**MoU INAF-Cineca**

**Report on project INA17_C2A11**

# GRMHD simulation of the binary neutron star merger event GW170817

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In this project, we performed general relativistic magnetohydrodynamics (GRMHD) simulations of the merger of two neutron stars in a binary system. In particular, we reproduced possible scenarios consistent with the recently observed event GW170817, the first and only binary neutron star (BNS) merger detected so far in gravitational waves by the LIGO and Virgo interferometers. This crucial discovery was also accompanied by the observation of a variety of electromagnetic signals across the entire spectrum, including a short gamma-ray burst (SGRB) and a radioactively-powered kilonova. In our work, we focussed specifically on the connection between SGRBs and BNS mergers, addressing the open question about the precise mechanism through which the merger remnant system would be able to launch a relativistic jet and thus act as a SGRB central engine.

Our investigation is unique in two ways. First, GRMHD simulations of BNS mergers focussed so far only on the case in which a black hole (BH) surrounded by an accretion disk is formed shortly after merger ($<100\,\mathrm{ms}$). This case corresponds to the well-studied SGRB scenario in which the accreting BH acts as the central engine powering the jet. There is however the alternative possibility that the merger results in a long-lived massive neutron star, able to survive for much longer timescales until the eventual collapse to a BH. In this scenario, a jet could be launched before BH formation, via a different mechanism not based on accretion. A systematic investigation of the latter case was initiated only recently in our previous work (Ciolfi et al. 2017) and now continued with the present project. No other numerical relativity group has so far published similar results.

The second aspect making our investigation unprecedented is the fact that we explored a very long post-merger evolution ($\sim$100 ms), much longer than previous GRMHD simulations (typically limited to $20-40$ ms). This gave us the opportunity to obtain a much more complete picture on the system rearrangement and the characteristics that define its ability to produce a jet.

We employed our resources to study both equal and unequal-mass BNS systems, keeping fixed the neutron star equation of state (i.e. APR4) and the total mass of the system (consistent with the value estimated for GW170817). The first equal-mass simulation was completed by the end of the allocation and we already wrote a paper containing detailed results on jet formation and several other crucial aspects. This paper (Ciolfi et al. 2019) will be submitted within the next 1-2 weeks, and until then we cannot present any specific result. The second simulation, with the two progenitor neutron star masses differing by a factor 0.9, was performed only in part and we are now continuing it with the new allocation INA17_C3A23. This will lead to at least one more publication by the end of 2019.

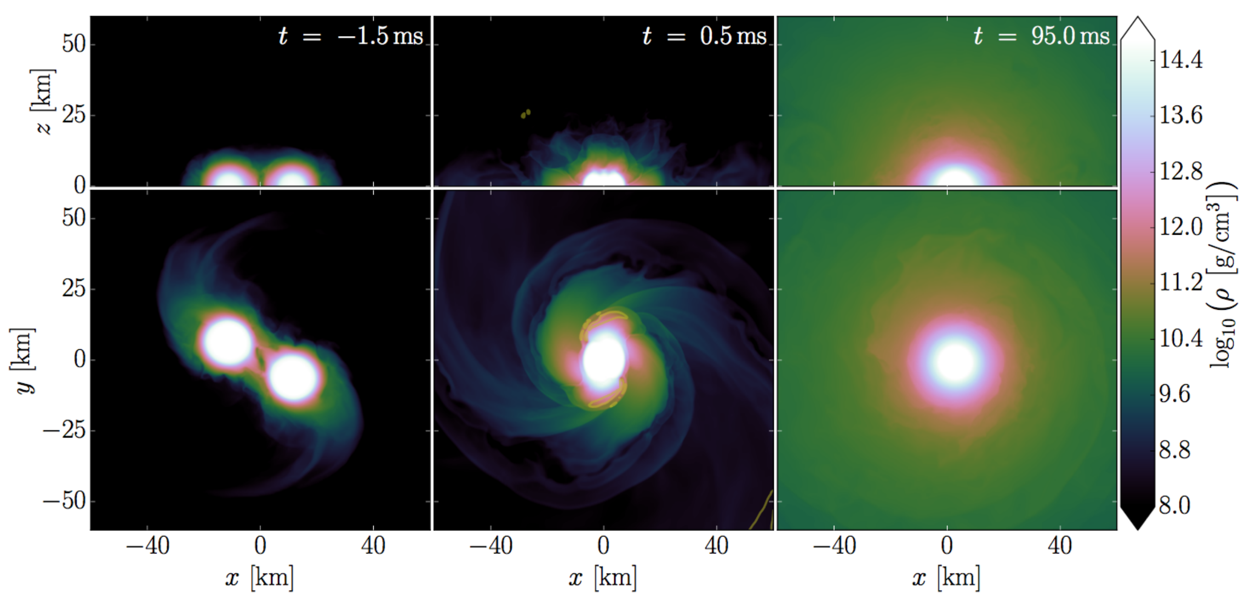


FIG. 1: Meridional (top) and equatorial (bottom) view of the rest-mass density evolution for our magnetized equal-mass BNS model from around merger time till the end of the simulation. Here $t = 0$ corresponds to the merger time.

Our two projects based on the MoU INAF-Cineca (INA17_C2A11 and INA17_C3A23) represent a significant step forward in the GRMHD investigation of BNS mergers leading to long-lived NS remnants. As such, they also pose a solid basis for a very competitive new proposal in a future PRACE and/or ISCRA call. In this respect, a project like INA17_C2A11 was extremely useful to maintain our leadership on a cutting-edge research line while providing convincing preliminary steps towards larger computational resource applications.

**References**

Ciolfi R., et al. 2017, PRD 95, 063016

Ciolfi R., et al. 2019, in preparation