Constraining the inclinations of binary mergers from gravitational-wave observations

Cameron Mills[1], Samantha Usman[1,2], Stephen Fairhurst[1]

[1] School of Physics and Astronomy, Cardiff University, The Parade, Cardiff, CF24 3AA, UK

[2] Department of Astronomy and Astrophysics, University of Chicago, Chicago, Illinois 60637, USA

Much of the information we hope to extract from the gravitational-wave signatures of compact binaries is only obtainable when we can accurately constrain the inclination of the orbital plane relative to the line-of-sight. For instance poor inclination constraints were the dominant source of uncertainty in the first standard siren measurement of the Hubble constant. In this presentation we discuss a degeneracy between the measurement of the binary distance and inclination which limits our ability to accurately measure the inclination using gravitational waves alone. This degeneracy is exacerbated by the expected distribution of events in the universe, which leads us to prefer face-on systems at a greater distance. We use a simplified model that only considers the binary distance and orientation but gives comparable results to full parameter estimates. For the advanced LIGO-Virgo network, it is only binaries which are close to edge-on, i.e. with inclinations $\iota \gtrsim 75°$, that will be distinguishable from face-on systems. Extended networks which have good sensitivity to both gravitational-wave polarizations will only be able to constrain the inclination of a face-on binary at signal-to-noise ratio 20 to $\iota \lesssim 45°$. Even for loud signals, with signal-to-noise ratio of 100 and equal measurement of both polarizations, face-on signals will only be constrained to have inclinations $\iota \lesssim 30°$. In the absence of observable higher modes or orbital precession, this degeneracy will dominate the mass measurements of binary black hole mergers at cosmological distances. We investigate to what extent inclusion of the next-to-dominant mode can break the degeneracy, with a particular focus on the impact this will have on mass measurements of seed black holes with the Einstein Telescope.