W47a Binary Black Boles from First Stars: Dependence on Initial Conditions and Stellar Models

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Recently, mergers of binary black holes (BH-BHs) have been discovered by gravitational wave (GW) observations. However, the origins of these BH-BHs have been under debate. One of promising candidates is massive star binaries. First star binaries are also promising, since they tend to form BH-BHs with $30M_\odot$ BHs frequently observed by GW observations.

We examine the dependence of first star BH-BHs on initial conditions and stellar models. We adopt 10 and $200R_\odot$ for initial minimum pericenter distances ($a_{\rm min}$), and 0.0 and 0.9 for initial minimum mass ratios ($q_{\rm min}$). We also investigate stellar models with and without stellar winds and supernova kicks, and stellar models with large and small convective overshooting. The fiducial model has $a_{\rm min} = 10R_\odot$, $q_{\rm min} = 0.0$, no stellar wind nor supernova kick, and the larger convective overshooting. In the fiducial model, the current merger rate density is 0.1 $\rm yr^{-1}$ $\rm Gpc^{-3}$. The merger rate density weakly depends on initial conditions and stellar models. However, BH mass distributions are largely changed. If we adopt $a_{\rm min} = 200R_\odot$, the presence of stellar winds, or the smaller convective overshooting, first star binaries are hard to form $30M_\odot$ BHs. Moreover, if we choose the smaller convective overshooting, we find first star binaries can easily form GW 190521-like BH-BHs, which should be hard to form due to pair instability supernovae.