# Binary Neutron Star Mergers with Spritz

**Bruno Giacomazzo**

University of Milano-Bicocca

www.brunogiacomazzo.org

In collaboration with **Riccardo Ciolfi** (INAF Padova) and **Jay Kalinani** (RIT)



# The Spritz Code

## https://zenodo.org/record/4350072

Cipolletta, Kalinani, **Giacomazzo***, Ciolfi 2020, CQG 37, 135010
Cipolletta, Kalinani, Giangrandi, **Giacomazzo***, Ciolfi, Sala, Giudici 2021, CQG 38, 085021
Kalinani, Ciolfi, Kastaun, **Giacomazzo**, Cipolletta, Ennoggi 2022, PRD 105, 103031

BNS sims require to account for magnetic fields, but also for EOS and neutrino emission. No public code was available that included all these effects.

We therefore developed a new General Relativistic MHD code named Spritz:

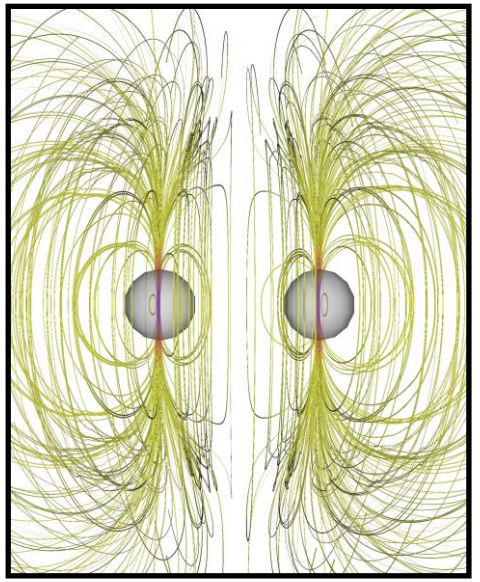
- Publicly available on Zenodo
- Based on the Einstein Toolkit Infrastructure (http://einsteintoolkit.org)
- GRMHD Valencia formulation
- **Staggered vector potential** formulation to evolve the magnetic field
- Support for finite-temperature tabulated Equations Of State
- Neutrino transport via a leakage scheme with a grey approximation (https://stellarcollapse.org/Zelmani) and 3 neutrino species ($\nu_e, \bar{\nu}_e, \nu_x$)
- 5-th order WENO-Z scheme for hydro
- Currently used for NS-NS simulations

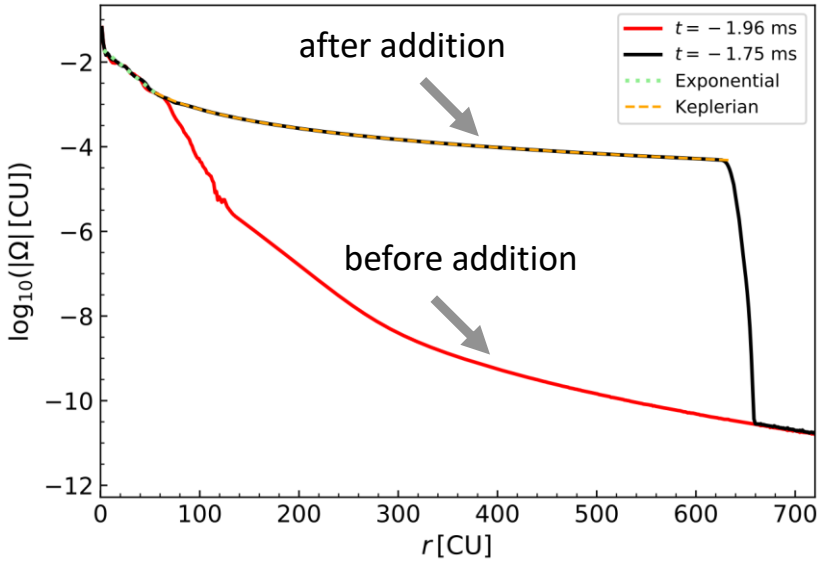
# BNS with Spritz using RePrimAnd

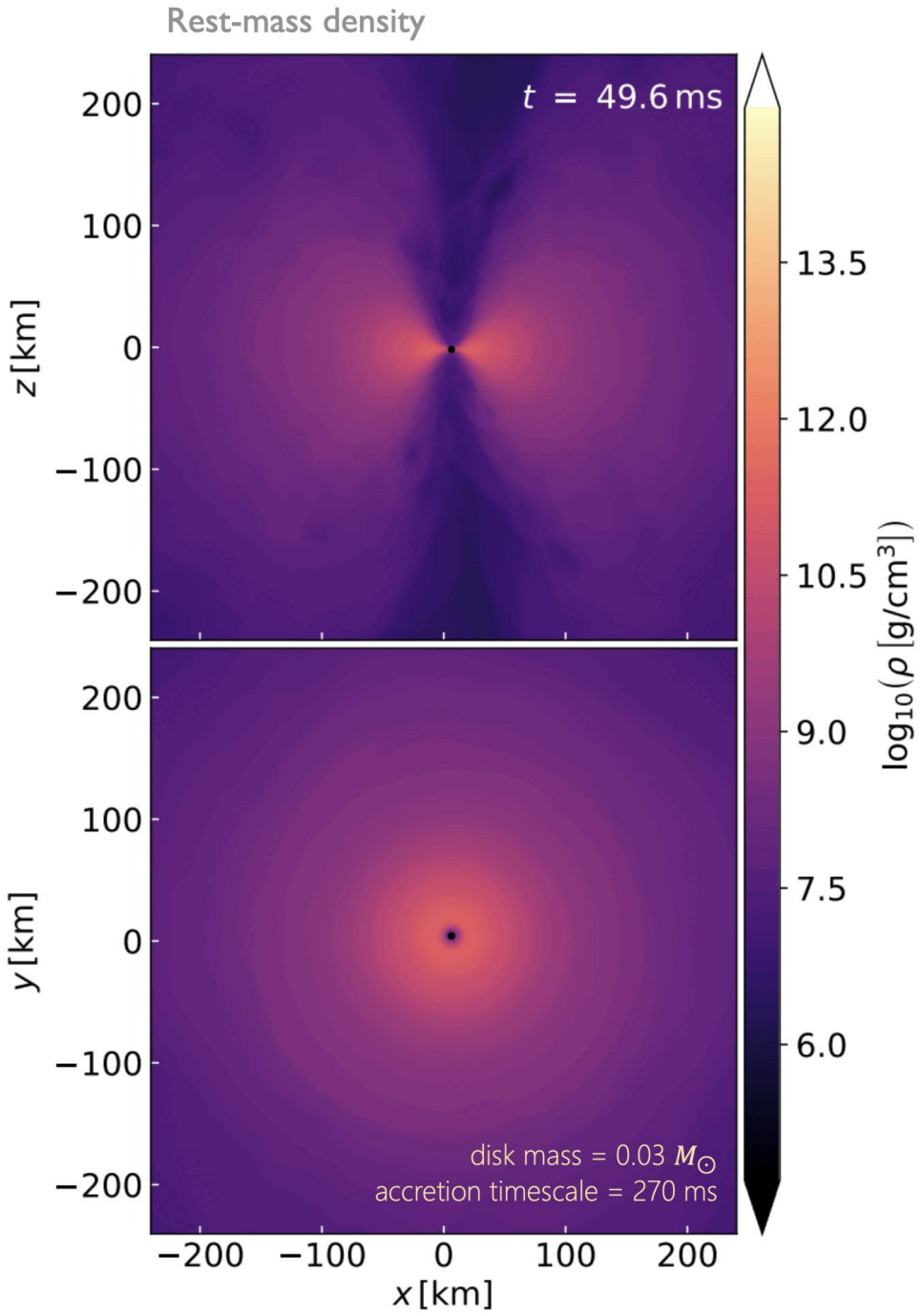
## (Kalinani et al, in prep.)

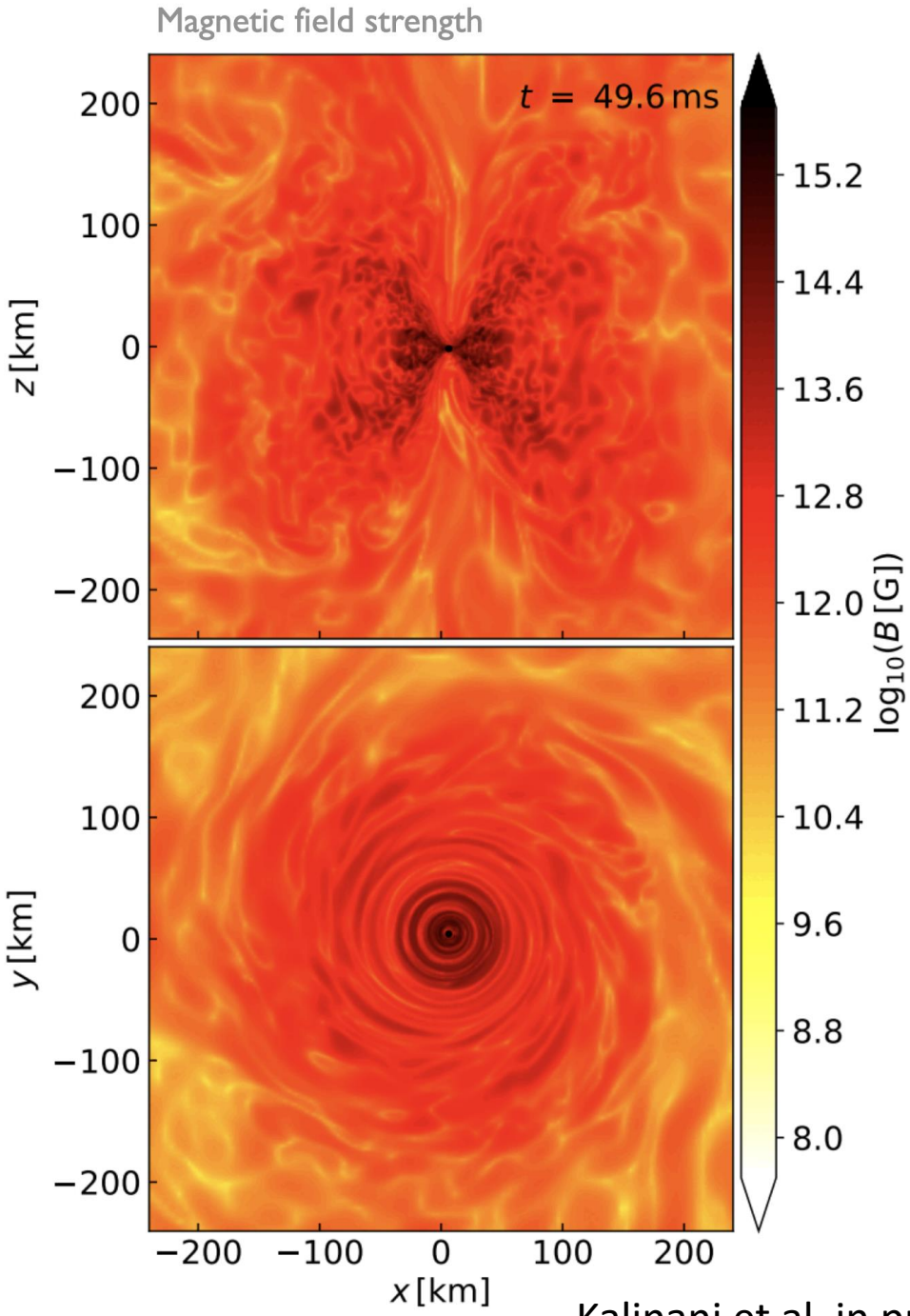
- Equal mass system ($1.5\ M_\odot$ each)
- Ideal fluid EOS for evolution
- Finest dx ~227m (finer reflevel dx ~114m added before collapse to BH)
- Dipolar magnetic fields added after two orbits with $B_{max} = 6.9 \times 10^{16} G$ ($E_{mag} \approx 8 \times 10^{48} erg$)
- Addition of co-rotating material ($M < 0.001\ M_\odot$)

Initial B field configuration



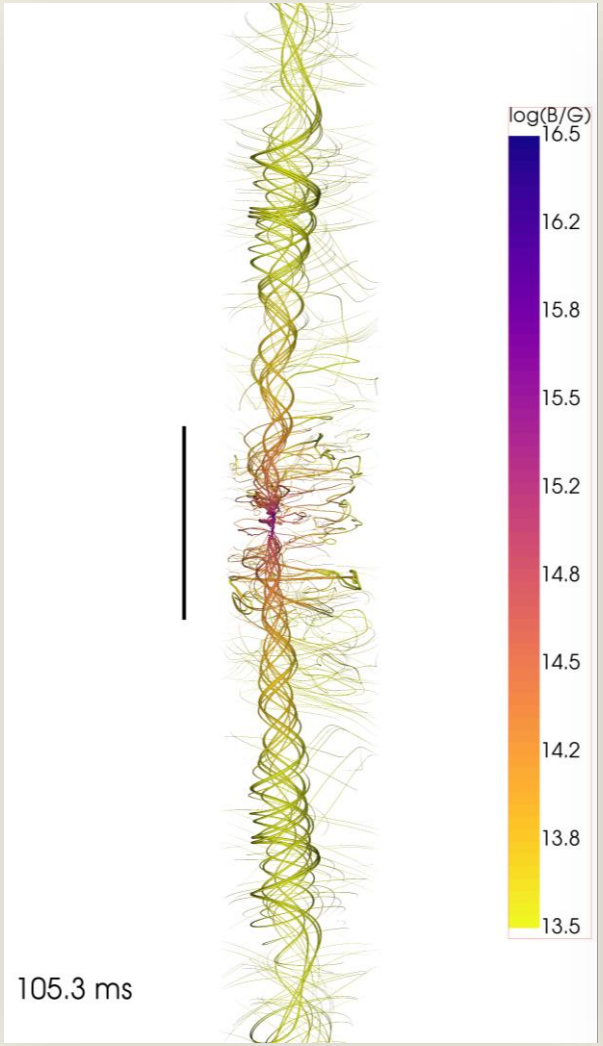


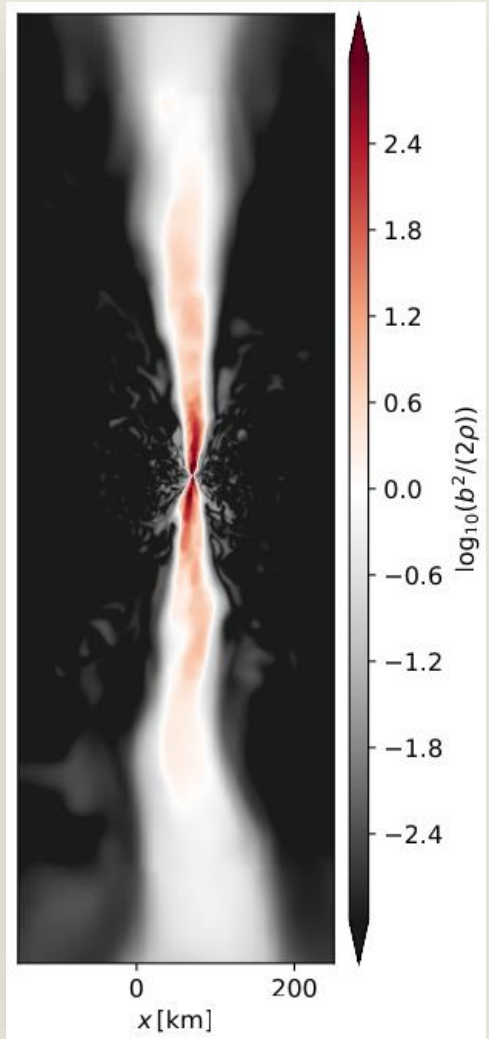


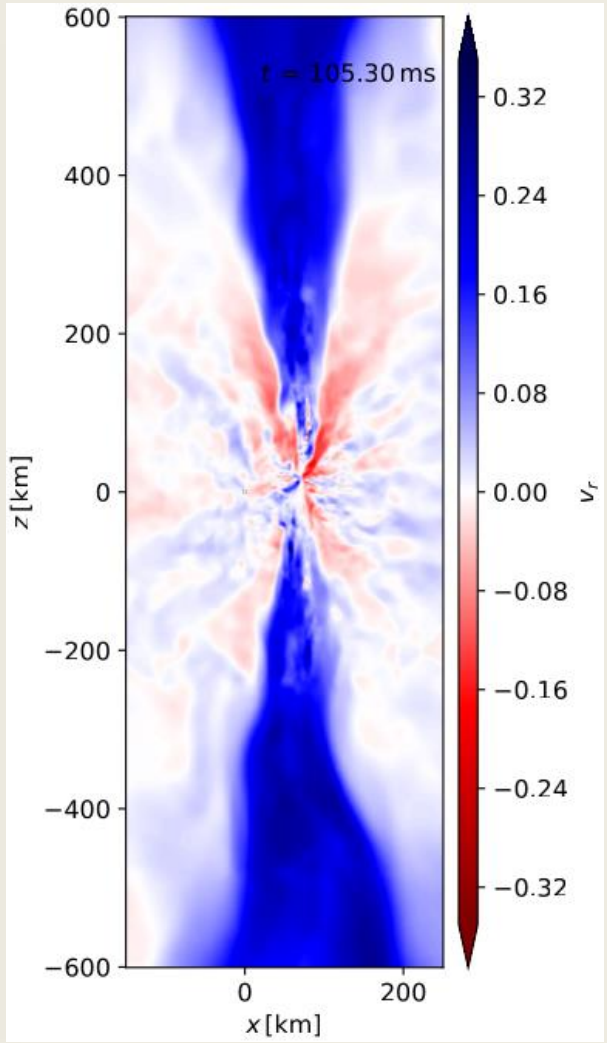




Kalinani et al, in prep

# APR4 EOS




- Equal mass (1.36-1.36)
- Initial $E_{mag} = 8 \times 10^{49}$ erg (B~$10^{17}$G)
- Finest dx ~227m (two finer reflevels, dx ~114m and ~57m are added before collapse to BH)
- Collapse induced 50 ms after merger
- ~50 ms after collapse a jet is launched

Kalinani et al, in prep

# Conclusions

- Spritz works with magnetic fields, finite-temperature tabulated EOSs, and neutrino emission
- The code (Cipolletta et al 2020, 2021) is **publicly available on Zenodo**: https://doi.org/10.5281/zenodo.3689752
- New version (not yet publicly available) also includes:
  - RePrimAnd C2P (Kalinani et al 2022) that allows to evolve NS-NS with external dipolar fields
  - UpwindCT scheme for the vector potential evolution (instead of fluxCT)
- We are currently testing it with **NS-NS mergers** leading to jet formation
- Jet formation possible, but really high magnetic fields are needed (as in Ruiz et al 2016)
- Stay tuned!