Distinguishing Between Formation Channels for Binary Black Holes with LISA

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Abstract

The recent detections of GW150914 and GW151226 imply an abundance of stellar-mass binary-black-hole mergers in the local universe. While ground-based gravitational-wave detectors are limited to observing the final moments before a binary merges, space-based detectors, such as the Laser Interferometer Space Antenna (LISA), can observe binaries at lower orbital frequencies where such systems may still encode information about their formation histories. We explore the orbital eccentricity and mass of binary black hole populations as they evolve through the LISA frequency band. Overall we find two distinct populations discernable by LISA. We show how the measurement of both chirp mass and eccentricity can be used to constrain formation channels for binary black holes. Finally, we note how measured eccentricities of low-mass binary black holes could provide detailed constraints on the physics of black-hole-natal kicks and common-envelope evolution.

Simulation Details: Globular Cluster vs Galactic Field

Globular Cluster: Dynamics=On

- Stellar evolution using BSE with updated:
  - BH formation and natal kicks
  - metallicity-dependent wind prescriptions
  - fallback in neutrino-driven supernovae

Galactic Field: Dynamics=Off

- Stellar evolution using BSE with updated:
  - BH formation and natal kicks
  - solar metallicity: must evolve to LISA band by 1 Gy before present

Eccentricity Evolution: Globular Cluster vs Galactic Field

BBHs from the globular cluster (GC) and the galactic field (0CE, 1CE) are compared for eccentricity evolution. The GC BBHs show a wider range of eccentricities compared to the galactic field.

Chirp Mass - Eccentricity Correlations at 1 mHz

- The chirp mass, $M_c$, can be computed for any BBH detected with a measured chirp
- Red vertical lines show the chirp mass of the (a) GW151226, (b) LVT151012, and (c) GW150914 progenitors with 90% confidence limits
- BBHs formed in the galactic field that undergo common-envelope evolution (1CE) may have measurable eccentricities.

References