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Approaching ballistic motion in 3D simulations of gamma-ray burst jets emerging from realistic binary neutron star merger environments

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The concomitant observation of the gravitational wave signal from a binary neutron star (BNS) merger and its electromagnetic counterparts in 2017 confirmed that these events can produce relativistic jets responsible for short Gamma-Ray Bursts (sGRBs). The complex interaction between the jet and the surrounding post-merger environment shape the angular structure of the outflow, that is then imprinted in the prompt and afterglow sGRB emission. The outcome of relativistic (magneto)hydrodynamic simulations of jets piercing through post-merger environments is often used as input to compute the corresponding afterglow signal to be directly compared with sGRB observations. However, for a reliable comparison the jet propagation has to be followed until a nearly ballistic phase, in which jet acceleration is essentially over and the angular structure is no longer evolving. Such a condition is typically met in 2D simulations, but not in 3D. Here, we present the methods that we developed to extend our 3D jet simulations up to a nearly ballistic phase. As reference model, we consider the fiducial case presented in Pavan et al. (2023), representing the first 3D simulation of a magnetized sGRB jet emerging from the realistic magnetized post-merger environment directly imported from a BNS merger simulation. Extending the 3D evolution from about 3 to 10 seconds, the final jet available energy is about 98 per cent kinetic and its angular structure is frozen, offering proper input for computing the afterglow emission.

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