Detection of Gravitational Wave Signals from Core-Collapse Supernovae Using Distributional Methodologies

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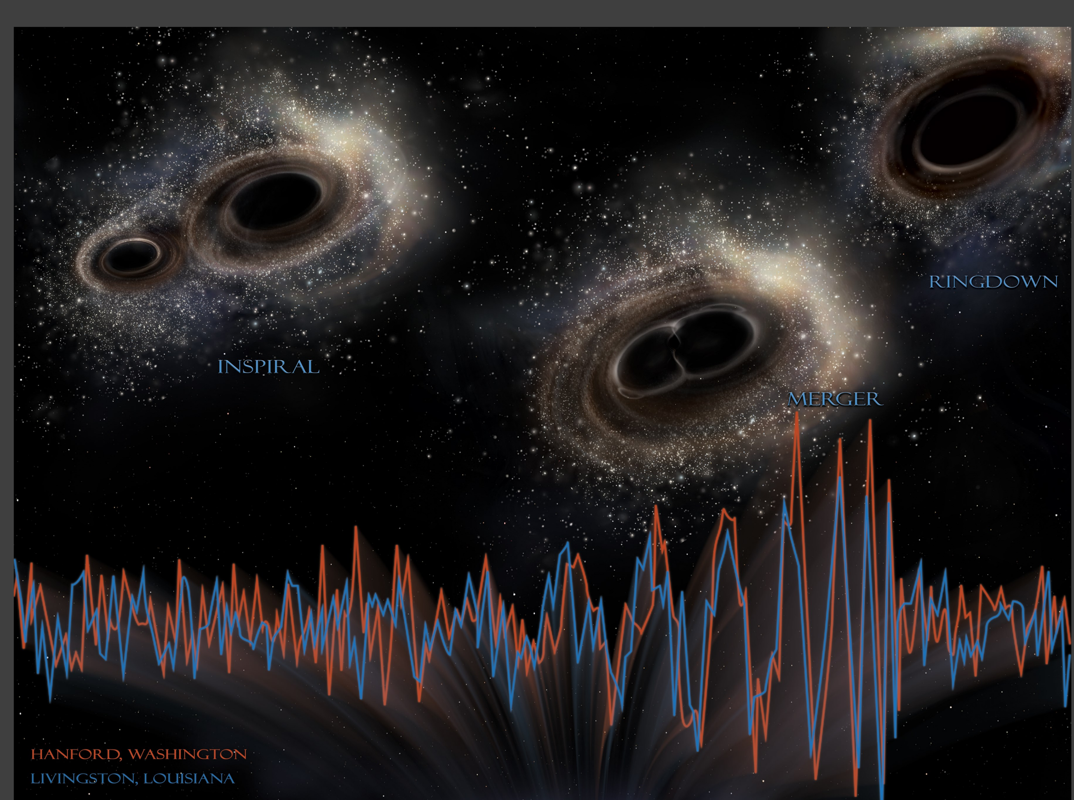
Introduction

To date, no gravitational waves have been detected from core-collapse supernovae. However, the sheer force of their explosions, especially amongst the most massive stars, show strong evidence for the production of gravitational waves. The Laser Interferometer Gravitational-Wave Observatory (LIGO) records and analyzes these ripples in spacetime .

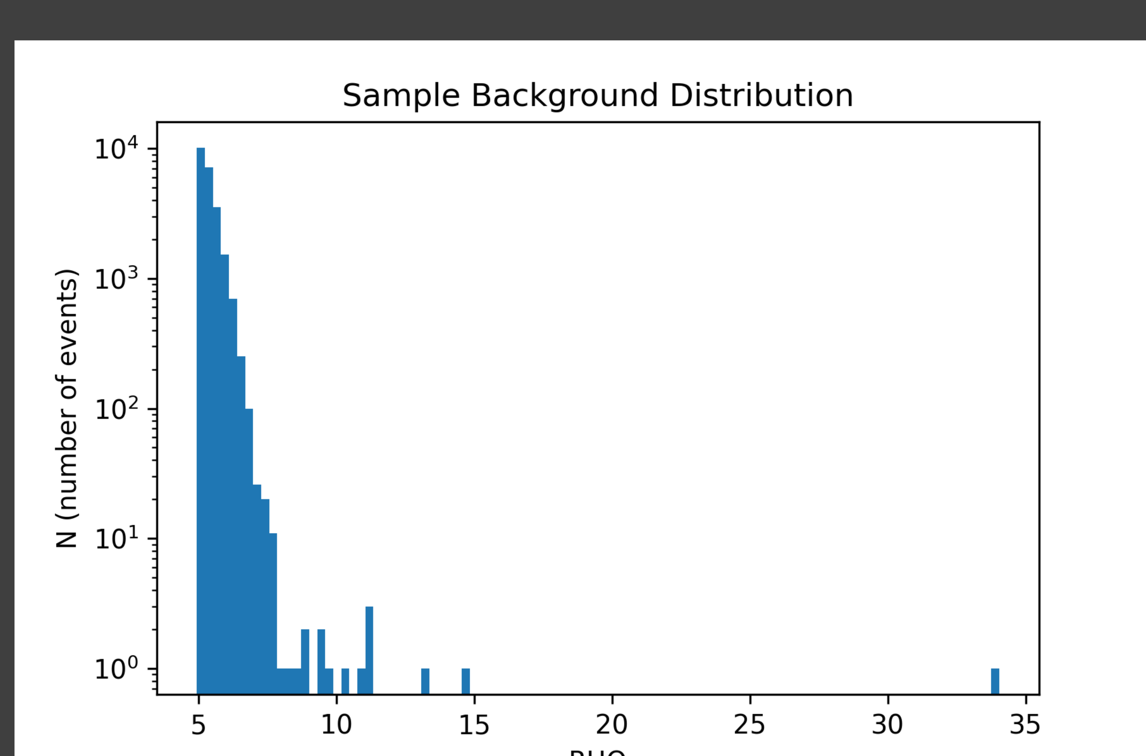


- This illustration shows the first observation of a black hole merger! It was detected by LIGO, using laser interferometers.
- Gravitational waves warp spacetime, which disrupts the constant lasers in the interferometers.

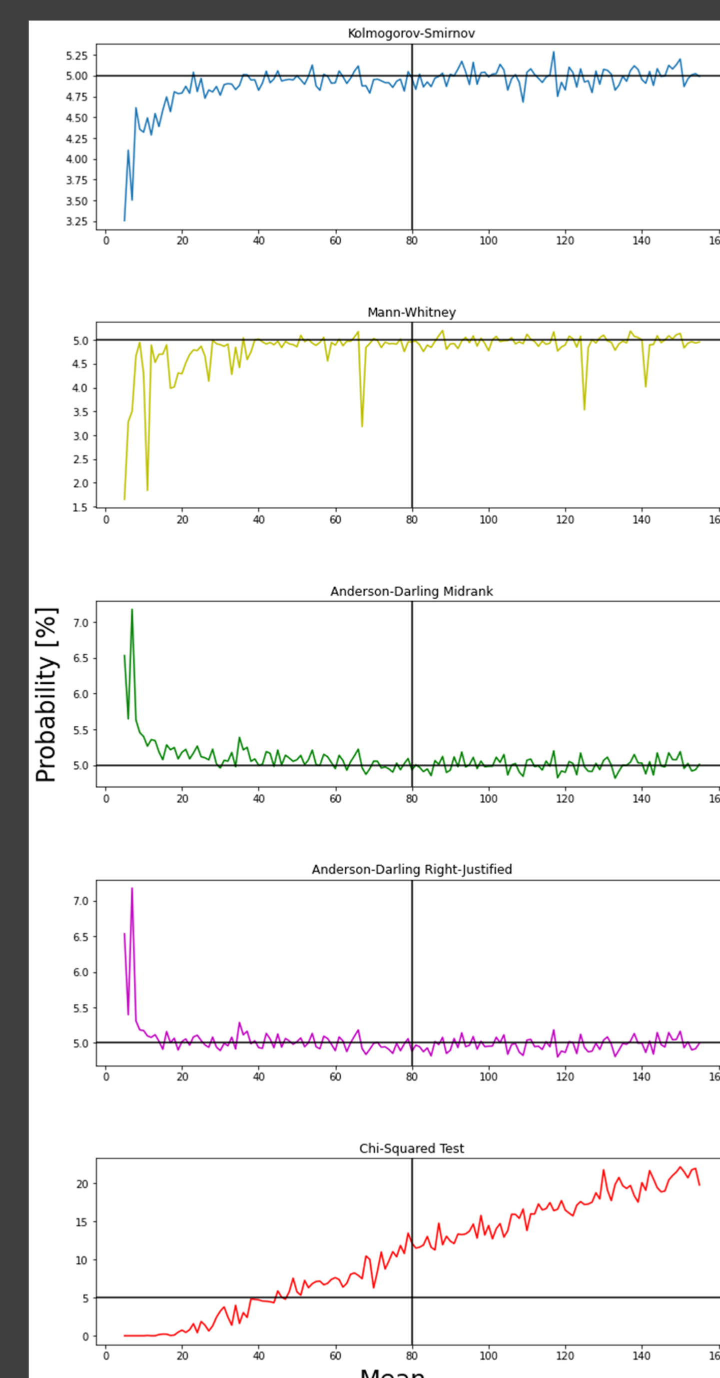
Credit: AURORE SIMONNET, JUNE 28, 2017, GW150914 FIRST LIGO DETECTION

Methods

The overarching methodology of this project is to compare a dataset that may contain supernovae to a noisy background. Then, each statistical test determines if the two distributions come from one parent distribution. Over many iterations, this forms a probability that the tests will conclude that the two distributions are from the same source.



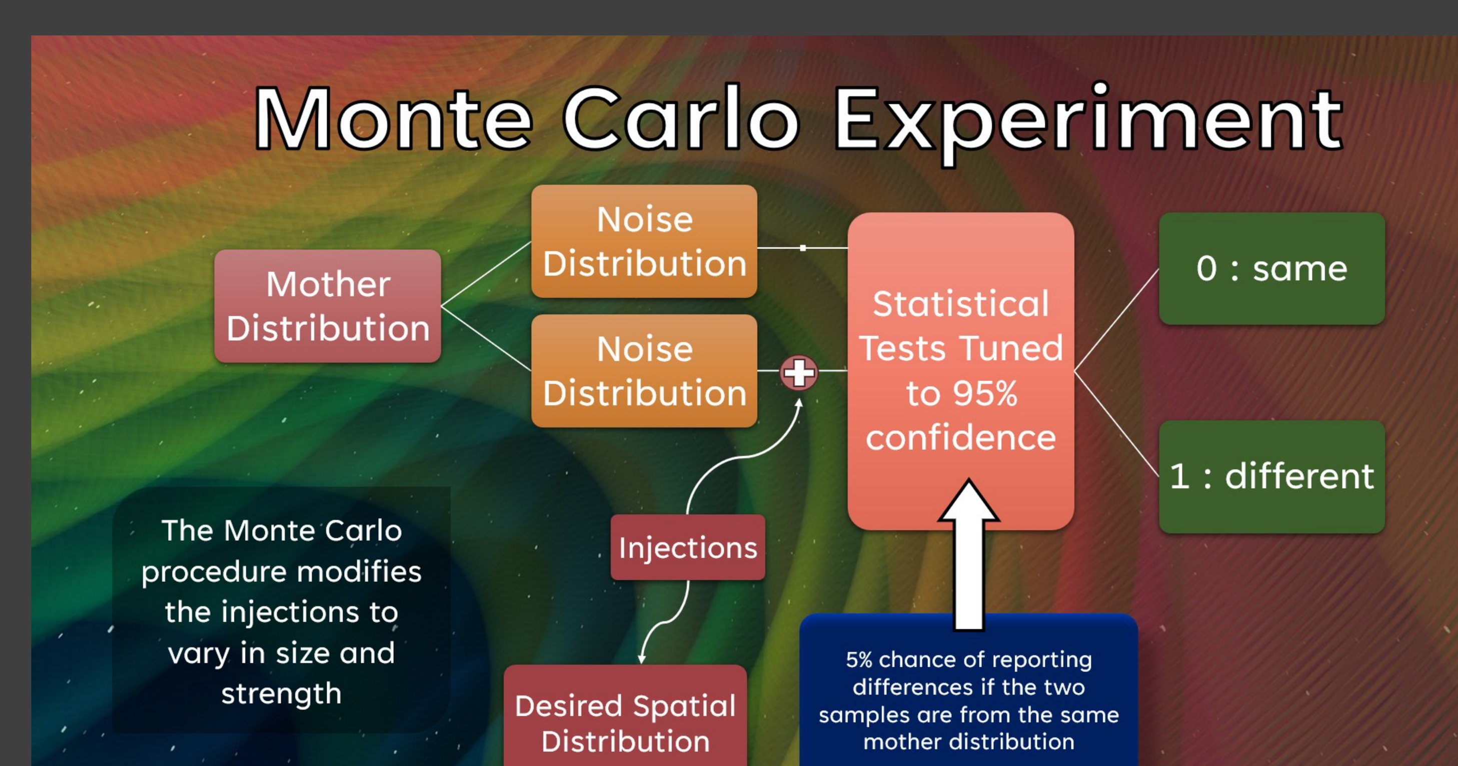
Preliminary Results



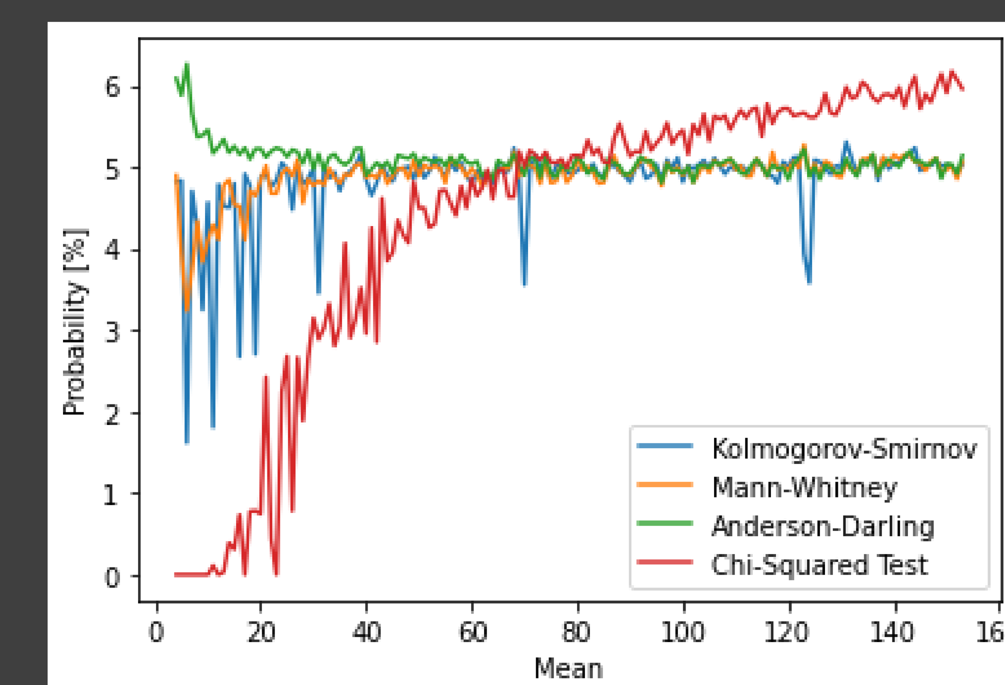
Meet the Tests

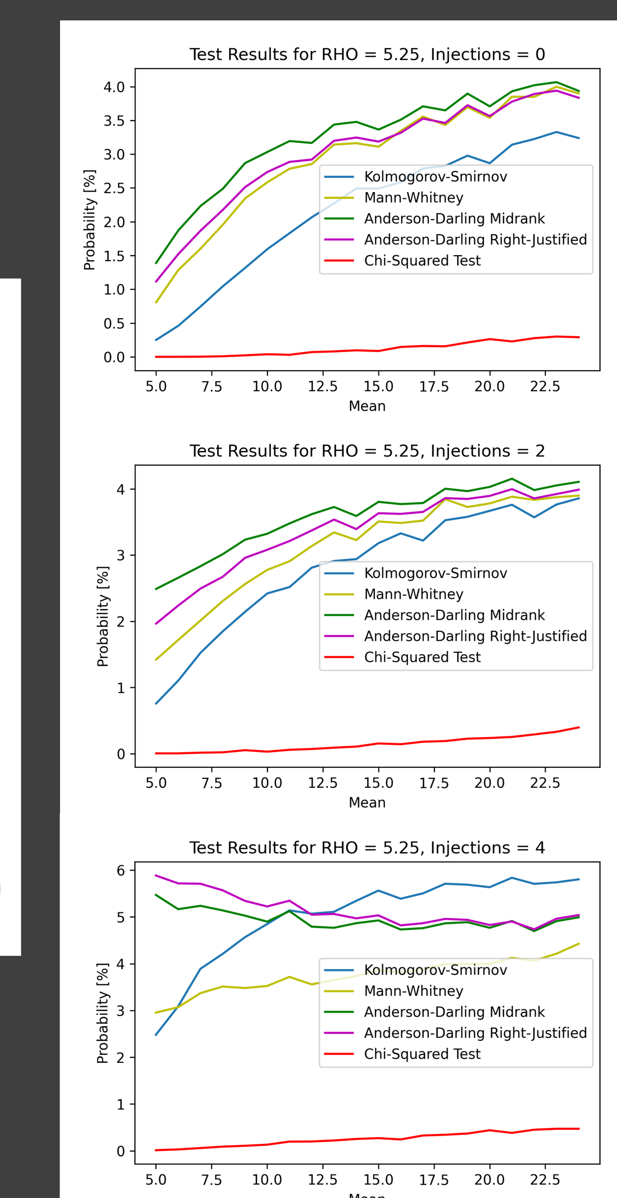
- Kolmogorov-Smirnov
- Mann-Whitney
- Anderson-Darling Midrank
- Anderson-Darling Right Justified
- Chi-Squared

- The horizontal black line represents a probability of 5%
- The statistical significance of this value to our calculations is the implication of a *false alarm rate*
- 50000 iterations amongst randomly selected samples of background data
- nonparametric distributions of unknown shapes
- sample sizes chosen from a *Poissonian* (instead of something uniform or Gaussian)



- The Monte Carlo aspect ensures that the process does not assume the shape of the incoming distribution.
- The injections are the supernovae; the goal is to better distinguish them from the background instead of the previous methods of choosing only the loudest event.





Future Work

A common theme throughout this project has been the addition of complexities. For every question answered, there seems to be 2 more up next. This includes revising the work done previously on this topic, integrating new information based on the new LIGO candidates of the next observing run, which will hopefully catch the first confirmed gravitational wave sighting from a supernova!

These results will hopefully be helpful to other scientists in the LIGO Scientific Collaboration.

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