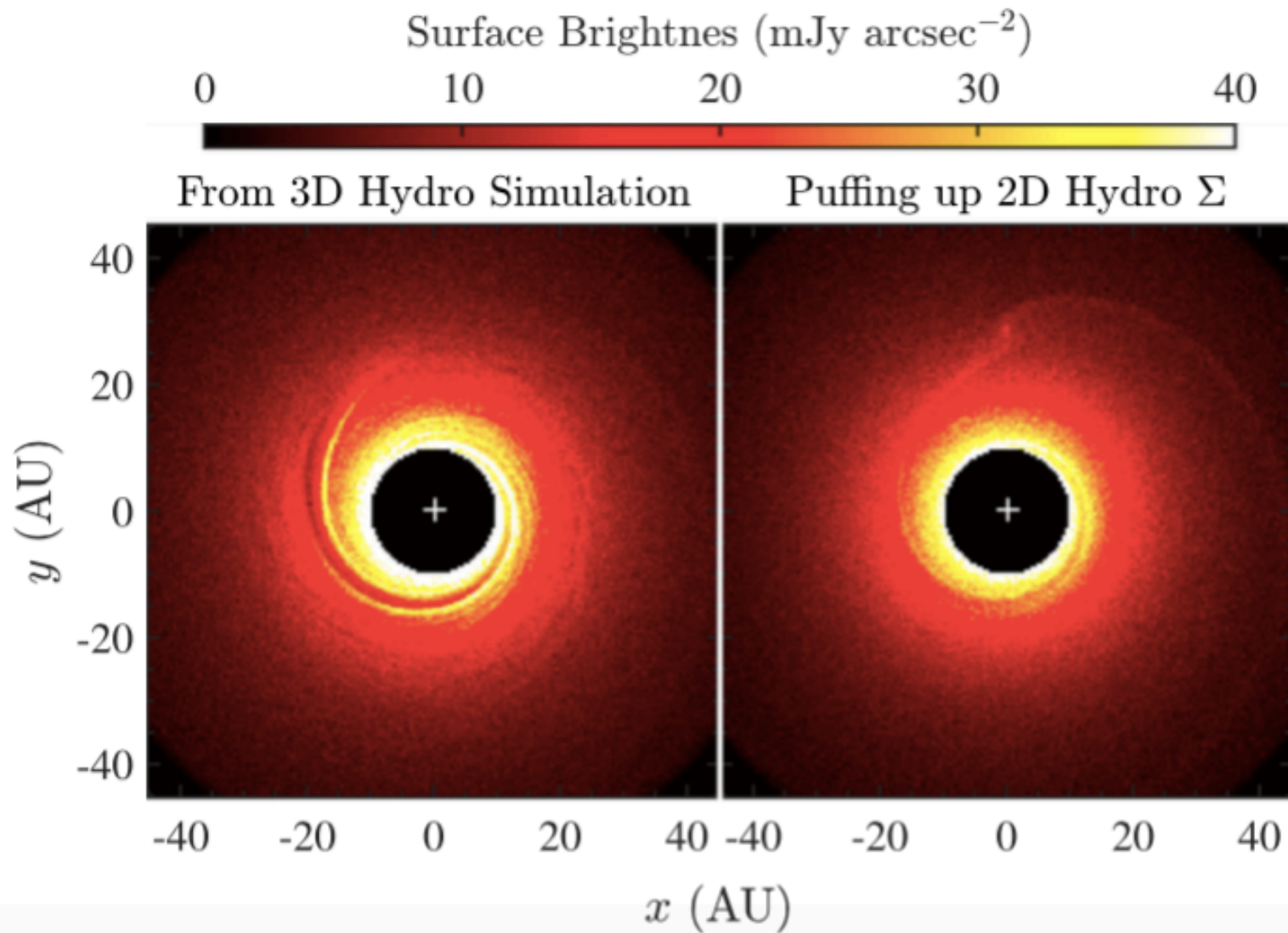
Primary and Secondary spiral arms



Scattered Light

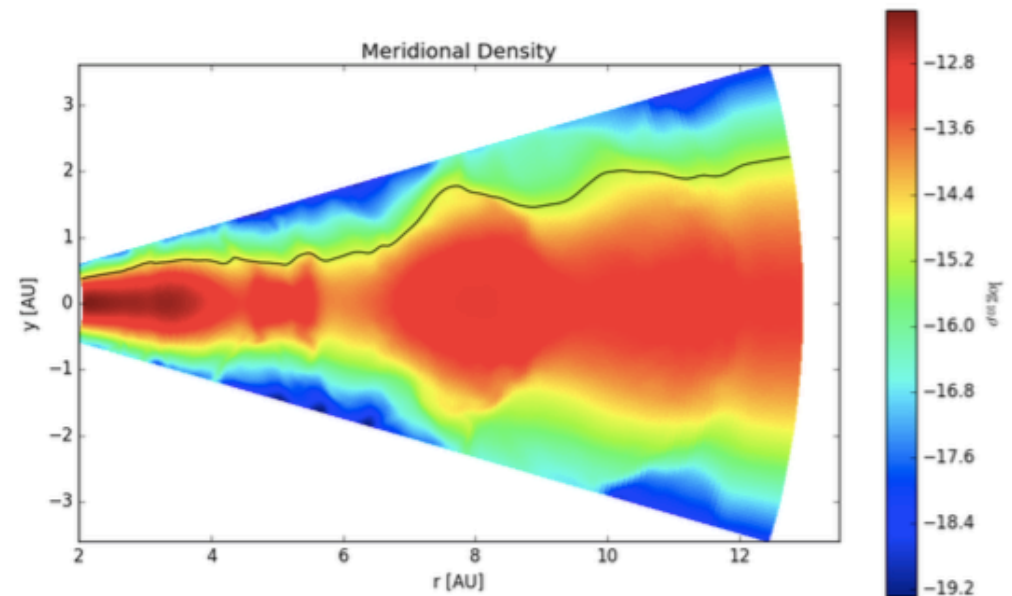
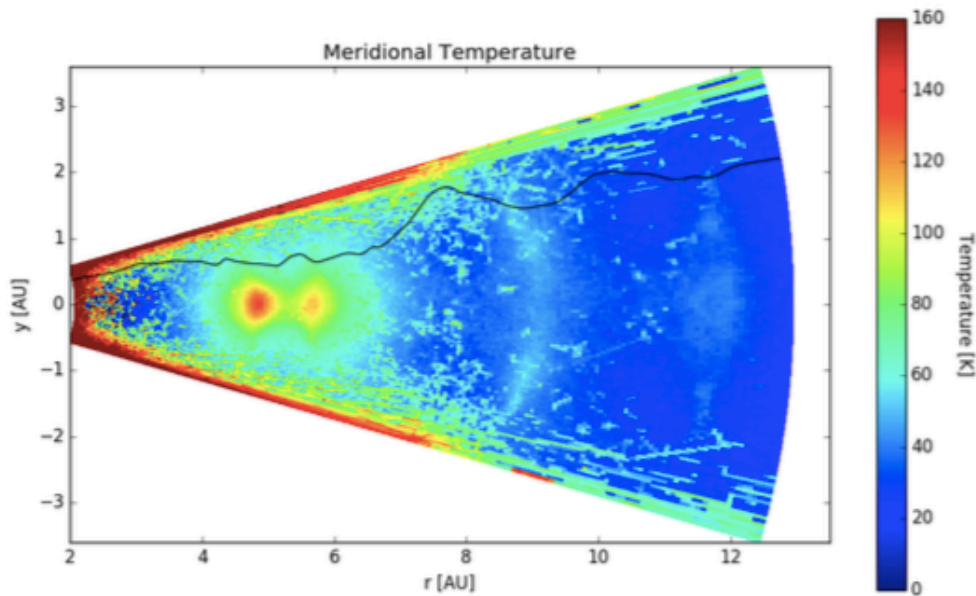


3D is needed



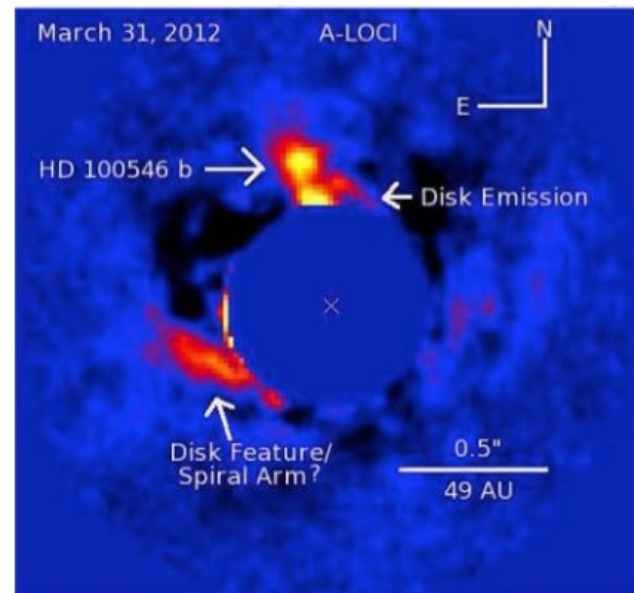
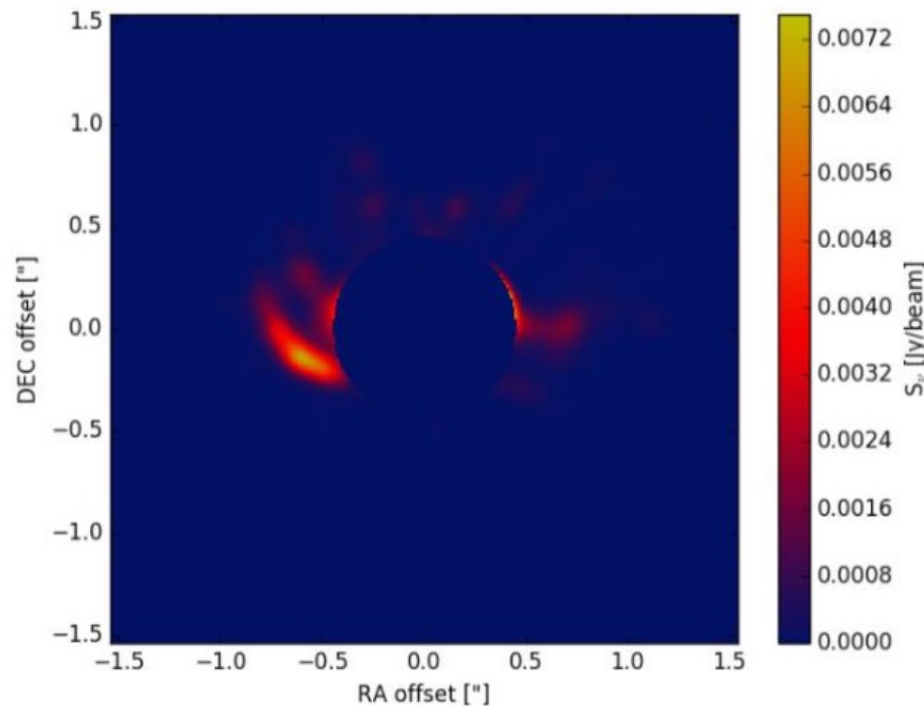
Conclusions

- 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



Conclusions

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



Scattering: “the light that never warms”



Rahul Patel
@DarthPatel

Following

Hey #ExSoCal attendees. Challenge time.
Include a 90's pop lyrics in your presentation
somewhere (written or verbal).



*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)***

