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Resolving the eccentricity of stellar mass binary black holes with next generation gravitational wave detectors

Next generation gravitational wave (GW) detectors are expected to detect 10^4–10^5 binary black holes (BBHs) per year. Understanding the formation pathways of these binaries is an open question. Orbital eccentricity can be used to distinguish between the formation channels of compact binaries as different formation channels are expected to yield distinct eccentricity distributions. Due to the rapid decay of eccentricity caused by the emission of GWs, measuring smaller values of eccentricity poses a challenge for current GW detectors due to their limited sensitivity. In this study, we explore the potential of next generation GW detectors such as Voyager, Cosmic Explorer (CE), and Einstein Telescope (ET) to resolve the eccentricity of BBH systems. Considering a GWTC-3 like population of BBHs and assuming some fiducial eccentricity distributions as well as an astrophysically motivated eccentricity distribution (Zevin et $al.$ (2021)), we calculate the fraction of binaries that can be confidently distinguished as eccentric. We find that for Zevin eccentricity distribution, Voyager, CE, and ET can confidently measure the non-zero eccentricity for $\sim 3\%$, 9%, and 13% of the detected BBHs, respectively. In addition to the fraction of resolvable eccentric binaries, our findings indicate that Voyager, CE, and ET require minimum eccentricities
$gtrsim 0.02$, 5×10^{-3}, and 10^{-3} at a GW frequency of 10 Hz, respectively, to identify a BBH system as eccentric. The better low-frequency sensitivity of ET significantly enhances its capacity to accurately measure eccentricity.

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