BBH and BNS source catalogs used for the CoBA Science study (ET-0084A-23)

This is an explanation for the catalogs in this folder, which have been used to produce the results in arXiv:2303.15923. Those are:

- BBH: 1yr_Catalog_BBH.h5
- BNS: 1yr_Catalog_BNS.h5 and 1yr_Catalog_BNS_massGauss.h5

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——— ASSUMPTIONS FOR BINARY BLACK HOLES

The catalog results from the mixture of BBHs from (i) isolated binary evolution, (ii) dynamical formation in young, globular and nuclear star clusters.

Masses, spins, redshifts and luminosity distances have been obtained with the open-source code FASTCLUSTER, described in Mapelli et al. 2022, MNRAS, in press (https://arxiv.org/abs/2109.06222) and Mapelli et al. 2021, MNRAS, 505, 339 (https://ui.adsabs.harvard.edu/abs/2021MNRAS.505..339M/abstract). In particular:

- metallicity spread: sigmaZ = 0.3;
- spin magnitude: truncated Maxwellian with sigma = 0.1;
- alpha (common envelope): 1.0;
- supernova model: rapid (Fryer et al. 2012, ApJ, 749, 91);
- natal kicks from a Maxwellian with sigma=150 km/s (Atri et al. 2019, MNRAS, 489, 3, 3116–3134).

The name of the 1yr catalog is “1yr_Catalog_BBH.h5”.

——— ASSUMPTIONS FOR BINARY NEUTRON STARS

Redshifts and luminosity distances come from Santoliquido et al. 2021, MNRAS, with a common envelope ejection efficiency equal to 3.

The source frame masses of the two objects are sampled uniformly in the interval [1.1; 2.5] Msun, and re-labelled so that m1>m2. We also provide a catalog with masses sampled from independent Gaussian distributions with mean 1.33 Msun and standard deviation 0.09 Msun, and re-labelled so that m1>m2.

The aligned spin components are sampled uniformly and independently in the interval [-0.05; 0.05].

The tidal deformabilities of the two objects are sampled uniformly and independently in the interval [0; 2000] (in some parts of the document a realistic EoS has been adopted, but the differences at the population level only show up in the reconstruction of the tidal parameters, see App. D of Iacovelli et al. 2022, ApJ, 941, 2, 208).

The name of the 1yr catalog with uniform masses is “1yr_Catalog_BNS.h5”.
The name of the 1yr catalog with gaussian masses is “1yr_Catalog_BNS_massGauss.h5”.

——— COMMON ASSUMPTIONS AND UNITS

- All the quantities with the units of a mass are given in solar masses (detector frame chirp mass and the mass ratio are also provided in the catalogs).

- Luminosity distances are given in giga-parsec.

- The sky position (given both as (RA-dec) and (θ - ϕ)) and coalescence phase are sampled uniformly in the sky, i.e. uniform distributions between [0, 2π] for ϕ and Φc and distribution uniform in cosine for θ. Also, the inclination angle (ι) is sampled from a uniform

distribution in cosine and the polarization (ψ) is sampled uniformly in the interval [0, π]. All these quantities are given in radians.

- The time of coalescence is sampled uniformly between January 1st 2030 and January 1st 2040, and given both as a GPS time in seconds (tGPS entry) and as a GMST in days (tcoal entry).

- The cosmology is Planck 2018 as in astropy.

————— SUMMARY OF PARAMETERS IN THE CATALOGS

Parameter name	**Description**	**Distribution**
Mc	Detector-frame chirp mass (solar massses)	BBH: from m1, m2 in pop synthesis catalogs BNS: m1, m2 uniform in [1.1, 2.5] or gaussian N(1.33,0.09), m1>m2, then converted
eta	Symmetric mass ratio	as above
dL	Luminosity distance (Gpc)	Computed from redshift and Planck18
phi	Polar angle (rad)	Flat [0, 2π]
theta	Azimutal angle (rad)	Flat [0, π]
psi	Polarization angle (rad)	Flat [0, π]
iota	Inclination angle (rad)	Flat [- π, π]
tGPS	GPS time at coalescence (s)	Flat between 1st Jan 2030, 1st Jan 2040

Phicoal	Phase at coalescence (rad)	Flat [0, 2π]
chi1z	Primary spin along z axis	BBH: from pop synthesis catalogs BNS: uniform in [-0.05, 0.05]
chi2z	Secondary spin along z axis	as primary spin
z	Redshift	From pop synthesis catalogs
m1_source	Primary mass in source frame (solar masses)	BBH: from pop synthesis catalogs BNS: uniform in [1.1, 2.5] or gaussian N(1.33,0.09), m1>m2
m2_source	Secondary mass in source frame (solar masses)	BBH: from pop synthesis catalogs BNS: uniform in [1.1, 2.5] or gaussian N(1.33,0.09), m1>m2
ra	Right ascension (rad)	= phi
dec	Declination (rad)	= π/2 - theta
tcoal	GMST time at coalescence (fraction of days)	Computed from tGPS, Flat [0, 1]
Lambda1	Tidal deformability of primary object (NS only)	Flat [0, 2000]

Lambda2	Tidal deformability of secondary object (NS only)	Flat [0, 2000]

——— LOADING THE CATALOGS

All catalogs are given as .h5 files.

A quick Python code to load the files is reported here (it requires the *h5py* package to be installed):

```
#####################################

import numpy as np
import h5py

catalogName = 'PATH/TO/CATALOG.h5'

events={}
with h5py.File(catalogName, 'r') as f:
    for key in f.keys():
        events[key] = np.array(f[key])

#####################################
```

events will then be a dictionary with keys corresponding to the various parameters.