Department of Physics and Astronomy
Stony Brook University
Stony Brook NY 11794
United States

August 24, 2019

Dr. Leslie Sage
Springer Nature
One New York Plaza, Suite 4600
New York NY 10004-1562
USA

Dear Dr. Sage:

Please find enclosed a submission for consideration as a Nature 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 distance ladder. Our work is a natural follow-up from three previous Nature standard siren articles: Schutz 1986, Abbott+ 2017, and Chen+ 2018. In this work, 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 1, and thereby constrain the dark energy and deviations from LambdaCDM 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, $\sim 100\,\mathrm{Mpc}$, 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 note that the submitted manuscript is not yet compliant with the Nature Letter formatting standards (particularly with respect to the number of references). We do not believe that it would be too difficult to bring it in line with your requirements, however, should you be interested in publishing it.

We thank you for your careful consideration of this manuscript.

Sincerely,

Will Farr
Maya Fishbach
Jiani Ye
Daniel Holz