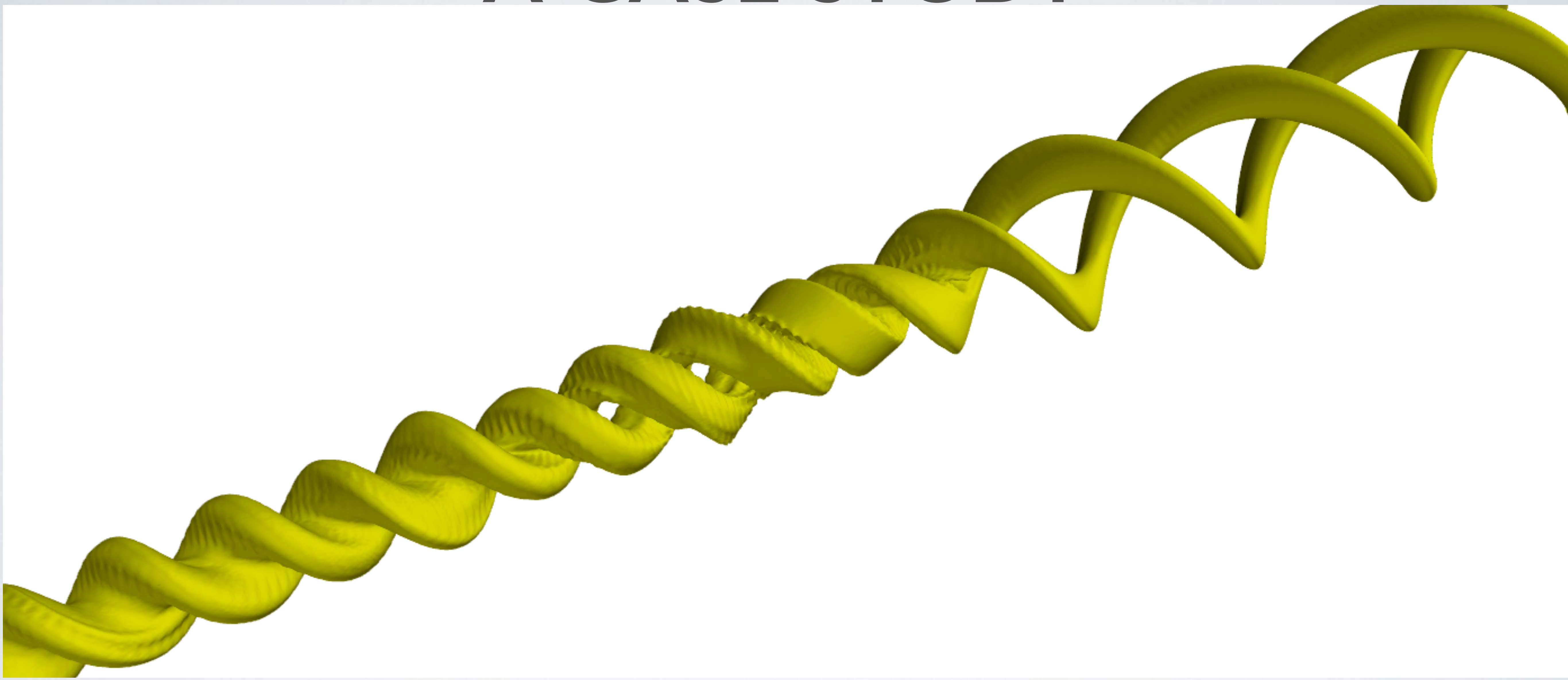
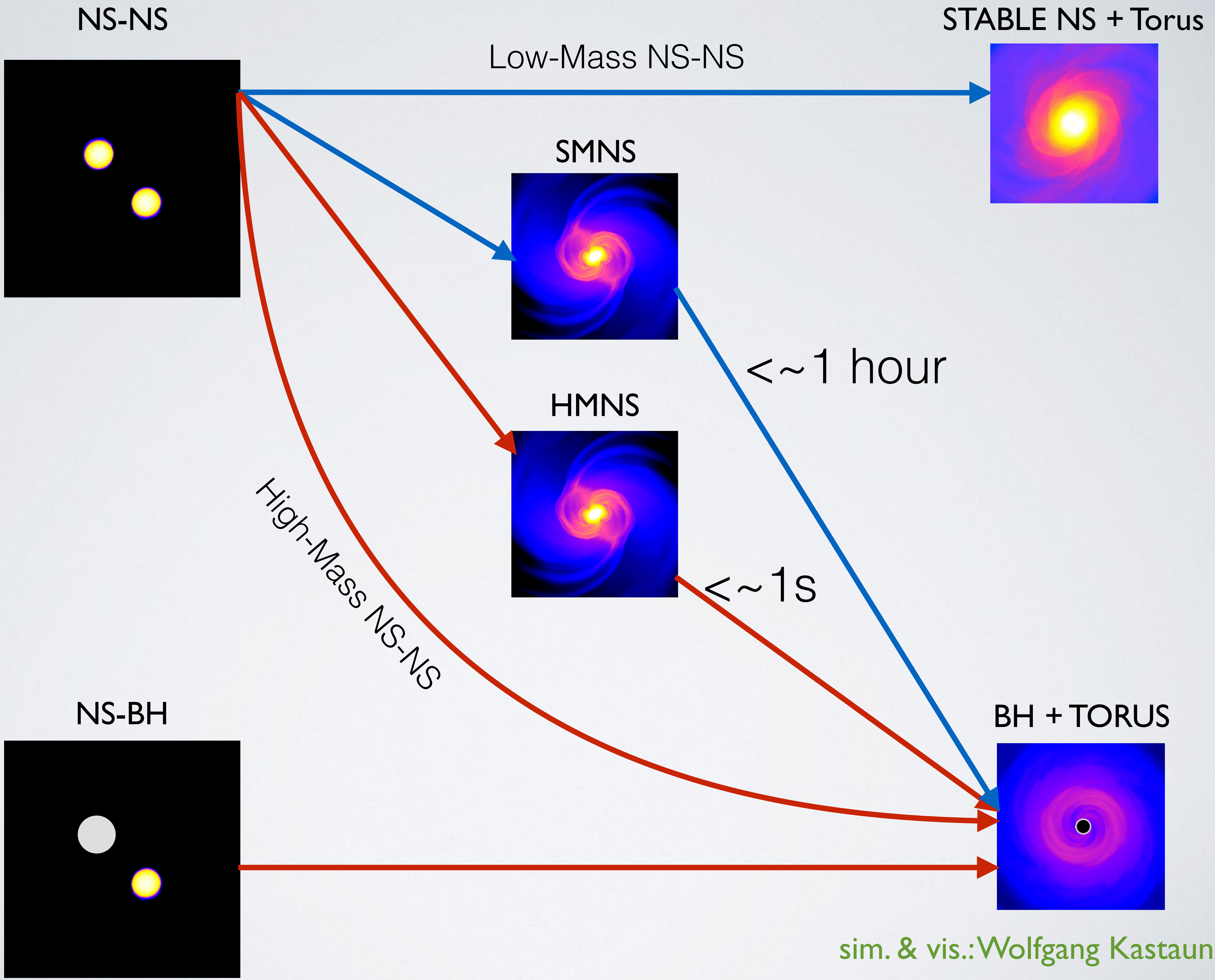
STRUCTURE OF STABLE BINARY NEUTRON STAR MERGER REMNANTS: A CASE STUDY



Bruno Giacomazzo
University of Trento, Italy
www.brunogiacomazzo.org

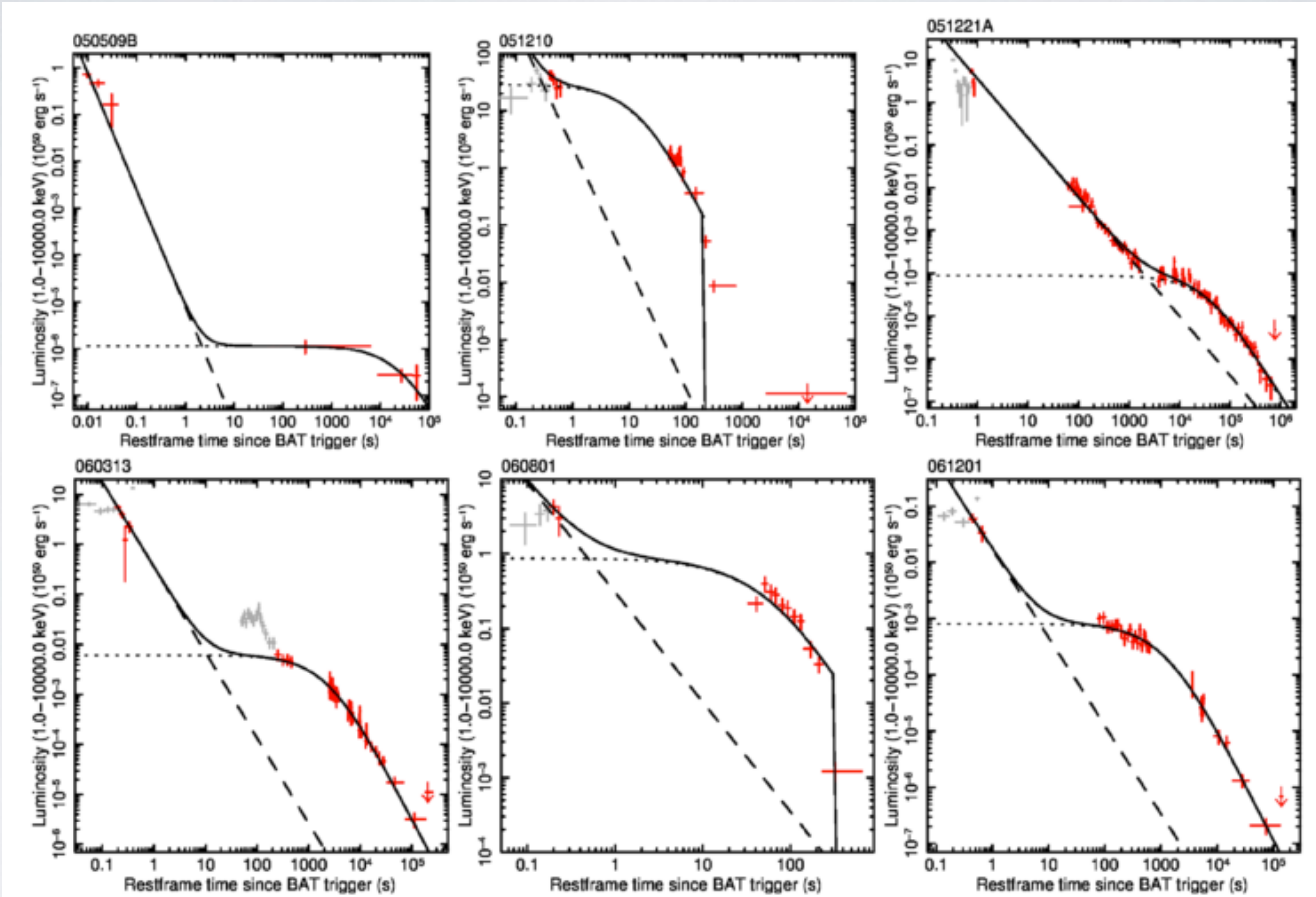
Trento Institute for Fundamental Physics and Applications

BNS MERGER OUTCOME



sim. & vis.: Wolfgang Kastaun

WHY DO WE NEED A LONG-LIVED REMNANT?



Rowlinson et al 2013

A stable magnetar could be used to explain X-ray plateaus and extended emissions from SGRBs (e.g., Rowlinson et al 2013).

TIME-REVERSAL SGRB MODEL

(Ciolfi & Siegel 2015, ApJL 798, L36)

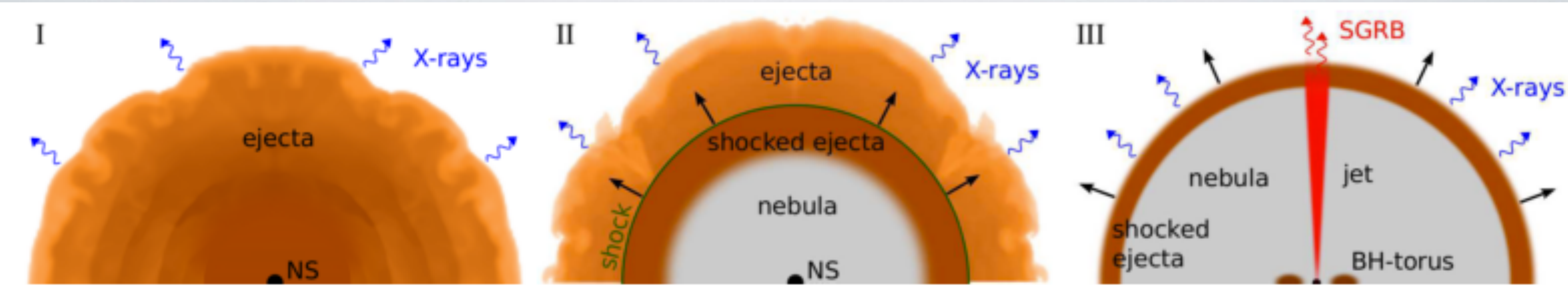
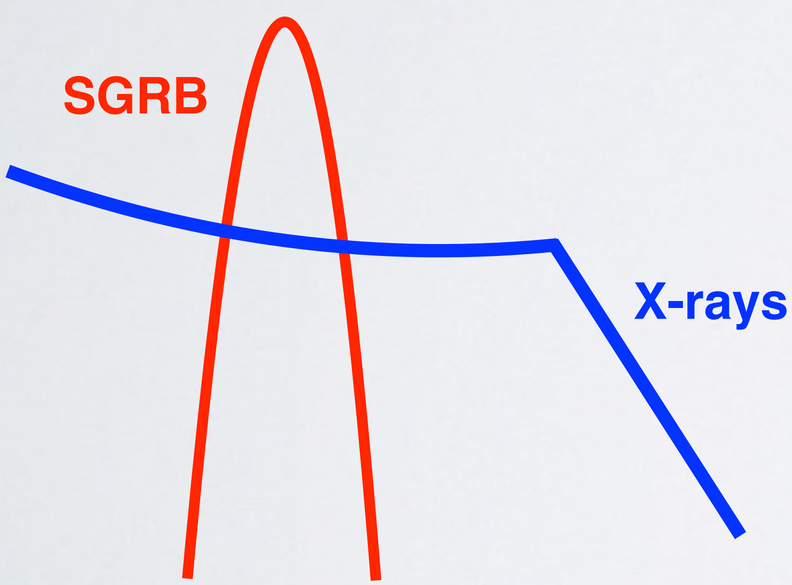


Figure 1. Evolution phases: (I) The differentially rotating supramassive NS ejects a baryon-loaded and highly isotropic wind; (II) The cooled-down and uniformly rotating NS emits spin-down radiation inflating a photon-pair nebula that drives a shock through the ejecta; (III) The NS collapses to a BH, a relativistic jet drills through the nebula and the ejecta shell and produces the prompt SGRB, while spin-down emission diffuses outwards on a much longer timescale.

Ciolfi & Siegel 2015



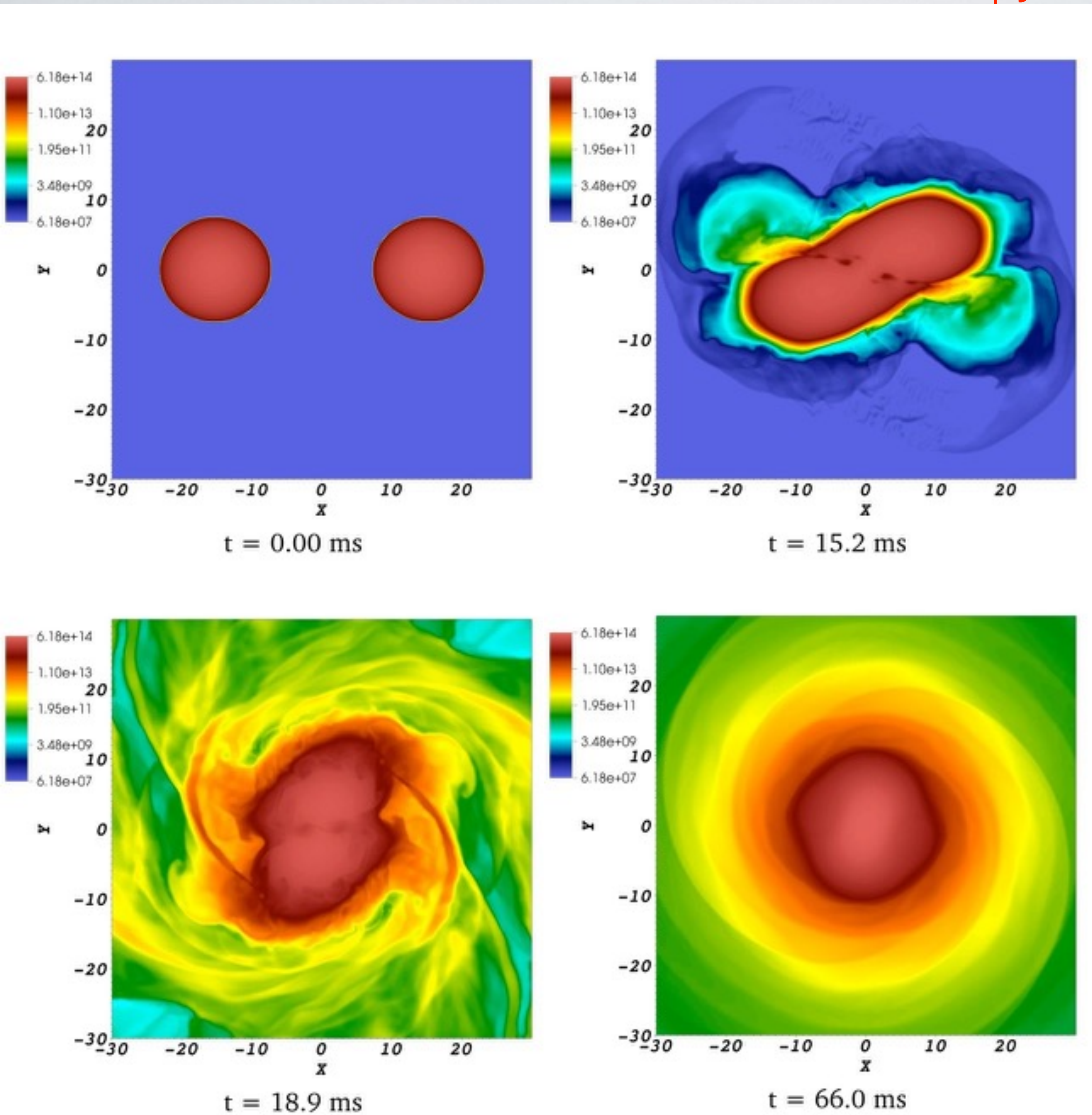
X-ray afterglow emitted by magnetar

SGRB emitted by BH after magnetar collapse

Can we form magnetars from BNS mergers?

MAGNETAR FORMATION

Giacomazzo & Perna 2013, ApJ Letters, 771, L26



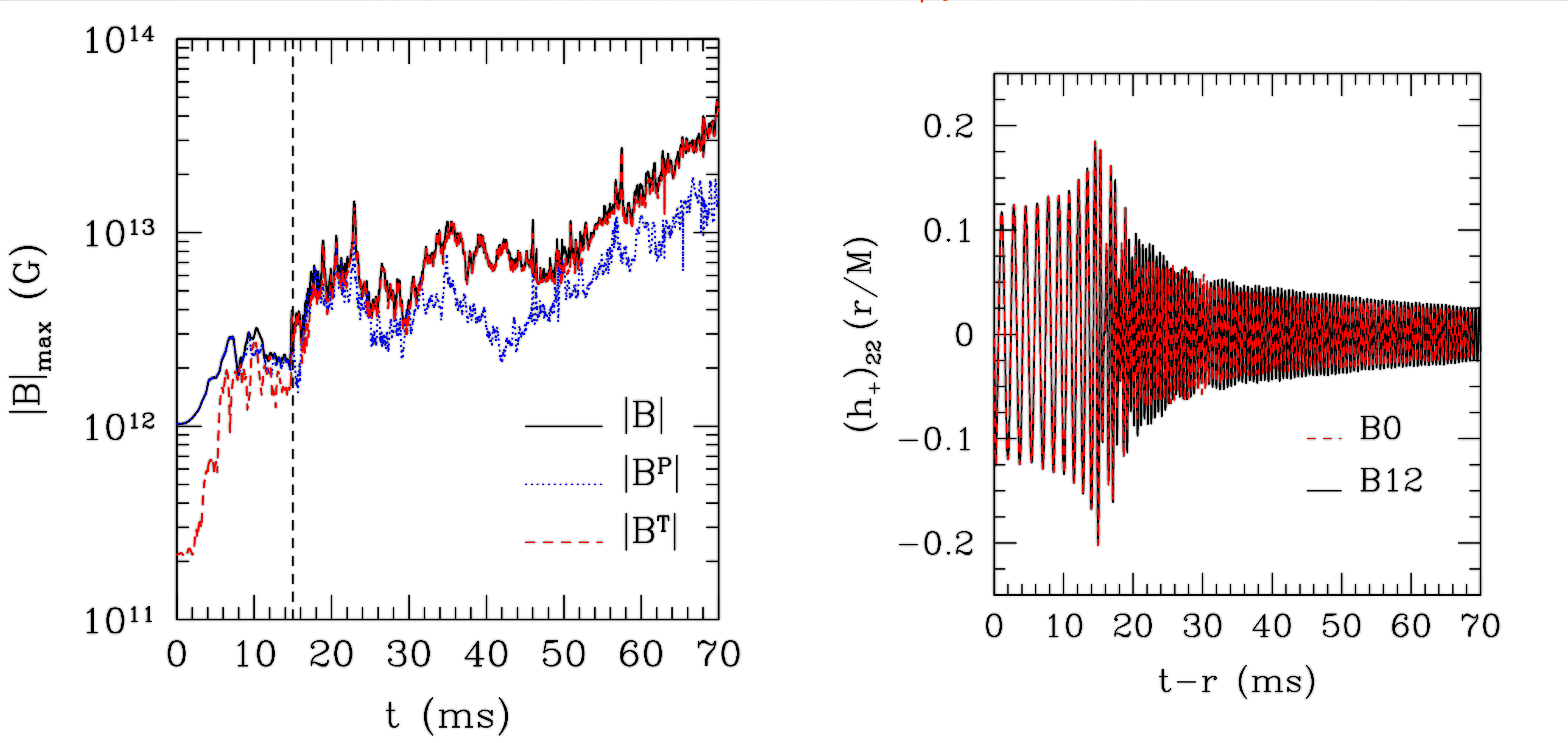
Investigated merger of two 1.2 M⊙ NSs

Used Ideal Fluid, Gamma=2.75, k=30000 (Oechslin et al 2007)

Produced a stable “ultraspinning” NS surrounded by a magnetized disk of ~0.1 M⊙.

MAGNETAR FORMATION

Giacomazzo & Perna 2013, ApJ Letters, 771, L26

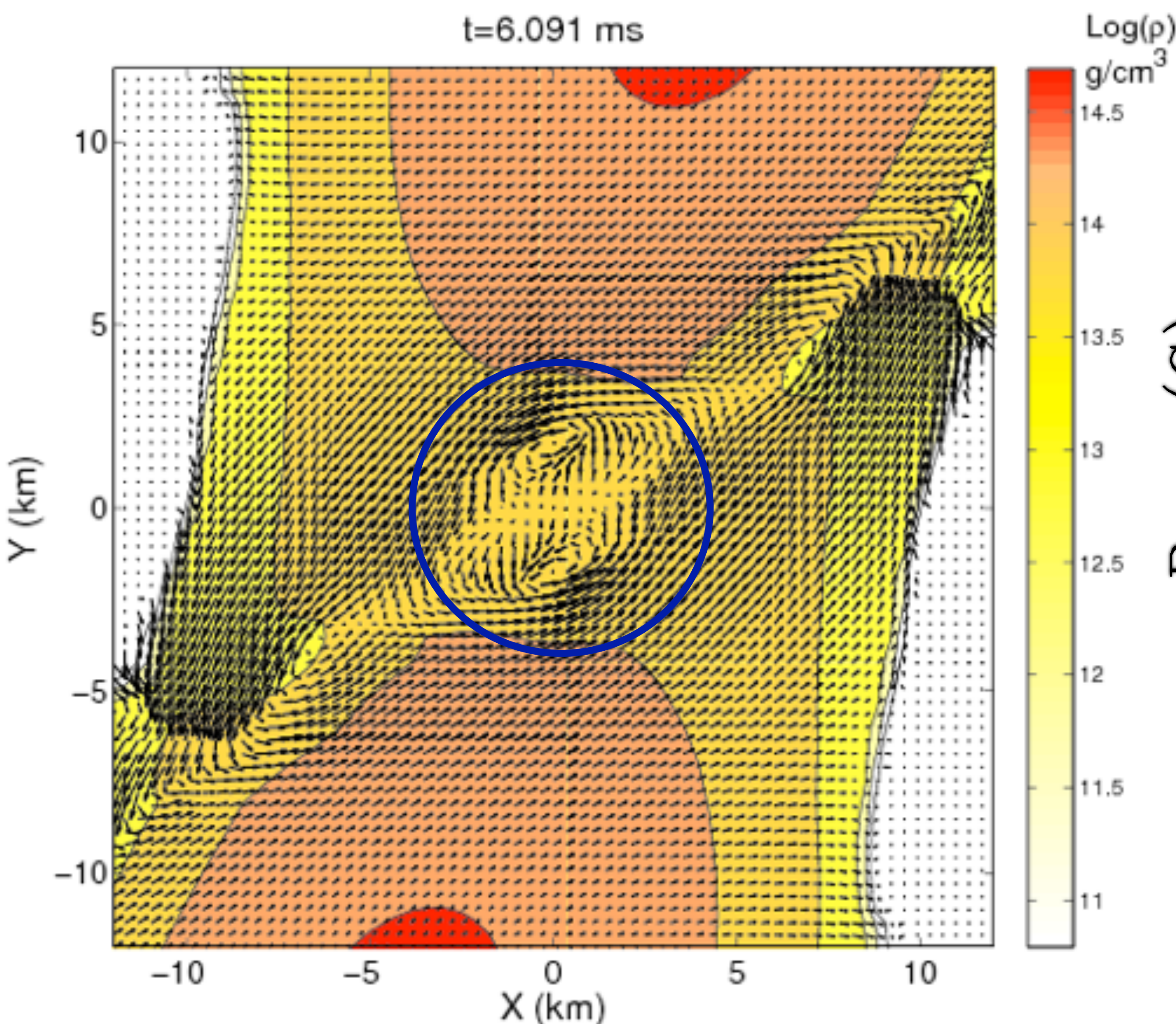


Magnetic field amplified of ~2 orders of magnitude. Difference in the GW signal are small and present only in the post-merger phase.

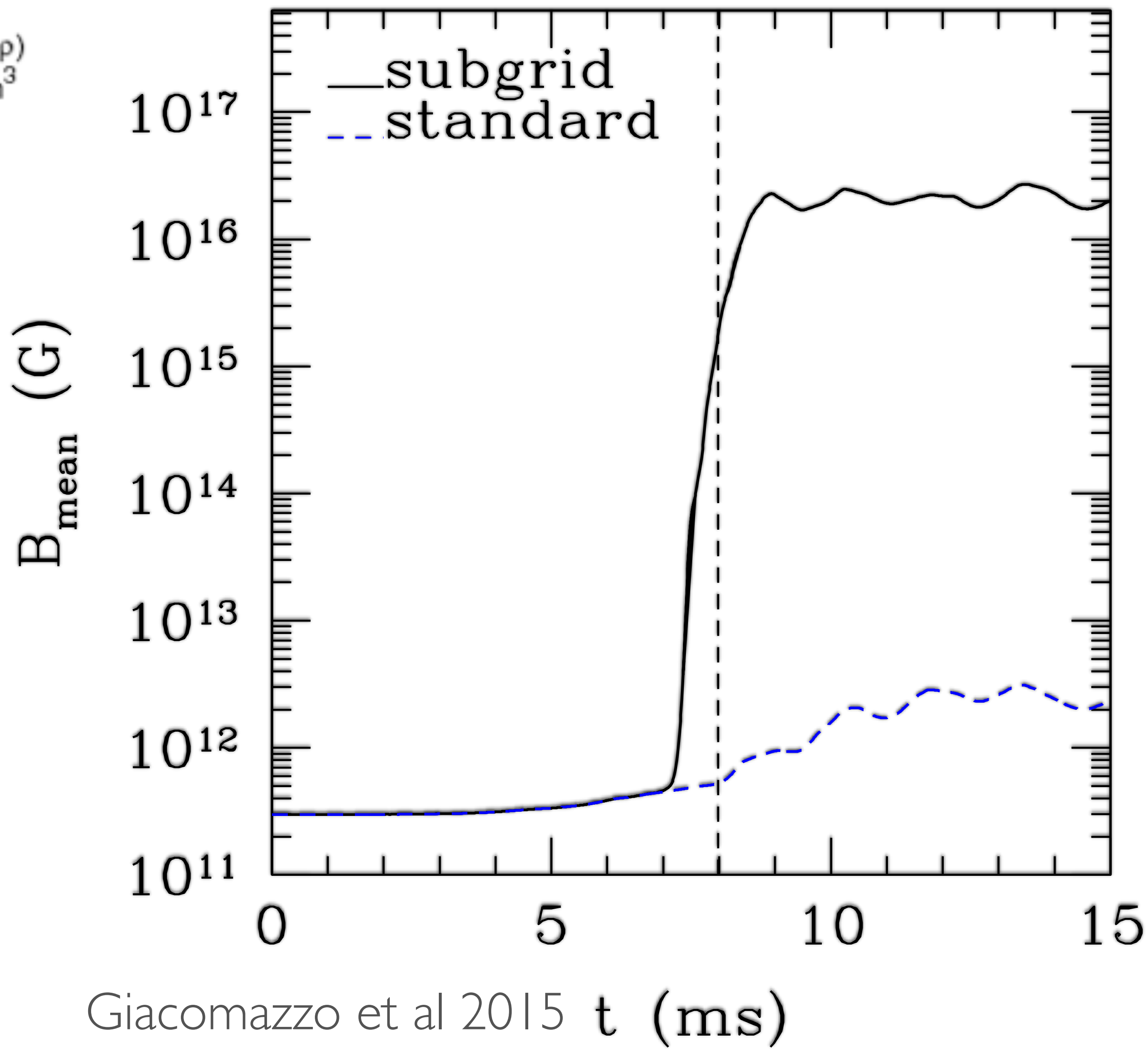
GWs publicly available for download at www.brunogiacomazzo.org/data.html

Magnetic Field Amplification

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



Baiotti et al 2008



Giacomazzo et al 2015

We implemented a sub-grid model in our GRMHD code Whisky to account for small scale (under-resolved) turbulence.
Effects on post-merger to be investigated…

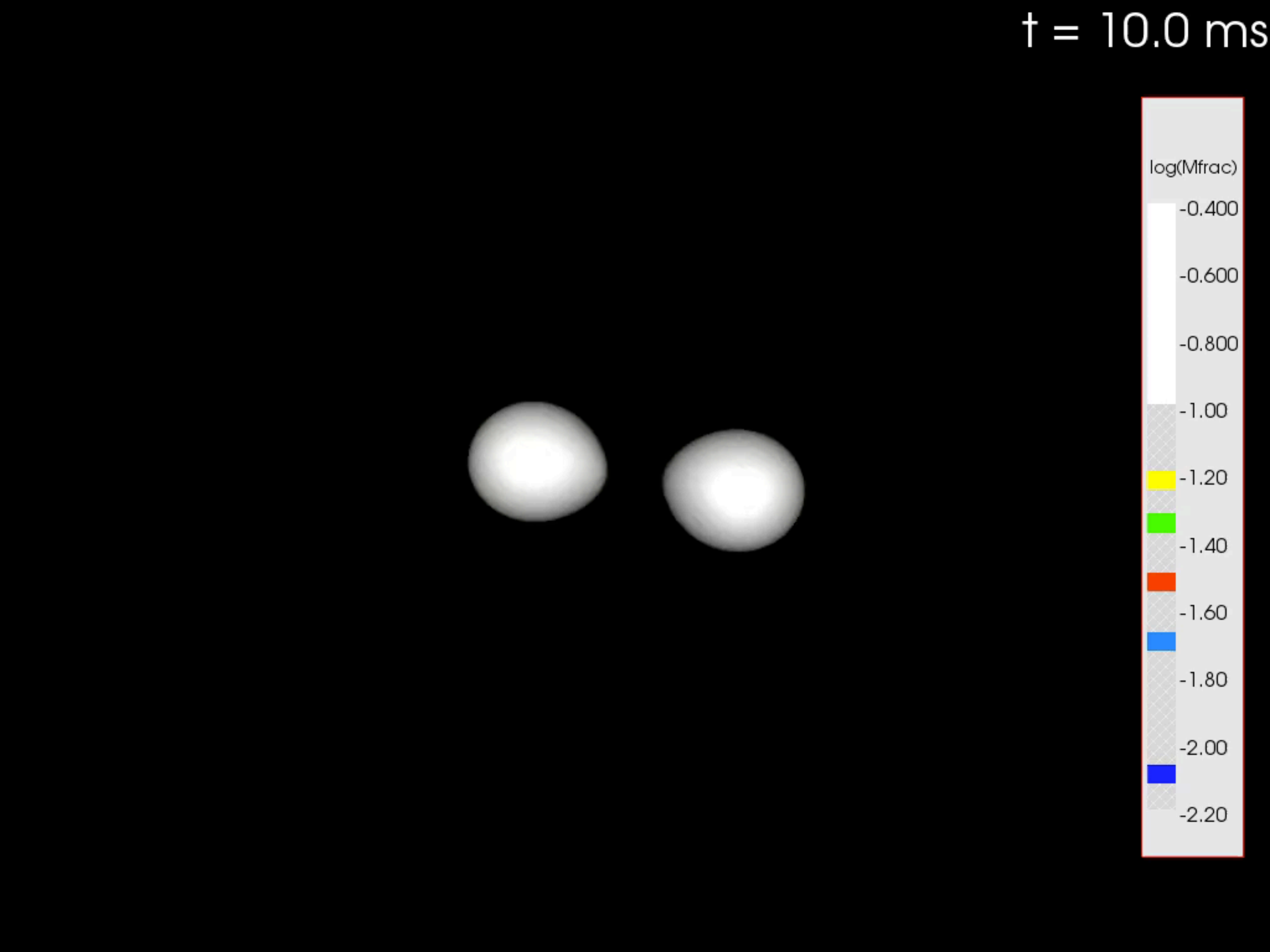
Part I - Summary

- Possible to form stable NS after merger
- Magnetar level field expected inside (outside?)

Structure of Stable Binary Neutron Star Merger Remnants: a Case Study

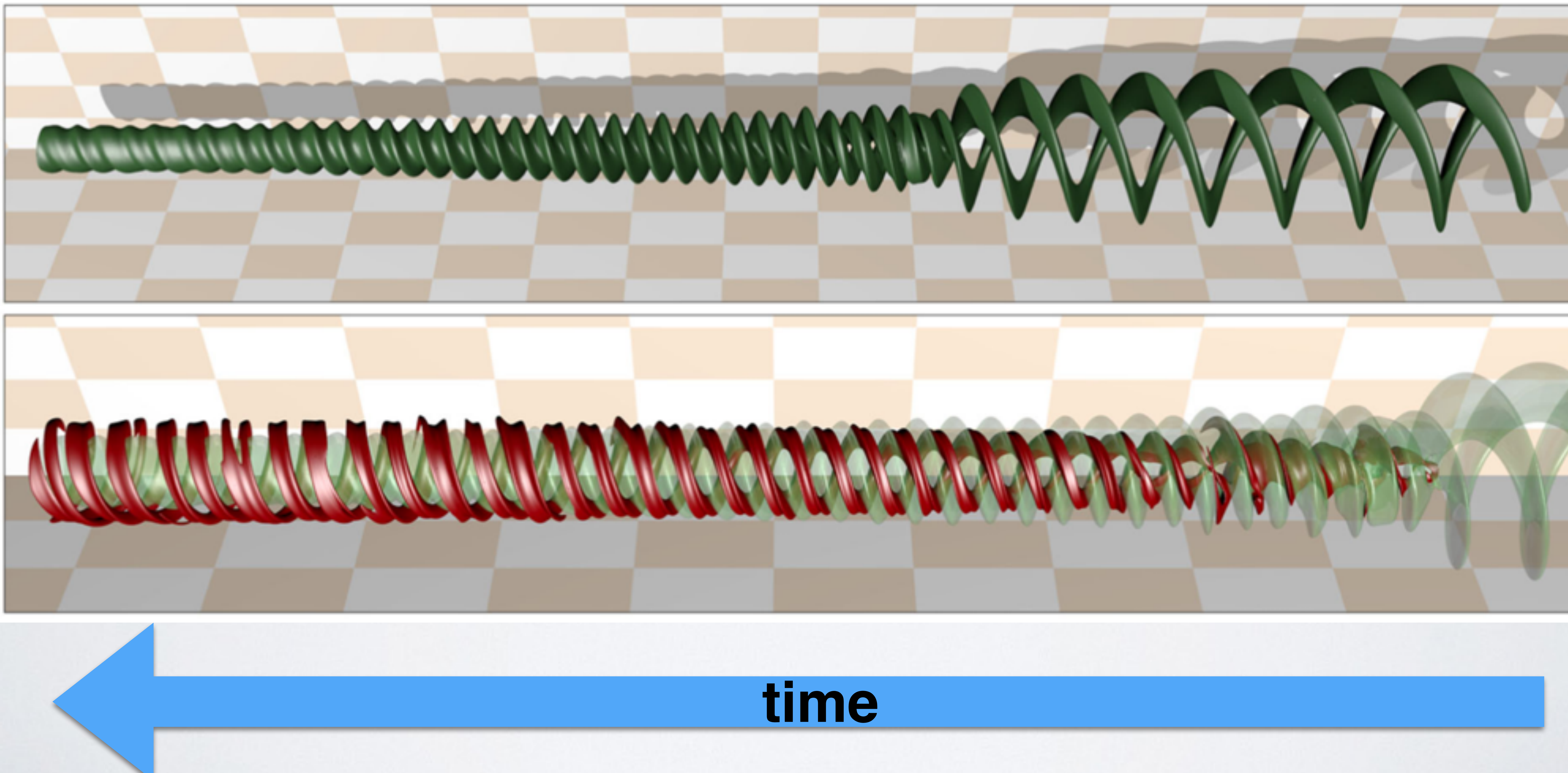
Kastaun, Ciolfi, and Giacomazzo 2016, PRD 94, 044060

- Equal mass, M=1.4 $M_{\odot}$
- EOS: G. Shen, Horowitz, Teige (finite temperature EOS)
- Maximum TOV baryonic mass 3.38 $M_{\odot}$ (Remnant is stable!)
- No magnetic field
- No neutrino radiation
- Evolved with WhiskyThermal (Galeazzi, Kastaun et al 2013)

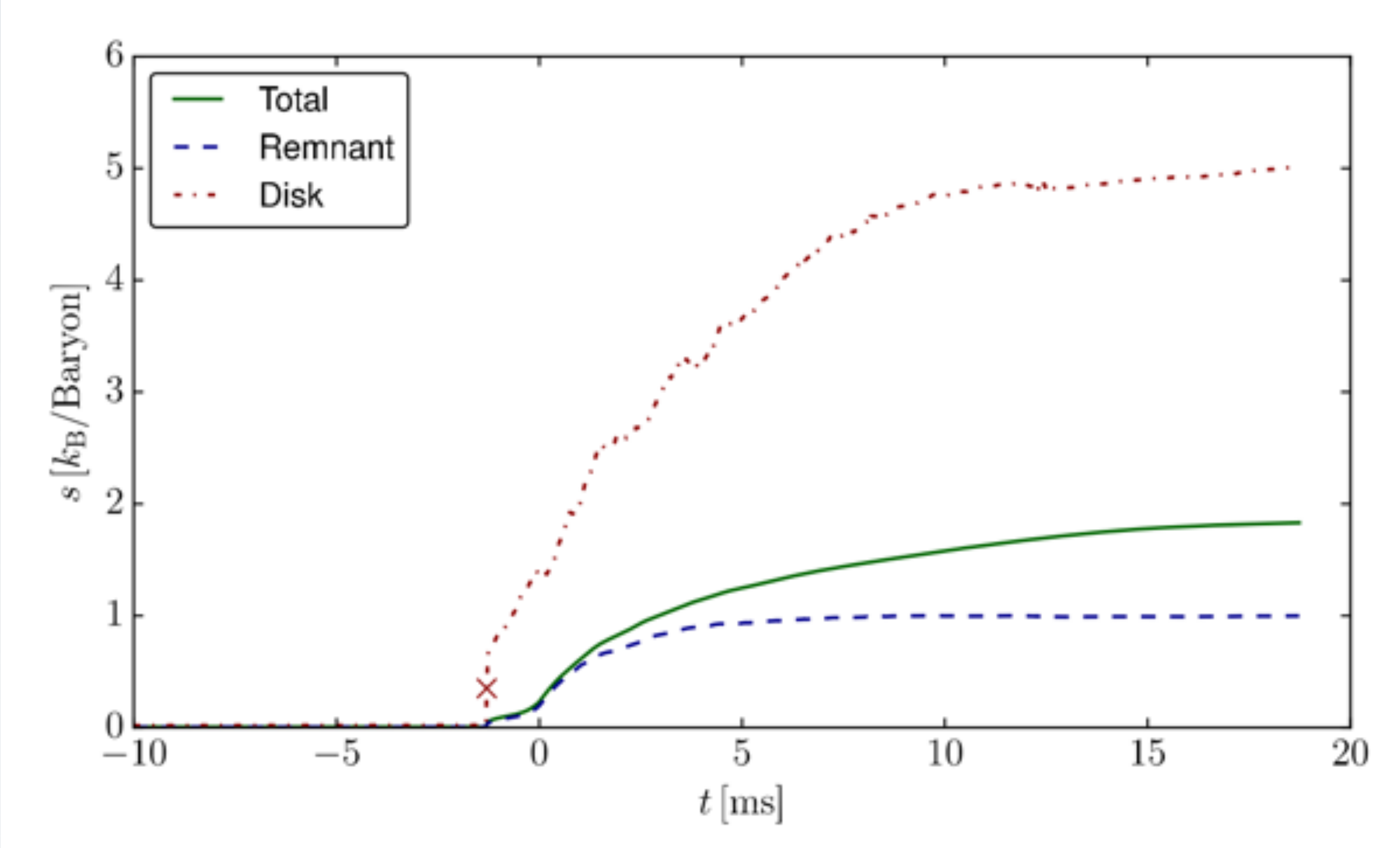

t = 10.0 ms
log(Mfrac)
-0.400
-0.600
-0.800
-1.00
-1.20
-1.40
-1.60
-1.80
-2.00
-2.20

Structure of Stable Binary Neutron Star Merger Remnants: a Case Study

Kastaun, Ciolfi, and Giacomazzo 2016, PRD 94, 044060

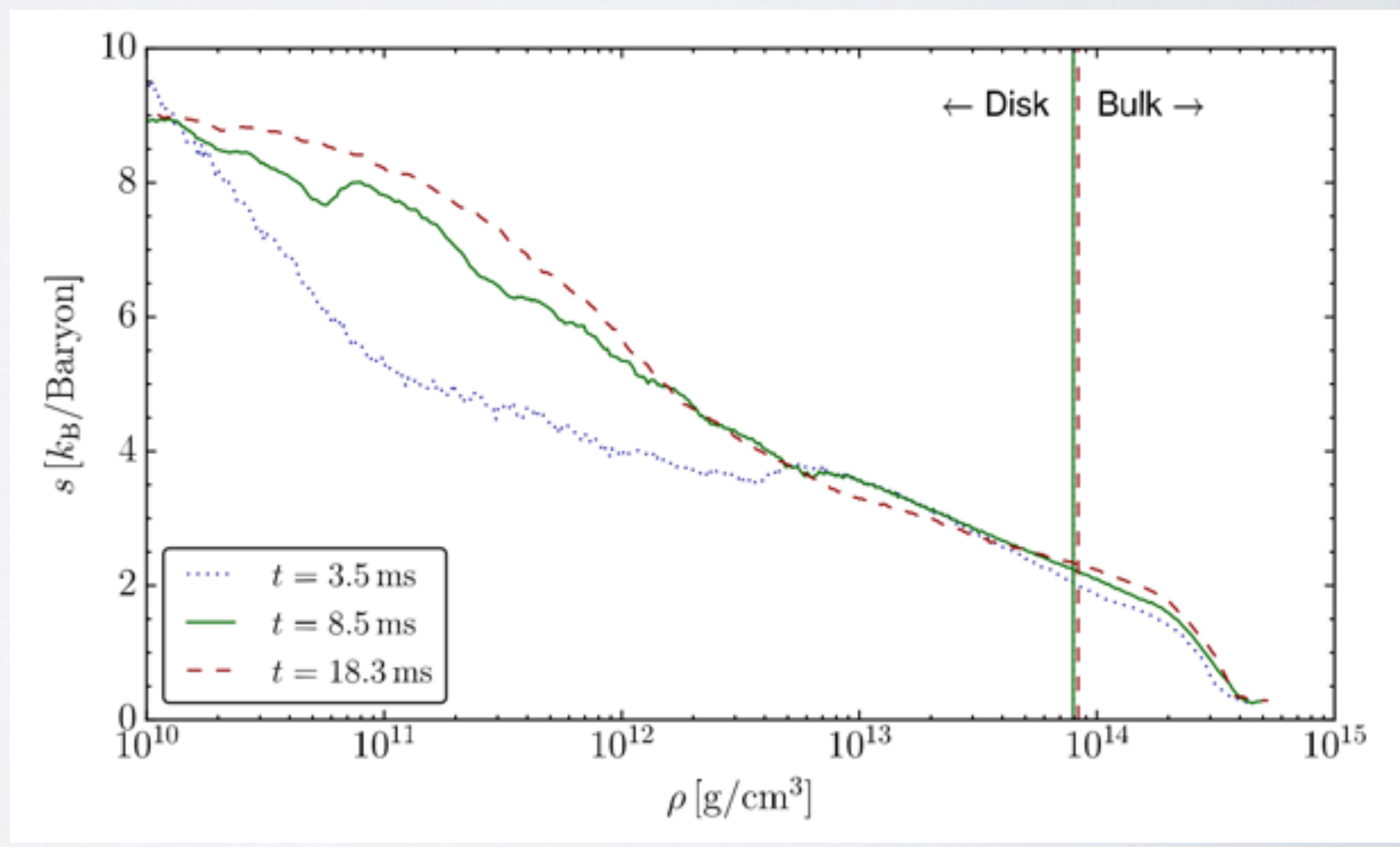


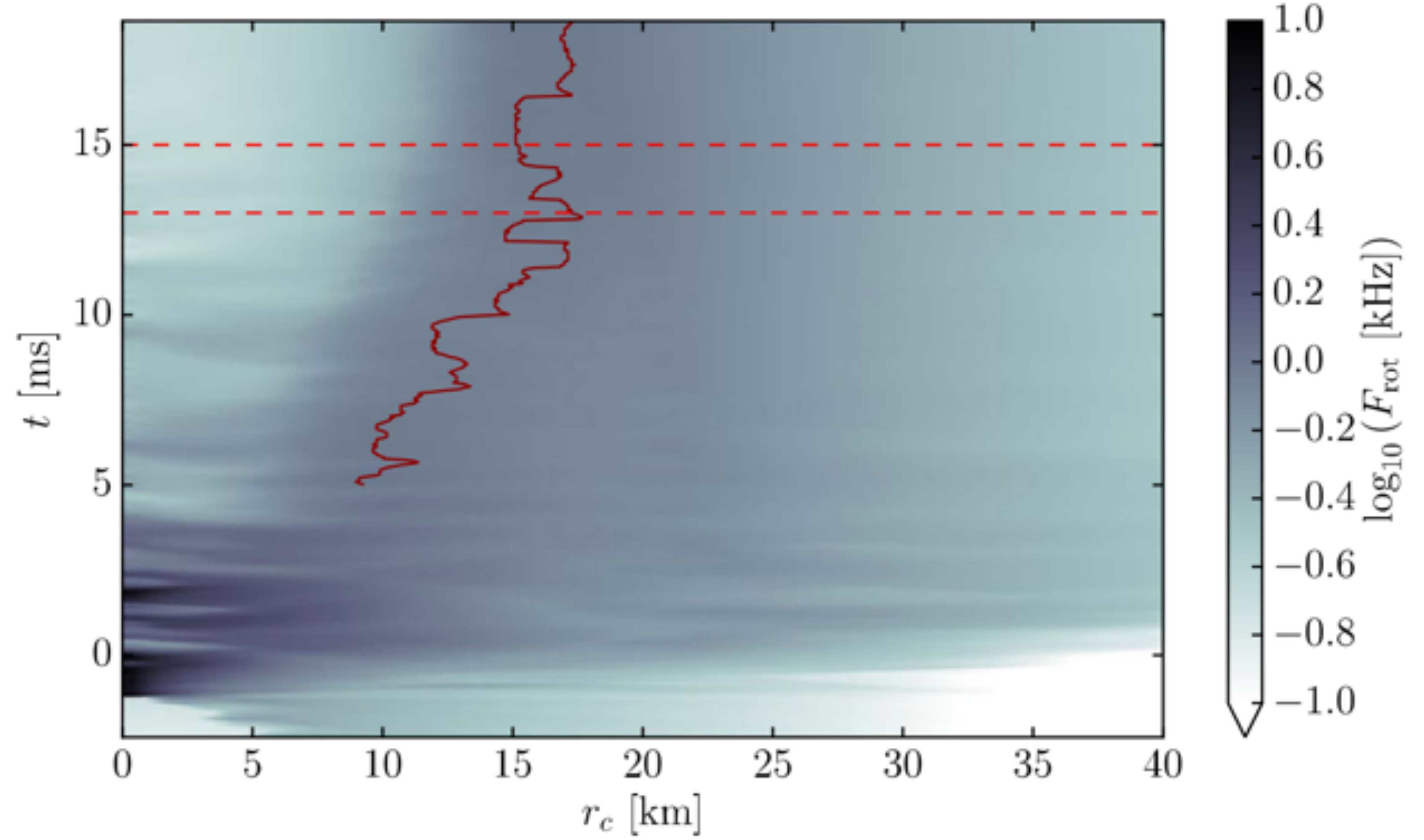

t = 10.0 ms



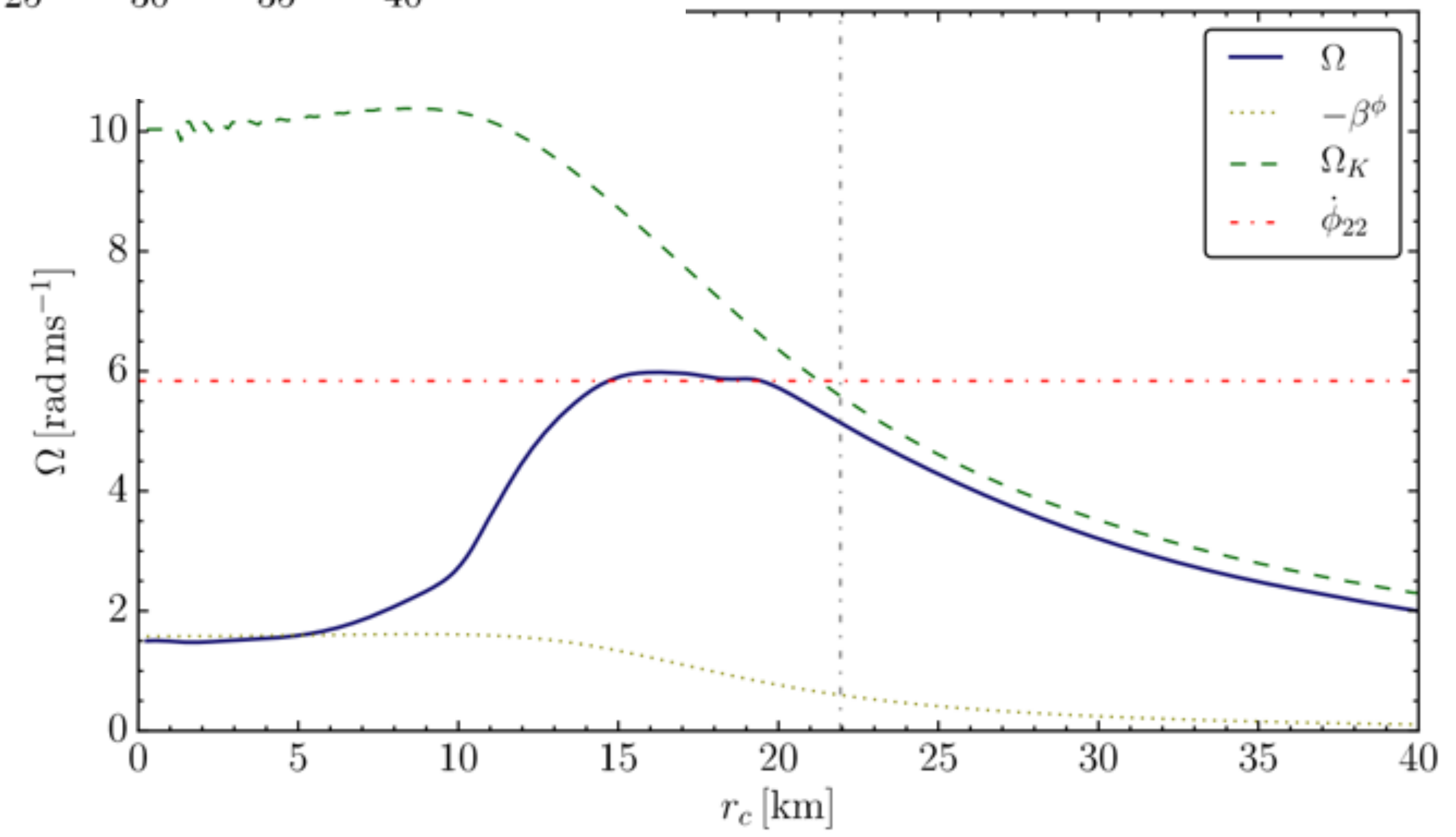
Average specific entropy stays constant in the core

Disk continuously heated by shock waves



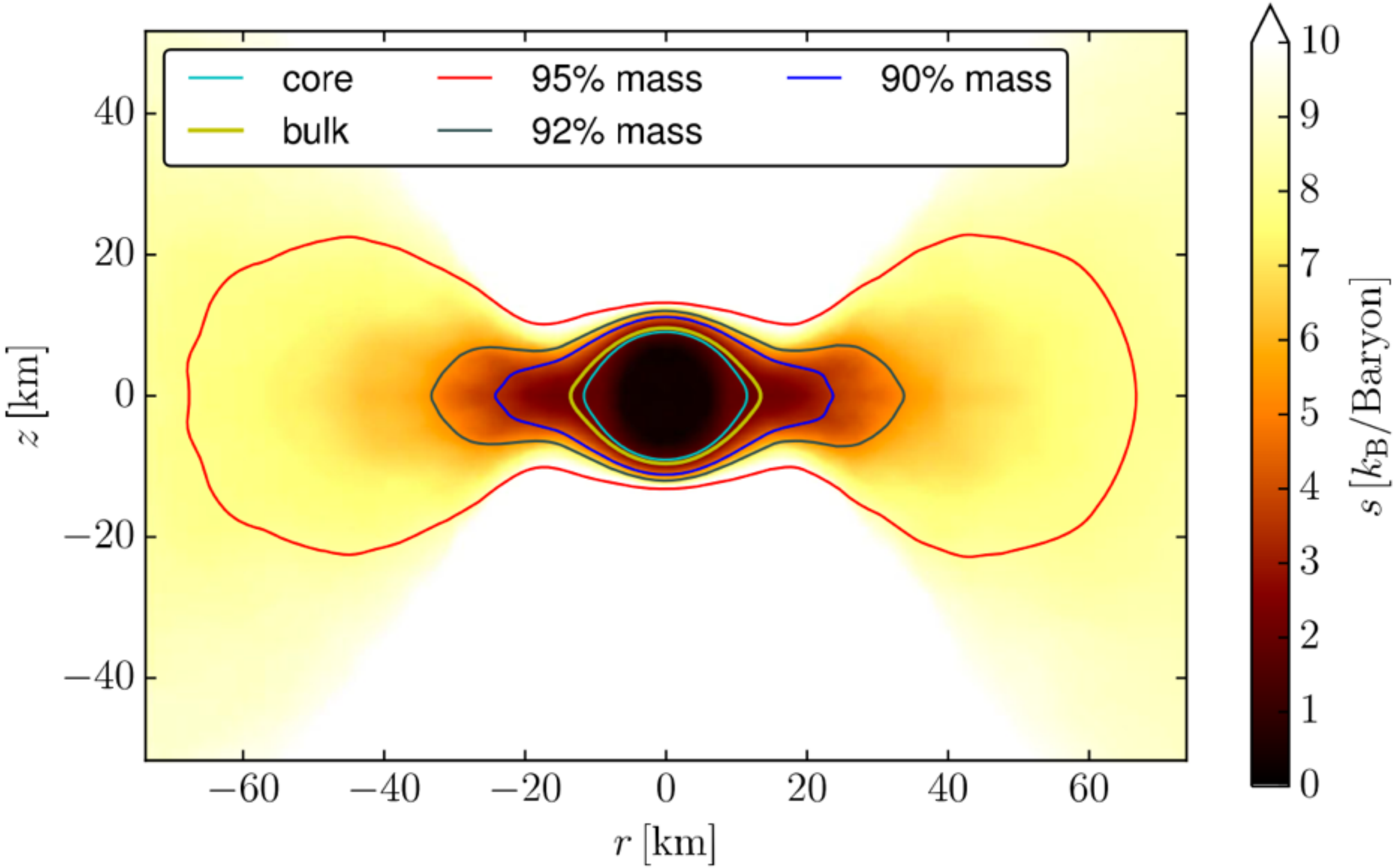


Core faster rotating soon after merger, but "slows" down



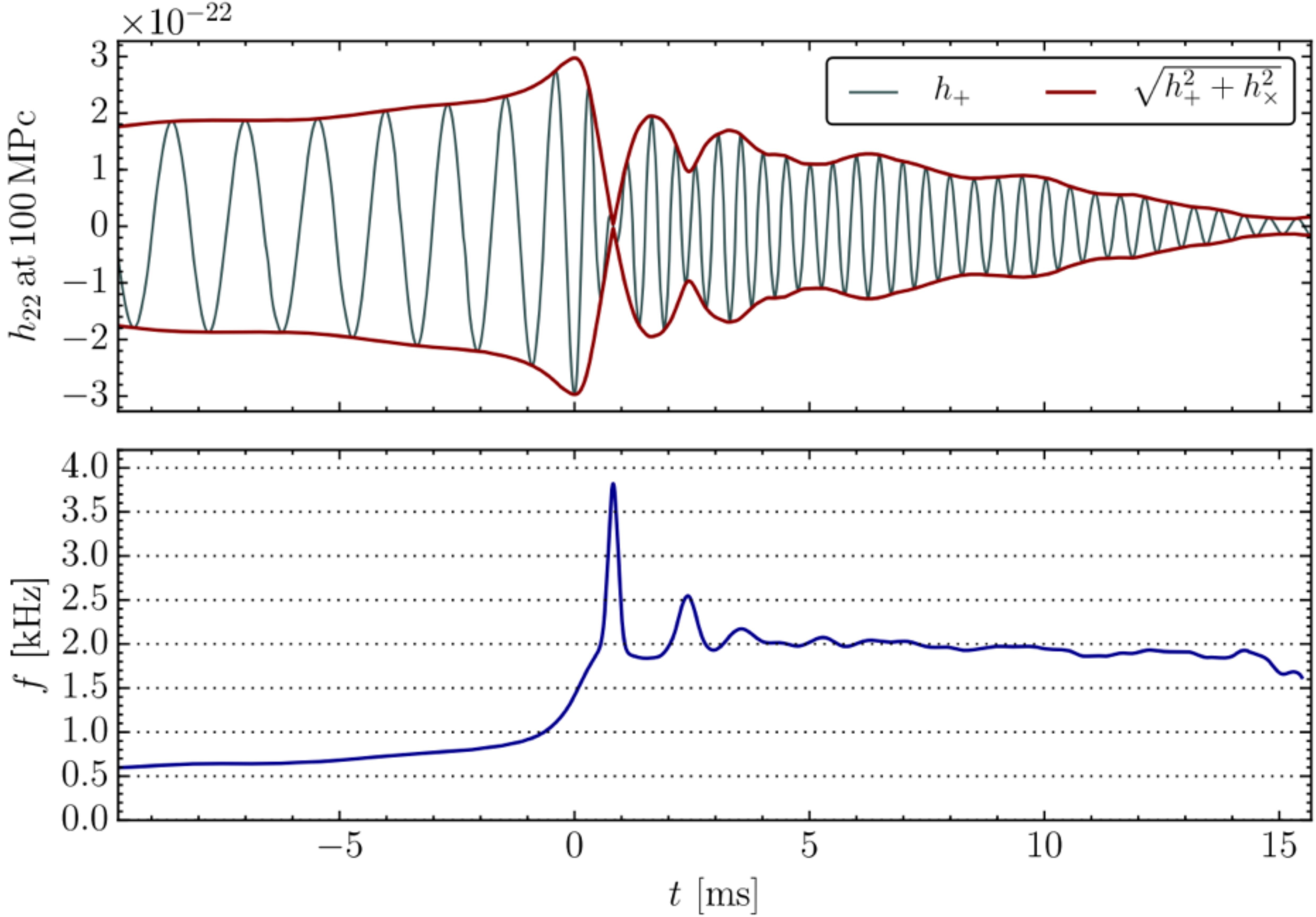
Uniformly rotating core surrounded by Keplerian disk

Disk

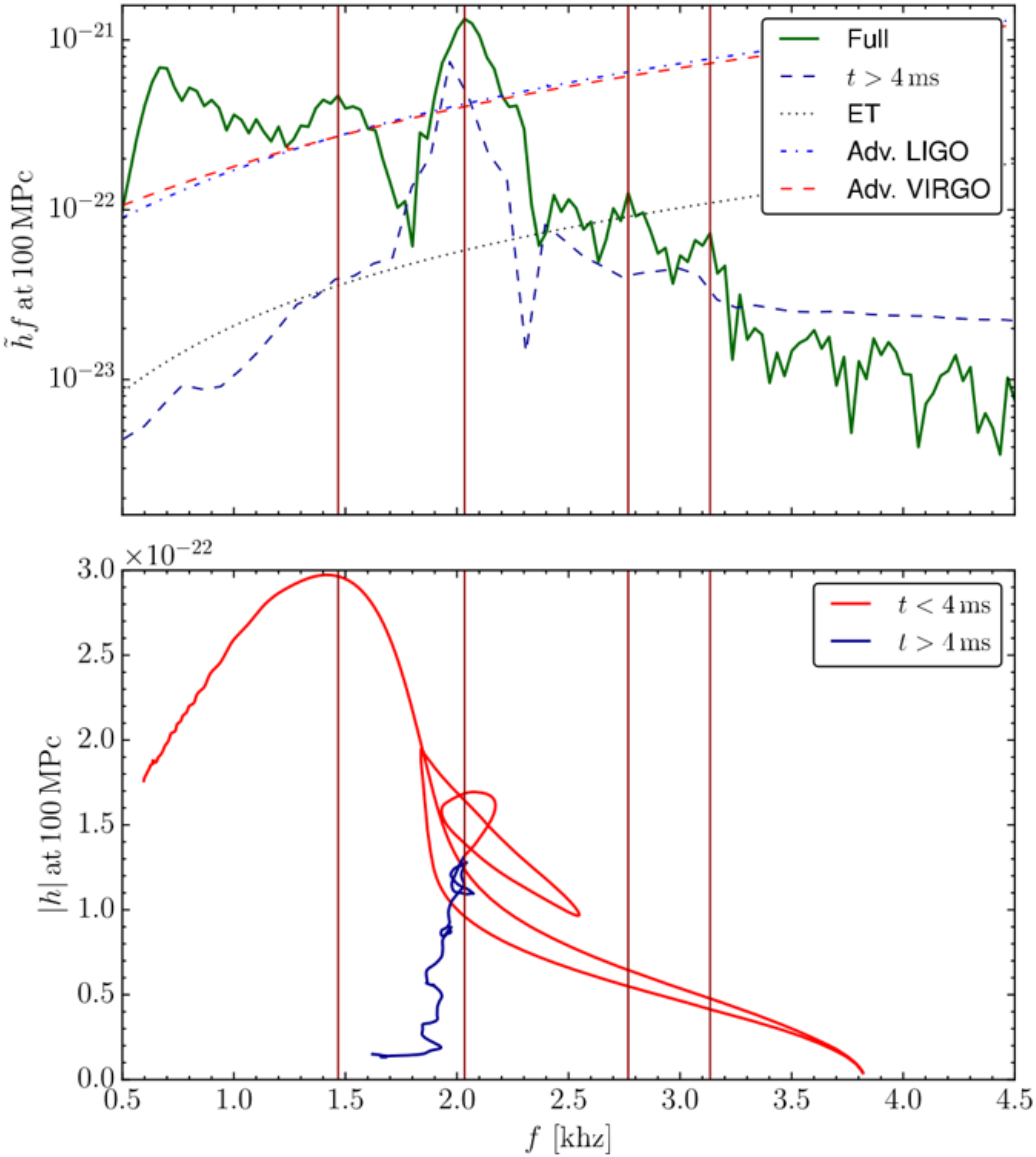


~3x10^{-4} M$_\odot$ ejected few ms after merger with v~0.12 c.

Gravitational Waves



Gravitational Waves



Prominent peak at ~2 kHz mainly due to post-merger evolution

Note that we evolved this model for ~20 ms after merger

Summary

- GRHD/GRMHD simulations of low-mass BNS mergers
- Possible to form stable or long-lived NS after merger
- Magnetar level fields expected inside (outside?)
- no j-constant law: slowly rotating core surrounded by Keplerian disk
- no uniform temperature: hot spots forming a ring (neutrino cooling role to be investigated)
- Bulk temperature almost constant, but increasing in the disk
- GWs can provide information on post-merger dynamics
- Numrel can only simulate few ms of post-merger evolution…