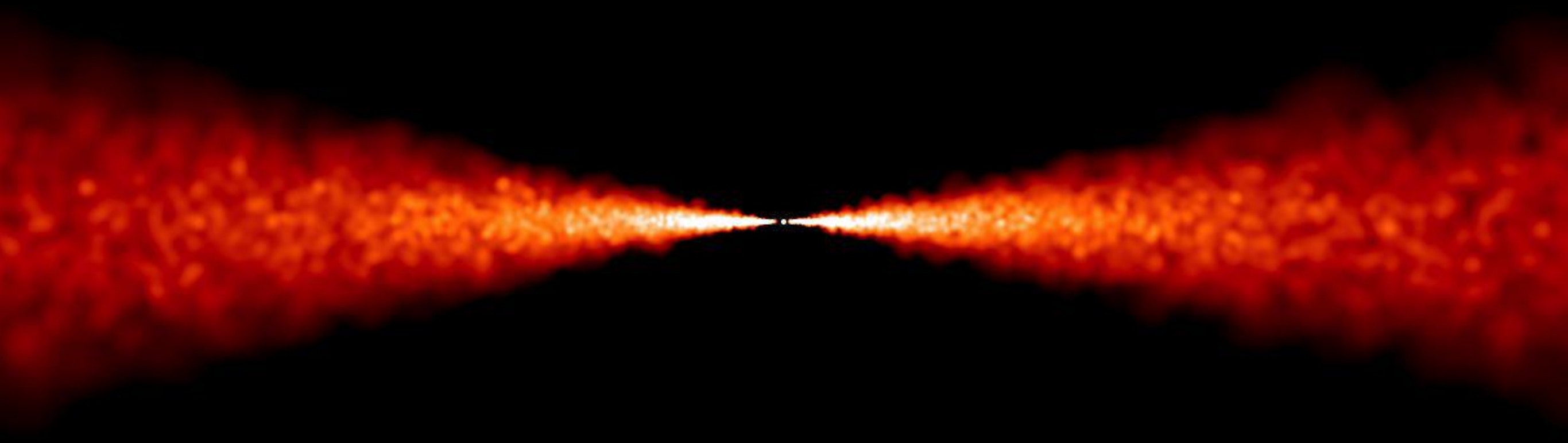


Does TW Hya host a misaligned planet?



Rebecca Nealon with
Christophe Pinte, Richard
Alexander, Daniel Mentiplay,
Giovanni Dipierro,
Chris Nixson and Rebecca Martin

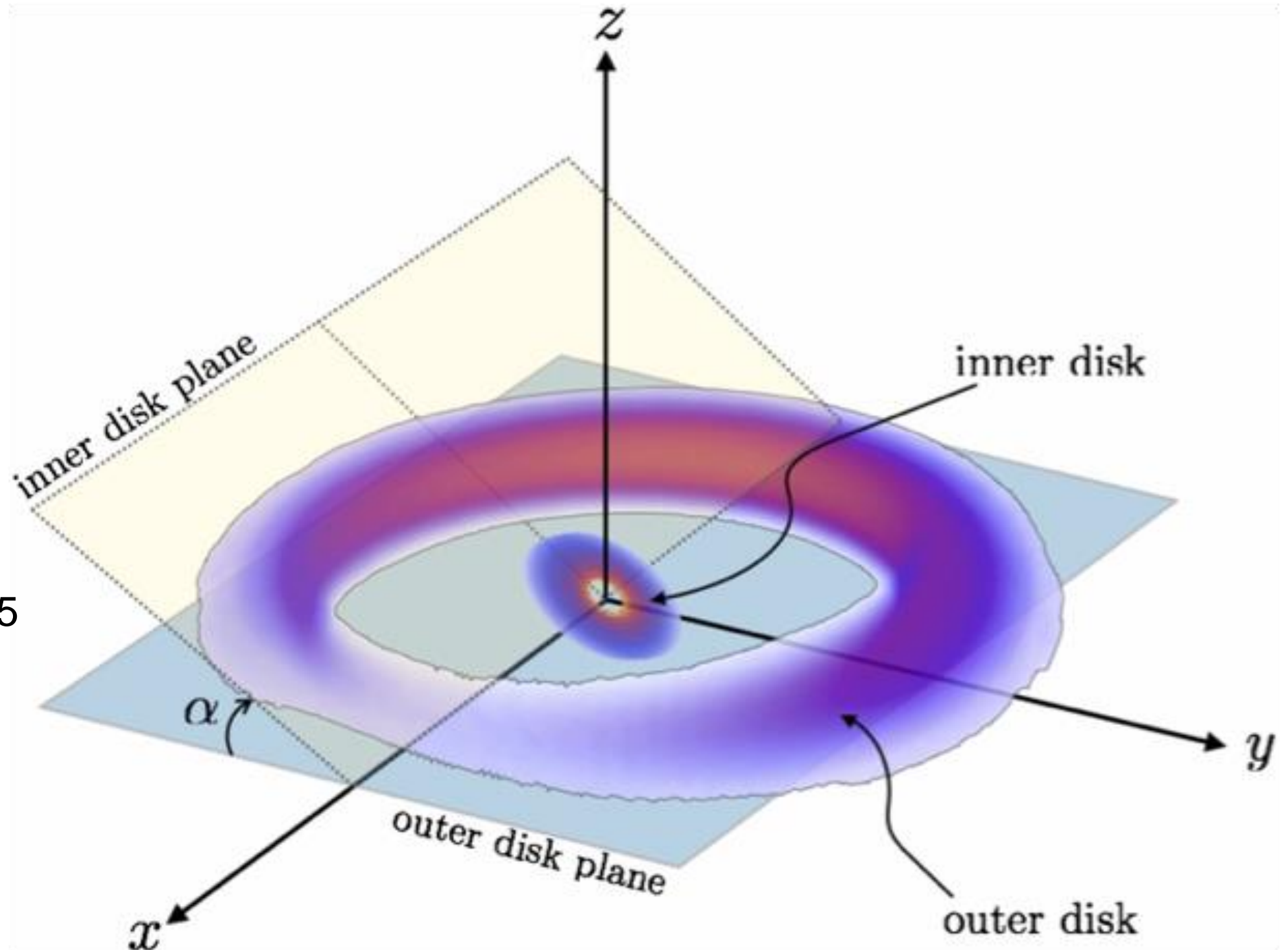


UNIVERSITY OF
LEICESTER

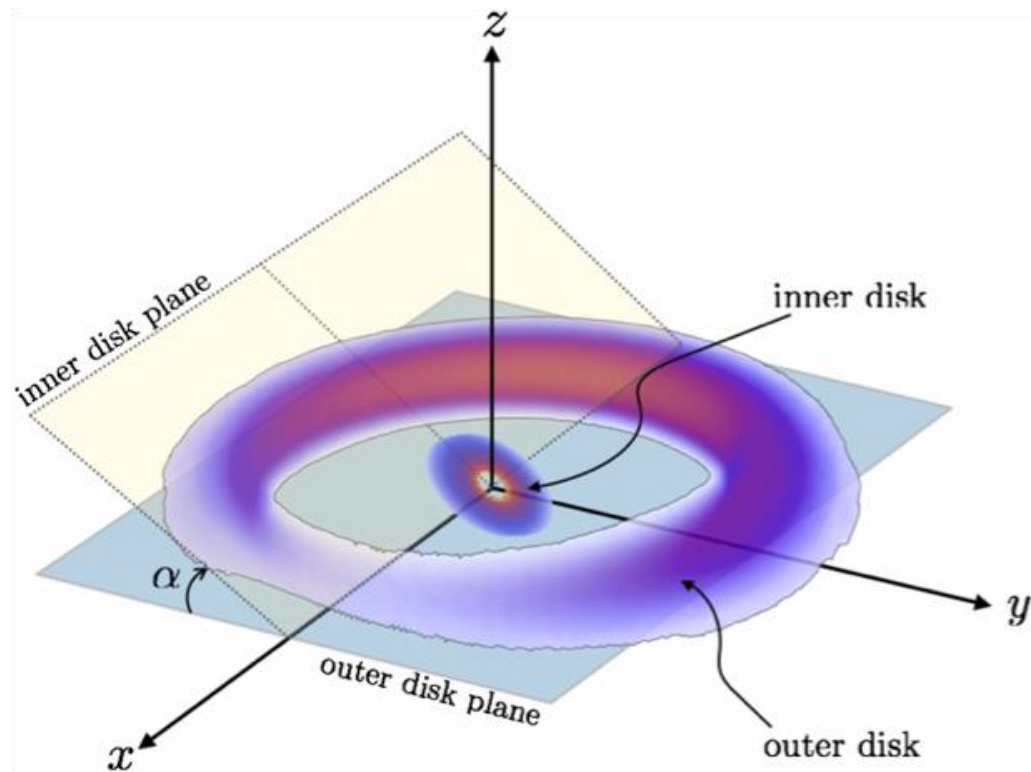


Misalignments in protoplanetary discs are not rare

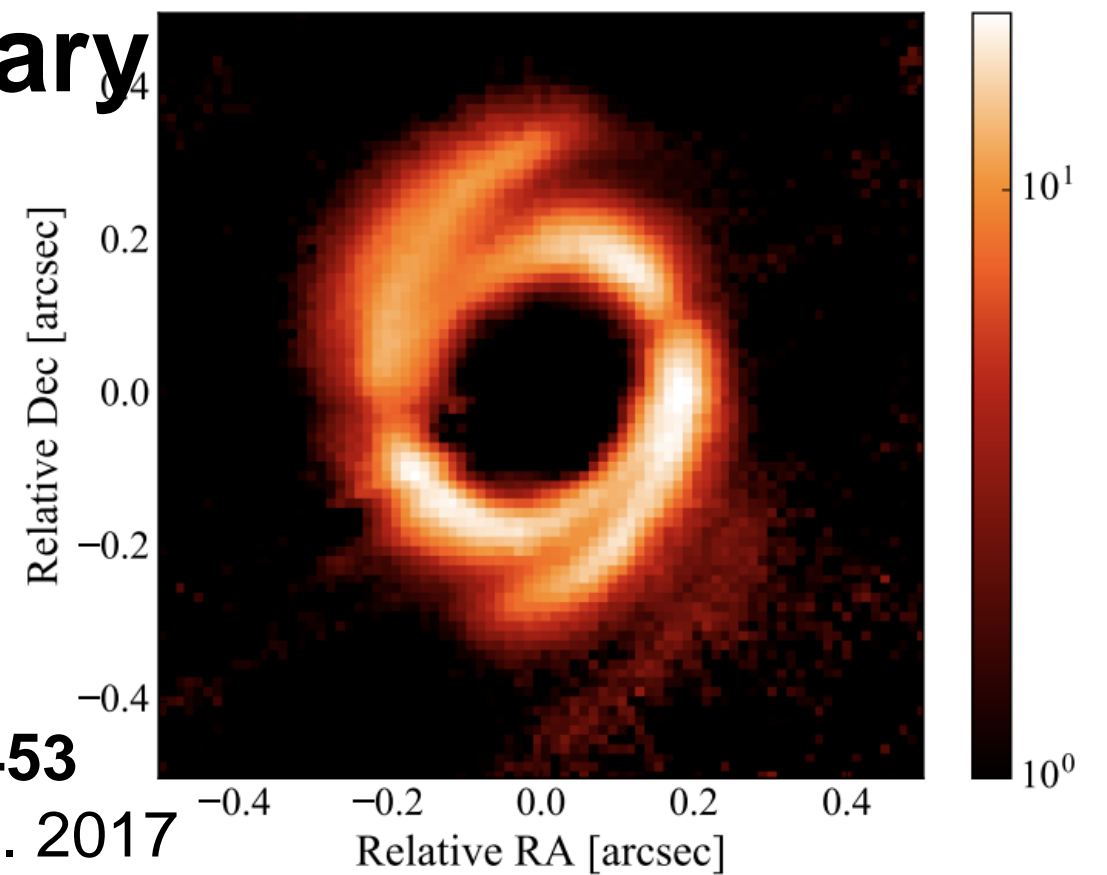
Marino et al. 2015



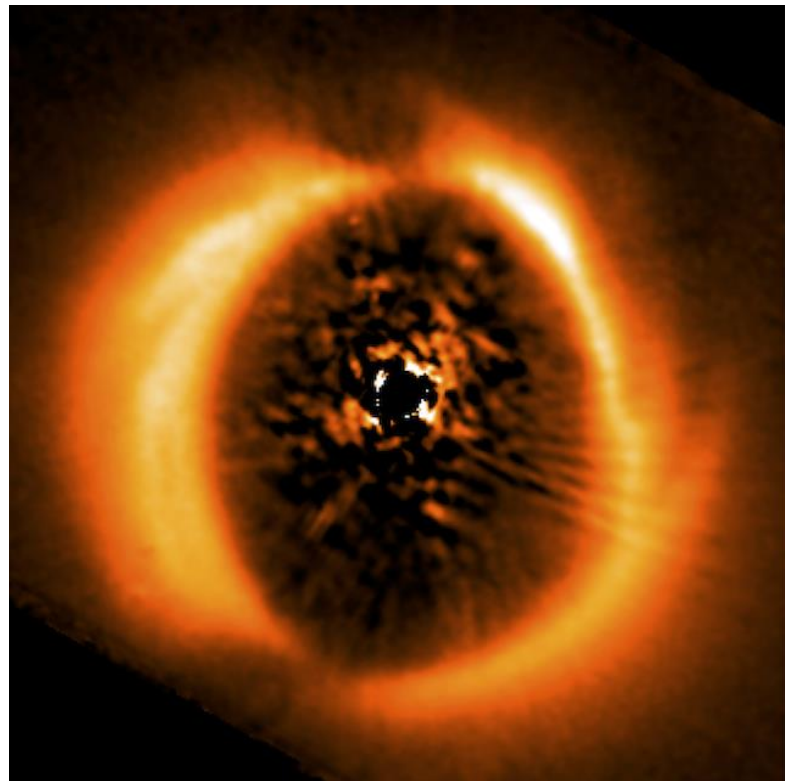
Misalignments in protoplanetary discs are not rare



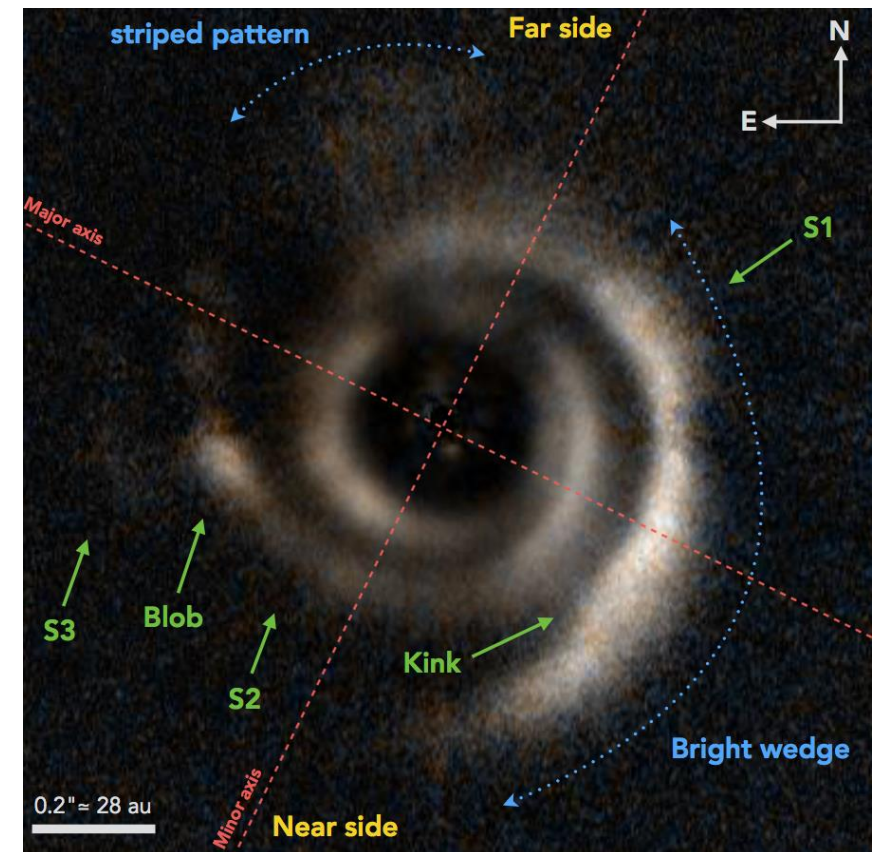
HD 100453
Benisty et al. 2017



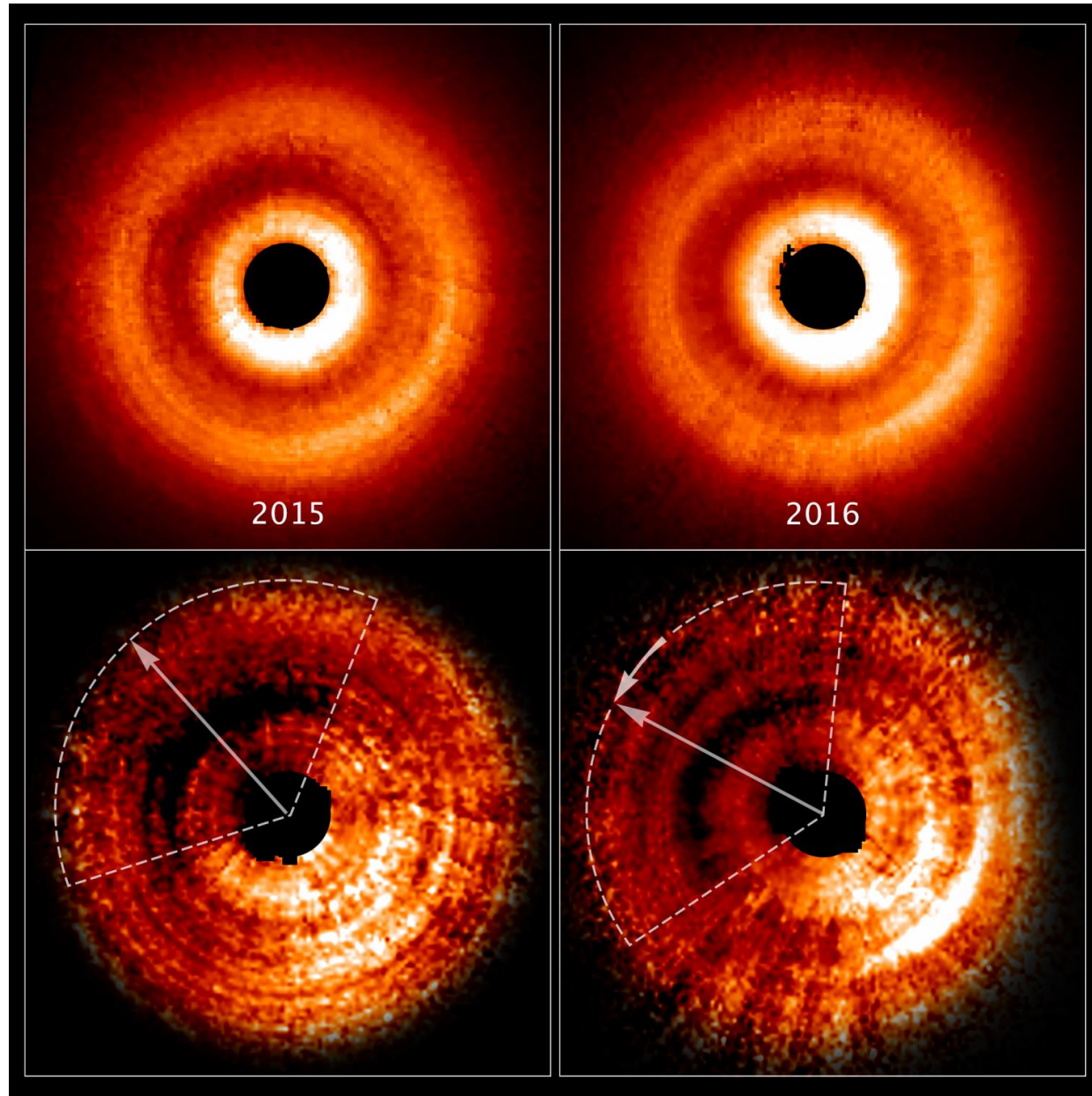
HD 142527
Marino et al. 2015



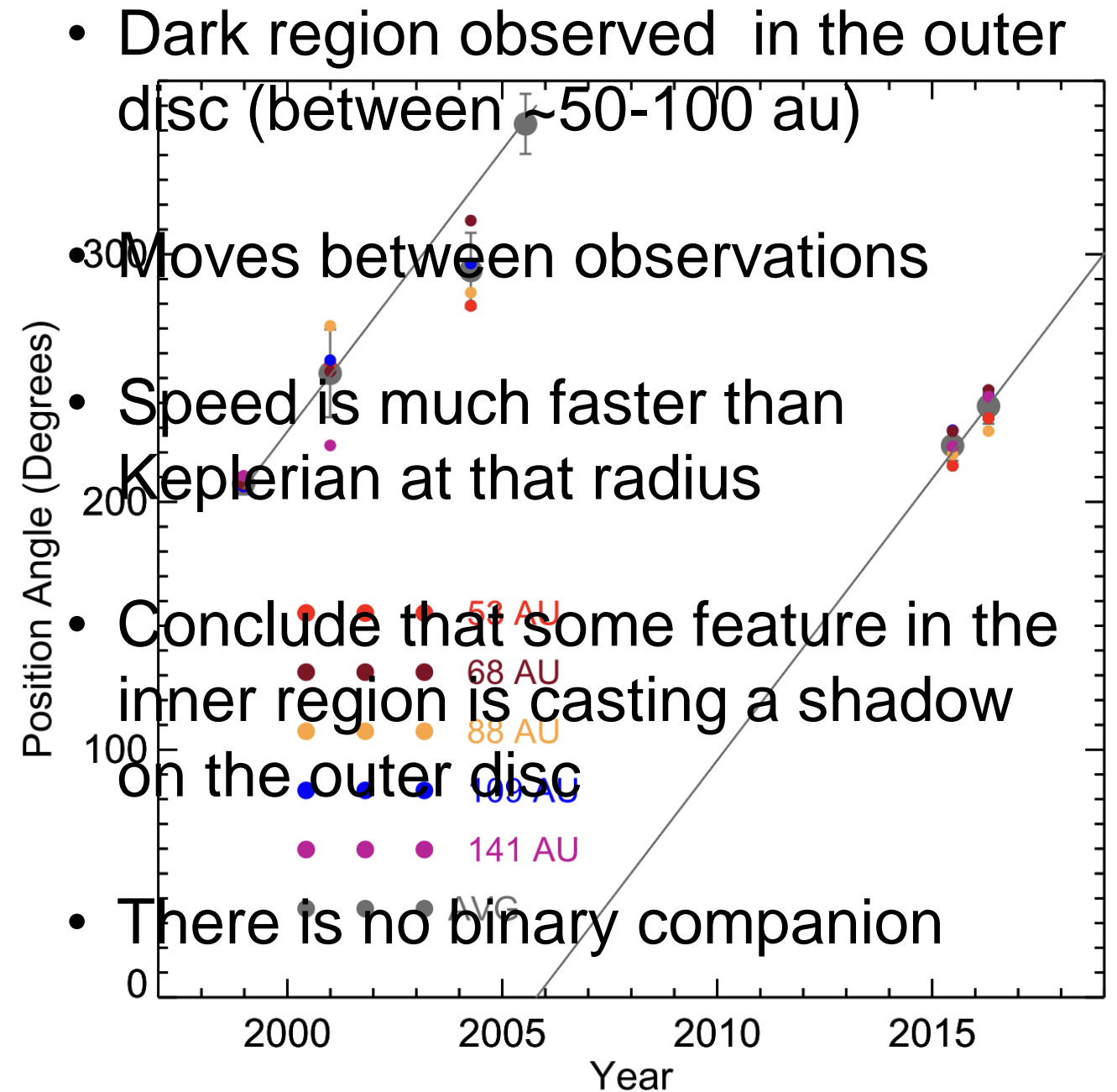
HD 135344B
Stolker et al. 2016



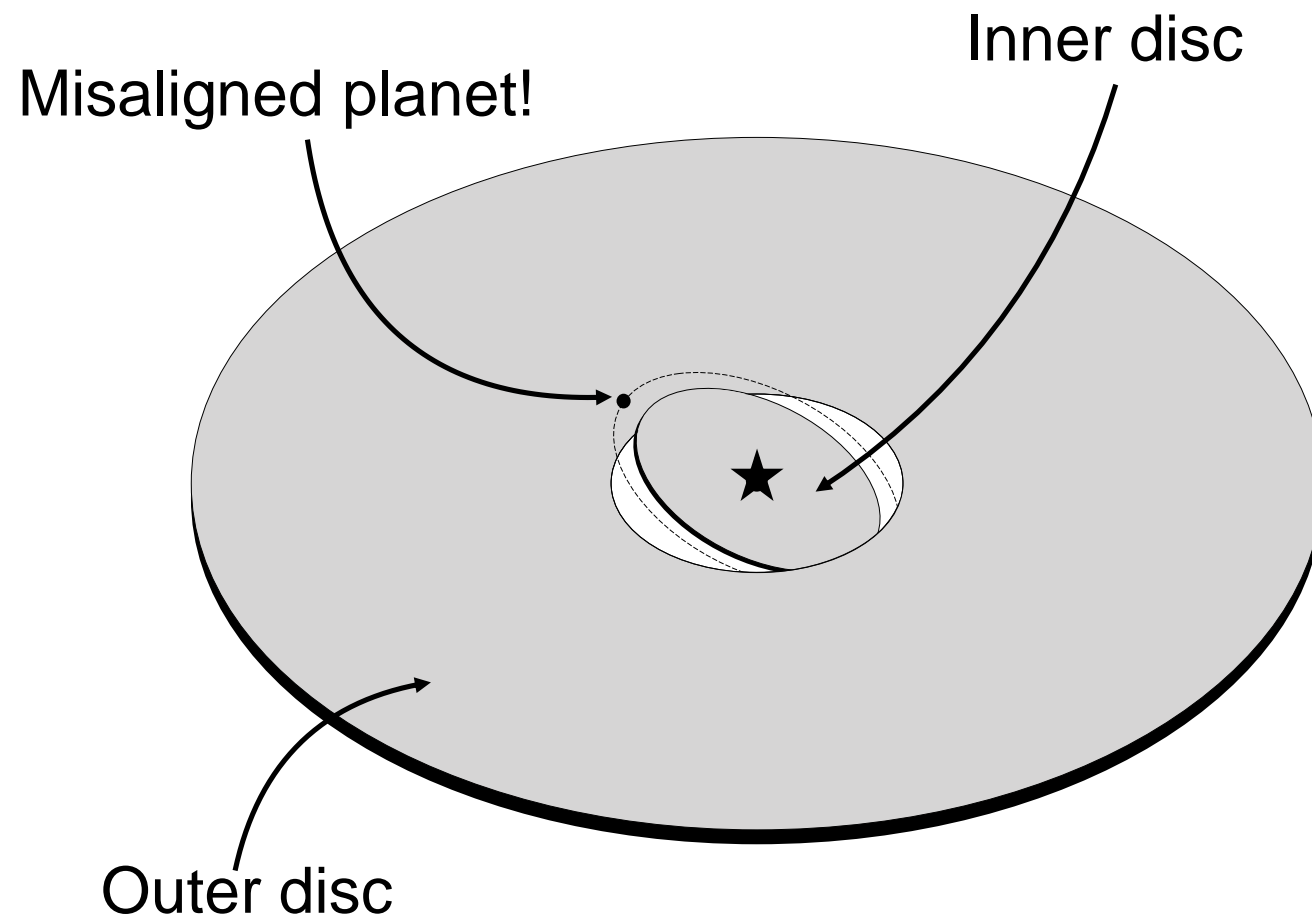
The shadowy case of TW Hya: observations



(Debes et al. 2017 + Poteet et al. 2018)



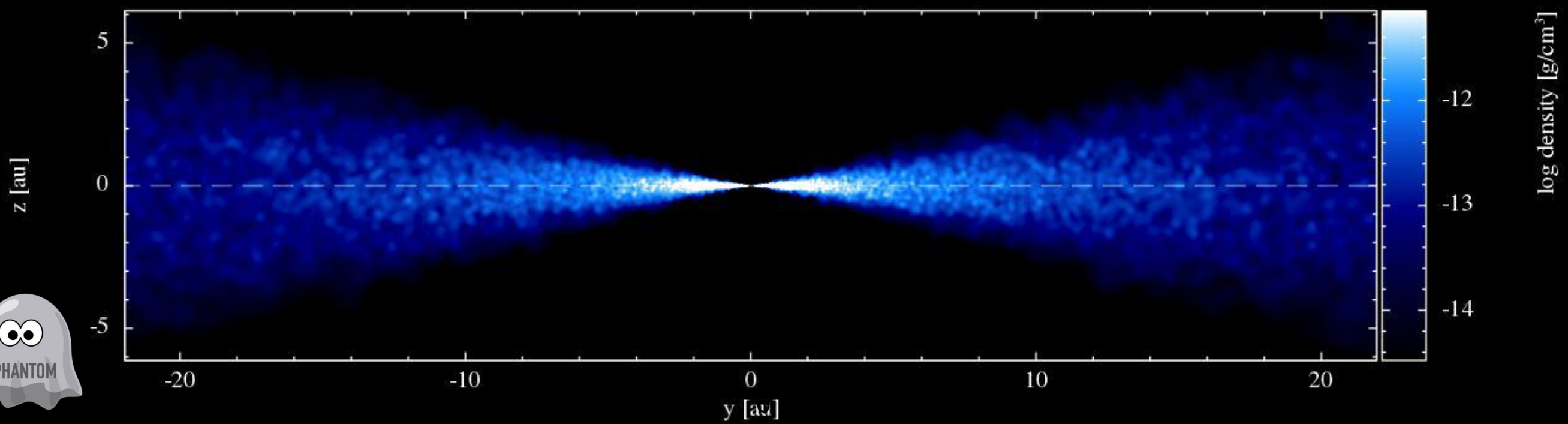
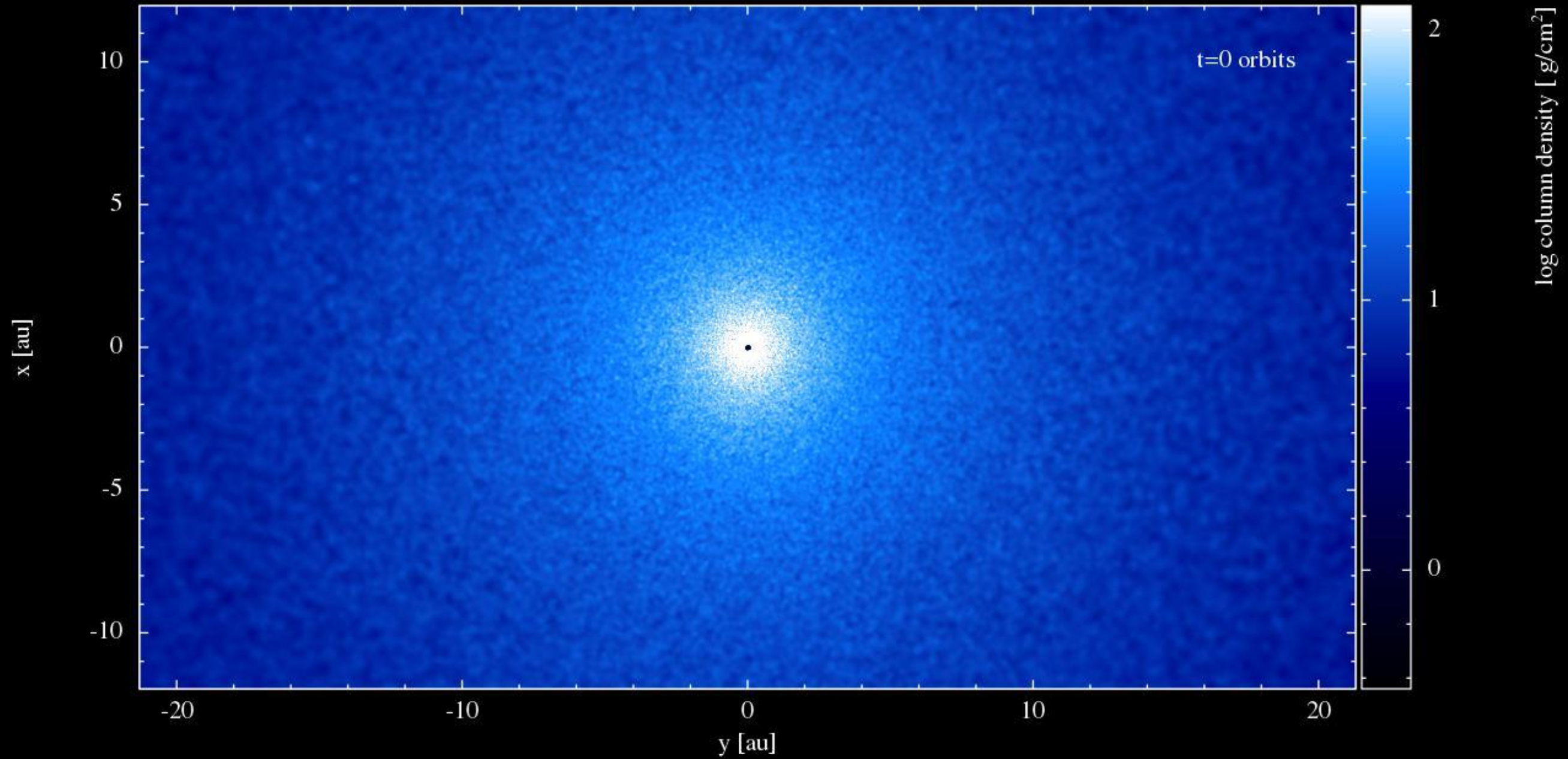
The shadowy case of TW Hya: proposed model



(Dramatic schematic)

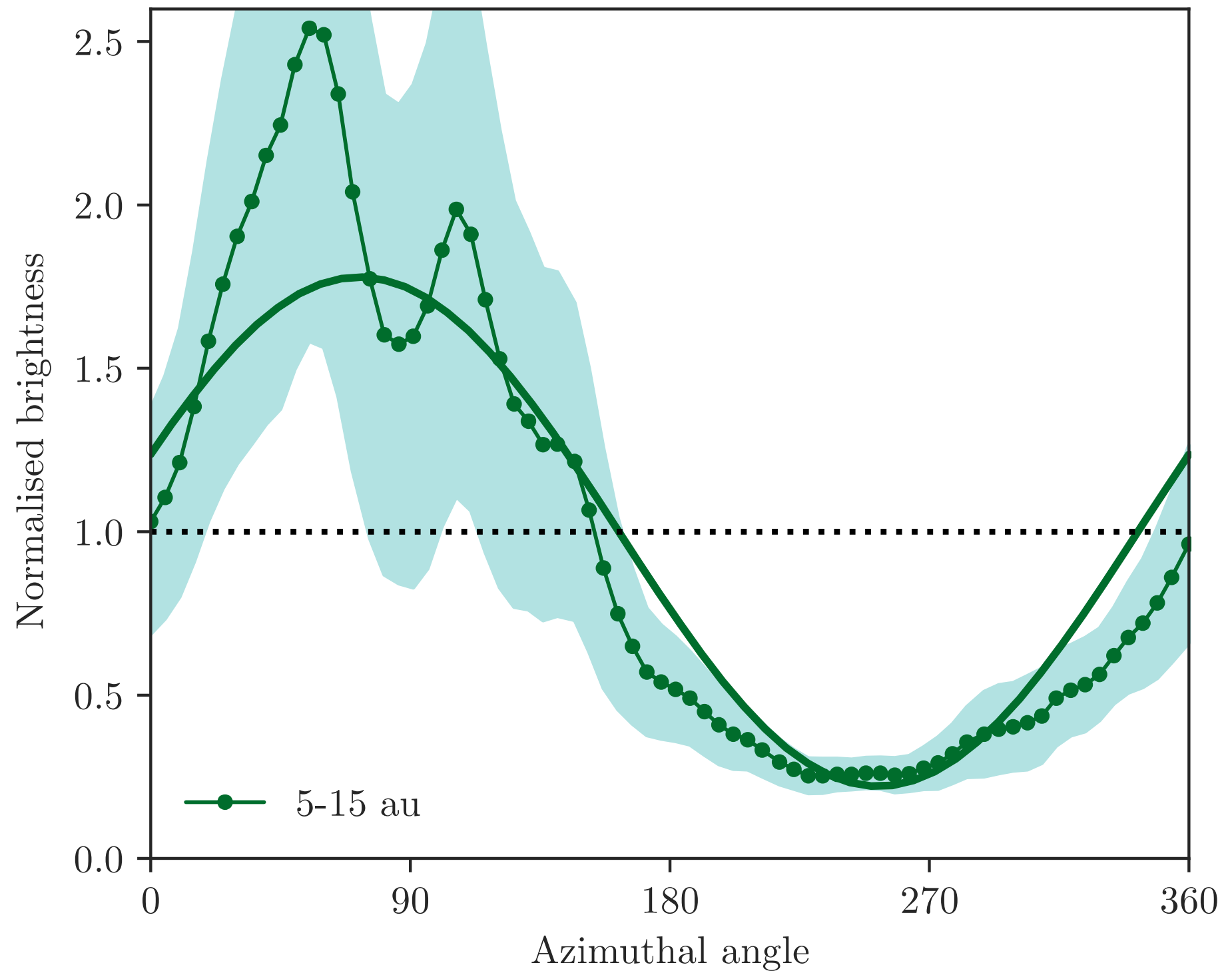
The proposed model:

- Planet is misaligned to **both** the inner and outer disc
- This causes inner disc to be tilted to outer disc -> casts a shadow
- Inner disc precesses -> moving shadow

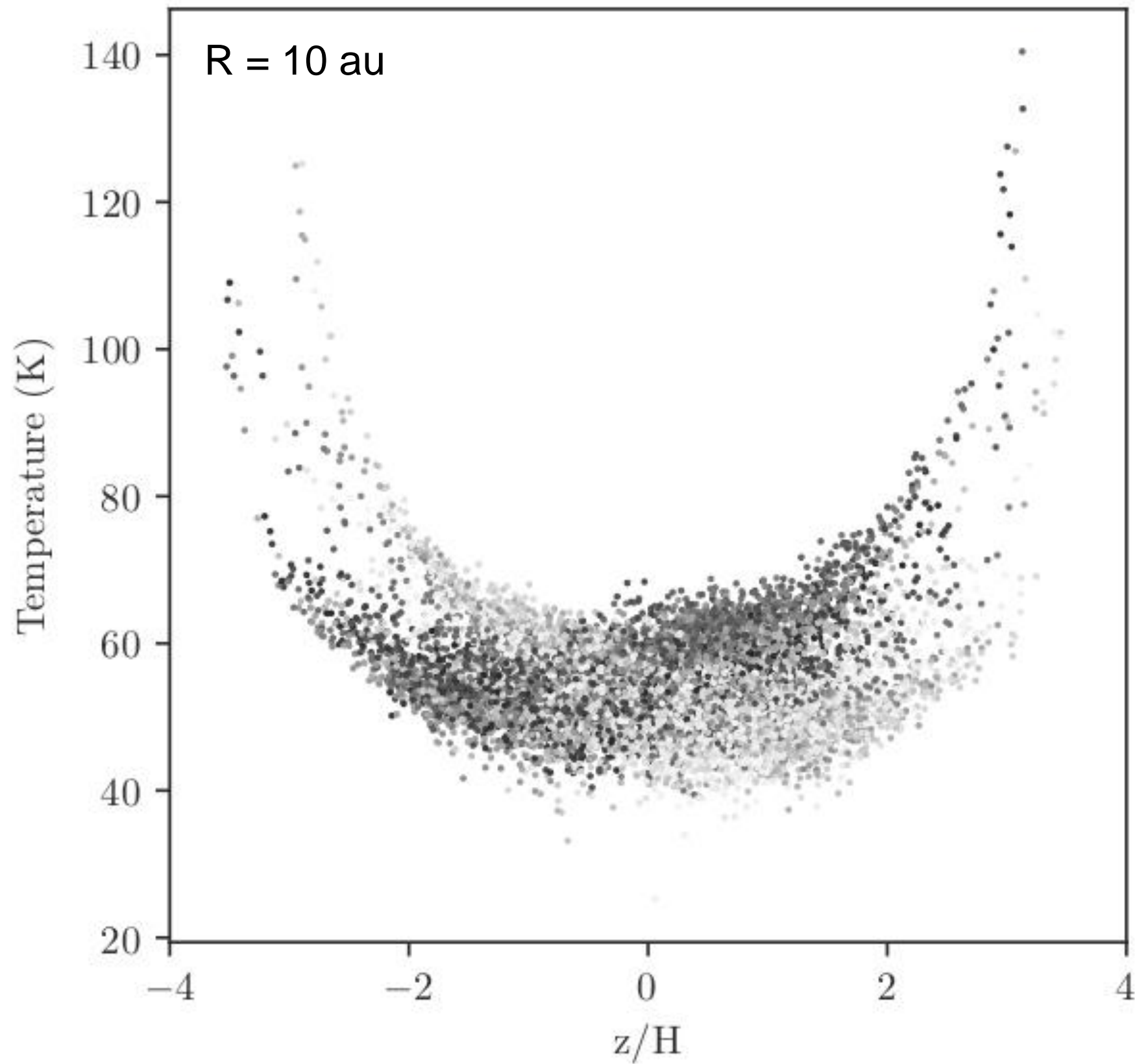


Measuring the shadow

1. Simulation with a misaligned planet
2. Generate scattered light with MCFOST
3. Make an azimuthal surface brightness profile

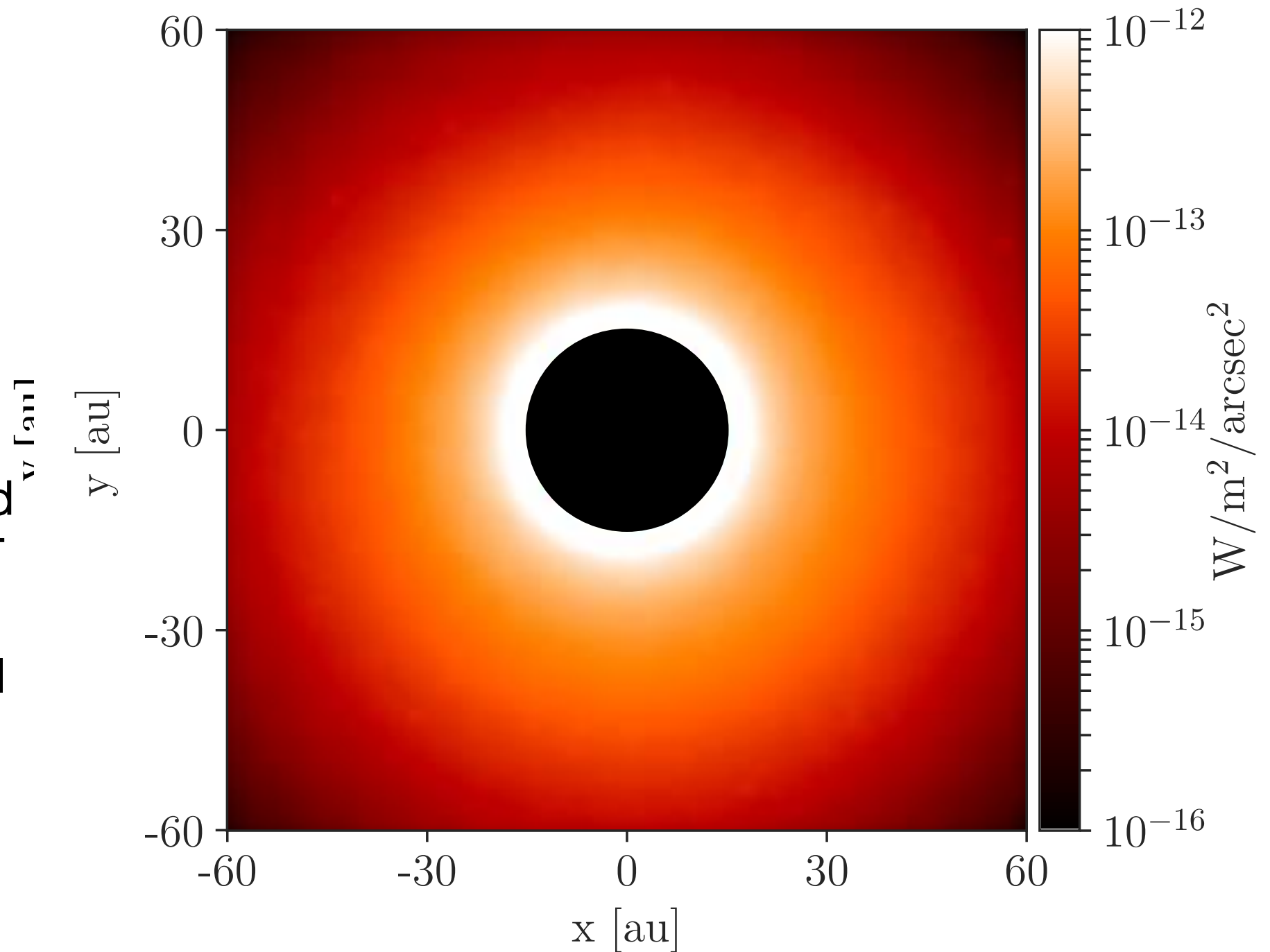


It's cooler in the shade ...

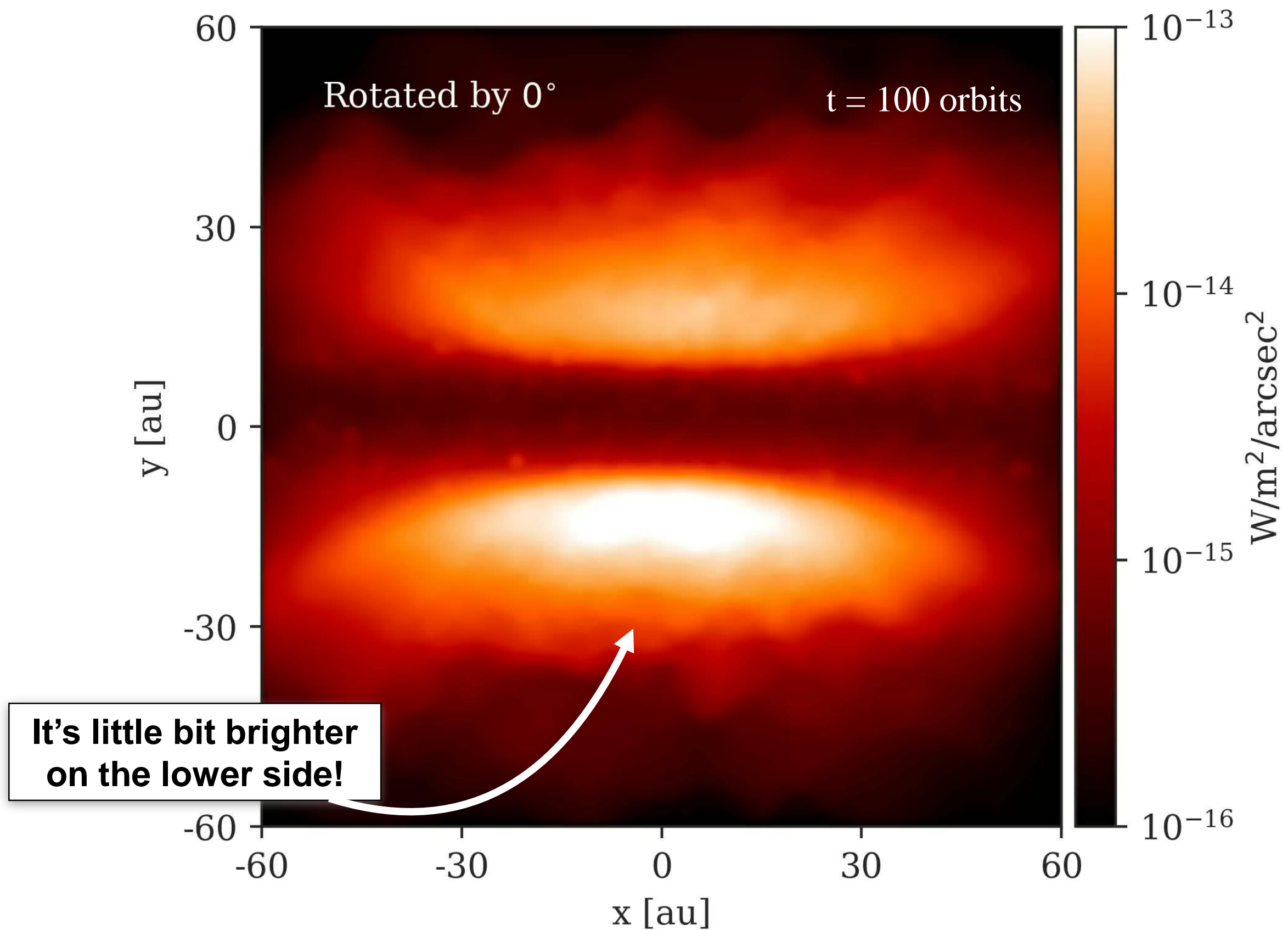


Measuring the warp

1. Simulation with a misaligned planet
2. Remove particles inside 15 au
3. Generate scattered light with MCFOST
4. Make an azimuthal surface brightness profile



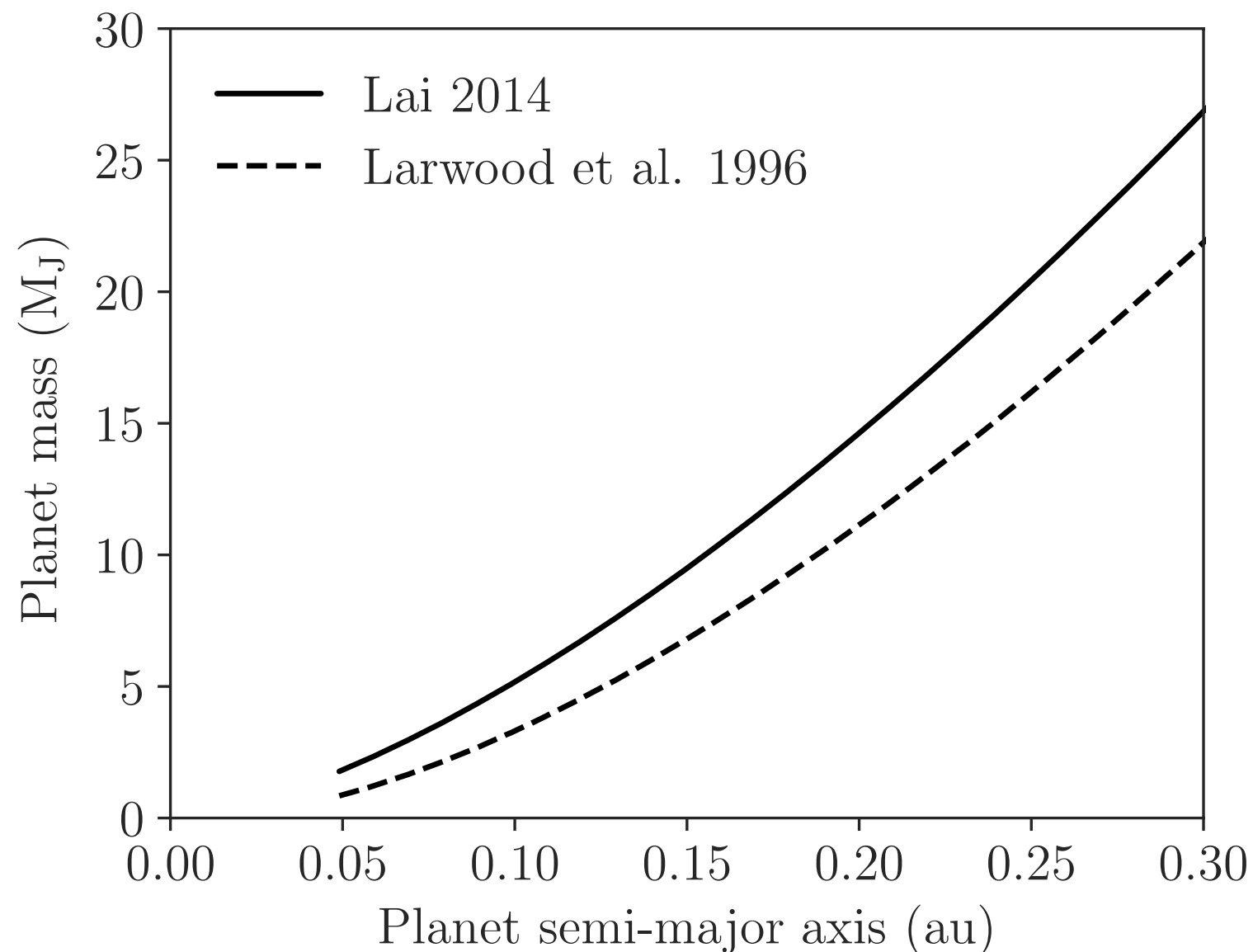
Seeing the warp edge-on



What about TW Hya?

Precession rate:

$$\omega = \frac{3GM_p}{4a^3} \frac{\int \Sigma R^3 dR}{\int \Sigma \Omega_k R^3 dR} \cos i$$

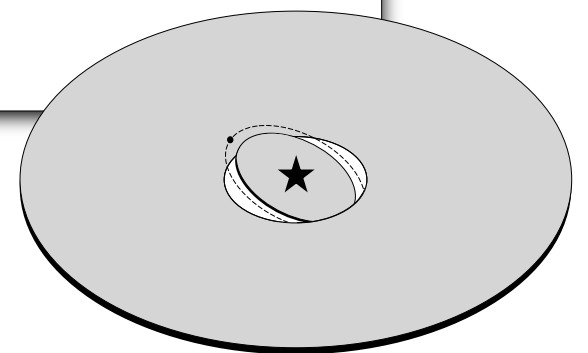


Location?

Depth/intensity?

Speed?

Longevity?



To agree with the observed precession rate, the planet must be **massive** and **close to the truncation** radius of the disc.

What about TW Hya?

Consider the accretion and alignment timescales ...

Accretion:

$$\dot{M} \sim 1.8 \times 10^{-9} M_{\odot}/\text{year} \quad (\text{Ingelby et al. 2013})$$

$$t_{\text{accrete}} \sim 10^3 - 10^5 \text{ years}$$

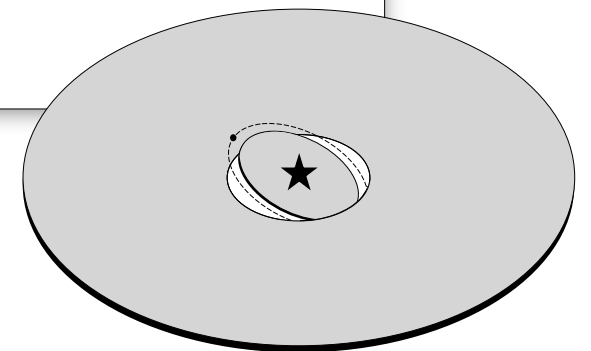
... or ~1% of TW Hya's age.

☺ Location?

☺ Depth/intensity?

☐ Speed?

Longevity?

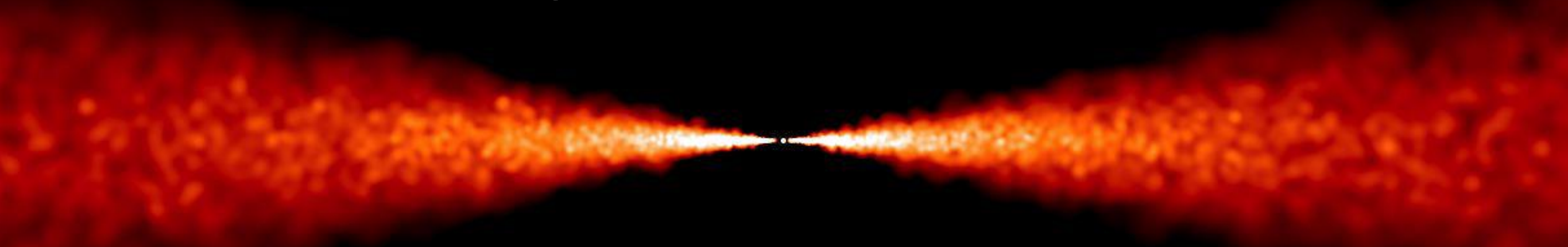


Alignment: $t_{\text{align}} \sim t_{\text{precess}}$ (Bate et al. 2000)

... or <<< 1% of TW Hya's age.

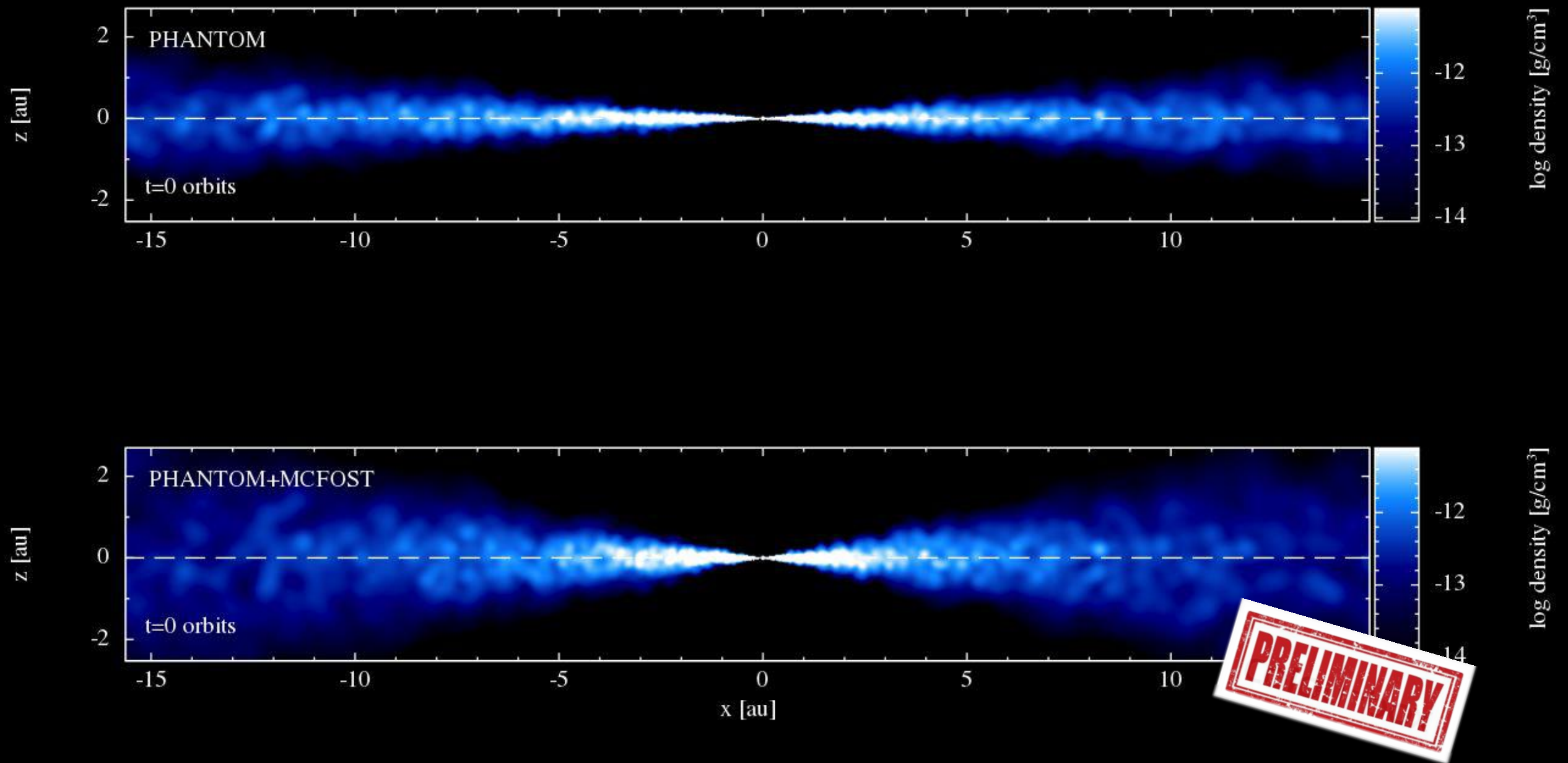
A precessing disc driven by a misaligned planet is unlikely to be observed in TW Hya as it is a **very short-lived feature.**

The moving shadow in TW Hya is **not likely** to be caused by a **precessing disc** governed by **misaligned planet**.



- We can recover the predicted structure in simulations
- The **misaligned inner disc** and **warp** in the outer disc generate observational features that are consistent with features in TW Hya
- However, the lifetime of this scenario is so short lived we do not consider it reasonable that this is observed
- Alternative models include MHD effects or a dynamical feature at 5au

Including radiation effects



What causes the biggest variation?

