PHANTOM SIMULATIONS OF A TRANSITING CIRCUMBINARY DISC

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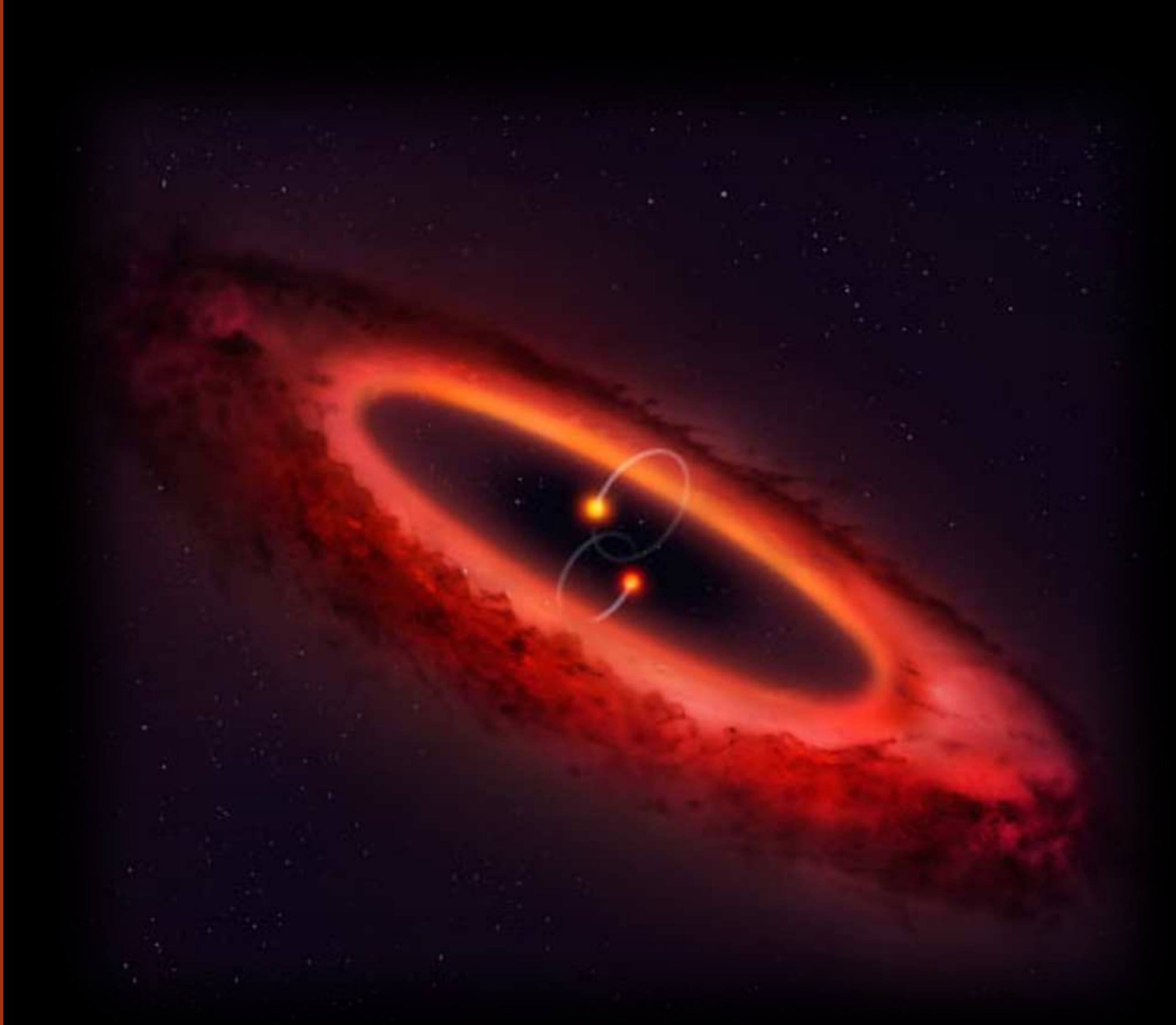

Credit: Mark Garlick, University of Warwick.

BACKGROUND & MOTIVATION

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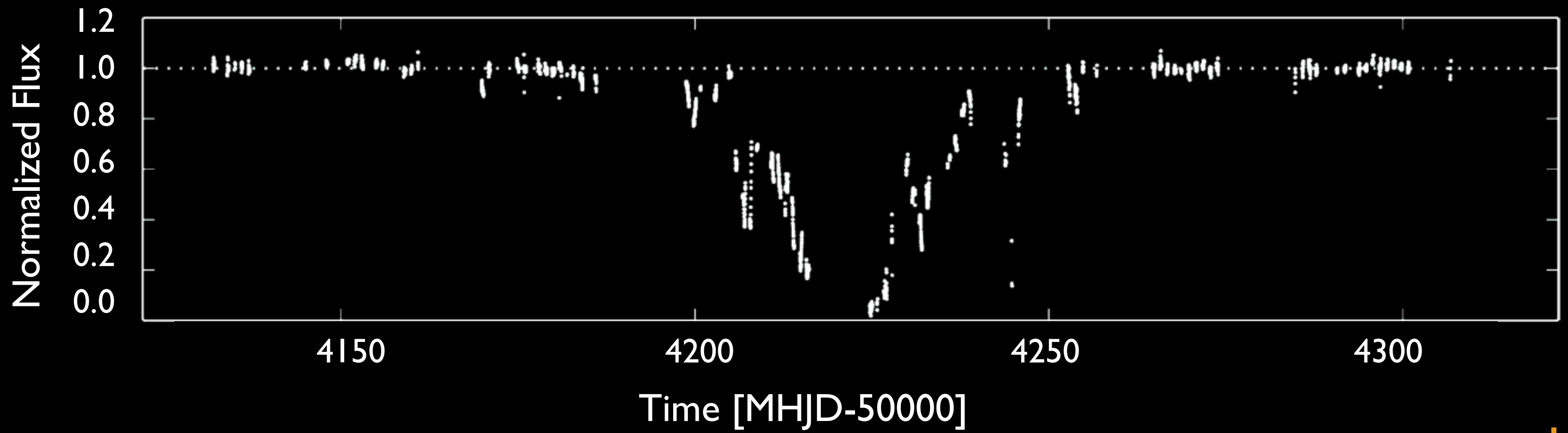
Circumstellar disc properties can be difficult to directly measure…

Is there a way to constrain these?

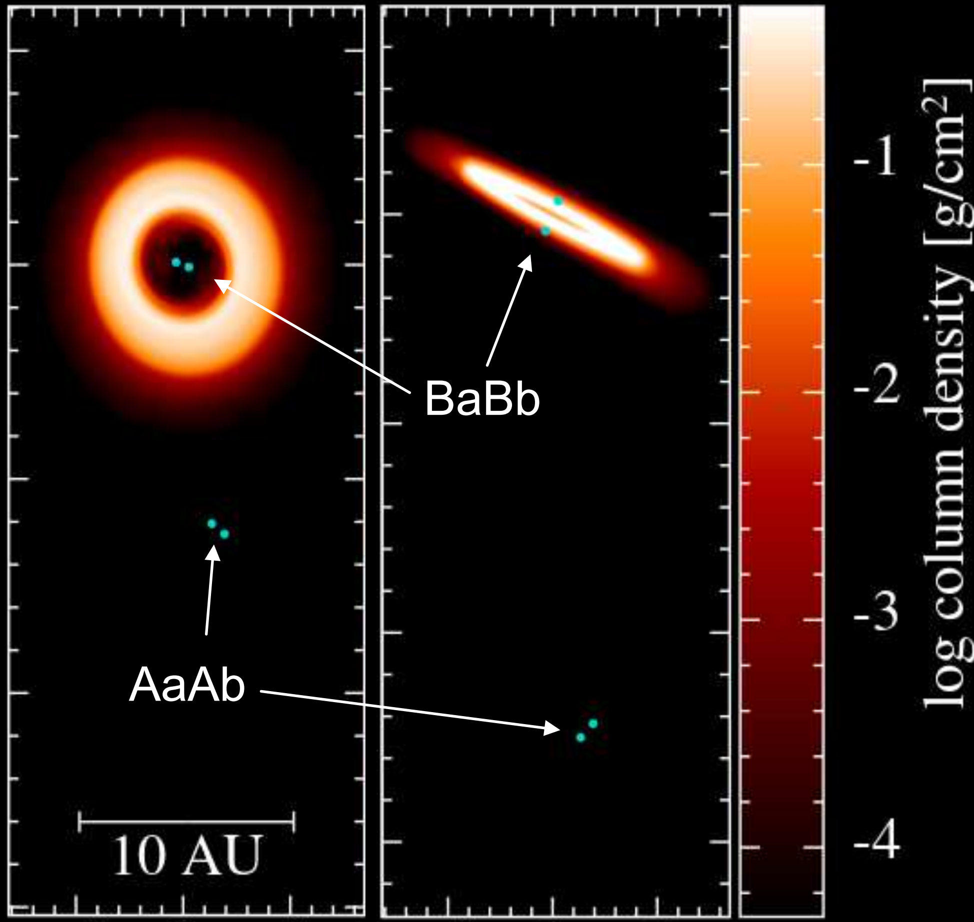
(See also: Rodriguez et al. 2014, Kloppenborg et al. 2010…)

Van Werkhoven et al. 2016 - J1407 eclipsed by ring of substellar companion



HD98800

- Two binaries, one with a disc in the polar configuration.
- Stellar trajectories and disc alignment are known.
- AaAb will pass behind the disc in 2026 (Kennedy et al. 2019.)
- Transit can allow us to constrain disc properties.



PROJECT GOALS

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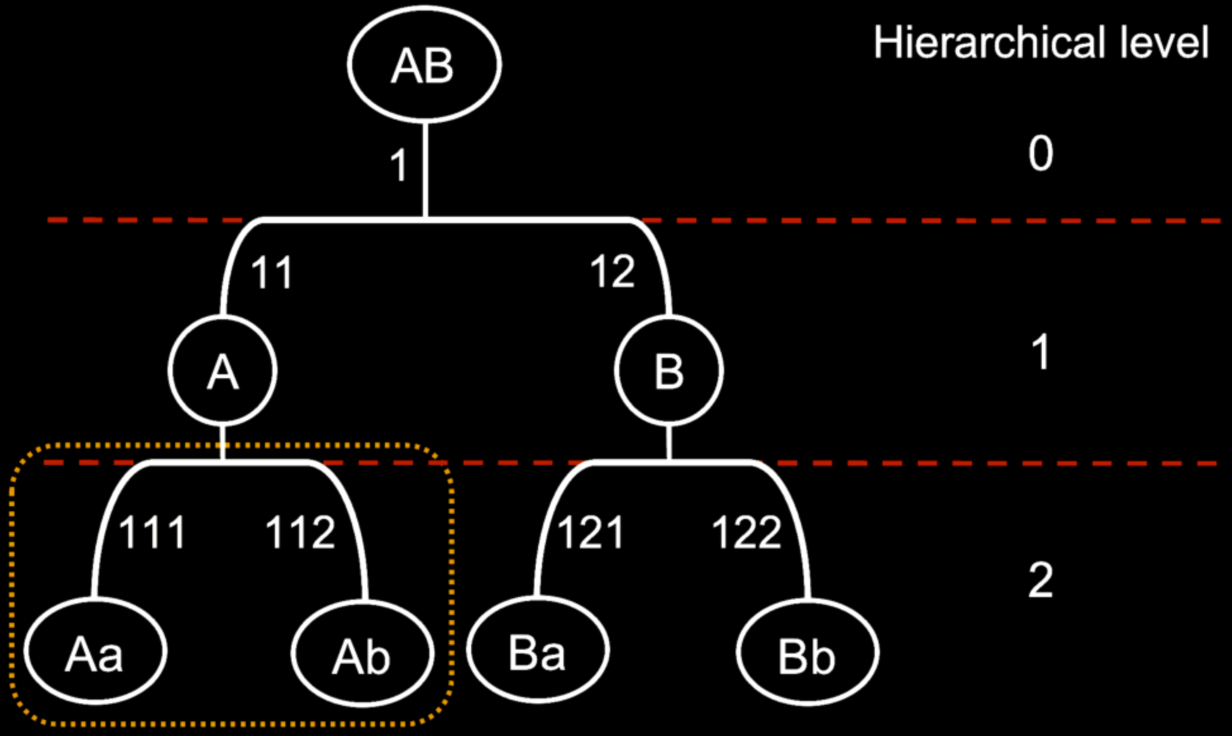
1. Run SPH simulations of HD98800.
2. Generate light curves of the expected transit:
   - What affect do disc parameters have on the shape?
   - Which set of parameters will most closely match what we observe?
   - How can synthetic light curves inform observations of real transit event?

1. PHANTOM – SPH MODELS

Phantom code modified to allow 4 sink particles for a `disc` setup type

Grid of Phantom models run

Dumps files → ASCII density grids



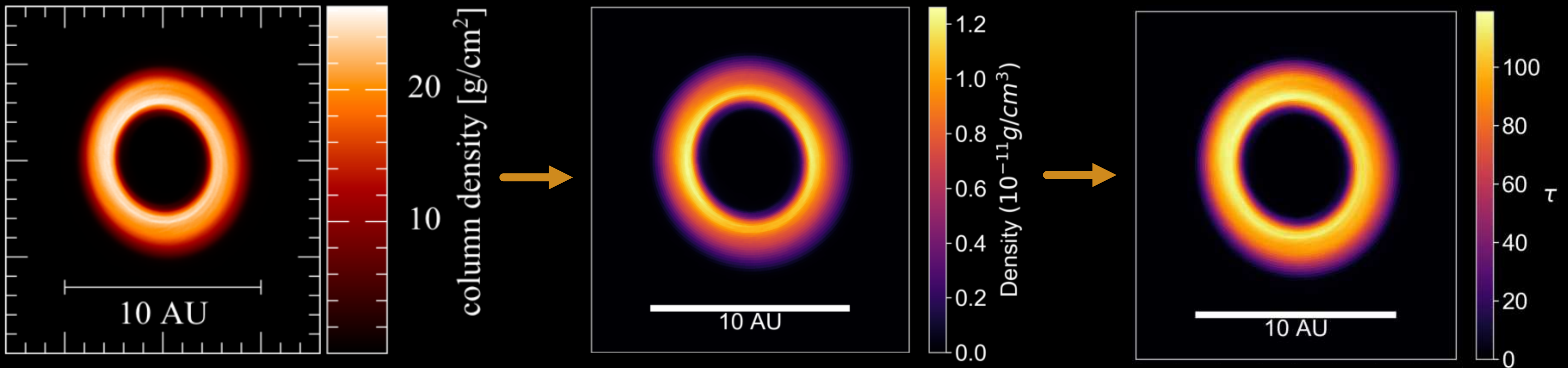
2. MCFOST – RADIATIVE TRANSFER MODELS

MCFOST grid created

Phantom density data interpolated onto it

Grid flipped along x, y

MCFOST run on density grids to create optical depth maps



3. PRODUCING A LIGHT CURVE

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At each timestep,

1. Get (x,y) locations of stars Aa and Ab
2. Use optical depth map of corresponding timestep to obtain τ along line-of-sight to Aa and Ab.
3. Calculate flux drop of each star using

$$F = F_0 \exp(-\tau)$$

(F_0 taken from Ribas et al. 2018)

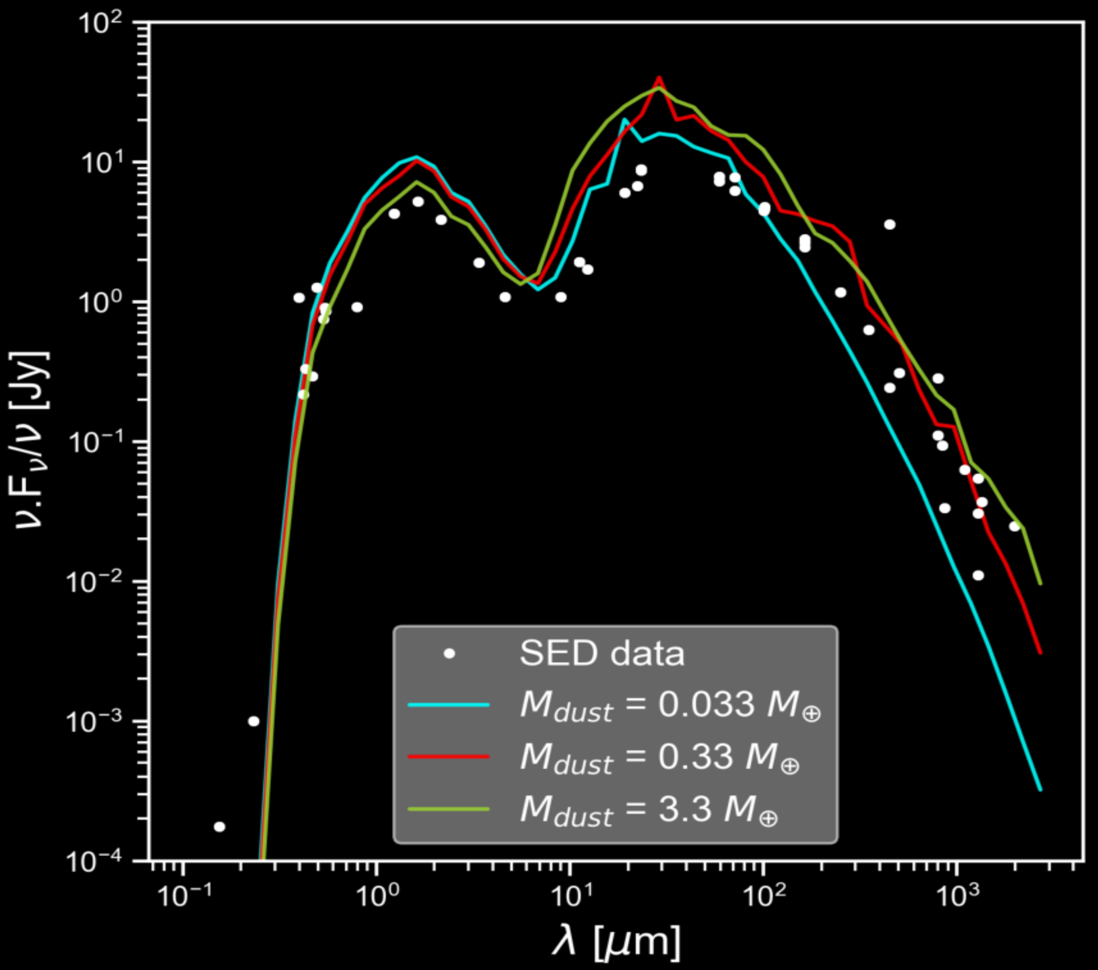
How do we define the parameter space?

DUST AND GAS MASSES

SEDs generated for different dust masses and compared to observational data

3 closest dust masses chosen

Assumed gas-dust ratio of 100 to obtain 3 gas masses



GRID OF MODELS

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Orbital parameters for disc and 4 stars taken from Zúñiga-Fernández et al. 2021 and Kennedy et al. 2019.

Model Number	**1**	**2**	**3**	**4**	**6**	**7**	**8**
α_S viscosity	0.005	0.005	0.005	0.005	0.005	0.05	0.01
Gas mass ($\mathbf{M}_\oplus$)	3.3	33	330	33	33	33	33
Dust mass ($\mathbf{M}_\oplus$)	0.33	0.33	0.33	0.033	3.3	0.33	0.33

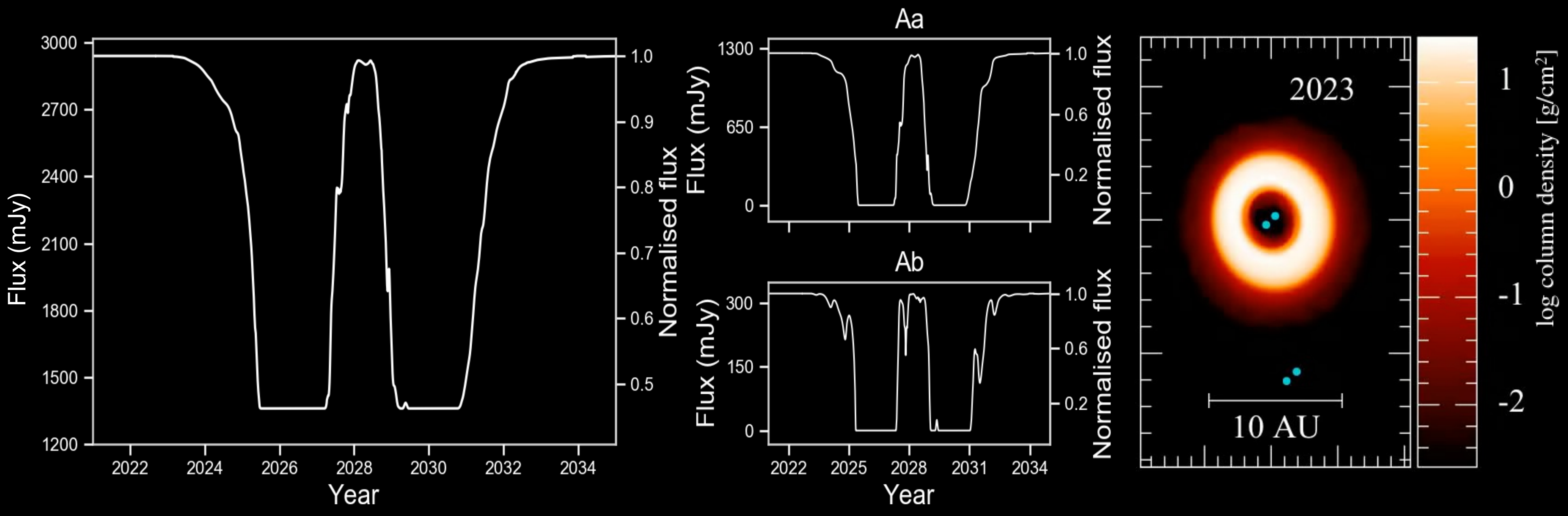
Varying gas mass (models 1, 2, 3)

Varying dust mass (models 4, 6)

Varying disc viscosity (models 7, 8)

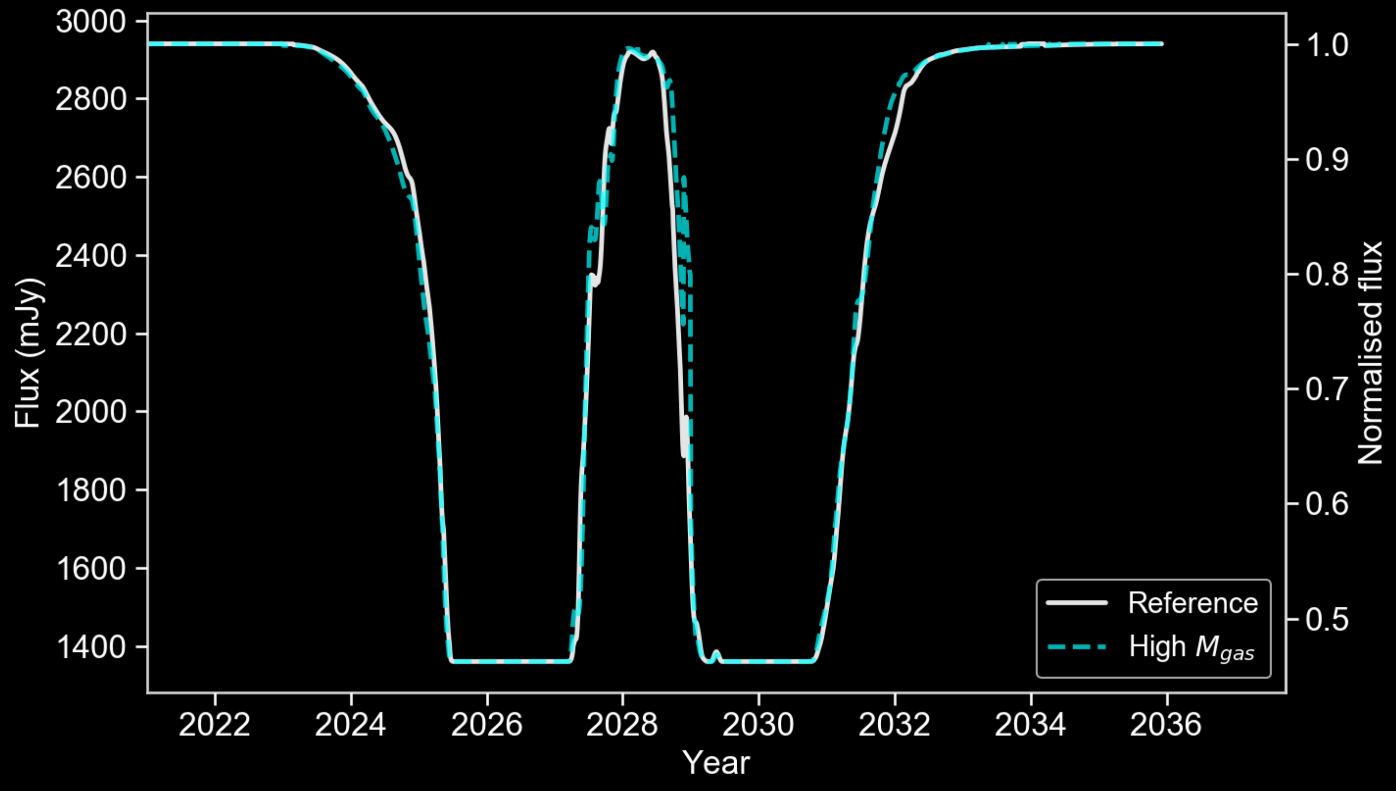
All run for ~55 yrs, model 2 rerun for ~1150 yrs to consider outer binary interactions

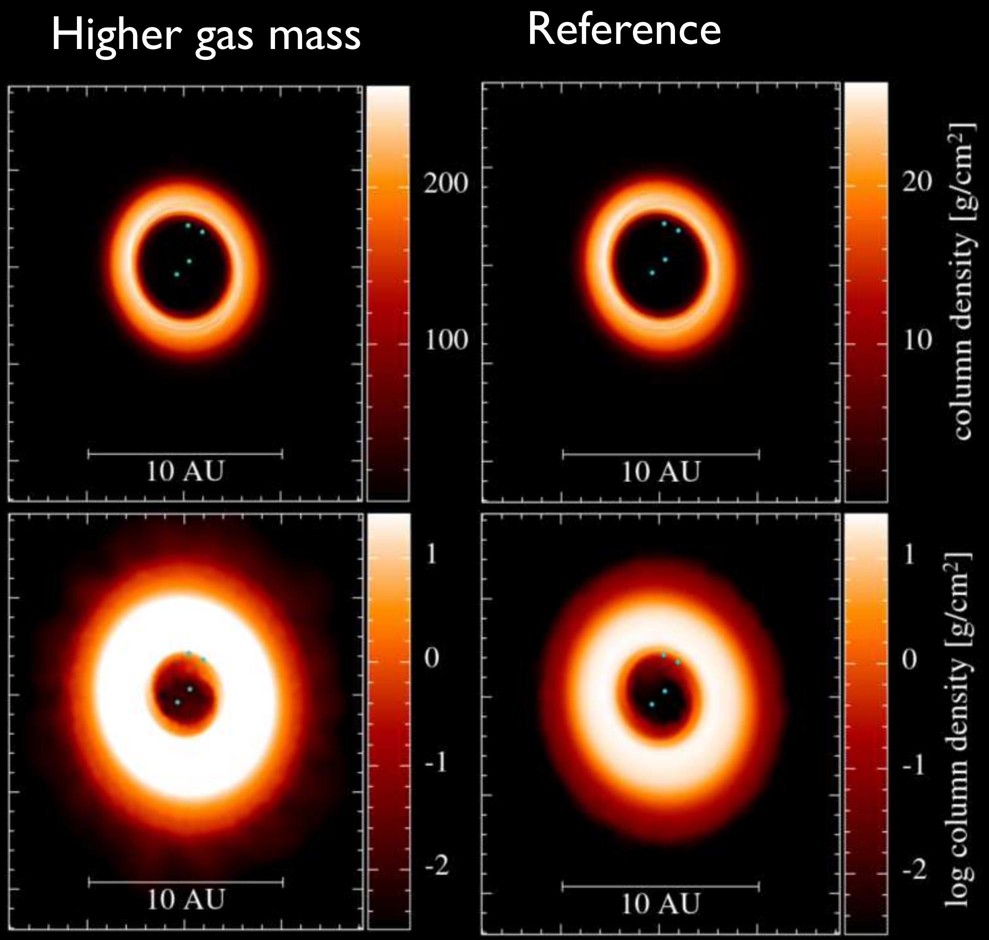
RESULTS



3000
2700
2400
2100
1800
1500
1200
Flux (mJy)
1.0
0.9
0.8
0.7
0.6
0.5
Normalised flux
2022
2024
2026
2028
2030
2032
2034
Year
Aa
1300
650
0
Flux (mJy)
1.0
0.6
0.2
Normalised flux
Ab
300
150
0
Flux (mJy)
1.0
0.6
0.2
Normalised flux
2022
2025
2028
2031
2034
Year
2023
10 AU
1
0
-1
-2
log column density [g/cm²]

RESULTS – GAS MASS





No observable difference

RESULTS – ALPHA VISCOSITY

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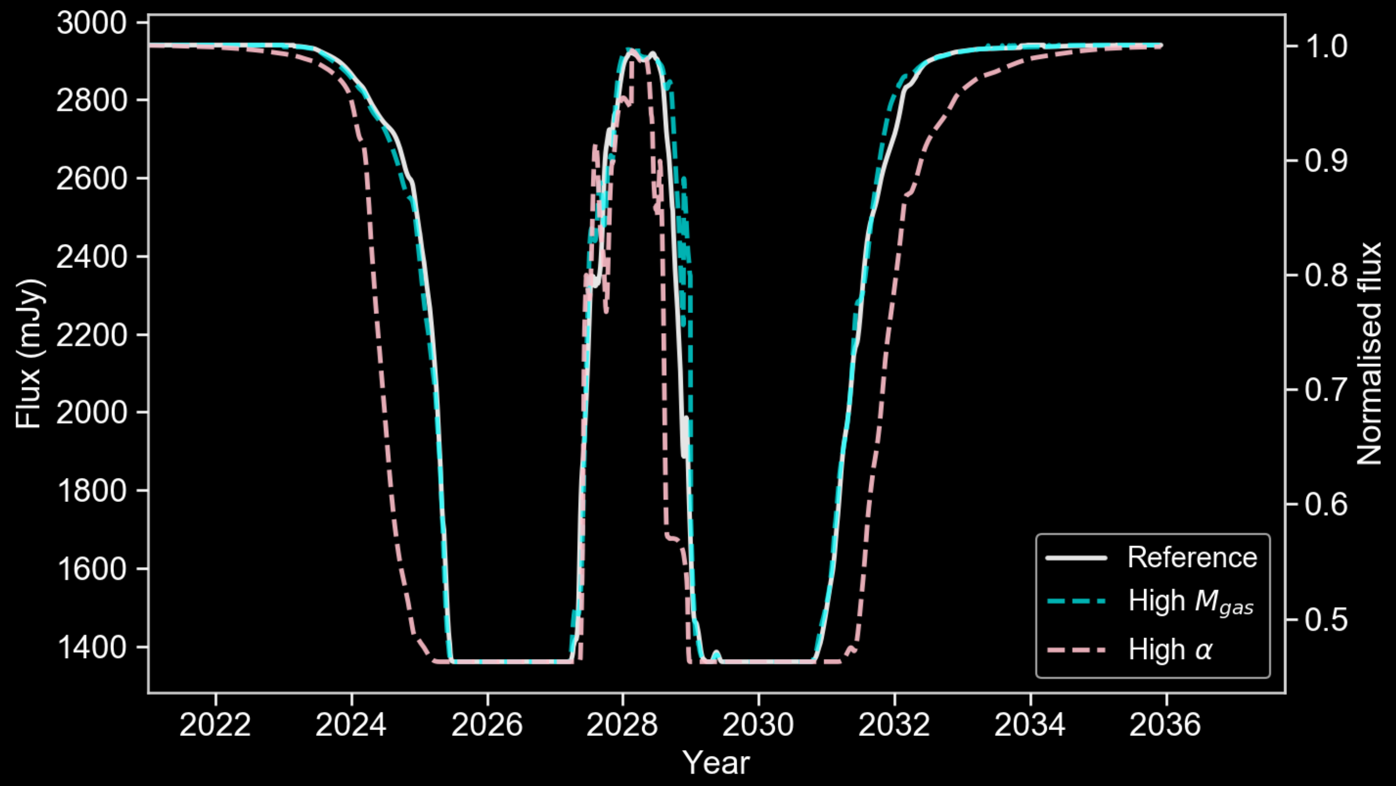

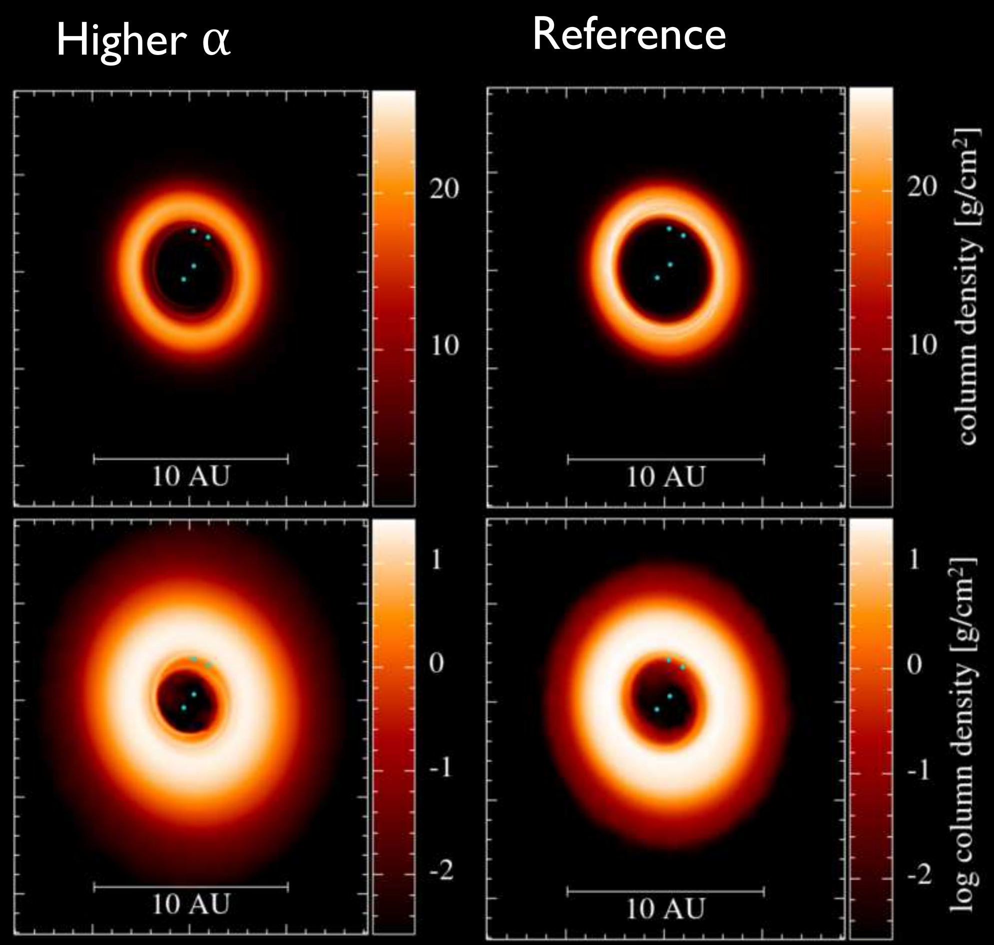

Dips widen at disc outer edges

RESULTS – DUST MASS

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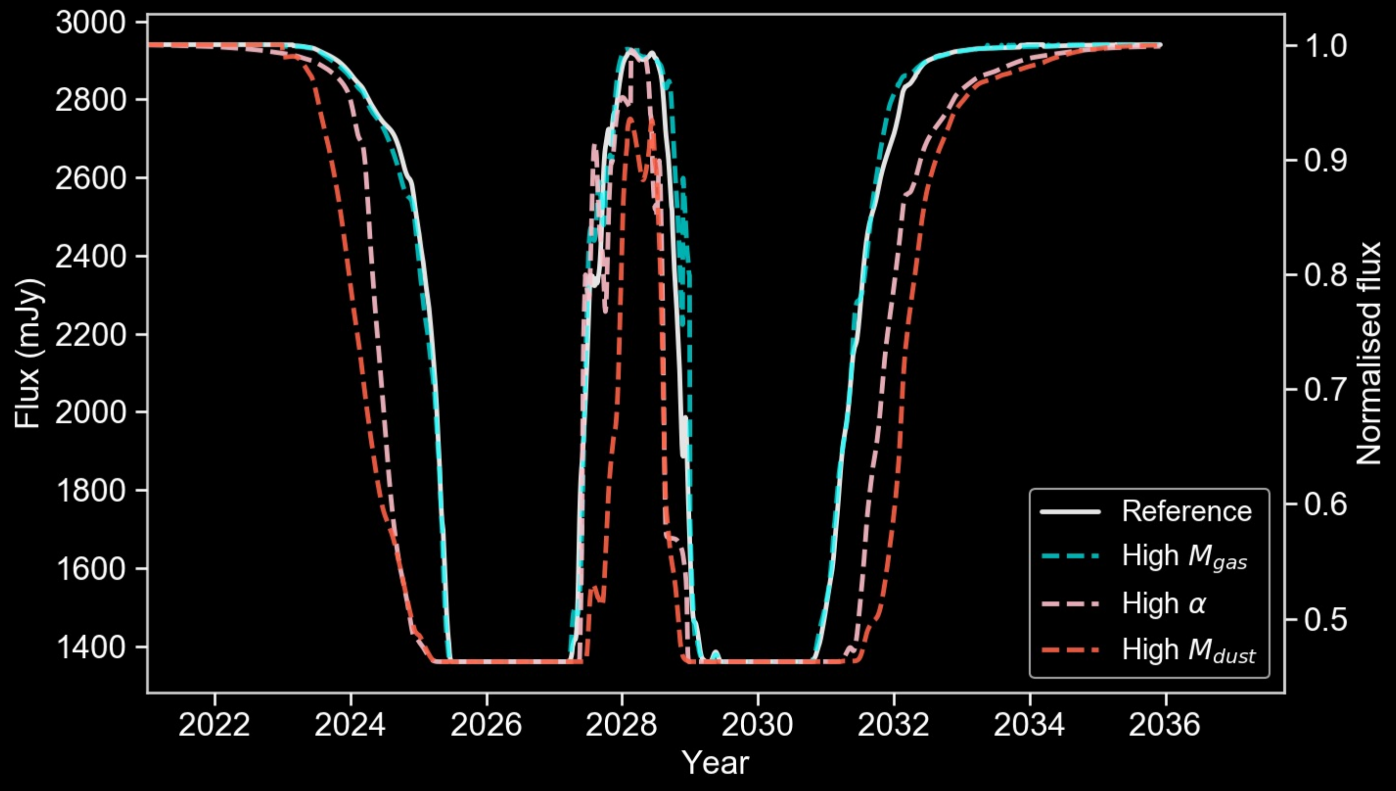
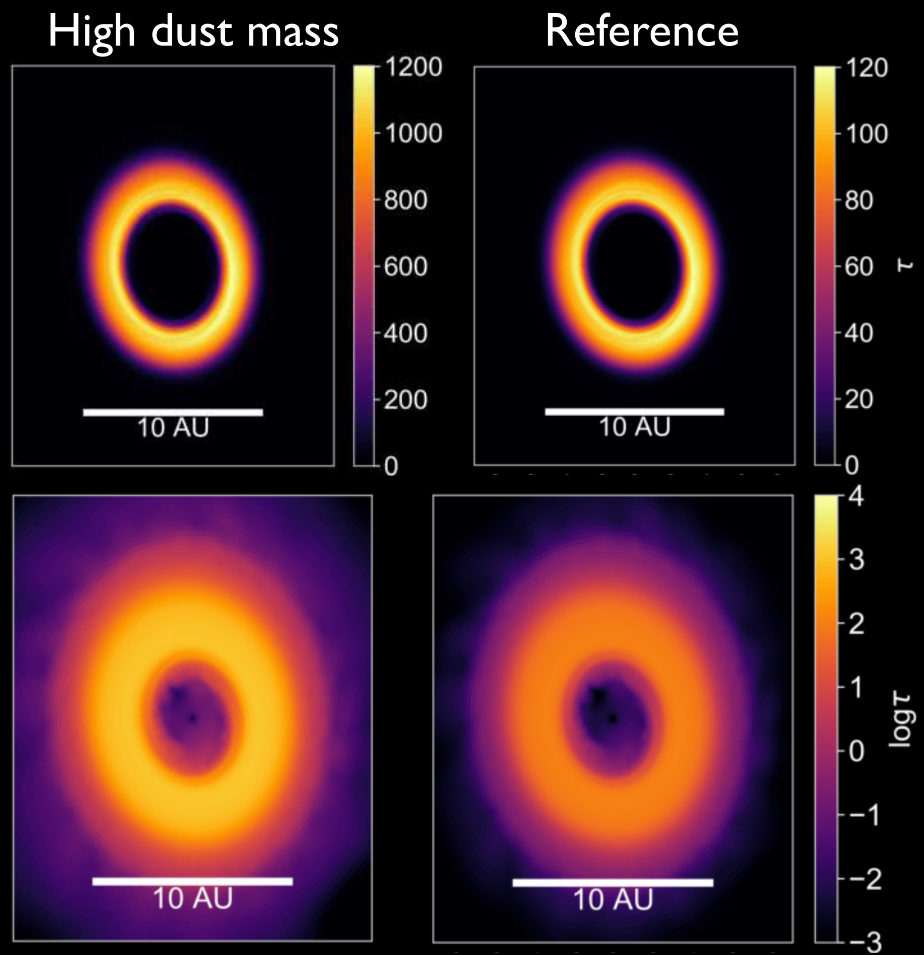
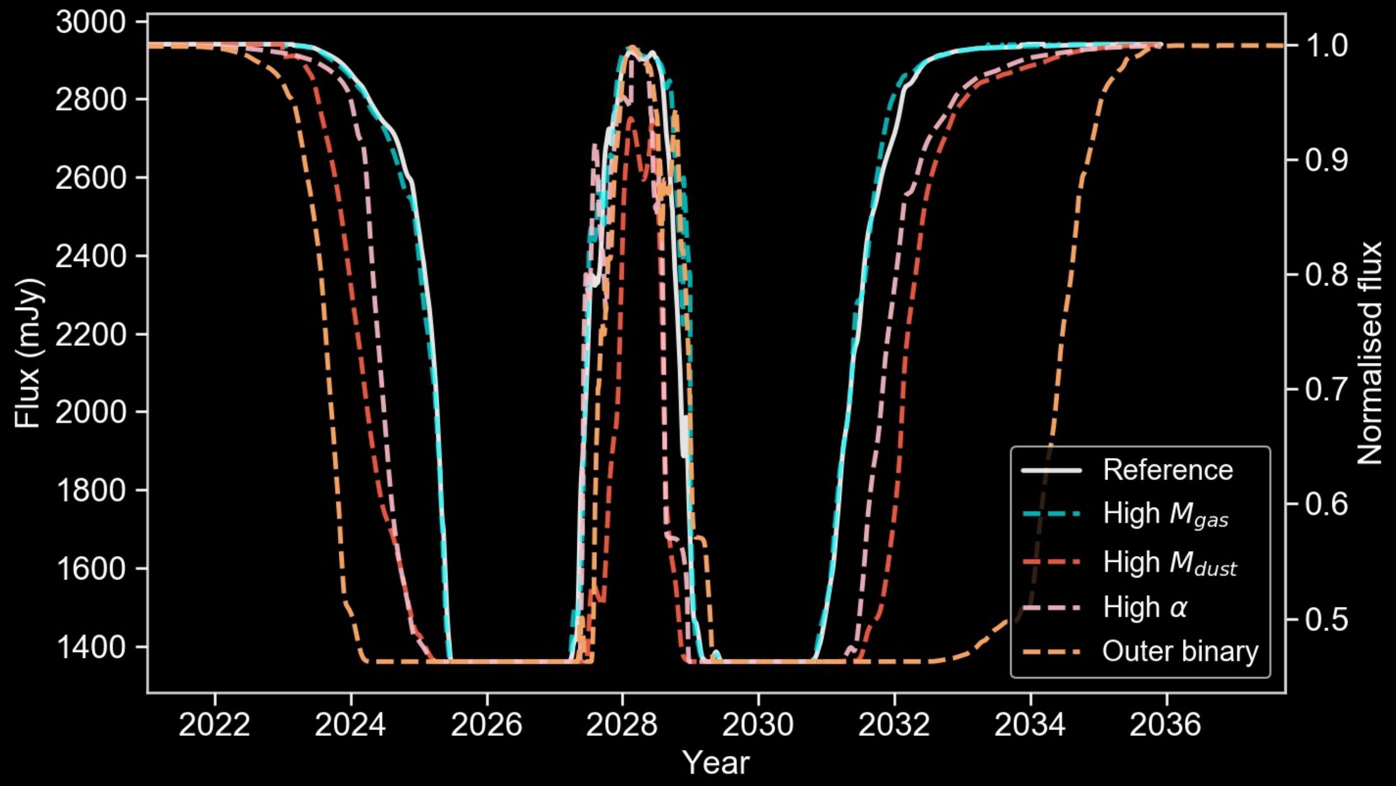
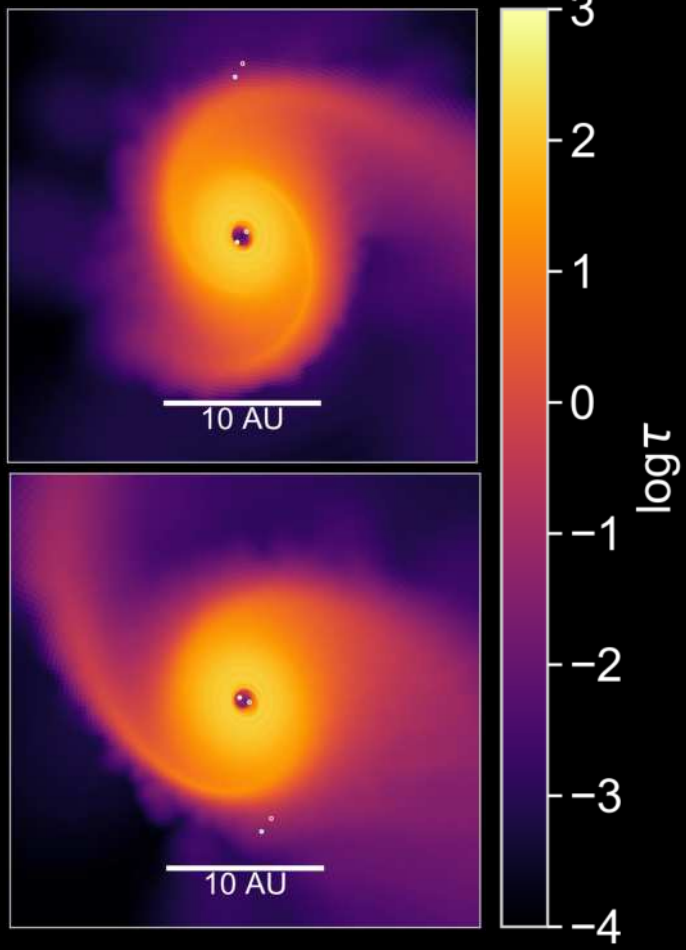




Dips widen at disc inner and outer edges

RESULTS – OUTER BINARY INTERACTIONS





Dips widen, asymmetry in light curve observed

REAL OBSERVATIONS

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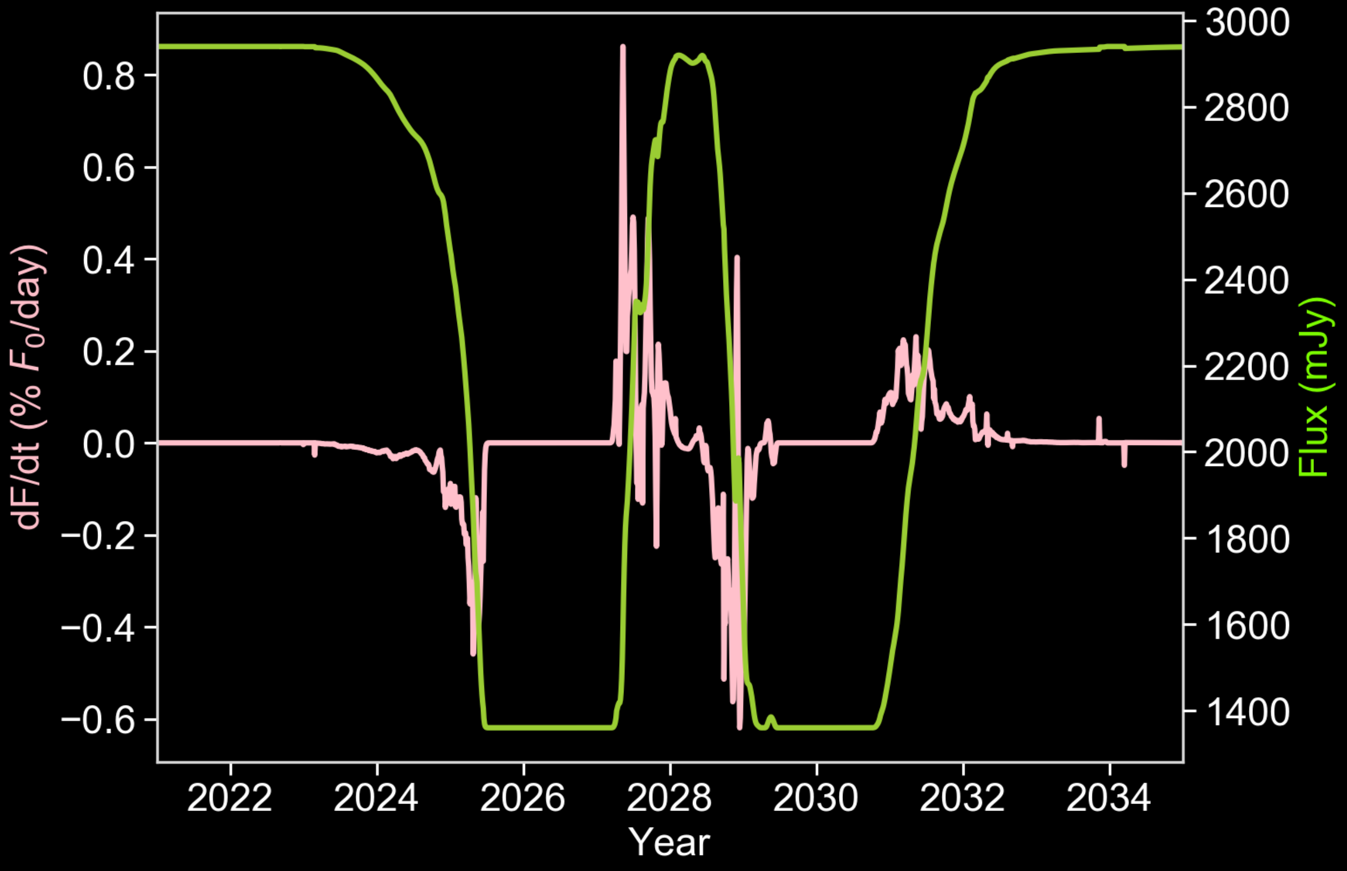
Minimum cadence needed to observe fastest changes: ~ 6 days (assuming $\Delta F \geq 5\%$ to be detectable).

Observe from mid 2023 to early 2033, ideally

LCO has begun observing HD98800



SUMMARY

- Phantom/MCFOST used to produce synthetic light curves of future transit event.
- Disc parameters directly affect observations.
- Synthetic observations like these can help connect theoretical and observational work.