MAGNETAR FORMATION FROM THE MERGER OF BNS

Bruno Giacomazzo
University of Trento and INFN-TIFPA, Italy
Depending on mass and EOS several post-merger scenarios:

- Magnetic fields play fundamental role in post-merger dynamics (jets from BH/NS+torus, NS collapse to BH, ...)

All these scenarios may lead to SGRBs with different properties.
WHY DO WE NEED A MAGNETAR?

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

X-ray afterglow emitted by magnetar
SGRB emitted by BH after magnetar collapse

X-ray precursors or GW emission can be used to validate this model

Can we form magnetars from BNS mergers?
Investigated merger of two 1.2 M☉ NSs

Used Ideal Fluid, Gamma=2.75, k=30000 (Oechslin et al 2007)
Investigated merger of two 1.2 $M_\odot$ NSs

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

Produced a stable “ultraspinning” NS ($J/M^2\sim0.9$) surrounded by a magnetized disk of $\sim0.1 M_\odot$. 

MAGNETAR FORMATION


Magnetic field amplified of $\sim 2$ 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 AT MERGER

During the merger a shear interface forms and it develops a Kelvin-Helmholtz instability which produces a series of vortices.

\[ \rho | \nabla \times \mathbf{v} |^2 \]

\[ (v^x, v^y) \text{ in "corotating" frame} \]
Even with quite high resolutions (up to ~170m) we do not observe strong magnetic field amplifications in our simulations. It looks difficult to produce magnetar-level fields.
Performed local very high resolution relativistic MHD simulations of turbulent flows.

Magnetic energy reaches equipartition with kinetic energy.

Similar results (in Newtonian MHD) were obtained by Obergaulinger et al 2010.
We developed a sub-grid model to account for small scale effects:

\[ \partial_t A_i = -E_i + S_{\text{subgrid}} A_i \]

\( S_{\text{subgrid}} \) is different from zero only in the central turbulent region. Magnetic field amplification is larger in the central vortices.
We implemented the sub-grid model in our GRMHD code Whisky and run a set of NS-NS simulations.
IS IT “REAL”?  
(Kiuchi et al. 2015, arXiv:1509.09205)

Used resolutions more than 10 times higher than “standard” BNS simulations (17.5 m vs ~200 m).

Magnetic field grows of at least ~3 orders of magnitude

Magnetic energy grows to ~$10^{50}$ erg

Very expensive supercomputer simulation. Subgrid model may help when investigating large parameter space.
Strong toroidal field can deform the NS in a prolate shape

We used new twisted torus NS equilibrium configurations
GWS FROM MAGNETARS


If NS EOS supports 2.4 $M_\odot$ then long post-merger signal in $\sim$kHz range.
Signal may be truncated by collapse or EM spindown.

SNR for stable magnetar at $D \sim 75$ Mpc

Figure by Dall’Osso
CONCLUSIONS

• Stable and Supramassive NSs may be formed after merger
• Magnetic fields can be strongly amplified via small scale turbulence (but still a lot of work to do to get an actual magnetar)
• GW and EM signals may be affected by magnetar formation
• GW detection from long-lived magnetar could also constrain EOS
• Note: magnetar scenario strongly dependent on max NS mass!

References: