Accurate evolutions of unequal-mass neutron-star binaries: properties of the torus and short GRB engines

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We present new results from accurate and fully general-relativistic simulations of the coalescence of unmagnetized binary neutron stars with various mass ratios. The evolution of the stars is followed through the inspiral phase, the merger and prompt collapse to a black hole, up until the appearance of a thick accretion disk, which is studied as it enters and remains in a regime of quasi-steady accretion. Although a simple ideal-fluid equation of state with \Gamma=2 is used, this work presents a systematic study within a fully general relativistic framework of the properties of the resulting black-hole--torus system produced by the merger of unequal-mass binaries. More specifically, we show that: (1) The mass of the torus increases considerably with the mass asymmetry and equal-mass binaries do not produce significant tori if they have a total baryonic mass M_tot >~ 3.7 M_sun; (2) Tori with masses M_tor ~ 0.2 M_sun are measured for binaries with M_tot ~ 3.4 M_sun and mass ratios q ~ 0.75-0.85; (3) The mass of the torus can be estimated by the simple expression M_tor(q, M_tot) = [c_1 (1-q) + c_2] (M_max-M_tot), involving the maximum mass for the binaries and coefficients constrained from the simulations, and suggesting that the tori can have masses as large as M_tor ~ 0.35 M_sun for M_tot ~ 2.8 M_sun and q ~ 0.75-0.85; (4) Using a novel technique to analyze the evolution of the tori we find no evidence for the onset of non-axisymmetric instabilities and that very little, if any, of their mass is unbound; (5) Finally, for all the binaries considered we compute the complete gravitational waveforms and the recoils imparted to the black holes, discussing the prospects of detection of these sources for a number of present and future detectors.

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