

Matter simulations in the LISA era

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When do we need hydro simulations?

- Electromagnetic counterparts to BBH mergers
 - Help localize events, study environment of merger
 - **EM signal from gas accreting onto SMBH binary, and relativistic jets**
 - **EM signal from Tidal Disruption Events (TDEs)**
- BBH merger rates in wet galaxy mergers
- WD binaries undergoing mass transfer (interpretation of LISA observations), pop. synth. of WD binaries

Accretion Disks: Overview

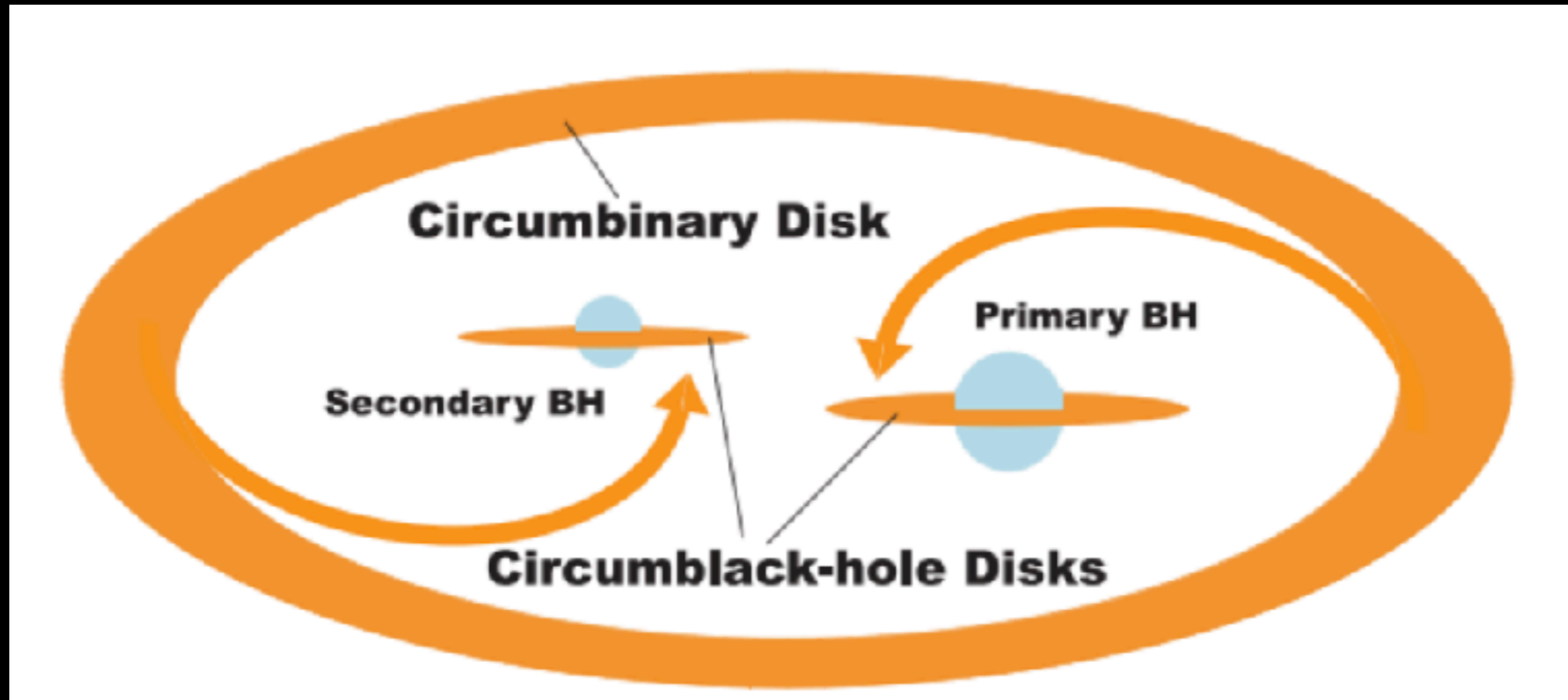


Image: Hayasaki et al 2007

- Complex system, e.g. slowly evolving perturbed circumbinary disk accreting onto mini-disks
- Timescales: orbital timescale in minidisks, orbital motion of binary, GW inspiral, viscous timescale in circumbinary disk,...
- Actual configuration depends on amount of gas density / BH masses

Accretion Disks: 2D

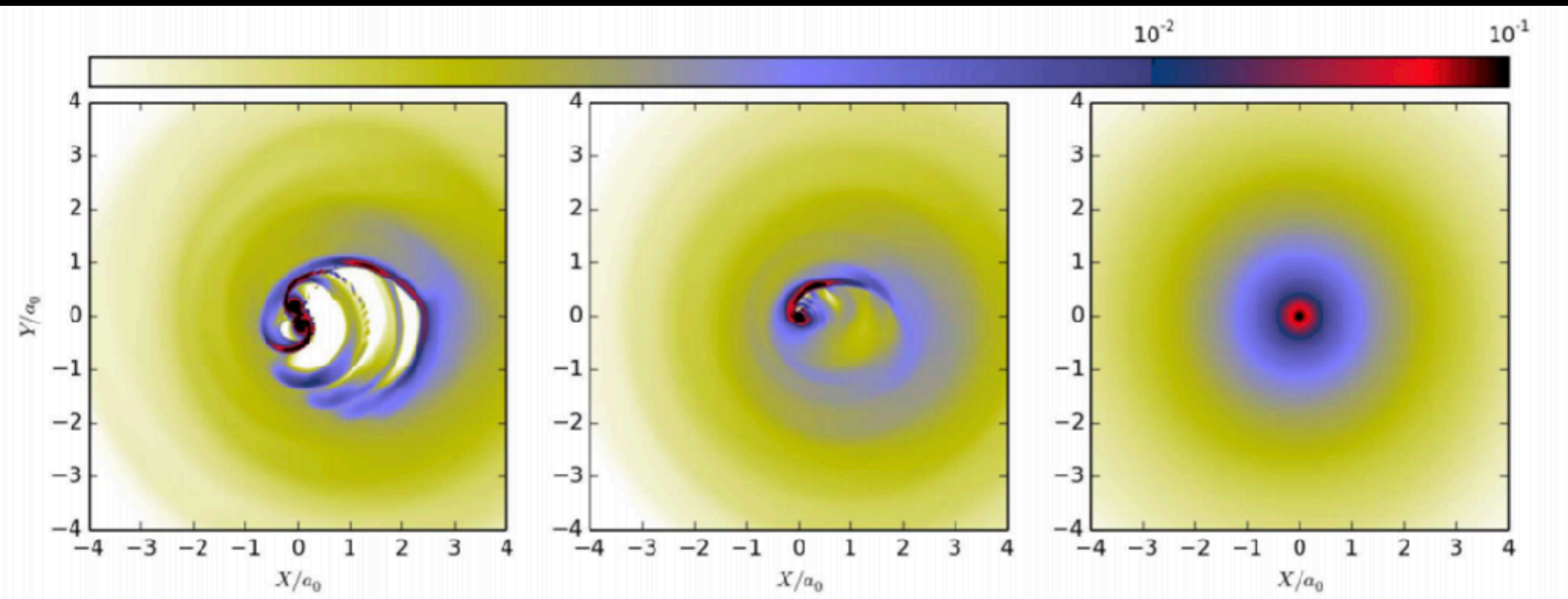


Image: Farris et al 2014 - Luminosity before, at, and after merger

Accretion Disks: 2D

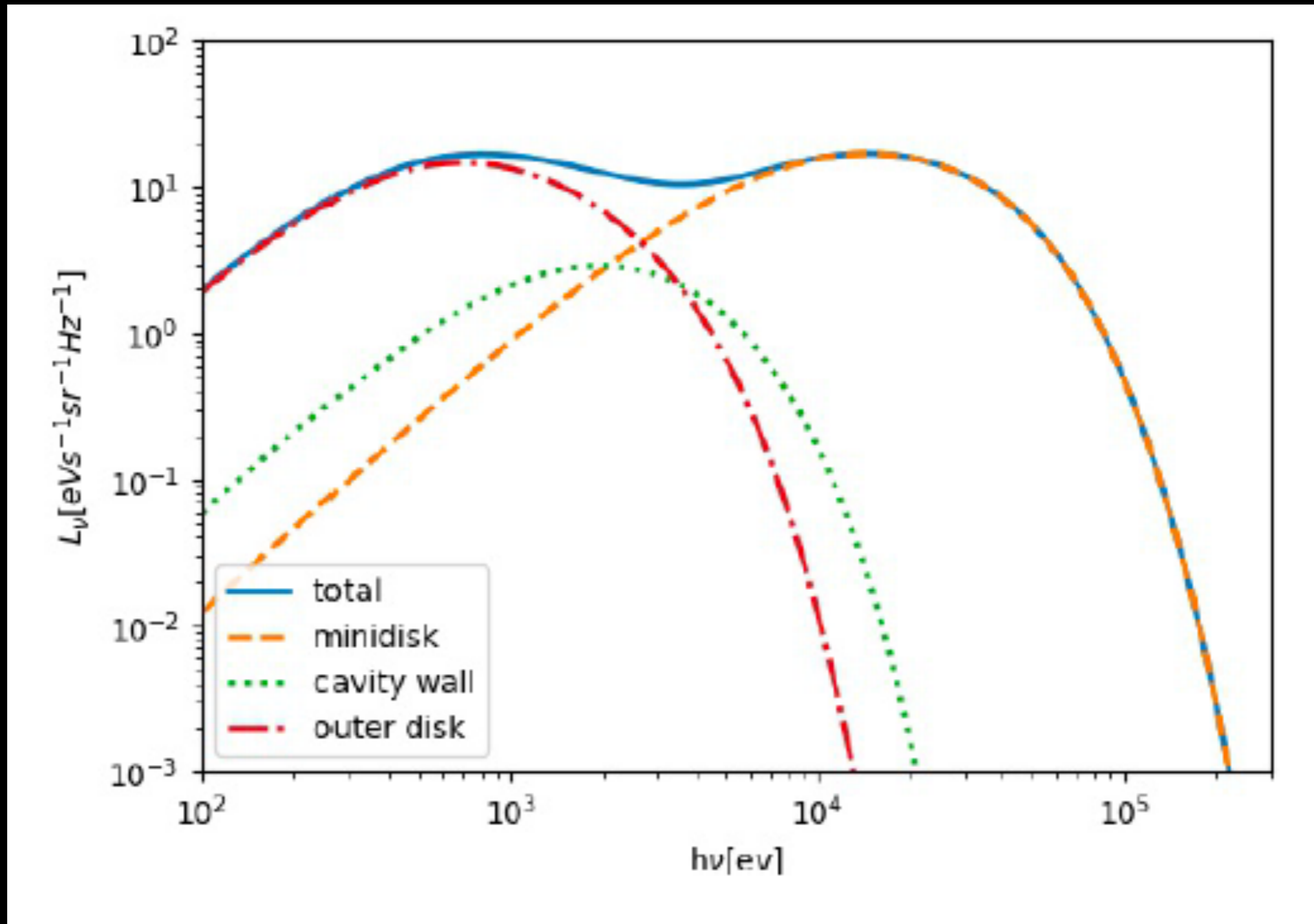
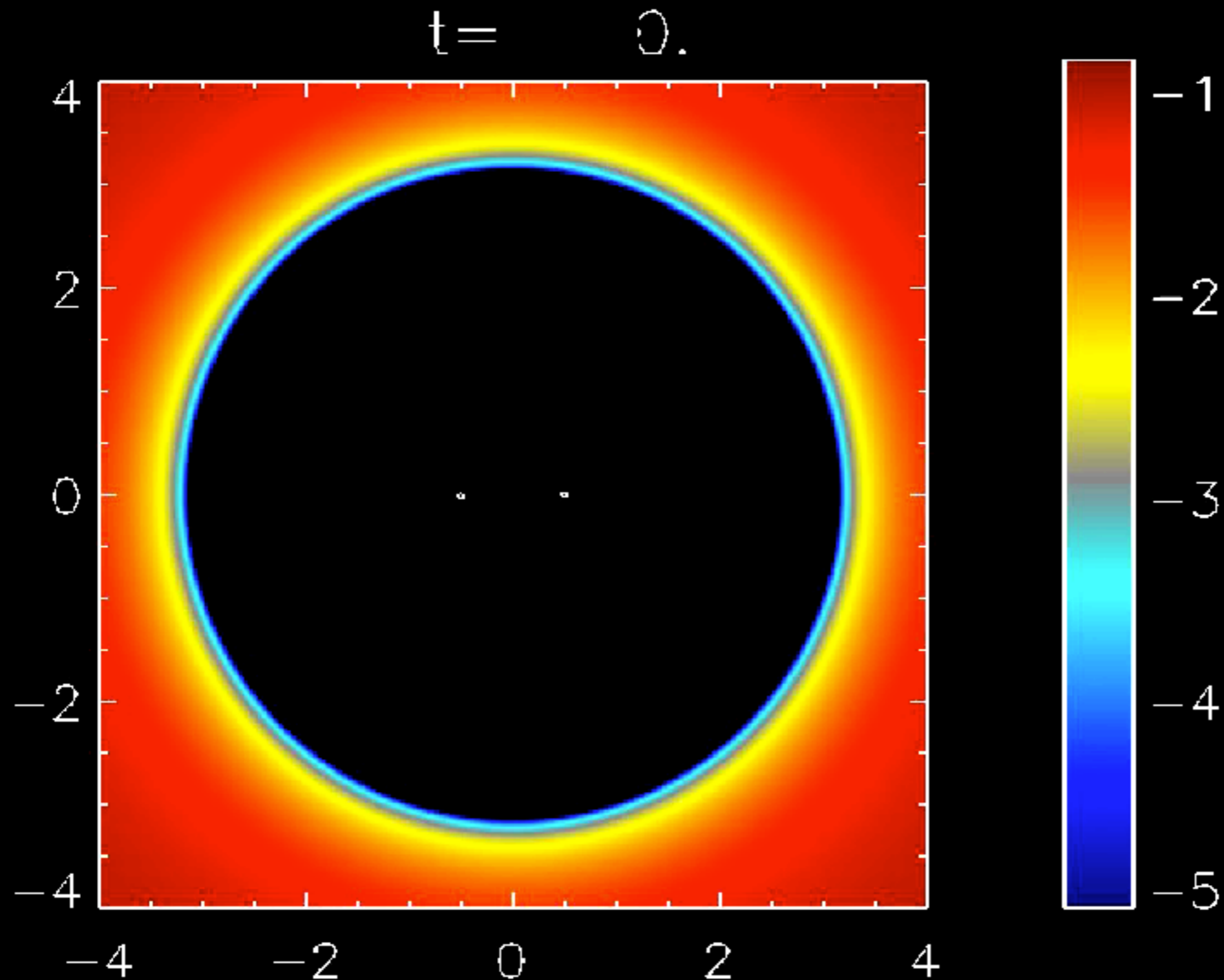


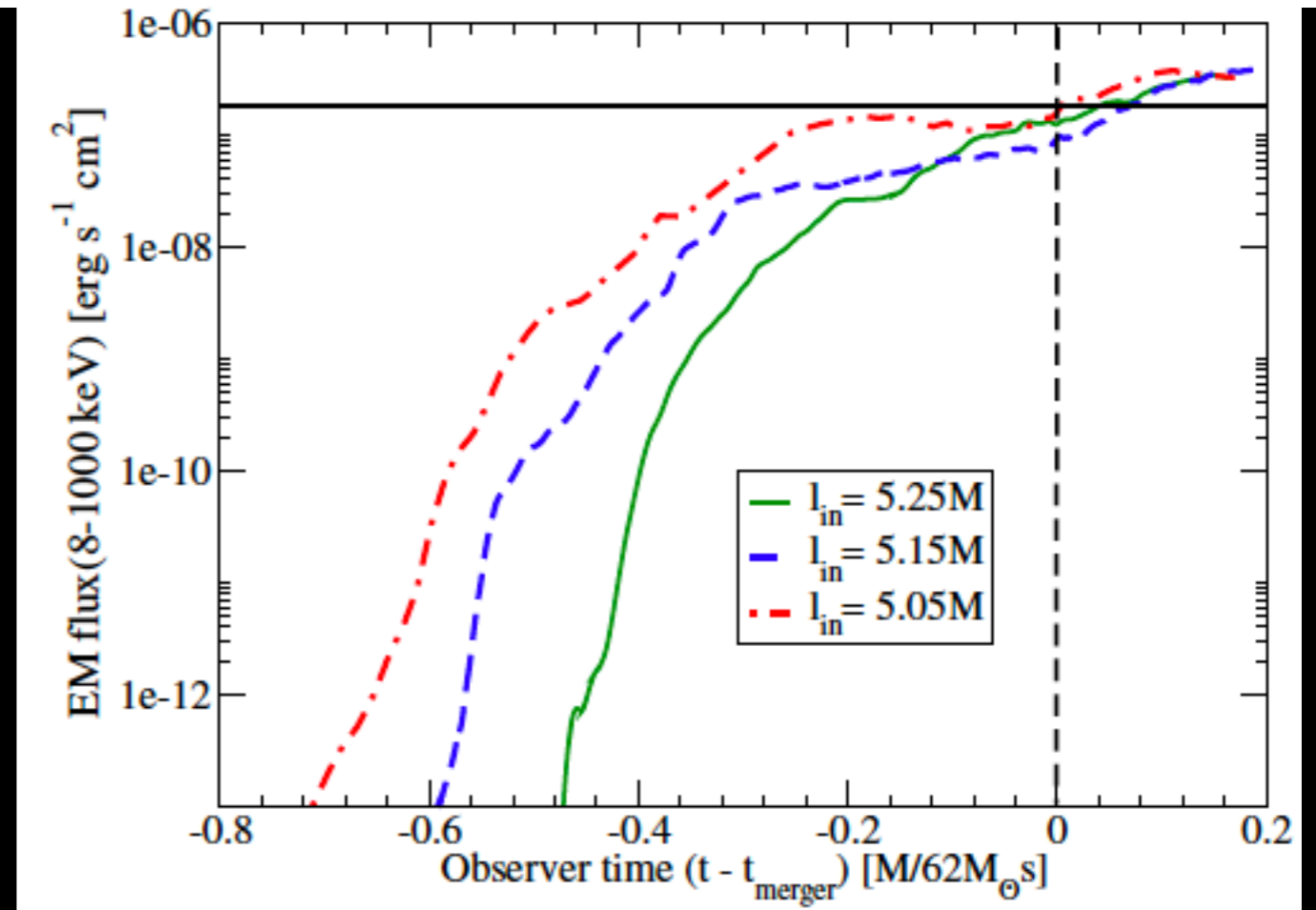
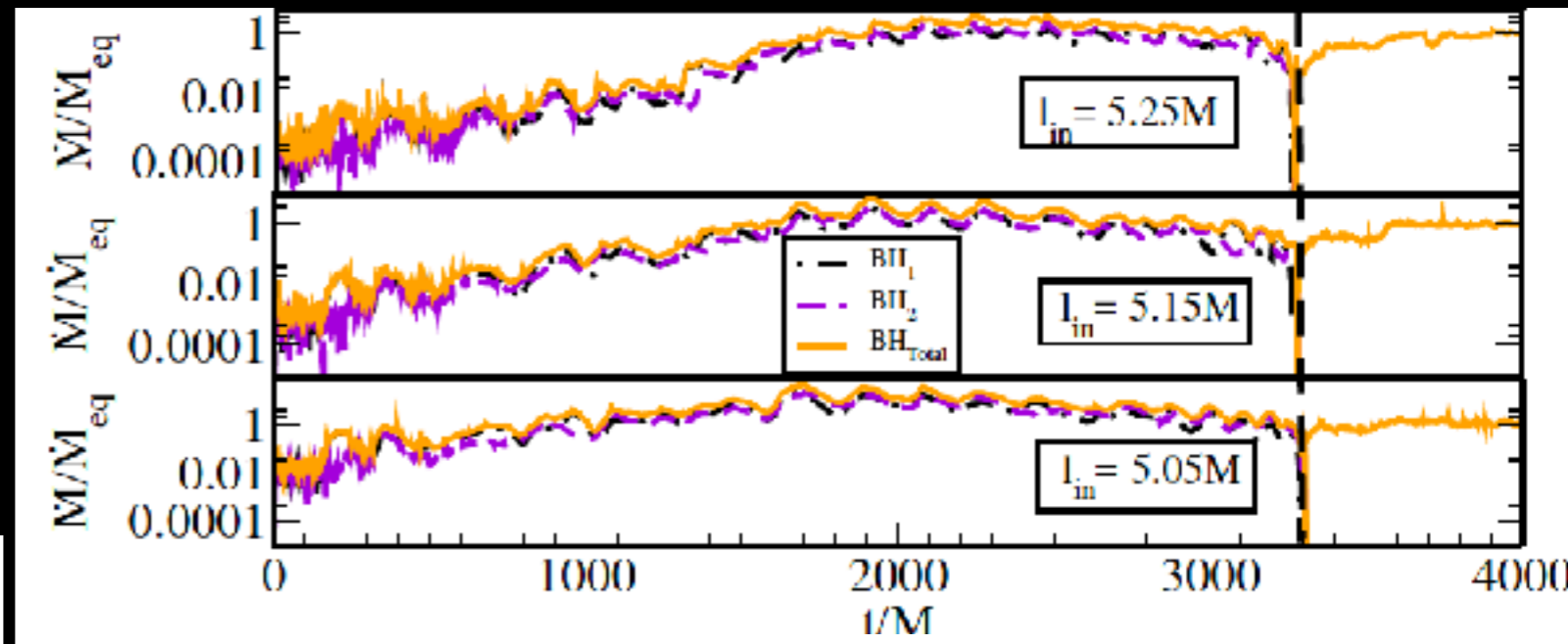
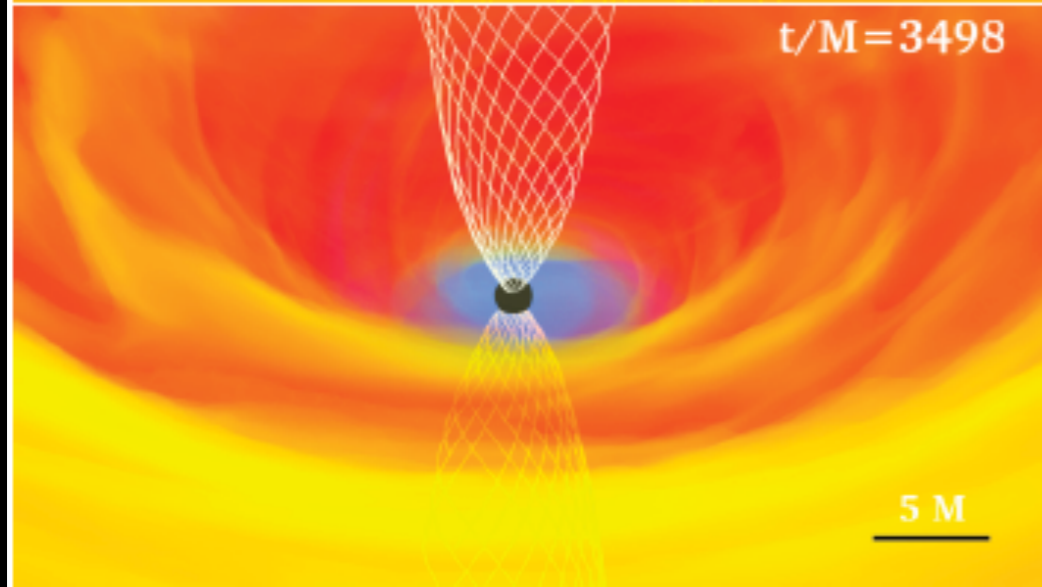
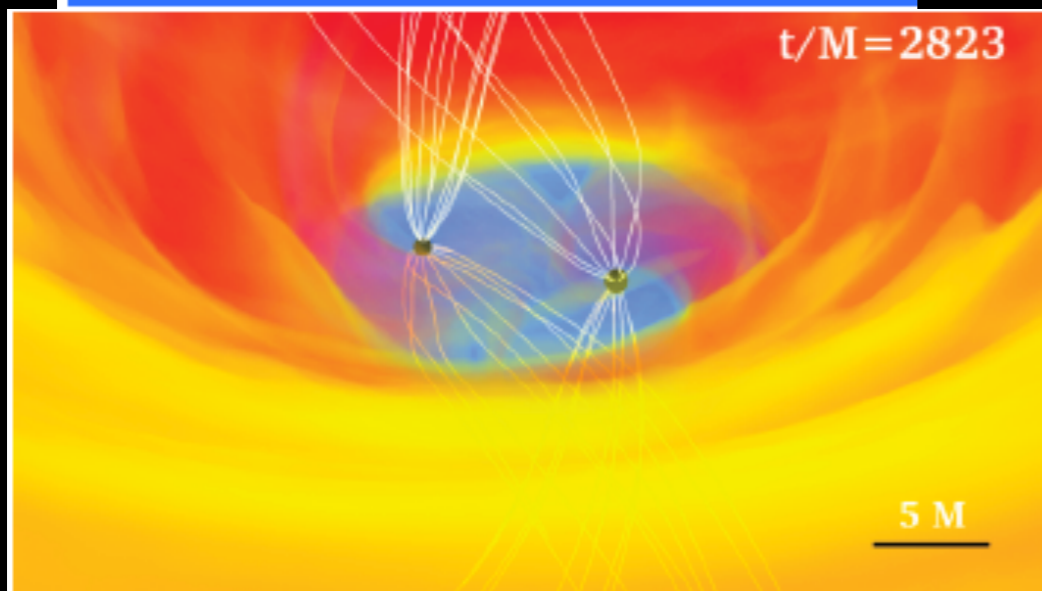
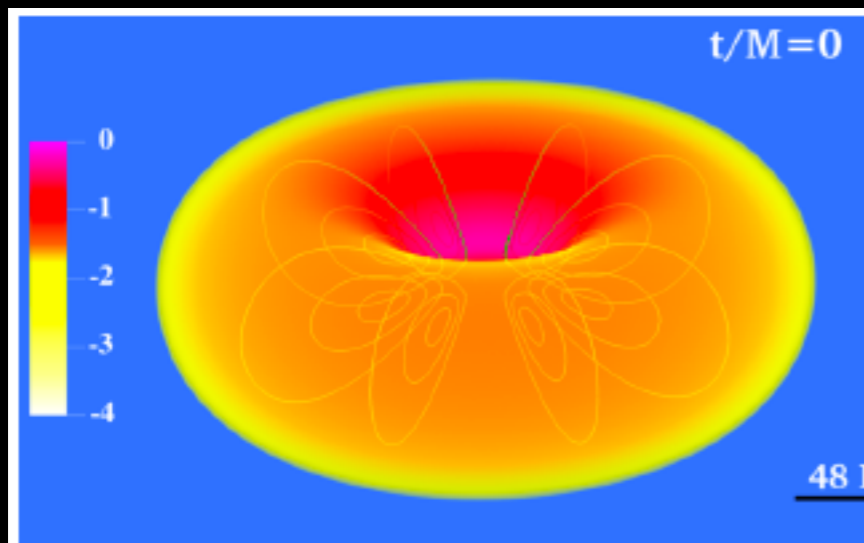
Image: Tang et al 2018 - Spectra

Accretion Disks: 3D



Noble et al. 2012 [HARM3D, PN inspiral, excision]

Accretion Disks: 3D



TDEs and disk formation

Varying length scales:

- Stream width,
- Periaspse, apoapse

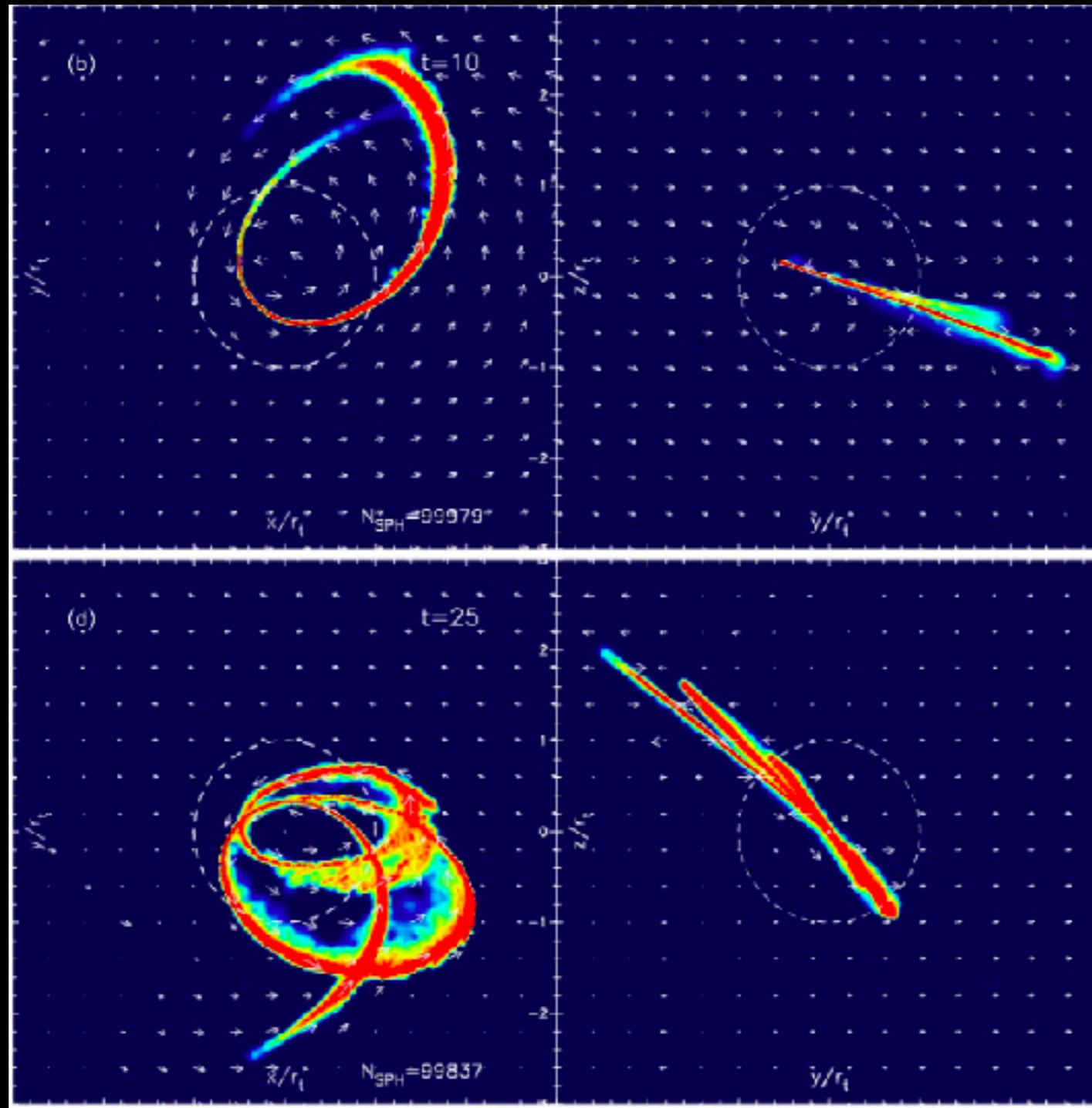
and time scales:

- Disruption
- Circularization of debris
- Viscous evolution of disk
- Disk precession



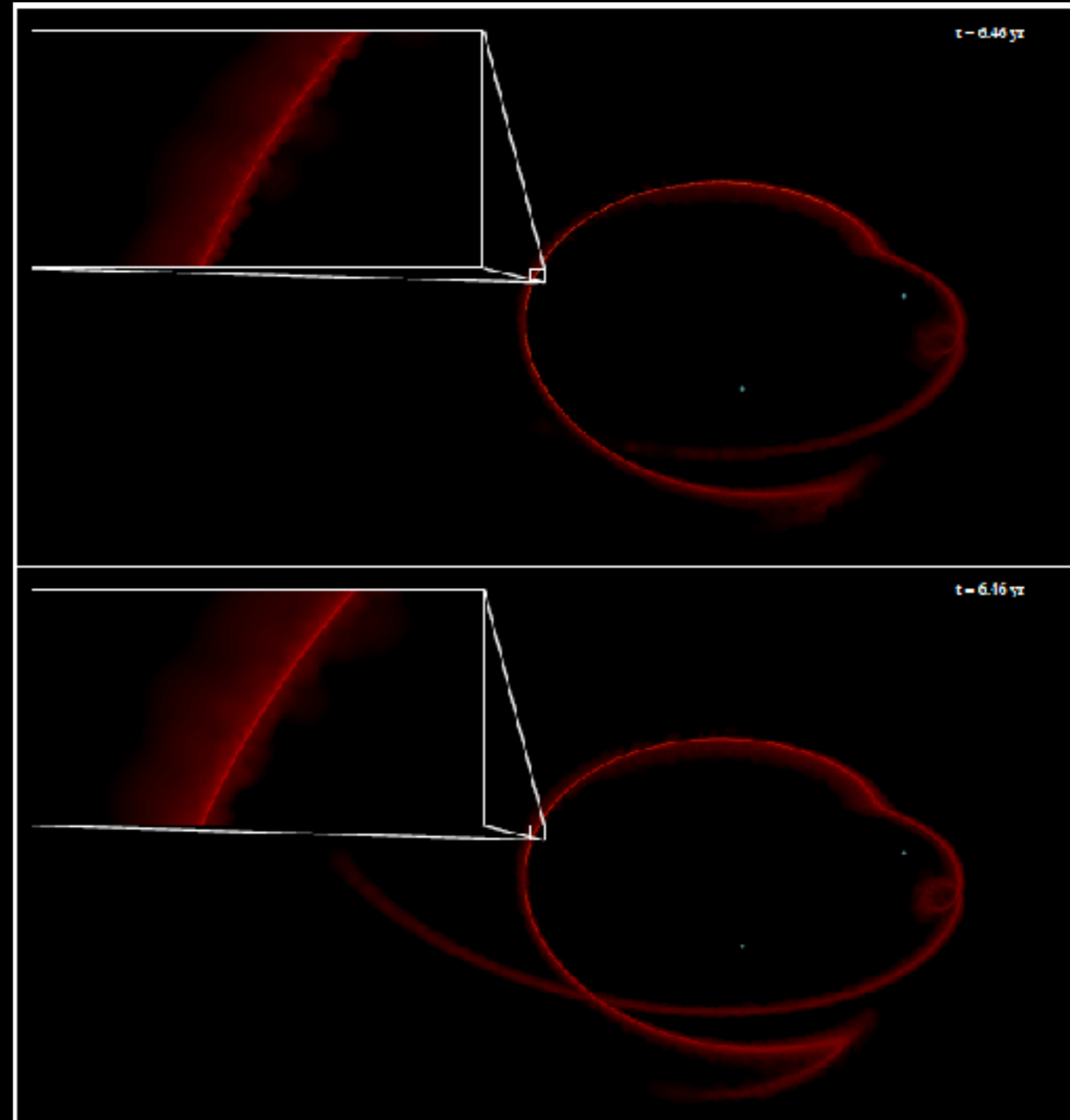
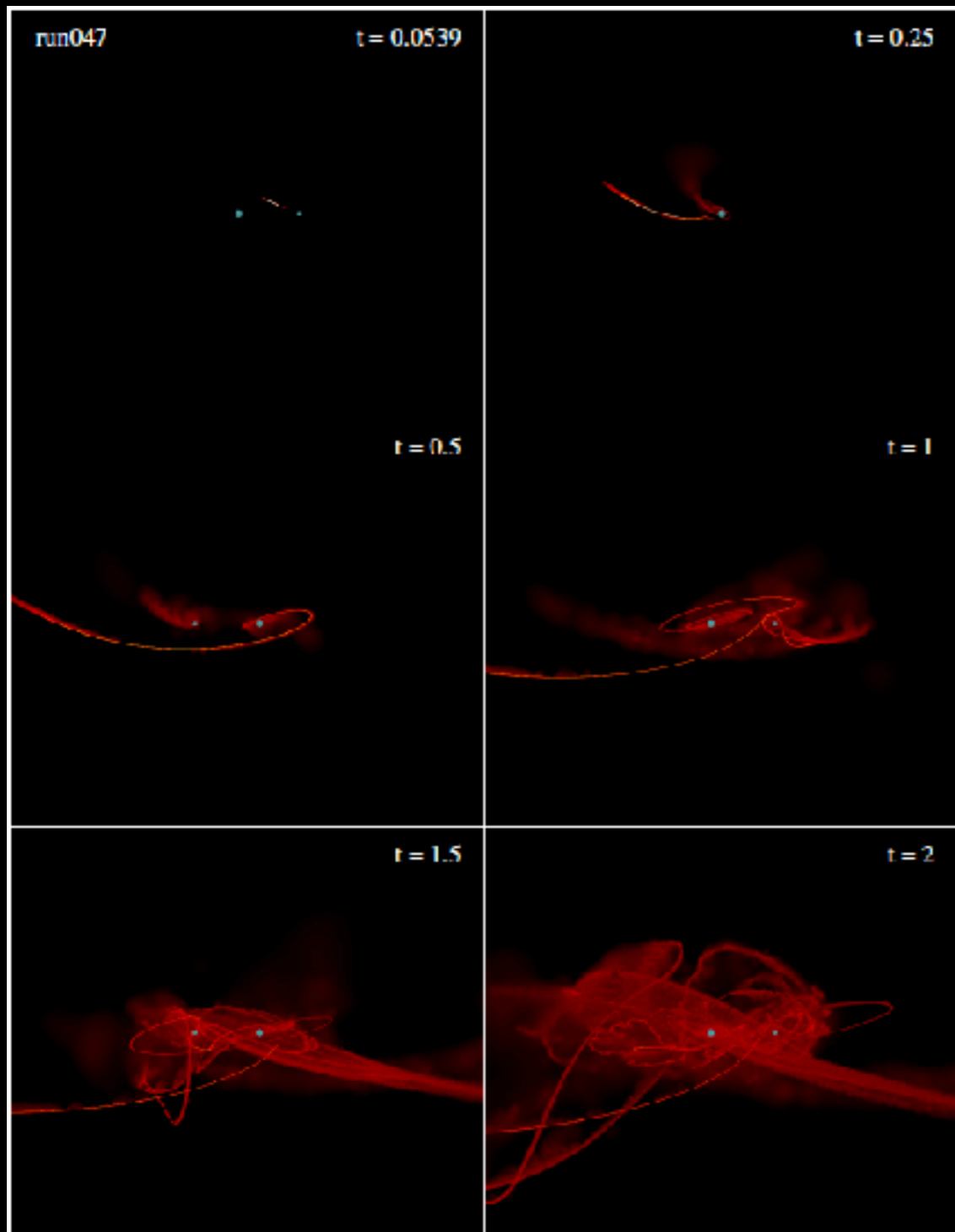
TDEs and disk formation

Circularization/Disk formation impacted by:
GR (precession, periastron adv.), Stream self-gravity, Radiative cooling



TDEs and disk formation

Around BBH: TDE can replenish the accretion disk!



Coughlin et al 2016, 2017 [TDE around BBH, SPH simulation]

Radiation transport

- Radiation hydrodynamics costly but important at many levels:
 - Radiatively dominated disks
 - Cooling of TDE debris
 - Reprocessing of emission by ejecta / wind
 - Predictions for EM signal in circumbinary disks/minidisks
- Current simulations use simple prescriptions, e.g. cooling functions, isothermal flows,...
- GR radiation transport currently only done in post-processing
- **With RT, simulations are no longer rescalable!!**

Magnetic fields

- In circumbinary disks:
 - Drive angular momentum transport / winds
 - High resolution required, or sub grid models (alpha-disks)
 - Initial conditions? Large scale structure?
- In TDEs:
 - Role of MHD in evolution of tidal debris?
 - Growth of magnetic fields during circularization process? [MRI, shear instabilities,...]

Conclusions

- Main challenge in both disks and TDEs: range of length and time scales
- For reliable EM models, we'll also need more detailed physics
 - Radiation transport
 - Numerically resolved magnetic fields
 - Initial conditions!