LISA Catalog Sensitivity to Metallicity in the Milky Way

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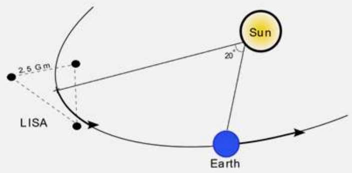
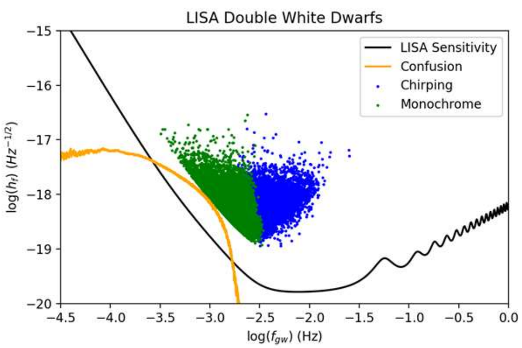
Introduction

LISA (Laser Interferometer Space Antenna) is a space-based gravitational-wave detector that is composed of 3 spacecraft forming a triangle with arm lengths of 2.5 million km. When it launches in the 2030s, it will open a new window into the low frequency gravitational wave spectrum covering a wide range of gravitational wave sources such as compact object binaries and EMRIs.



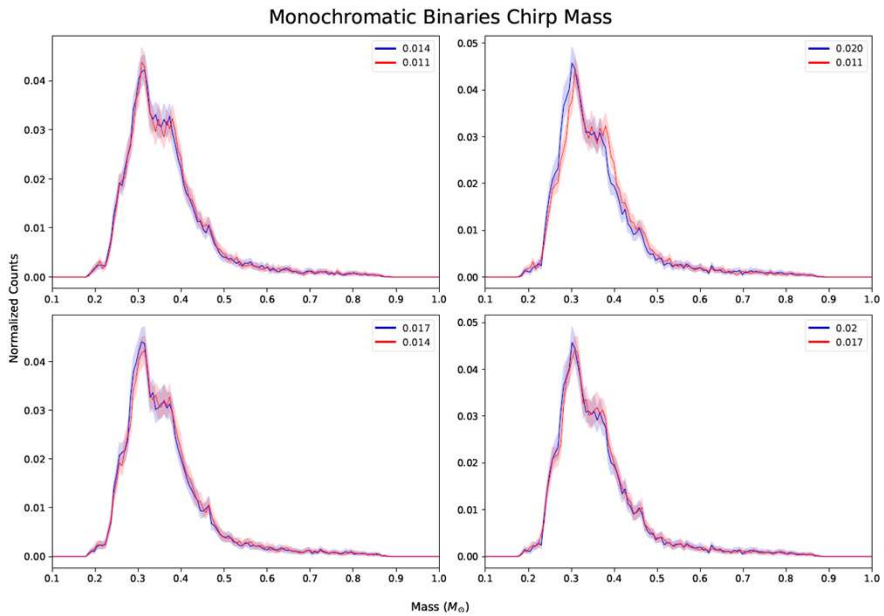
The most numerous of these sources will be white dwarf binaries (DWDs) with around 30,000 individually resolvable DWDs and several million forming a confusion background. This catalog of DWDs provides an opportunity to examine the structure and history of the Milky Way. Through the population synthesis code COSMIC, we can create simulated DWD populations to examine how different galactic parameters will affect the galactic DWD catalog. The chirp mass examined in the included plots is related to the mass of each star through:

$$M_{chirp} = \frac{(m_1 m_2)^{\frac{3}{5}}}{(m_1 + m_2)^{\frac{1}{5}}}$$



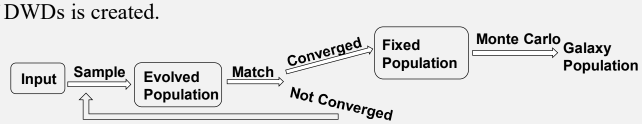
Metallicity

We chose the metallicity grid values based on the assumption built into COSMIC that the metallicity of the thin disk and bulge of the Milky Way are equal to that of the Sun, while the metallicity of the thick disk is 15%. The standard COSMIC values are 0.014 (Asplund 2009) and 0.017 (Grevesse 1998). From these two values, we expanded the grid to 4 metallicities: 0.011, 0.014, 0.017, and 0.02.



COSMIC

COSMIC (Breivik 2020) is a rapid population synthesis code that uses Monte Carlo sampling from a small fixed population to create galactic populations of stars. Using input like metallicity, groups of stars are evolved and added to the fixed populations until the statistics of the population stop changing. COSMIC then Monte Carlo draws from the fixed population until a set mass is reached and the galactic population of DWDs is created.

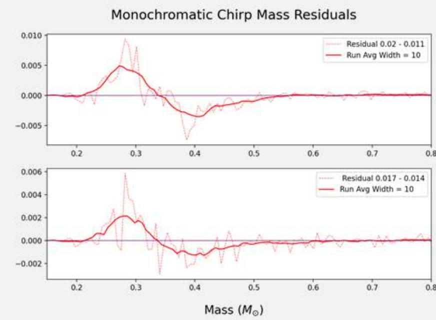


The galaxies are random, so we create 500 from each of the four fixed populations. For each catalog we create histograms of the masses and orbital periods of the binaries which we use to find the median galaxy at a given metallicity to use for comparisons.

Github: https://github.com/COSMIC-PopSynth/COSMIC

Conclusion

As these plots show, the metallicity of the galaxy will change the LISA double white dwarf catalog in a detectable way. The biggest gaps were in the mass distributions, but all properties examined (mass of each binary, chirp mass, and orbital period) showed changes. As the metallicity increased, the mass distributions generally shifted toward lower masses and the peaks lowered. The most significant points are around 0.25 $M_\odot$ and 0.4 $M_\odot$ where the ranges of possible histograms completely separate.



The conclusions drawn from this work come from visual inspection of the plots, but Bayesian statistics can be implemented in the future for a more statistical analysis. Additionally, the grid can be expanded to other tunable galactic parameters like scale height, total mass, and star formation history.

Acknowledgements

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References

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