Massive black hole binary catalogs used in Barausse *et al*, 2023

This directory contains the catalogs used Barausse *et al* (2023), generated by updating the model described in Barausse (2012). Please reference both.

Detailed File Content

Each catalog file contains the following columns:

1. z of the merger
2. m_1, black hole mass in solar masses
3. m_2, black hole mass in solar masses
4. a_1, spin parameter
5. a_2, spin parameter
6. α, defined so that $\mathbf{a}_1 \cdot \mathbf{a}_2 = \cos\alpha$
7. β, defined so that $\mathbf{a}_1 \cdot \mathbf{l} = \cos\beta$ (where $\mathbf{l}$ is the orbital angular momentum)
8. γ, defined so that $\mathbf{a}_2 \cdot \mathbf{l} = \cos\gamma$
9. ψ, defined as the angle between the projections of $\mathbf{a}_1$ and $\mathbf{a}_2$ onto the binary orbital plane
10. $a_{\rm fin}$, merger remnant spin parameter
11. $m_{\rm fin}$, merger remnant mass in solar masses
12. $v_{\rm kick}$, kick velocity in km/s
13. $v_{\rm esc,halo}$, escape velocity from the dark matter halo in km/s
14. $v_{\rm esc,bar}$, escape velocity considering only baryonic matter in km/s
15. $M_{\rm cluster}$, mass of the dark matter (DM) halo in solar masses
16. $M_{\rm disk,stars}$, mass of the stellar component of the galactic disk in solar masses
17. $M_{\rm disk,gas}$, mass of the gas component of the galactic disk in solar masses
18. $M_{\rm bulge,stars}$, mass of the stellar component of the galactic bulge in solar masses
19. $M_{\rm bulge,gas}$, mass of the gas component of the galactic bulge in solar masses

20. $M_{\rm NSC}$, mass of the nuclear star cluster in solar masses

21. $M_{\rm reservoir}$, mass of the gas reservoir feeding the MBH in solar masses

22. $M_{\rm halo,final}$, mass of the DM halo hosting the system at $z = 0$, in solar masses

23. Comoving number density of the DM halo hosting the merger at $z = 0$ per $\rm Mpc^3$ of comoving volume, divided by the number of realizations of the halo with that specific mass (i.e., W_{PS}: weight on the PS mass function divided by the number of realizations)

Using the Files

The files can be used to construct the distribution of merging MBHBs in the universe. To do so, the entries of each file must be weighted according to the halo number density (column 23) and integrated over the volume shell at the corresponding redshift, given in column 1.

For example, to construct the merger rate as a function of redshift, one can numerically set a grid of z and sum all the events falling in each z interval according to the following prescription:

$$\frac{d^2N}{dz\,dt} = \frac{4\pi c}{(1+z)^2} \sum \frac{W_{PS}}{D_L^2(z)}$$

where $D_L(z)$ is the luminosity distance at redshift z.

Then the total merger rate is given by:

$$\frac{dN}{dt} = \int \frac{d^2N}{dz\,dt} dz$$

This is the merger rate (per second) of massive black hole binaries in the universe. By setting grids on m_1 and m_2, the same prescription can be used to construct the distribution of merging MBHBs per unit masses and redshift. Monte Carlo sampling can then be performed from the distribution to simulate a population of merging MBHBs in a random realization of the universe.

References

- E. Barausse, K. Dey, M. Crisostomi, A. Panayada, S. Marsat and S. Basak, "Implications of the pulsar timing array detections for massive black hole mergers in the LISA band," Phys. Rev. D **108**, no.10, 10 (2023)

- E. Barausse, "The evolution of massive black holes and their spins in their galactic hosts," Mon. Not. Roy. Astron. Soc. **423**, 2533-2557