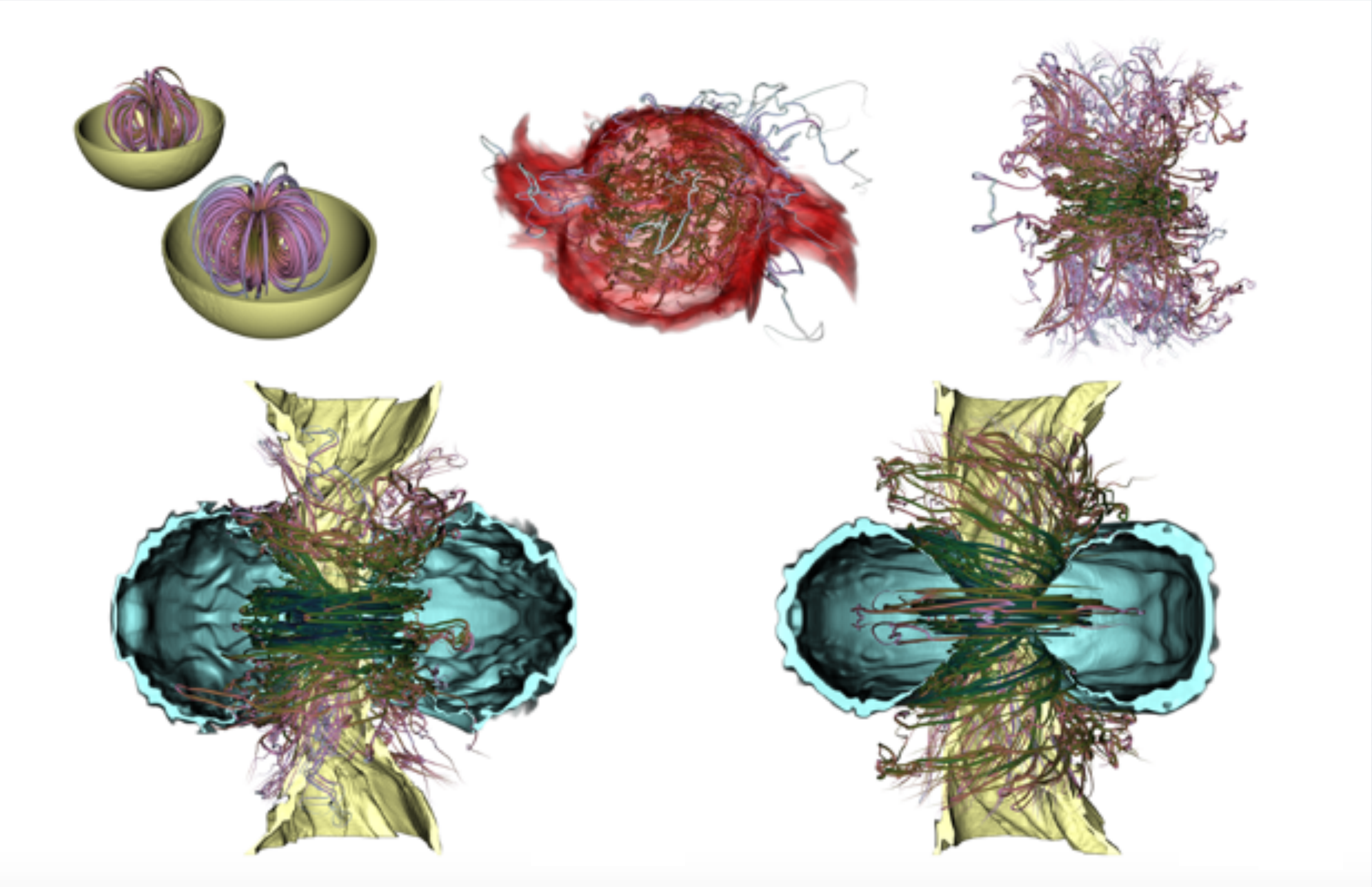
General Relativistic Simulations of Binary Neutron Star Mergers with WhiskyMHD



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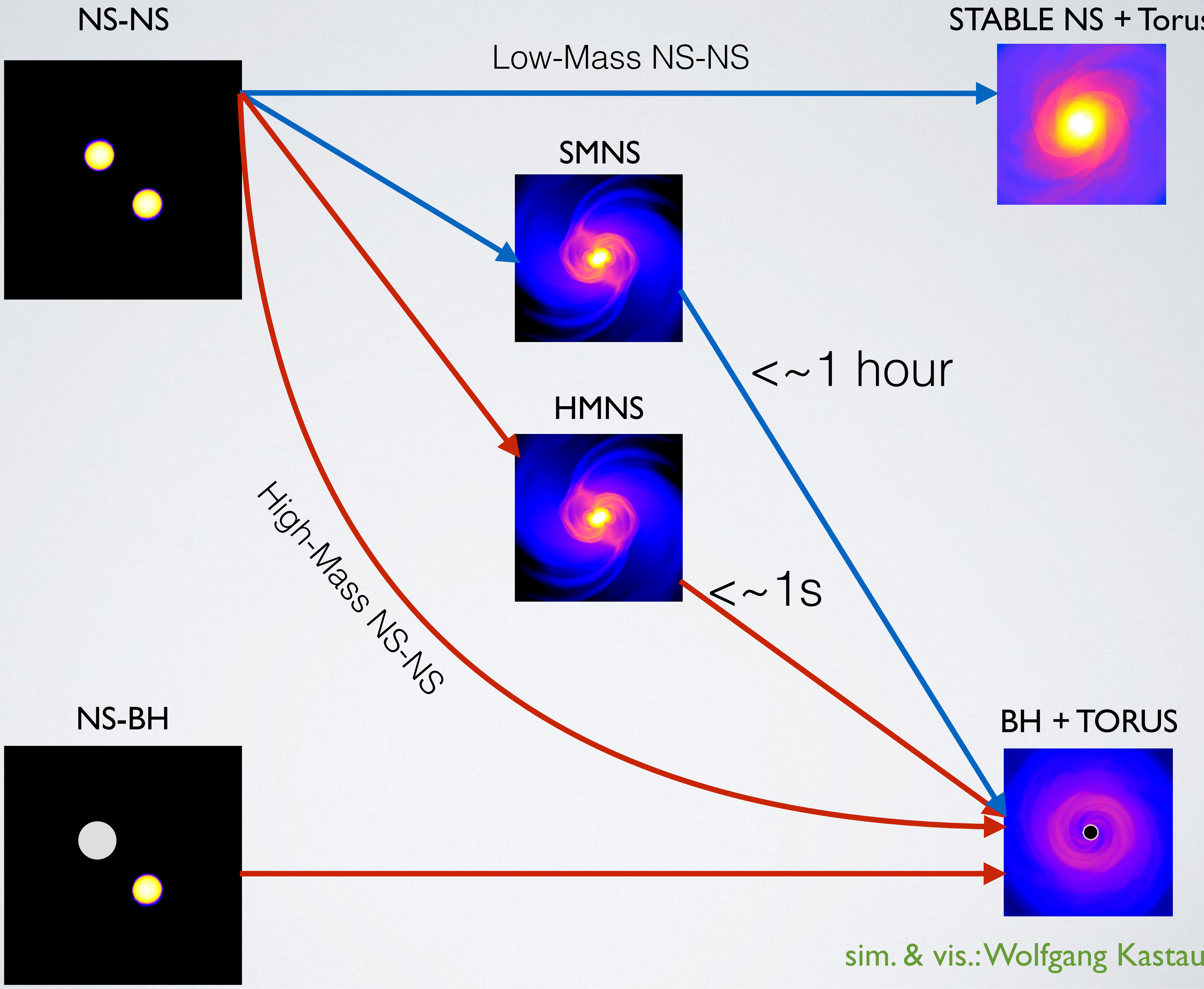
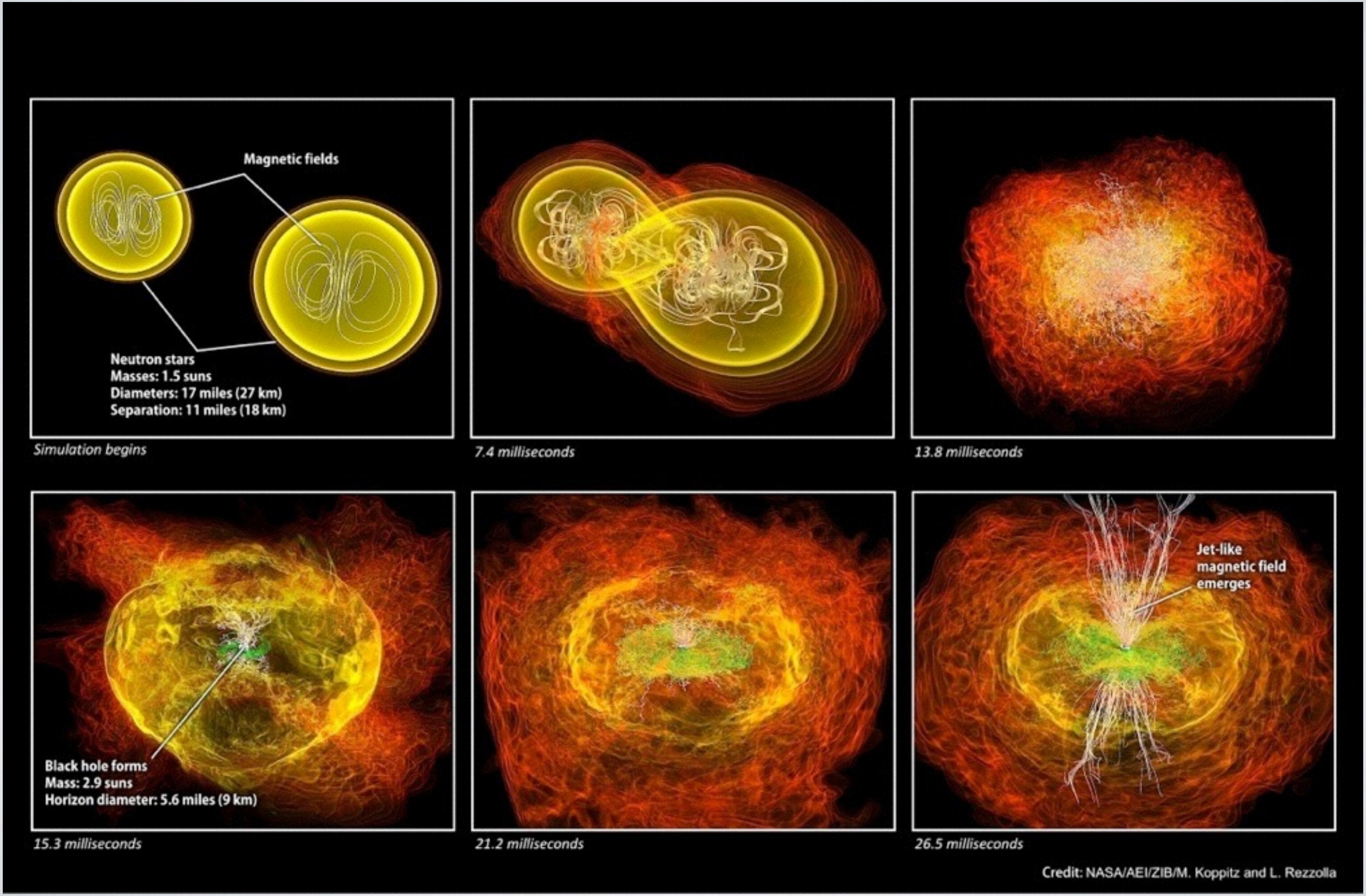
BNS MERGER OUTCOME



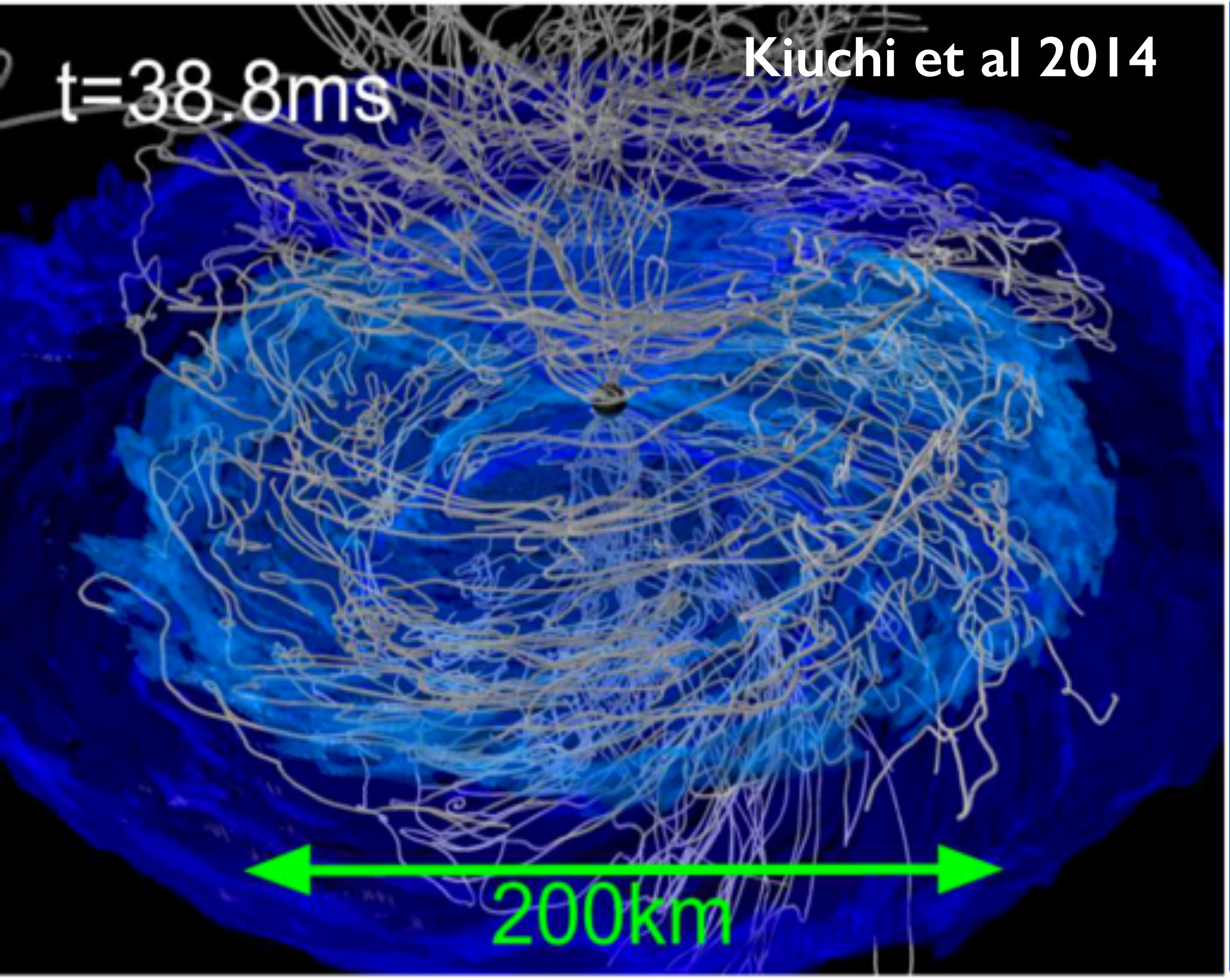
sim. & vis.: Wolfgang Kastaun

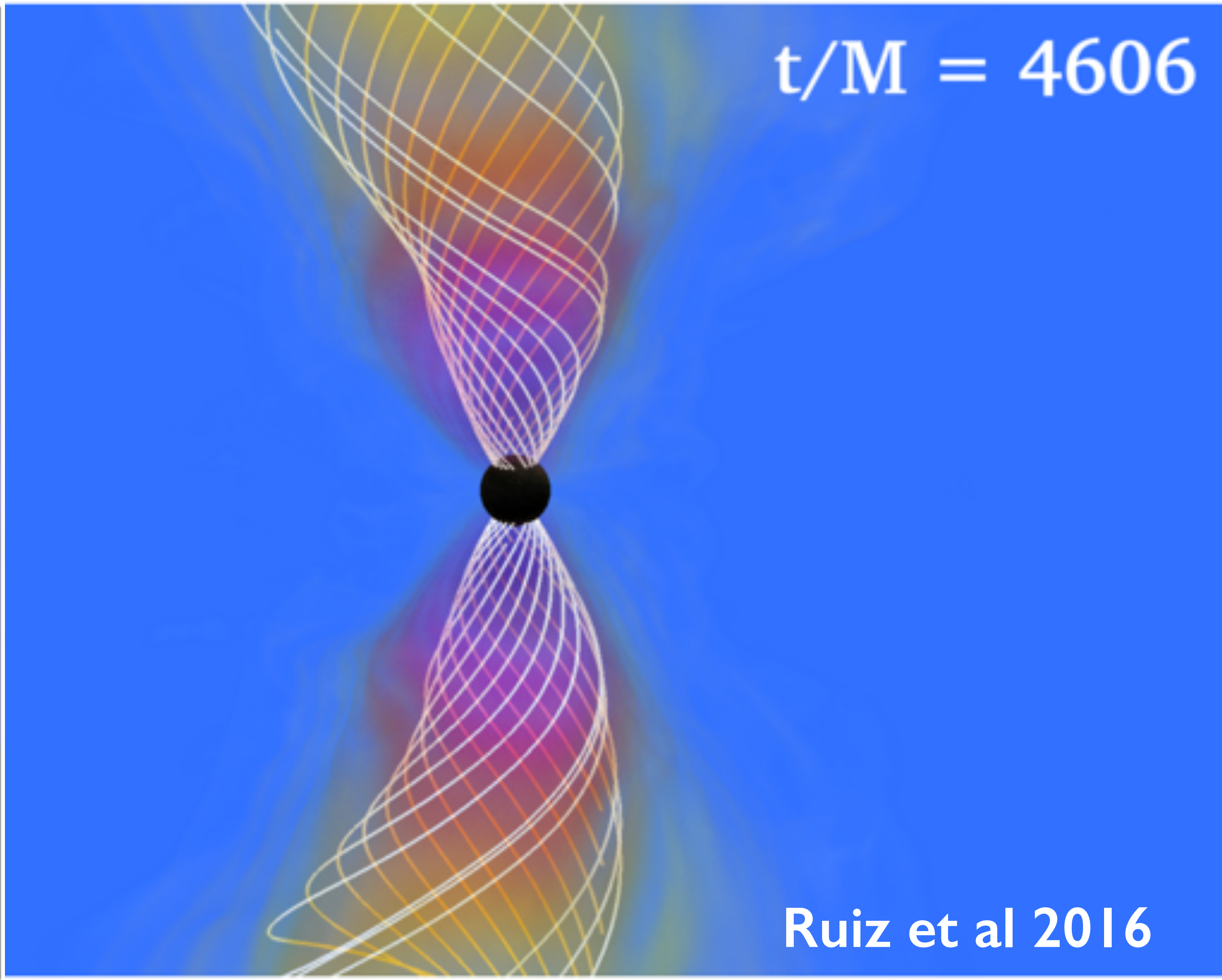
JETS FROM BNS MERGERS?

Rezzolla, **Giacomazzo**, Baiotti, Granot, Kouveliotou, Aloy 2011, ApJL 732, L6



Jet or no Jet?





Missing Link (Rezzolla et al 2011): showed formation of strongly collimated magnetic fields after collapse to BH.

Kiuchi et al 2014: reported no ordered structure in the magnetic field.

Ruiz et al 2016: mildly relativistic collimated outflow

Effects of EOS, mass-ratio, and initial magnetic fields

Kawamura, Giacomazzo, Kastaun, Ciolfi, Endrizzi, Baiotti, Perna 2016, PRD 94, 064012

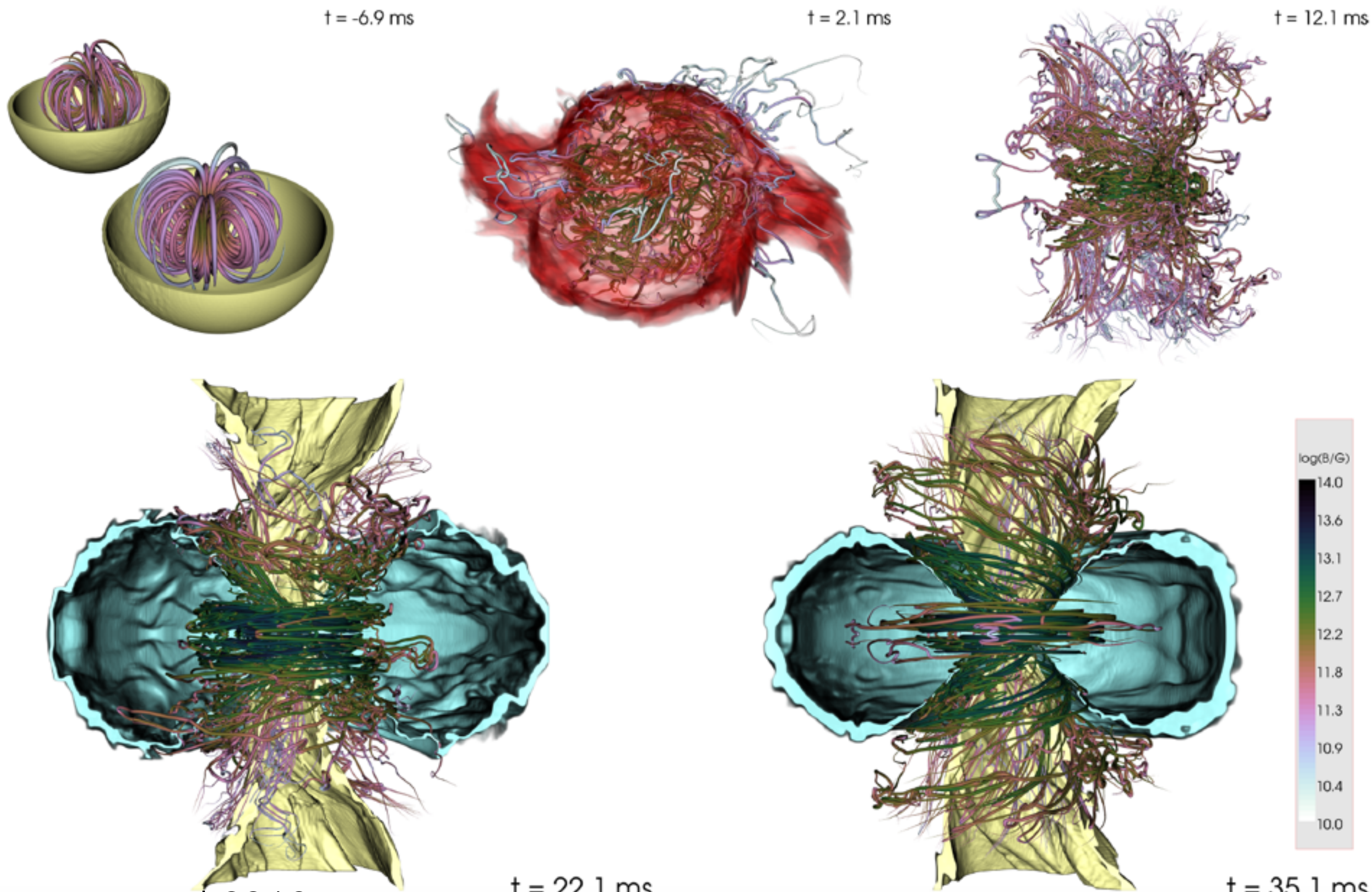
We performed a set of new GRMHD simulations:

- Ideal-Fluid EOS:
  - Equal-Mass (1.5-1.5) with field alignment UU, UD, DD
  - Unequal-Mass (1.4-1.7)
- H4 EOS:
  - Equal-Mass (1.4-1.4)
  - Unequal-Mass (1.3-1.5)

All models start with an initial magnetic field of ~10^{12} G (vs ~10^{15} G of Ruiz et al 2016).

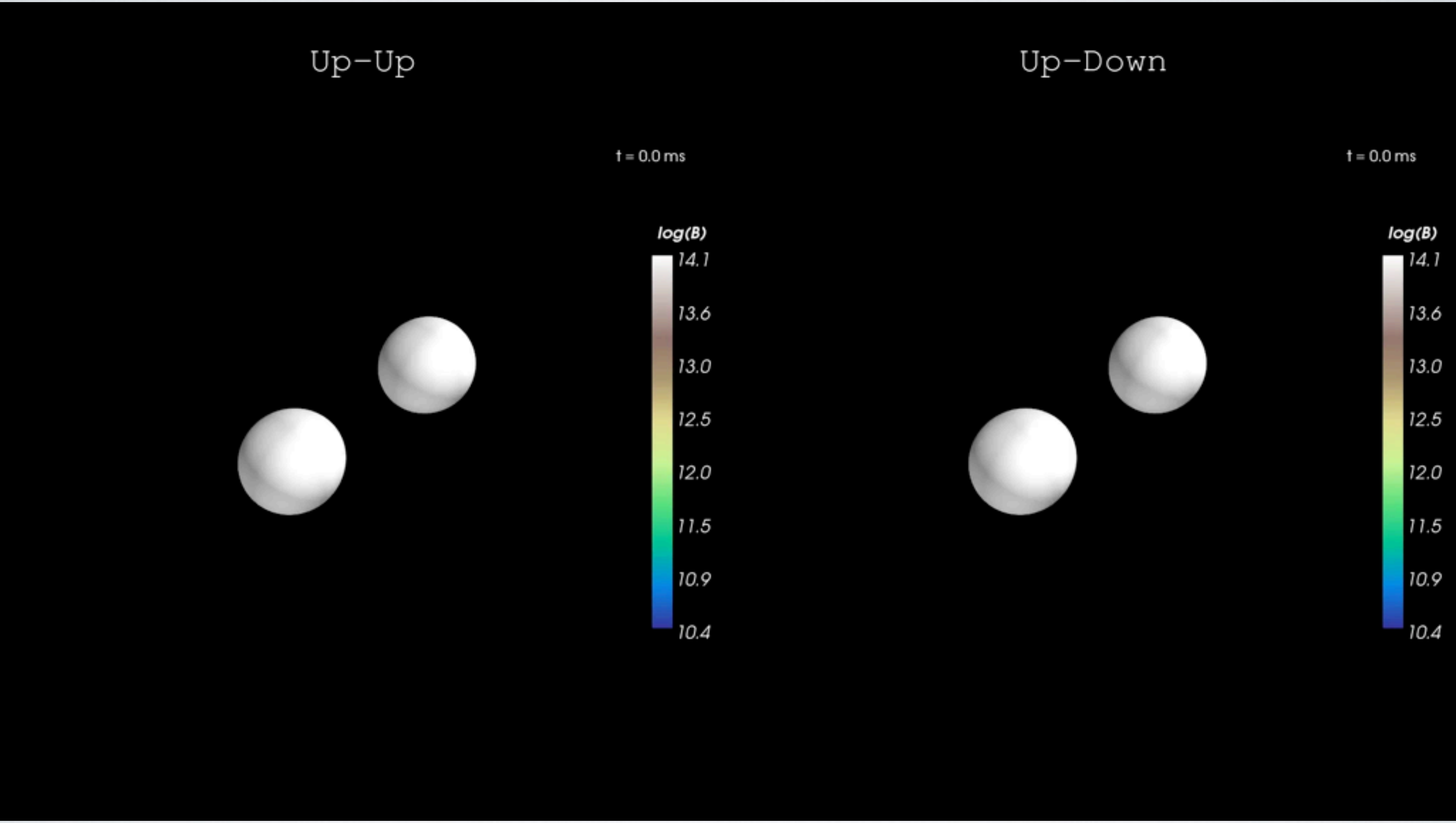
Unequal-mass models studied for the first time.

Typical Magnetic Field Structure Evolution

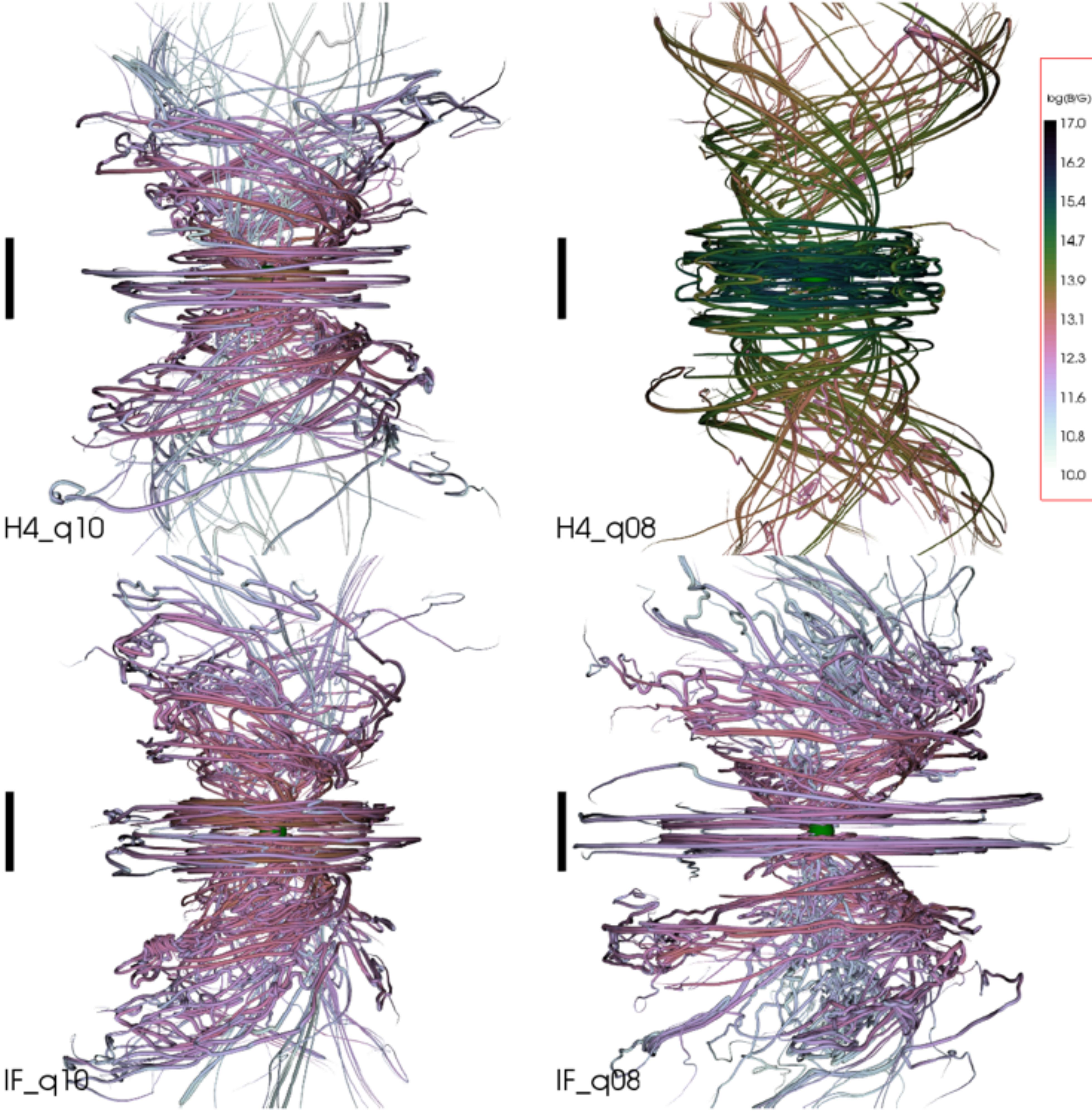


Kawamura et al 2016

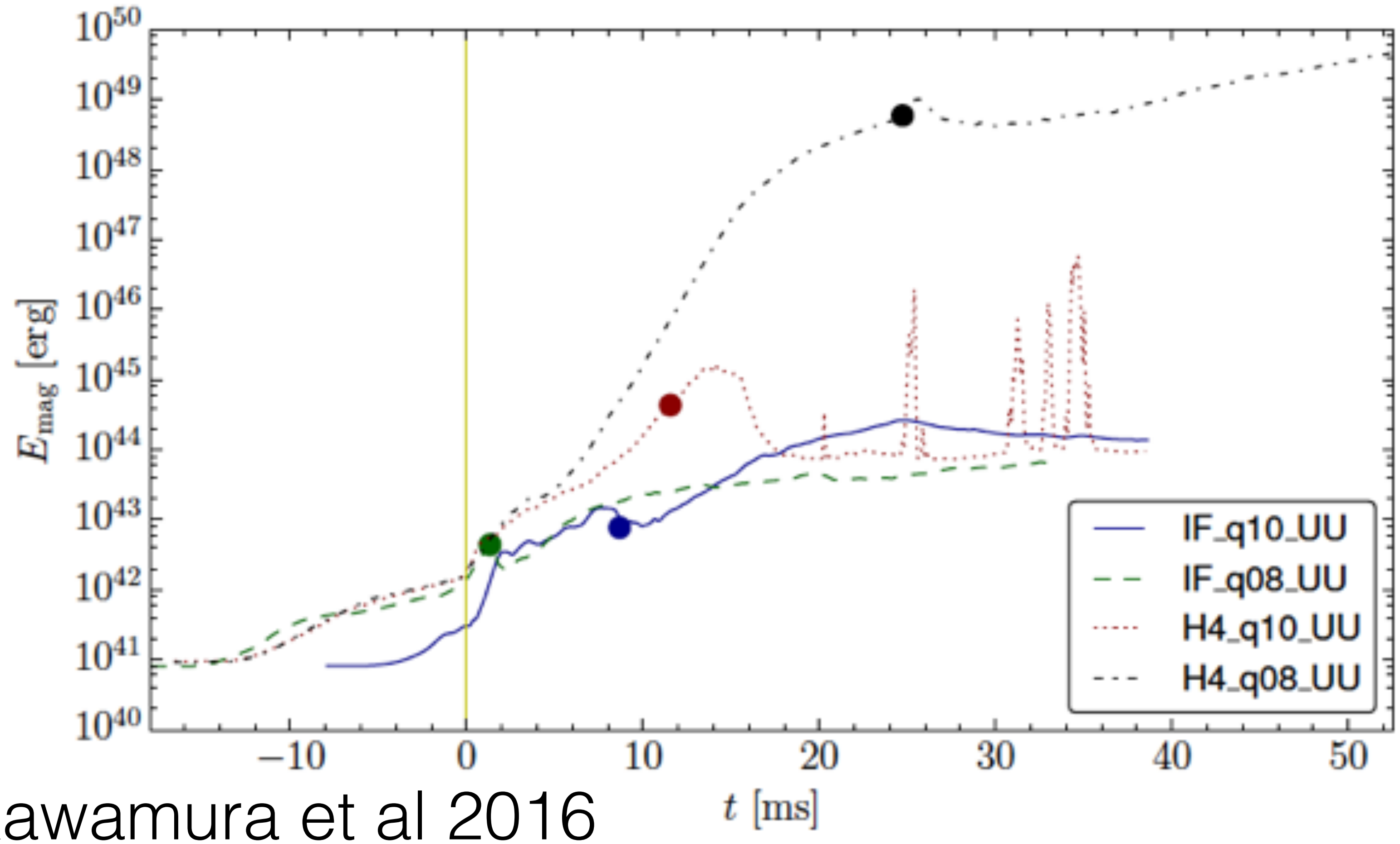
UU vs UD (Ideal Fluid Equal Mass)



Role of **EOS** and **Mass Ratio**



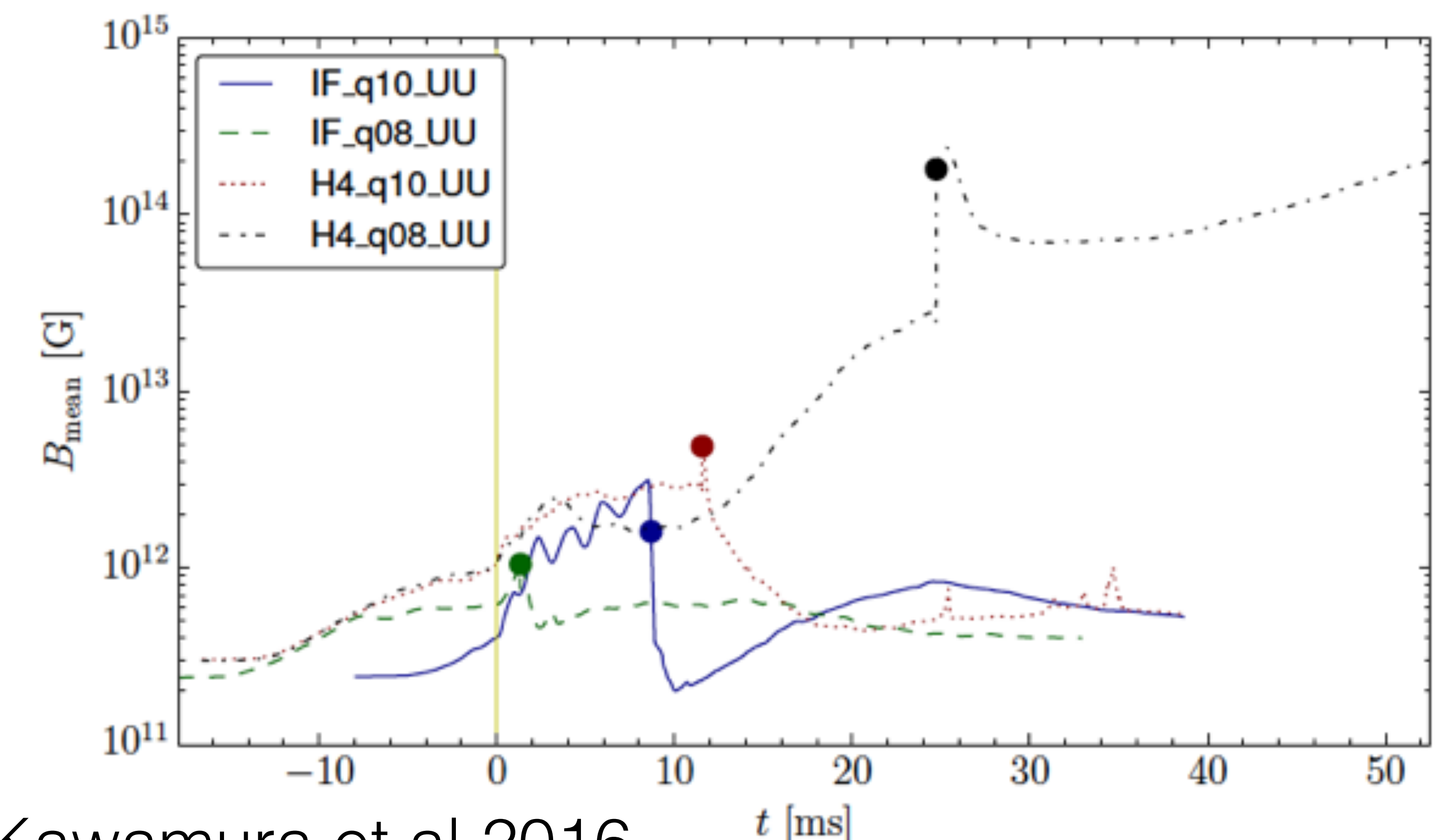
Kawamura et al 2016



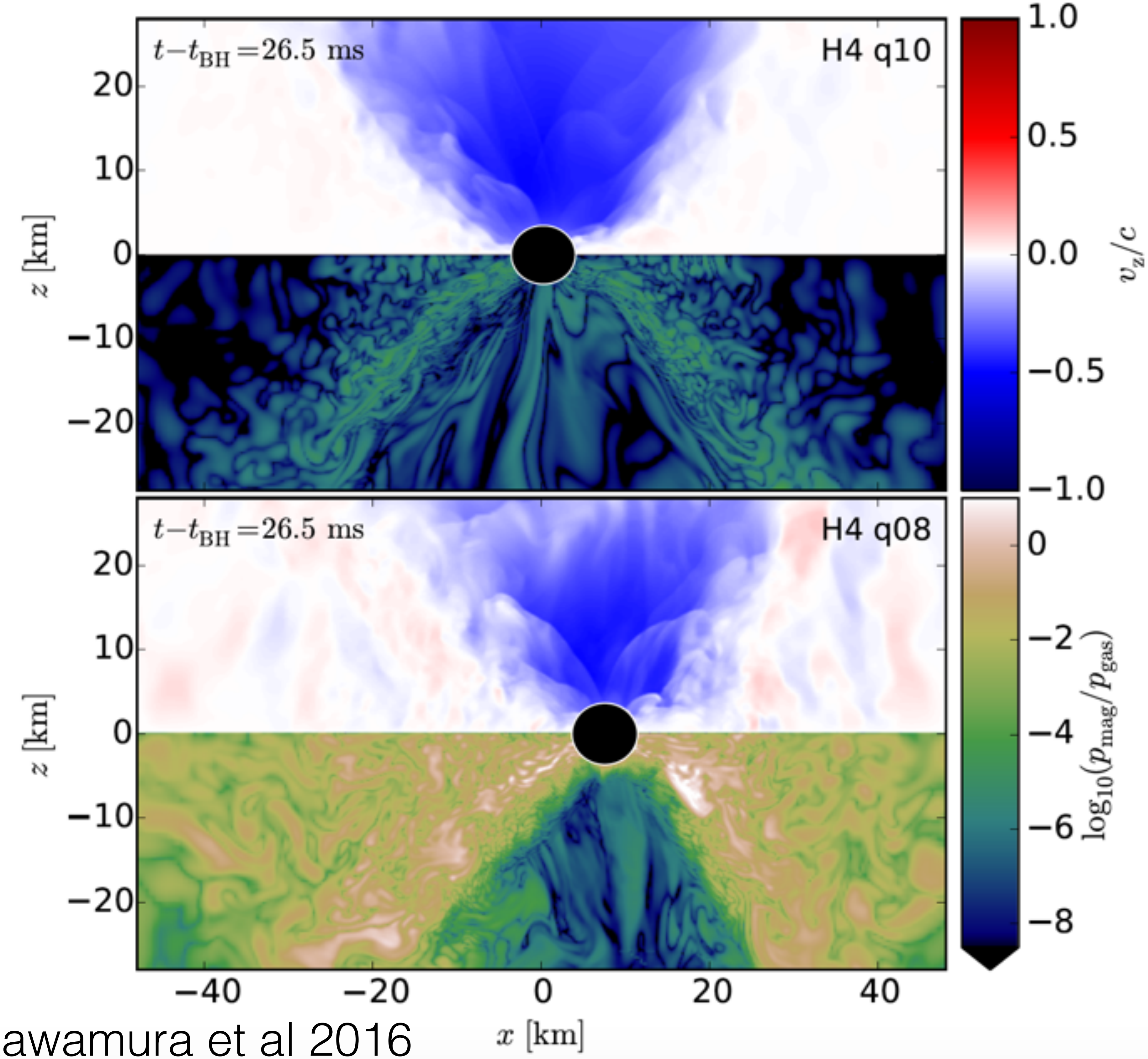
Kawamura et al 2016

H4_q08 has the longest-living HMNS and show largest magnetic field amplification.

Large magnetic fields survives also after BH collapse.
Possible to resolve MRI in this case.



Kawamura et al 2016

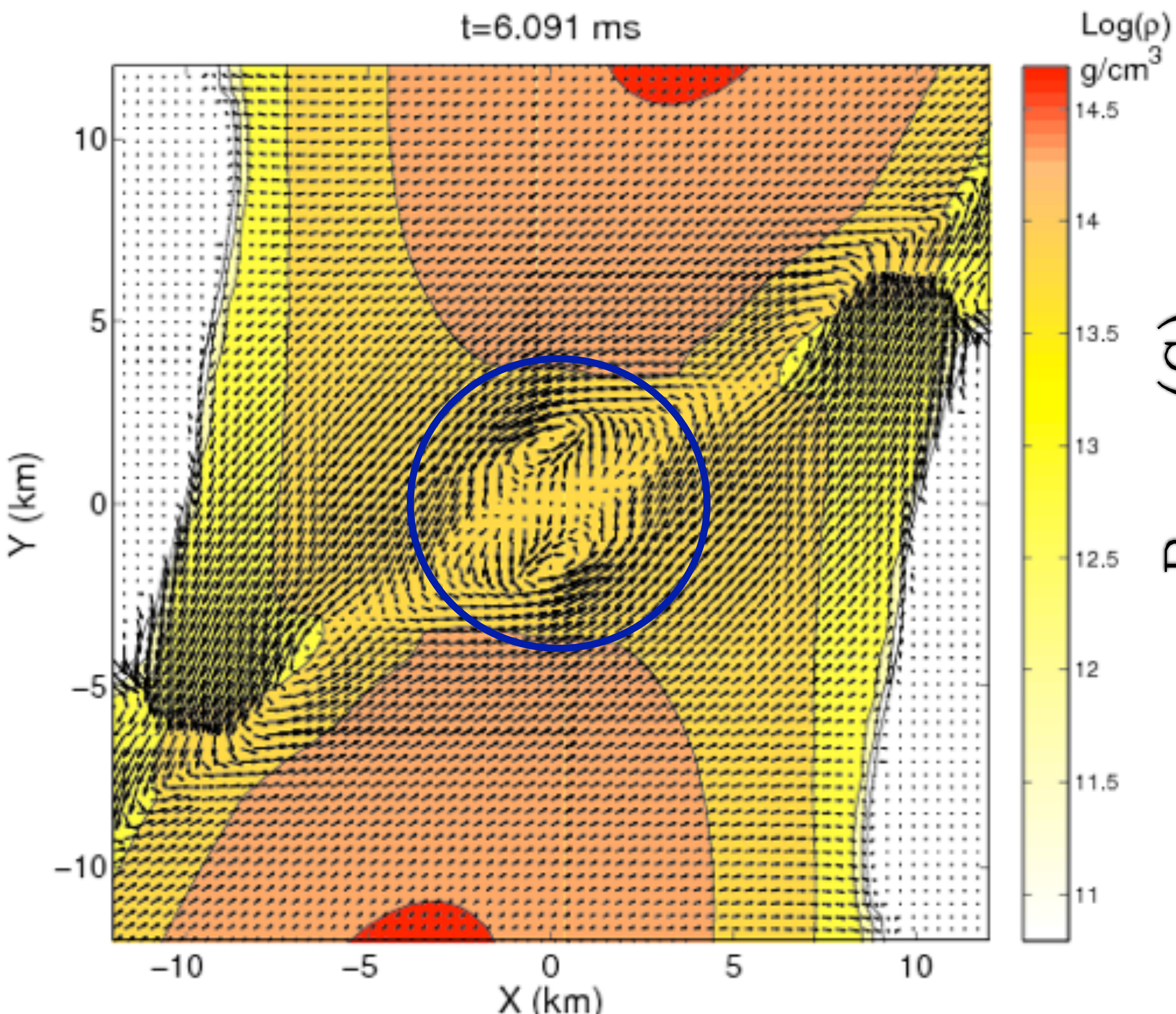


Kawamura et al 2016

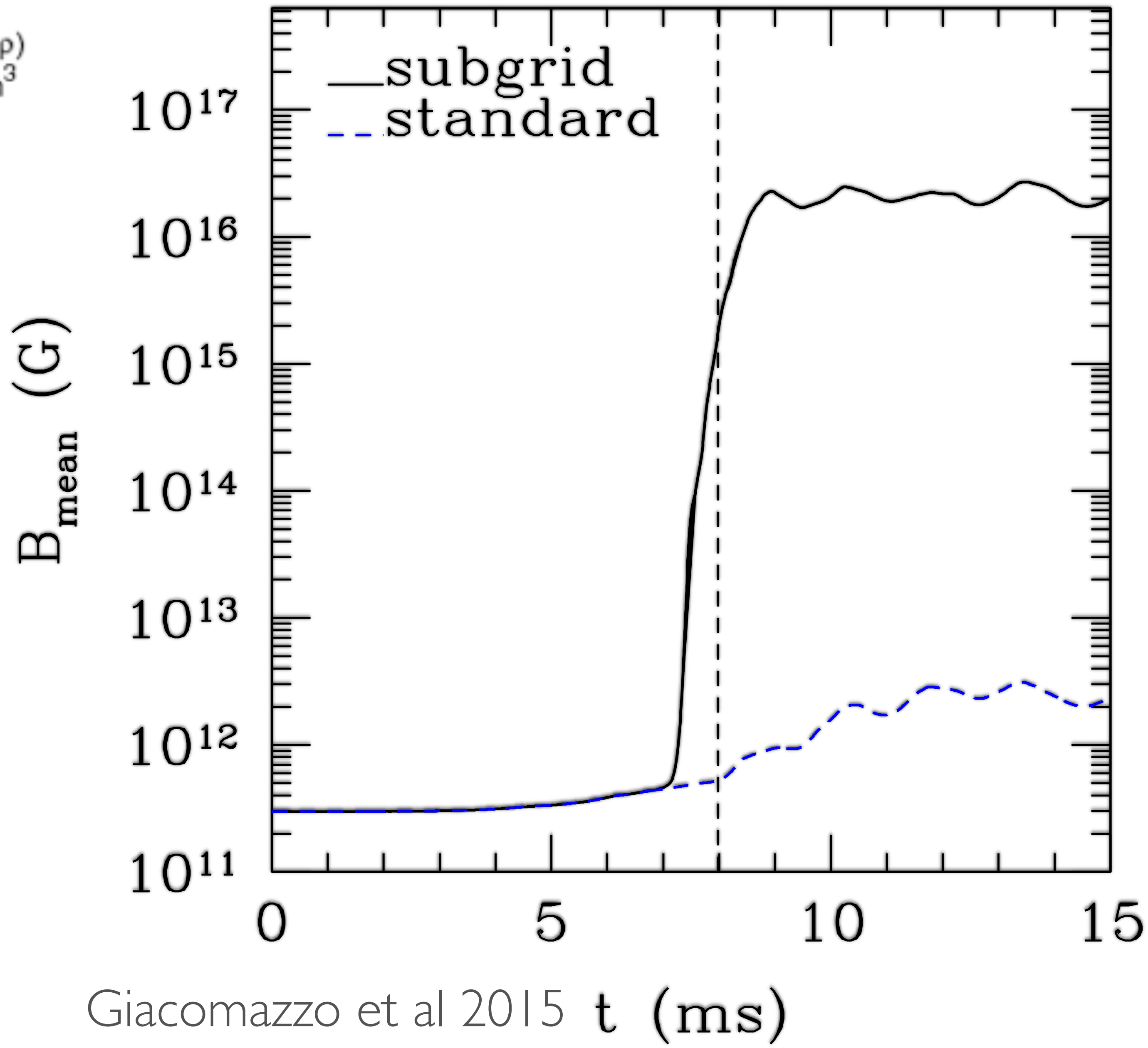
No Jet observed, but it may change with longer evolutions and (much) higher resolutions.

Magnetic Field Amplification

Giacomazzo, Zrake, Duffell, MacFadyen, Perna 2015, ApJ, 809, 39



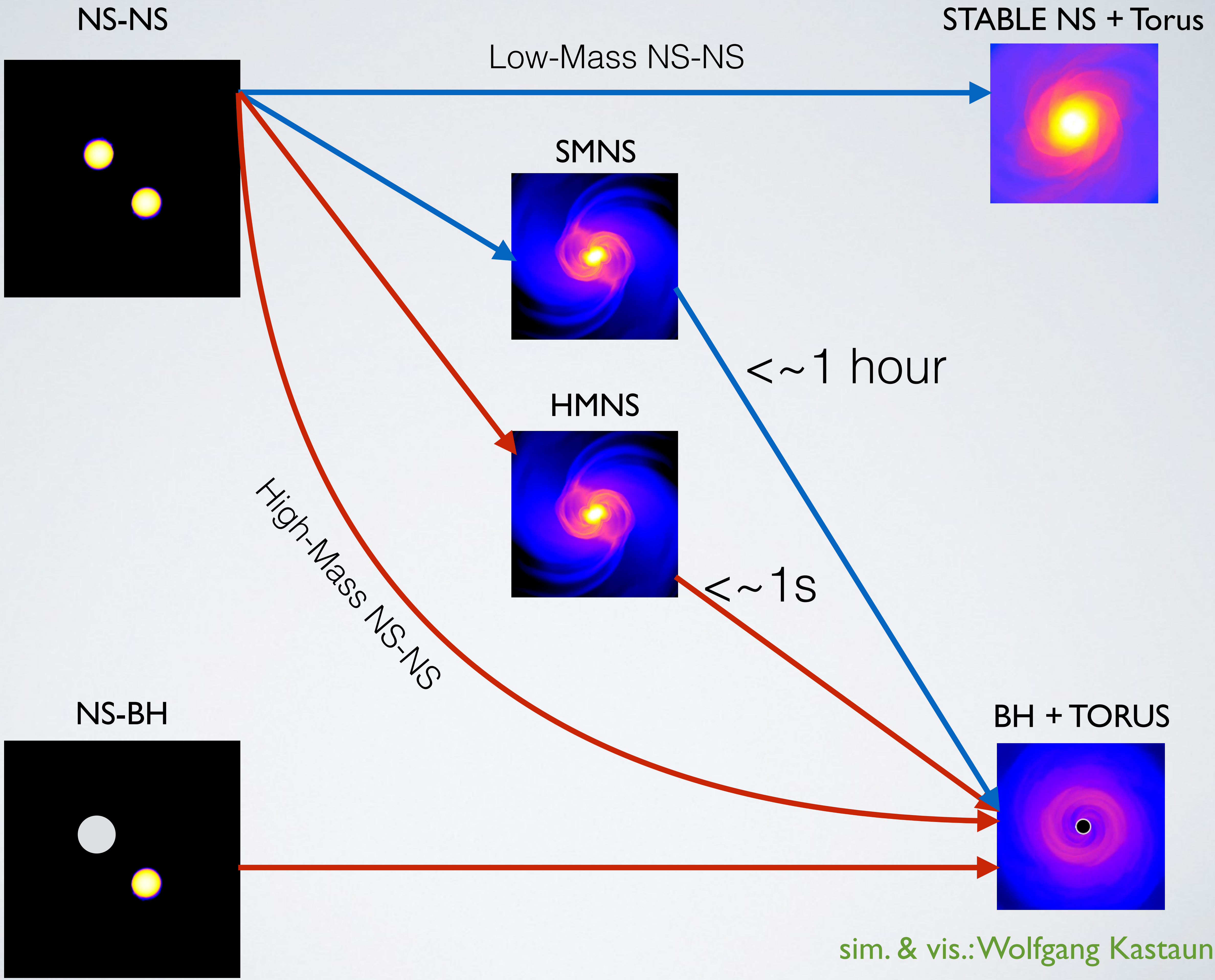
Baiotti et al 2008



Giacomazzo et al 2015

Hydrodynamic turbulence (KH) during merger can strongly amplify magnetic fields, but ultra-high resolutions (Kiuchi et al 2015) or subgrid models are required (Giacomazzo et al 2015).

WHAT ABOUT THE BLUE PATH?



Simulations of Long-Lived Post-Merger Remnants

Ciolfi et al 2016, in preparation

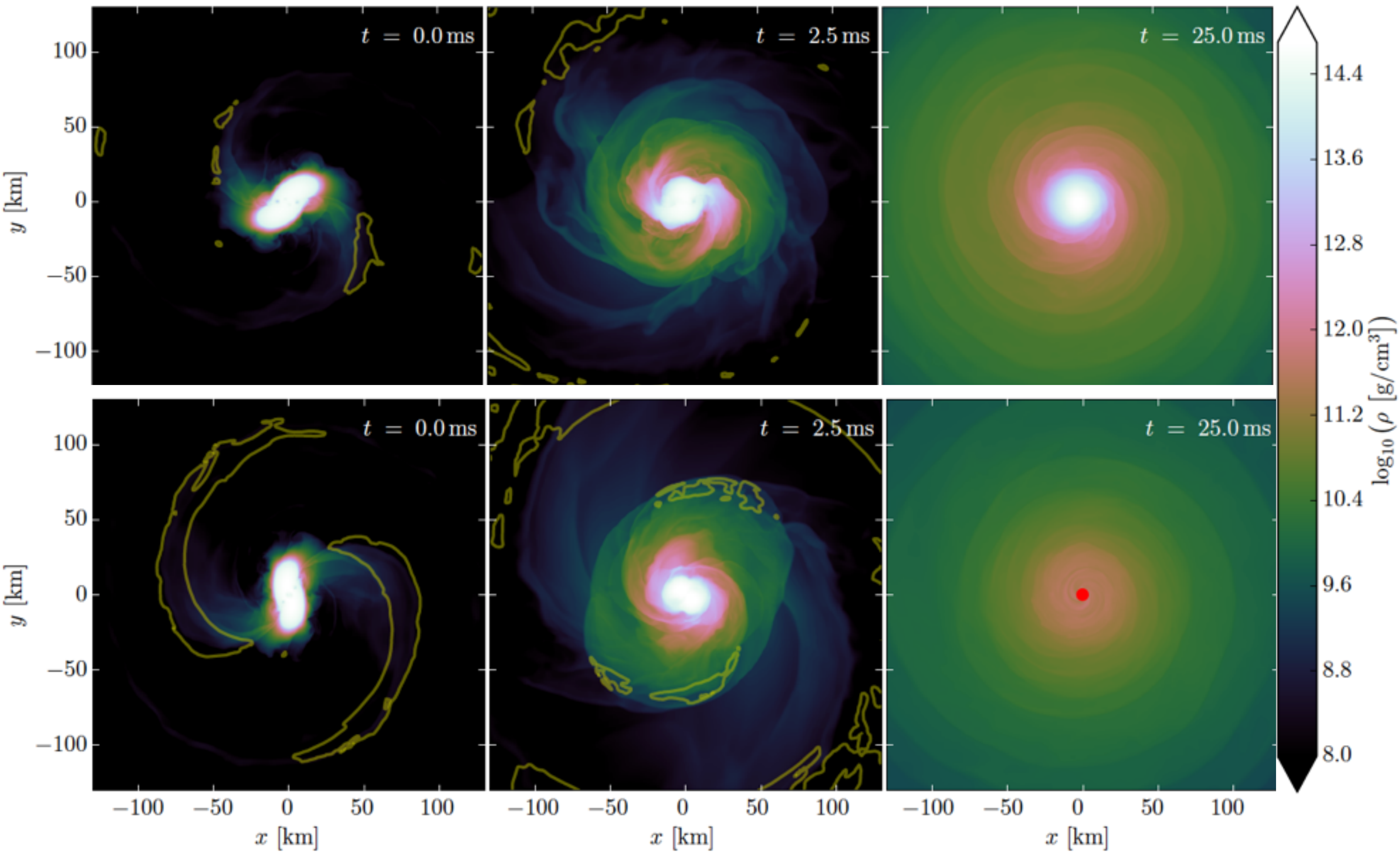
We considered 6 BNS systems:

- 2 different mass ratios
- 3 equations of state (APR4, MS1, H4)

All models have an initial magnetic field of $\sim 10^{15}$ G

4 models produce an SMNS and 2 an HMNS that collapses to a BH.

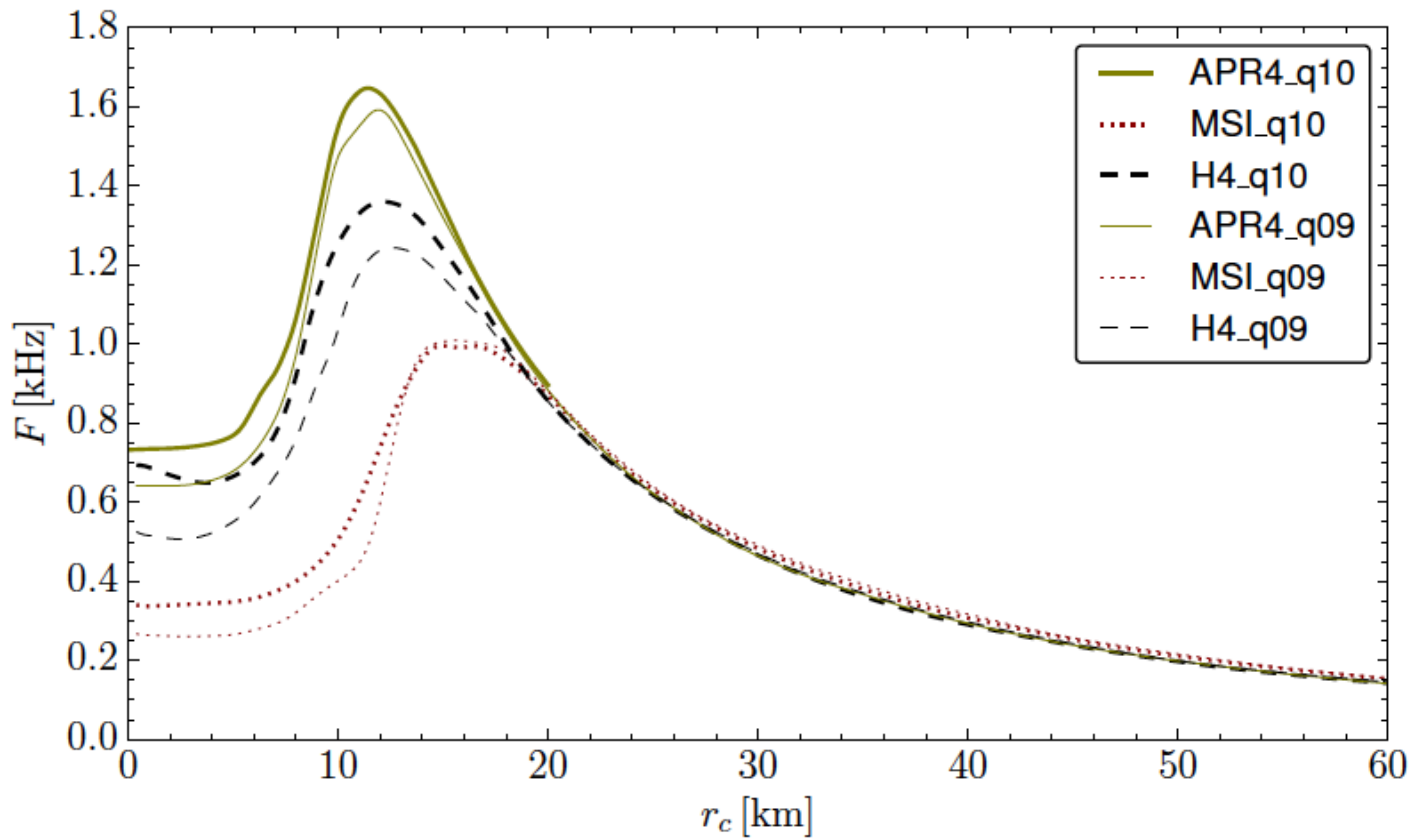
MS1



Ciolfi et al 2016, in preparation

H4

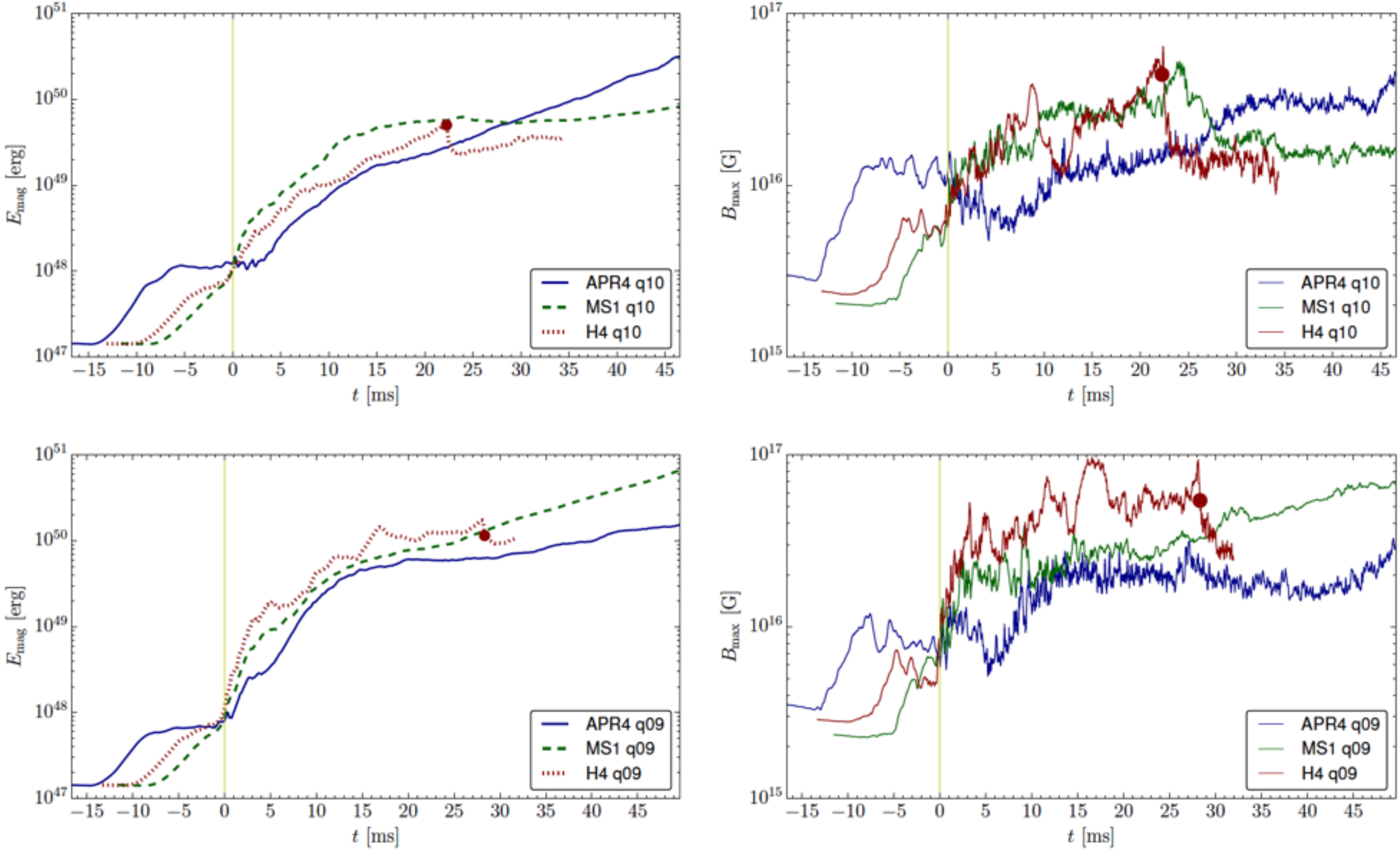
Rotation Rates



Ciolfi et al 2016, in preparation

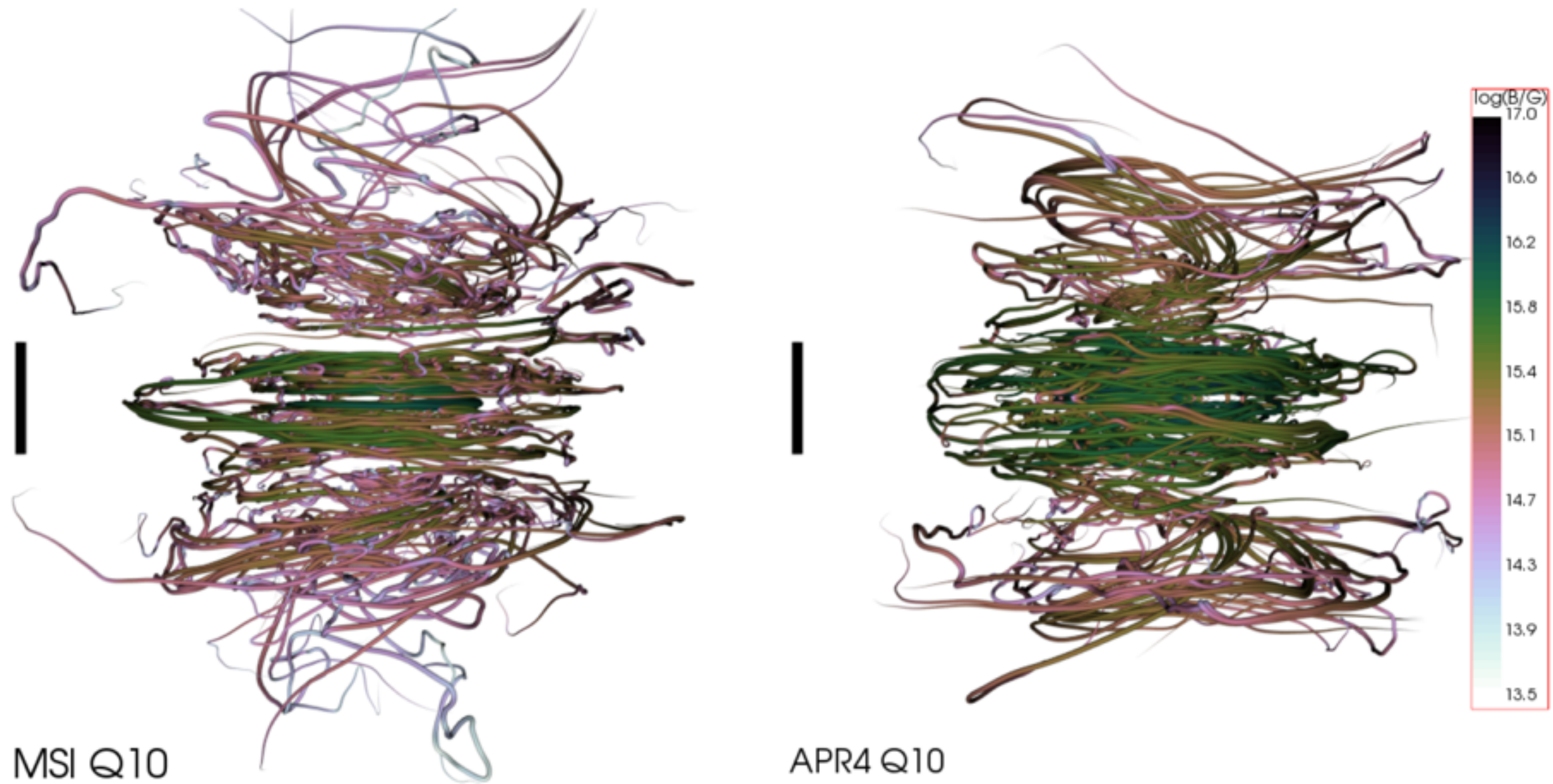
Similar rotation profiles between HMNS and SMNS.
Uniformly rotating core surrounded by Keplerian “disk”.

MAGNETIC FIELD EVOLUTION



Ciolfi et al 2016, in preparation

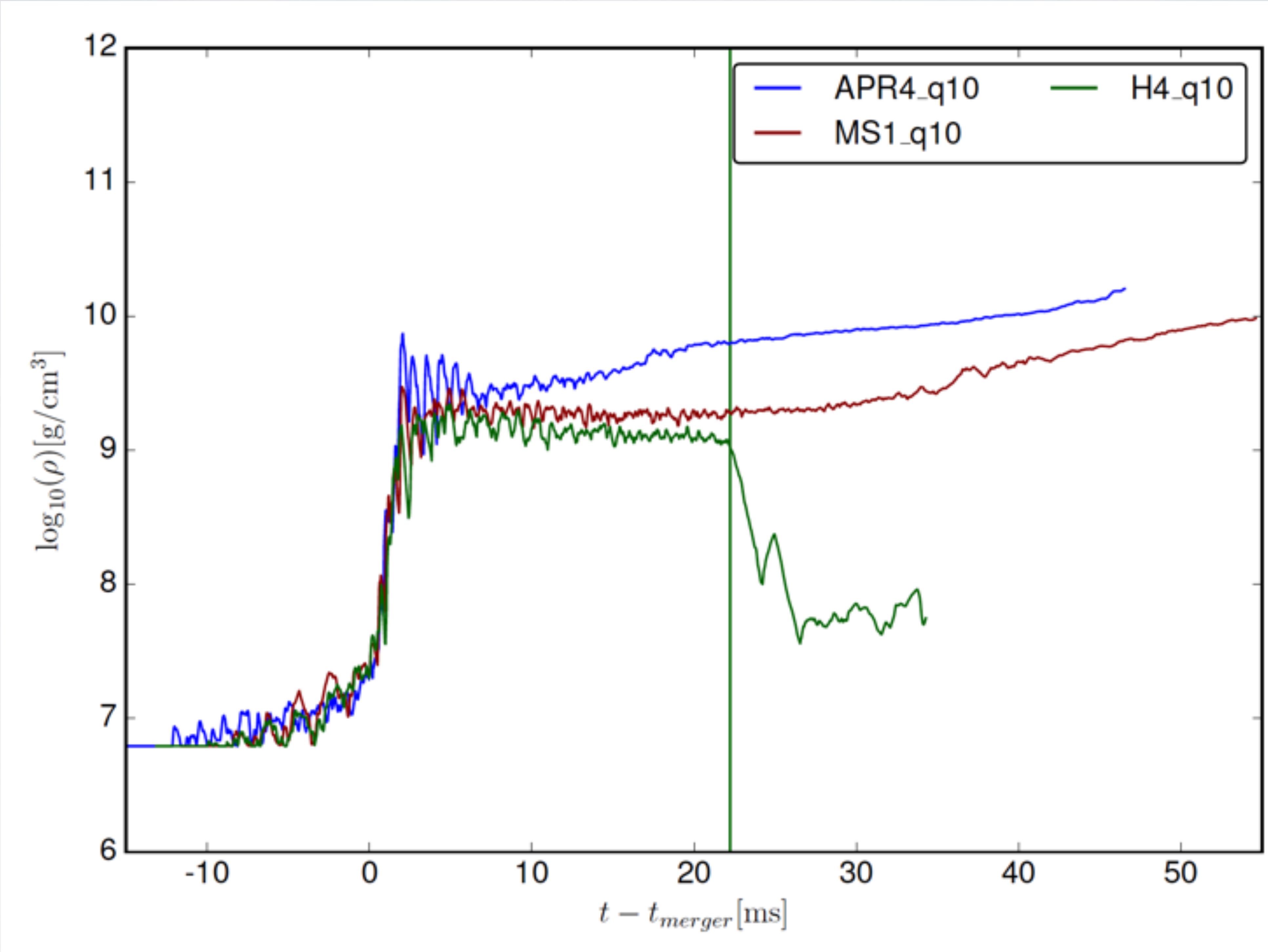
MAGNETIC FIELD STRUCTURE



Ciolfi et al 2016, in preparation

Twisted magnetic field structure formed in all cases.
Strong toroidal component on the equatorial plane.

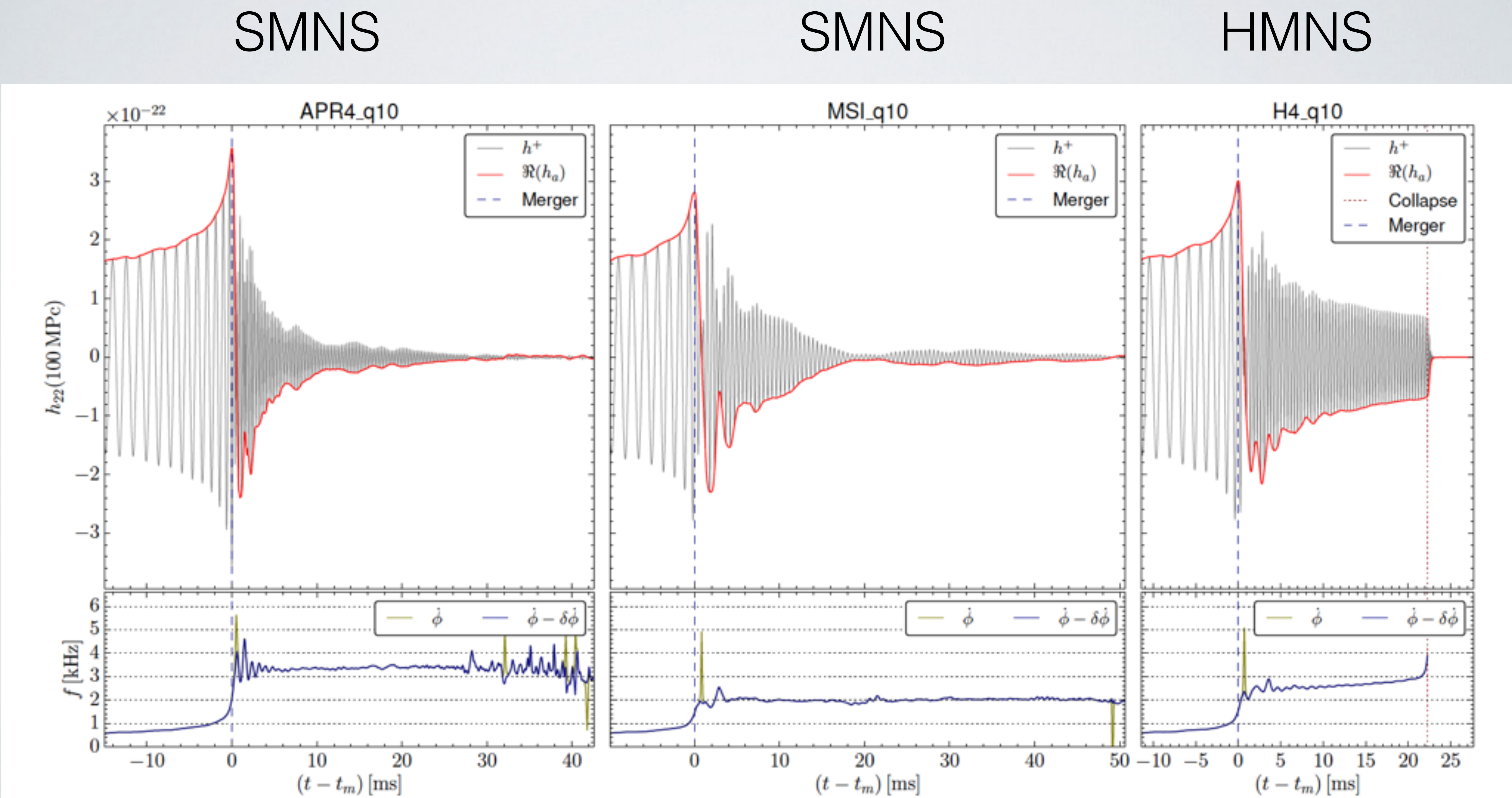
BARYON POLLUTION



Ciolfi et al 2016, in preparation

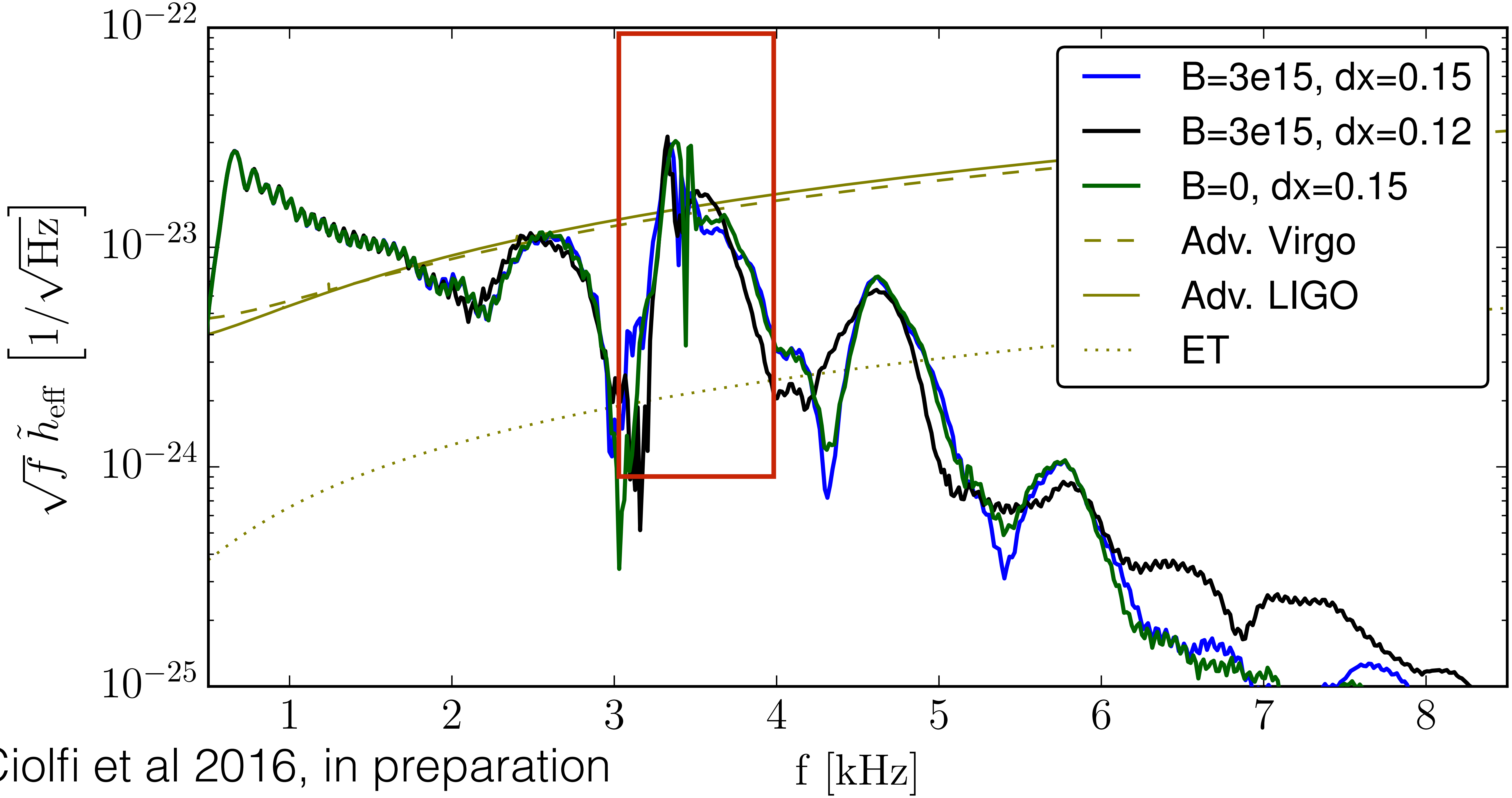
Strong baryon pollution in the SMNS case. Difficult to launch a jet until after BH formation (e.g., Ciolfi & Siegel 2015)

Gravitational Waves



Ciolfi et al 2016, in preparation

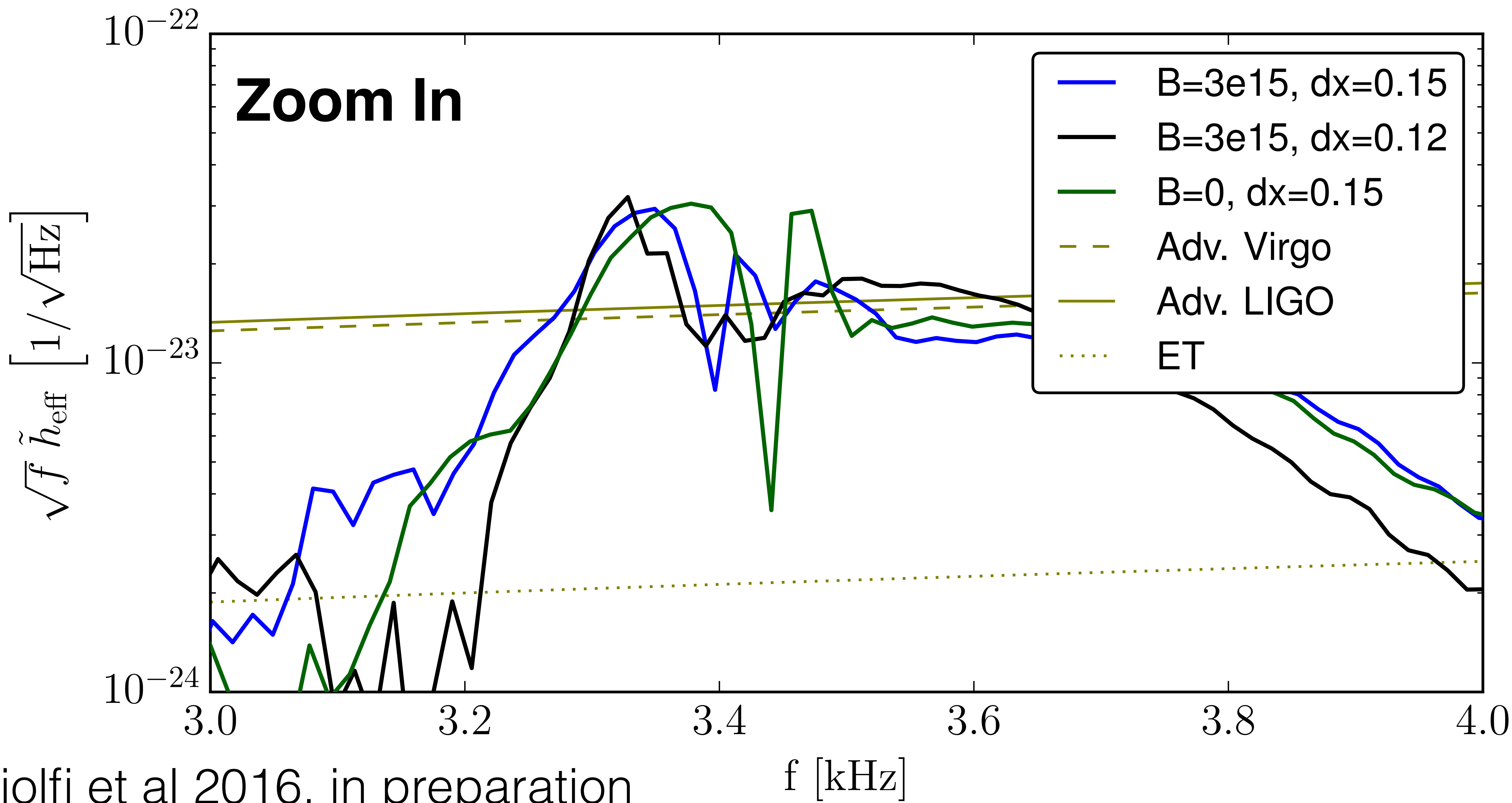
MAGNETIC FIELD EFFECTS



Ciolfi et al 2016, in preparation

Large magnetic fields may affect the frequency of the main post-merger peak.

MAGNETIC FIELD EFFECTS



Ciolfi et al 2016, in preparation

Peak frequency changed by less than 100 Hz.

CONCLUSIONS

- We study both BNS merger scenarios in full GRMHD
- SGRB connection (BH+disk):
  - we always observe ordered twisted magnetic field structure (independently of EOS, mass ratio, and B-field orientation)
  - No jet observed, but magnetic field amplification not resoved
- Properties of the post-merger remnant:
  - All models show uniformly rotating core surrounded by Keplerian disk
  - Strong baryon pollution in HMNS/SMNS case
  - GW slightly affected by magnetic fields (to be better investigated)