Contribution ID: **31** Type: **Talk**

Gravitational waves and galaxies cross-correlations: a forecast on GW biases for future detectors

Gravitational waves (GWs) have rapidly become important cosmological probes since their first detection in 2015. As the number of detected events continues to rise, upcoming instruments like Einstein Telescope (ET) and Cosmic Explorer (CE) will observe millions of compact binary (CB) mergers. As GWs carry information on their luminosity distance, but remain uninformative about their redshifts, I present the difference between clustering analysis in luminosity distance space as opposed to the traditional galaxy clustering in redshift space. These detections, coupled with galaxy surveys by instruments such as DESI, Euclid, and the Vera Rubin Observatory, will provide unique information on the large-scale structure of the universe by cross-correlating GWs with the distribution of galaxies hosting them. In this talk, I focus on how cross-correlations constrain the clustering bias of GWs emitted by the coalescence of binary black holes (BBH). This parameter links BBHs to the underlying dark matter distribution, hence informing us how they populate galaxies. Using a multi-tracer approach, we forecast the precision of these measurements under different survey combinations. Our results indicate that current GW detectors will have limited precision, with measurement errors as high as $\sim 50\%$. However, third-generation detectors like ET, when cross-correlated with LSST data, can improve clustering bias measurements to within 2.5%. Furthermore, we demonstrate that these cross-correlations can enable a percent-level measurement of the magnification lensing effect on GWs. Our analysis opens new avenues for studying the distribution of BBHs and testing the nature of gravity through large-scale structure.

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Session Classification: Flash talks

Track Classification: UK Cosmo