GW Compact Remnant Mass Distributions as Probes of the Supernova Engine

Gravitational Waves (GWs) have the potential to measure the masses of a large number of compact remnants (neutron stars and black holes) at accuracies rivaling all other methods in astronomy. Cosmic Explorer would provide enough measurements to provide full populations of these remnants, allowing supernova astronomers to constrain the supernova engine and how it evolves with metallicity.

Compact remnant masses can be tied to details of the supernova engine. The current standard-paradigm behind normal core-collapse supernova relies upon convection above the collapsed core (proto-neutron star) that enhances the conversion of the gravitational potential energy released in the collapse into the kinetic energy of the explosion[1-3]. Understanding the nature of this convection and its dependence on the physics is at the heart of most current studies of the supernova engine. Because the proto-neutron star accretes quickly during the convective phase, the remnant mass can be used to determine the growth time and magnitude of this convection[4]. By measuring the remnant mass distribution, astronomers can differentiate the different physical models and validate this paradigm.

The tie between remnant masses and the convective region requires both a systematic study of the supernova engine (including a study of fallback material) to make mass predictions and binary studies to understand the biases of the mass distribution caused by the subset of compact remnants in tight, merging binaries observed by GWs. Figure 1 shows an example of such a study showing the effect of convective growth time on the extent of the lower mass gap in merging binaries[5]. With Cosmic Explorer, the compact remnant distribution will be sufficiently precise to not only constrain the current-day supernova engine but also study the evolution with redshift, and hence, metallicity.

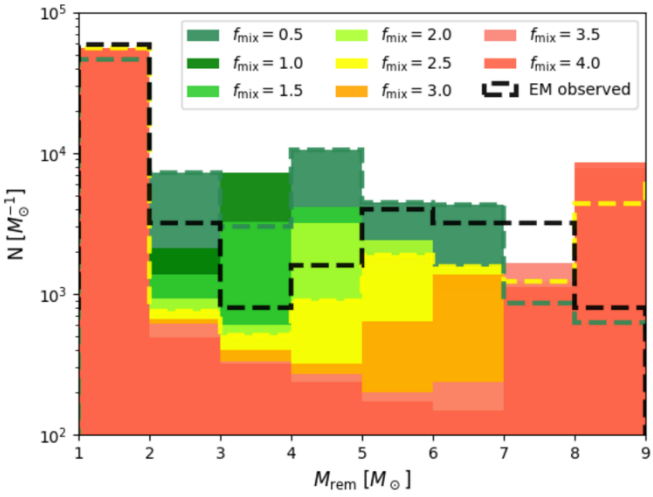

Figure 1: Remnant masses in the mass gap based on different convective growth times for merging binaries.

If you choose to have some discussion on this science, I can flesh out the description and add more details at whatever level you like.

[1] Herant M., Benz W., Hix W.R., Fryer C.L., Colgate S.A., 1994, ApJ, 435, 339
[2] Mezzacappa A., Liebendorfer M., Messer O.E., Hix W.R., Thielemann F.K., Bruenn S.W., 2001, PhRvL, 86, 1935
[3] Janka H.T., 2001, A&A, 368, 527.
[4] Fryer C.L., Olejak A., Belczynski K., 2022, ApJ, 931, 94
[5] Olejak A., Fryer C.L., Belczynski K., Baibhav V., 2022, MNRAS, 516, 2252