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Statistical studies of Spinning Black-Hole Binaries[1]

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We study the statistical distribution of the spins of generic black-hole binaries during the inspiral and merger, as well as the distribution of the remnant mass, spin, and recoil velocity. For the inspiral regime, we start with a random uniform distribution of spin directions $\vec{S}_1$ and $\vec{S}_2$ over the sphere and magnitudes $|\vec{S}_i/m_i^2| = 0.97$ for different mass ratios. Starting from a fiducial initial separation of $r_i = 50m$, we performs 3.5 post-Newtonian evolutions down to a separation of $r_f = 5m$, where $m = m_1+m_2$. At this final separation, we compute the angular distribution of the spins with respect to the final orbital angular momentum. We perform 16^4 simulations for mass ratios between $q = 1$ and $q = 1/16$ and compute the distribution of the angles $\hat{\vec{L}} \cdot \hat{\vec{\Delta}}$ and $\hat{\vec{L}} \cdot \hat{\vec{S}}$, directly related to recoil velocities. We find a small but statistically significant bias of the distribution towards counter-alignment of both scalar products. To study the merger of black-hole binaries, we introduce empirical formulae to describe the final remnant black hole mass, spin, and recoil velocity for merging black-hole binaries with arbitrary mass ratios and spins. Our formulae are based on the post-Newtonian scaling with amplitude parameters chosen to fit recently available fully nonlinear numerical simulations. We then evaluate these formulae for randomly chosen directions of the individual spins and magnitudes, and the binary's mass ratio. We found that the magnitude of the recoil velocity has a decaying e-folding distribution with a mean value of 2500 km/s, and a highly peaked angular distribution along the final orbital axis. The distribution of the final black-hole spin magnitude show an universal distribution highly peaked at $S_f/m_f^2 = 0.73$ and with a nearly 25° degree misalignment with respect to the final orbital angular momentum, just prior to full merger of the holes.

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