Global 3D Simulations of Common Envelope Evolution Using AMR

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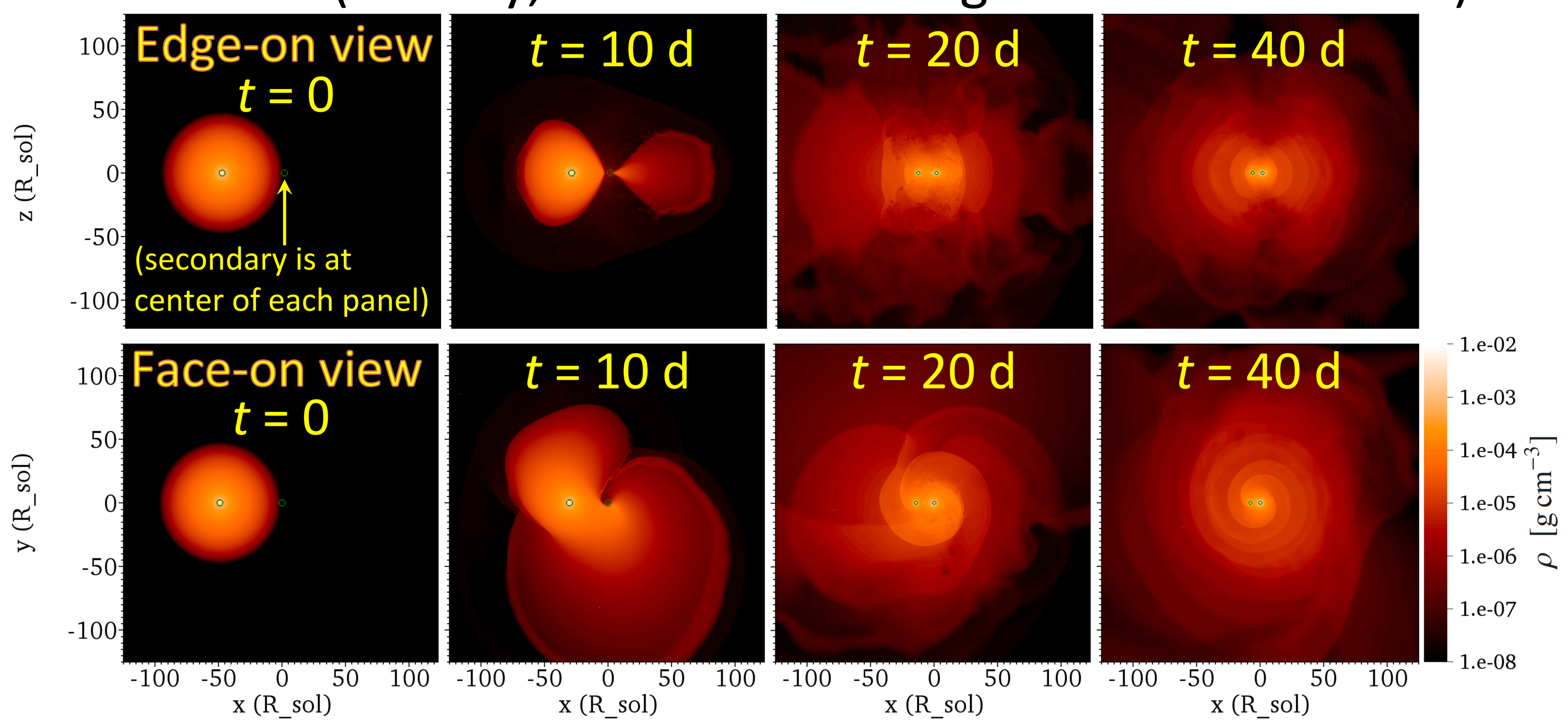
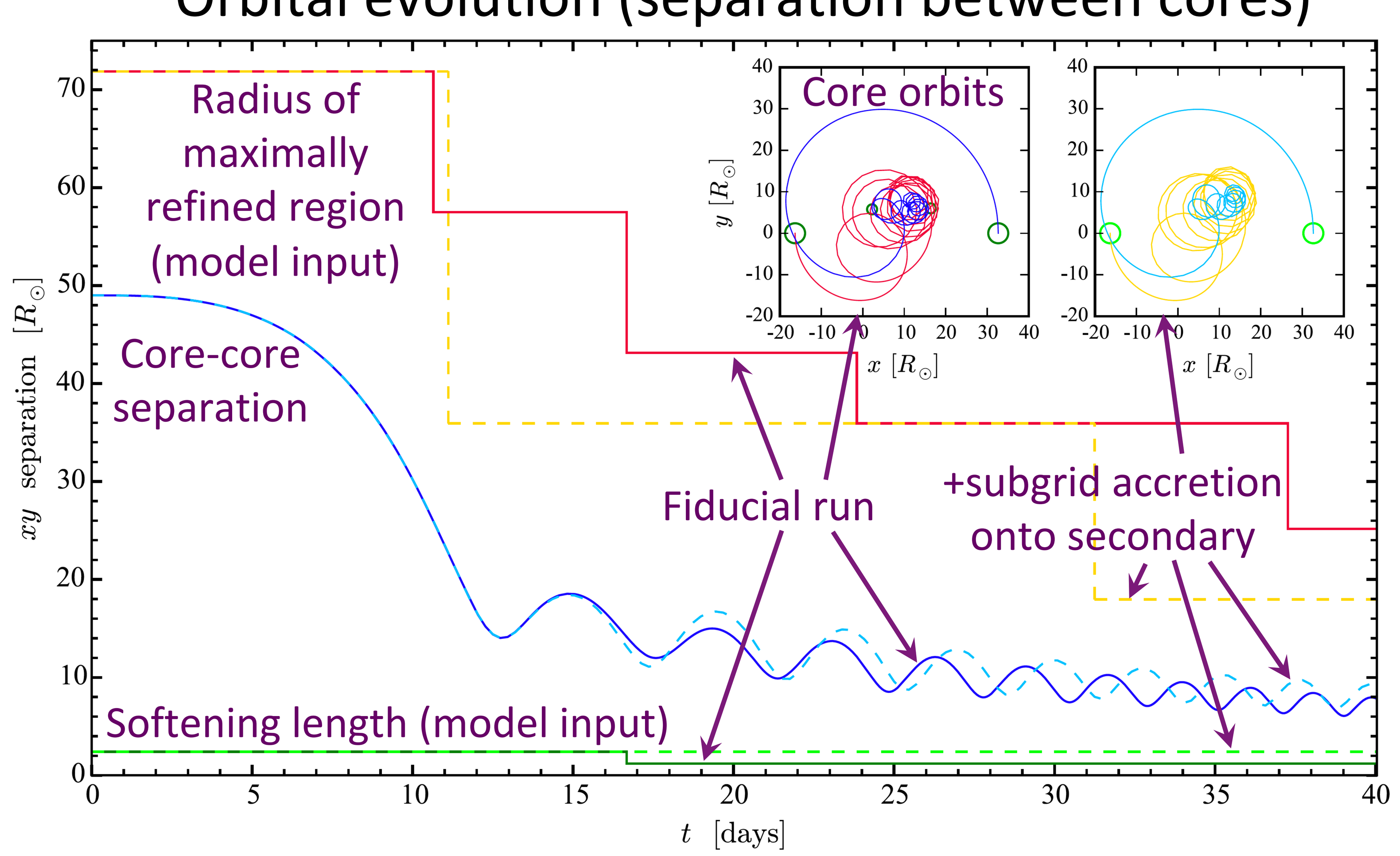
Introduction

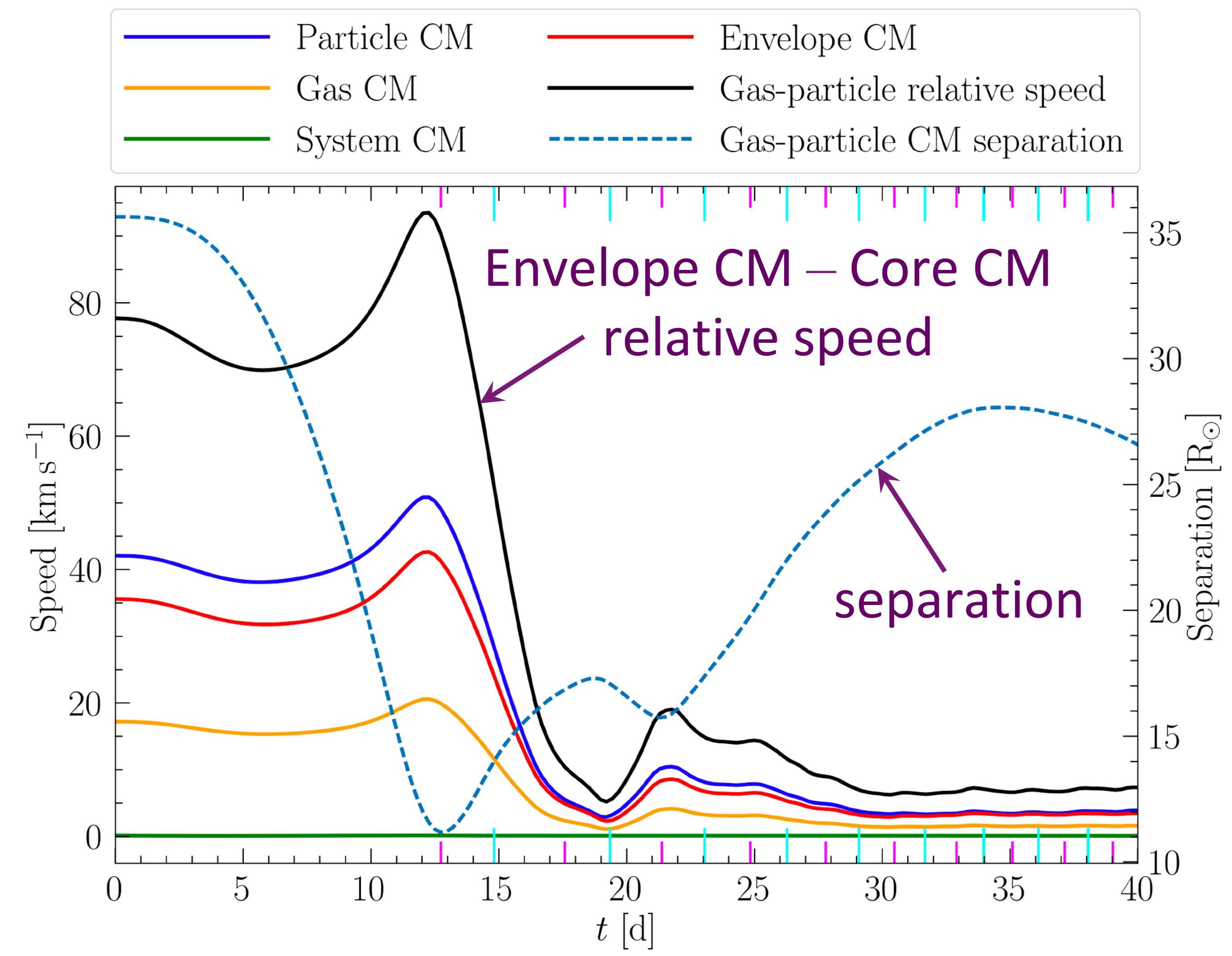
Common envelope evolution is presently a poorly understood, yet critical, process in binary stellar evolution. Numerical studies have yet to conclusively determine how the envelope ejects and a tight binary results, if only the binary orbital energy is used to propel the envelope. Additional power sources might be necessary and accretion onto the inspiraling companion is one such source. We perform 3D hydrodynamical simulations of common envelope evolution using the AMR code AstroBEAR, following the merger of a 2 solar mass red giant branch primary and a 1 solar mass white dwarf or main sequence secondary. The primary core and secondary are modeled as point particles. Here two runs are discussed—the fiducial run (slices shown below) does not allow accretion onto the secondary while the other run includes a subgrid accretion model.

Evolution (density, frame co-rotating with orbit of cores)



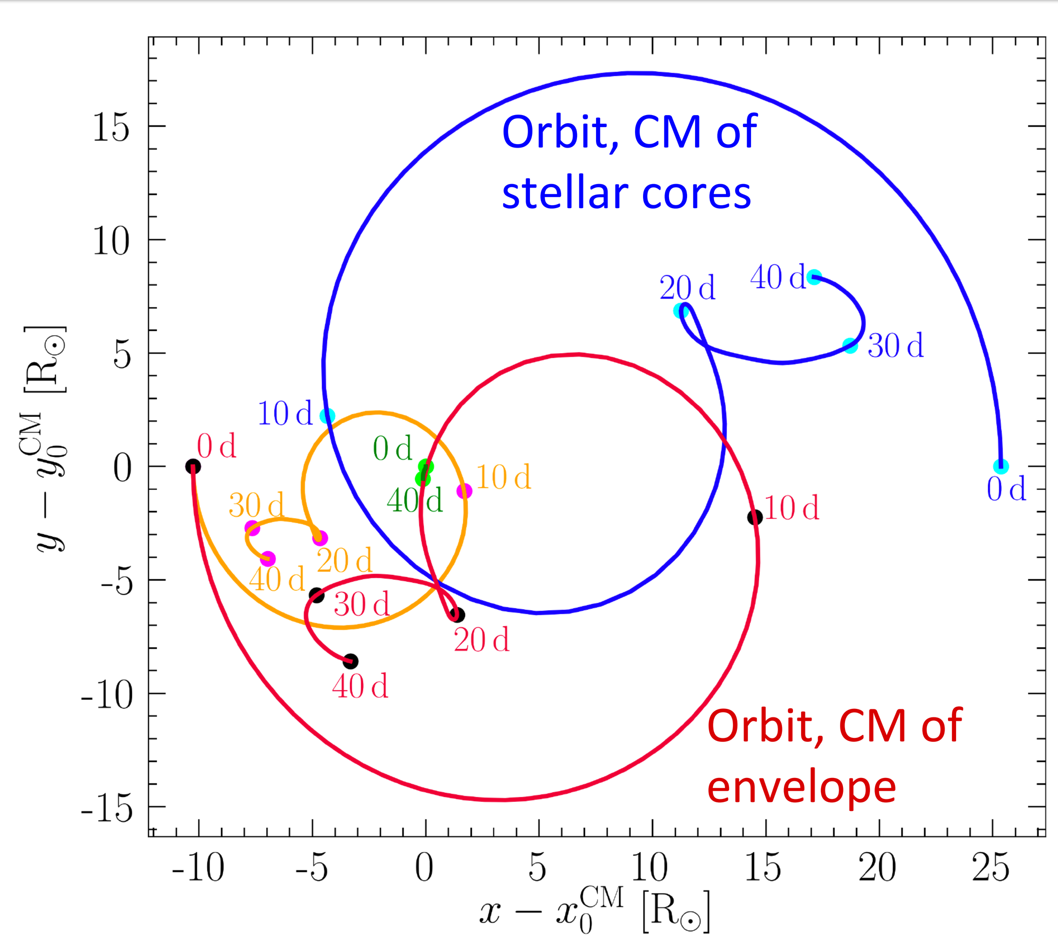
Orbital evolution (separation between cores)



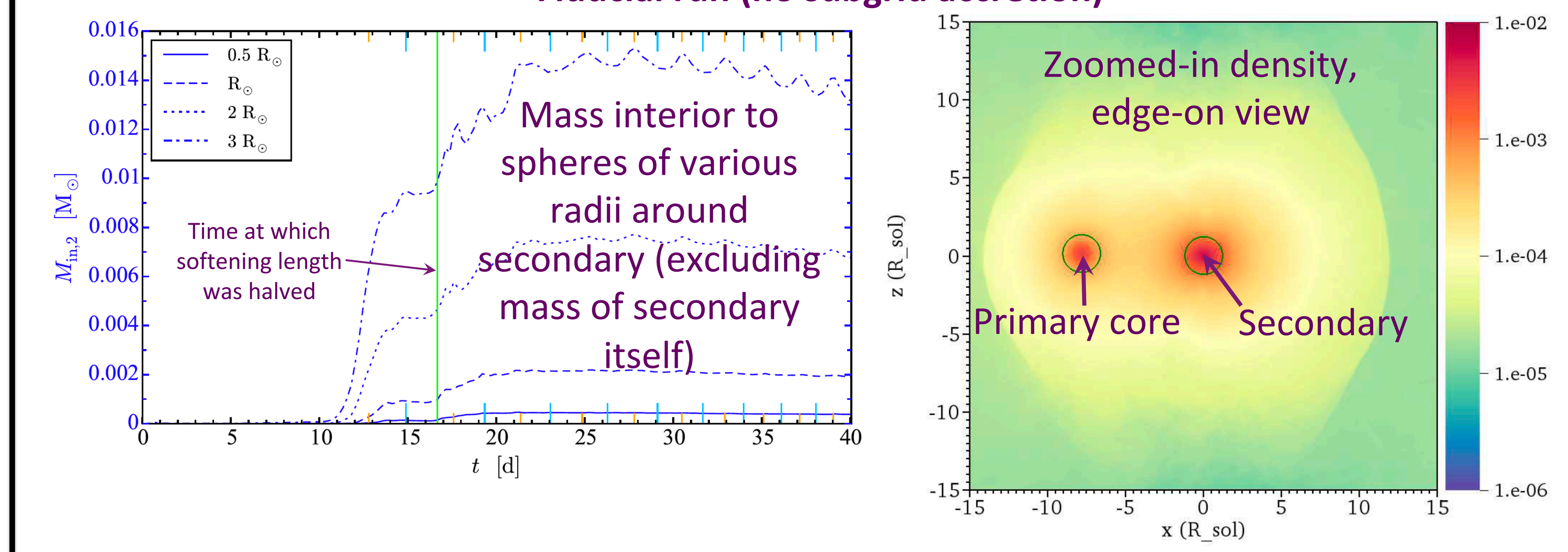


Core-Envelope Relative Motion

- ✧ Envelope mass loss is found to be highly asymmetric during the initial plunge-in of the secondary.
- ✧ This leads to relative motion between envelope gas and the core particles; this motion is confined to the orbital plane.
- ✧ The center of mass of the envelope and that of the core particles move at speeds of 6-8 km/s with respect to one another at late times (fiducial run without subgrid accretion).
- ✧ Such relative motion could account for observed offsets of planetary nebula binary central stars from the geometric centers of their respective nebulae, as in MyCn 18.



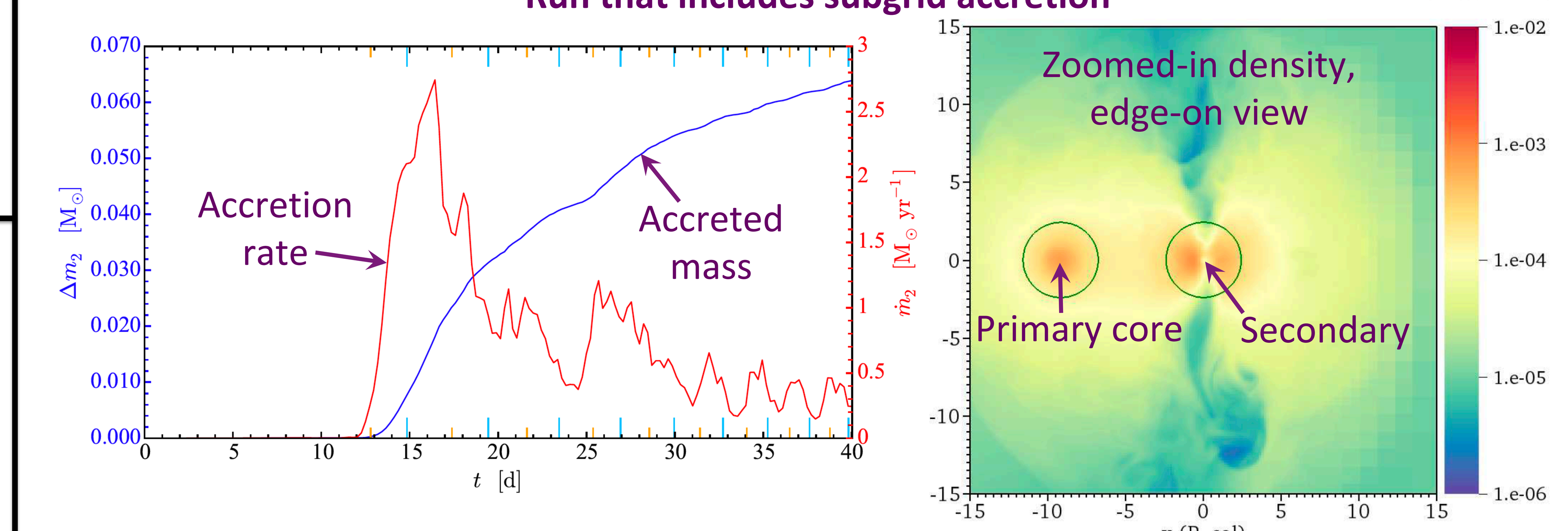
Fiducial run (no subgrid accretion)



Accretion onto the Secondary

- ✧ Accretion is likely common in post-asymptotic giant branch binary interactions but how it operates and how its consequences depend on binary separation remain open questions.
- ✧ We bracket the range of accretion rates onto the secondary by comparing a run that removes mass and pressure via a subgrid accretion model with a run that does not.
- ✧ The results show that if a pressure release valve is available, as in our subgrid accretion model, super-Eddington accretion may be common.
- ✧ Jets are a plausible release valve in these environments, and they could also help to unbind and shape the envelopes.

Run that includes subgrid accretion



Outlook

- ✧ In order to be able to eject the envelope, simulations need to be run for longer.
- ✧ This requires improved numerical reliability at small inter-core separations and/or a shift in the parameter space studied (e.g. AGB instead of RGB primaries).
- ✧ Ejection can be helped by additional energy sources including accretion/jets.

See poster by Yisheng Tu on energy budget and mass loss in CE simulations!