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Binary neutron star formation and the origin of GW170817

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The first neutron star-neutron star merger (NS-NS: GW170817) was detected in gravitational waves by LIGO/Virgo in a galaxy in which the majority of star formation was taking place a long time ago (~11 Gyr). Only some extreme evolutionary models (with small NS natal kicks and high common envelope efficiency) can generate NS-NS merger rates in old host galaxies consistent with the LIGO/Virgo estimate (>100 Gpc−3yr−1). However, we show that these models generate rates exceeding empirical Galactic NS-NS merger rates based on the large population of Milky Way NS-NS binaries. Typically, evolutionary models produce NS-NS merger rates that are consistent with the Milky Way empirical rates (~10–200 Myr−1). However, these models generate local cosmic NS-NS merger rate in old host galaxies (~1–70 Gpc−3yr−1) below the LIGO/Virgo estimate. The reason behind this tension is the predicted delay time distribution between star formation and NS-NS mergers that favors short delays. Evolutionary models produce a generic steep power-law NS-NS delay time distribution. This limits NS-NS merger rates in old host galaxies. However, we show that such distribution is consistent with observations of Galactic NS-NS binaries; 50% of which show very long merger times (much longer than Hubble time). Once model distributions are convolved with continuous prolonged star formation in the Galactic disk, then~20–70% of the predicted NS-NS population has very long current Galactic merger times (>30 Gyr). Although NS-NS binaries are formed predominantly with short delay times, many of short delay time systems merge, while long delay time systems survive and contribute to the current Galactic NS-NS population. This study highlights the tension between the current evolutionary predictions and the observation of the first NS-NS merger in an old host galaxy. It is crucial to understand that models need to explain not only the LIGO/Virgo rate estimate, but also the merger site.

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