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Localizing binary neutron star inspirals and constraining primordial black hole abundance using continuous wave methods in ET

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Next-generation gravitational-wave detectors will provide unprecedented sensitivity to inspiraling binary neutron stars and black holes, enabling detections at the peak of star formation and beyond. However, the signals from these systems will last much longer than those in current detectors, and overlap in both time and frequency, leading to increased computational cost to search for them with standard matched filtering analyses, and a higher probability that they are observed in the presence of non-Gaussian noise. We therefore present a method to search for gravitational waves from compact binary inspirals in next-generation detectors that is computationally efficient and robust against gaps in data collection and noise non-stationarities. Our method, based on the Hough Transform, finds tracks in the time/frequency plane of the detector that uniquely describe specific inspiraling systems. We find that we could detect ~ 5 overlapping, intermediate-strength signals (matched-filter signal-to-noise ratio $\rho \approx 58$) without a sensitivity loss. Additionally, we demonstrate that our method can enable multi-messenger astronomy: using only low frequencies ($2-20$ Hz), we could warn astronomers ~ 2.5 hours before a GW170817-like merger at 40 Mpc and provide a sky localization of ~ 20 deg^2 using only one "L" of Einstein Telescope. Comparing matched filtering searches to our proposed method at a fixed sensitivity, we find a factor of $\sim 10-50$ speed-up when we begin an analysis at a frequency of 5 Hz up to 12 Hz for a system with a chirp mass between $\mathcal{M} \in [1,2] M_\odot$. We also project constraints on stellar-mass and sub-solar mass primordial black hole abundance using our method.

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