Contribution ID : **14** Type : **not specified**

Measuring the cosmic dipole with golden dark sirens in the era of next-generation ground-based gravitational wave detectors

The tensions between cosmological parameter measurements from the early-universe and the late-universe datasets offer an exciting opportunity to explore new physics, if not accounted for unknown systematics. Apart from the well-known Hubble tension, a tension up to ~ 4.9σ in the cosmic dipole has also been reported. While the cosmic dipole is mainly induced by the observer's kinetic motion, an intrinsic dipole arising from the anisotropy of the universe could also play an import role. Such an intrinsic anisotropy can be a dark energy mimicker that causes the observed accelerating expansion of the universe. As a new and powerful tool, gravitational waves can serve as an independent probe to the cosmic dipole. A useful type of events to achieve this is the "golden dark sirens", which are near-by well-localized compact binary coalescences whose host galaxies can be identified directly due to precise localization. By forecasting golden dark sirens obtained from 10-year observations using different possible detector networks in the future, we find that the standard LIGO-Virgo-KAGRA detectors are not able to detect a meaningful amount of golden dark sirens, and hence next-generation ground-based detectors are essential to obtain a strong constraint on the cosmic dipole. In particular, we find that a three-detector network consisting of more than one next-generation detectors can yield a constraint on the cosmic dipole at an order of 10^{-3} when jointly measured with H_0. Moreover, a constraint on the cosmic dipole at an order of 10^{-4} can be achieved when fixing H_0.

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