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Dr. Leslie Sage
Springer Nature
One New York Plaza, Suite 4600
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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." As you will see from the manuscript, the goal of this work is to point out how a recently-discovered feature in the mass distribution of merging binary black holes enables precision cosmology at redshift $z \simeq 0.8$.

General relativity predicts the amplitude of a gravitational wave signal; such signals are "standard sirens" that enable a direct measurement of the luminosity distance to the source. In contrast to electromagnetic astronomy, the challenge with gravitational wave sources is to measure the redshift to the source. There are a number of ways to do this (see references in the manuscript, including the "counterpart method," published in Nature by the LIGO and Virgo collaborations following GW170817).

Here we propose to exploit an "absorption" feature in the mass distribution of merging binary black holes to infer redshifts without any corresponding electromagnetic measurements. Hints of a maximum mass of merging black holes are apparent in the first gravitational wave transient catalog; a physical process, the "pair instability supernova," has been proposed to reduce the remnant mass of or disrupt a high mass star completely, leaving no black holes in binaries above a mass $\simeq 45\,M_\odot$. Because gravitational wave detectors measure a redshifted mass, $m_{\mathrm{detector}} = m_{\mathrm{source}}(1+z)$, tracking the detector-frame mass at which the black hole mass distribution tails off measures the redshift of a population of mergers.

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, $\mathcal{O}\,(100\,\mathrm{Mpc})$, 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 predict that with five years of Advanced LIGO and Virgo observations the Hubble expansion can be constrained to better than 3% at $z \simeq 0.8$. Besides the intrinsic excitement in such an independent measurement of the expansion rate of the universe (see manuscript), we believe that this method will become the dominant cosmological tool in the emerging field of gravitational wave cosmology. The measurement relies on understanding and calibrating the amount of intrinsic evolution in the pair instability scale (which is degenerate with the redshift measurement); by analogy to type Ia supernovae, remnants near the pair instability gap become standard*izable* sirens. Thus, we expect this result to drive a large portion of the near-term research agenda of *two* important astronomical fields: gravitational wave cosmology *and* the evolution of massive stars in binaries.

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