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Determining the Masses of Black Holes and Neutron Stars seen in Merger Events Detected by the LIGO and Virgo Gravitational Wave Observatories

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Celebration of Scholars 2022: Exposition of Student & Faculty Research, Scholarship & Creativity

Analysis Method

- We analyze 83 compact binary merger events gathered from the Gravitational Wave Open Science Center (GWOSC)
- In utilizing the GWOSC API, we create parameter estimations to calculate various posterior distributions for the two component masses throughout the 83 events (as shown in Figure 1 below)
- The posterior distributions used in our research utilize bayesian inference to extract an event's source properties and fit the collected interferometer data
- We further correct our data by accounting for the natural redshift which these waves experience to calculate the masses at the event's source rather than as is received in the interferometer's frame of reference
- From these likelihood distributions, we produce mass scatter plots of the two component masses, as well as the total mass of the system (m1 + m2) and the final mass after the merger event (Two plots shown in Figures 2 and 3) to compare the two and ultimately confirm the necessary existence of gravitational waves

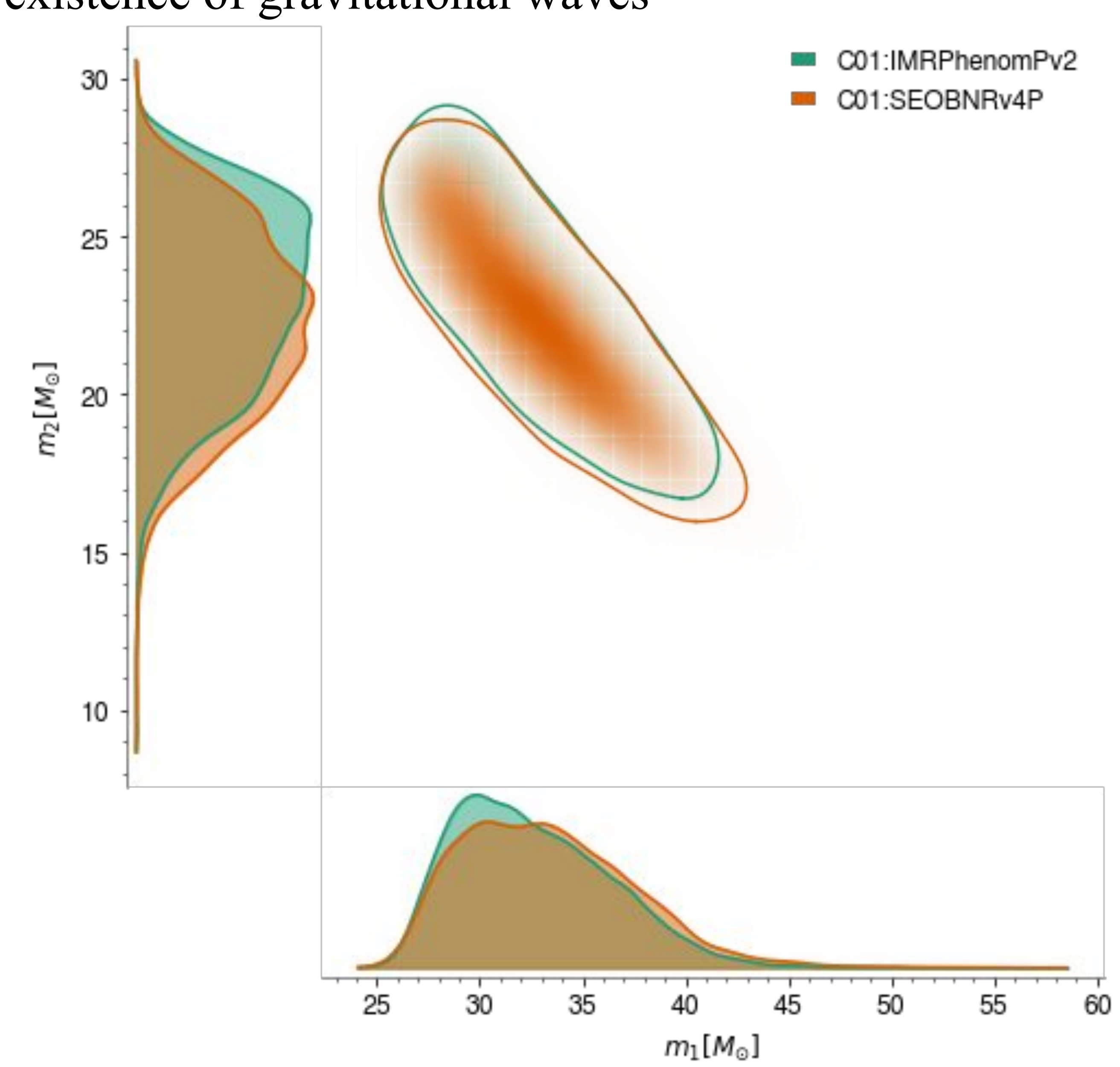

Figure 1: Joint and Marginalized Likelihood Distributions of Two Component Masses for GW190408_181802.

Abstract

In this investigation, we analyze several dozen black-hole and neutron-star merger events seen in data provided by the Gravitational Wave Open Science Center. With analysis tools acquired in the LIGO-Virgo Open Data Workshops, we determine the masses of each of the two binary components, the chirp mass characterizing both the binary infall and emission of gravitational waves, and the luminosity distances. We also catalog the spectrograms ("chirps") of mergers occurring since the original 2015 event detected by the LIGO and Virgo interferometers. We find our results in mass histograms and scatter plots, confirming the apparent "mass gap" in these compact objects. We hope to better understand the nature of this mass gap and why it arises in subsequent research.

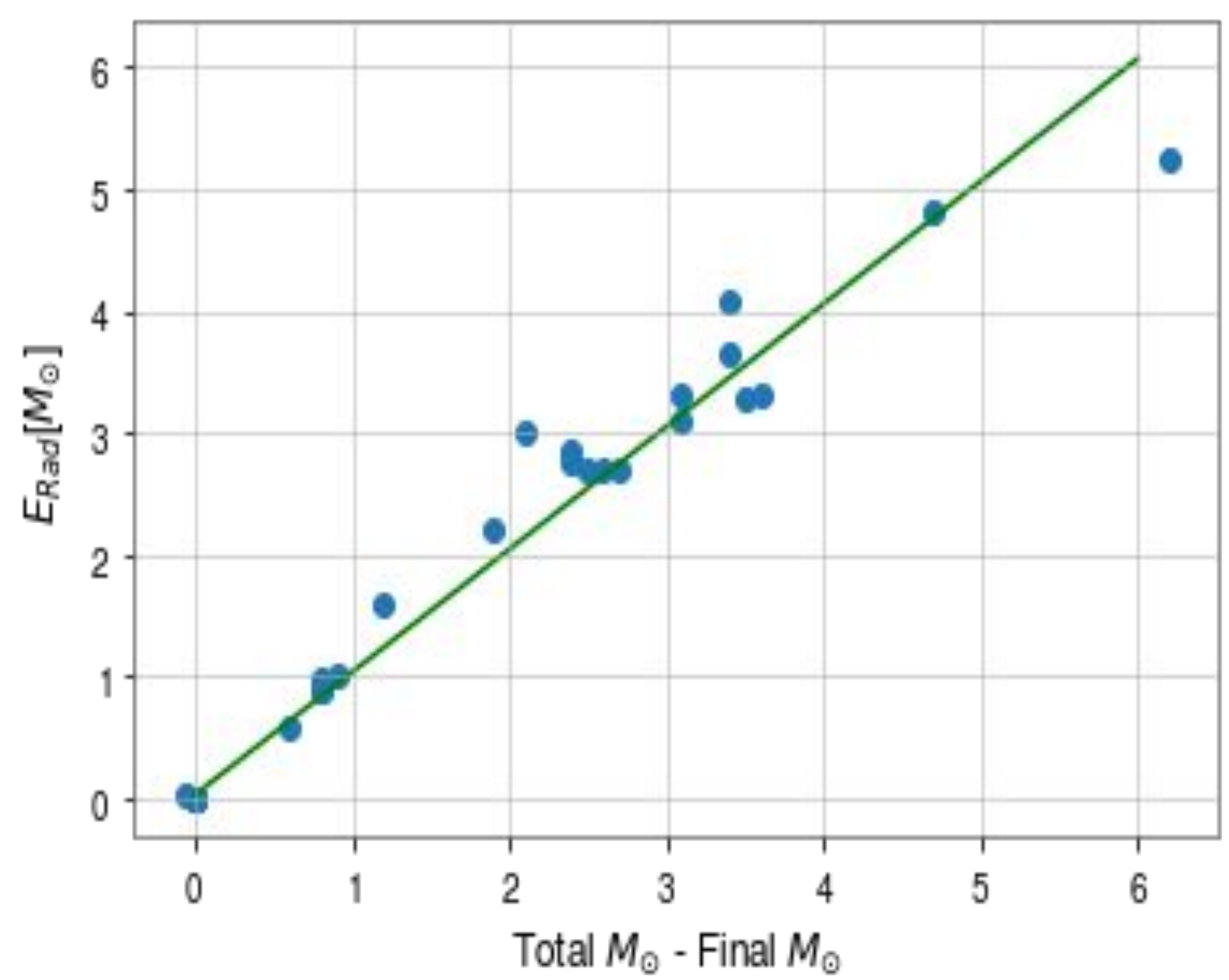

Figure 4: Radiated Mass-Energy of Gravitational Waves vs. Mass Difference. Green line shows best fit for slope of 1.01. Expected slope is 1.00.

Mass Results

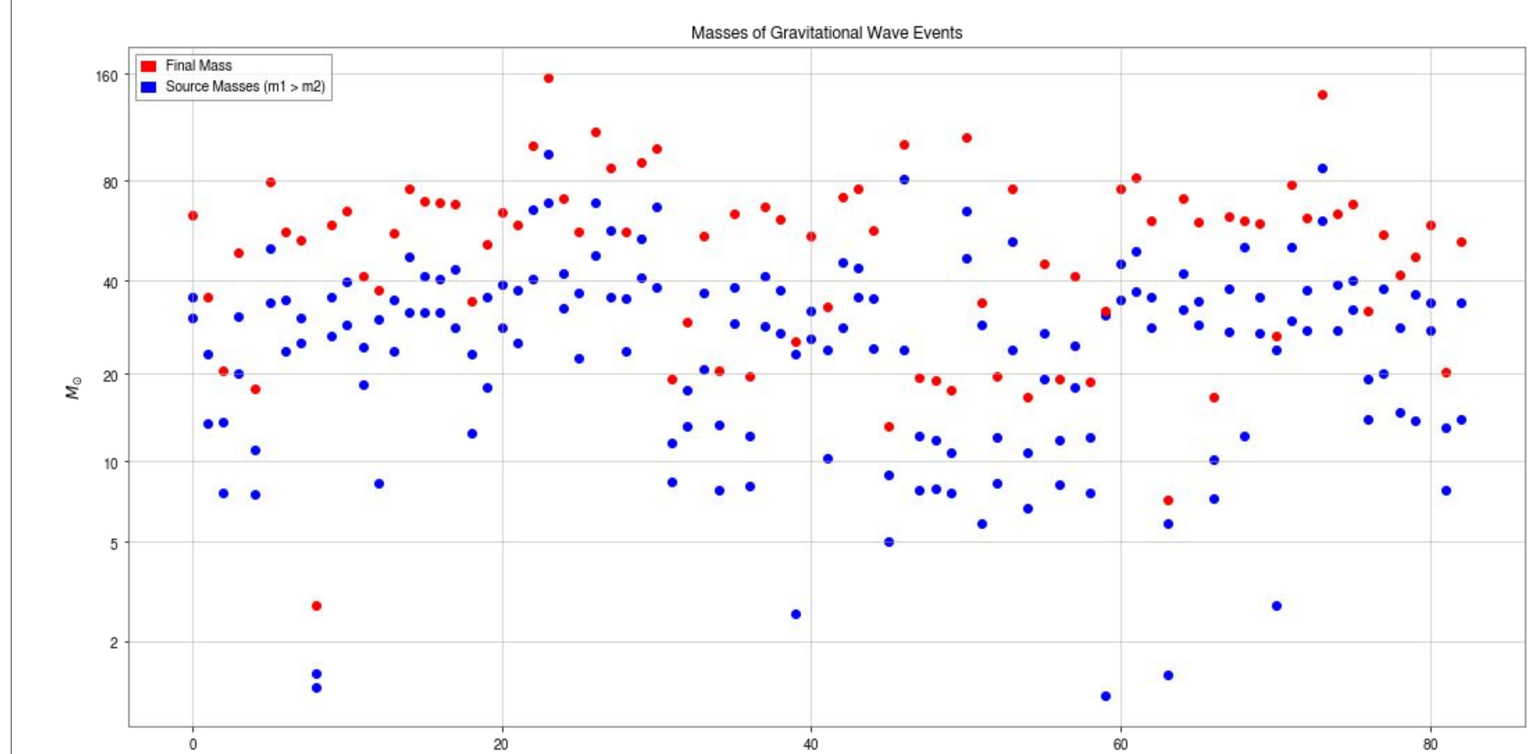

Figure 2: Masses of Binary Components (Blue) and Resulting Black Hole Merger Mass (Red) vs. Event (2015-2019)

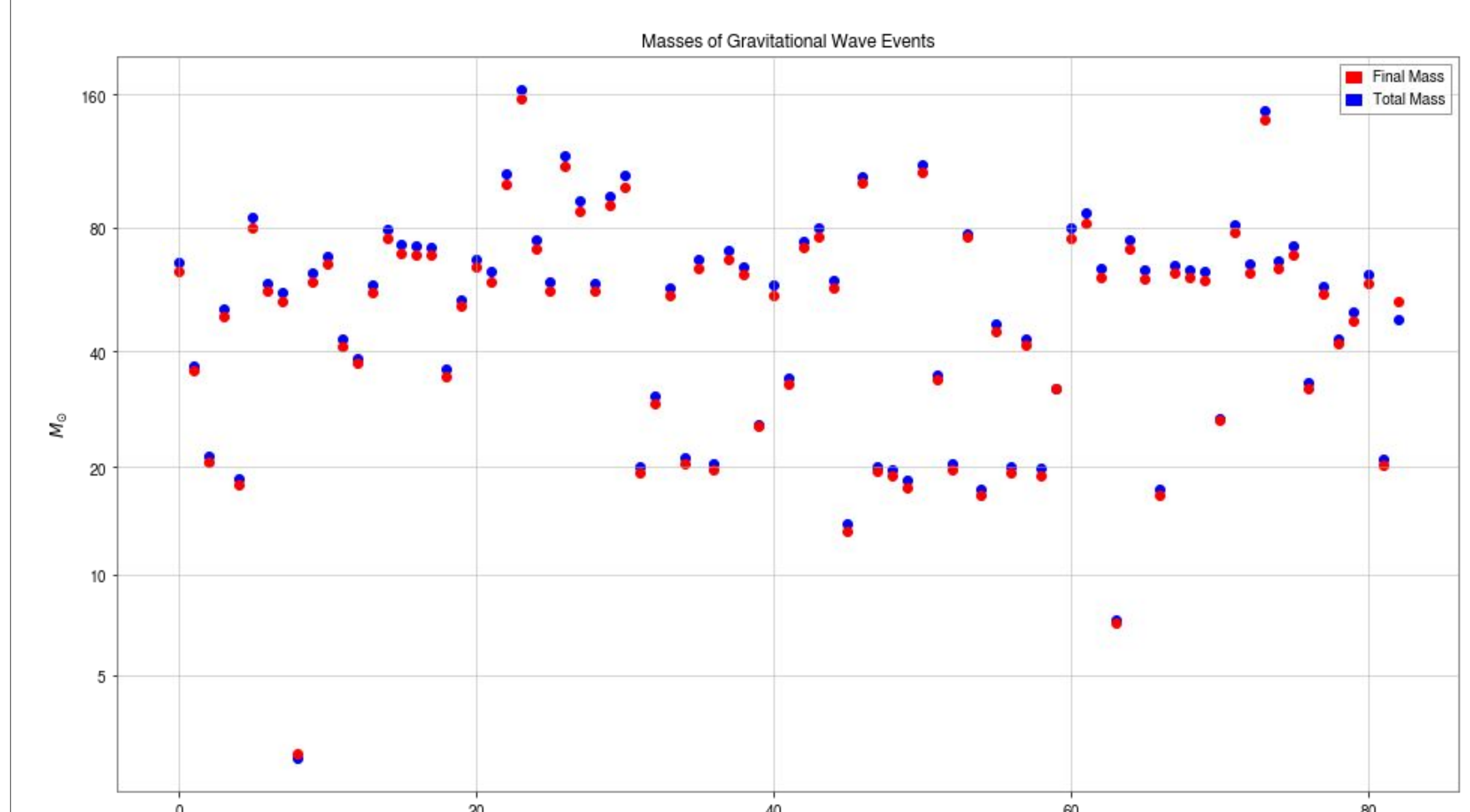

Figure 3: Sum of Masses (Blue) and Resulting Black Hole Merger Mass (Red) vs Event (2015-2019)

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Reference:

- Abbott, Rich, et al. "Population properties of compact objects from the second LIGO–Virgo Gravitational-Wave Transient Catalog." *The Astrophysical journal letters* 913.1 (2021): L7.