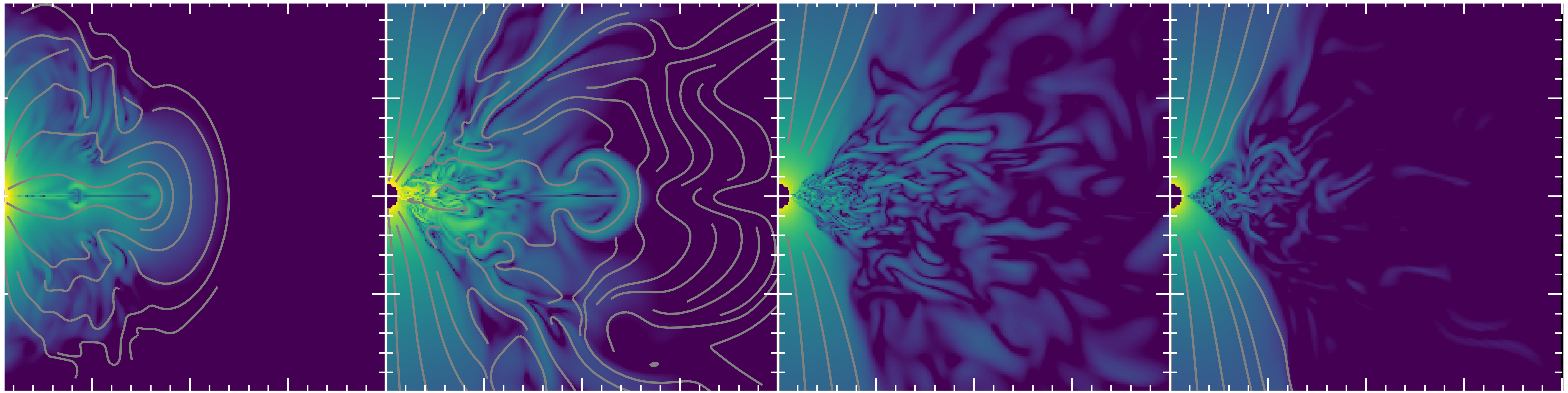

Long-term GRMHD Simulations of NS Merger Accretion Disks

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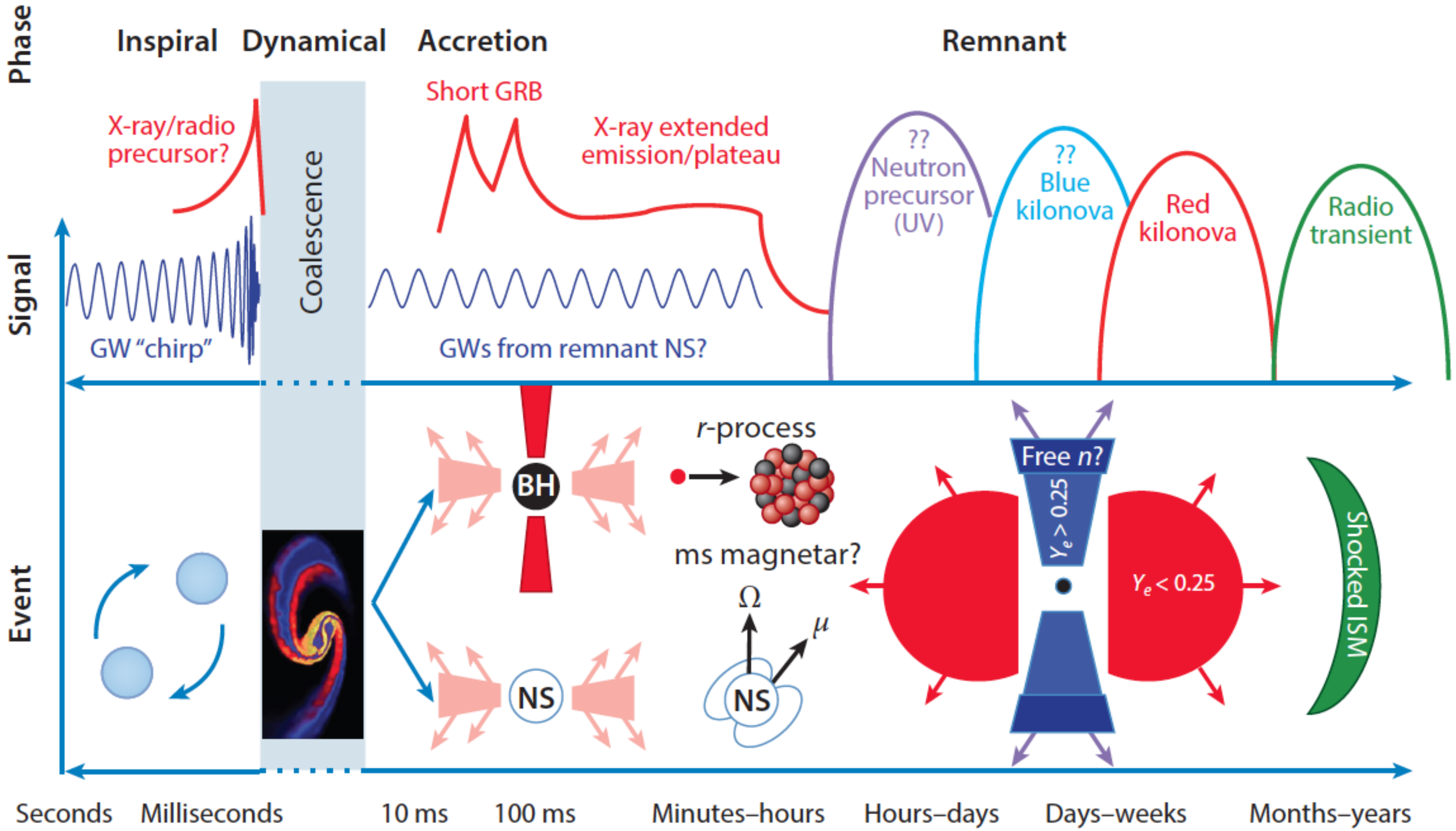
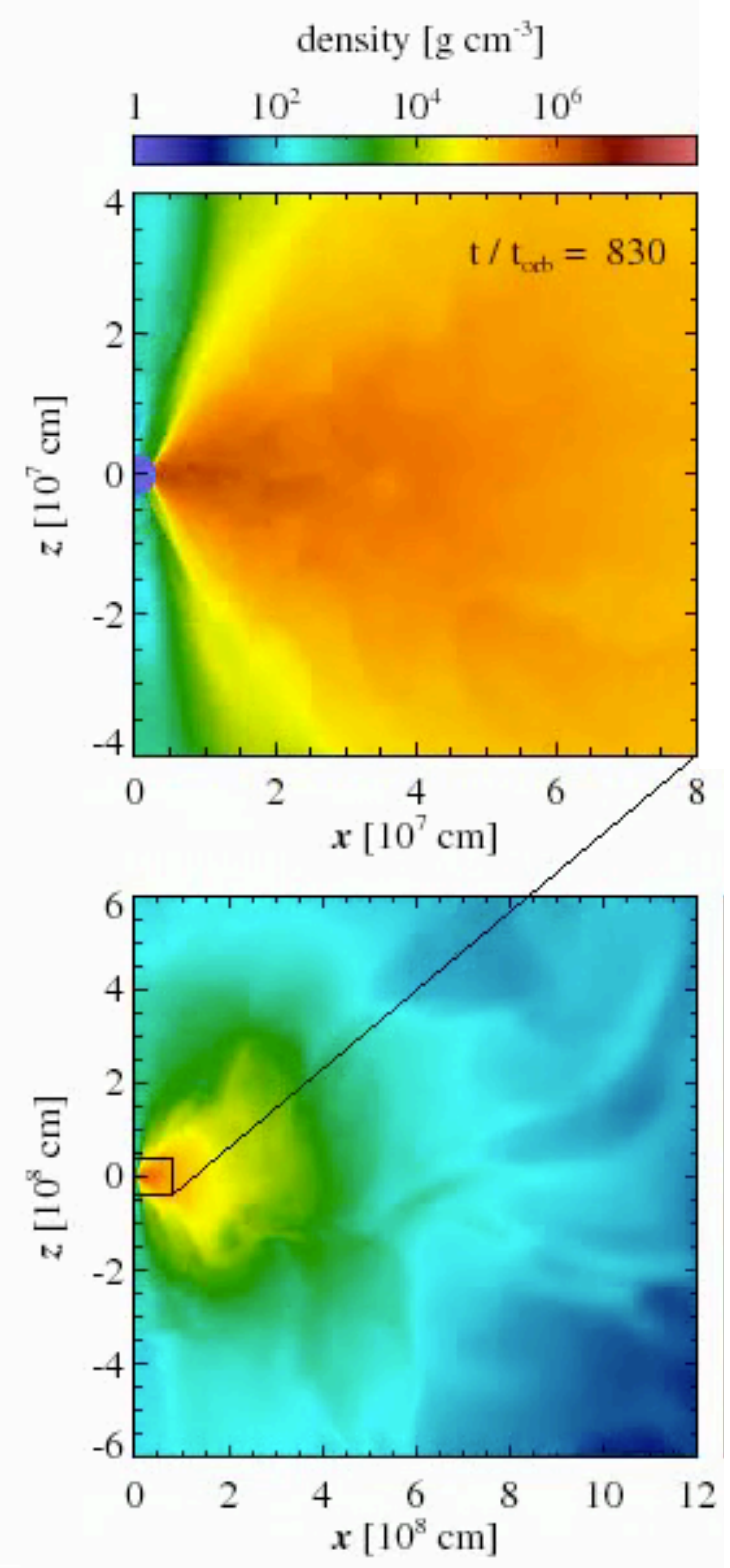
Dan Kasen (UC Berkeley / LBL)

Neutron Star Mergers



RF & Metzger (2016)



Outflow from remnant accretion disk

- Neutrino cooling shuts down as disk spreads on viscous timescale (~100-300ms) >> orbital time
- Viscous heating & nuclear recombination are unbalanced
- If BH at center, eject ~10-20% of initial disk mass, more if HMNS at the center
- Material is neutron-rich (Ye ~ 0.2-0.4), mostly light r-process and some heavy, depending on parameters
- Mass-averaged wind speed (~0.05c) is slower than dynamical ejecta (~0.1-0.3c)

RF & Metzger (2013), MNRAS

Just et al. (2015), MNRAS

RF et al. (2015), MNRAS

Lee, Ramirez-Ruiz, & Lopez-Camara (2009)

Setiawan et al. (2005)

Metzger (2009)

GRMHD

Use HARM, extended to 3D and parallelized with MPI

Parameterized neutrino cooling and nuclear recombination, gamma-law EOS, Kerr metric

Black hole mass: $3M_{sun}$, spin = 0.8

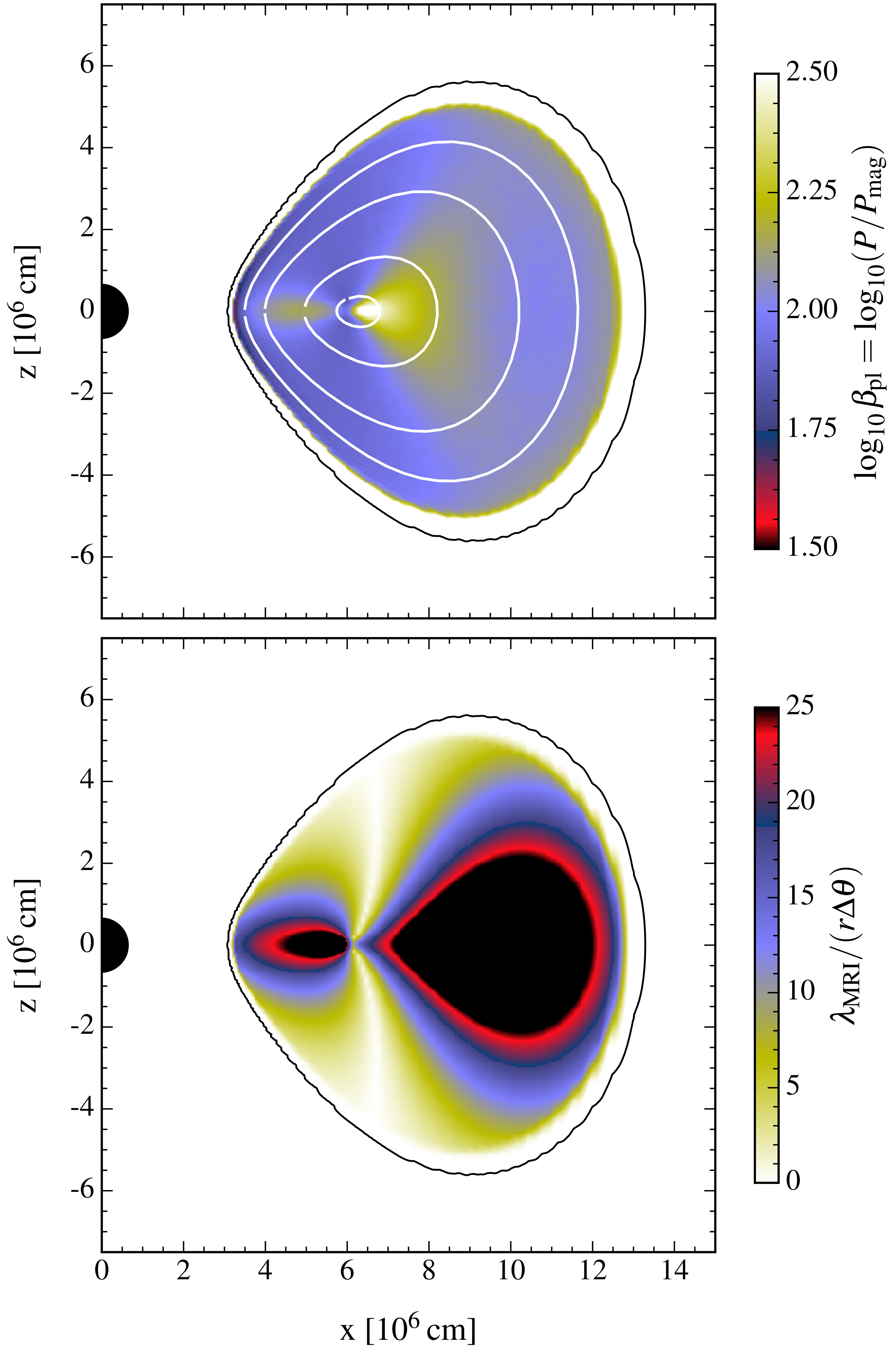
Start from equilibrium torus, constant Ye, entropy, and angular momentum, $M_{disk} = 0.03M_{sun}$

Impose strong initial poloidal field, fully resolve MRI in equatorial plane

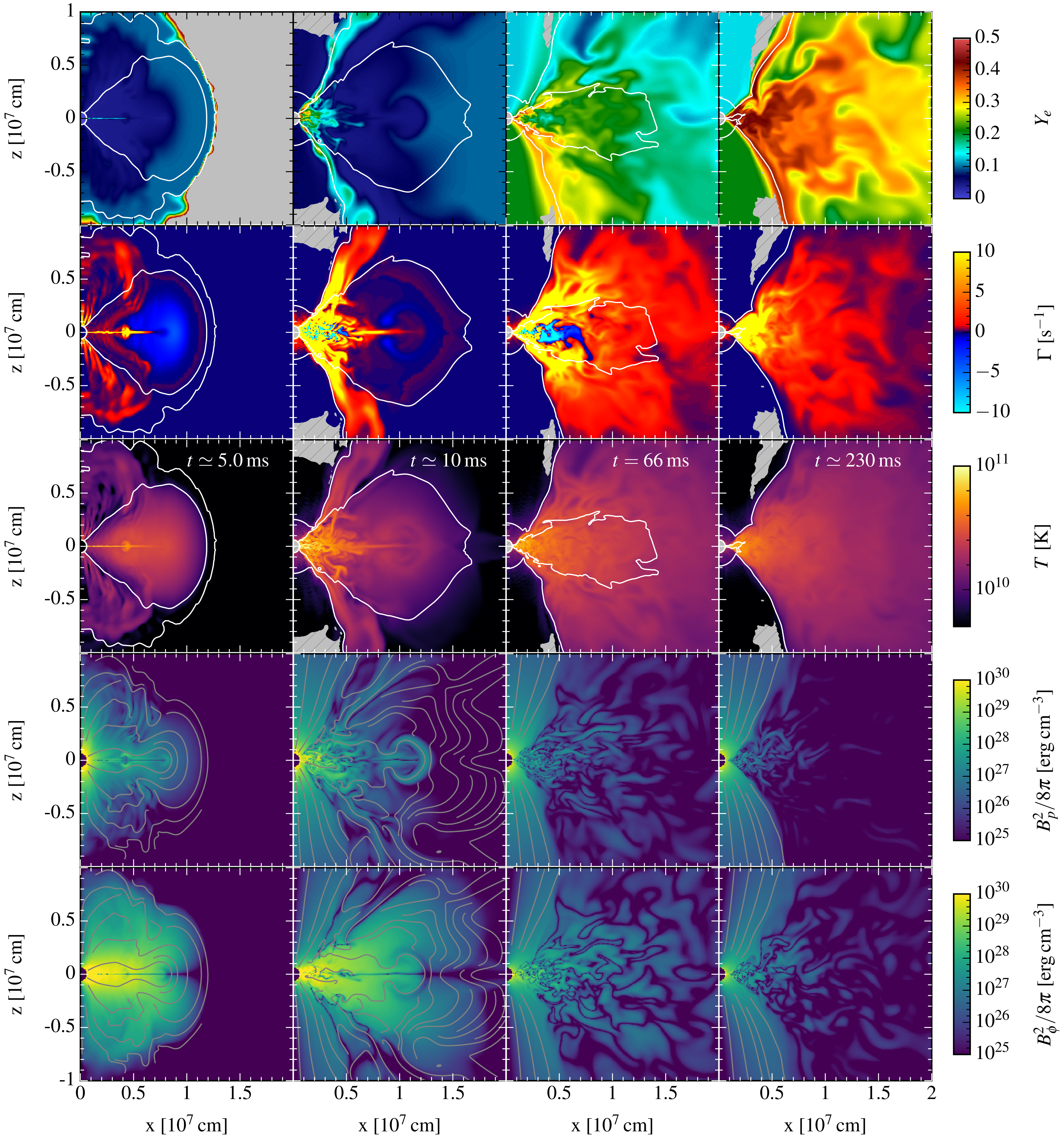
Compare with hydro models with identical microphysics

see also Siegel & Metzger (2017, 2018)

Shibata+ (2007,2012), Janiuk+(2013), Nouri+ (2017)



RF, Tchekhovskoy, Quahaert, Foucart, & Kasen (2019)



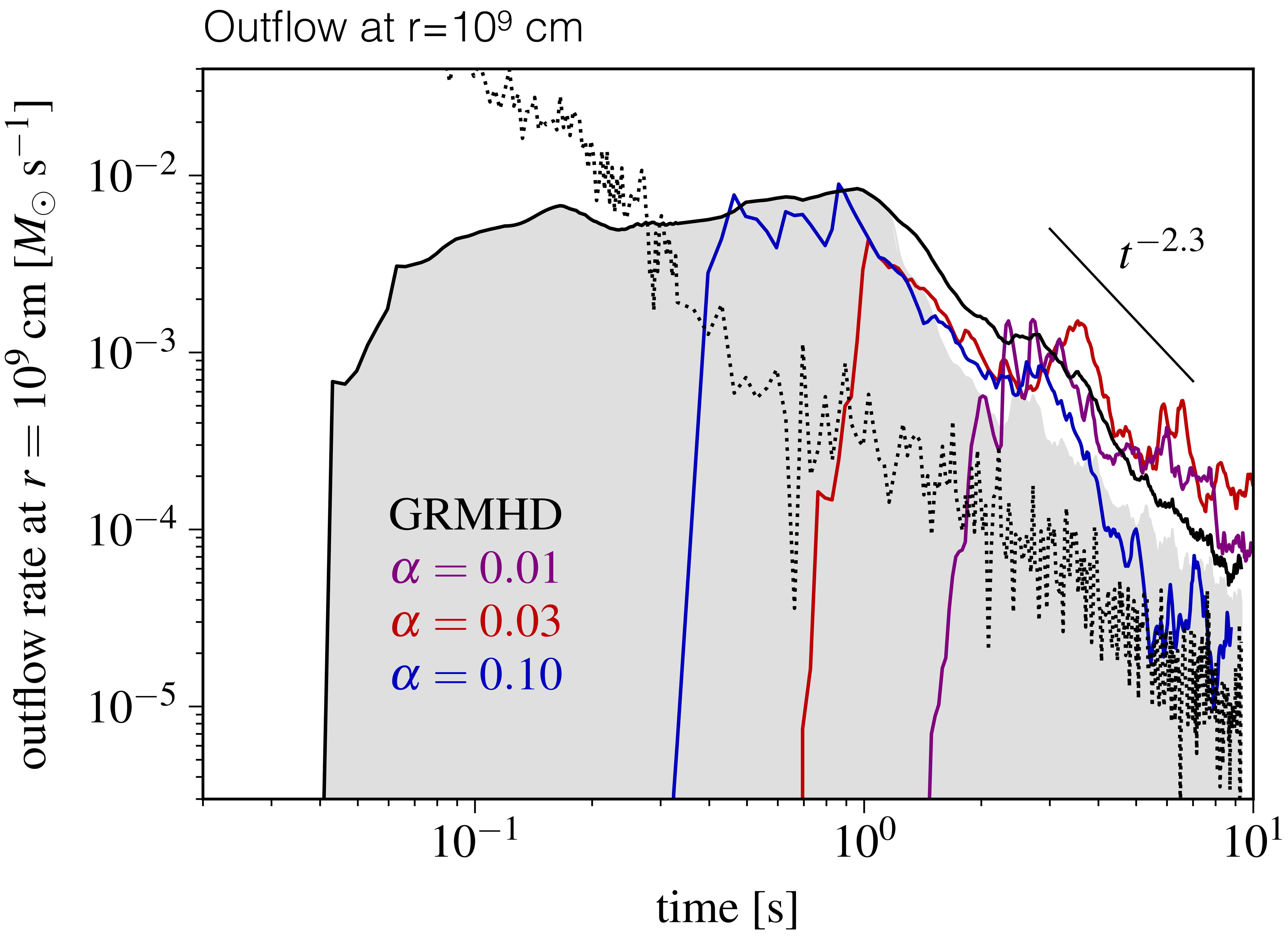
Early evolution

Development of MRI starts accretion

Magnetic field winding and amplification launch outflow over the first few orbits

MRI heating increases entropy and equilibrium Ye

RF et al. (2019)



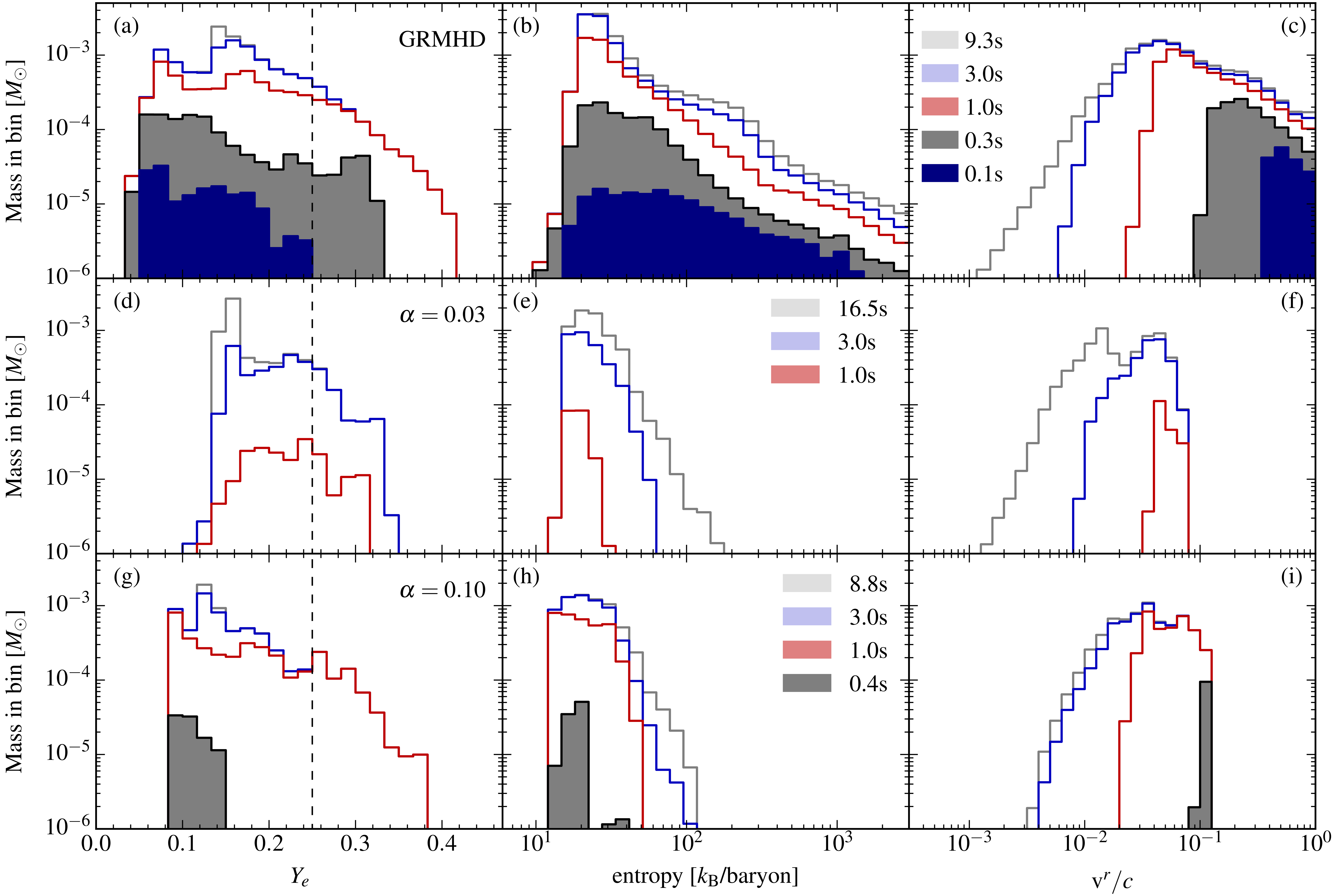
RF et al. (2019)

Long-term mass ejection

MHD outflow ejects twice more mass than equivalent hydrodynamic model

50% of the mass is ejected before 1s

Late time behavior of MHD and hydro models is very similar: shared mass ejection mechanism

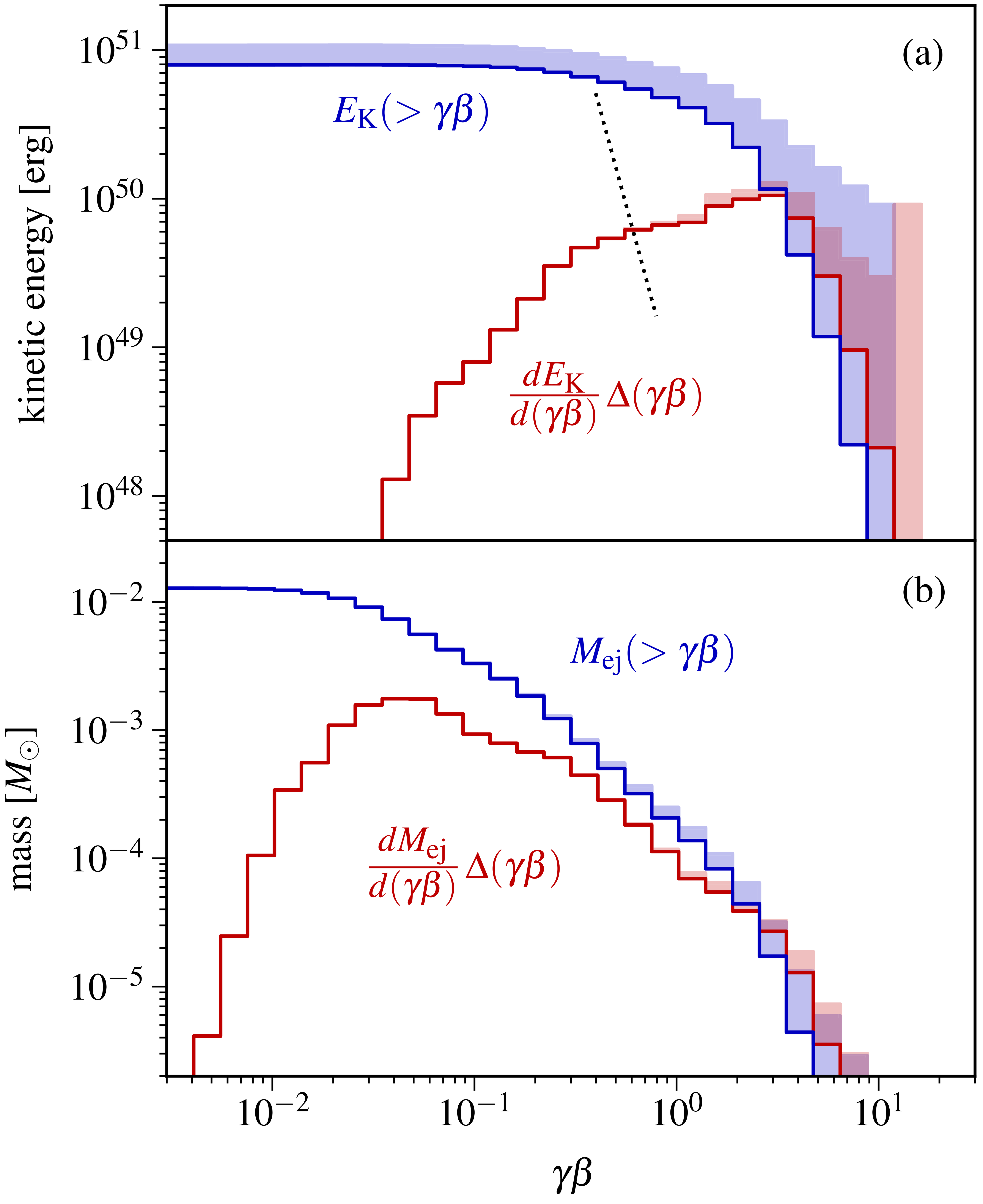


RF et al. (2019)

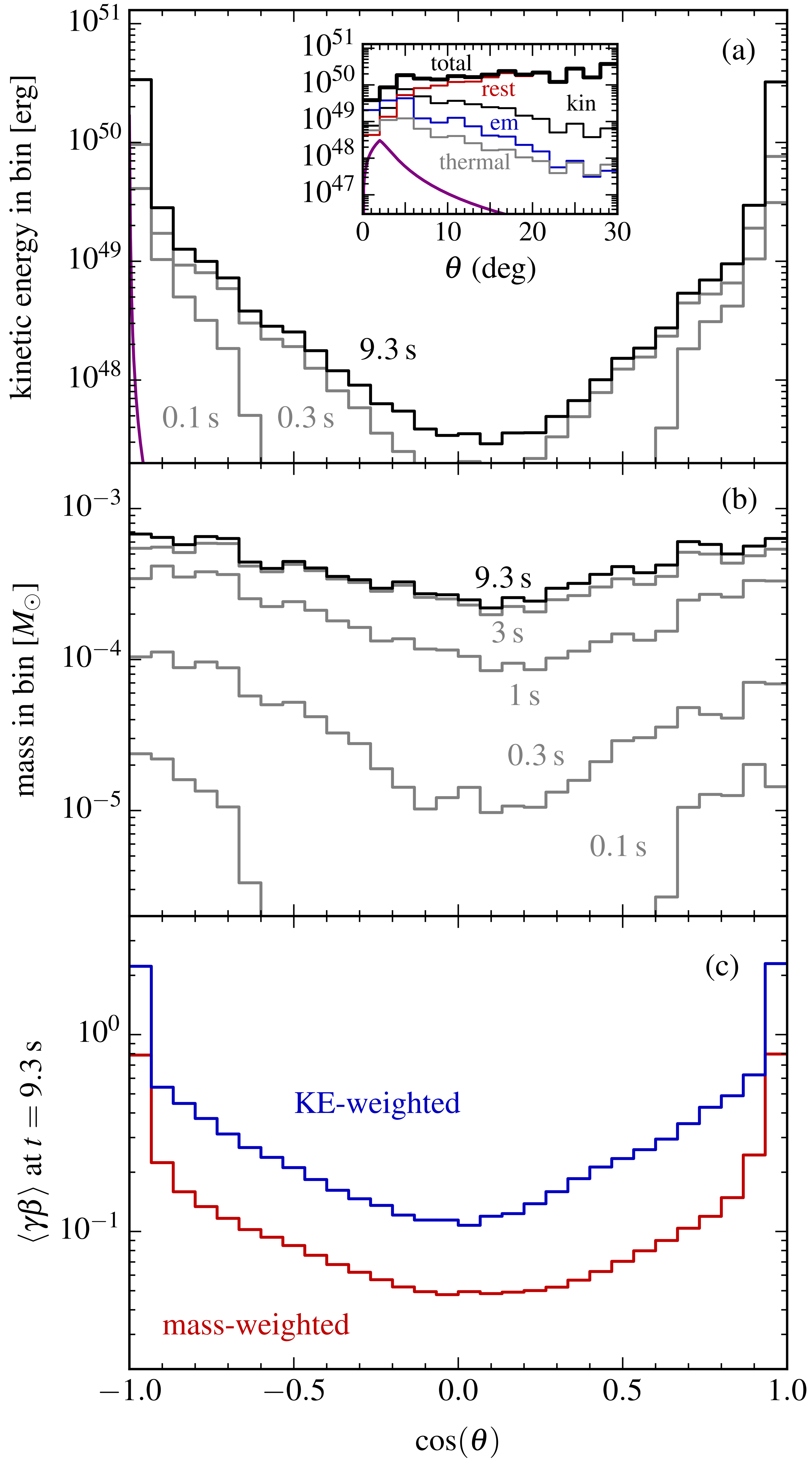
Mass histograms at $r=10^9$ cm

Early ejecta is more neutron rich: imprint of initial disk composition

GRMHD model has broader Ye distribution and faster average velocity



RF et al. (2019)



More kinetic energy than required to explain non-thermal emission from GW170817

Dependent on initial magnetic field geometry

Powerful jet is obtained

Summary

1. GRMHD disks can eject twice more mass than disks evolved in viscous hydrodynamics, have faster average speed and lower average Ye (depending on initial disk composition)

2. Two-component outflow: thermally-driven (MRI turbulence or viscosity) and magnetically-driven (Lorentz force)

3. More than sufficient kinetic energy to account for non-thermal emission from GW170817, but sensitive to initial field geometry

Fernández, et al. (2019), MNRAS, 428, 3373

Thanks to: