# Magnetic field effects on gravitational waves from binary neutron stars

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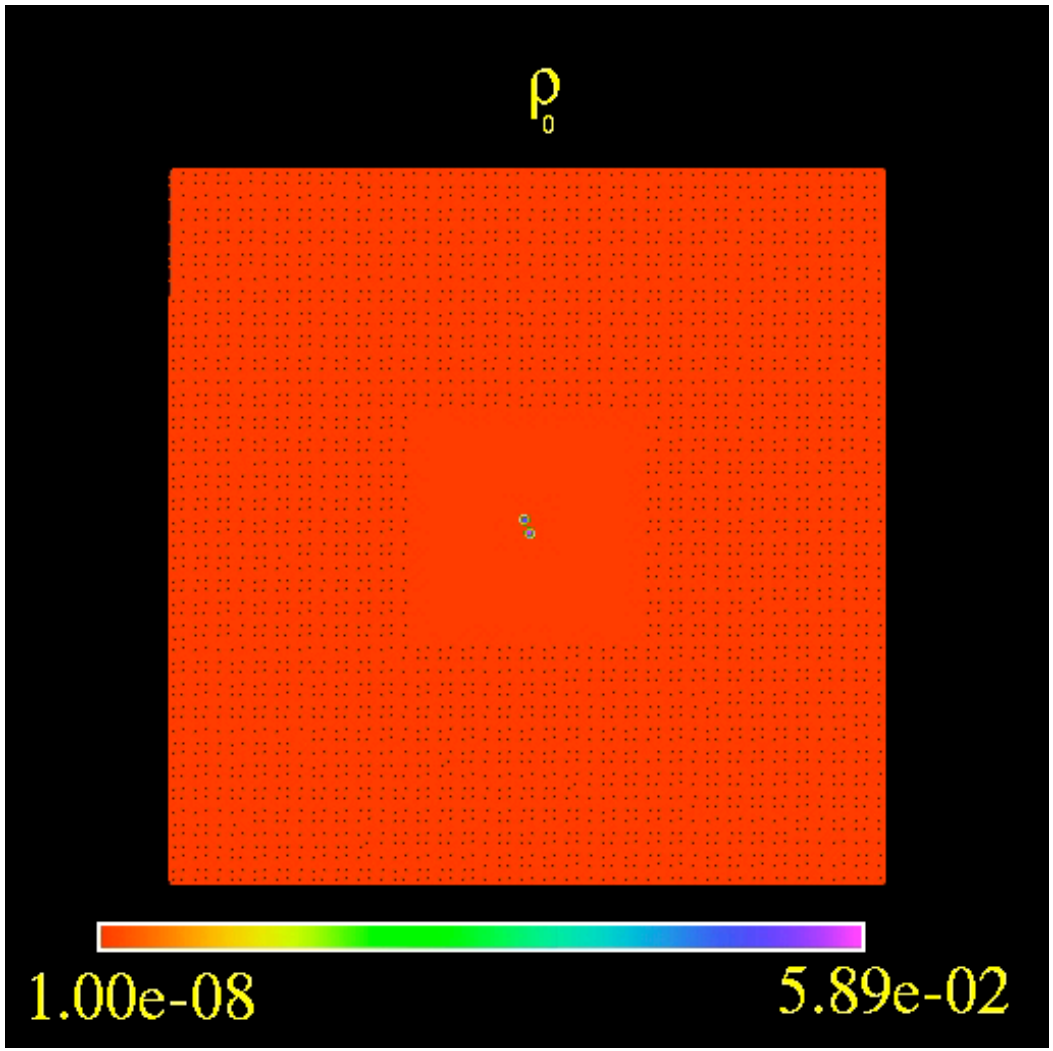
# Overview

- Magnetic fields are present in most astrophysical systems
- They can strongly influence the dynamics of stars
- They play important roles in AGN's, pulsars, GRB's
- We want to make connections to GRB's

# AMR




Berger-Oliger style AMR

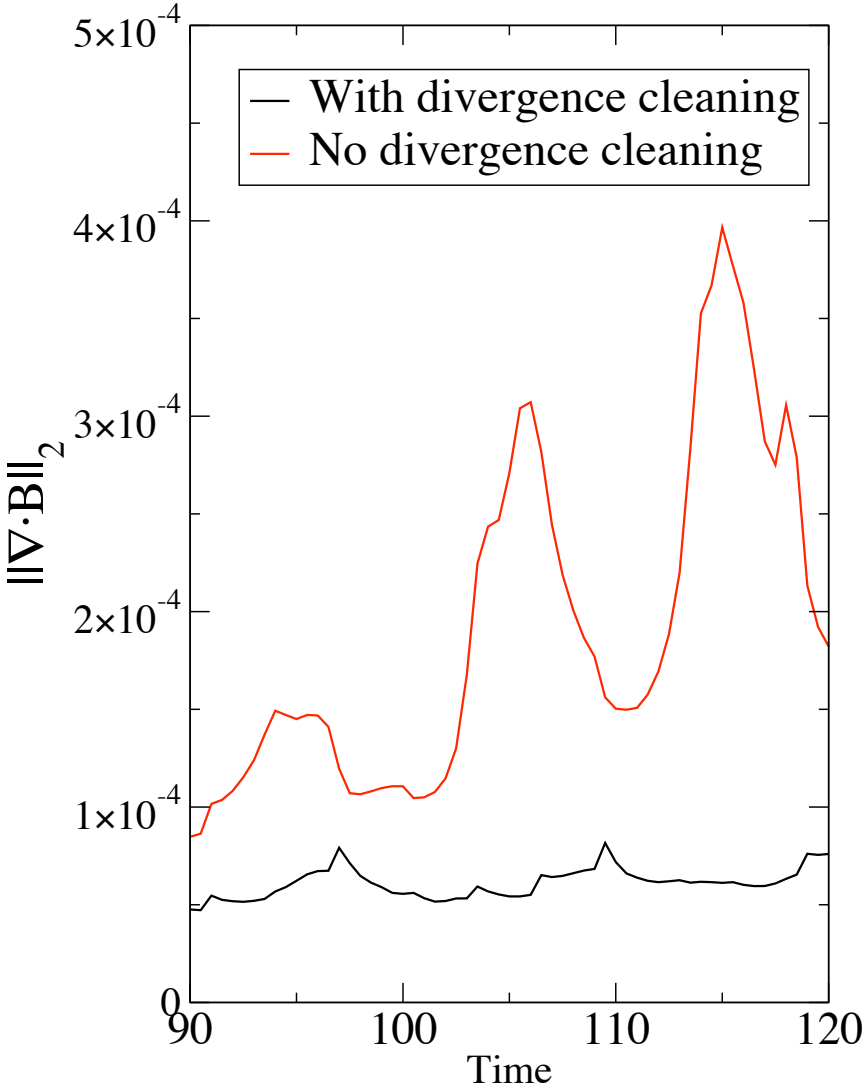
Vertex centered AMR

Shadow hierarchy for refinement

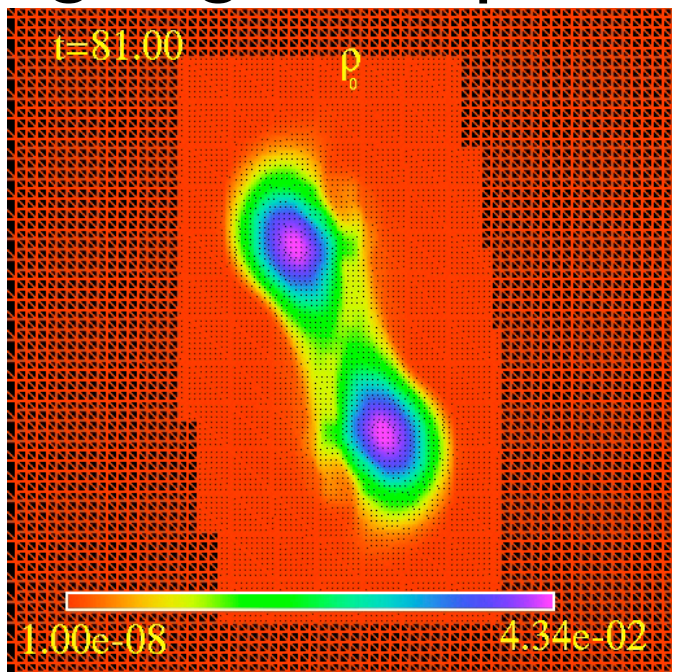
HAD toolkit: http://had.liu.edu

Tapered AMR boundaries

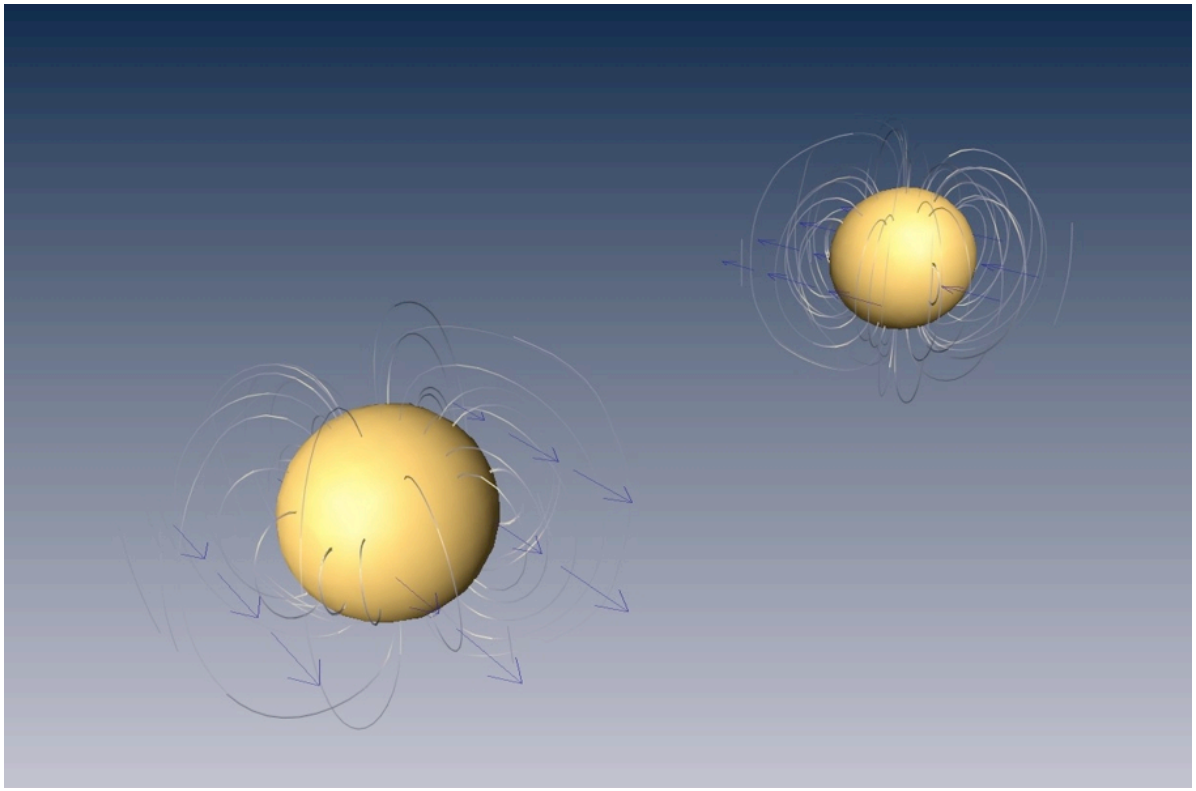
# Hyperbolic Divergence Cleaning




- Control the solenoidal constraint: $\nabla \cdot B = 0$
- Introduce a generalized Lagrange multiplier



# Simulation Description



$M = 0.89\ M_\odot$

$r = 16.26\text{km}$

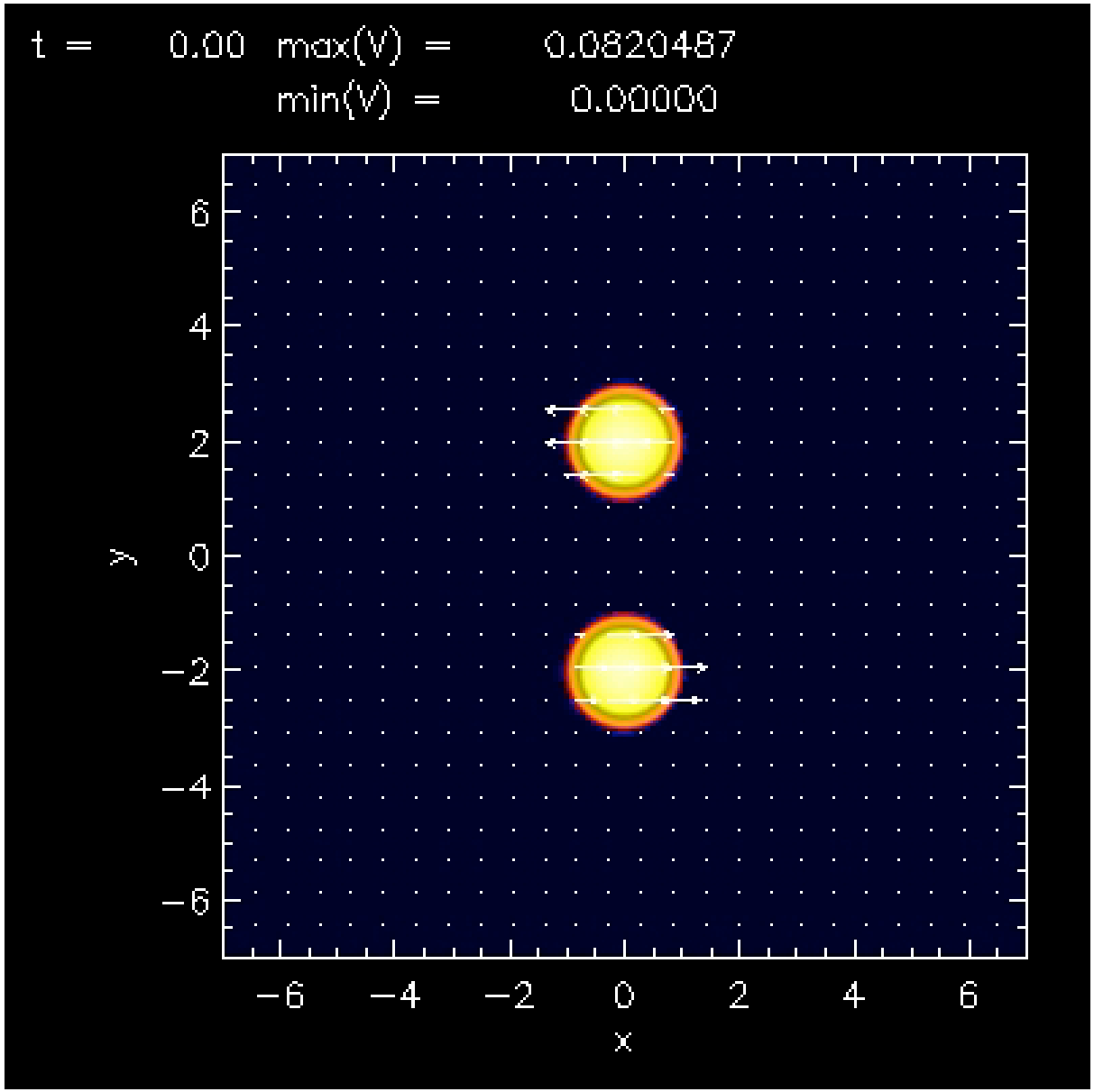
$\rho_c = 3.24 \times 10^{14}\ \text{g/cm}^3$

$\Gamma = 2$

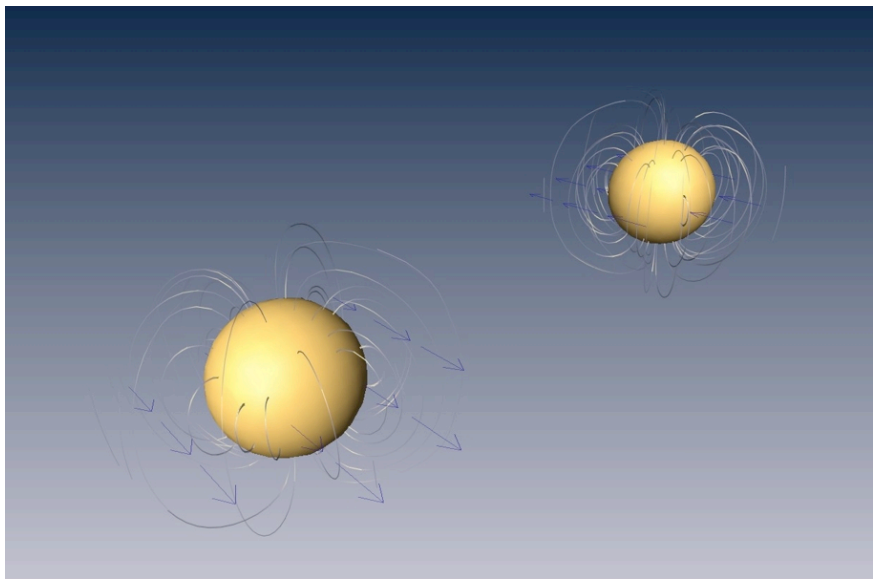
$\max(|B|) \sim 9.6 \times 10^{15}\text{G}$

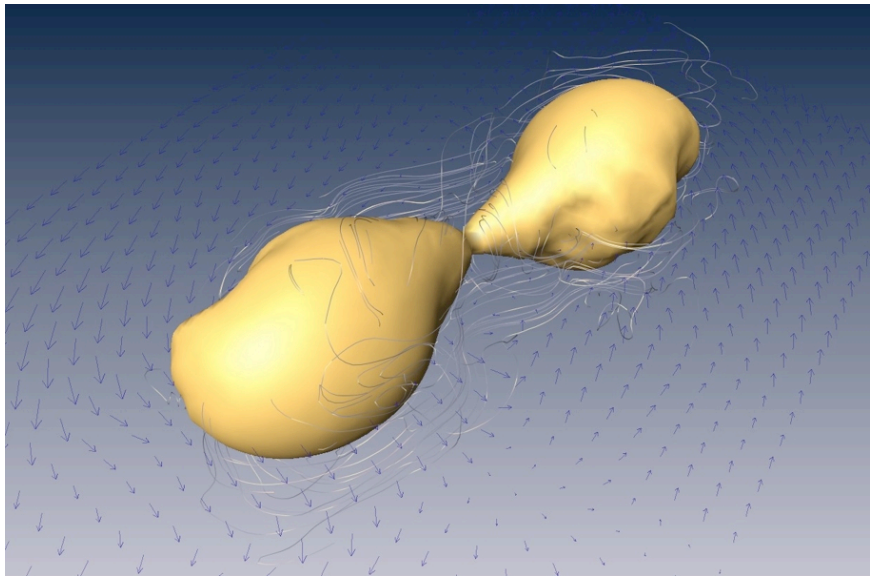
- Initial separation: 60 km
- Domain: $[-1540\,\text{km}, 1540\,\text{km}]$
- 7 levels of refinement, highest resolution $\Delta = 0.46$ km.
- $\Psi_4$ extraction radii: $r = \{440, 590, 740\}$ km

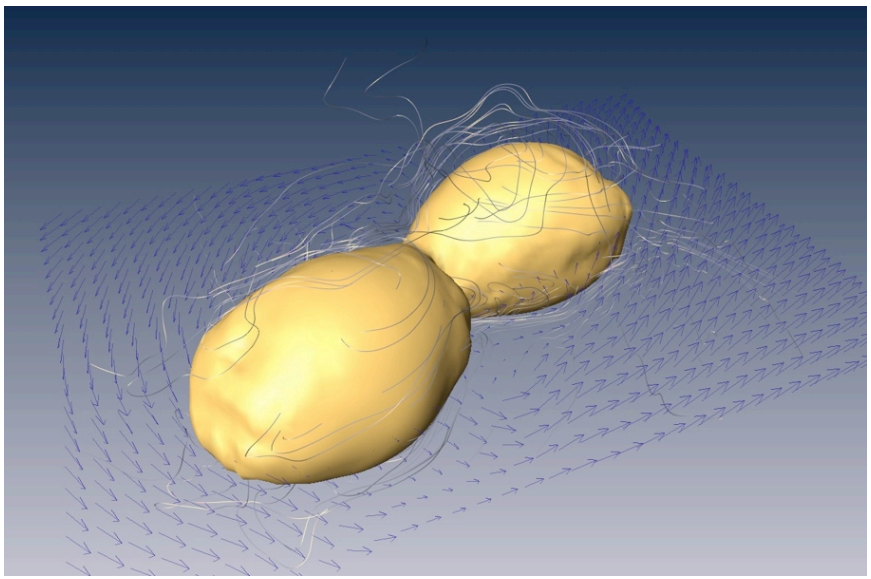
# MHD Results

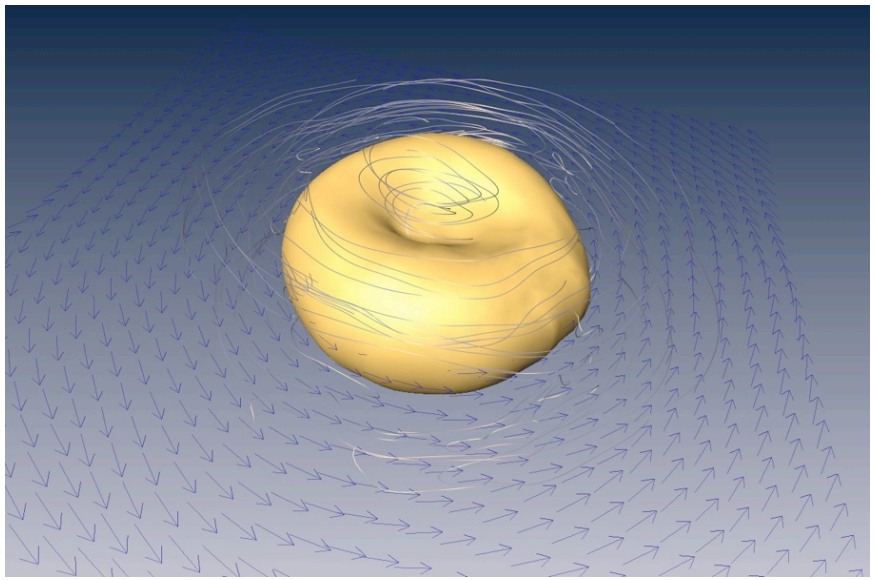


# MHD Results

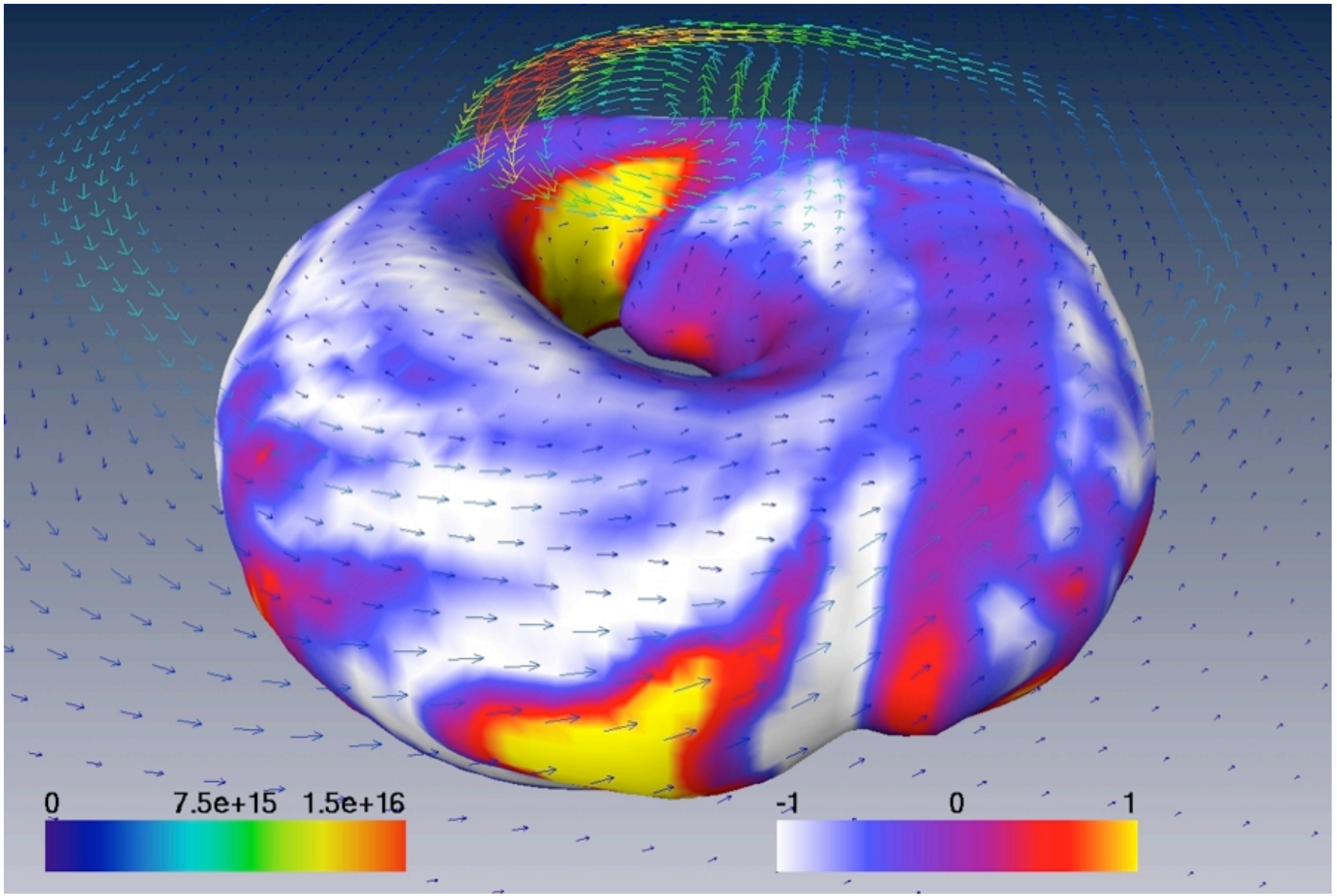




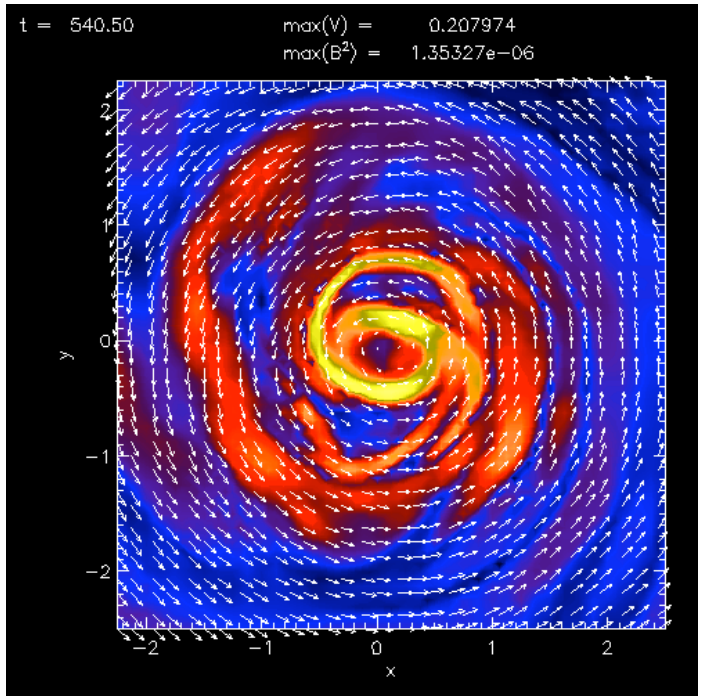


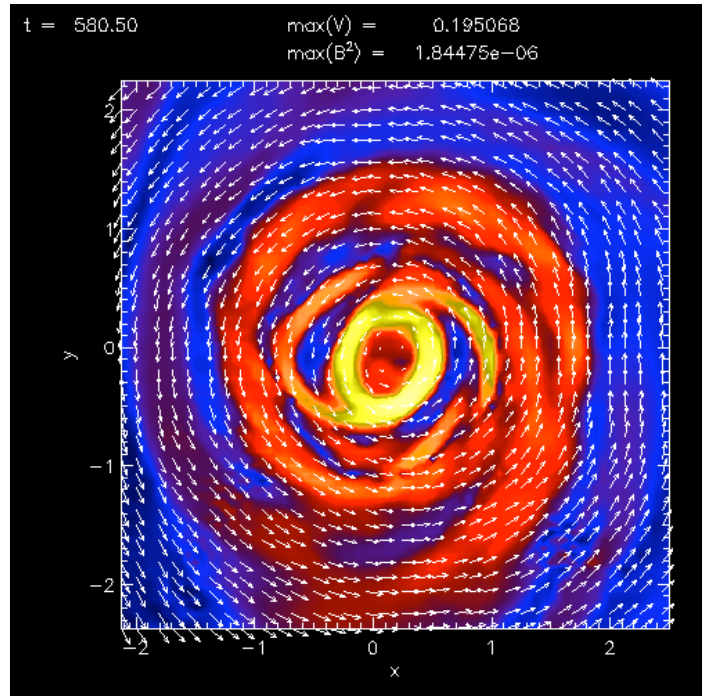


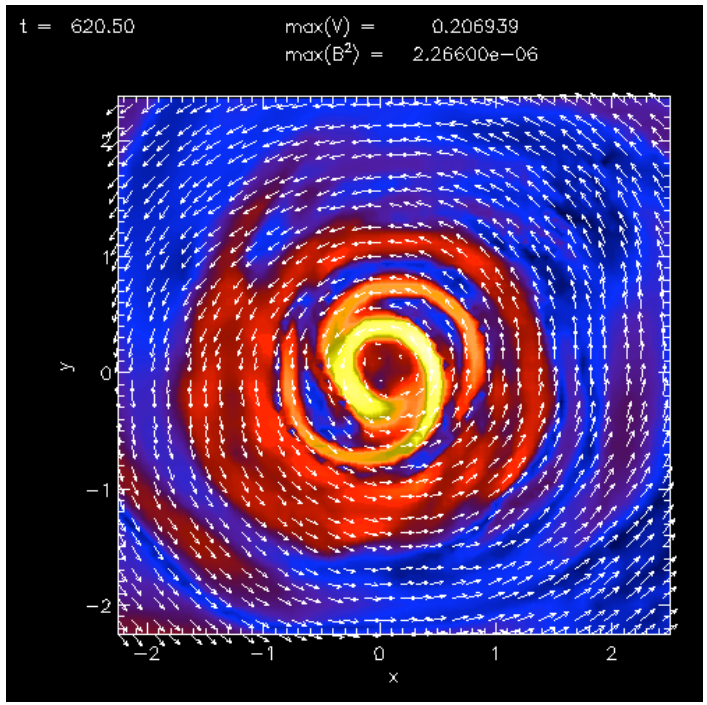
# MHD Results

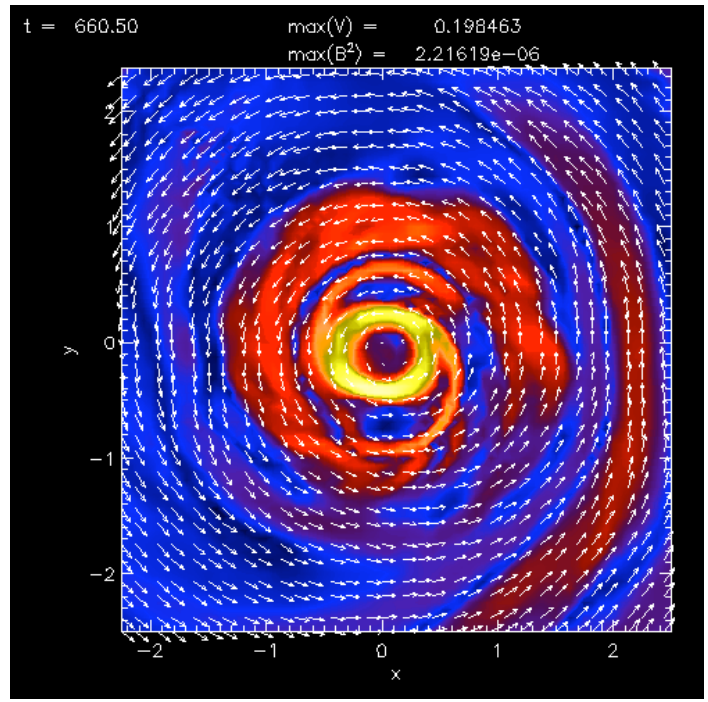


# MHD Results

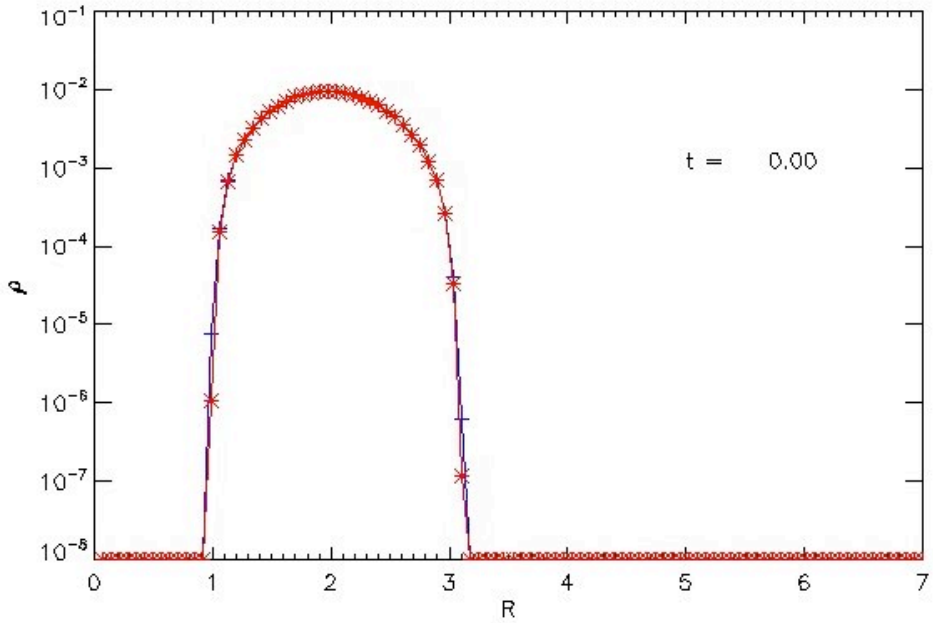

t = 540.50
max(V) = 0.207974
max(B²) = 1.35327e-06
y
x

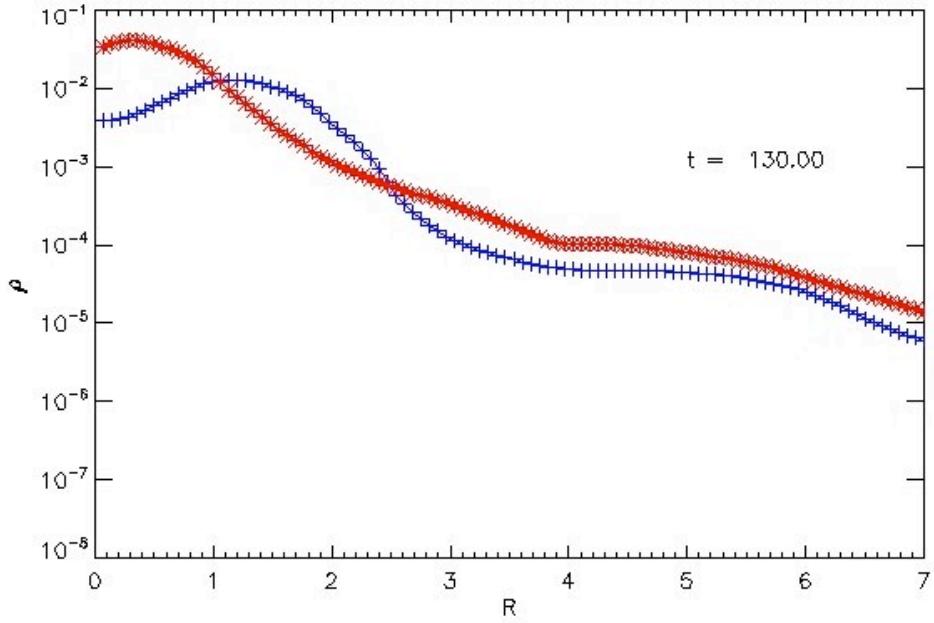

t = 580.50
max(V) = 0.195068
max(B²) = 1.84475e-06
y
x

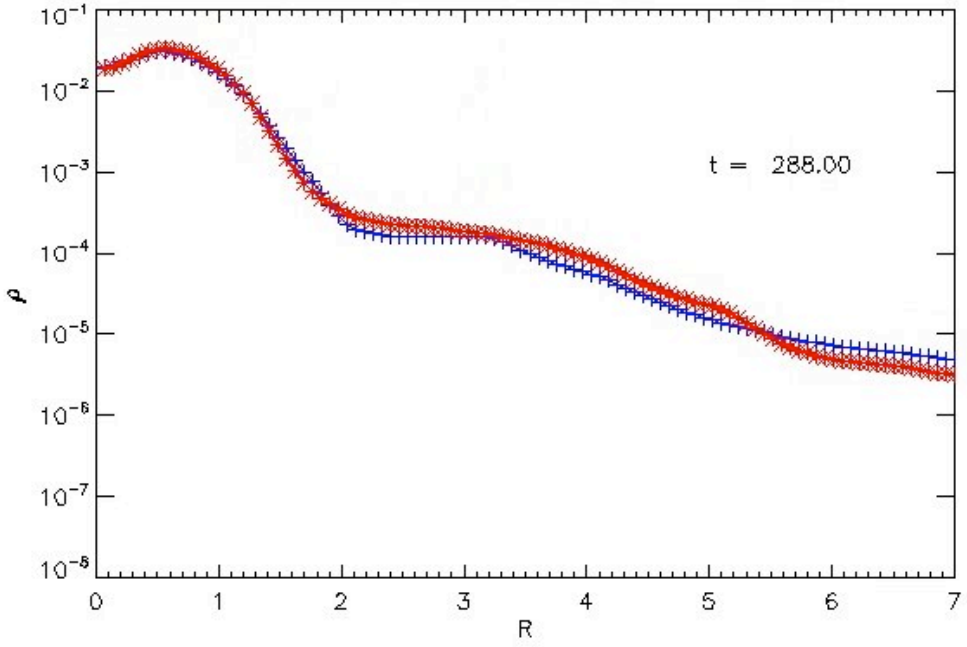

t = 620.50
max(V) = 0.206939
max(B²) = 2.26600e-06
y
x

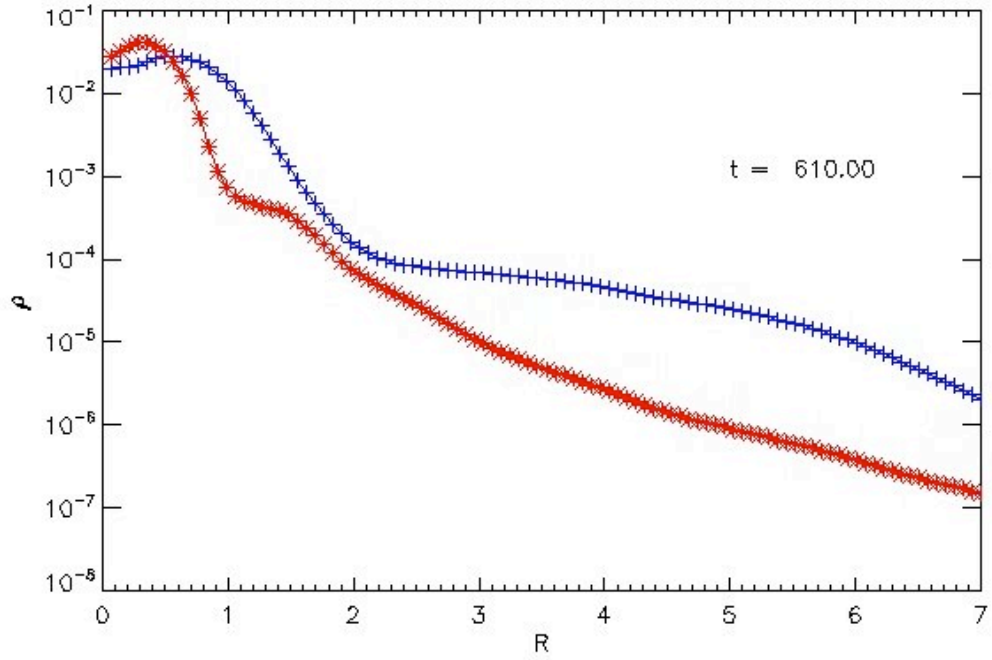

t = 660.50
max(V) = 0.198463
max(B²) = 2.21619e-06
y
x

# MHD vs HD

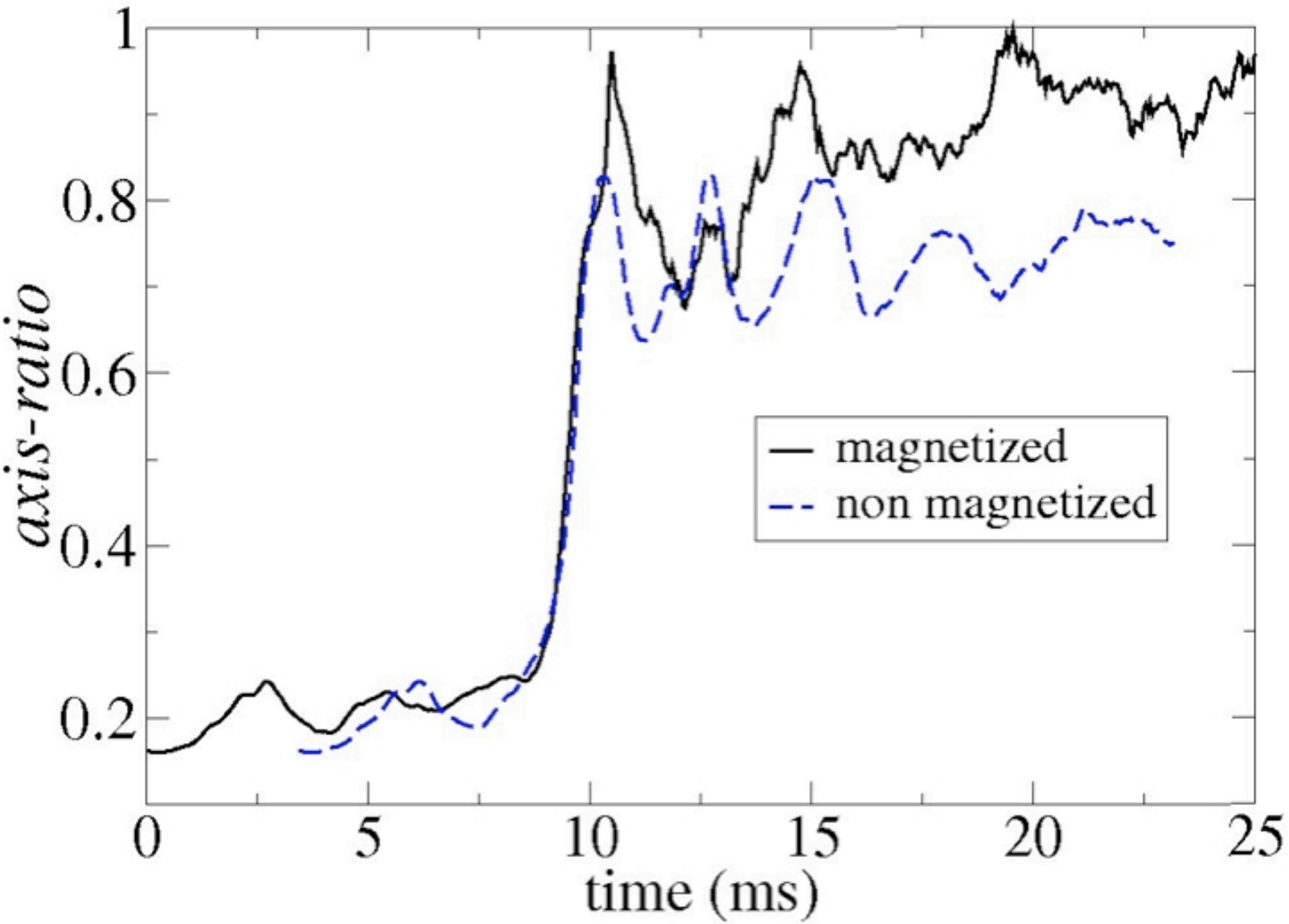


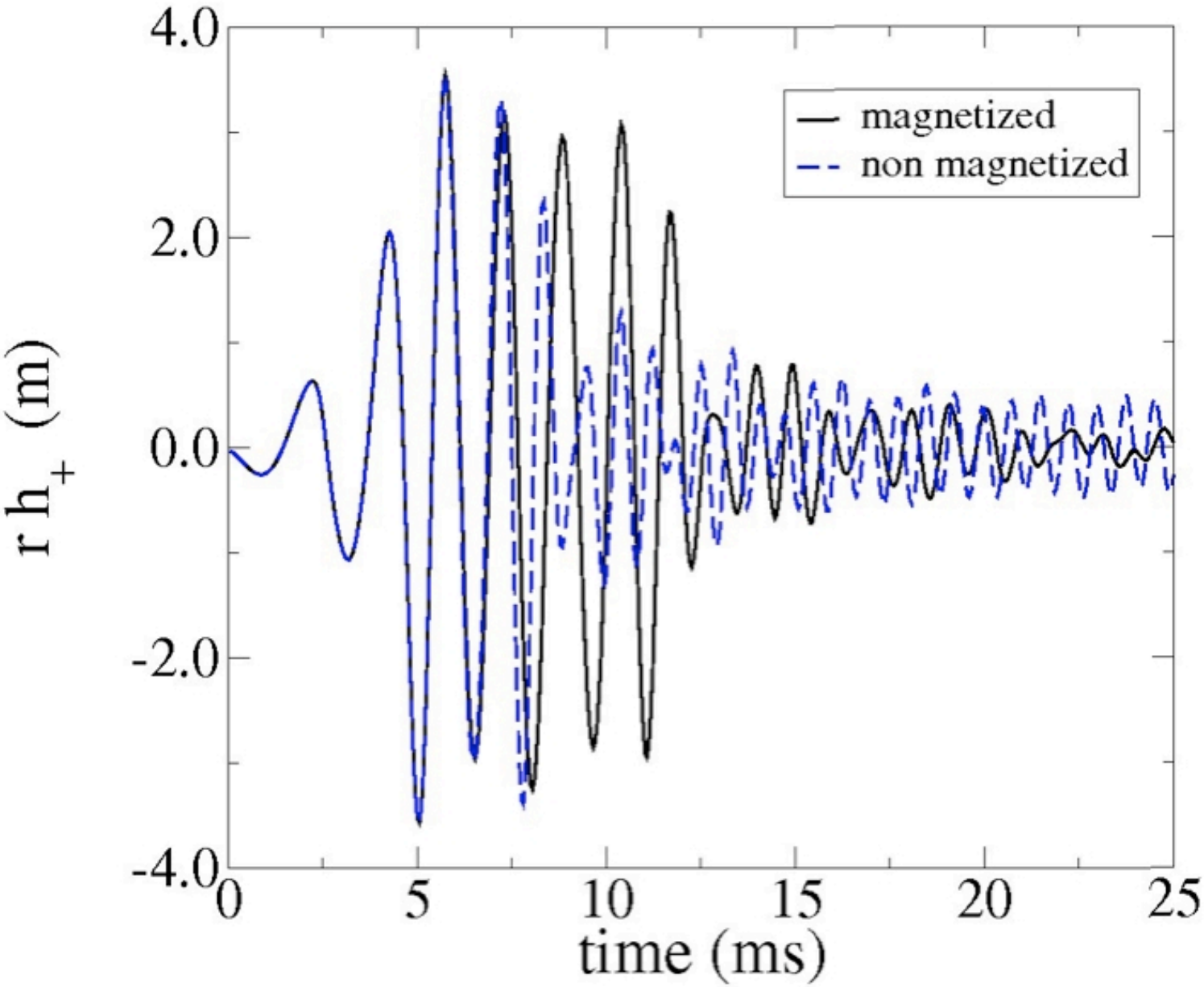



# MHD vs HD


axis-ratio
1
0.8
0.6
0.4
0.2
0
5
10
15
20
25
time (ms)
magnetized
non magnetized

# MHD vs HD


4.0
2.0
0.0
-2.0
-4.0
0
5
10
15
20
25
time (ms)
r h+ (m)
magnetized
non magnetized

# Conclusions

- Magnetic fields impact rotation profile, merger timescale, and waveforms
- Future work: explore realistic equations of state
- Supported by NSF grants PHY-0653369, PHY-0653375, AST-0407070, AST-0708551, PHY-0326378, PHY-0502218, PHY-0325224.