Contribution ID: **41**

Type: **Oral contribution**

Multimessenger Parameter Estimation of GW170817: From Jet Structure to the Hubble Constant

Wednesday, 28 September 2022 15:00 (20 minutes)

The electromagnetic radiation that followed the neutron star merger event GW170817 revealed that gamma-ray burst afterglows from jets misaligned with our line of sight exhibit a light curve with slowly rising flux. The slope of the rising light curve depends sensitively on the angle of the observer with respect to the jet axis, which is likely to be perpendicular to the merger plane of the neutron star binary. Therefore, the afterglow emission can be used to constrain the inclination of the merging system. Here, we calculate the gamma-ray burst afterglow emission based on the realistic jet structure derived from general-relativistic magnetohydrodynamical simulations of a black hole torus system for the central engine of the gamma-ray burst. Combined with gravitational wave parameter estimation, we fit the multi-epoch afterglow emission of GW170817. We show that with such a jet model, the observing angle can be tightly constrained by multimessenger observations. The best fit observing angle of GW170817 is $\theta_{\rm v} = 0.38 \pm 0.02$ rad. With such a constraint, we can break the degeneracy between inclination angle and luminosity distance in gravitational wave parameter estimation, and substantially increase the precision with which the Hubble constant is constrained by the standard siren method. Our estimation of the distance is $D_{\rm L} = 43.4 \pm 1$ Mpc and the Hubble constant constraint is $\rm H_0 = 69.5 \pm 4$ km s^{-1} Mpc^{-1}. As a result, multimessenger observations of short-duration gamma-ray bursts, combined with a good theoretical understanding of the jet structure, can be powerful probes of cosmological parameters.
https://arxiv.org/abs/2009.04427

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Session Classification: Session 6