MASS ACCRETION RATE AND RADIATIVE FEEDBACK IN CIRCUMBINARY DISKS AROUND SUPERMASSIVE BLACK HOLE BINARIES

José Barría C.
Universidad de Valparaiso

2nd European Phantom code family users workshop

2025

TITANS Nucleo Milenio
Universidad de Valparaíso CHILE

ABOUT ME

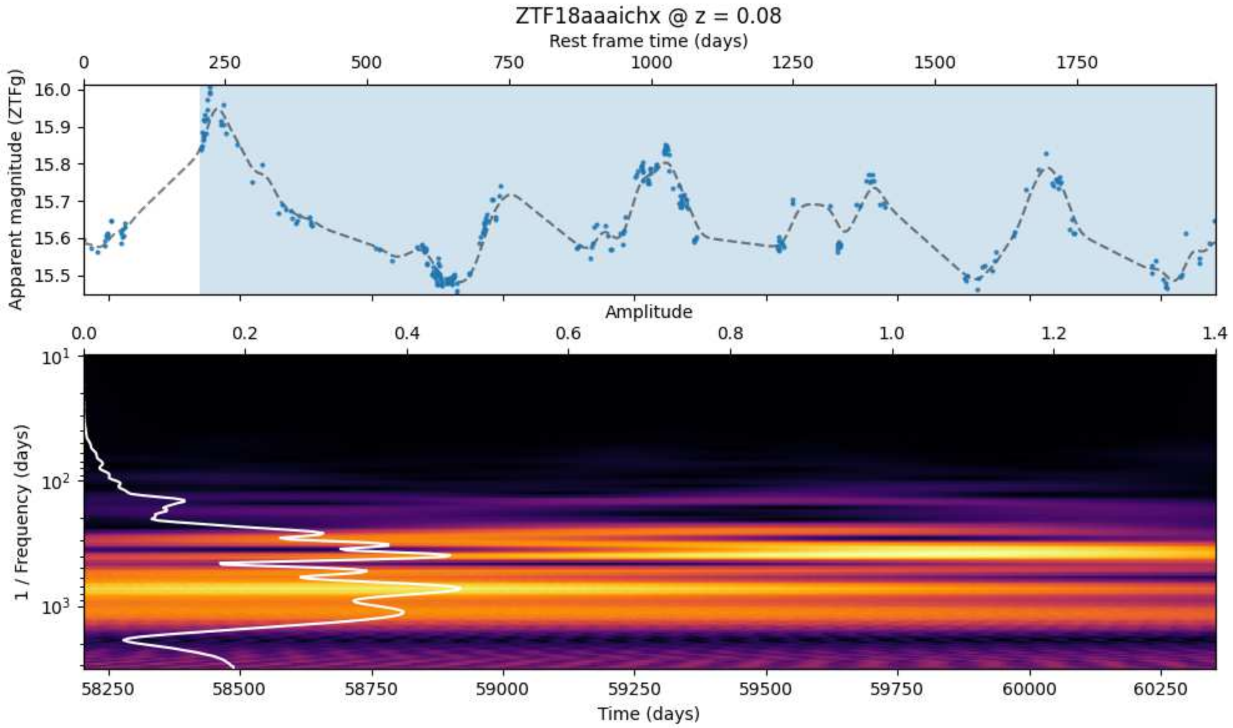
PhD student at **Universidad de Valparaiso**, Chile.

Worked with **Dr. Patricia Arevalo** studying variability properties of accreting supermassive black holes using large amounts of data and automated classifiers to prepare for the upcoming sky surveys like **LSST**.

Currently working on my thesis on **accretion variability of supermassive black hole binary systems** with **Dr. Jorge Cuadra** as supervisor and **Dr. Patricia Arevalo** as co-supervisor.

TITANS
Nucleo Milenio

Valparaiso, Chile (2025, colorized)



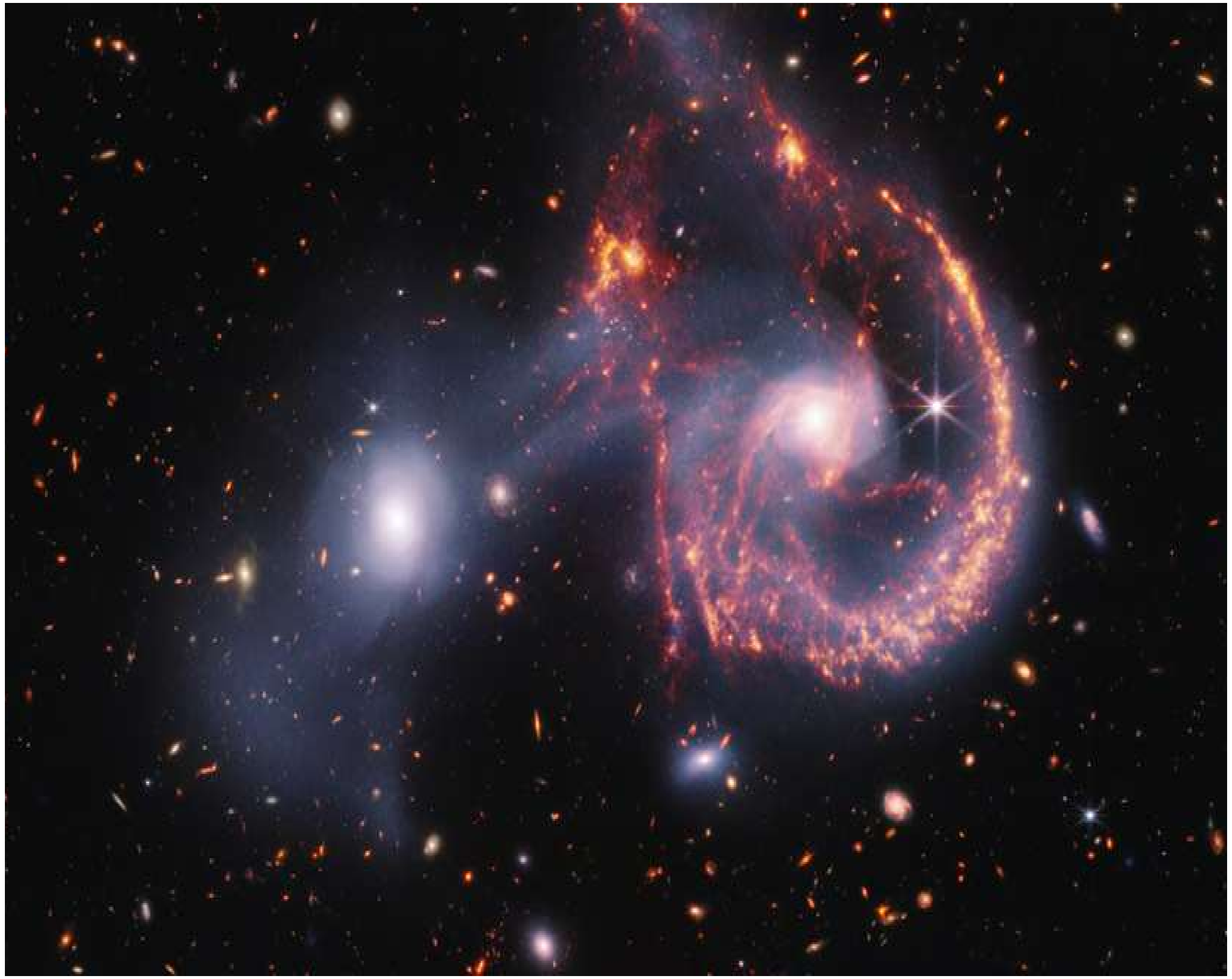
BINARY SUPERMASSIVE BLACK HOLE SYSTEMS

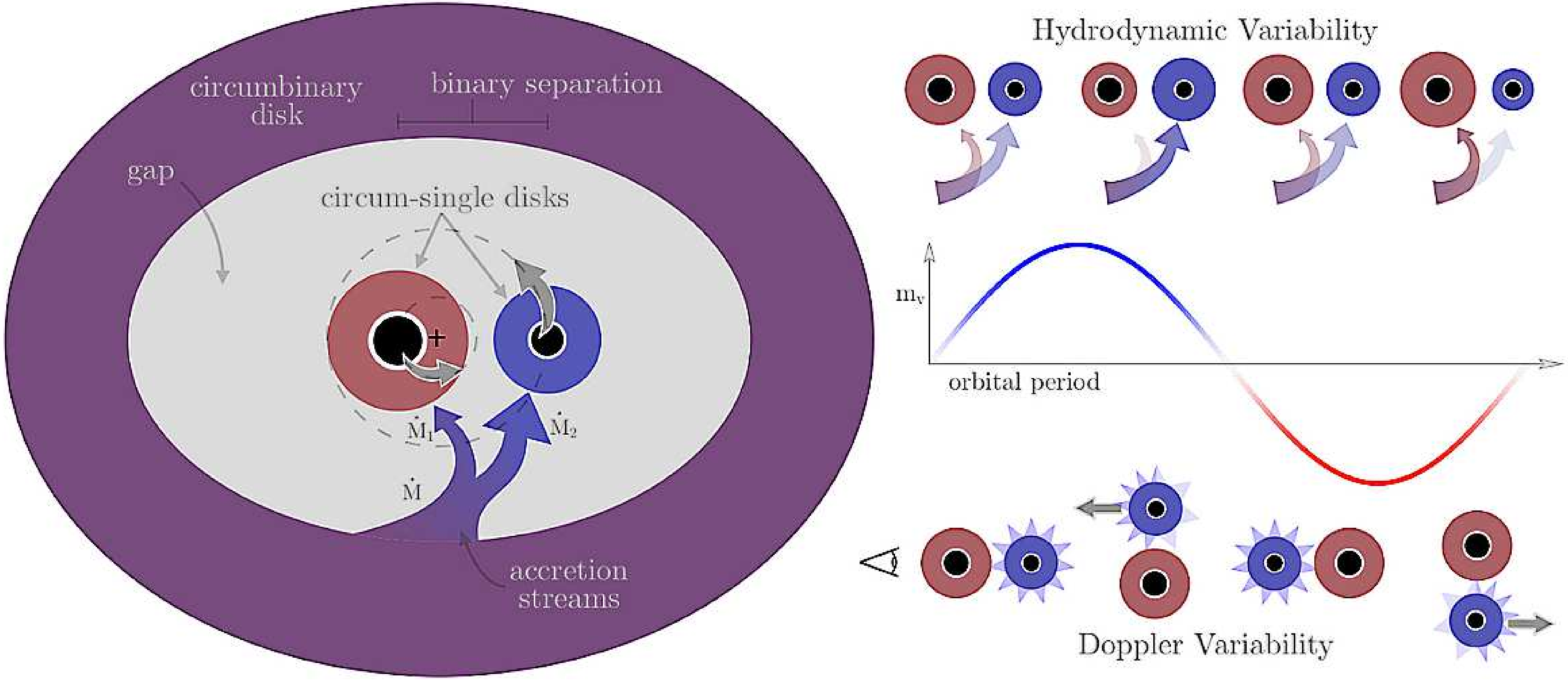
Binary supermassive black hole (BSMBH) systems are expected to form naturally as a result of a **galaxy merger**.

Dynamical friction with surrounding stars drives the black holes into tight orbits at sub-parsec scales.

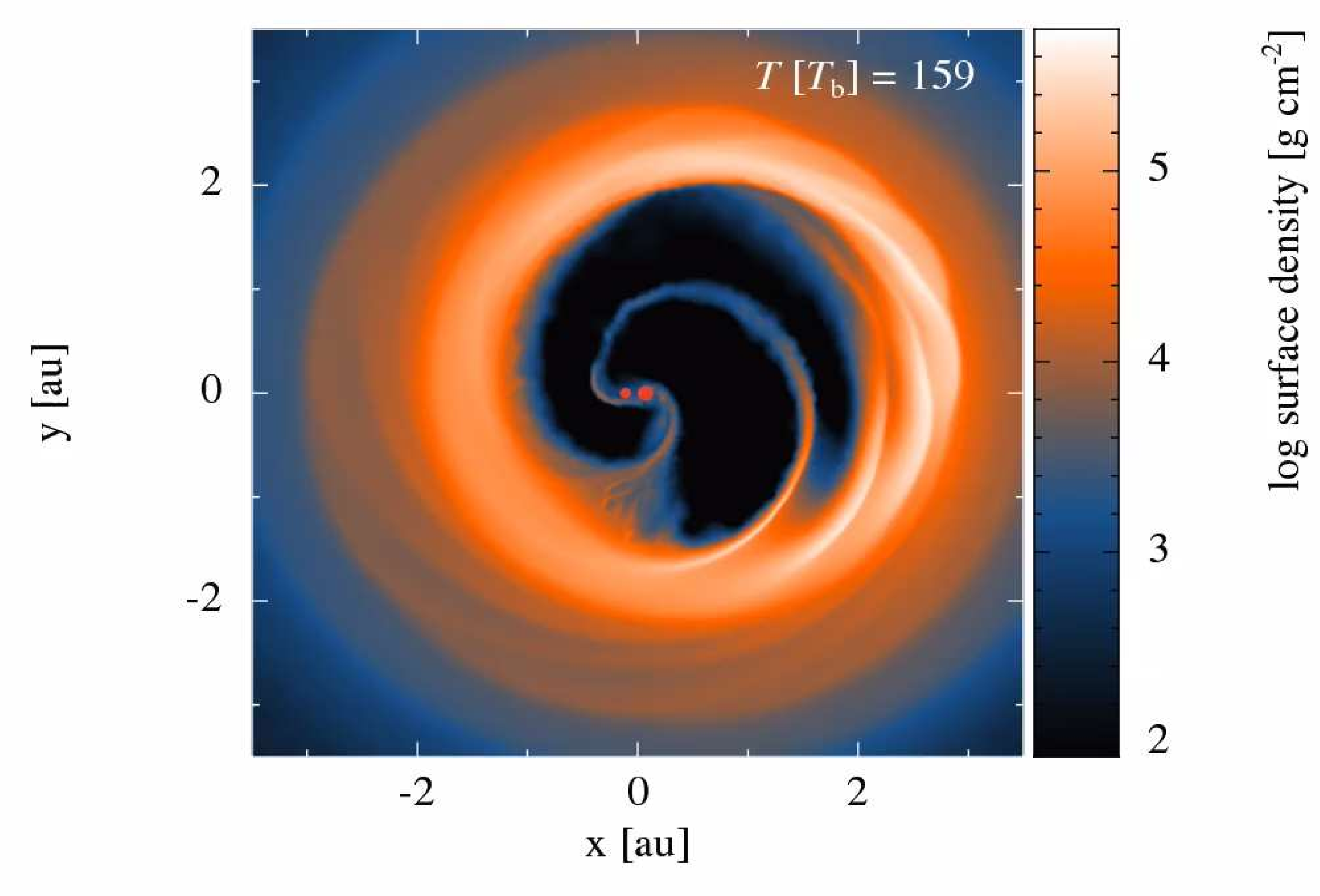
The in-falling gas will form a **circumbinary disk** around the two black holes.

The orbital motion of the black holes perturbs the gas resulting in flows that change the **mass accretion rate** with a period tied to the binary's orbit.





From: L.Z. **Kelley (2018)**



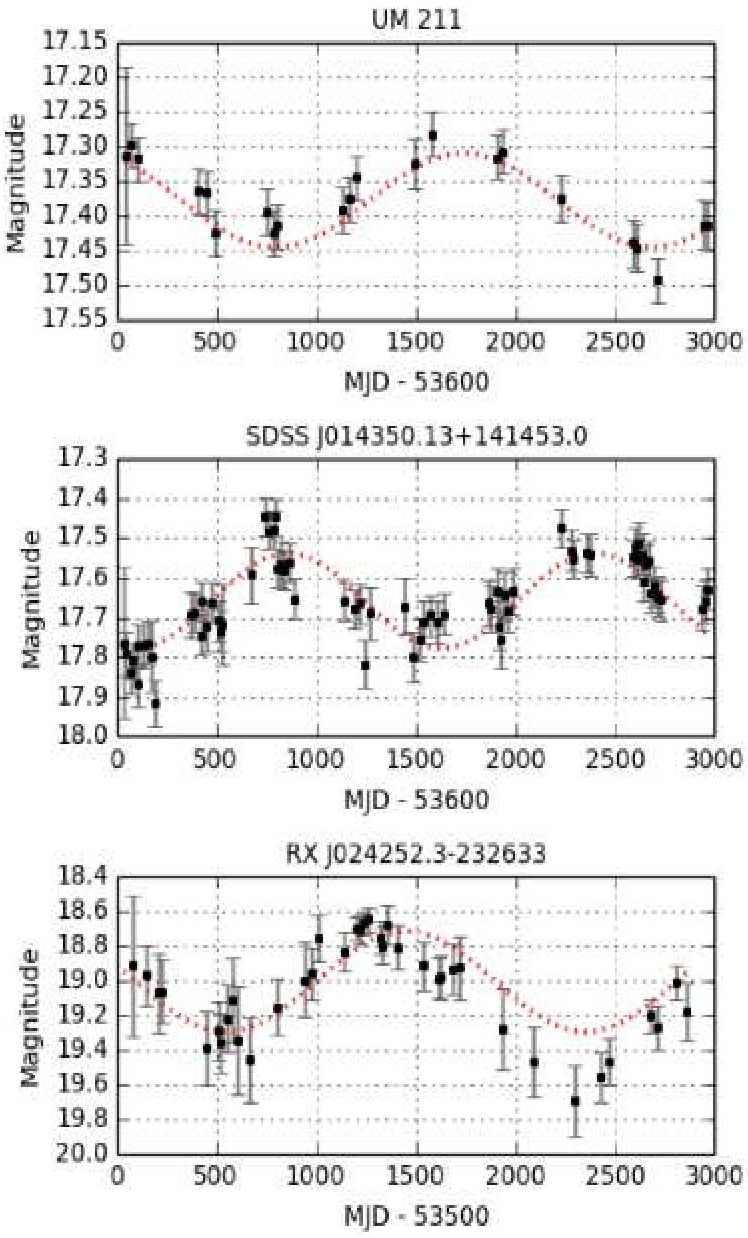
Example of a locally isothermal disk around a binary star system using 2 million particles.
(Credit: **A. C. Dunhil, J. Cuadra, C. Dougados 2015**)

DETECTION METHODS

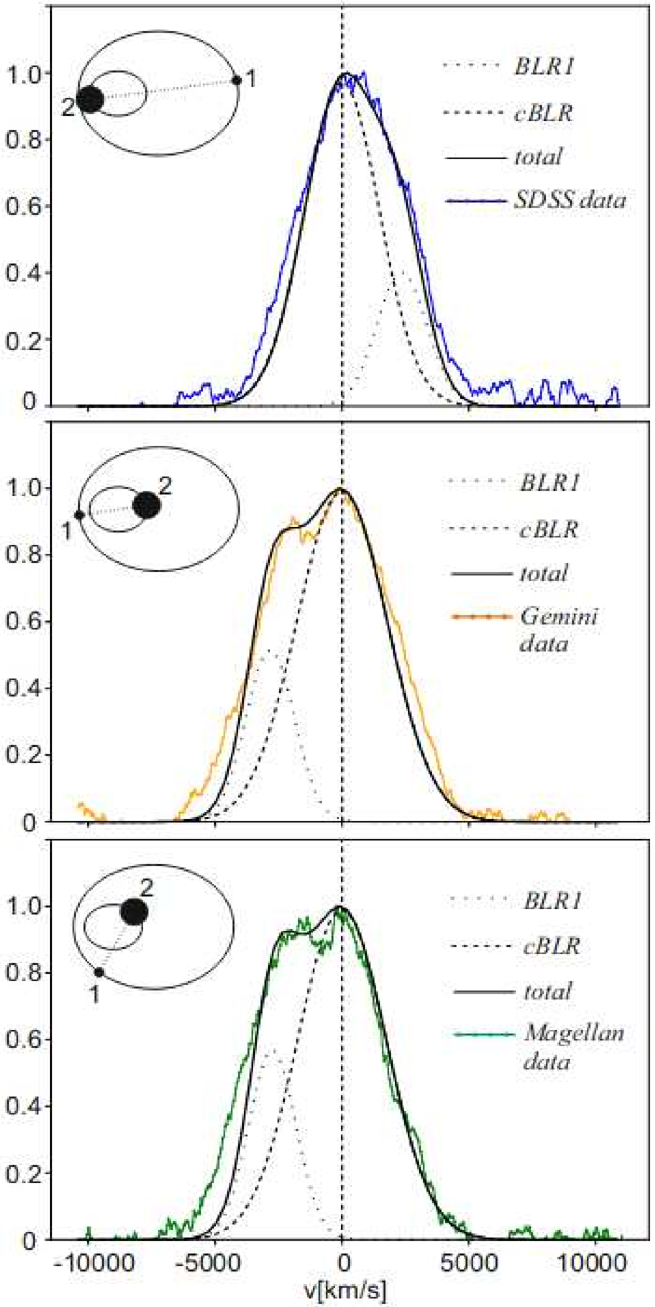
Accretion onto SMBH releases radiation.

Because these sources are extremely far away, we **cannot resolve their disk with direct imaging** and thus we rely on indirect approaches to study their interaction:

- **Periodic variability**
- Multi-epoch Spectroscopy
- Gravitational waves

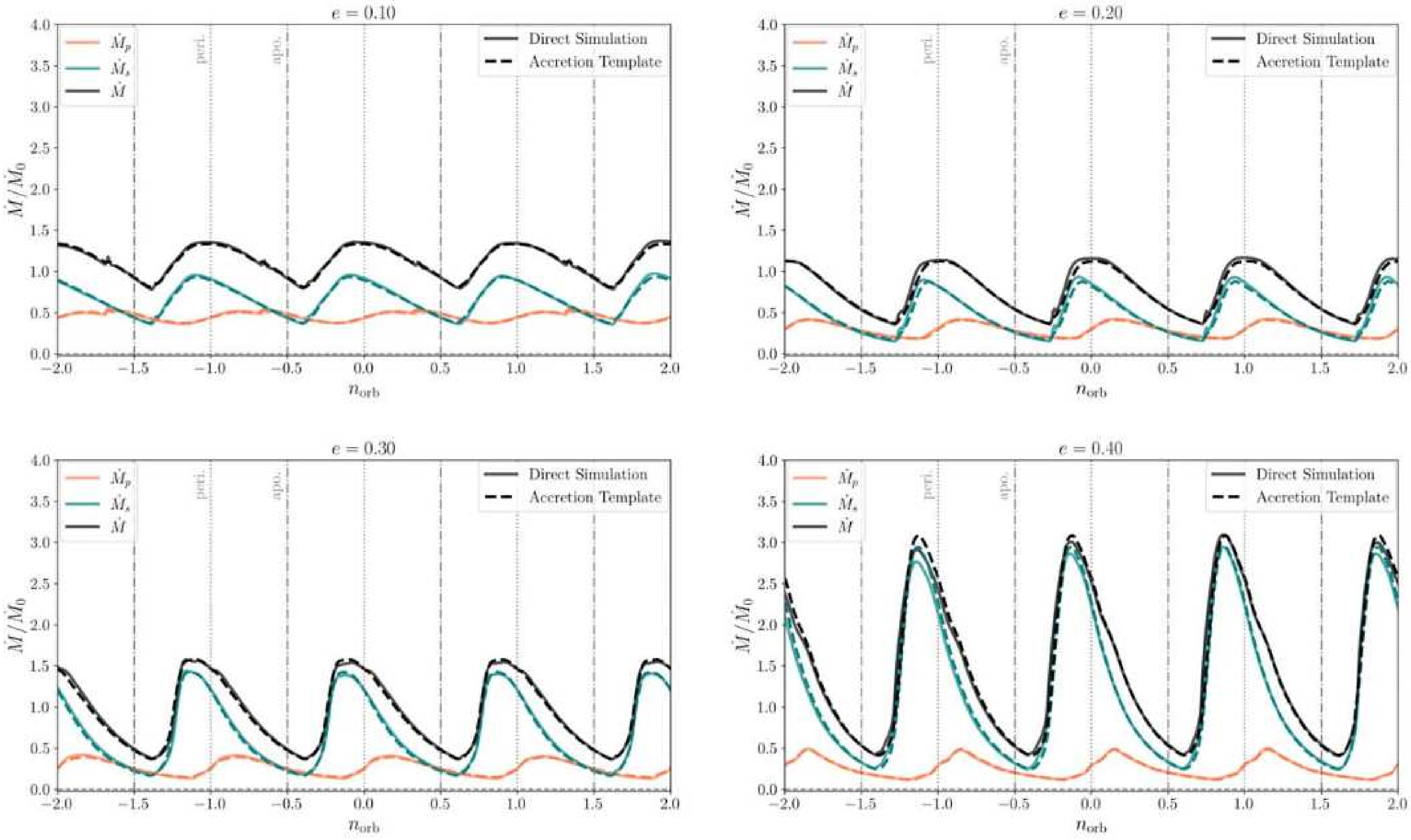


From: **M. Graham (2015)**



From: **M. Fatović (2025)**

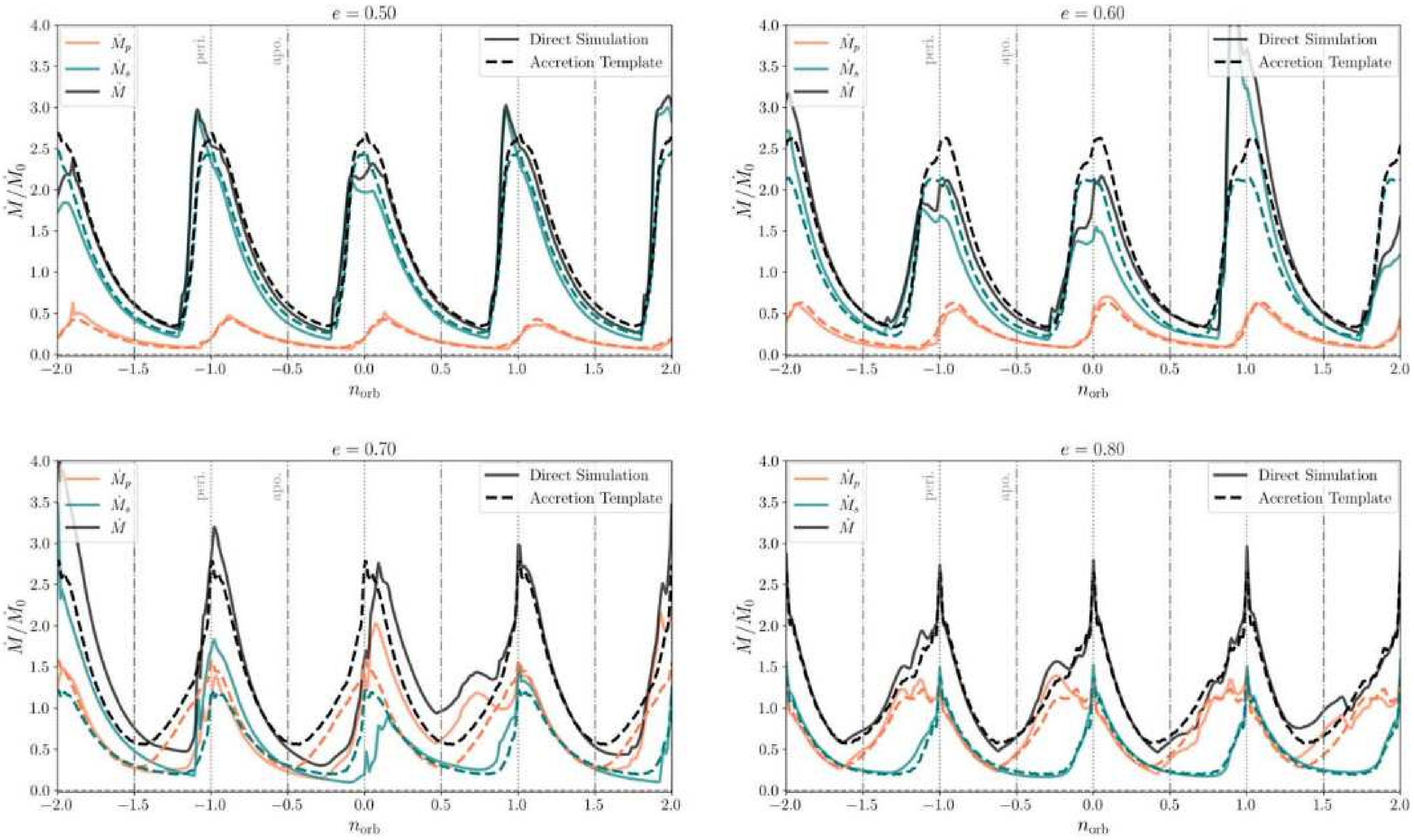
Previous studies



Mass accretion rates for a prograde binary system of equal masses, over a range of eccentricities (0.1 – 0.4).

From: **D'Orazio et al. (2024)**

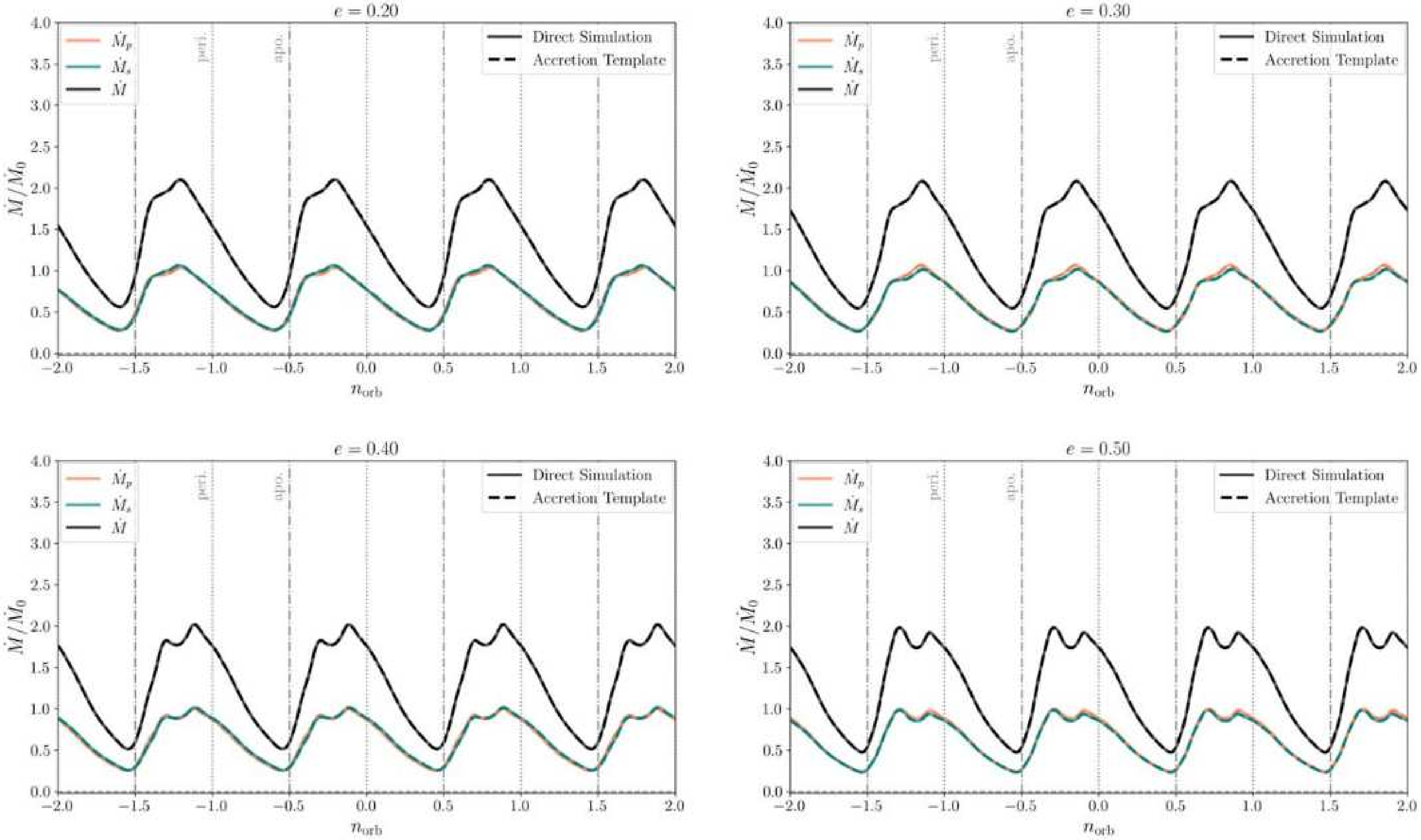
Previous studies



Mass accretion rates for a prograde binary system of equal masses, over a range of eccentricities (0.5 – 0.8).

From: **D'Orazio et al. (2024)**

Previous studies



Mass accretion rates for a **retrograde** binary system of equal masses, over a range of eccentricities (0.5 – 0.8).

From: **D'Orazio et al. (2024)**

MAIN OBJECTIVES

In this work, we will model the **circumbinary disk** around a BSMBH system using PHANTOM for smooth particle hydrodynamic simulations, in conjunction with MCFOST to simulate radiative transfer within the disk.

Our goal is to study the effect of **radiative feedback** due to **accretion luminosity** on the mass accretion rate of the binary.

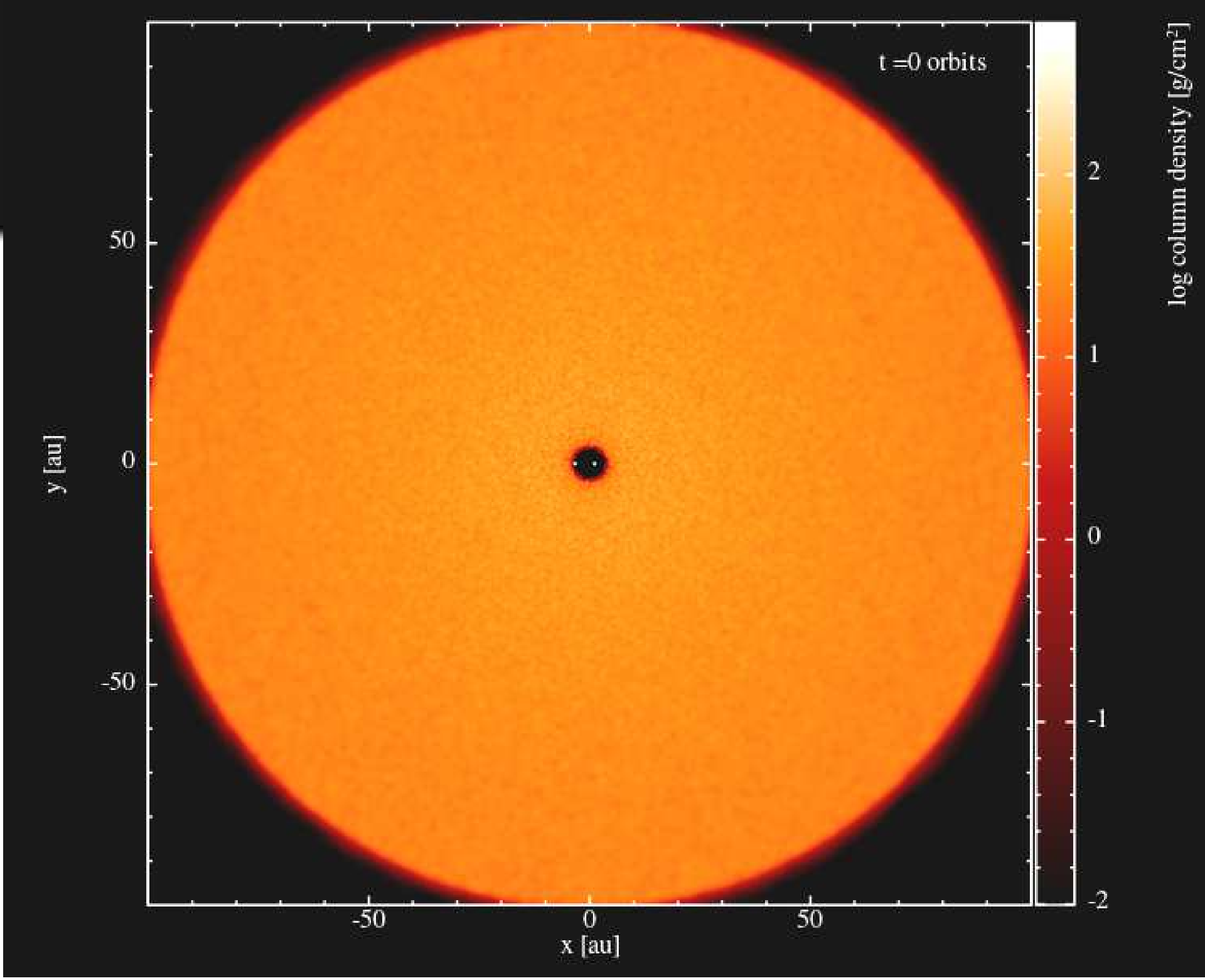
We expect the mass accretion rate to be reduced by the effects of radiation.

CIRCUMBINARY DISK MODEL: FIRST STEPS

We start with disks around stars before simulating black hole binaries.

Our initial model was built using the parameters by S. Rowther et al (2024), which consist on a protoplanetary disk of 0.1 M⊙ placed around a 1 M⊙ star.

We replaced the central star with a binary of 1 M⊙ on a 3:1 mass ratio with a separation of 3.7 AU.



Initial conditions for our SPH simulation, based on the model by Rowther+ 2024.

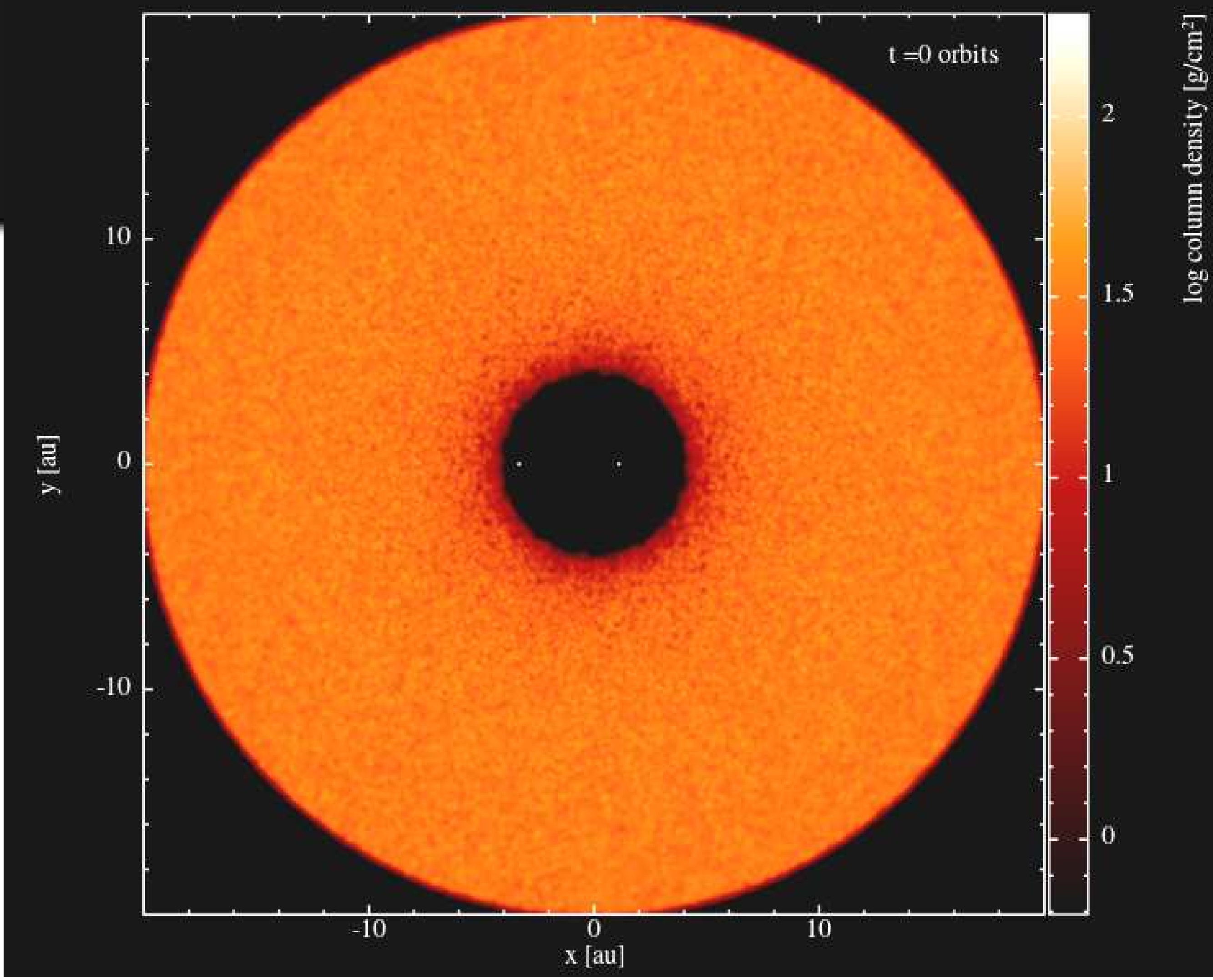
CIRCUMBINARY DISK MODEL: FIRST STEPS

We start with disks around stars before simulating black hole binaries.

Our initial model was built using the parameters by S. Rowther et al (2024), which consist on a protoplanetary disk of 0.1 M☉ placed around a 1 M☉ star.

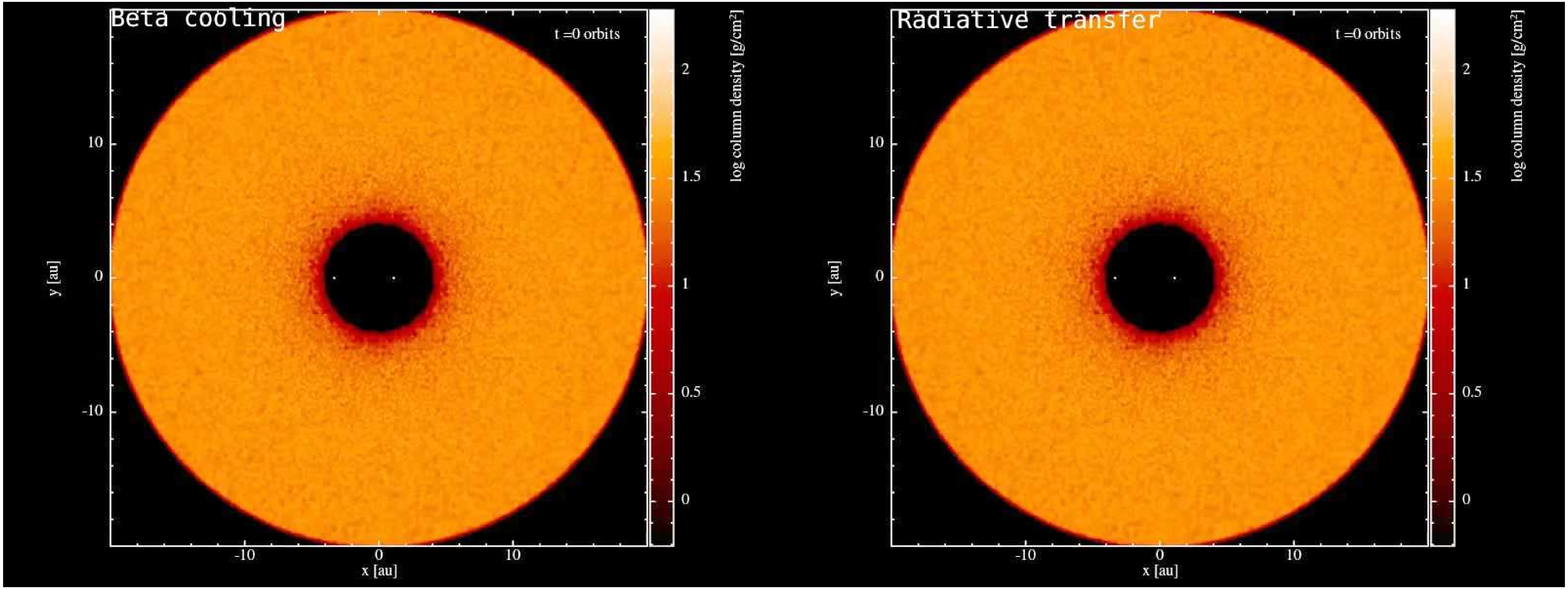
We replaced the central star with a binary of 1 M☉ on a 3:1 mass ratio with a separation of 3.7 AU.

- No accretion luminosity

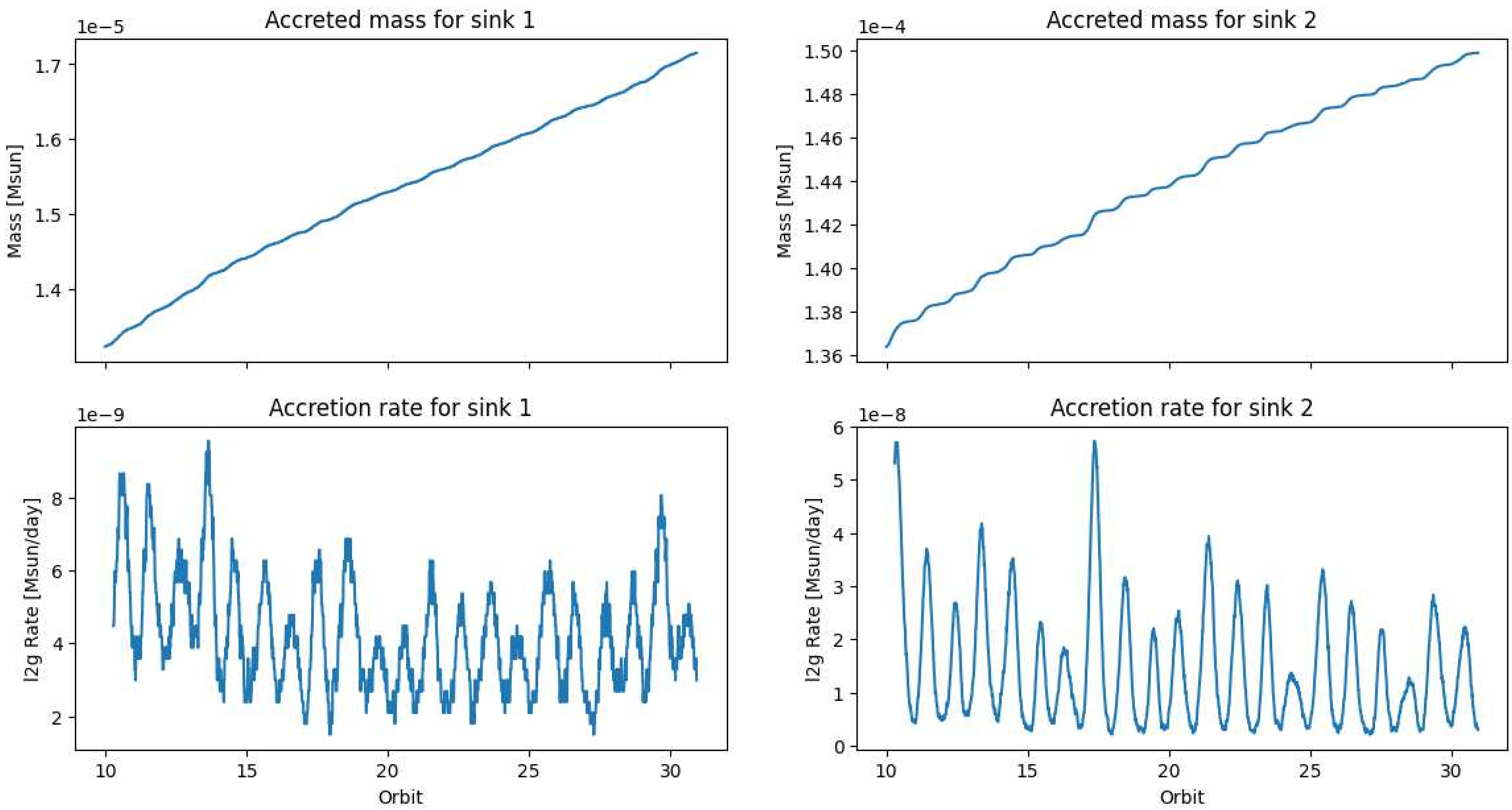


Initial conditions for our SPH simulation, based on the model by Rowther+ 2024.

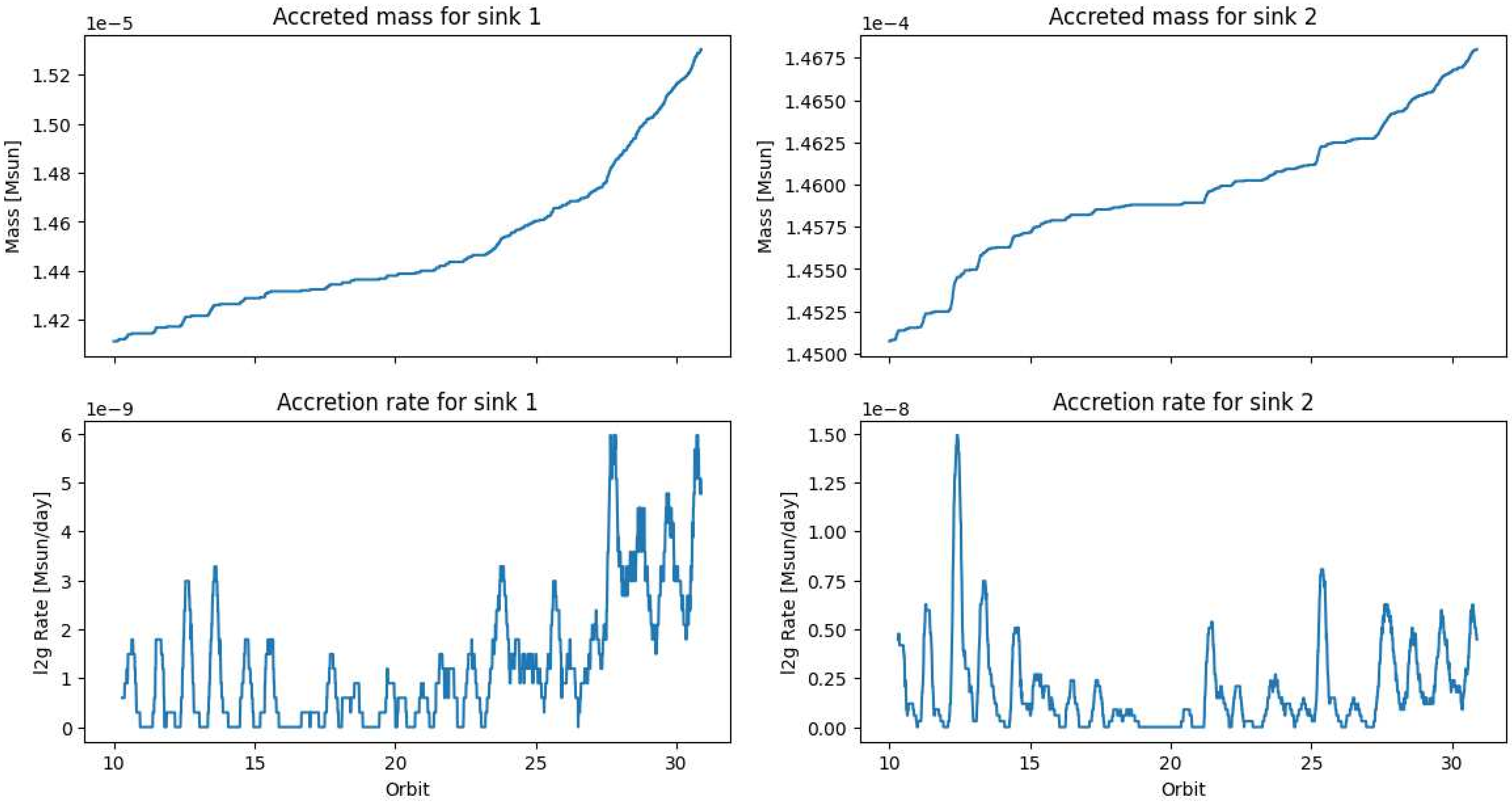
CIRCUMBINARY DISK MODEL: FIRST STEPS



PRELIMINARY RESULTS: DISK WITH BETA COOLING



PRELIMINARY RESULTS: DISK WITH RADIATIVE TRANSFER



SUMMARY AND FUTURE WORK

We are simulating circumbinary disks around binaries, using MCFOST to simulate radiative transfer on the fly.

As a starting point, we are using stellar binaries and we aim to simulate black holes in the future.

Our current challenges are:

- Replace dust opacity with electron scattering.
- Replace stellar radiation with accretion luminosity.
- Include viscous heating of the disk.

Any feedback from the community is gratefully appreciated!