Supplementary material to Rates of Compact Object Coalescences

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ABSTRACT
This is an accompanying note to "Rates of Compact Object Coalescences" by Mandel & Broekgaarden. Here, we describe the details of how inferred and predicted coalescence rates are extracted from the literature and converted into units of $\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$. The descriptions are typically based on the literature quoted and we refer the reader to the mentioned studies for more details. We welcome suggestions.

1 CONVERSION FACTORS

Coalescence rates are, in general, functions of redshift; we quote current local rates at redshift $z = 0$ per unit source time per unit comoving volume in units of $\mathrm{Gpc}^{-3}\ \mathrm{yr}^{-1}$. Where initially stated in different units, we convert these, using, as appropriate, factors of

$$1.7 \times 10^{10} \tag{1}$$

solar blue-light luminosities per Milky Way equivalent galaxy (MWEG),
a MWEG space density of

$$1.17 \times 10^{-2}\ \mathrm{MWEG}\ \ \mathrm{Mpc}^{-3} \tag{2}$$

from (Kopparapu et al. 2008),
a globular cluster space density of

$$2.9\ \mathrm{GC}\ \mathrm{Mpc}^{-3} \tag{3}$$

from (Portegies Zwart & McMillan 2000)
and a local supernova rate of

$$1.06 \cdot 10^{5}\ \mathrm{SN}\ \ \mathrm{Gpc}^{-3}\ \mathrm{yr}^{-1} \tag{4}$$

from (Taylor et al. 2014).

2 OBSERVATIONS

Here we list how we retrieved the different observational based merger rate densities that we quote in Tables 1, 2 and 3 and Figures 1,2 and 3 of the paper. They are ordered based on the groups of type of obesrvations, similar to the figures and tables. The order is: gravitational waves, kilonovae, galactic double neutron stars. Within a group we order the studies per year of the publication.

2.1 Gravitational-wave observations

2.1.1 BH-BH

We obtain the BH-BH merger rate densities based on gravitational-wave observations from Section 5.3 of Abbott et al. (2020), which presents the population analysis based on the events from the second gravitational-wave catalog GWTC-2. We do not quote the estimated BH-BH merger rate from the GWTC-1 catalog, since the gravitational GWTC-2 catalog gives the updated merger rate densities. We retrieve four different BH-BH merger rate densities from the GWTC-2 population paper (Abbott et al. 2020) listed below.

First, we took the redshift independent BH-BH rate $\mathcal{R}_{\mathrm{BH-BH}} = 23.9^{+14.3}_{-8.6}\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ (Section 5.3), that assumes a power law + peak mass model, a constant-in-comoving-volume merger rate and log uniform prior. Second, we took their merger rate density that the authors obtained assuming a redshift dependence. This rate is $\mathcal{R}_{\mathrm{BH-BH}} = 19.3^{+15.1}_{-9}\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ (Section 5.3), which the authors obtained using the POWER-LAW mass distribution model. Third, we quote the merger rate density from the 'Truncated model' presented by the authors in Section 5.3, which yields a higher merger rate than the other models; $\mathcal{R}_{\mathrm{BH-BH}} = 33^{+22}_{-12}\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ Fourth, we quote the merger rate density that is obtained by the authors whilst including GW190814. The models used above all exclude GW190814, which has a component mass below $3\,\mathrm{M}_{\odot}$. This gives the rate presented in their Section 5.3 of $\mathcal{R}_{\mathrm{BH-BH}} = 52^{+52}_{-26}\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$

2.1.2 NS-BH

We quote the two rate estimates based on the gravitational waves observations from Abbott et al. (2021): a rate of $\mathcal{R}_{\mathrm{NS-BH}} = 45^{+75}_{-33}\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ when assuming that GW200105 and GW200115 are representative of the NSBH population and the merger rate density of $\mathcal{R}_{\mathrm{NS-BH}} = 130^{+112}_{-69}\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ under the assumption of a broader distribution of component masses.

2.1.3 NS-NS

We retrieve the gravitational-wave observational merger rate density from Abbott et al. (2020). We report their NS-NS rate which is $\mathcal{R}_{\mathrm{NS-NS}} = 320^{+490}_{-240}\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

2.2 Short gamma-ray bursts (SGRB)

Coward et al. (2012) study the rate of short gamma-ray bursts using Swift data. We retrieve their rates from, e.g., their abstract. They find an SGRB lower rate density of $8^{+5}_{-3}\,\mathrm{Gpc^{-3}\,yr^{-1}}$ (assuming isotropic emission) and a beaming corrected upper limit of $1100^{+700}_{-470}\,\mathrm{Gpc^{-3}\,yr^{-1}}$. We decide to quote for their estimated range the range between the lowest lower limit and highest upper limit including the error bars and obtain the rate $\mathcal{R}_{\mathrm{NS-NS}} = [5, 1800]\,\mathrm{Gpc^{-3}\,yr^{-1}}$. We include all lower, center and upper values as points in the plot.

Petrillo et al. (2013) use data from the SWIFT satellite to estimate the NS-NS rate. We retrieve their rate, e.g., from the abstract, and find that this spans the range $\mathcal{R}_{\mathrm{NS-NS}} = [500, 1500]\,\mathrm{Gpc^{-3}\,yr^{-1}}$.

Fong et al. (2015) calculate the NS-NS rate from 11 short gamma-ray burst observations with opening angle measurements and lower limits. They calculate a beaming-corrected event rate of $\mathcal{R}_{\mathrm{NS-NS}} = 270^{+1580}_{-180}\,\mathrm{Gpc^{-3}}$ assuming a median opening angle of $16 + /-10$ degrees. We retrieve this, e.g., from their abstract.

Della Valle et al. (2018) calculate the NS-NS and/or short gamma-ray burst rate based on GRB170817 like events. We retrieve their rates from their Conclusion section (or see e.g. abstract). This gives a rate of $\mathcal{R}_{\mathrm{NS-NS}} = 352^{+810}_{-281}\,\mathrm{Gpc^{-3}\,yr^{-1}}$.

Jin et al. (2018) calculate the short gamma-ray burst and NS-NS rate based on short gamma-ray burst observations with redshift estimates. In particular, three Swift bursts in their sample have redshifts $z \lesssim 0.2$, with which they estimate the local neutron star merger rate density to be $\mathcal{R}_{\mathrm{NS-NS}} = 1109^{+1432}_{-657}\,\mathrm{Gpc^{-3}\,yr^{-1}}$, as given in the main text (e.g. abstract) when including GRB 061201.

Zhang et al. (2018) calculate the NS-NS and short gamma-ray burst rate based on GRB170817 like events. We retrieve their rate estimate from their Equation 1. This gives a rate of $\mathcal{R}_{\mathrm{NS-NS}} = 190^{+440}_{-160}\,\mathrm{Gpc^{-3}\,yr^{-1}}$.

Dichiara et al. (2020) examine the SWIFT database and calculate the short gamma-ray burst (and NS-NS) rate based on GRB170817 like events. We retrieved their ate from the Conclusion section. This gives a rate of $\mathcal{R}_{\mathrm{NS-NS}} = 160^{+200}_{-100}\,\mathrm{Gpc^{-3}\,yr^{-1}}$.

2.3 Kilonovae

Jin et al. (2016) use the two kilonovae detections to calculate an NS-NS merger rate estimate. However, the authors emphasize that their estimate should be a lower limit, since there can be a contribution from NS-BH and only a fraction of NS-NS might have kilonovae. We therefore take their lowest value, which is their estimate minus the lower error bar as a lower limit for the local NS-NS rate. This gives a rate estimate of $\mathcal{R}_{\mathrm{NS-NS}} \gtrsim 8.1\,\mathrm{Gpc^{-3}\,yr^{-1}}$, see e.g. their conclusions.

Doctor et al. (2017) find an upper limit using DES of $\mathcal{R}_{\mathrm{NS-NS}} \lesssim 24000\,\mathrm{Gpc^{-3}\,yr^{-1}}$ based on the paucity of transients like the kilonova accompanying GW170817.

Kasliwal et al. (2017) find an upper limit of $\mathcal{R}_{\mathrm{NS-NS}} \lesssim 800\,\mathrm{Gpc^{-3}\,yr^{-1}}$, using PTF, based on the paucity of transients like the kilonova accompanying GW170817.

Smartt et al. (2017) use ATLAS and find an upper limit of $\mathcal{R}_{\mathrm{NS-NS}} \lesssim 30000\,\mathrm{Gpc^{-3}\,yr^{-1}}$ based on the paucity of transients like the kilonova accompanying GW170817.

Yang et al. (2017) use DLT40 to find upper limit of $\mathcal{R}_{\mathrm{NS-NS}} \lesssim 99000\,\mathrm{Gpc^{-3}\,yr^{-1}}$ based on the paucity of transients like the kilonova accompanying GW170817.

Andreoni et al. (2021) use ZTF and find an upper limit of $\mathcal{R}_{\mathrm{NS-NS}} \lesssim 900\,\mathrm{Gpc^{-3}\,yr^{-1}}$ based on the paucity of transients like the kilonova accompanying GW170817.

2.4 Galactic double neutron stars

O'Shaughnessy et al. (2010) revisit the observed pulsar binaries to examine the sensitivity of birthrate predictions to different assumptions regarding opening angle and alignment. We retrieve their estimated rates from their Figure 5 from the black solid line (total tight NS-NS rate). We read out that the rate from this graph spans the range $\mathcal{R}_{\mathrm{NS-NS}} = 10^{-4.9}$–$10^{-3.6}\,\mathrm{yr^{-1}}$ per MWEG, with as peak the value $\mathcal{R}_{\mathrm{NS-NS}} \approx 10^{-4.15}\,\mathrm{yr^{-1}}$ per MWEG. We convert this to $\mathrm{Gpc^{-3}\,yr^{-1}}$ using Equation 2 and find that the authors predict a NS-NS rate in the range of about $[150, 2940]\,\mathrm{Gpc^{-3}\,yr^{-1}}$, with peak around $\mathcal{R}_{\mathrm{NS-NS}} \approx 800\,\mathrm{Gpc^{-3}\,yr^{-1}}$, this gives the rate estimate: $\mathcal{R}_{\mathrm{NS-NS}} \approx 830^{+2110}_{-680}$.

Kim et al. (2015) consider four pulsars that represent three NS-NS binaries in the Galactic disc to calculate the merger rate of double pulsars. We retrieve their Galactic merger rate, e.g., from their discussion (section 5) where they quote a rate of $\mathcal{R}_{\mathrm{d}} = 21^{+40}_{-17}\,\mathrm{Myr^{-1}}$ per MWEG, where we used the 99% confidence interval. Using Equation 2 we convert this to $\mathrm{Gpc^{-3}\,yr^{-1}}$ and obtain a rate of $\mathcal{R}_{\mathrm{NS-NS}} = 245^{+468}_{-199}\,\mathrm{Gpc^{-3}\,yr^{-1}}$.

Pol et al. (2020) update the estimate of the Galactic double neutron star merger rate based on their latest catalog of Galactic pulsars. We retrieve their NS-NS merger rate estimate from their Equation 1, which we convert to $\mathrm{Gpc^{-3}\,yr^{-1}}$ by multiplying with a factor $\times 10^3/(4/3\pi)$. This gives a range predicted as $\mathcal{R}_{\mathrm{NS-NS}} = 450^{+290}_{-140}\,\mathrm{Gpc^{-3}\,yr^{-1}}$.

3 MODELS

We mention below the predicted merger rate densities based on (theoretical) models. We order them by the different groups and then based on year. Only for isolated binary evolution group, we instead order the studies based on the binary population synthesis code that they used, as this database is very large. Note that this is slightly different ordering compared to the tables and figures in the paper.

3.1 Isolated binary evolution

3.1.1 BPASS

Eldridge et al. (2019) use BPASS and predict the rate of many different types of transients. We obtain their BH-BH, NS-BH and NS-NS rates from their Table 1 and Table 2, where we use the NSNS

NSBH and BH-BH rates from the redshift $z = 0$ column (note that these are given in log). We take into account the uncertainties that are quoted in the table by also adding the rate values that one obtains when adding or subtracting the uncertainties. We round the answer to ones. We retrieve $\mathcal{R}_{\rm NS-BH} = [209, 269]\,{\rm Gpc^{-3}\,yr^{-1}}$, $\mathcal{R}_{\rm NS-NS} = [339, 2178]\,{\rm Gpc^{-3}\,yr^{-1}}$ and $\mathcal{R}_{\rm BH-BH} = [65, 174]\,{\rm Gpc^{-3}\,yr^{-1}}$.

Tang et al. (2020) use BPASS and vary stellar evolution and star formation rate prescriptions to predict the compact object rates. We retrieve their rates from their Table 2 (using the first 3 columns) as well as all the rates from Table A1, which quotes the rates for all model realizations. We quote the rates interval on the order O(1). The rates obtained are $\mathcal{R}_{\rm BH-BH} = [10, 219]\,{\rm Gpc^{-3}\,yr^{-1}}$, $\mathcal{R}_{\rm NS-BH} = [58, 6225]\,{\rm Gpc^{-3}\,yr^{-1}}$ and $\mathcal{R}_{\rm NS-NS} = [394, 3190]\,{\rm Gpc^{-3}\,yr^{-1}}$.

Ghodla et al. (2021) use BPASS to model the NS-NS, NS-BH and BH-BH rates for several supernova model variations. We retrieve their local merger rates by taking the numbers in brackets from Table 1. For BH-BH we do not include the model with 0 BH-BH (AlwaysNS) as this is likely dominated by sampling noise. This gives: $\mathcal{R}_{\rm BH-BH} = [31, 873]\,{\rm Gpc^{-3}\,yr^{-1}}$, $\mathcal{R}_{\rm NS-BH} = [8.7, 498]\,{\rm Gpc^{-3}\,yr^{-1}}$, and $\mathcal{R}_{\rm NS-NS} = [43, 745]\,{\rm Gpc^{-3}\,yr^{-1}}$.

3.1.2 Brussels code

Mennekens & Vanbeveren (2014) use the Brussels code to predict the coalescence rate of BH and NS. We retrieve their merger rate densities for a MWEG from their Table 2 from their 'Galactic merger rates' column. We convert these rates to ${\rm Gpc^{-3}\,yr^{-1}}$ using Equation 2. We do not quote the simulations where they find 0 mergers (shown by having '0' in the Galactic merger rates column) as these simulations likely suffer from sampling noise. Doing this, we retrieve that they find the following ranges for the merger rate densities BH-BH: $[96, 1140]\,{\rm Gpc^{-3}\,yr^{-1}}$, NS-BH: $[0.06, 800]\,{\rm Gpc^{-3}\,yr^{-1}}$, and NS-NS: $[0, 1800]\,{\rm Gpc^{-3}\,yr^{-1}}$.

3.1.3 BSE

Lamberts et al. (2016) focus in their study on studying where and when gravitational GW150914 formed. They base their star formation history model on data/studies including **? ?** (that is based on the FIRE simulations) and **?**. For the binary stellar evolution they use the BSE code that they update to match more recent population synthesis codes. We retrieve their single estimate for the total BH-BH merger rate density from their Section 4, which yields $850\,{\rm Gpc^{-3}\,yr^{-1}}$.

3.1.4 COMBINE

Kruckow et al. (2018) developed the code COMBINE to predict the compact object coalescence rates. We retrieve the merger rates for NS-NS, BH-BH and NS-BH from their Table 8 and Table B3. We use the rates quoted in the column $\mathcal{R}_{z=0}$ as well as the rates in the column $\mathcal{R}_{\rm cSFR}$. The two columns are estimates that are calculated with two different star-formation history and galaxy-density scaling methods. For the NS-BH estimates we sum the quoted NSBH and BHNS rates in the tables. We retrieve: BH-BH $[0.6, 109]\,{\rm Gpc^{-3}\,yr^{-1}}$, NS-BH: $[2, 53]\,{\rm Gpc^{-3}\,yr^{-1}}$, NS-NS: $[2.7, 159]\,{\rm Gpc^{-3}\,yr^{-1}}$.

3.1.5 COMPAS

Vigna-Gómez et al. (2018) use COMPAS to study the merger rate of NS-NS for a range of simulation assumptions. We retrieve their NS-NS merger rates from their Table 2 from the column $\mathcal{R}$. As this rate is quoted in Myr per MWEG we convert these rates to ${\rm Gpc^{-3}\,yr^{-1}}$ using Equation 2. Doing so we obtain NS-NS rates in the range $\mathcal{R}_{\rm NS-NS} = [61.5, 362]\,{\rm Gpc^{-3}\,yr^{-1}}$.

Neijssel et al. (2019) use COMPAS to estimate the BH-BH, NS-BH and NS-NS coalescence rate. They vary many different prescriptions for the star formation history and also vary both the 'optimistic' and 'pessimistic' common-envelope scenario. We retrieve their rates from their Table C1 (both the optimistic and pessimistic table) that are quoted under the column $z = 0$ for local rates. We do not use the sampling uncertainties that are given in the table as these are small compared to the predicted range of merger rates. We obtain rate ranges in $\mathcal{R}_{\rm BH-BH} = [59, 1157]\,{\rm Gpc^{-3}\,yr^{-1}}$, $\mathcal{R}_{\rm NS-BH} = [19, 204]\,{\rm Gpc^{-3}\,yr^{-1}}$ and $\mathcal{R}_{\rm NS-NS} = [20, 245]\,{\rm Gpc^{-3}\,yr^{-1}}$.

Riley et al. (2020) use COMPAS and study the formation rate of the classic isolated binary evolution channel as well as Chemically homogeneous evolution as a function of redshift. We retrieve the isolated binary evolution BH-BH merger rates from Figure 10 from the CHE + Non CHE model (solid lines) for redshift 0 for the four different wolf-rayet factors from private communication with the lead author. The rates lie in the range $\mathcal{R}_{\rm BH-BH} = [51, 87]\,{\rm Gpc^{-3}\,yr^{-1}}$.

Broekgaarden et al. (2021) use COMPAS to model a large range of analytical cosmological models in combination with variations of stellar evolution assumptions. We retrieve their rates from their Figure 9, where the range is indicated with the arrow, as well as the individual simulations from the file `rates_MSSFR_Models_NS-BH_AllDCOsimulation` within `SummarizedRates.zip` from `https://zenodo.org/record/4574727`. The rates span the range $\mathcal{R}_{\rm NS-BH} = [4, 830]\,{\rm Gpc^{-3}\,yr^{-1}}$.

3.1.6 MOBSE

Mapelli et al. (2017) study the formation of BH-BH mergers by coupling MOBSE with Illustris. We take their BH-BH rates from their Table 2 for redshift $z \approx 0$, which gives a rate estimate for BH-BH in the range $[20, 572]\,{\rm Gpc^{-3}\,yr^{-1}}$.

Giacobbo & Mapelli (2018) use MOBSE to estimate the BH-BH, NS-BH and NS-NS merger rates as a function of metallicity and assumptions for the common envelope phase and supernovae. We retrieve their local merger rates from their Table 2. We use the local merger rates and only quote the rates under 'Model 1' and 'Model 2' for each simulation, which are based on a simplistic metallicity distribution/model. This gives predicted rates in the ranges BH-BH: $[43, 1500]\,{\rm Gpc^{-3}\,yr^{-1}}$, NS-BH: $[5, 780]\,{\rm Gpc^{-3}\,yr^{-1}}$, NS-NS: $[10, 510]\,{\rm Gpc^{-3}\,yr^{-1}}$.

Mapelli & Giacobbo (2018) use MOBSE in combination with the cosmological code Illustris-1 simulations to estimate the BH-BH, NS-BH and NS-NS merger rates as a function of redshift and assumptions for the common-envelope phase and supernovae. We retrieve their local merger rates from their Table 2. This gives predicted rates in the ranges BH-BH: $[146, 240]\,{\rm Gpc^{-3}\,yr^{-1}}$,

NS-BH: $[9, 115]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$, NS-NS: $[19, 591]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Artale et al. (2019) use MOBSE to calculate the BH-BH, NS-BH and NS-NS rate from isolated binary evolution by combining this with the galaxy catalogs from the hydro-dynamical cosmological simulation EAGLE. We retrieve their local merger rates from their Table 4, where we add the rates from the early-type and the late-type columns for a given compact object type. This gives predicted local merger rates of about $\mathcal{R}_{\mathrm{BH-BH}} = 142\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ $\mathcal{R}_{\mathrm{NS-BH}} = 78\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ and $\mathcal{R}_{\mathrm{NS-NS}} = 238\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Baibhav et al. (2019) use MOBSE to calculate the compact object merger rate densities for future gravitational-wave detectors for a range of common-envelope phase and supernovae assumptions. We retrieve their merger rate densities from reading the rates from Figure 1 at redshift 0 using a plot digitalizer. We retrieve the following rate ranges, $\mathcal{R}_{\mathrm{BH-BH}} = [30, 60]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$, $\mathcal{R}_{\mathrm{NS-BH}} = [4, 37]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ and $\mathcal{R}_{\mathrm{NS-NS}} = [12, 400]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Giacobbo & Mapelli (2020) use MOBSE and calculate the compact object merger rate densities for several different supernova natal kick prescriptions. We obtain their predicted merger rates from Figure 4 and Figure 5 and used a plot digitalizer tool to obtain numerical values for each of the merger rates. In total there are 12 different model realizations rates (Figure 5 has 2 overlapping simulations with figure 4). For each model realization, we retrieved the rates for both the two cosmic evolution of the metallicity models. See captions of their Figure 4 and 5 for more details. We find that they predict the following ranges: $\mathcal{R}_{\mathrm{BH-BH}} = [43, 160]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$, $\mathcal{R}_{\mathrm{NS-BH}} = [6, 80]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ and $\mathcal{R}_{\mathrm{NS-NS}} = [20, 640]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Mapelli et al. (2020) use MOBSE to simulate BH-BH mergers from the isolated binary evolution channel and in nuclear star clusters, globular clusters and young star clusters. They compare the results for a variety of model assumptions including common-envelope assumptions and mass transfer efficiency assumptions. We obtain their isolated rates from the yellow lines in Figure 10 and Figure 11. We retrieve the local merger rates by reading out the rate value using a plot digitalizer at lookback time of 0 Gyr. The quoted numbers obtained are hence approximate. They find BH-BH rates in the range $\mathcal{R}_{\mathrm{BH-BH}} = [6, 37]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Santoliquido et al. (2020) use MOBSE to study the rate of BH-BH, NS-BH and NS-NS for isolated and YSC formation. We take their isolated rates from their table 1 from the lowest redshift bin and the 'Isolated' column. We retrieve the following merger rate densities: BH-BH: $\mathcal{R}_{\mathrm{BH-BH}} = 50^{+71}_{-37}\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$, NS-BH: $\mathcal{R}_{\mathrm{NS-BH}} = 49^{+48}_{-34}\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ and $\mathcal{R}_{\mathrm{NS-NS}} = 283^{+97}_{-75}\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Santoliquido et al. (2021) use MOBSE to study the rate of BH-BH, NS-BH and NS-NS as a function of redshift for a large variety of assumptions for the star formation history as well as several stellar evolution models. We obtain their rates from their Table 2 where we take the values in the column $\mathcal{R}_0$ for the local rates. We find that their rates lie in the ranges $\mathcal{R}_{\mathrm{BH-BH}} = [10, 105.4]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$, $\mathcal{R}_{\mathrm{NS-BH}} = [1.8, 128]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ and $\mathcal{R}_{\mathrm{NS-NS}} = [4.3, 1036.8]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

3.1.7 POSYDON

Román-Garza et al. (2021) use POSYDON to calculate the merger rates of BH-BH and NS-BH for several different population synthesis assumptions. We retrieve their rates from their Table 3 and use the combined CE + SMT rate (both formation channels). We quote all 9 model combination rates. This gives rates in the ranges $\mathcal{R}_{\mathrm{BH-BH}} = [70, 203]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ and $\mathcal{R}_{\mathrm{NS-BH}} = [5.7, 77]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Bavera et al. (2021) use POSYDON to calculate the merger rates of BH-BH for several different population synthesis assumptions. We retrieve their rates from their Table 1, Table 3 and Table 4. We combine the rates from the CE and SMT (both formation channels). We note that this in Table 1 gives 7 rate estimates based on the first 8 columns, where we added each of the 7 first CE entries with the 8th SMT rate (since the SMT channel does not change for these 7 variations). The lower 6 rows in Table 1 give another 3 BH-BH rate estimates (CE+SMT), and table 3 and 4 give an additional 3 and 2 rate estimate (the first entry in these tables are the fiducial model already retrieved from table 1). So in total there are 15 BH-BH rate estimations. This gives rates in the ranges $\mathcal{R}_{\mathrm{BH-BH}} = [39, 170]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

3.1.8 Scenario Machine

Lipunov & Pruzhinskaya (2014) use Scenario Machine to calculate the merger rate density of NS-NS mergers from the isolated binary evolution channel. We take their predicted NS-NS rates from their Figure 3 (gray bands) which span approximately $0.9 \cdot 10^{-5}$–$3.3 \cdot 10^{-4}\,\mathrm{yr}^{-1}$ for a MWEG. We convert this to $\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ using Equation 2, which gives the range of $\mathcal{R}_{\mathrm{NS-NS}} = [1050, 3860]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Lipunov et al. (2017) use Scenario Machine to simulate the merger rate density of BH-BH systems. We retrieve their rate estimation from the text just below Equation 2 which gives a rate of $\mathcal{R}_{\mathrm{BH-BH}} = 100\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

3.1.9 SEVN

Boco et al. (2019) use single stellar evolution results based on simulations with SEVN. For the double compact object merger rates, they calibrate their models based on a local observed BH-BH rate of $30\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ from the first gravitational waves catalog of LIGO and Virgo, and use this to normalize their predictions. We therefore decide to only use the NS-NS and NS-BH merger rate predictions from the paper, which we retrieve from their Section 4 (and Figure 5 at redshift 0), $\mathcal{R}_{\mathrm{NS-NS}} = 70\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ and $\mathcal{R}_{\mathrm{NS-BH}} = 20\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Spera et al. (2019) use the code SEVN to study the formation of BH-BH mergers from the isolated binary evolution channel. The authors calculate the merger rate density for one model realization. We retrieve the local merger rate prediction for BH-BH from their Section 4.3 of $\mathcal{R}_{\mathrm{BH-BH}} = 90\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

3.1.10 StarTrack

O'Shaughnessy et al. (2010) estimate the binary compact object rates for gravitational-wave detector using StarTrack. They particularly focus on the potential significant contribution from binaries produced in elliptical versus spherical galaxies and create their star formation history based on a two-component model with elliptical and spherical galaxy contributions. We take the rates as quoted in their abstract and Section 4.5 . They find NS-BH rates in $[10, 280]$, NS-NS rates in $[30, 1700]$ and BH-BH rates in $[2, 40]$ $\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

de Mink & Belczynski (2015) use StarTrack and explore how the merger rate densities are impacted by uncertain initial conditions such as the binary fraction and initial period, mass, mass ratio and eccentricity distributions. We retrieve their predicted rates from their Table 2, which are quoted relative to their fiducial model. We then multiplied these relative rates with the fiducial rate to obtain absolute merger rate densities and converted this to $\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ using their conversion given by their Equation 9. We quote that they find a BH-BH rate in $[14, 2500]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$, NS-BH rate of $[9, 115]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ and NS-NS rate in $[30, 540]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Dominik et al. (2015) use StarTrack and a metallicity evolution (with two scenarios) to study compact object coalescence rates. We retrieve their merger rate densities from their Table 1 under the column $\mathcal{R}_0$. We use both the rates for their high end and low end scaling (number in front and inside the parenthesis in Table 1). They find BH-BH rate of $[0.5, 221]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$, NS-NS of $[30, 1700]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ and NS-BH of $[0.04, 20]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Belczynski et al. (2018) use StarTrack to simulate NS-NS mergers from the isolated binary evolution channel. We retrieve their rates for isolated binary evolution based on this study from their Table 1, from the row 'classical binaries' for the three models pessimistic, realistic and optimistic. We multiply with a factor 1000 to obtain a rate in units of $\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$. This gives an merger rate density estimate of $\mathcal{R}_{\mathrm{NS-NS}} = [8, 50]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Chruslinska et al. (2018) use StarTrack and take into account the cosmic star formation rate of the Universe. They focus on NS-NS. We obtain the local BH-BH rates from their Table 3, which are based on 6 different models (when including both the optimistic and pessimistic common-envelope values quoted) and find a BH-BH rate in the range $\mathcal{R}_{\mathrm{BH-BH}} = [32, 1072]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$. For the NS-NS we take the rates from their Table 2 for their variety of models which are all calculated using 32 metallicity bins and take the $\mathcal{R}_{\mathrm{local}}$ rates from this table. We find their NS-NS rate lies in the range $\mathcal{R}_{\mathrm{NS-NS}} = [1.5, 631]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Klencki et al. (2018) uses StarTrack to study the impact of initial distributions on the compact object coalescence rates. We retrieve their rates from their Table 2 using the column 'Rate density' for the local merger rate. This gives rate ranges of $\mathcal{R}_{\mathrm{NS-NS}} = [24, 68]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$, $\mathcal{R}_{\mathrm{BH-BH}} = [89, 203]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ and $\mathcal{R}_{\mathrm{NS-BH}} = [13, 27]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Chruslinska et al. (2019) use StarTrack to investigate the impact from different star formation histories on the double compact object rates. We take the rates as quoted in Figure 3, where we include the three star formation rate models and the four stellar evolution models (so including the reference model). We obtained the numerical values of the predicted rates from private communication with the lead authors. The rates are $\mathcal{R}_{\mathrm{BH-BH}} = [12, 1072]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$, $\mathcal{R}_{\mathrm{NS-NS}} = [48, 885]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ and $\mathcal{R}_{\mathrm{NS-BH}} = [6, 222]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Belczynski et al. (2020) use StarTrack to model a large set of stellar evolution models. We retrieve their rates from their Table 3 and Table 4 under the column 'Rate density' and use thus both their optimistic model (A) and pessimistic model (B) predicted rates. Doing so we find the rates: $\mathcal{R}_{\mathrm{BH-BH}} = [1.24, 1368]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$, $\mathcal{R}_{\mathrm{NS-NS}} = [49.3, 524]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$, and $\mathcal{R}_{\mathrm{NS-BH}} = [0.48, 297]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Olejak et al. (2021) use StarTrack to explore different CE prescriptions and their effect on COC rates and properties. We retrieve their NS-NS, NS-BH and BH-BH rates from their Table 3 and find BH-BH in $[18, 89]$, NS-BH in $[4, 16]$ and NS-NS in $[148, 322]$

3.2 Chemically homogeneous evolution

Marchant et al. (2016) use MESA to model chemically homogeneous evolution formation leading to BH-BH mergers for a grid of initial conditions. To retrieve the BH-BH merger rates, we use the numbers quoted in Table 1. The top two rows quote the number of merging BH-BH systems below and above the PISN gap relative to the number of SNe. We add the 'below PISN' and 'above' PISN gap numbers to obtain a total BH-BH rate estimate, and use the fraction under the column 'integrated Z' to use the rates based on their metallicity weighting. We then convert this to $\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$ using Equation 4. This gives that they predict BH-BH merger rates roughly in the range $[0.7, 16]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

Mandel & de Mink (2016) perform calculations of the BH-BH merger rate from chemically homogeneous evolution formation channel based on simulations that are based on a grid of detailed stellar evolution models from Yoon et al. (2006) and couple this with a star-formation history. We retrieve their local merger rates from the second column of their Table 1, which gives rates in the range $\mathcal{R}_{\mathrm{BH-BH}} = [2, 80]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$. We do not include their model 'Alternative 4.1' as it does not give a rate prediction and is likely dominated by sampling noise.

Riley et al. (2020) use COMPAS and study the formation rate of the classic isolated binary evolution channel as well as CHE as a function of redshift. We retrieve the CHE BH-BH merger rates from Figure 10 for the CHE only model (dashed lines) for redshift 0 for the four different wolf-rayet factors from private communication with the lead author. The rates lie in the range $\mathcal{R}_{\mathrm{BH-BH}} = [4, 32]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

du Buisson et al. (2020) use cosmological simulations from Taylor & Kobayashi (2015) which are self-consistent, hydrodynamical simulation that includes star formation, feedback from supernovae, active galactic nuclei and the effects of chemical enrichment. They combine this with binary evolution models from MESA from Marchant et al. (2016) that they extend to obtain a fine grid of models as a function of metallicity. We retrieve the local BH-BH rate from Section 3.2 of $\mathcal{R}_{\mathrm{BH-BH}} = 5.8\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$. We also include a rate estimate by increasing this by 20% based on an estimate for updated nucleosynthesis yields (see their footnote 4). This gives an estimate of $\mathcal{R}_{\mathrm{BH-BH}} = [5.8 - -7]\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.

3.3 Population-III stars

Kinugawa et al. (2014) study the formation of BH-BH mergers from population-III stars. We retrieve their BH-BH rate range from the abstract and/or Section 2, where the authors quote a rate $\mathcal{R}_{\text{BH-BH}} = [12, 25]\,\text{Gpc}^{-3}\,\text{yr}^{-1}$.

Belczynski et al. (2017) study the formation of double compact object mergers from population-III stars using StarTrack. We retrieve their BH-BH, NS-BH and NS-NS rates from their Table 5, at z=0 (before arrow), we took the four models except M10 which is Pop I/II stars. Note that the ArXiv has an outdated table so we took the numbers from the journal published version. This gives numbers in the rate: BH-BH: $[0.016, 1.9]\,\text{Gpc}^{-3}\,\text{yr}^{-1}$, NS-BH: $[0.0002, 0.016]\,\text{Gpc}^{-3}\,\text{yr}^{-1}$ and NS-NS: $\lesssim 10^{-5}\,\text{Gpc}^{-3}\,\text{yr}^{-1}$ (we did not add the latter to the table since its such a low rate).

Hijikawa et al. (2021) study the formation of BH-BH mergers from population-III stars using BSE. We retrieve their rates from Section 3.3 from the quoted $\mathcal{R}^{\text{all}}$. We also retrieve the quoted $\mathcal{R}^{\text{all}} = 2.89\,\text{Gpc}^{-3}\,\text{yr}^{-1}$ from their Section 4. We retrieve therefore a BH-BH rate range of about $\mathcal{R}_{\text{BH-BH}} = [0.38, 2.9]\,\text{Gpc}^{-3}\,\text{yr}^{-1}$.

Kinugawa et al. (2021) study the formation of BH-BH mergers from population-III stars using BSE. We retrieve their merger rates from e.g. their abstract, where they quote the range $\mathcal{R}_{\text{BH-BH}} = [0.13, 0.66]\,\text{Gpc}^{-3}\,\text{yr}^{-1}$.

Tanikawa et al. (2021) study the formation of BH-BH mergers from population-III stars using BSE. We retrieve their estimated merger rate for BH-BH mergers from their abstract for the sum of hBH1s and hBH2s, for which they state a rate of $\mathcal{R}_{\text{BH-BH}} = 0.1\,\text{Gpc}^{-3}\,\text{yr}^{-1}$.

3.4 Hierarchical Triples

Silsbee & Tremaine (2017) study the formation of BH-BH mergers from black-hole binaries with an external companion (triple) undergoing Lidov-Kozai cycles that cause a close pericenter passage, leading to a rapid merger due to gravitational-wave emission. We retrieve their rates from their Table 2, which gives for BH-BH the range $\mathcal{R}_{\text{BH-BH}} = [0.14, 6.3]\,\text{Gpc}^{-3}\,\text{yr}^{-1}$.

Antonini et al. (2017) use the triple code TRES (which is based on SeBa) to study the formation of BH-BH mergers from field triples in hierarchical triple-star (field) systems. In such systems, the tertiary can induce Lidov-Kozai (LK) oscillations in the inner binary, accelerating its coalescence, and potentially enhancing compact object merger rates. They derive the properties of the merging binaries and compute a black hole merger rate in the range $\mathcal{R}_{\text{BH-BH}} = [0.31.3]\,\text{Gpc}^{-3}\,\text{yr}^{-1}$, or up to $2.5\,\text{Gpc}^{-3}\,\text{yr}^{-1}$ if the black hole orbital planes have initially random orientation. We retrieve their rates in 0.3–1.3 $\text{Gpc}^{-3}\,\text{yr}^{-1}$ from their Table 1 from their last column and add to data the more optimistic rate of $2.5\,\text{Gpc}^{-3}\,\text{yr}^{-1}$ from their Section 5.2. Doing so, we obtain the possible BH-BH rate range predicted by this study of $\mathcal{R}_{\text{BH-BH}} = [0.3, 2.5]\,\text{Gpc}^{-3}\,\text{yr}^{-1}$.

Rodriguez & Antonini (2018) study stellar triples to calculate the merger rate of BH-BHs from triples (from Lidov-Kozai effects). We retrieve their triple rates from their abstract and from their Figure 12 (top panel) where we retrieve and write down the individual data points at redshift 0 in our data file using a plot digitalizer. We find a range $\mathcal{R}_{\text{BH-BH}} = [2, 25]\,\text{Gpc}^{-3}\,\text{yr}^{-1}$.

Fragione & Loeb (2019b) study the formation of NS-BH from triples. We retrieve their rates from their abstract and quote the range for NS-BH of $\mathcal{R}_{\text{NS-BH}} = [1.9 \cdot 10^{-4}, 22]$. In a second work, Fragione & Loeb (2019a), the authors use very similar methods, but slightly different assumptions to achieve a rate of $\mathcal{R}_{\text{NS-BH}} = 1.0 \cdot 10^{-3}\,\text{Gpc}^{-3}\,\text{yr}^{-1}$, $\mathcal{R}_{\text{NS-BH}} = 2.5 \cdot 10^{-2}\,\text{Gpc}^{-3}\,\text{yr}^{-1}$ and $\mathcal{R}_{\text{NS-BH}} = 19\,\text{Gpc}^{-3}\,\text{yr}^{-1}$ (for no notal kicks). We combine the rates from both papers into one entry in our figure and database. Doing so, we find that the authors predict NS-BH merger rates in the range $\mathcal{R}_{\text{NS-BH}} = [1.9 \cdot 10^{-4}, 22]$.

Hamers & Thompson (2019) use SeculiarMultiple and BSE to investigate the merger rates of NS and black hole (BH)-NS binaries in hierarchical triple-star (field) systems. In such systems,the tertiary can induce Lidov-Kozai oscillations in the inner binary, accelerating its coalescence, and potentially enhancing compact object merger rates. They also provide rates for isolated binary evolution, which we decide not to quote. We obtain the triple rates from their Table 8 for NS-NS and NS-BH mergers, where we use the 'Total' rates under the columns 'Triple' for both the high-mass tertiary and low-mass tertiary simulations. This gives predicted rates in the ranges $\mathcal{R}_{\text{NS-NS}} = [164, 3793]\,\text{Gpc}^{-3}\,\text{yr}^{-1}$ and $\mathcal{R}_{\text{NS-BH}} = [345, 680]\,\text{Gpc}^{-3}\,\text{yr}^{-1}$.

Martinez et al. (2020) use the code Cluster Monte Carlo (CMC) to study the rate of BH-BH mergers from triple BH systems in globular clusters. They find a merger rate lower limit $\mathcal{R}_{\text{BH-BH}} \gtrsim 0.35\,\text{Gpc}^{-3}\,\text{yr}^{-1}$ (e.g. retrieved from the abstract) for KL mergers. We retrieve their predicted BH-BH merger rate from their bottom left panel in Figure 9, where we read out the local merger rate for 'all triples' at redshift 0 as $1\,\text{Gpc}^{-3}\,\text{yr}^{-1}$. Based on this we end with a range $[\gtrsim 0.35, 1]$

3.5 Globular Clusters

? study the formation and properties of NS-NS mergers from globular clusters. We retrieve their NS-NS rates from their Conclusion (section 6), second paragraph, which gives $\mathcal{R}_{\text{NS-NS}} = 30\,\text{Gpc}^{-3}\,\text{yr}^{-1}$.

Clausen et al. (2013) find a merger rate between 0.01 and 0.17 $\text{Gpc}^{-3}\,\text{yr}^{-1}$ for NSBH. We retrieve the rates from Section 4.2, which the authors averaged over all globular clusters. We retrieve from this section their rates $\bar{\mathcal{R}}_{\text{GC}}$ that they quote for 'the models that do not allow single BHs' of $\bar{\mathcal{R}}_{\text{GC}} = 3.4 \cdot 10^{-12}$, as well as 'Models with the FIR binary population and $f_b = 0.75'$ of $\bar{\mathcal{R}}_{\text{GC}} = 4.2 \cdot 10^{-11}$. We convert this to $\text{Gpc}^{-3}\,\text{yr}^{-1}$ using Equation 3 and find that the authors predict a merger rate density in the range $\mathcal{R}_{\text{NS-BH}} = [0.01, 0.12]\,\text{Gpc}^{-3}\,\text{yr}^{-1}$.

Bae et al. (2014) study NS-NS and BH-BH formation in globular clusters. We retrieve their rates from their Table 2 from column a, b and c for the 'merger rates per GC'. We use Equation 3 to convert these rates to $\text{Gpc}^{-3}\,\text{yr}^{-1}$. We quote for the NS-NS merger rate a range: $[0.32, 3.2]\,\text{Gpc}^{-3}\,\text{yr}^{-1}$ for BH-BH we retrieve the range $[7.25, 29]\,\text{Gpc}^{-3}\,\text{yr}^{-1}$.

Samsing et al. (2014) study binary-single stellar scatterings occurring in dense stellar systems as a source of eccentrically inspiraling binaries such as NS-NS mergers. To obtain a total

NS-NS rate we add the eccentric and non eccentric rates by adding the rates from Equation 52 and Equation 56 together which gives $\mathcal{R}_{\rm NS-NS} \sim 121$.

Rodriguez et al. (2015) use the Cluster Monte Carlo code (CMC) to make predictions for the BH-BH merger rates from globular clusters. We retrieve their local merger rates from their Table 1 from the erratum, where we use all the rates quoted and divide by 12 Gyr and use Equation 3 to convert to $\rm Gpc^{-3}\,yr^{-1}$. We retrieve the range $\mathcal{R}_{\rm BH-BH} = [3.8, 13]\,\rm Gpc^{-3}\,yr^{-1}$.

Antonini & Rasio (2016) study dynamical formation of merging BH-BH systems in nuclear clusters and globular clusters. We retrieve their globular cluster rate from their equation 23, which is $\mathcal{R}_{\rm BH-BH} = 5\,\rm Gpc^{-3}\,yr^{-1}$.

Rodriguez et al. (2016) use the Cluster Monte Carlo code (CMC) to make predictions for the BH-BH merger rates from globular clusters. We retrieve their local merger rates from their Figure 12, where we retrieve the numerical values by using a plot digitalizer and take the rate at redshift 0 and find rates in the range: $\mathcal{R}_{\rm BH-BH} = 2\,\rm Gpc^{-3}\,yr^{-1}, \mathcal{R}_{\rm BH-BH} = 5\,\rm Gpc^{-3}\,yr^{-1}, \mathcal{R}_{\rm BH-BH} = 20\,\rm Gpc^{-3}\,yr^{-1}$ (lower, median and upper limit of the interval). This gives a range of $[2, 20]\,\rm Gpc^{-3}\,yr^{-1}$.

Askar et al. (2017) study GC BH-BHs using MOCCA and find that their predicted rates should lie between $\mathcal{R}_{\rm BH-BH} = 5.4$–$30\,\rm Gpc^{-3}\,yr^{-1}$. See abstract (and Equation 8) for lower limit and Discussion (last paragraph) for upper limit .

Fujii et al. (2017) estimate the detection rate of merging BH-BHs which dynamically formed in dense star clusters by combining the results of N-body simulations, modeling of globular clusters, and cosmic star-cluster formation history. We retrieve from their abstract that they estimate that the BH-BH merger rate density in the local universe within the redshift of ≈ 0.1 is $\mathcal{R}_{\rm BH-BH} = 13$–$57\,\rm Gpc^{-3}\,yr^{-1}$. See also their Figure 5 (right two panels) for more details.

Park et al. (2017) use direct N-body simulations (Nbody6) to study the formation of BH-BH mergers from globular clusters. We retrieve their rates from their Section 4.1 We retrieve a rate of $\mathcal{R}_{\rm BH-BH} = 6.5\,\rm Gpc^{-3}\,yr^{-1}$ as a lower limit, and also added a higher rate by multiplying this with a factor 4 to obtain $\mathcal{R}_{\rm BH-BH} = 26\,\rm Gpc^{-3}\,yr^{-1}$, as suggested in the last paragraph of Section 4.1 by the authors: 'We note that Paper I argued that the actual merger rate of BBHs formed and ejected from clusters can be up to four times higher than their rate estimates obtained from the reference model'.

Belczynski et al. (2018) use MOCCA to simulate NS-NS mergers from the globular cluster channel. We retrieve their rates for isolated binary evolution based on this study from their Table 1, from the row 'globular clusters' for the three models pessimistic, realistic and optimistic. We multiply with a factor 1000 to obtain a rate in units of $\rm Gpc^{-3}\,yr^{-1}$. This gives an merger rate density estimate of $\mathcal{R}_{\rm NS-NS} = [0.02, 0.5] \cdot 10^4\,\rm Gpc^{-3}\,yr^{-1}$.

Fragione & Kocsis (2018) study formation of BH-BH mergers in globular clusters using . We retrieve their predicted local BH-BH merger rates from their Figure 1, where we take the rates at redshift $z = 0$ and use for the median the black line at $19\,\rm Gpc^{-3}\,yr^{-1}$, and for the interval we consider the range the authors also quote in the discussion of $\mathcal{R}_{\rm BH-BH} = [4, 60]\,\rm Gpc^{-3}\,yr^{-1}$

Hong et al. (2018) study the BH-BH merger rate in Globular Clusters. We retrieve (e.g. from abstract) that they find a local merger rate density of 0.18–$1.8\,\rm Gpc^{-3}\,yr^{-1}$ for primordial (globular cluster) BH-BH mergers and 0.6–$18\,\rm Gpc^{-3}\,yr^{-1}$ for dynamical BH-BH mergers, depending on the GC mass and size distributions, initial binary fraction and the number density of GCs in the Universe. To obtain a total GC rate we sum the lowest and highest rate values in the predictions and obtain a range of 0.78–$19.8\,\rm Gpc^{-3}\,yr^{-1}$.

Rodriguez & Loeb (2018) use the cluster monte carlo (CMC) code to calculate the BH-BH merger rate densities as a function of redshift for globular cluster formation. We retrieve their rates from e.g. their abstract of $\mathcal{R}_{\rm BH-BH} = [4, 18]\,\rm Gpc^{-3}\,yr^{-1}$. We also add $14\,\rm Gpc^{-3}\,yr^{-1}$ as a data point, which we retrieve from their Section 4 for their 'standard' model.

Choksi et al. (2019) study the formation of BHBH mergers and combine a cosmological model of globular cluster formation with analytic prescriptions for the dynamical assembly and evolution of black hole binaries to constrain which types of clusters are most likely to form binaries tight enough to coalesce within a Hubble time. Part of their simulations are based on the SEVN code. We retrieve their rate from their Figure 10 at redshift 0 and from the text (e.g. abstract). They find a rate of $\mathcal{R}_{\rm BH-BH} = 6\,\rm Gpc^{-3}\,yr^{-1}$.

Arca Sedda (2020) use N-body simulations to study BH-NS mergers forming in globular and nuclear clusters. We retrieve the rates from the Discussion section. They find an upper limit for NSBH from Globular clusters of $\lesssim 0.1\,\rm Gpc^{-3}\,yr^{-1}$

Antonini & Gieles (2020) use the population synthesis code cBHBd to determine the redshift evolution of the merger rate density and masses of black hole binaries formed in globular clusters for a range of simulation assumptions. We retrieve their predicted BH-BH rates from their Table 2. We use the individual values from models 1, 2 and 3, under $\mathcal{R}_0$ (including the lower and upper values when including the error bars) of $7.2\,\rm Gpc^{-3}\,yr^{-1}$, $12.2\,\rm Gpc^{-3}\,yr^{-1}$ and $3\,\rm Gpc^{-3}\,yr^{-1}$ (see also Figure 2, top panel). We also use the rate retrieved from combining models 1, 2 and 3, from Equation 29, which is given by $\mathcal{R}_{\rm BH-BH} = 7.2^{+21.5}_{-5.5}\,\rm Gpc^{-3}\,yr^{-1}$. Last, we also added the lower and uper limit from Figure 11 by the authors of $0.2\,\rm Gpc^{-3}\,yr^{-1}$ (lowest error bar of the most left point) and $50\,\rm Gpc^{-3}\,yr^{-1}$ (upper bar of the highest point). All in all, we retrieve a total range of $\mathcal{R}_{\rm BH-BH} = [0.2, 50]\,\rm Gpc^{-3}\,yr^{-1}$.

Kremer et al. (2020) use CMC to calculate the BH-BH merger rate in Globular Clusters. We retrieve their rate from Figure 14, by taking the rate values at redshift 0 and retrieve rates in the range $\mathcal{R}_{\rm BH-BH} = [9, 30]\,\rm Gpc^{-3}\,yr^{-1}$. The authors also state this range at the end of Section 9.3.

Mapelli et al. (2020) use MOBSE to simulate BH-BH mergers from isolated binary evolution and in nuclear star clusters, globular clusters and young star clusters. They compare the results for a variety of model assumptions including common envelope and mass transfer efficiency. We obtain their globular cluster rates from the purple ('GC') lines in Figure 10 and Figure 11. We retrieve the local merger rates for reading out the rate value using a plot digitalizer at lookback time of 0 Gyr. Doing this we quote that the authors find BH-BH rates in the range $\mathcal{R}_{\rm BH-BH} = [0.8, 7]$ $\rm Gpc^{-3}\,yr^{-1}$. We do not include the HIGH MASS Model as the rate there seems to be 0.

Ye et al. (2020) use CMC to study the formation of merging NS-BH and/or NS-NS in globular clusters. We retrieve their rates from their Table 2 from the 'total' row (first row). We also include their optimistic rates (last column) as upper limits, giving a range of NS-BH: $[0.009, \lesssim 5.5]$ and NS-NS: $[0.009, \lesssim 25.5]$ $\rm Gpc^{-3}\,yr^{-1}$.

3.6 Nuclear Star Clusters

Miller & Lauburg (2009) study BH-BH mergers in nuclear star clusters without the presence of a super massive black hole (SMBH). We retrieve their rates from Section 3 where the authors state 'or few $\cdot 10^9$ $\rm Mpc^{-3}\,yr^{-1}$. We interpret this as a BH-BH merger rate density of about $\mathcal{R}_{\rm BH-BH} \approx [1, 10]\,\rm Gpc^{-3}\,yr^{-1}$ for BH-BH systems.

Antonini & Perets (2012) study the evolution of binaries in nuclear star clusters with an SMBH in their centers. We retrieve their BH-BH rates from their Table 1 and convert these to $\rm Gpc^{-3}\,yr^{-1}$. We find for BH-BH a range of $\mathcal{R}_{\rm BH-BH} = [0.002, 0.6]\,\rm Gpc^{-3}\,yr^{-1}$ and we find that for NS-NS they find $\mathcal{R}_{\rm NS-NS} = [0.004, 1.4]\,\rm Gpc^{-3}\,yr^{-1}$.

Antonini & Rasio (2016) study the dynamical formation of merging BH-BH systems in nuclear clusters without massive black holes in the centers and in globular clusters. We retrieve their nuclear cluster rate from their equation 22, which is $\mathcal{R}_{\rm BH-BH} = 1.5\,\rm Gpc^{-3}\,yr^{-1}$.

Bartos et al. (2017) study the formation of BH-BH mergers in active galactic nuclei with a SMBH. We retrieve their BH-BH rate from their equation 17, which gives for BH-BH of $\mathcal{R}_{\rm BH-BH} = 1.2\,\rm Gpc^{-3}\,yr^{-1}$.

Petrovich & Antonini (2017) study the formation of BH-BH mergers in galaxies with a SMBH embedded in a non-spherical nuclear star cluster. We retrieve their BH-BH rate from their equation 47 which gives a BH-BH range of $\mathcal{R}_{\rm BH-BH} = [0.6, 15]\,\rm Gpc^{-3}\,yr^{-1}$. We also added the points $\mathcal{R}_{\rm BH-BH} = 1\,\rm Gpc^{-3}\,yr^{-1}$ and $\mathcal{R}_{\rm BH-BH} = 5\,\rm Gpc^{-3}\,yr^{-1}$ from their comments directly under equation 47. For NS-BH we retrieve their rates from Equation 48 of $\mathcal{R}_{\rm NS-BH} = [0.02, 0.4]\,\rm Gpc^{-3}\,yr^{-1}$. For NS-NS we retrieve an upper limit of $\mathcal{R}_{\rm NS-NS} \lesssim 0.02$ $\rm Gpc^{-3}\,yr^{-1}$ from their Section 6.4.

Stone et al. (2017) study the evolution of stellar mass black hole binaries formed in the self-gravitating discs of active galactic nuclei around a SMBH. We retrieve the BH-BH rates from the end of their Section 4 (also quoted in the abstract) of $\mathcal{R}_{\rm BH-BH} \sim 3\,\rm Gpc^{-3}\,yr^{-1}$.

Belczynski et al. (2018) study the formation of NS-NS mergers in nuclear cluster formation using a semi-analytical approach for modeling the nuclear cluster coupled with MOCCA models to calculate the properties and rates of NS-NS mergers in globular clusters. We retrieve their rates for nuclear cluster evolution based on this study from their Table 1, from the row 'nuclear clusters' for the range of three models. We multiply with a factor 1000 to obtain a rate in units of $\rm Gpc^{-3}\,yr^{-1}$. This gives a NS-NS rate in the rate: $\mathcal{R}_{\rm NS-NS} = [0.007, 0.1]\,\rm Gpc^{-3}\,yr^{-1}$.

Hamers et al. (2018) study binaries within the sphere of influence of a SMBH in galactic nuclei, which are susceptible to the Lidov-Kozai mechanism, which can drive orbits to high eccentricities and trigger strong interactions within the binary such as the emission of gravitational waves and mergers of compact objects. We retrieve their nuclear cluster rates from their section 6.2.1 and find a BH-BH rate in the range $\mathcal{R}_{\rm BH-BH} = [0.01, 0.4]\,\rm Gpc^{-3}\,yr^{-1}$.

Hoang et al. (2018) study Lidov-Kozai interactions in galactic center nuclei around a SMBH for BH-BH mergers. We retrieve their rate estimates from their abstract and find for BH-BH a rate range of $\mathcal{R}_{\rm BH-BH} = [1, 3]\,\rm Gpc^{-3}\,yr^{-1}$.

Rasskazov & Kocsis (2019) study the rate of BH-BH mergers from formation in nuclear star clusters hosting a SMBH at its center. We retrieve their rate from their abstract and quote for BH-BH a rate range of $\mathcal{R}_{\rm BH-BH} = 0.002\text{–}0.04\,\rm Gpc^{-3}\,yr^{-1}$.

Stephan et al. (2019) study the formation of BH-BH binaries form hierarchical triples with a SMBH, undergoing Eccentric Kozai-Lidov (EKL) evolution, which can lead to high-eccentricity excitations for the binary companions' mutual orbit. They calculate BH-BH and NS-BH rates. We retrieve their rate estimates from e.g. their conclusion section (last paragraph). This is somewhat a lower limit since BH and NS mergers can also form without the EKL effect, we therefore quote it as lower limits (private communication SN). We retrieve the ranges $\mathcal{R}_{\rm BH-BH} \gtrsim [7, 15]\,\rm Gpc^{-3}\,yr^{-1}$, $\mathcal{R}_{\rm NS-BH} \gtrsim [2, 5]\,\rm Gpc^{-3}\,yr^{-1}$.

Mapelli et al. (2020) use MOBSE to simulate BH-BH mergers isolated binary evolution and in nuclear star clusters arounf SMBH, globular clusters and young star clusters. We obtain their nuclear star cluster rates from the blue dotted ('NSC') lines in Figure 10 and Figure 11. We retrieve the local merger rates for reading out the rate value using a plot digitalizer at lookback time of 0 Gyr. We also added the conservative upper limits of 7–10 $\rm Gpc^{-3}\,yr^{-1}$ when assuming the optimistic case that 10% of all stars form in NSCs, see their Section 5. Doing so, we quote that they find BH-BH rates in the range $\mathcal{R}_{\rm BH-BH} = [\lesssim 0.09, 10]\,\rm Gpc^{-3}\,yr^{-1}$. We did not include the model that predicts a BH-BH rate of 0, and instead mark the lowest point as an upper limit ($0.09\,\rm Gpc^{-3}\,yr^{-1}$).

Arca Sedda (2020) use N-body simulations to study BH-NS mergers forming in globular and nuclear clusters. We retrieve the rates from the Discussion section. They find an upper limit for NS-BH from Nuclear Clusters of $\mathcal{R}_{\rm NS-BH} \lesssim 0.01$ $\rm Gpc^{-3}\,yr^{-1}$.

McKernan et al. (2020) study the formation of NS-BH in Active Galactic Nucei discs and find an upper limit of NS-BH of $\mathcal{R}_{\rm NS-BH} \lesssim 300\,\rm Gpc^{-3}\,yr^{-1}$ and for NS-NS $\mathcal{R}_{\rm NS-NS} \lesssim 400\,\rm Gpc^{-3}\,yr^{-1}$. We retrieve this, e.g., from their abstract.

Tagawa et al. (2020) study the formation of double compact object mergers in AGNs. We retrieve their merger rates from their Equation 82 which gives a BH-BH range of $[0.02, 60]\,\rm Gpc^{-3}\,yr^{-1}$.

Wang et al. (2020) study galactic center dynamics (triple interactions with SMBH helping the formation of double compact object mergers). They predict BH-BH, NS-BH and NS-NS rates through SMBH interactions. These rates should be somewhat seen as lower limits since there can also be mergers without these interactions (priv. communication SN). We retrieve their rates from their Table 2 of: $\mathcal{R}_{\rm BH-BH} = [0.3, 5]\,\rm Gpc^{-3}\,yr^{-1}$, $\mathcal{R}_{\rm NS-BH} = [0.25, 0.3]$ and

$\mathcal{R}_{\rm NS-NS} = 0.15, 0.3]$ Gpc^{-3} yr^{-1}.

Yang et al. (2020) compute the cosmic evolution of the merger rate for stellar-mass binaries in the disks of active galactic nuclei with a SMBH. We retrieve their rates from Figure 1, at redshift 0 using a plot digitalizer and find rates in the range $\mathcal{R}_{\rm BH-BH} = [0.1, 1.6]$.

3.7 Young/Open star clusters

Ziosi et al. (2014) use starlab to study the formation of BH-BH mergers in in young star clusters with different metallicities. They find an upper limit of $\mathcal{R}_{\rm BH-BH} \lesssim 1.5\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$ for merging BH-BH, which we retrieve from their Section 5 (Conclusions) and have converted to Gpc^{-3} yr^{-1}. From the same paper we retrieve from Section 5 their upper limit for NS-BH of $\mathcal{R}_{\rm NS-BH} \lesssim 0.1\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$.

Mapelli (2016) use starlab to calculate the BH-BH merger rate in young stellar clusters. We retrieve their rate from their Equation 5 and converted this to Gpc^{-3} yr^{-1} to obtain a BH-BH rate of $\mathcal{R}_{\rm BH-BH} \gtrsim 1\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$. The authors mention that this should be taken as a strong lower limit.

Rastello et al. (2019) use NBODY7 to study stellar black hole binary mergers in open clusters. We retrieve their merger rate from their Equation 4 and find their upper limit BH-BH rate of $\mathcal{R}_{\rm BH-BH} \gtrsim 2\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$.

Di Carlo et al. (2020) use NBODY6 to study the BH-BH merger rate density estimate from young star clusters. We take their rate estimate from their Section 3.3 and retrieve $\mathcal{R}_{\rm BH-BH} = 55\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$ and $\mathcal{R}_{\rm BH-BH} = 110\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$ when the authors assume that all the cosmic star formation rate occurs in young star clusters. We follow the authors and quote these rates as upper limits (see their Section 3.3).

Kumamoto et al. (2020) study the BH-BH rate in open clusters using NOBODY6. We retrieve their two estimated BH-BH rates from their Equation 27 and Equation 36. And find BH-BH rate in the range $\mathcal{R}_{\rm BH-BH} = [35, 70]\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$.

Mapelli et al. (2020) use MOBSE to simulate BH-BH mergers from the isolated binary evolution channel and in nuclear star clusters, globular clusters and young star clusters. They compare the results for a variety of model assumptions including common envelope and mass transfer efficiency. We obtain their young star cluster rates from the orange ('YSC') lines in Figure 10 and Figure 11. We retrieve the local merger rates for reading out the rate value using a plot digitalizer at lookback time of 0 Gyr. This gives that they find BH-BH rates in the range $[0.1, 18]\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$.

Rastello et al. (2020) use MOBSE to study Young star Clusters and find a NSBH rate of $\mathcal{R}_{\rm NS-BH} \lesssim 28\ {\rm Gpc}^{-3}\,{\rm yr}^{-1}$ (e.g. from their conclusions). We interpret this as an upper limit due to the optimistic young stellar cluster assumptions.

Santoliquido et al. (2020) use MOBSE to study the rate of BH-BH, NS-BH and NS-NS for isolated and YSC formation. We take their isolated rates from their table 1 from the lowest redshift bin and the 'Dynamical' column. We retrieve the following merger rate densities: BH-BH: $64^{+34}_{-20}\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$ NS-BH: 41^{+33}_{-23} NS-NS:151^{+59}_{-38}.

Banerjee (2021) use an updated version of NBODY7 to study the contribution of young massive star clusters and open star clusters to the present day, intrinsic merger rate density of dynamically assembled binary black holes. We retrieve their rates, e.g. from their abstract: BH-BHs $[0.5, 37.9]\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$.

3.8 Primordial

Bird et al. (2016) use local dark matter constraints to study the primordial formation of BH-BH mergers. They find a BH-BH rate value between $\mathcal{R}_{\rm BH-BH} = 0.02\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$ (see text just after Equation 13) and $\mathcal{R}_{\rm BH-BH} = 3\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$ (see text just after Equation 14). We include $3\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$ as an upper limit and $0.02\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$ as a data point, resulting in the range from this study of $\mathcal{R}_{\rm BH-BH} = [0.02, \lesssim 3]\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$.

Ali-Haïmoud et al. (2017) study the formation of primordial BH-BH mergers. We retrive their upper limit as $\mathcal{R}_{\rm BH-BH} \lesssim 10^5\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$ from the top right of figure 5. We also add the data point of a merger rate of $\mathcal{R}_{\rm BH-BH} \sim 0.2\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$ which we retrieve from their Equation 106. Giving a rate range of $\mathcal{R}_{\rm BH-BH} = [0.2, \lesssim 10^5\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$.

Raidal et al. (2019) study the formation and evolution of primordial black hole binaries. We retrieve their rates from their Figure 3, but ignore the hatched region as the authors mention the rate estimate is not reliable there. We also add $6\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$ as a data point to our plot and data file, which we retrieve from their Equation 3.7. Doing so we retrieve that the authors find merger rates of $\mathcal{R}_{\rm BH-BH} = [6, \lesssim 10^4]\,{\rm Gpc}^{-3}\,{\rm yr}^{-1}$.

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