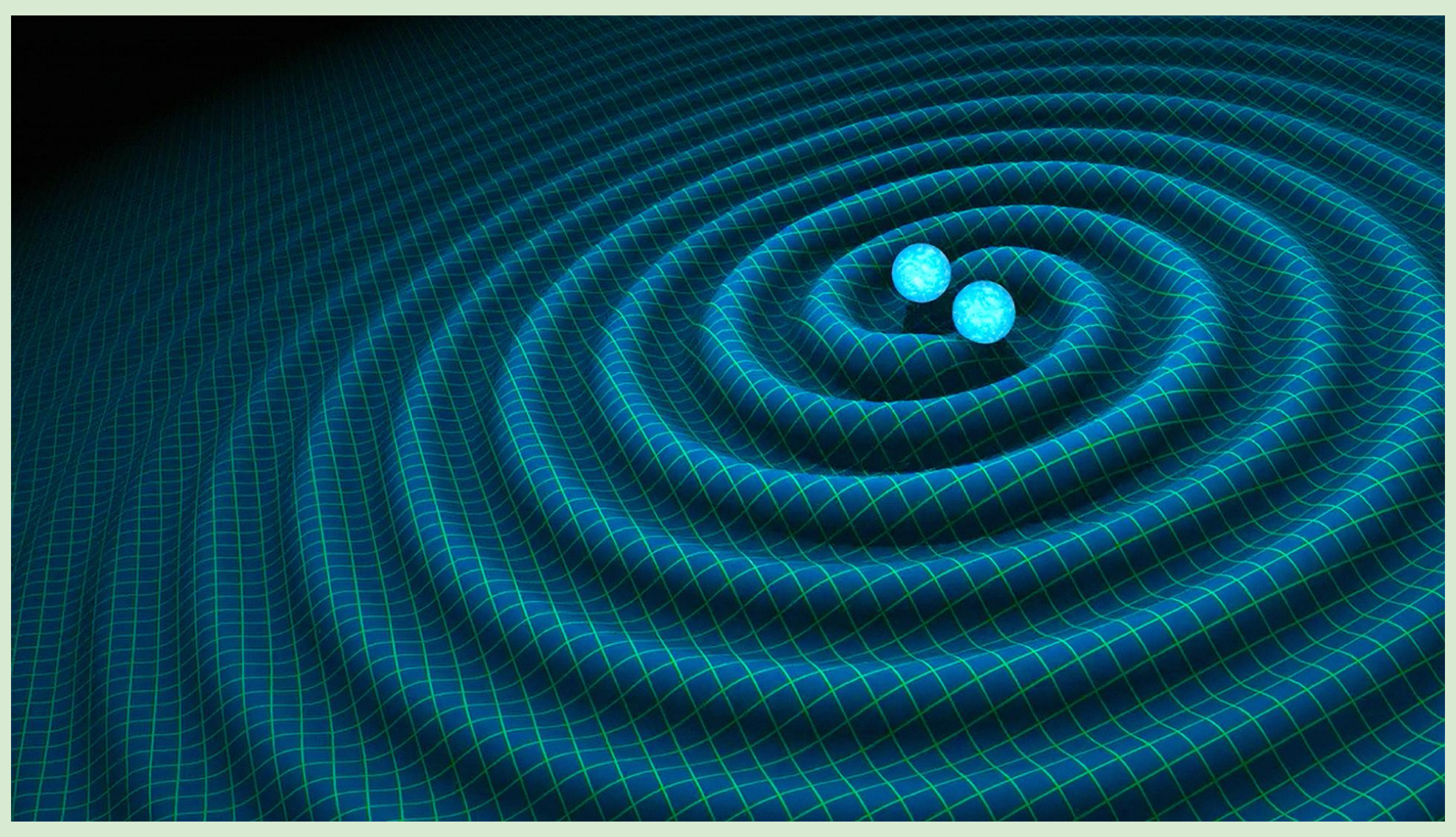
First Results from the Search for Binary Black Hole Coalescence with Advanced LIGO

Steven Reyes on behalf of the LIGO group - **G1601273**

Gravitational Waves and their Sources

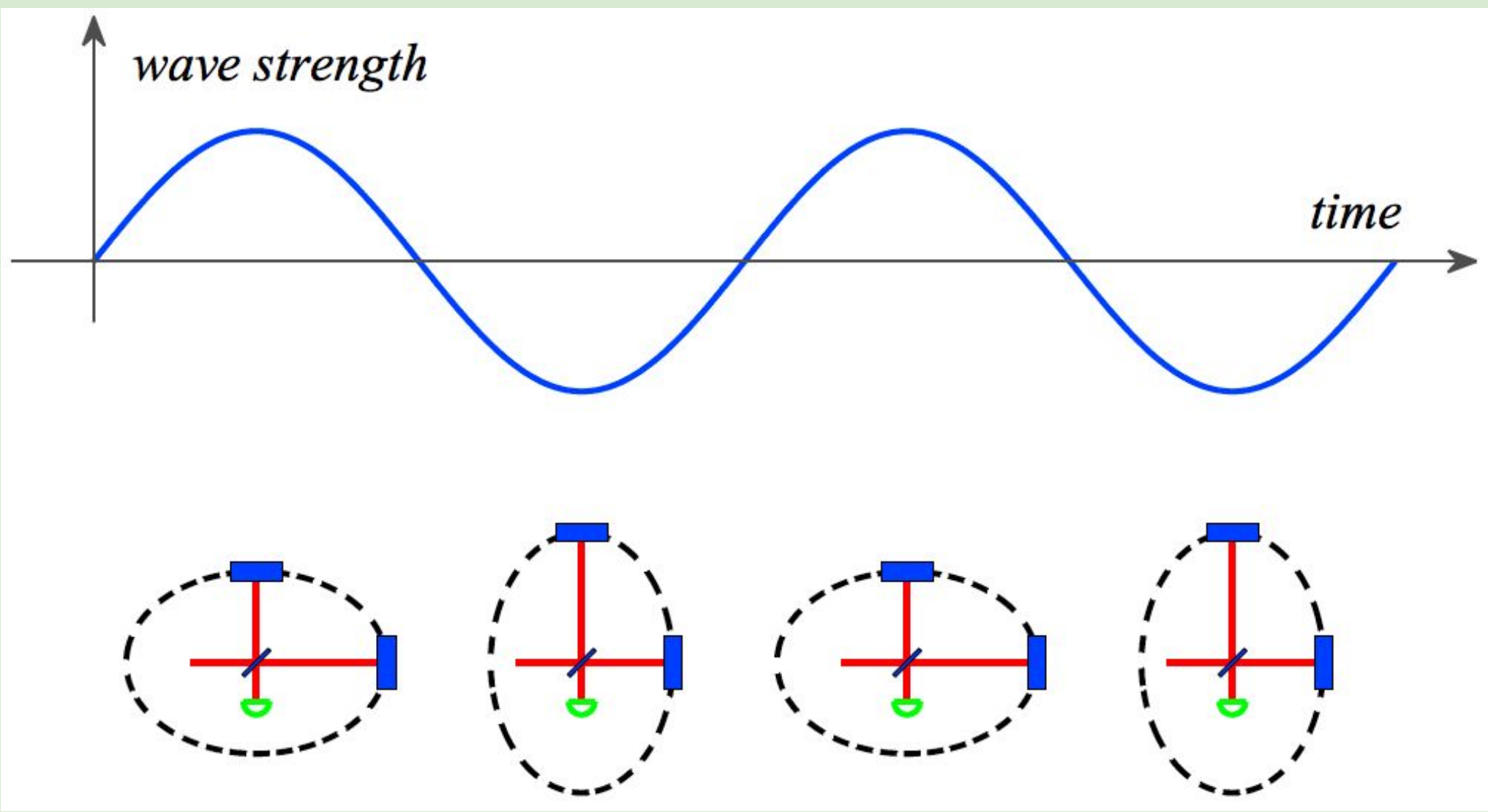
Einstein's general theory of relativity describes spacetime as being curved by matter and energy distributions. Matter tells space how to curve; curved space tells matter how to move.

Accelerated matter can produce waves in curved spacetime.



http://www.iflscience.com/sites/www.iflscience.com/files/blog/%5Bnid%5D/ns_gw_art.jpg

Gravitational waves transmit energy very weakly. However, astrophysical sources of gravitational waves (like binary black hole mergers, supernovae, or binary neutron star mergers) permit detection of the waves as variations in measured distances.

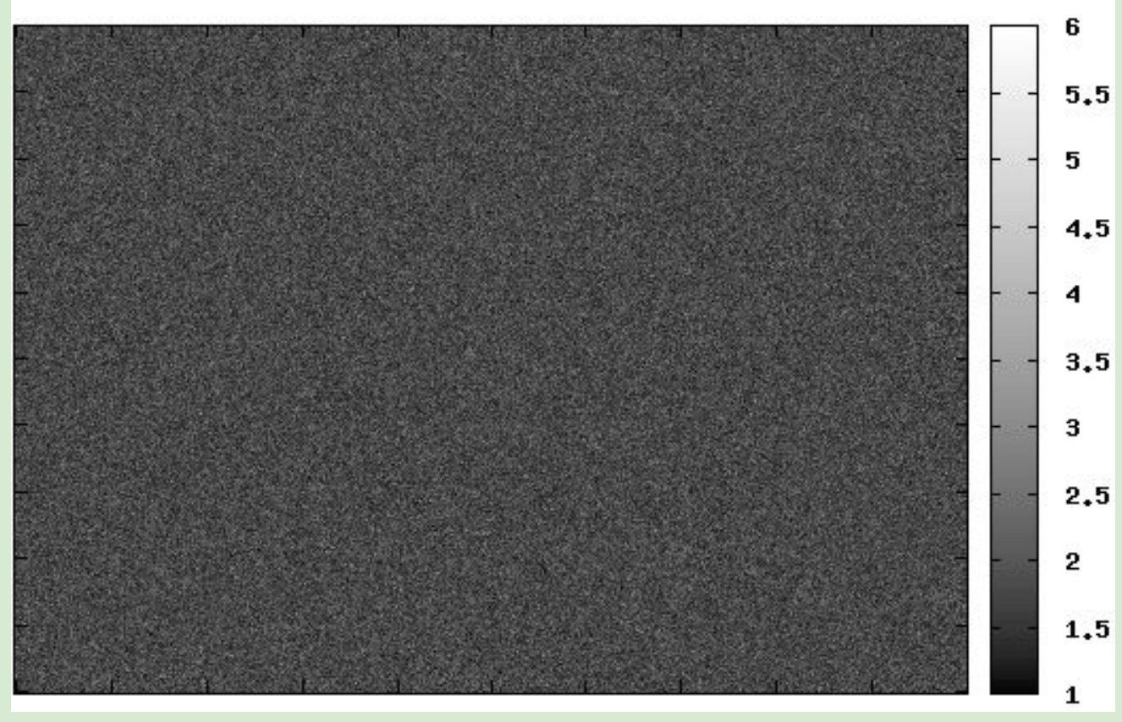


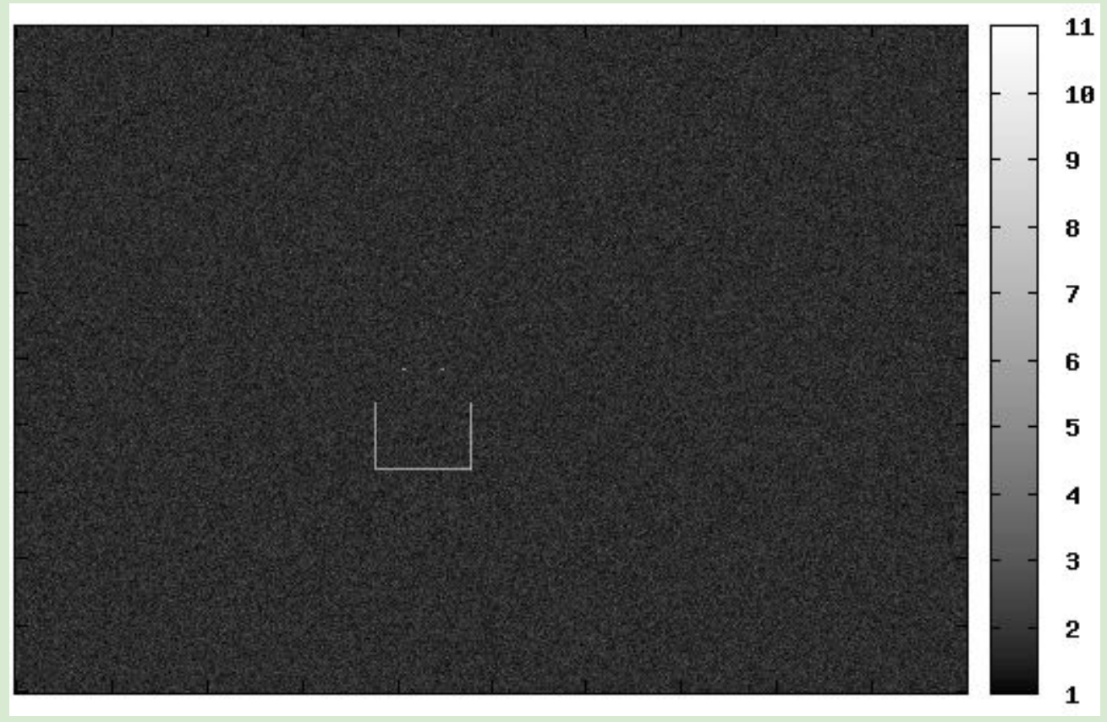
http://www.astro.cardiff.ac.uk/research/gravity/resources/simple_ifo-large.png

LIGO is an interferometer that uses lasers to measure changes in distances in its arms as gravitational waves pass through the detector.

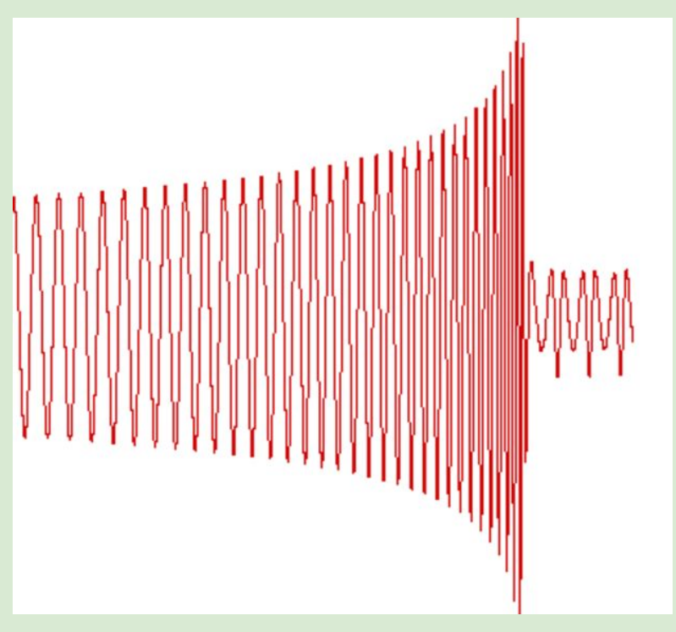
A Matched-Filter Search

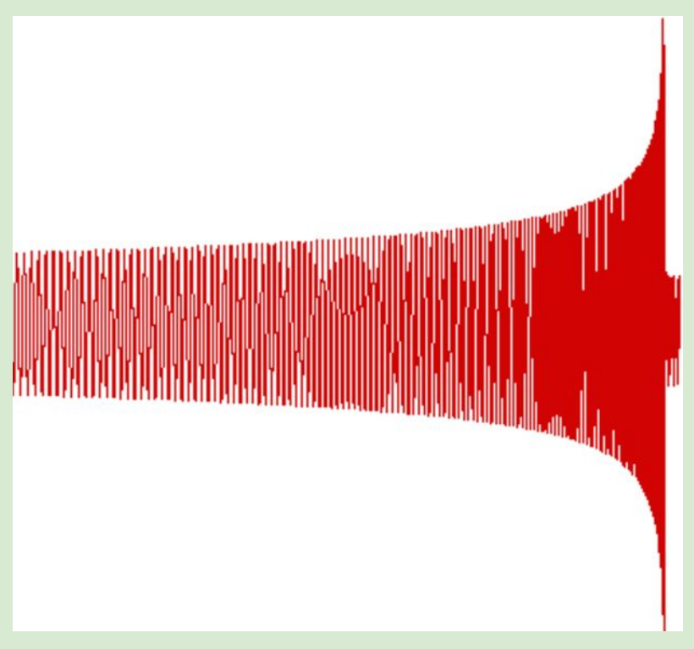
There are many other sources of oscillations in the lengths of LIGO's interferometer arms, and so the data can look quite noisy.





The louder a signal, the more likely it can be recovered amidst noisy data. However, quiet signals are difficult to recover from noisy data.





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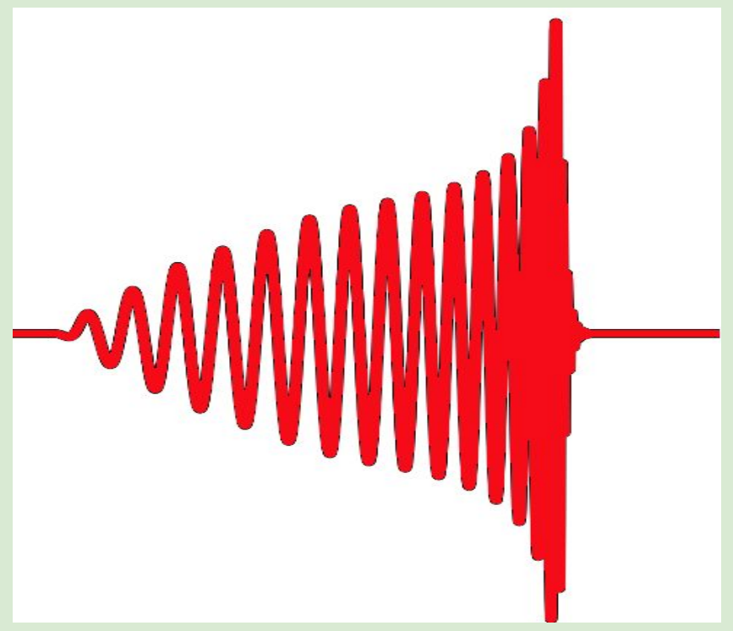
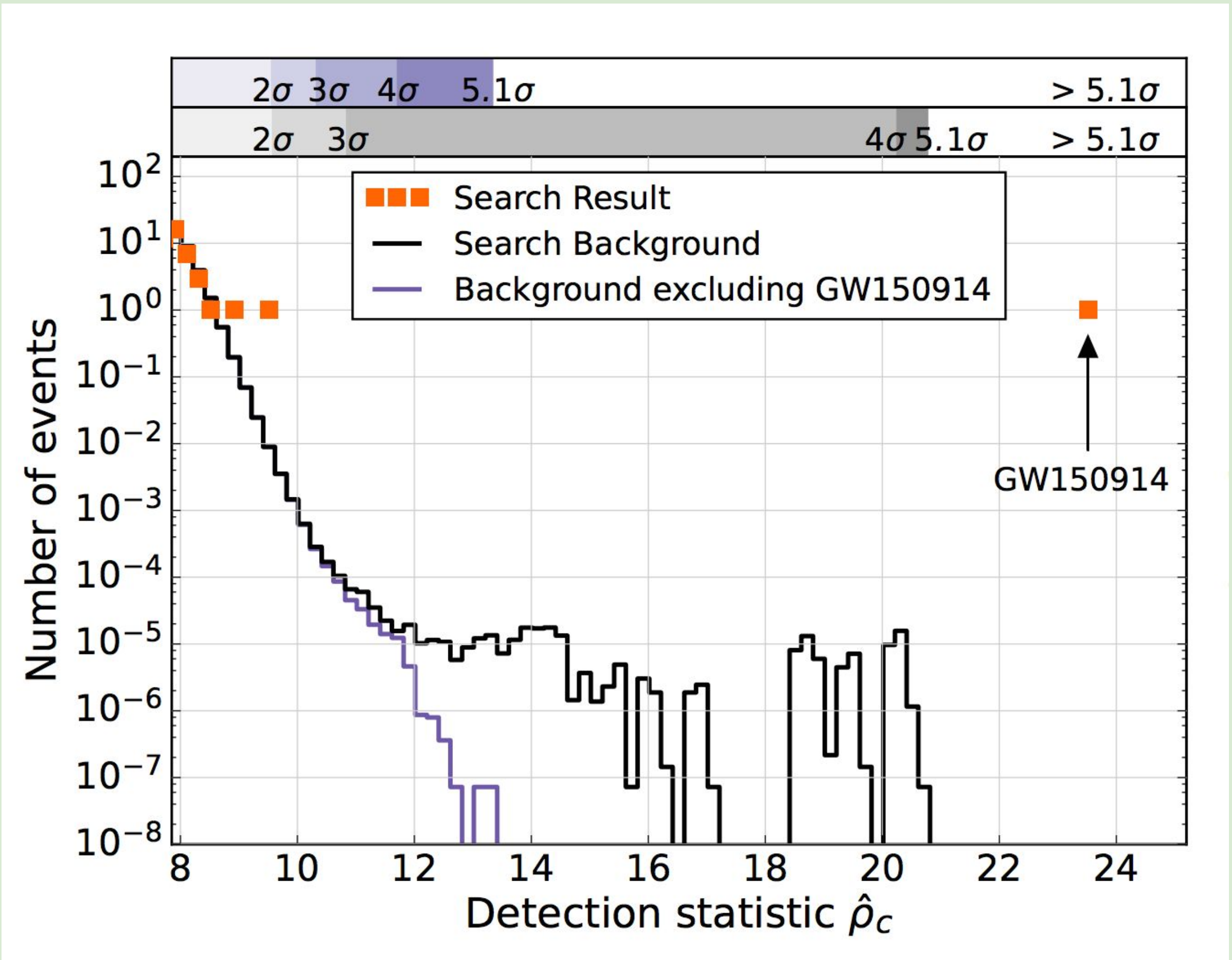


http://sites.psu.edu/ligo/wp-content/uploads/sites/35076/2016/02/20bbh.png

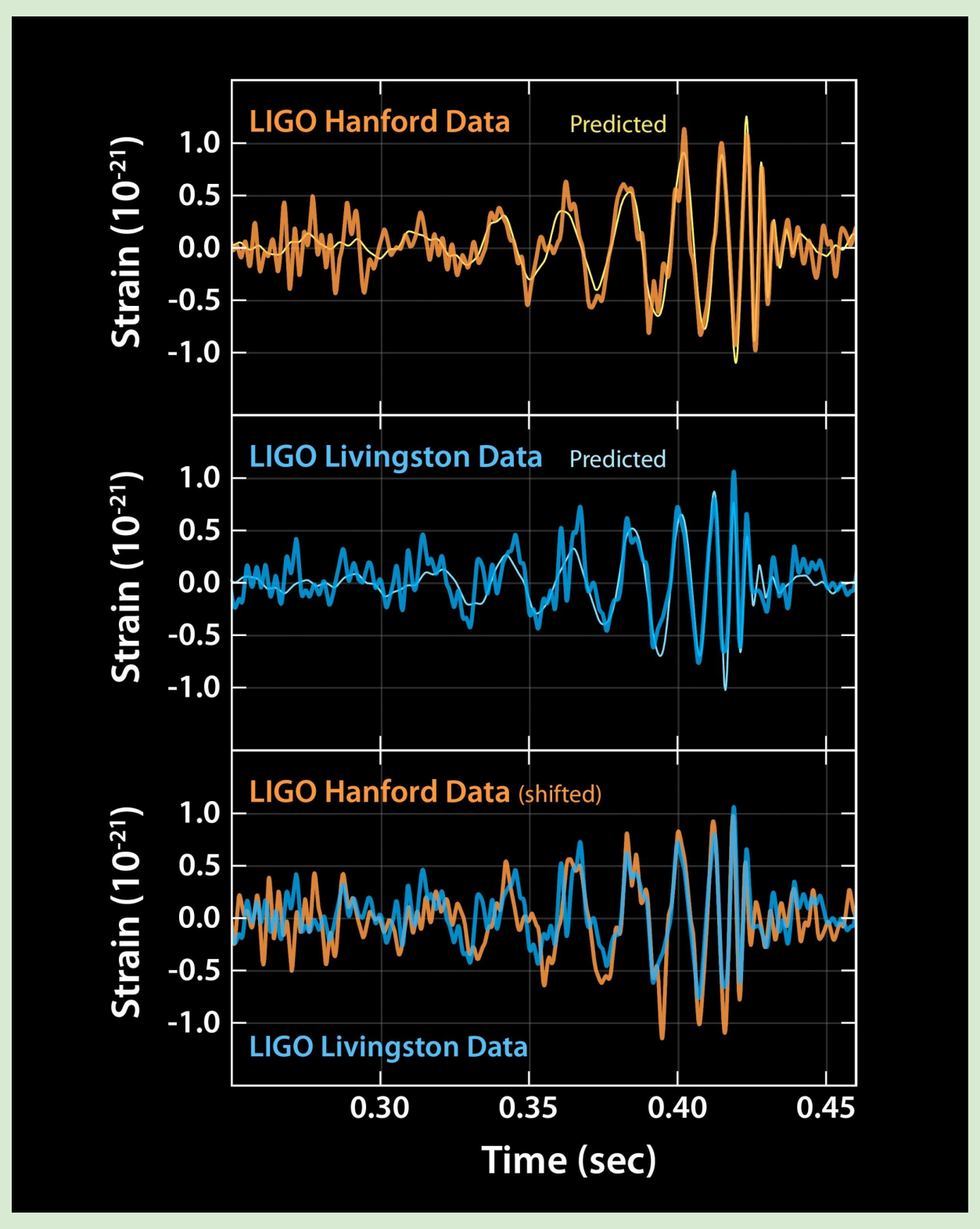
If there is a good prediction of what the morphology of a very quiet signal is, a matched-filter search with a theoretical model (template) of the signal can be used to recover the signal from the noisy data. LIGO carries out a matched-filter search with a bank of over 250,000 templates of possible signals. LIGO also performs searches for unmodeled sources.

Binary Black Hole Coalescence Search Results

The statistical significance of the loudest $(\hat{\rho})$ signal is tested for consistency with the search background under 2 hypotheses:



1. The loudest signal is a gravitational wave (purple curve).
2. The loudest signal is not a gravitational wave (black curve)



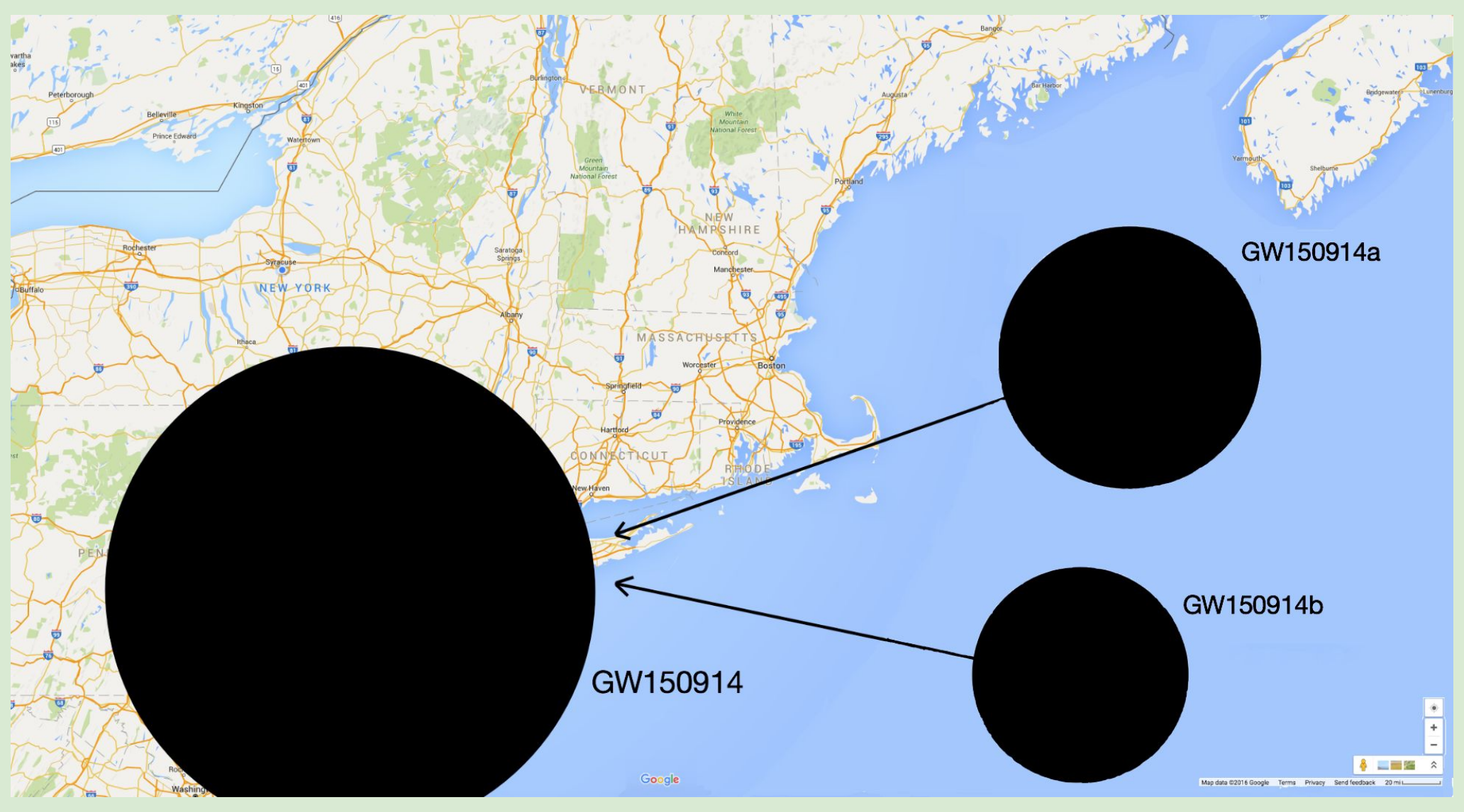
https://www.ligo.caltech.edu/system/avm_image_sqls/binaries/45/jpg_original/ligo20160211a.jpg?1455158181

On September 14th, 2015, LIGO discovered a gravitational wave from the merger of two binary black holes. They were observed by both detectors: one in Louisiana and the other in Washington.

The signal was named GW150914.

The black holes were 36 $M_{\odot}$ and 29 $M_{\odot}$. The resulting merger was 62 $M_{\odot}$.

3 $M_{\odot}$ were emitted as gravitational waves.



Acknowledgments

We are deeply grateful to the entire LIGO-Virgo collaboration for all of their many decades of dedicated work. The work presented here is the culmination especially of the members of the Compact Binary Coalescence group whose work can be found in the paper of the same name as this poster.