AN UPDATED GALACTIC DOUBLE NEUTRON STAR MERGER RATE BASED ON RADIO PULSAR POPULATIONS

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1. UPDATING THE GALACTIC DOUBLE NEUTRON STAR MERGER RATE

In this research note, we update the Galactic double neutron star (DNS) merger rate by including the new, highly eccentric DNS system J0509+3801 (Lynch et al. 2018) which was recently discovered with the Green Bank North Celestial Cap survey (GBNCC, Stovall et al. 2014). We follow the same procedure described in Pol et al. (2019), but add the GBNCC survey to the list of surveys chosen for simulations (see Sec. 2.2 in Pol et al. 2019). Since it has not been measured, we assume a beaming correction factor of 4.6 for this pulsar, which is the average of the beaming correction factor of the known DNS systems (see Sec. 2.5 of Pol et al. 2019).

Consequently, the new Galactic DNS merger rate is \( \mathcal{R}_{MW} = 37_{-11}^{+24} \) Myr\(^{-1} \), where the errors represent 90% confidence intervals. The small decrease (of \( \sim 12\% \)) in the total merger rate is due to the addition of the large GBNCC survey volume, but with the addition of only one merging DNS system to the total observed population. We can also see that the addition of a new DNS system results in tighter constraints on the Galactic DNS merger rate.

2. UPDATING THE MERGER DETECTION RATE FOR ADVANCED LIGO

Similar to Pol et al. (2019), we can use this Galactic DNS merger rate to predict the number of DNS merger events that LIGO (Harry & LIGO Scientific Collaboration 2010) will be able to detect. However, there was an error in the implementation of Eq. 15 in Pol et al. (2019). We used the range distance \( D_r \) instead of the horizon distance \( D_h \) in this equation, for a more conservative estimate, but have since realized that the derivation in Kopperapu et al. (2008) already accounted for the reduction in LIGOs sensitivity due to the orientation of the gravitational wave source with respect to the terrestrial detectors. Therefore, the horizon distance, which is a factor of 2.26 larger than the range distance \( D_h = 2.26 \times D_r \) (Chen et al. 2017), should be used with Eq. 15 in Pol et al. (2019) in place of the range distance.

Using the horizon distance in Eq. 15 of Pol et al. (2019) along with the updated Galactic DNS merger rate results in a merger detection rate for LIGO,

\[
\mathcal{R} = 1.9_{-0.6}^{+1.2} \times \left( \frac{D_r}{100 \text{ Mpc}} \right)^3 \text{yr}^{-1},
\]

where \( D_r \) is the range distance. Using the LIGO O3 range distance of 130 Mpc (Abbott et al. 2018), we predict that LIGO will detect anywhere between three and seven DNS mergers per year of observing at O3 sensitivity.

We can compare this merger detection rate derived from the observed Galactic DNS population to that calculated using LIGO’s second observation of a DNS merger event, GW190425 (The LIGO Scientific Collaboration et al. 2020). The DNS merger detection rate calculated using GW190425 and GW170817 (The LIGO Scientific Collaboration et al. 2020), converted to the above units, is,

\[
\mathcal{R}_{\text{LIGO}} = 4.6_{-3.4}^{+7.1} \times \left( \frac{D_r}{100 \text{ Mpc}} \right)^3 \text{yr}^{-1}.
\]

We plot this merger rate together with the merger detection rate predicted using the Galactic DNS population in Fig. 1. As in Pol et al. (2019), we also plot the merger detection rate predictions due to variations in the underlying pulsar luminosity distribution, as well as including the effect of inclusion of elliptical galaxies in the merger rate extrapolation (Chen et al. 2017).

We conclude that the Galactic DNS merger detection rate is consistent with the merger detection rate calculated using gravitational wave detection of DNS mergers by LIGO. The number of alerts issued by LIGO in O3 for potential (i.e. unconfirmed) DNS mergers is also consistent with the predictions made using the Galactic DNS population.

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Updated DNS merger rate
LIGO DNS detection rate prediction
Including elliptical galaxy contribution
Smaller mean luminosity
Include elliptical correction and smaller mean luminosity

Fig. 1.— We compare the merger detection rate calculated using the observed Galactic DNS population (Eq. 1) with the rate calculated by LIGO’s second detection of a DNS merger (Eq. 2). We also show the variation in the predicted merger detection rate due to an underlying pulsar population with a lower mean luminosity, as well as the effect of including the contribution of elliptical galaxies in the extrapolation of the Galactic merger rate to LIGO’s observable volume (Kopparapu et al. 2008). We also plot the modified merger detection rate that includes both the correction for elliptical galaxies and a fainter DNS population. The data required to make this figure is provided as a supplementary table in CSV format.

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