Searching for binary black holes in the Milky Way with LISA

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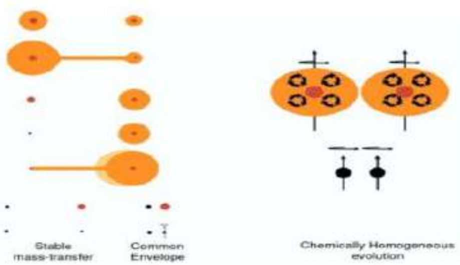
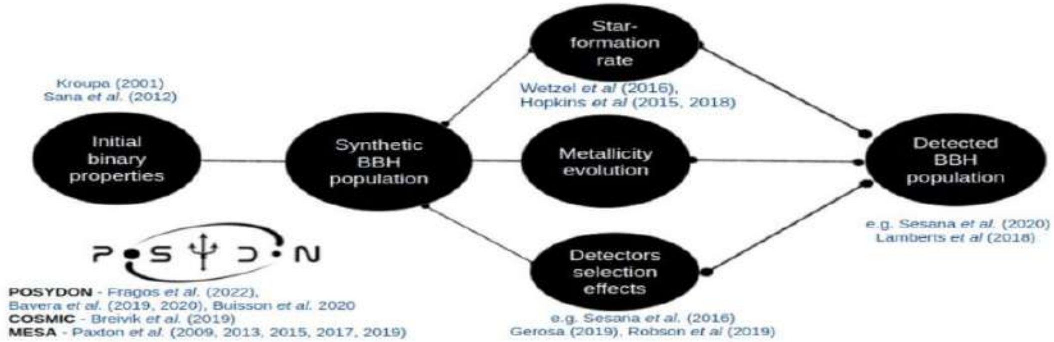
Introduction

In 2034, within the rapidly changing landscape of gravitational wave (GW) astronomy, the **Laser Interferometer Space Antenna (LISA)** will be the first space-based detector that will observe the gravitational spectra in the millihertz frequency band [1, 2]. It has recently been proposed that numerous LIGO/VIRGO sources will also be detectable by LISA [3]. LISA will be able to detect black hole binaries (BBHs) from the **Milky Way's neighbourhood**, evolving from their early inspiral stages [4]. Interestingly, the sources that appear to be circular in the LIGO band may be eccentric in the LISA band, depending on their formation pathways [3, 5]. Apart from BBHs, tens to hundreds of thousands of other compact binaries will be detectable with LISA, hosting neutron stars, and white dwarfs. A great number of these sources, such as double white dwarfs and neutron stars, ultra-compact X-ray binaries, and cataclysmic variables, will also have electromagnetic counterparts, enclosing the rich information of multi-messenger and multi-band gravitational-wave astronomy [6].

Formation channels of isolated BBHs





Results

By Figure 2, even if we will not be able to have any merging binary black holes from the Milky Way galaxy during the LISA mission we might be able to detect galactic binaries at different stages of their inspiral that might enable us to distinguish between their formation channels [6].

Figure 1: The distribution of observable properties of BBH chirp mass, χ_{eff} and mass ratio q, that would merge within the next 20 years.

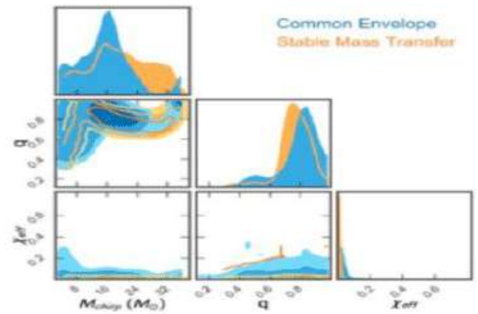
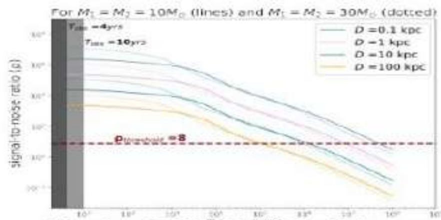
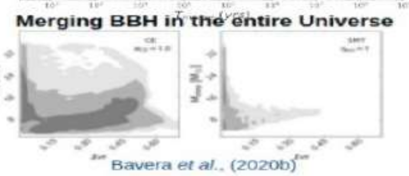


Figure 2: The plot shows the signal to noise ratio (ρ) for black holes binaries of $m_1 = m_2 = 10\mathrm{M}_{\odot}$ (lines) and $m_1 = m_2 = 30\mathrm{M}_{\odot}$ (dotted) as a function of their merger times T_{merge}(yrs) with LISA for different distances from 0.1kpc to as far as 100kpcs. The horizontal (dashed) red line represents here the detection threshold of SNR $\rho_{thr} = 8$ whereas the vertically shaded black and grey regions represent LISA observing times $T_{obs} = 4$ years.





Conclusion

LISA will also be sensitive to BBHs that are too wide to merge within a human lifetime. But all these signals detectable from a ground-based detector would be **"super-loud"**, SNR of 10′s to 100′s of thousands as shown in Figure 2.
The most striking difference in Figure 1 is the lack of fast-spinning BHs in the **common envelope channel** in the Milky way populations. This is because the Milky Way has formed relatively fewer metal-poor stars, compared to the average Universe, and it is those very metal-poor stars that are forming the fast-spinning BBHs.

References

[1] Pau Amaro-Seoane et al. Laser interferometer space antenna, 2017.

[2] John Baker et al. The laser interferometer space antenna: Unveiling the millihertz gravitational wave sky, 2019.

[3] Alberto Sesana. Multi-band gravitational wave astronomy: science with joint space- and ground-based observations of black hole binaries. *Journal of Physics: Conference Series*, 840:012018, may 2017.

[4] A Lamberts, S Garrison-Kimmel, P F Hopkins, E Quataert, J S Bullock, C-A Faucher-Giguère, A Wetzel, D Kereš, K Drango, and R E Sanderson. Predicting the binary black hole population of the Milky Way with cosmological simulations. *Monthly Notices of the Royal Astronomical Society*, 480(2):2704–2718, 07 2018.

[5] Katelyn Breivik, Carl L. Rodriguez, Shane L. Larson, Vassiliki Kalogera, and Frederic A. Rasio. Distinguishing between formation channels for binary black holes with lisaistinguishing. *The Astrophysical Journal*, 830(1):L18, oct 2016.

[6] Davide Gerosa, Sizheng Ma, Kaze W.K. Wong, Emanuele Berti, Richard O'Shaughnessy, Yanbei Chen, and Krzysztof Belczynski. Multiband gravitational-wave event rates and stellar physics. *Physical Review D*, 99(10), May 2019.

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