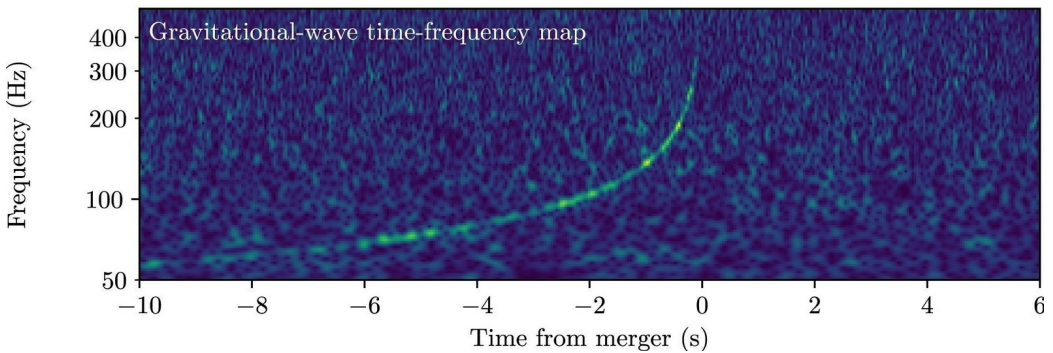
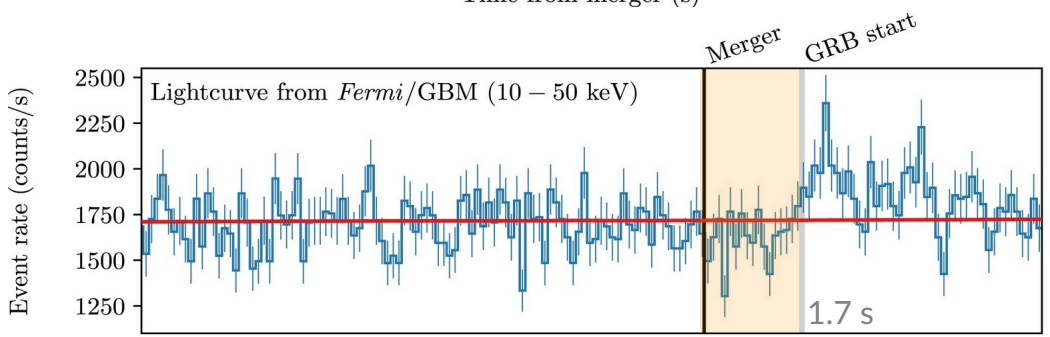
CNOC XII

Jet structure modelling with self-consistent binary neutron star merger environments

A. Pavan, R. Ciolfi, J. V. Kalinani, and A. Mignone

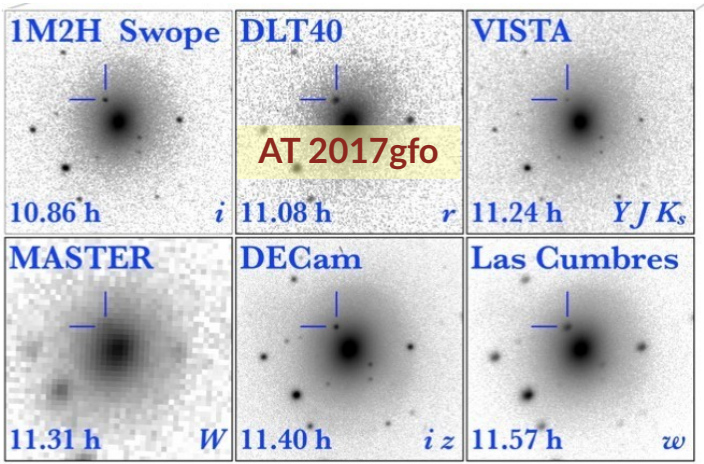
GW170817 / GRB 170817A

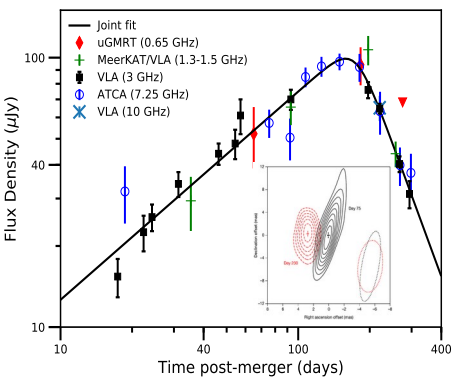




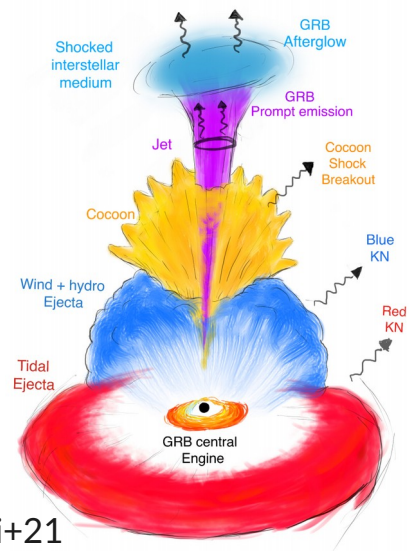
Abbott+17

Jet central engine ?
Jet propagation ?



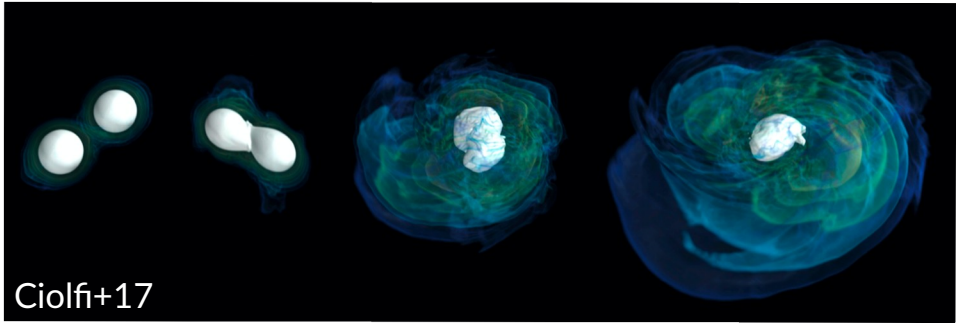


Mooley+18

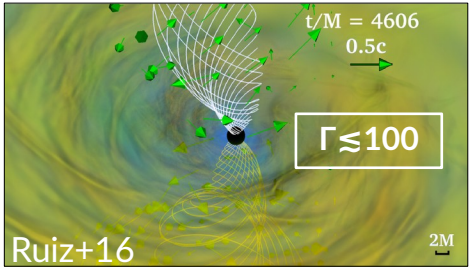


Ascenzi+21

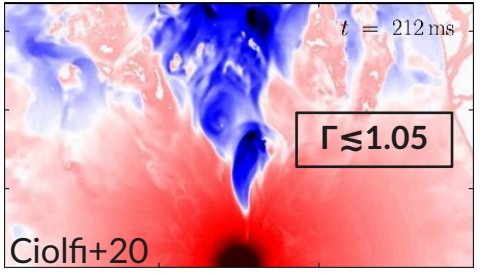
BNS Merger Simulations



BH – Accretion disk



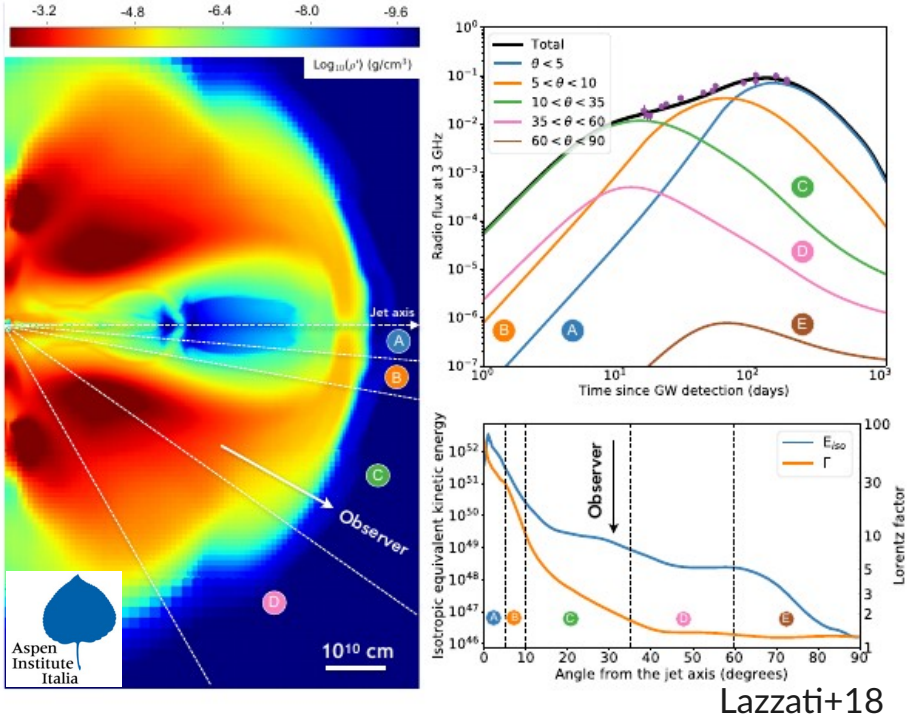
Magnetar



+ Neutrino leakage and Realistic EOS

e.g., Mosta+20, Ruiz+21, Sun+22

Short-GRB Jet Simulations



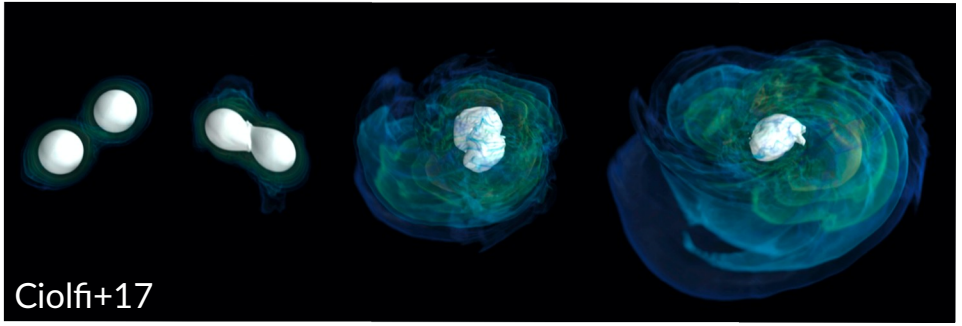
Lazzati+18

+ 3D (G)RMHD

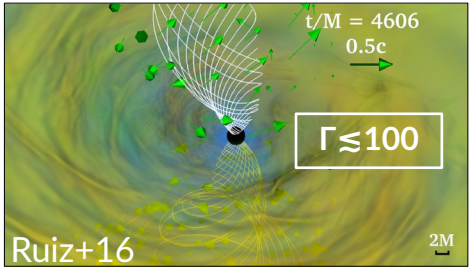
e.g., Geng+19, Nathanail+21, Gottlieb+22

NO DIRECT CONNECTION

BNS Merger Simulations



BH – Accretion disk



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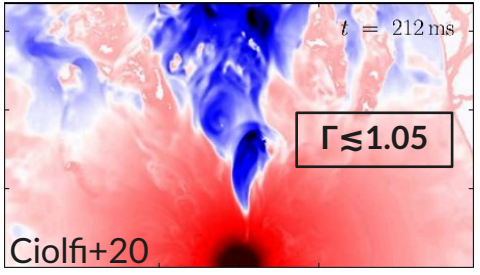
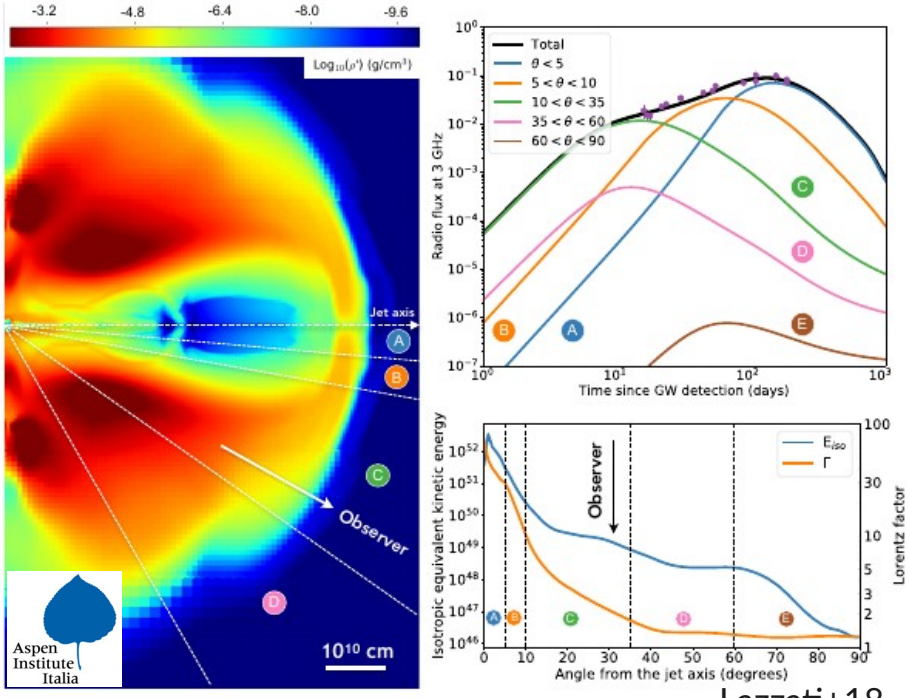


- ✗ High computational costs
- ✗ Resolution issues (e.g., magnetic field instabilities)
- ✗ Limited scales (≲250ms, ≲10^3 km)

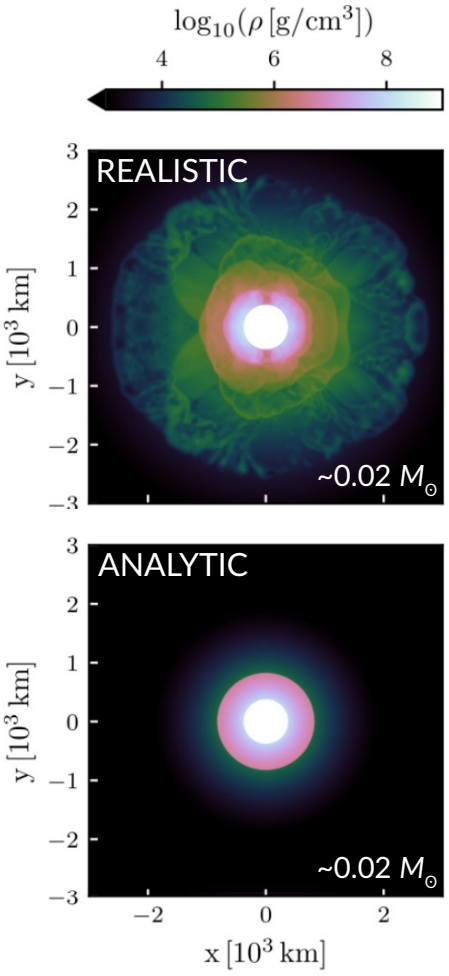
Short-GRB Jet Simulations



Lazzati+18

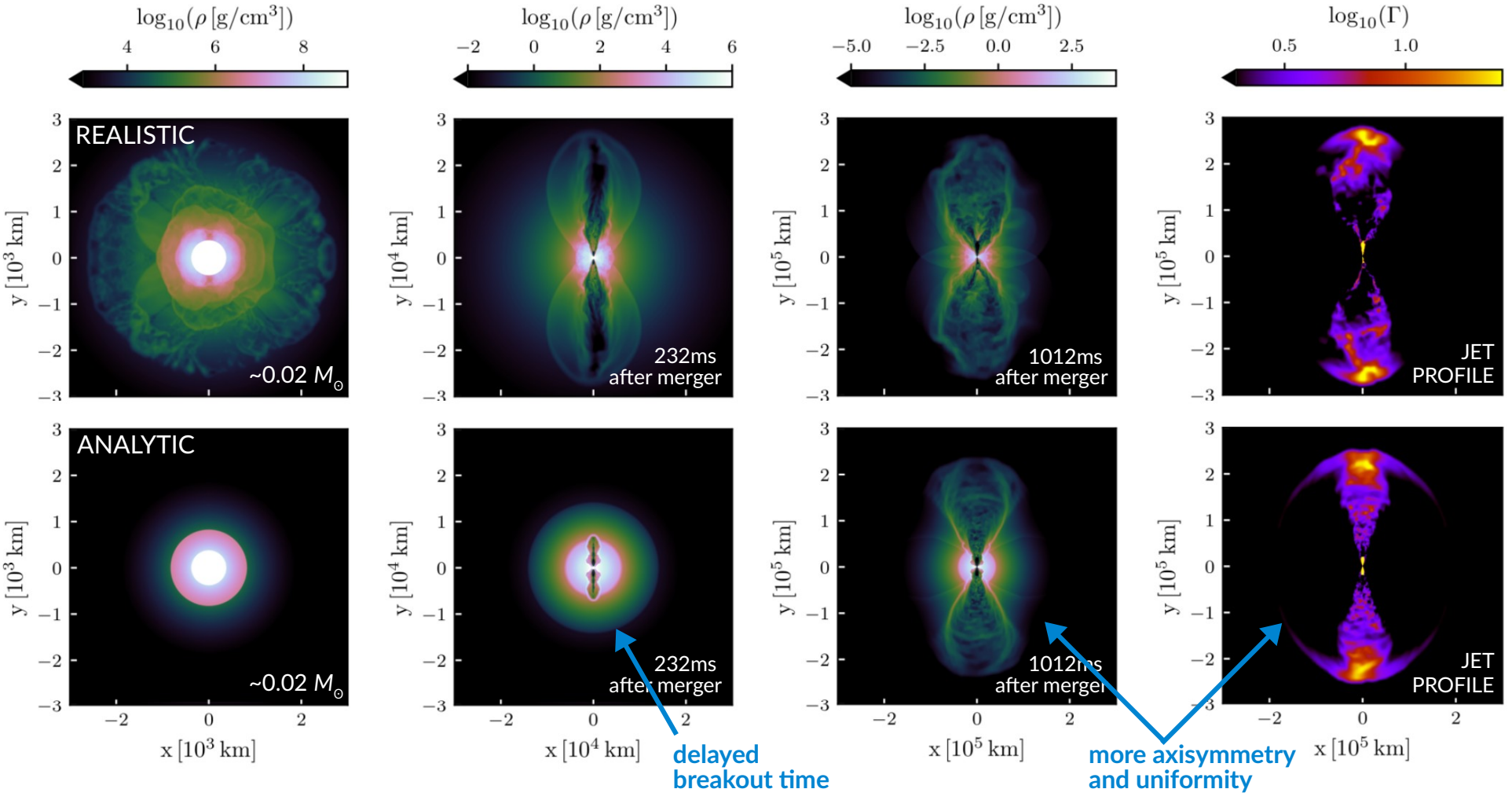
- ✗ 3D-(G)RMHD up to ~2s, ≳10^5 km
- ✗ Resolution issues (e.g., magnetic reconnection)
- ✗ <u>Analytic environment</u>

Pavan+21 (RHD jet in realistic environment)



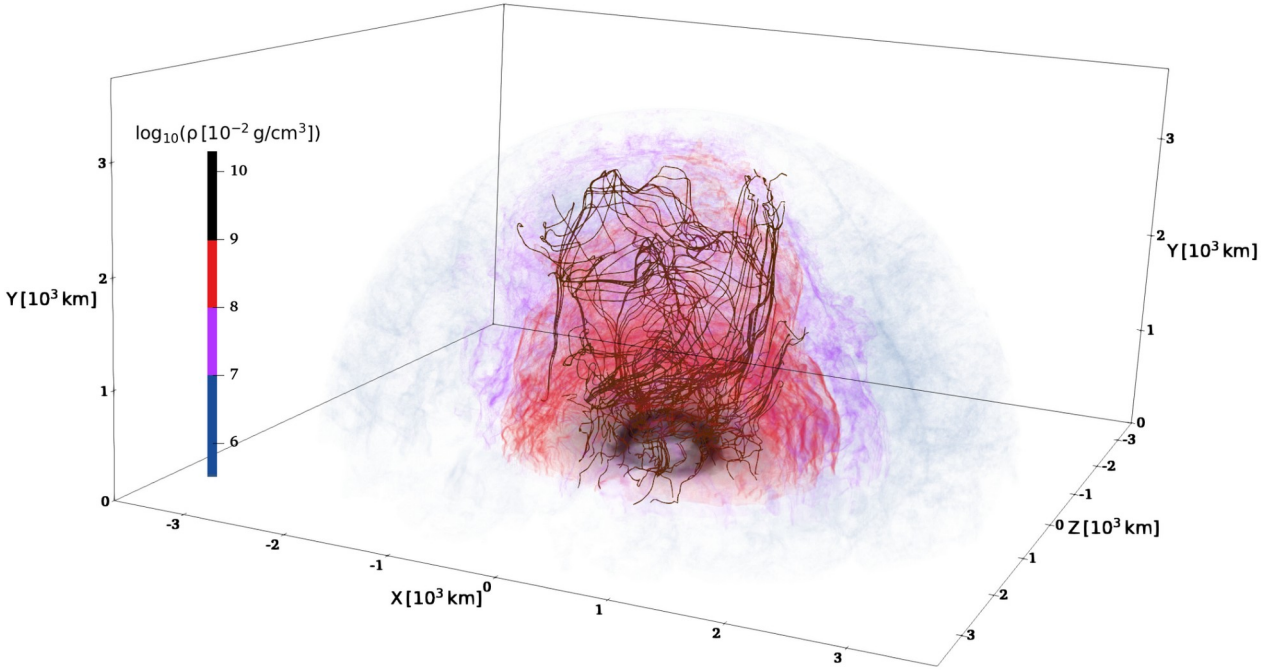
- 3D-GRHD BNS merger simulation by Kalinani
  (WhiskyMHD, Einstein Toolkit, PostCactus)
- Data import into special-relativistic code PLUTO
  (Mignone+07,+12)
- Domain setting
  - 3D spherical coordinates
  - Logarithmic radial spacing + “excision”
  - Power-law “atmosphere” (static)
- Newtonian gravity included
- Jet injection environment
  - REALISTIC → Self-consistent [P,ρ,**v**](r,θ,ϕ) and boundary conditions
  - ANALYTIC → Power-law + Homologous expansion

Pavan+21 (RHD jet in realistic environment)

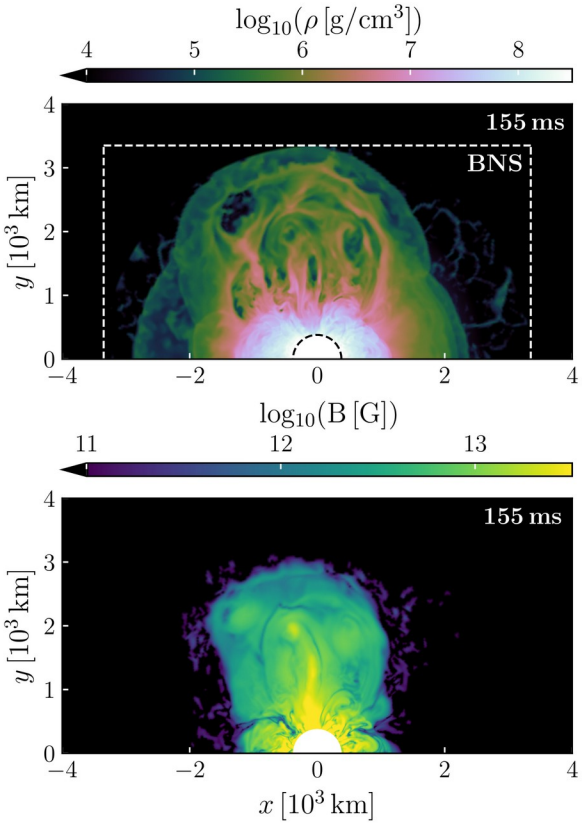


COMING SOON

Pavan+22 (RMHD jet in realistic environment)



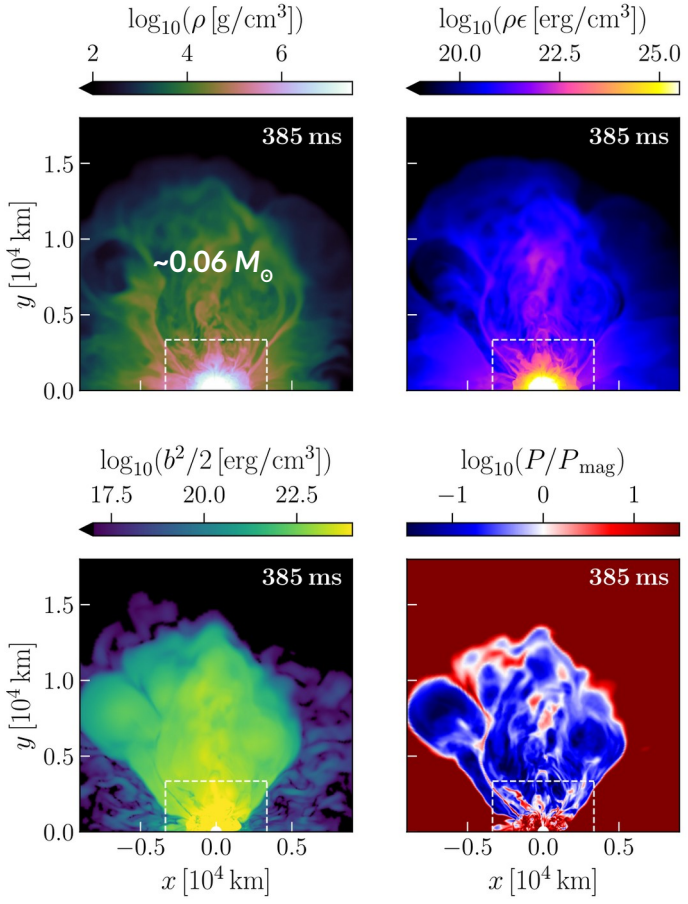
3D-GRMHD BNS merger simulation by Ciolfi20
(WhiskyMHD, Einstein Toolkit, PostCactus)



Import into PLUTO-RMHD
(Hyperbolic Divergence Cleaning)

COMING SOON

Pavan+22 (RMHD jet in realistic environment)



Jet injection setting

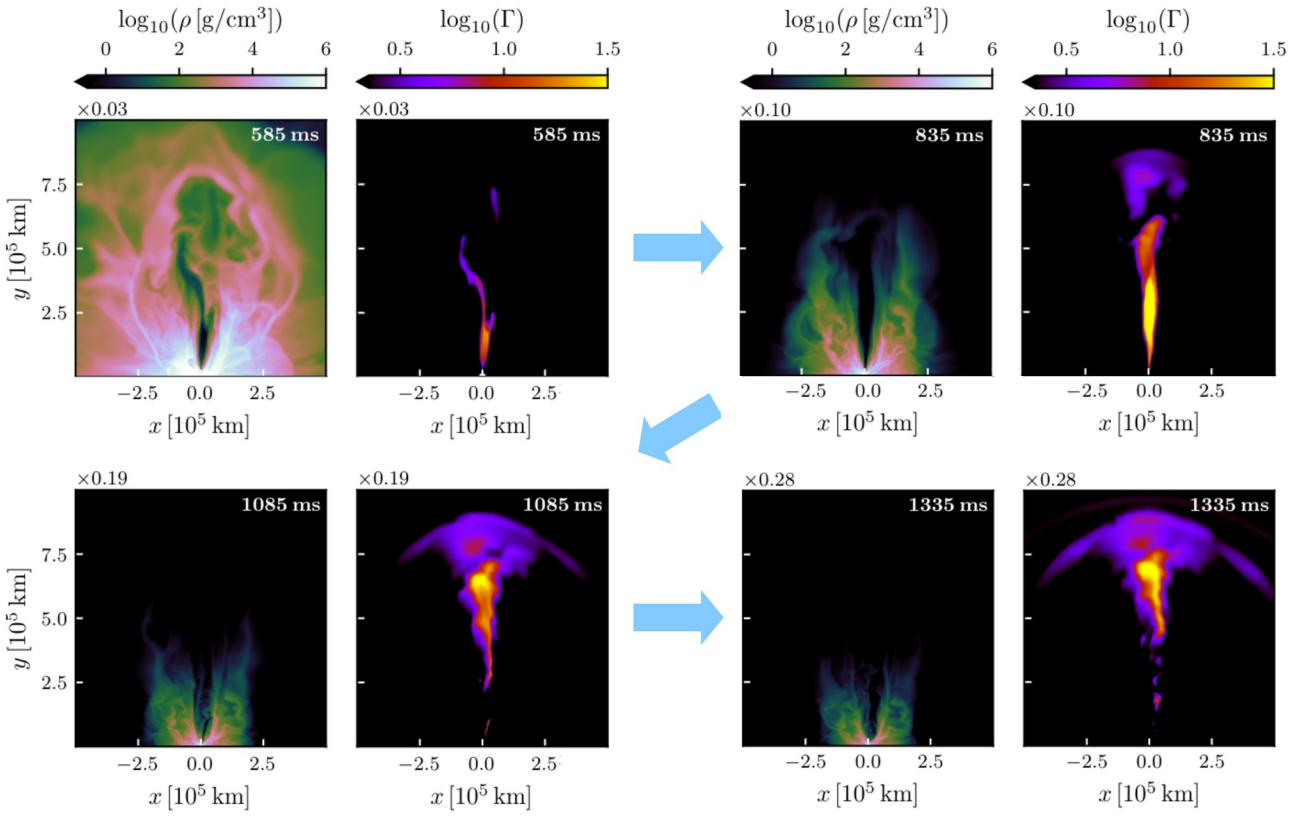
- 385ms after merger
- Newtonian gravity included
- Semi-analytic jet (Martí15, Geng+19)
  - Transversal equilibrium
  - Uniform rotation
  - Decaying luminosity (τ = 0.3s)

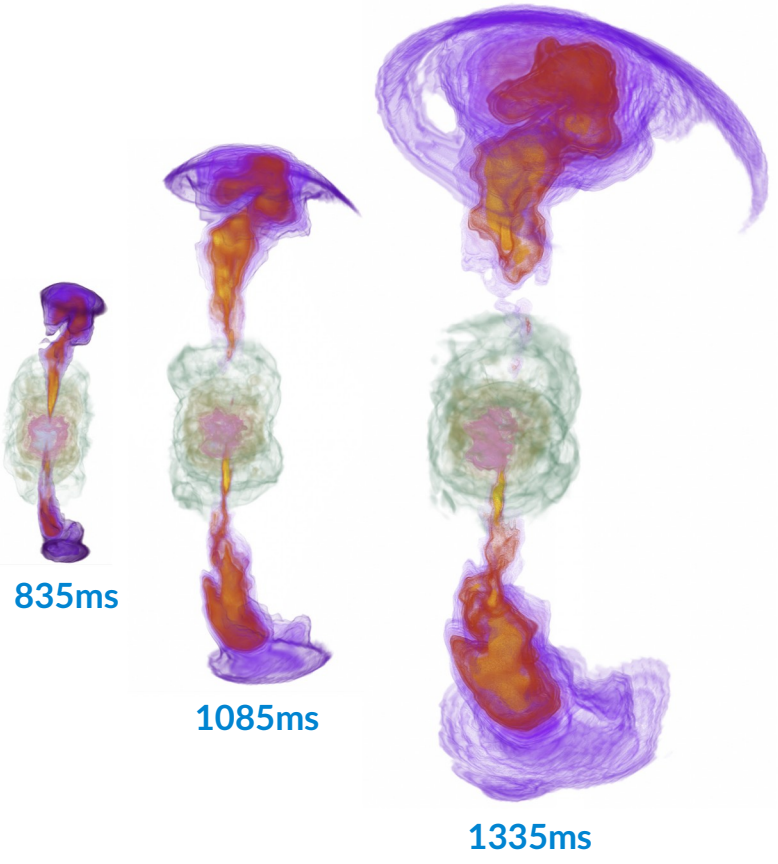
Table 1. Jet Injection Parameters

Δt_{j} [ms]	L_{j} [erg/s]	θ_{j} [°]	Γ_{j}	Γ_∞	$\theta_{\mathrm{j,m}}$ [°]	B^r_{j} [G]	$B^\phi_{\mathrm{j,m}}$ [G]
385	$3\cdot10^{51}$	10	3	300	4	$3.1\cdot10^{12}$	$6.2\cdot10^{12}$

COMING SOON

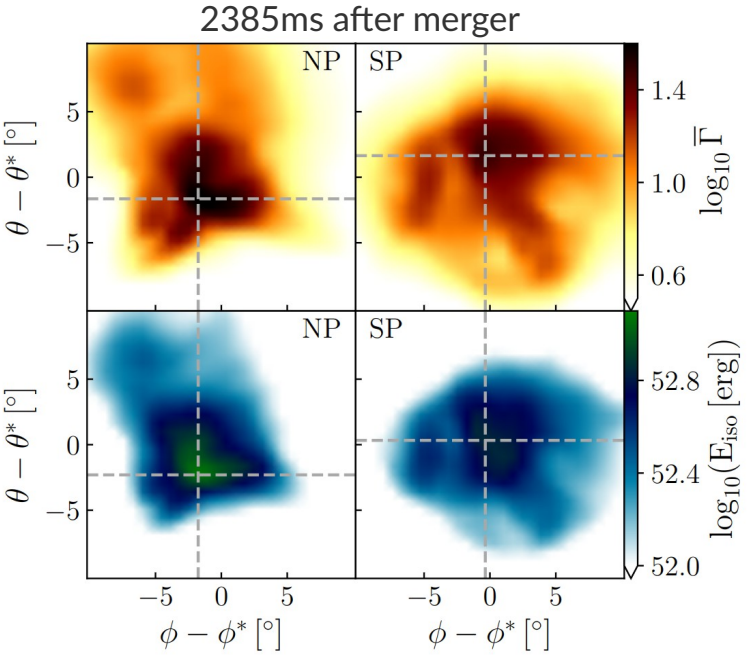
Pavan+22 (RMHD jet in realistic environment)





Summary & Ongoing Work

- ✔ SGRB jet simulations in fully-realistic BNS merger environments
- ✔ Realistic environments play a crucial role
  (jet breakout time, final structure & energetic)
- ✔ Jet injection time (with respect to merger) has strong influence
- ✔ Magnetic fields & Newtonian gravity must be included
- ✗ Dependence on jet injection parameters
- ✗ Afterglow modelling
- ✗ Realistic jet imported from BNS merger simulations



Structured jets
with 3D-asymmetries

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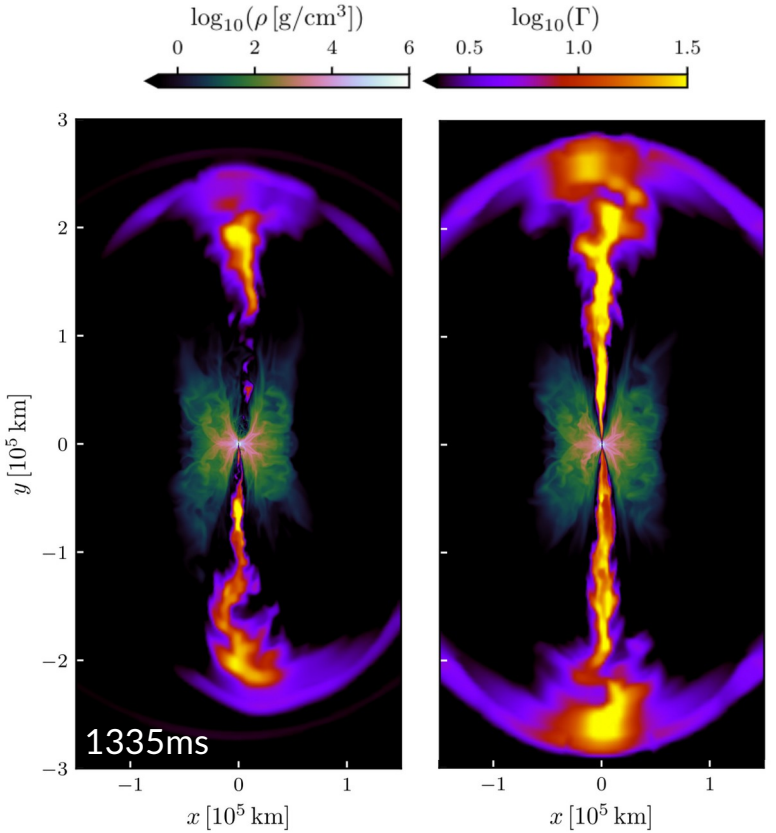

~8% magn. ~50% magn.

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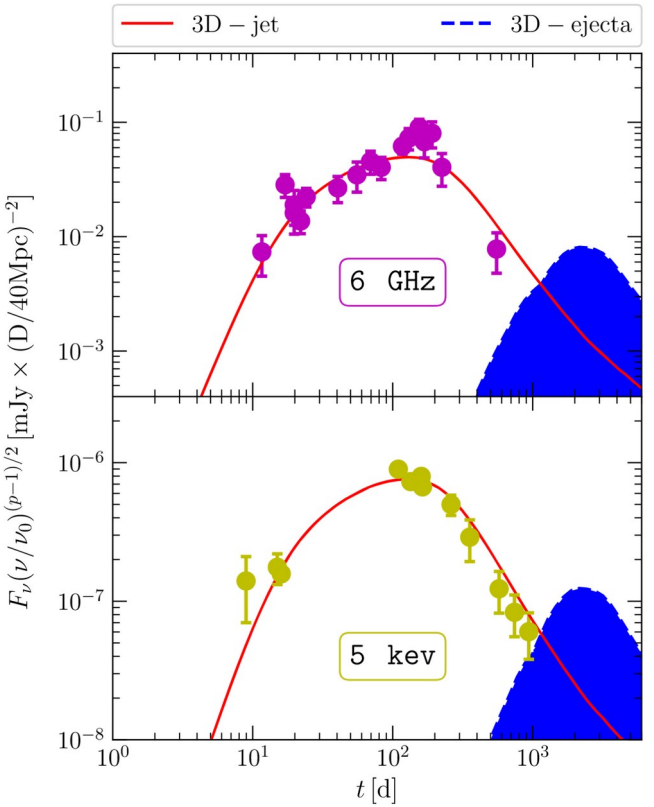

Nathanail+21

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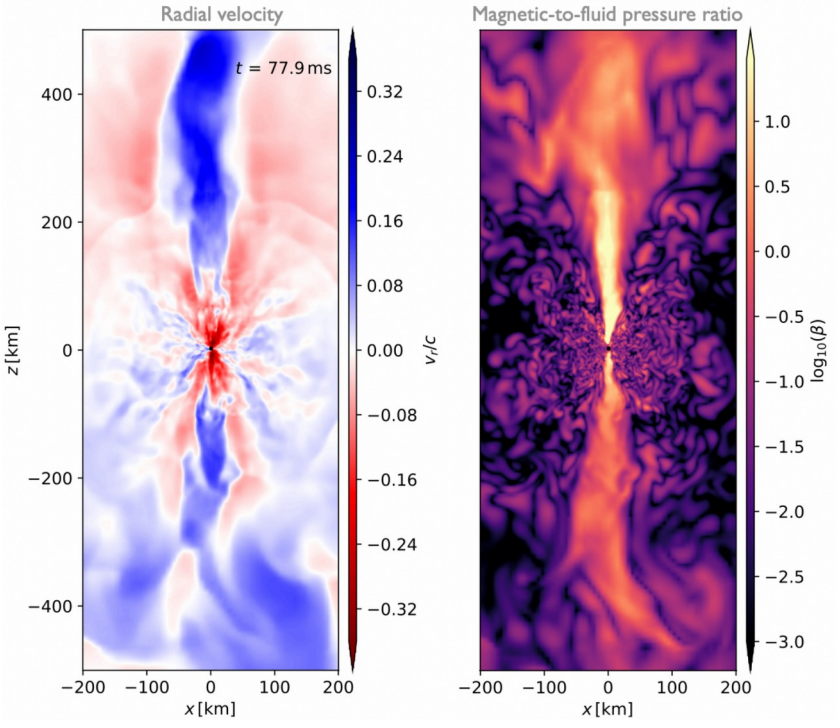
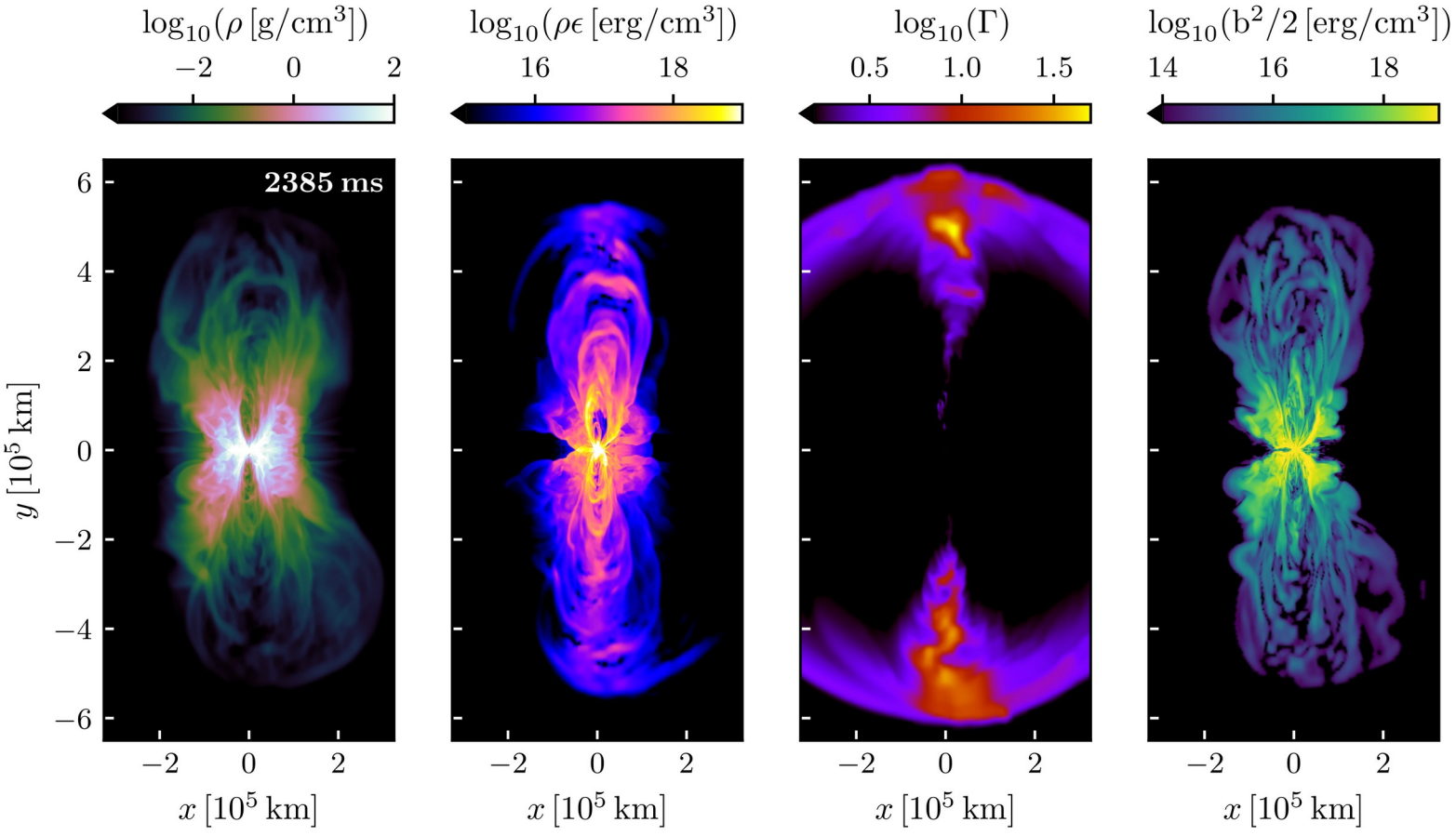


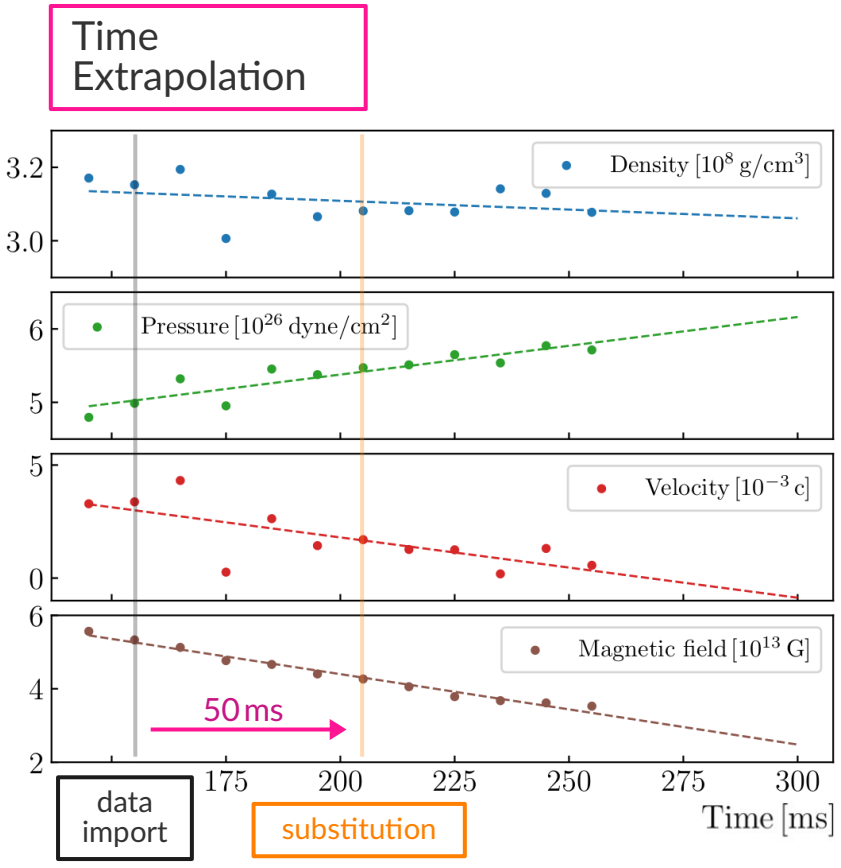
Simulation by Kalinani

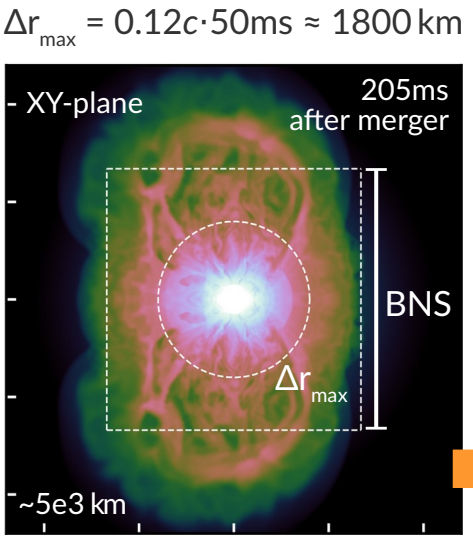
BACKUP SLIDES

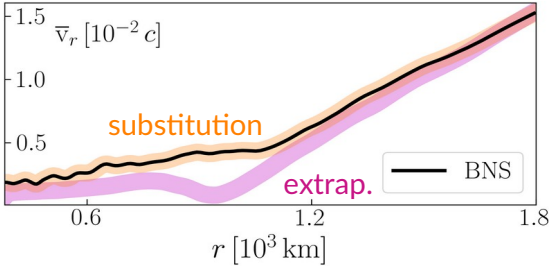
Configuration at ~2s



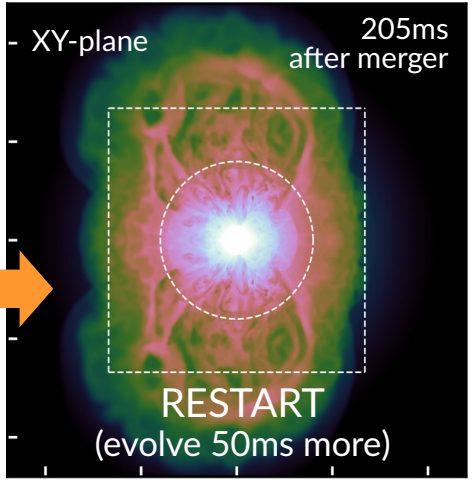
Pavan+22 (extrapolation procedure)







Substitution Step



Newtonian gravity impact