Title: Neutron Star Mergers: Probes of Extreme Matter

Speakers: Pablo Bosch Gomez

Collection/Series: Charting the Future Symposium

Subject: Cosmology, Particle Physics, Strong Gravity

Date: August 25, 2025 - 2:30 PM

URL: https://pirsa.org/25080023

Abstract:

Binary neutron star mergers are critical for understanding the dynamics of dense matter, the origin of gravitational waves, and the formation channels of the heaviest elements through the r-process. I will review how long-lived remnants can act as central engines for multimessenger observations. I will then discuss how we can identify phase transitions within neutron stars or their remnants using such observations. Phase transitions alter the system's dynamics and can produce distinct observable signatures, potentially detectable with next-generation facilities and observatories. These signatures can be used to probe matter at supranuclear densities and to test fundamental physics.

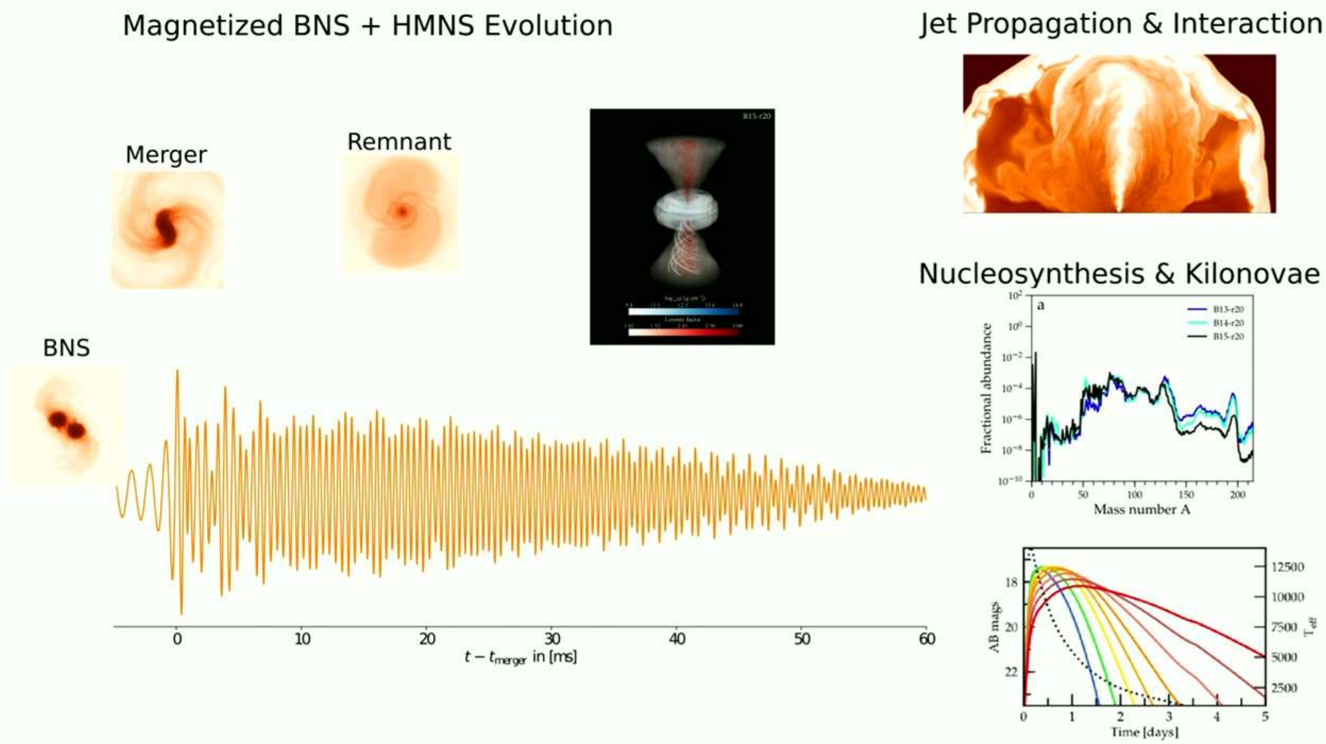
Neutron Star Mergers : Probes of Extreme Matter

Pablo Bosch Gómez

Institute for Theoretical Physics
Utrecht University

Charting The Future
Perimeter Institute
Waterloo, ON
August 2025

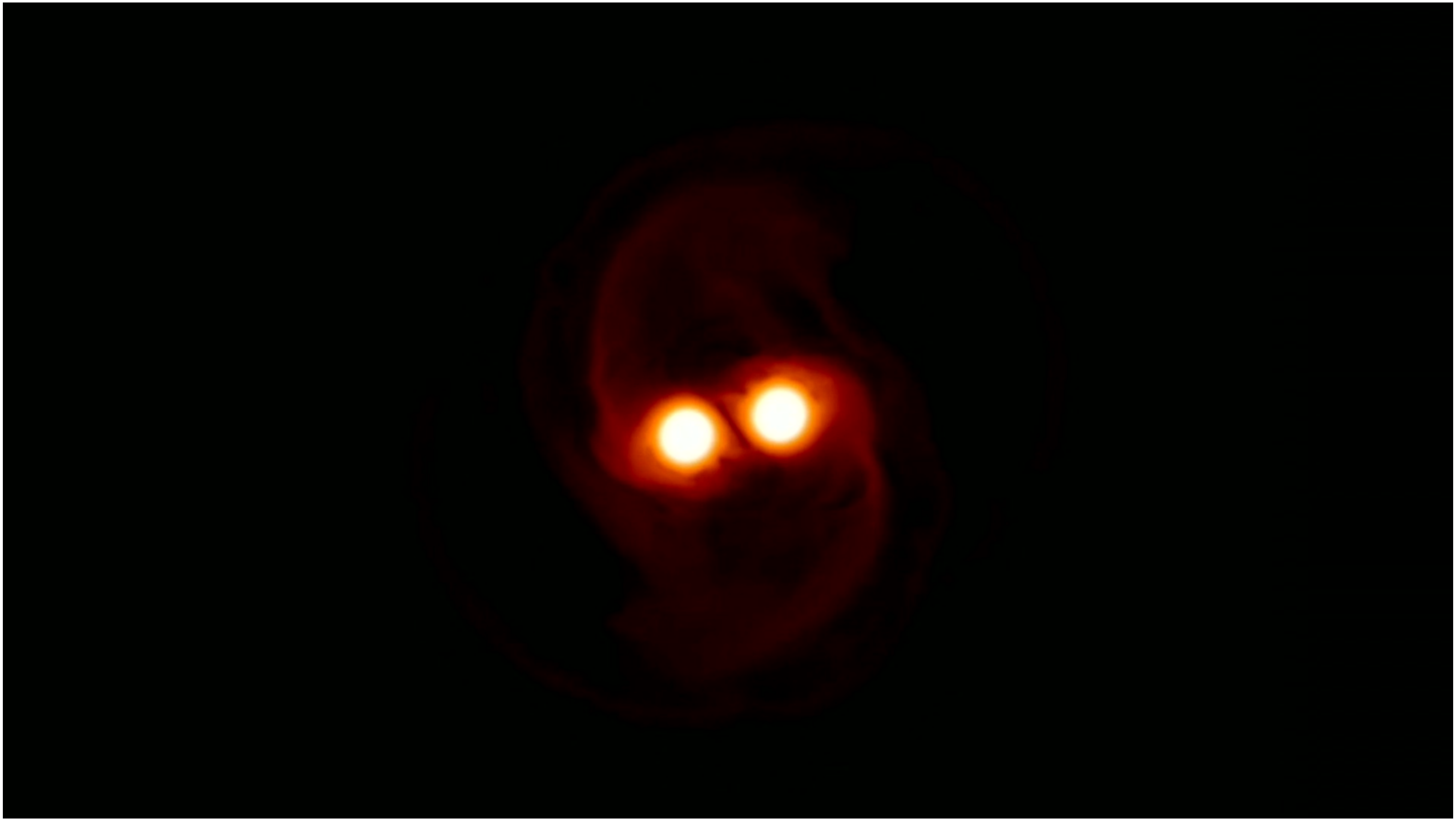
Introduction

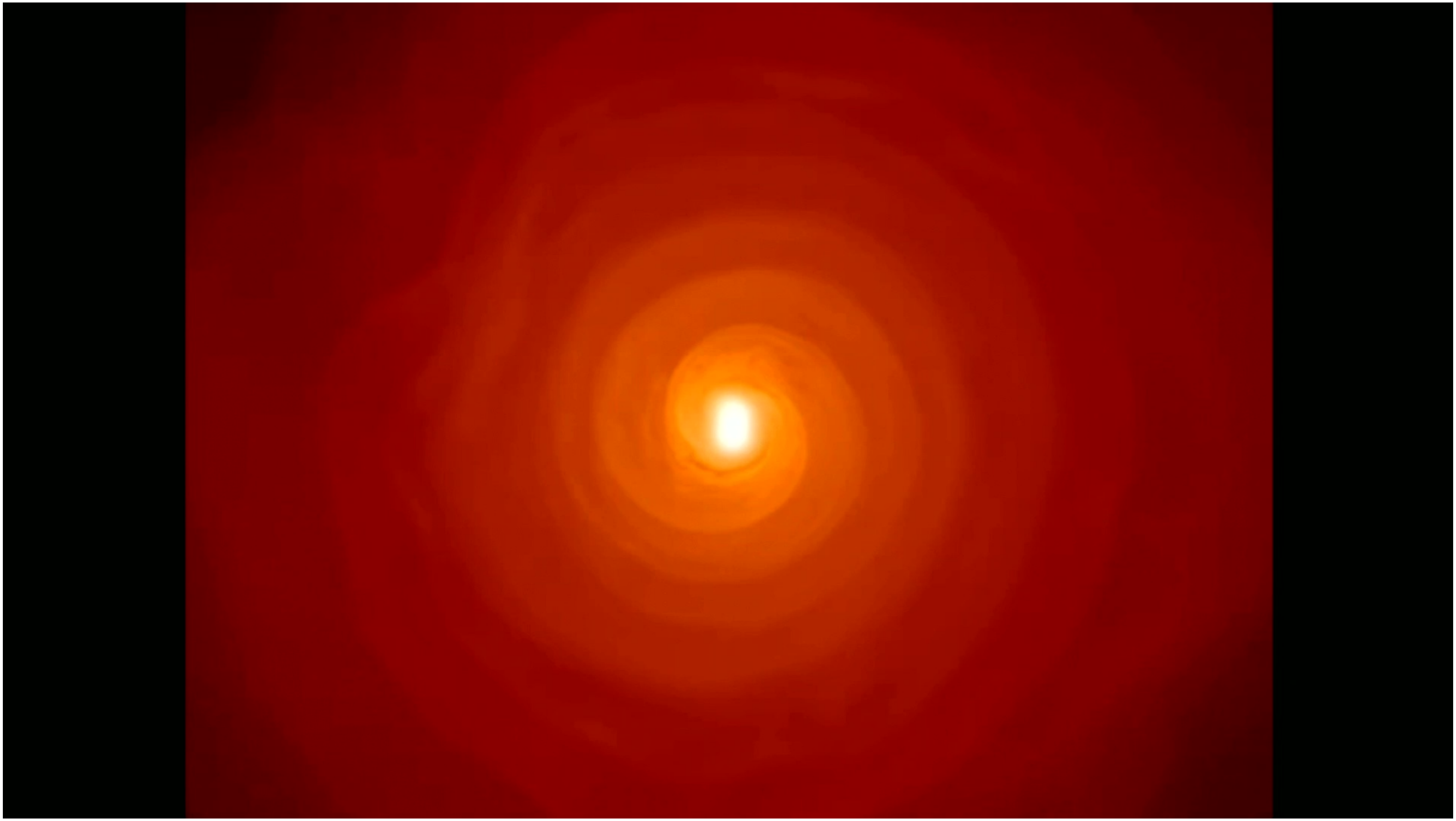


Model

A Multiphysics challenge

- Ideal GRMHD Evolution
  - General Relativity
    - Gravity
  - Magnetohydrodynamics
    - Gas/Plasma dynamics
  - Nuclear and Neutrino Physics
    - Nuclear EOS
    - Nuclear reactions and neutrino interactions
  - Boltzmann Transport Theory
    - Neutrino transport (leakage, M1)

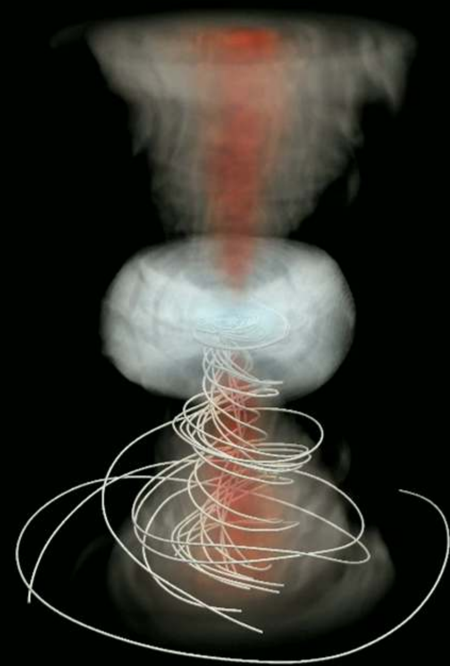




GRMHD Simulations

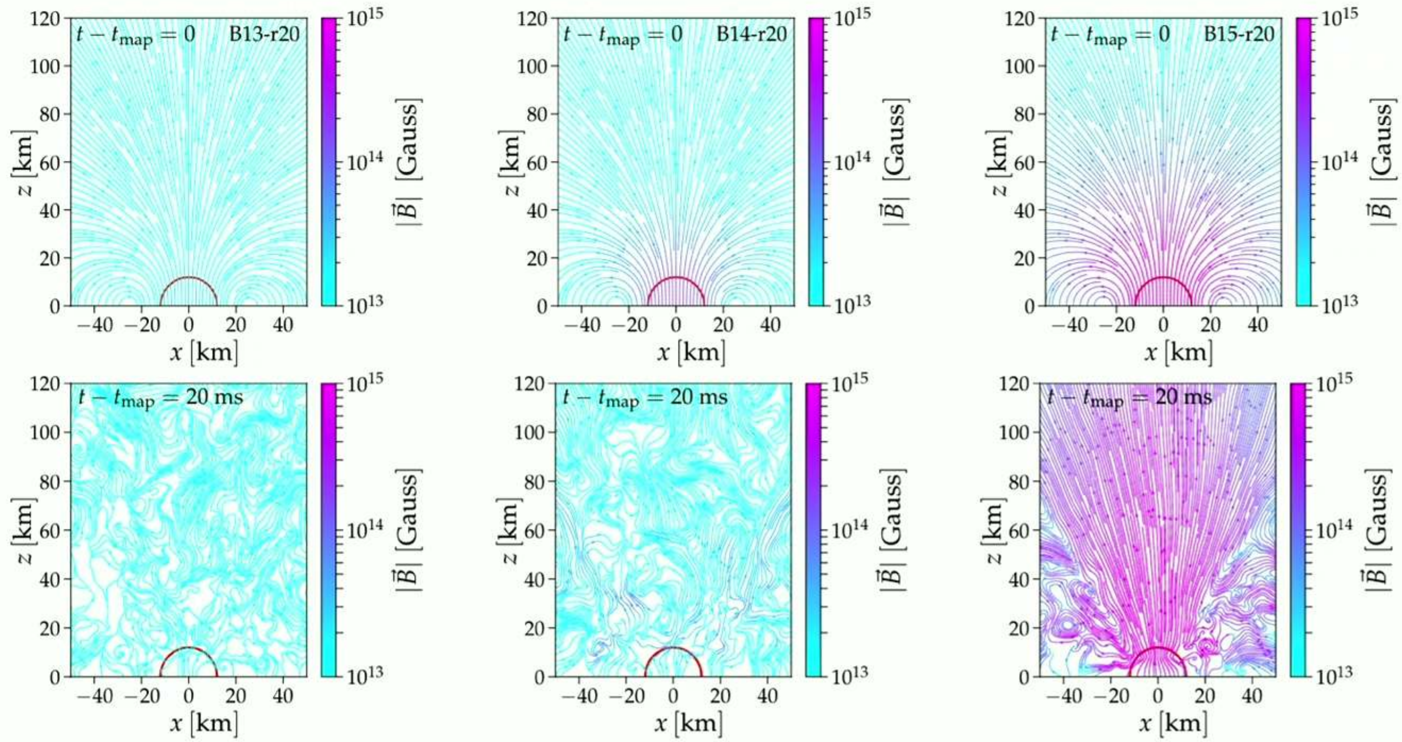
Magnetized Remnant Evolution

B15-r20



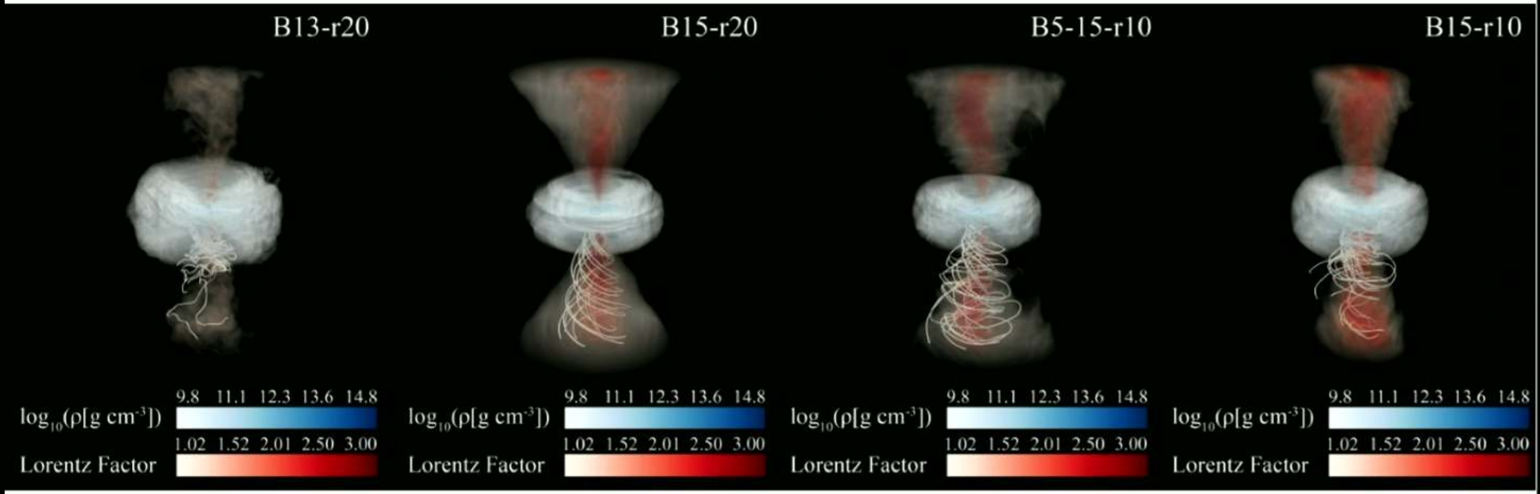
Parametrized Magnetic Field

Varying the strength



[de Haas, **PB**, Moesta, Curtis, Schut]

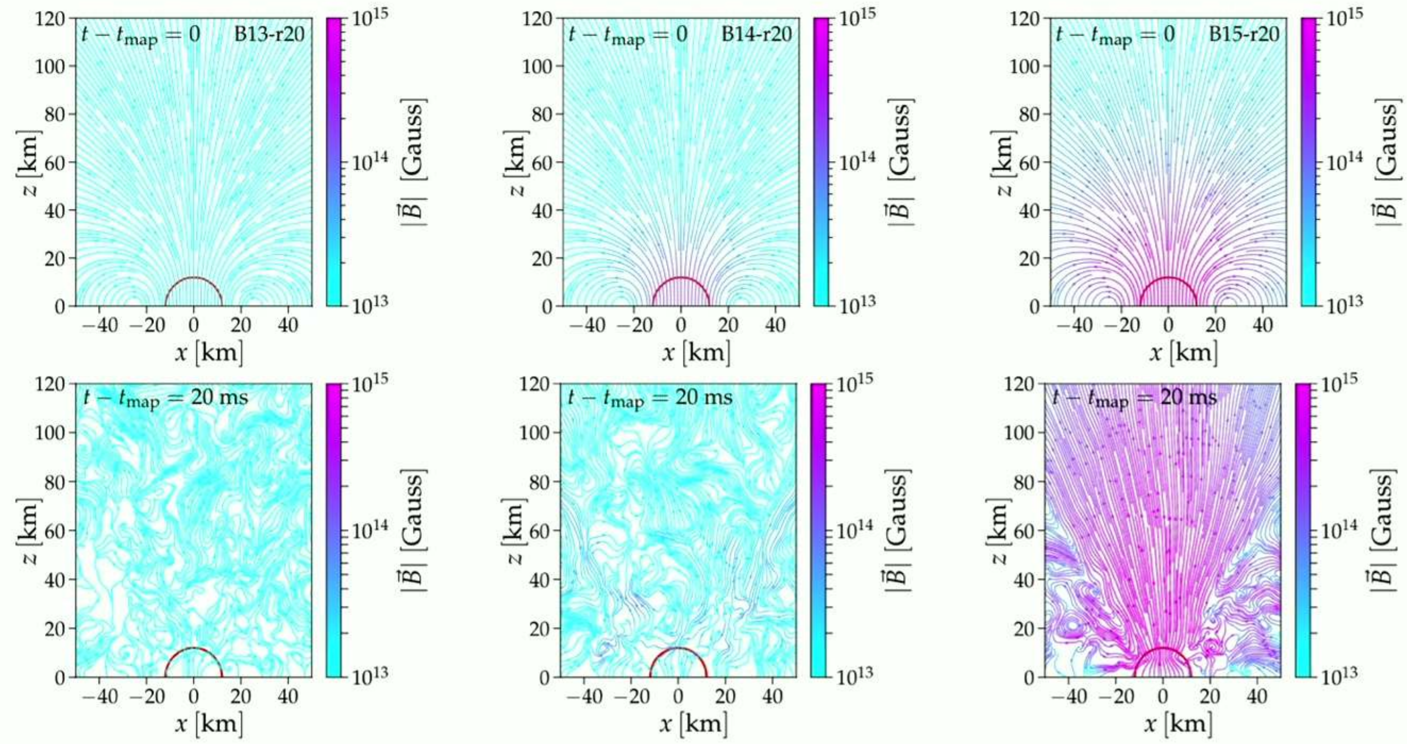
Parametrized Magnetic Field



[de Haas, **PB**, Moesta, Curtis, Schut]

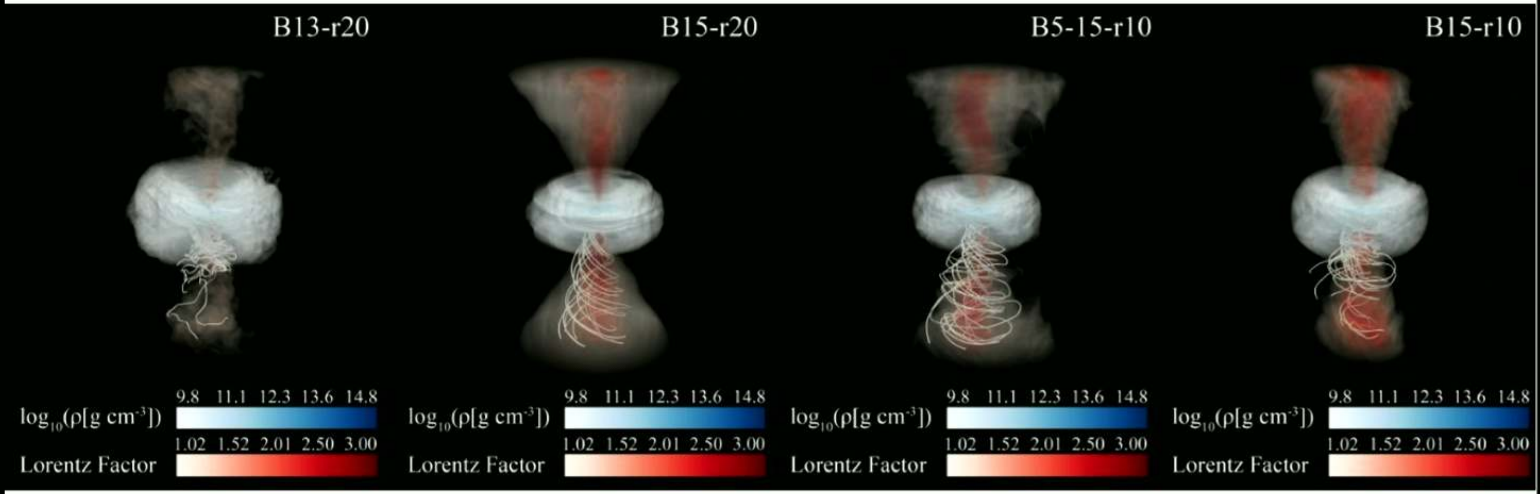
Parametrized Magnetic Field

Varying the strength



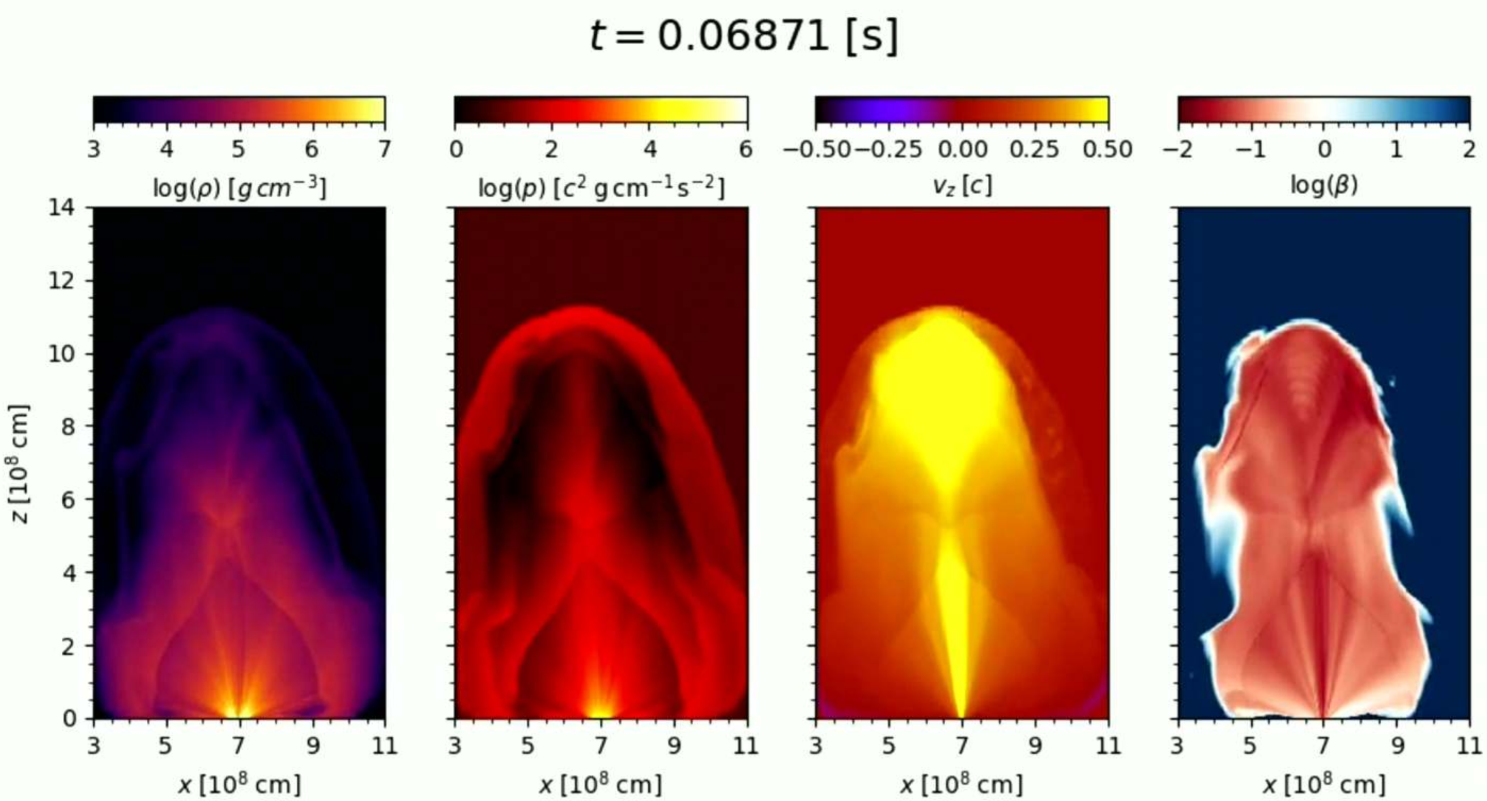
[de Haas, **PB**, Moesta, Curtis, Schut]

Parametrized Magnetic Field



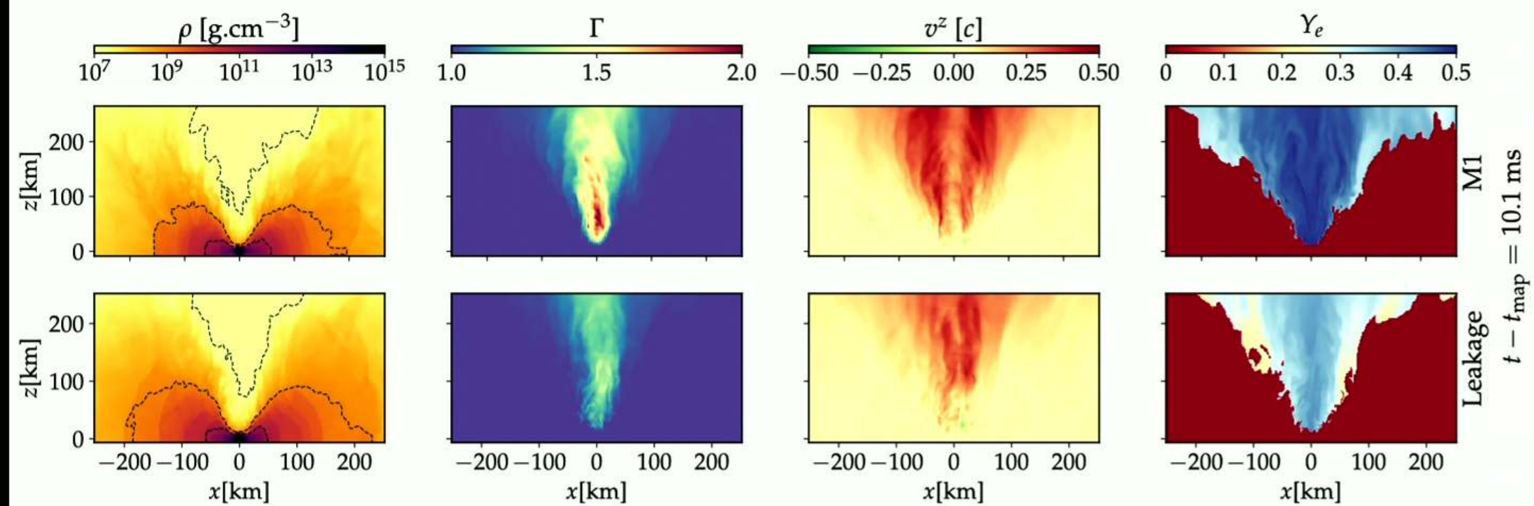
[de Haas, **PB**, Moesta, Curtis, Schut]

Propagation of the Jet



[Soares, **PB,** Lazzati, Moesta]

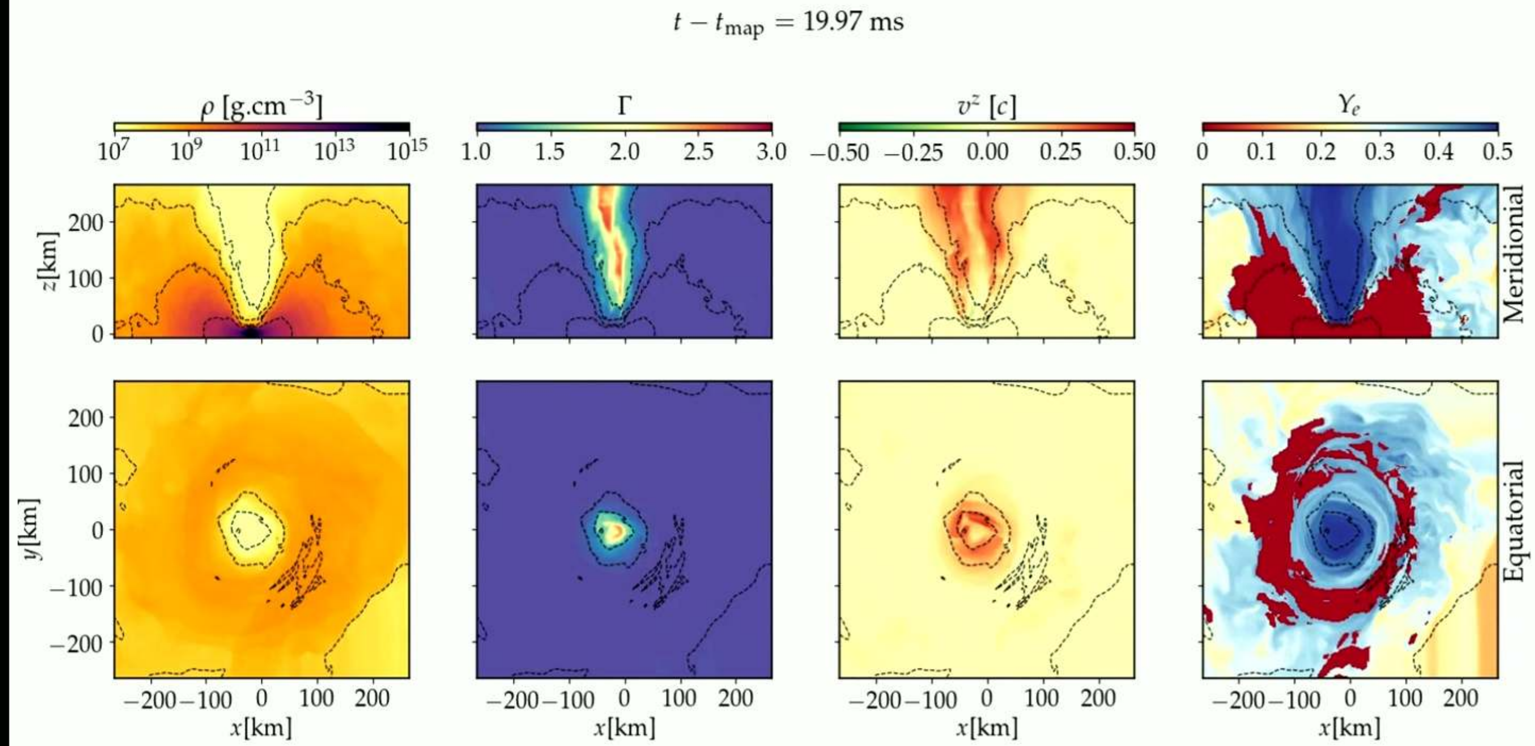
Soft EoS
LS220



[Curtis, **PB**, Moesta, Radice, Bernuzzi, Perego]

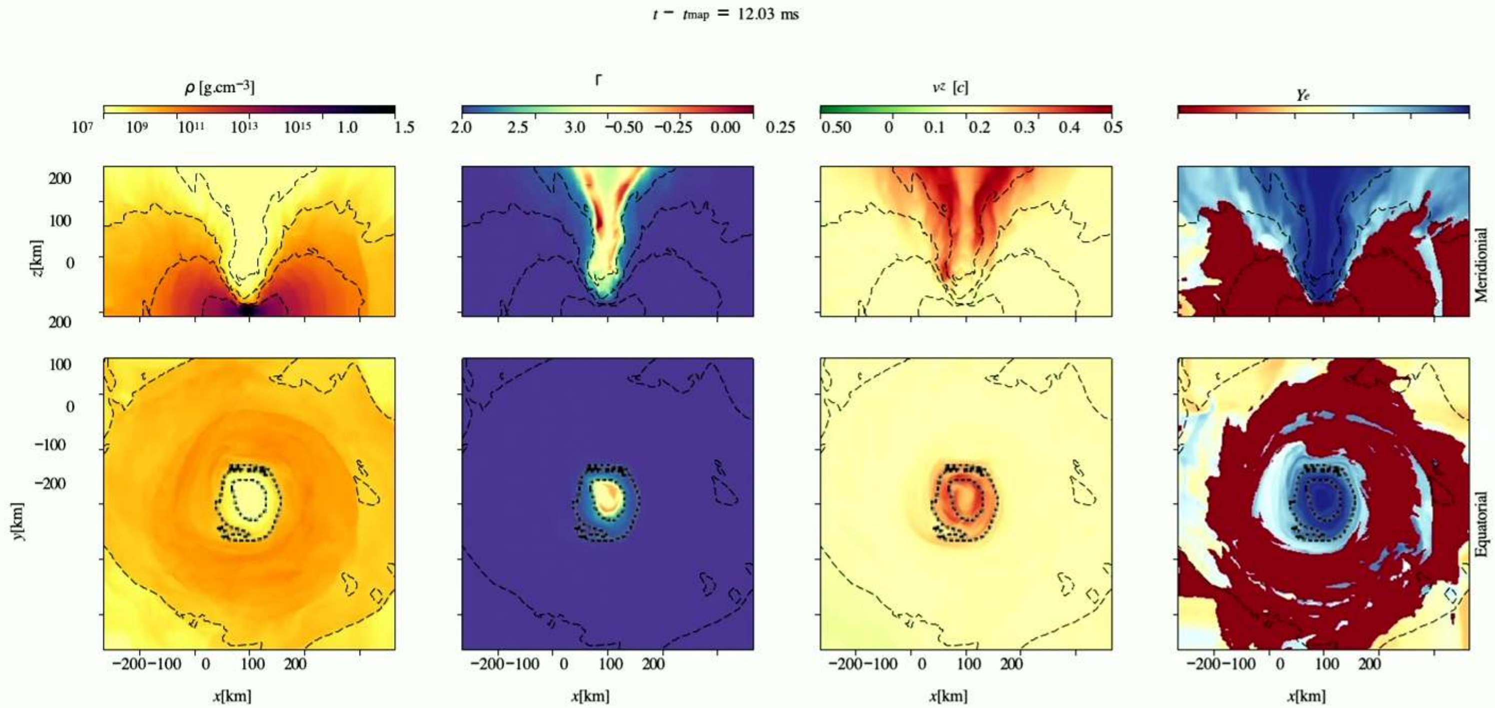
Stiffer EoS

DD2 + M1



Stiffer EoS

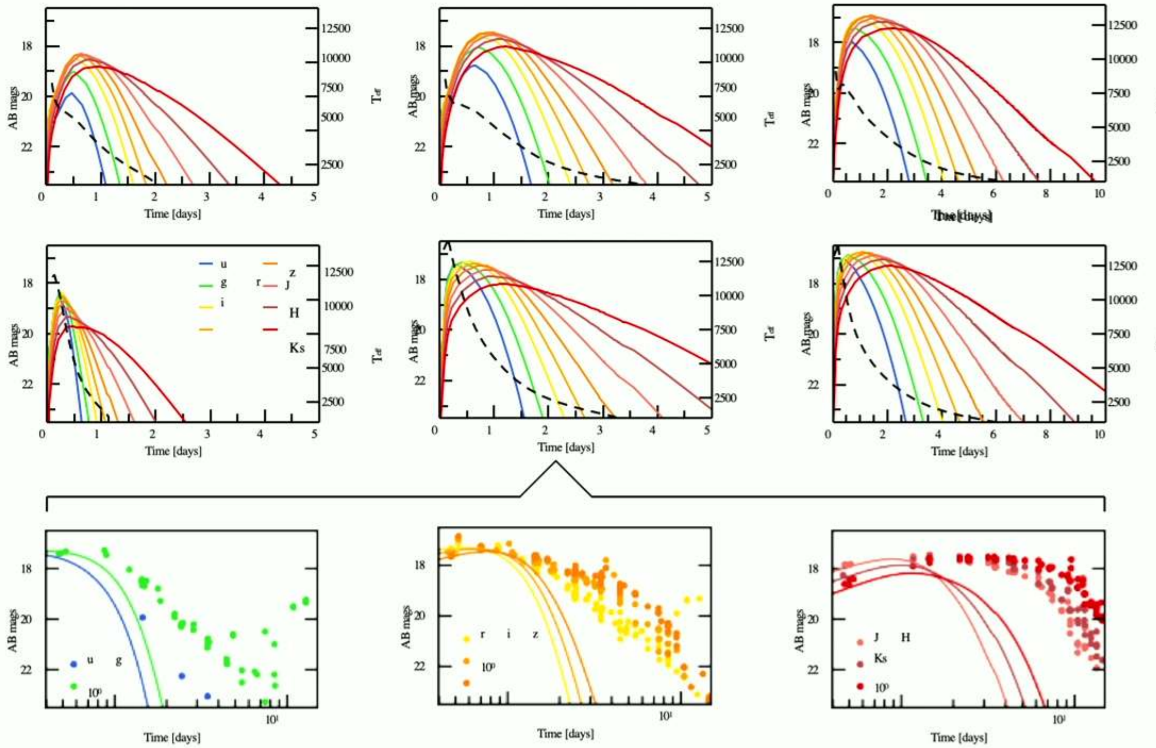
DD2 + M1



[**PB**, In Prep]

Kilonova from Long-lived Remnant Outflows

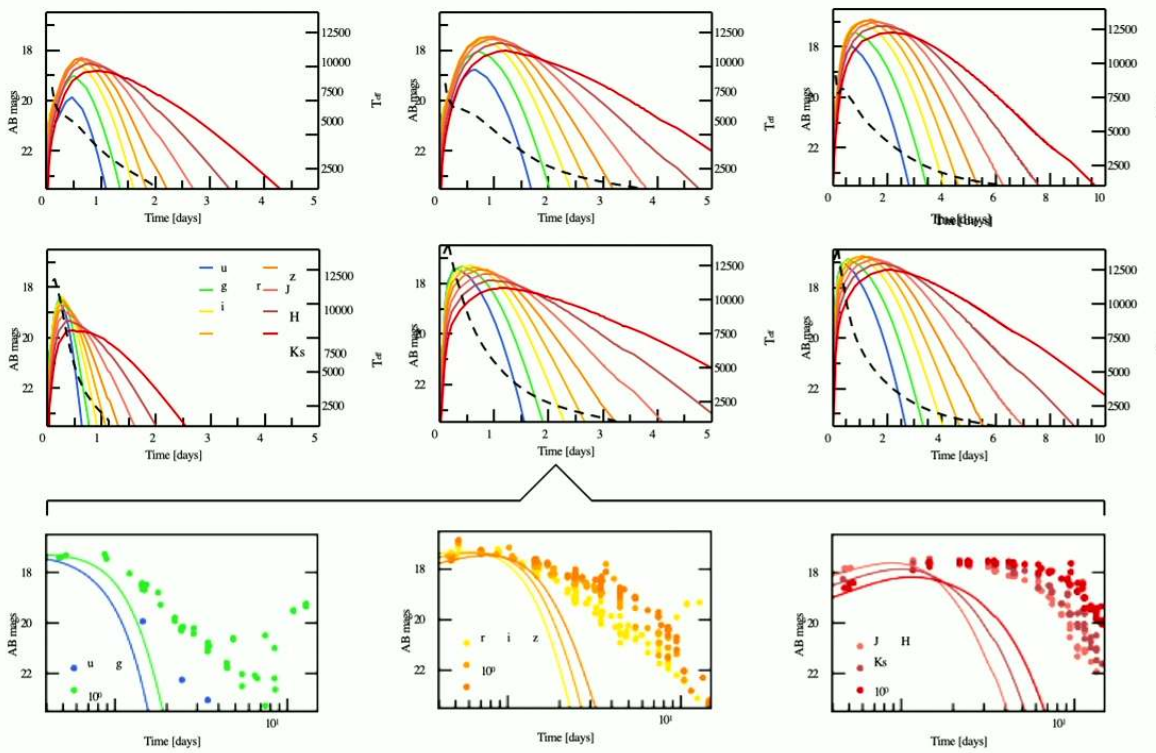
Radiation Hydro Code



[Curtis, **PB**, Moesta, Radice, Bernuzzi, Perego]

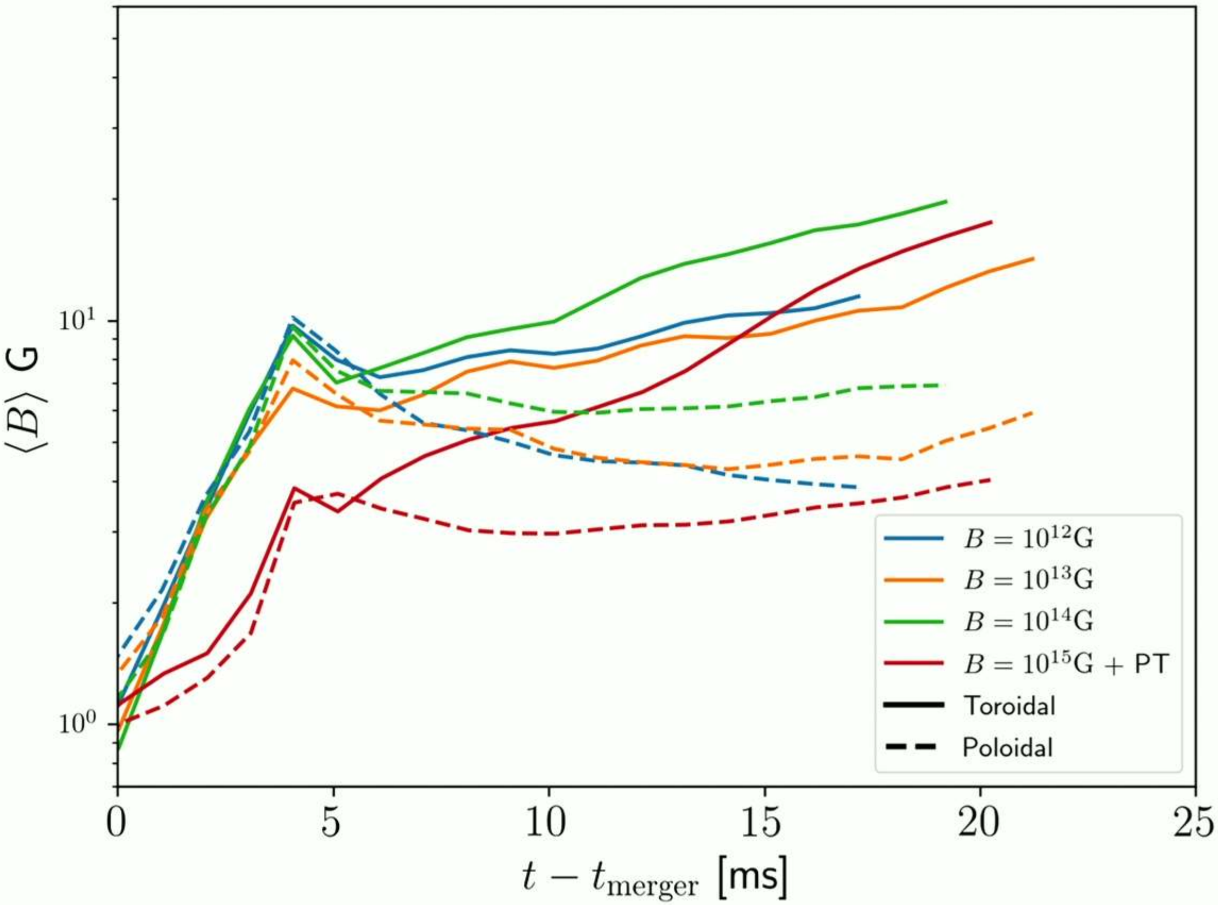
Kilonova from Long-lived Remnant Outflows

Radiation Hydro Code



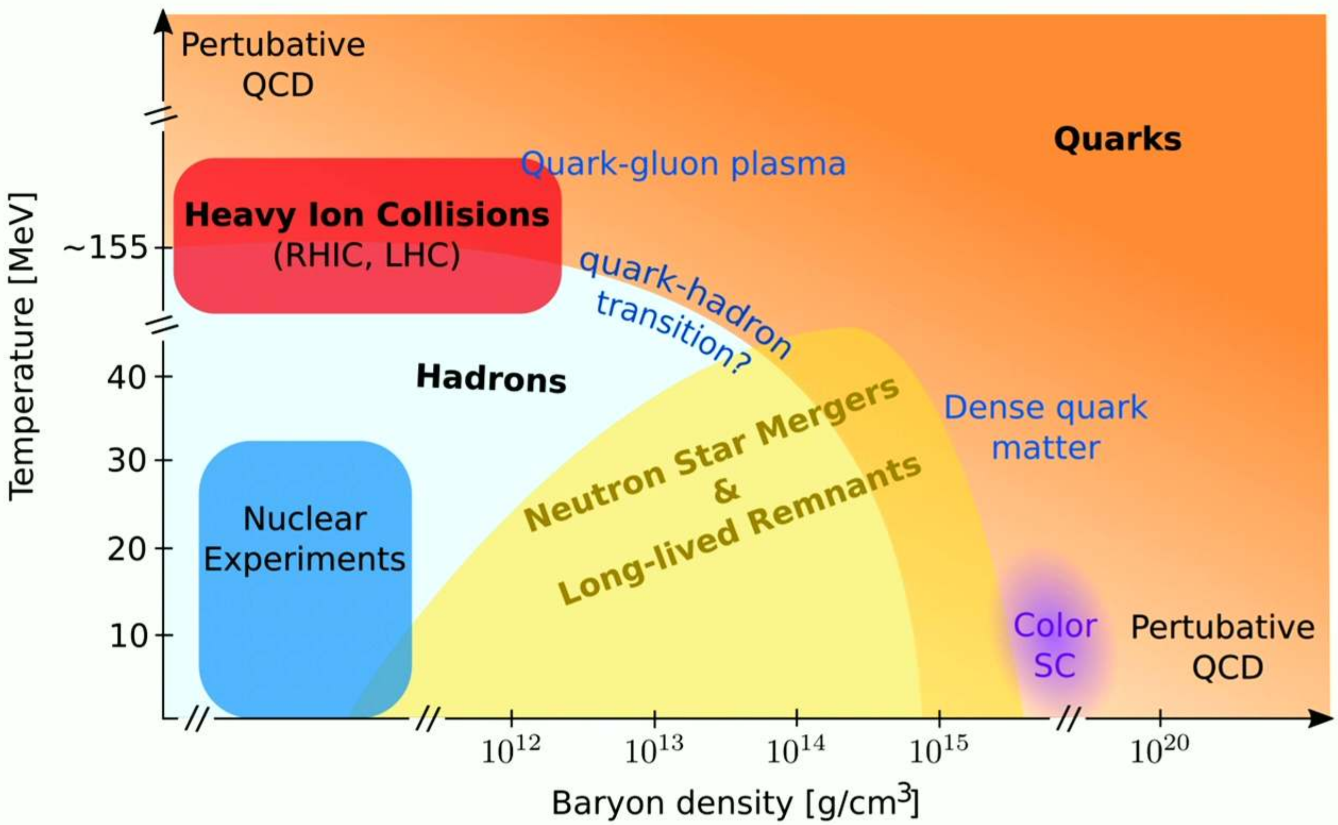
[Curtis, **PB**, Moesta, Radice, Bernuzzi, Perego]

Magnetic field growth?



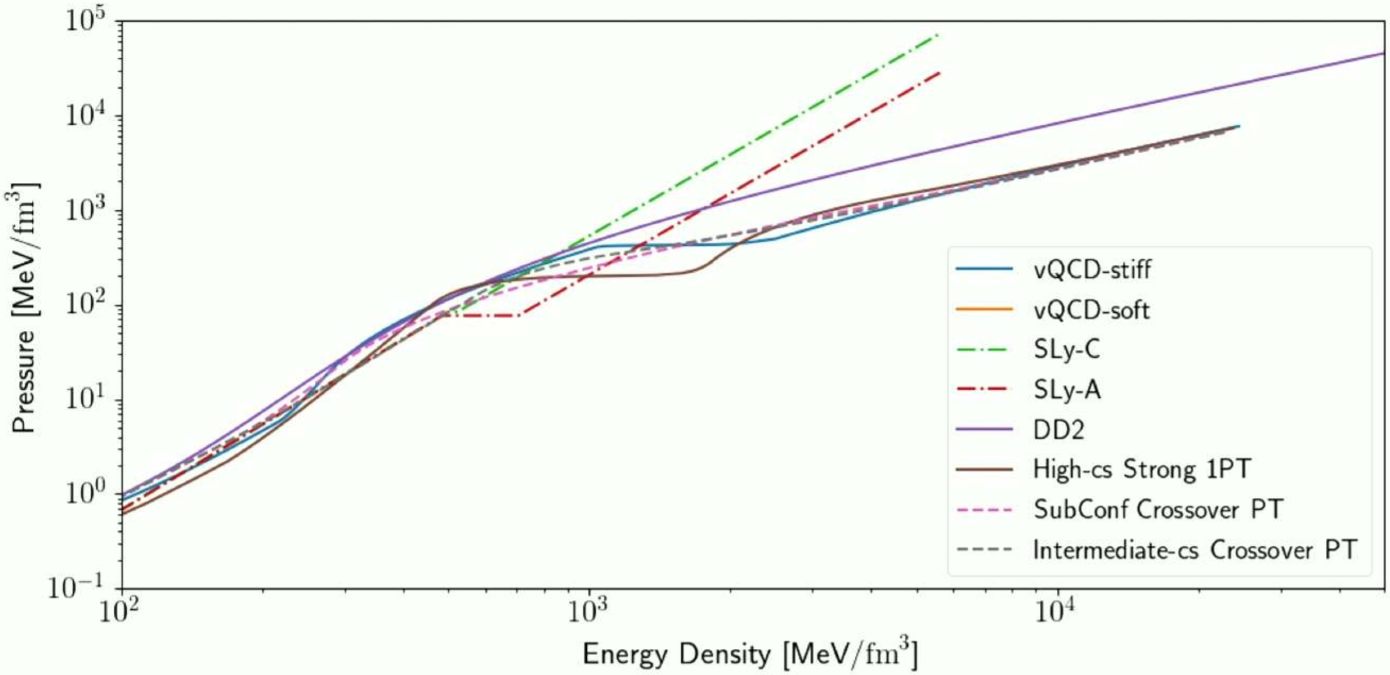
[**PB**, In Prep]

Probing the QCD Phase diagram



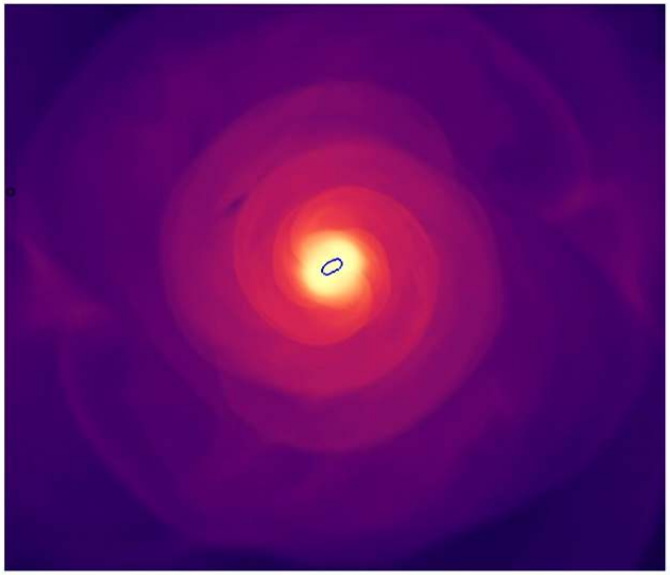
Effects of Phase Transition

Prelim

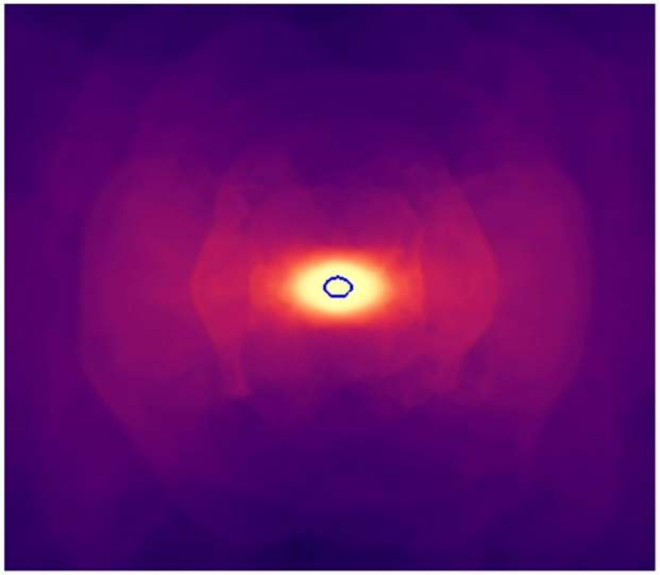


1PT leads to dense cores

Equatorial

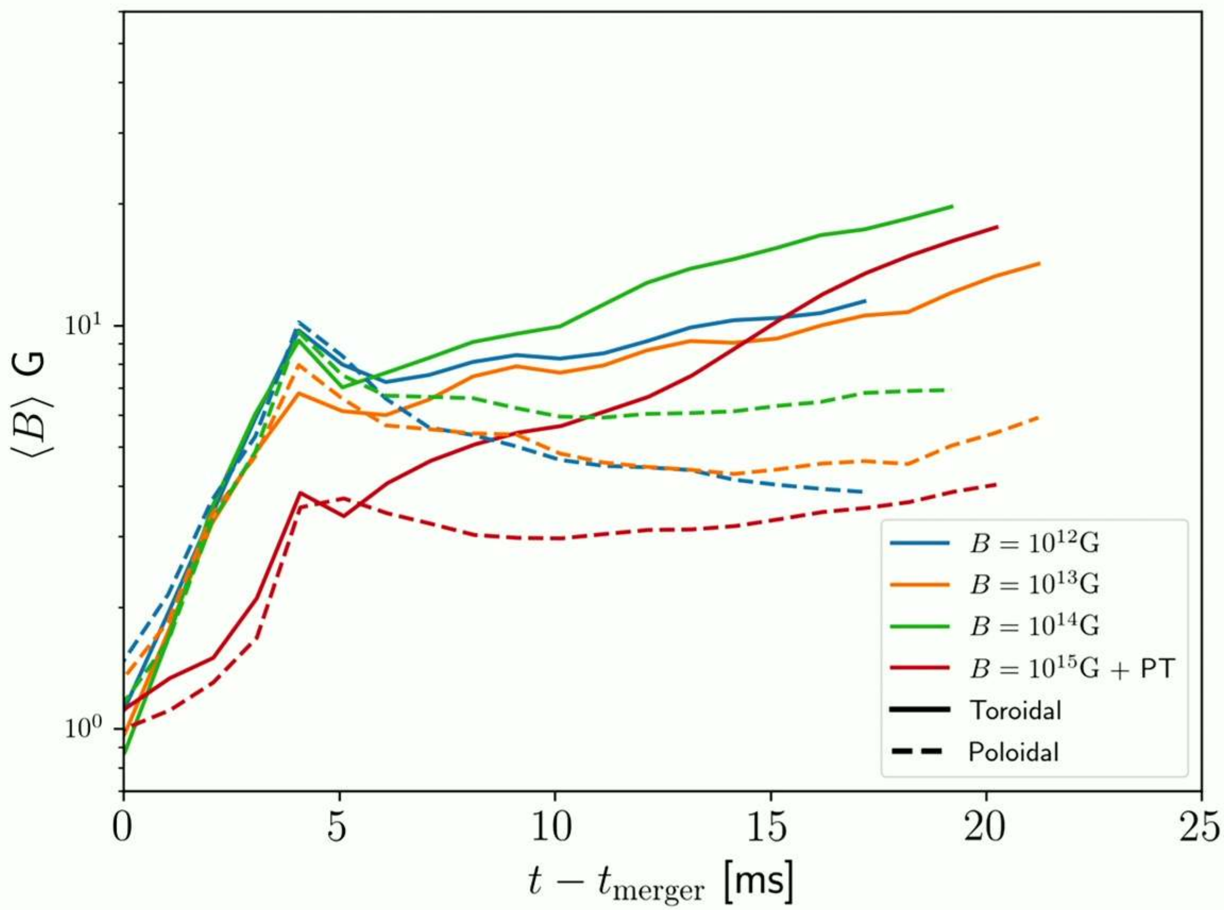


Meridional



[In Prep]

Magnetic field growth?

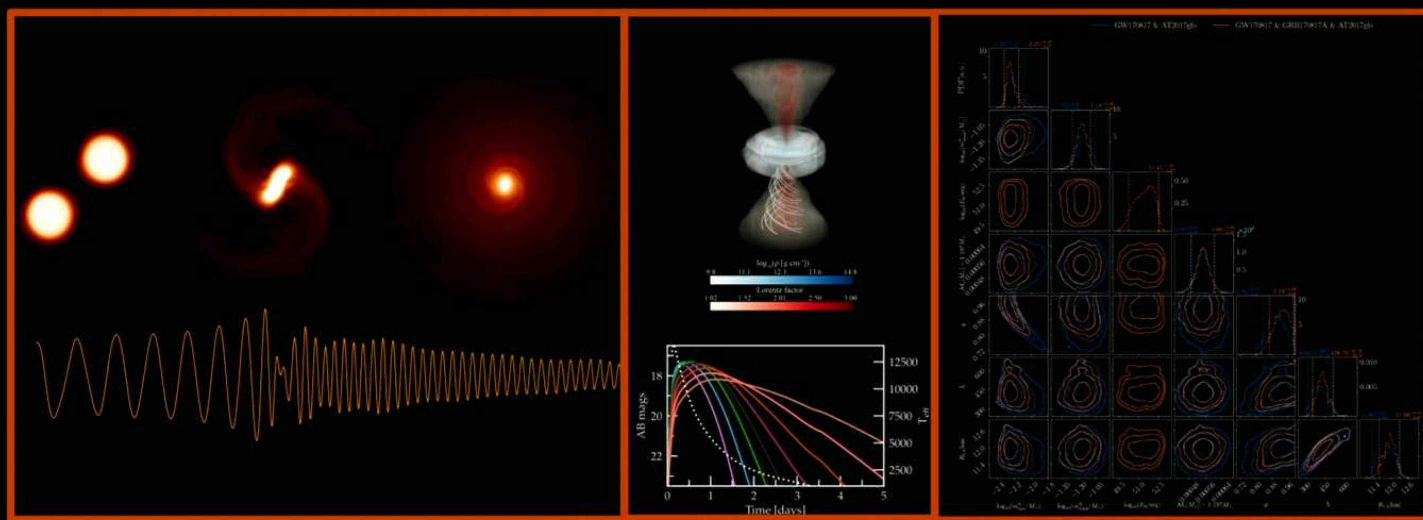


[**PB**, In Prep]

Conclusions

- **Magnetized and long-lived NS remnants**:
  - have outflows that contribute the the kilonova, in particular the "blue" kilonova
  - can be central engines for sGRB
- **We are getting ready for future multi-messenger detections**
  - Exploring the parameter space of the long-lived remnants
  - Parametrizing their EM counterparts provided the outflow rates
- **Towards joint GW+EM inference**
  - GW + EM data catalog
  - NMMA [Dietrich+]
  - GEMMA [Raaijmakers+]
    - better constraints on tidal deformability → EoS constraints

Future directions



Merger Evolution

Multimessenger Signatures

Parameter Inference

Conclusions

- **Magnetized and long-lived NS remnants**:
  - have outflows that contribute the the kilonova, in particular the "blue" kilonova
  - can be central engines for sGRB
- **We are getting ready for future multi-messenger detections**
  - Exploring the parameter space of the long-lived remnants
  - Parametrizing their EM counterparts provided the outflow rates
- **Towards joint GW+EM inference**
  - GW + EM data catalog
  - NMMA [Dietrich+]
  - GEMMA [Raaijmakers+]
    - better constraints on tidal deformability → EoS constraints


Congratulations PI!