Deciphering Gravitational Waves

BY COREY BOEHM

NOV 10TH, 2018

Introduction

- Gravitational waves were first discussed in 1893.
- Were then observed in 2015 by LIGO.
- Proved a new observational technique.

Pre-Einstein

- Possibility first discussed by Oliver Heaviside: 1893.
  - English Electrical Engineer.
  - Used inverse square law to infer gravitational waves.

- Henri Poincare: 1905.
  - Mathematician and Theoretical Physicist.
  - First proposed how Gravitational waves propagate

Einstein

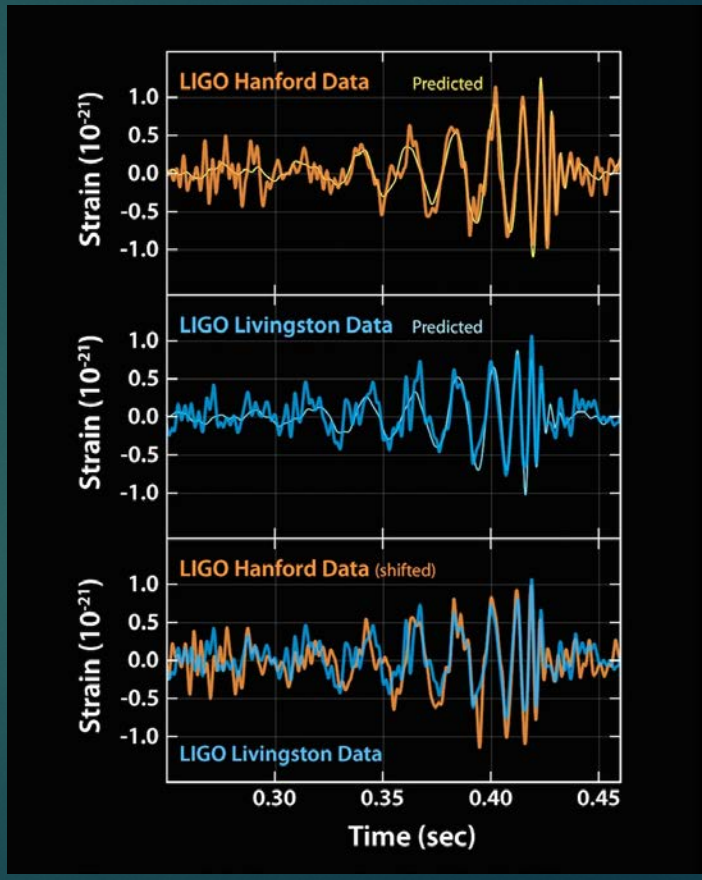
- First predicted Gravitational waves in 1916.
- This is due to his theory of general relativity.
  - Lorentz Invariance versus Newtonian.
- Predicted that they would transport energy as gravitational radiation.

Recent Advancements

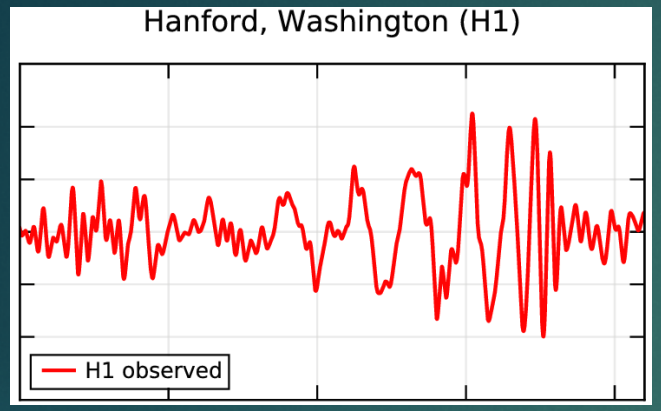
- 1974: A binary pulsar system is observed.
  - The system has a decaying orbital period.
- The system showed no increase in any form of radiation.
- The energy dissipated had to be radiated by gravitational radiation.
- First indirect evidence for Gravitational Waves.

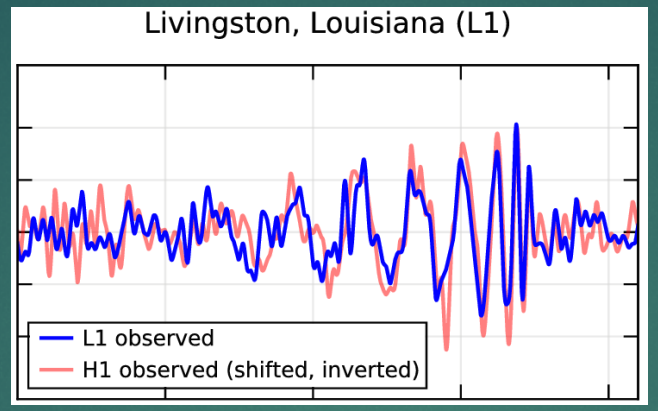
First Observation: LIGO

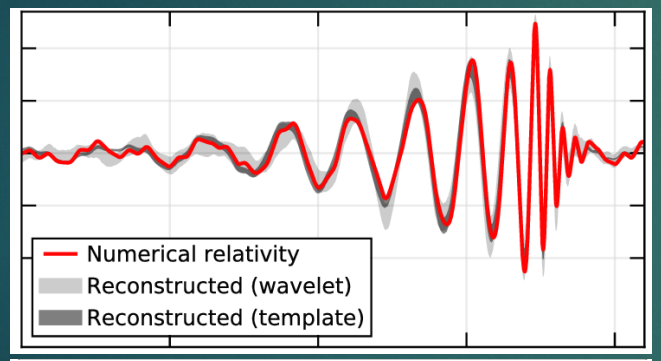
- Sept. 2015: Gravitational wave observatory LIGO Detects its first Gravitational wave.
- Observed two massive black holes merging.
- Only experienced a spacetime distortion of 1/1000th the width of a proton along a 4 km long measuring arm.
- Binary System lost 3 solar masses after merging, lost mass was radiated away as Gravitational radiation.

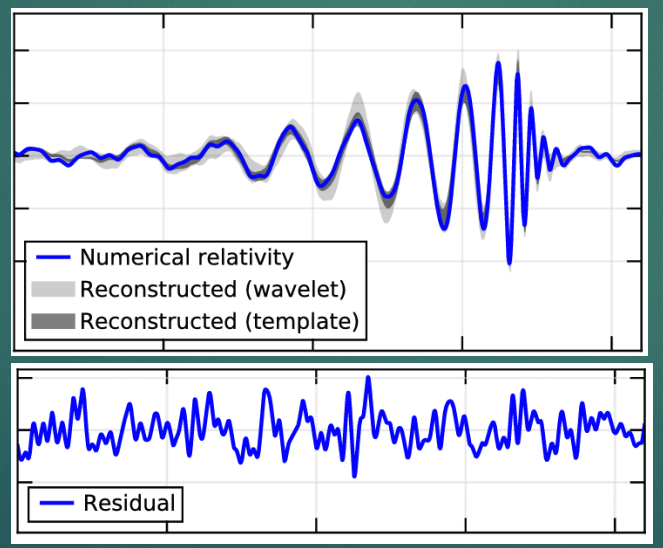


Data and Decomposition.



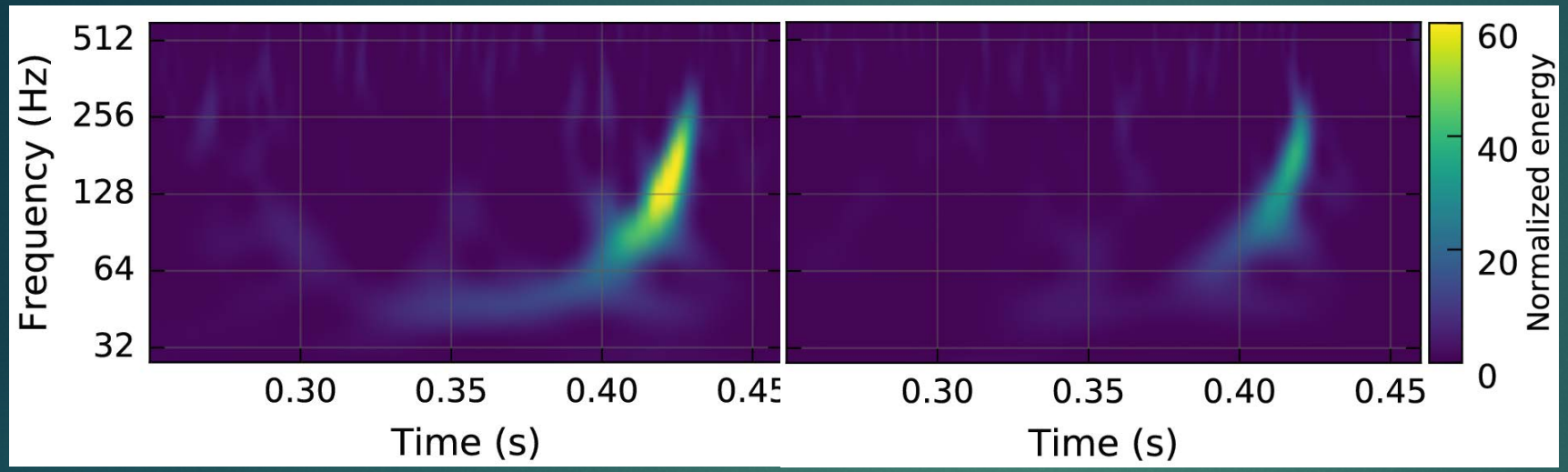




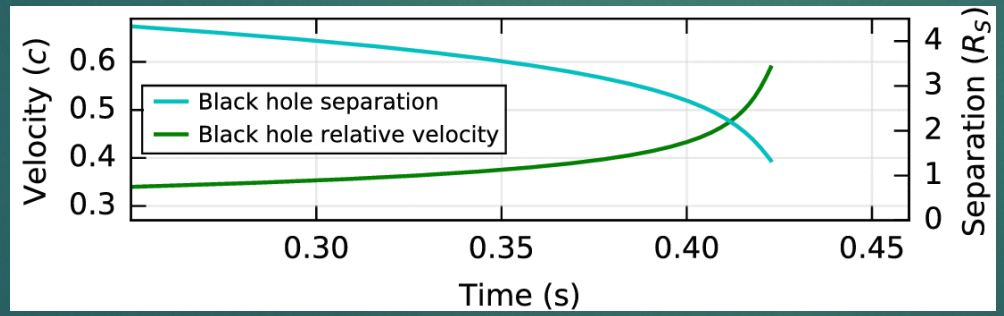


- Strain vs time measurements from Hanford and Livingston.
- Decomposing the data gives this.
- The Numerical Relativity.
- The Residual Data.

Data Cont.



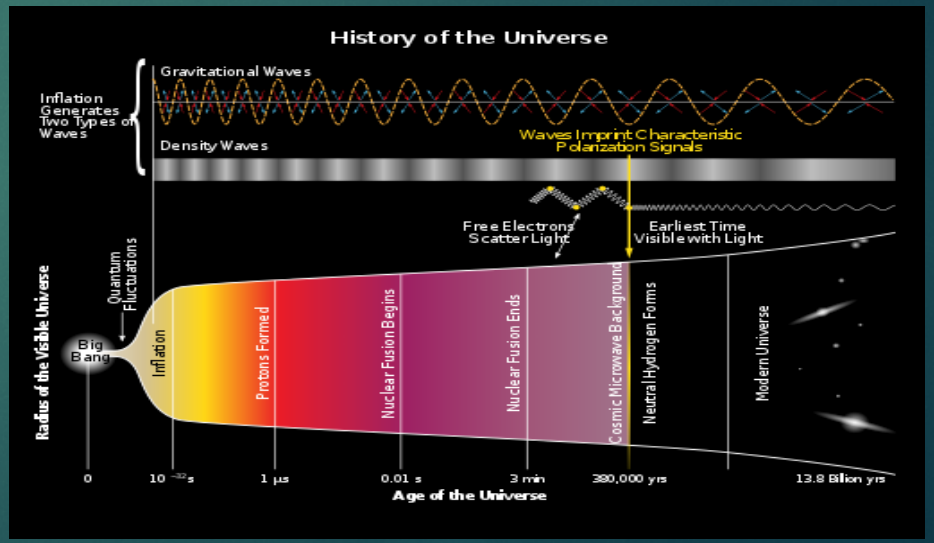
- The Time-Frequency decomposition of the signal power.



- Velocity vs separation of the merging black holes.

Properties

- Gravitational waves Obey the energy and momentum conservation laws.
- They have a wide range of frequencies and wavelengths, and experience redshift.
- They can be used to peer into the early universe.

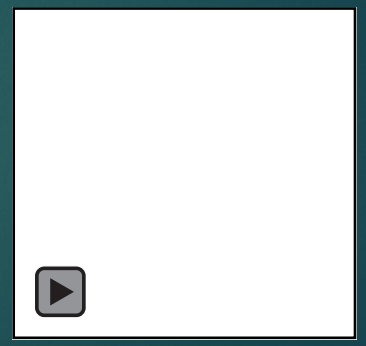


Sources

- Are created when a system is under some form of acceleration.
- The more moving mass, the more powerful the waves.
- Gravitational waves are even produced by uneven spinning objects, and supernovae.

Effects

- Gravitational Waves Pass by Earth all the time, but are too weak to be measured yet. (strain of 10^-21)
- The wave squeeze spacetime. However, there is no motion for the matter in that spacetime.
- Possible that Gravitational waves can permanently warp spacetime.



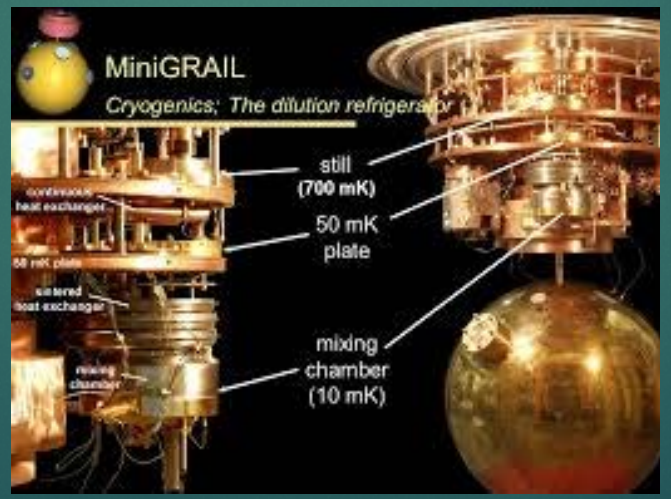
Visualization

Observation Techniques: Indirect

- This method watches inspiraling binary systems with high mass.
- Inspiraling systems lose energy and angular momentum, which is carried off by gravitational waves.
- These system's energy and Angular momentum are calculated, from there the energy of the waves can be determined.

Observation Technique: Resonant Antennae

- Spherical, Supercooled detector.
- Measured deformations of the sphere.
- MiniGrail.



Observation Technique: Interferometer

- Large Detectors that consist of two four km arms perpendicular to each other.
- Detector splits a beam of light of a certain frequency, and send each beam down one arm.
- Beams return and are recombined to create an interference pattern.
- Space based Virgo is in construction.

Conclusion

- Gravitational waves are under the same restrictions as other waves.
- Although only discovered recently, they may lead right to the beginning of the universe.
- Current detection methods are effective, but actual detectors are few in number.