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August 29, 2019

Prof. Frederic Rasio
Northwestern University
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Dear Dr. Rasio:

Please find enclosed a submission for consideration as an ApJ Letter, titled “A Future Percent-Level Measurement of the Hubble Expansion at Redshift 0.8 With Advanced LIGO.”

In the manuscript, we point out that by using a feature in the mass distribution of black holes, we are able to make precision cosmological constraints at $z \simeq 0.8$ and beyond. The mass feature which we use is the sharp reduction in the observed rate density of binary black hole mergers at $M \sim 45 M_{\odot}$, thought to be the result of pair instability supernovae (although understanding the physical mechanism isn’t crucial to the use of the feature). This “absorption” feature allows us to infer redshift, which, when coupled with the use of gravitational-wave sources as standard sirens, allows us to measure the distance-redshift relation without the use of a separate distance ladder.

We show that not only will standard sirens provide definitive measurements of the Hubble constant, but they will also measure the full expansion history out to $z \sim 1$, and thereby constrain the dark energy and deviations from Λ CDM over the crucial range where the universe’s expansion goes from deceleration to acceleration. This is a direct, absolute, self-calibrated cosmological measurement, and is therefore qualitatively different from Type Ia SNe, BAO, strong lensing, or other ways to constrain cosmology at this epoch.

We are not the first to propose using features in a mass distribution to measure redshifts in a gravitational wave detector (the idea goes back to Chernoff & Finn (1993)); but until now all such proposals exploited the narrow range of merging *binary neutron star* masses. Such mergers are not suitable for cosmography in the current era because the reach of present detectors to neutron star mergers, ~ 100 Mpc, is not sufficient for the mass to redshift meaningfully. In contrast, Advanced LIGO and Virgo operating at design sensitivity can detect a merger of two black holes near the pair instability limit at redshifts $z \simeq 1.5$, so precision

cosmography is possible with current detectors.

We thank you for your careful consideration of this manuscript.

Sincerely,

Will M. Farr
Maya Fishbach
Jiani Ye
Daniel Holz