SEEING THE UNIVERSE IN A NEW WAY – LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY

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- Gravitational Wave
- Laser interferometer
- LIGO
- Advanced LIGO
- Overview

Imagine this…

Bamberg Symphony Orchestra. Photograph: Peter Eberts

Why do we want to see the gravitational wave

- Observational purposes – neutron stars, black holes… etc.
- Prediction of the early universe.
- Exotic – for example: cosmic strings.

What is gravitational wave

- A gravitational wave is a fluctuation in the curvature of space-time which propagates as a wave (wiki definition).
- Ripples of space and time produced by violent events in the distant universe.

- Analogy: electromagnetic waves are produced by accelerating charges.
- Examples: collision of two black holes, shockwaves from the cores of supernova explosions.
- Binary neutron stars and black holes generates gravitational energy.

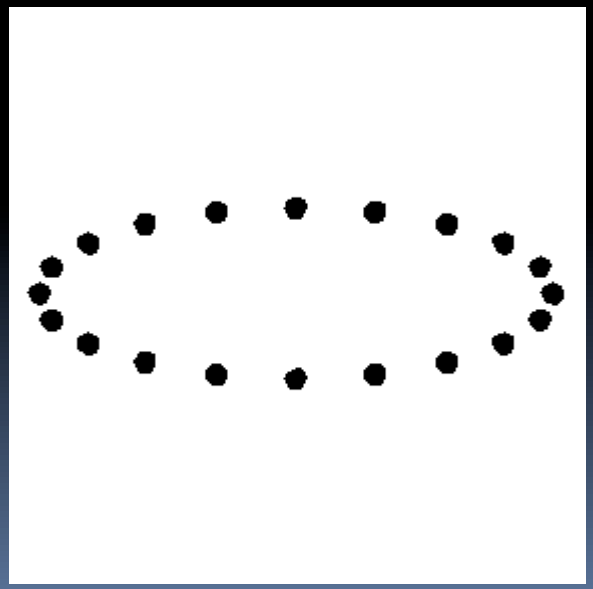
Video from LIGO

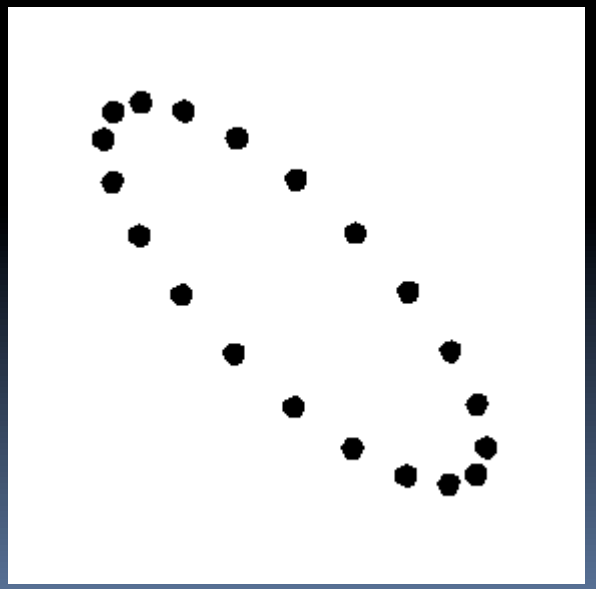
Einstein's theory of general relativity

- First predicted the existence of gravitational wave in 1916.
- Mass and energy distorts space-time.

Effects of passing gravitational wave

- Particles oscillate horizontally and vertically, or diagonally.





Animations from Wikipedia

Joseph Taylor and Russell Hulse

- Finding of the first pair of neutron stars which demonstrate the existence of gravitational wave in 1974.
- Nobel Prize winning discovery.
- One of the star is pulsar which beams radio wave to the Earth.
- New way to study gravitational wave.

What is LIGO

- Laser Interferometer Gravitational-Wave Observatory.
- Directly detect gravitational wave
- Sponsored by National Science Foundation and found in 1992
- Initial cost of 365 million USD
- One in Hanford, Washington and one in Livingston, Louisiana.

Image from LIGO

What is laser interferometer

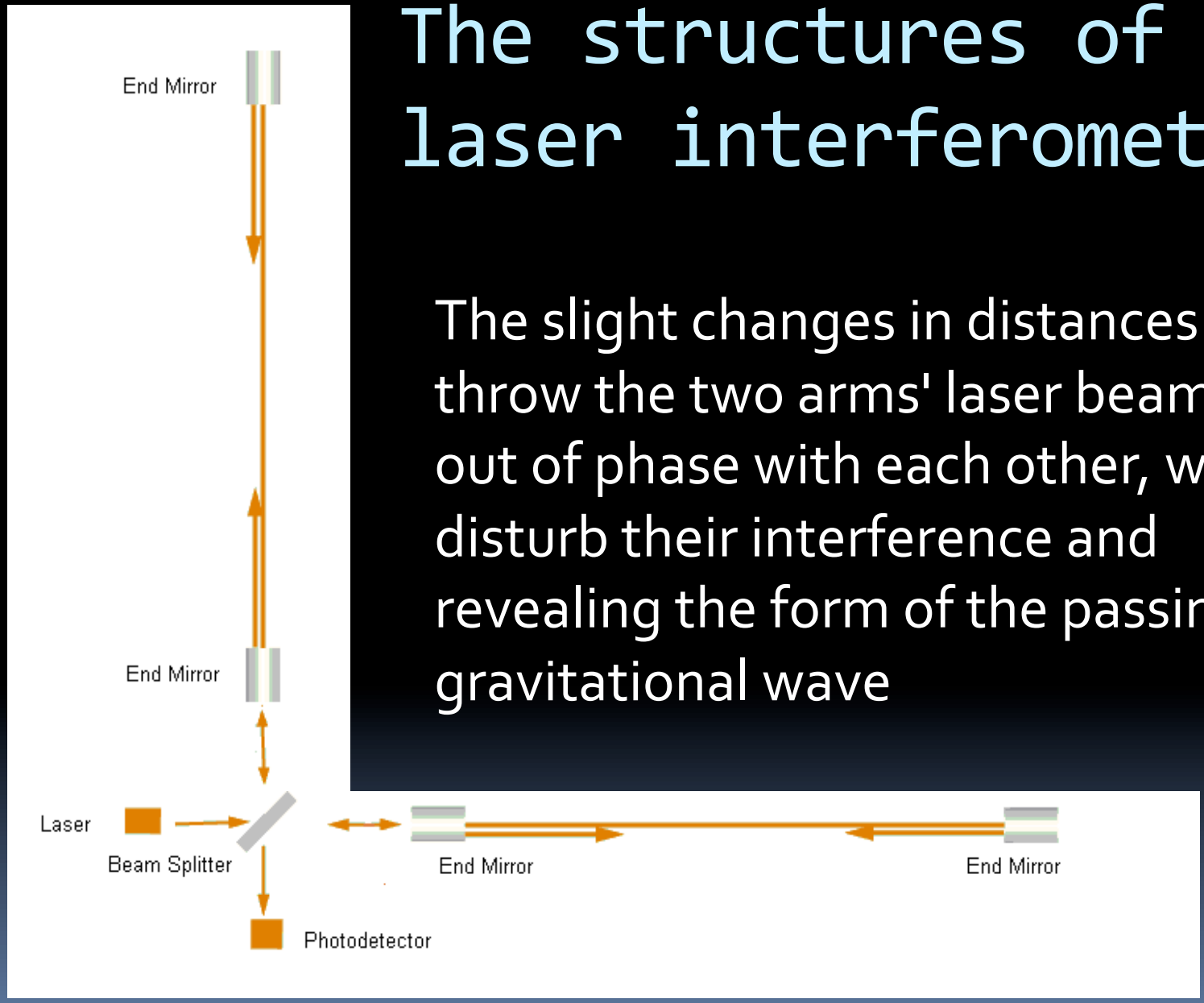
- Device for collecting gravitational wave.
- Measure time for light to travel between suspended mirrors.
- In LIGO, the laser interferometer is 4 foot in diameter and 2.5 mile in length.

How to use laser interferometer to collect gravitational wave

- Arranging mirrors hang far apart, forming an arm of interferometer.
- Two arms of interferometer perpendicular from each other form a L shape.
- Laser light enters from the corner of L shape.

- Different in length of the arms resulting light being recorded by photo detector.
- Space-time ripples cause distance measured by light beam to change.
- Convert gravitational wave to electrical signals.

The structures of the laser interferometer



The slight changes in distances throw the two arms' laser beams out of phase with each other, which disturb their interference and revealing the form of the passing gravitational wave

Image from LIGO Hanford

Observatory Results

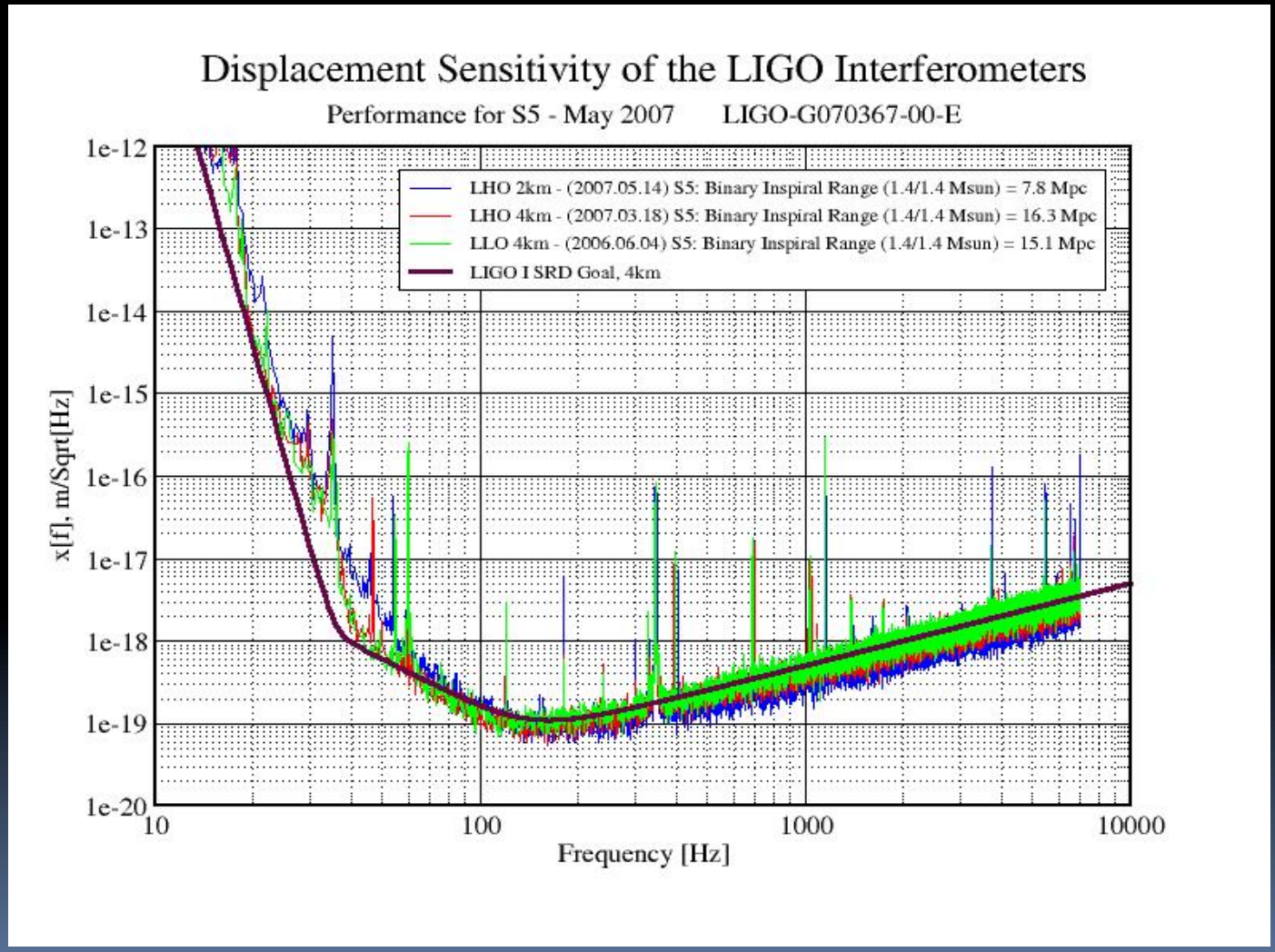


Diagram from LIGO

Introduction of Advanced LIGO

- Limitation on gravitational signal in the initial LIGO interferometers.
- Building of Advanced LIGO to improve sensitivity.
- Proposal approved in Oct. 2004, started in April, 2008.
- Observation starts in 2015.

What are advanced?

- Improve sensitivity by a factor of 10.
- Increase source reach by factor of 1000.
- Allow to look at the inspiral pairs of black holes up to 50 solar masses.
- Pinpoint periodic signals from the many known pulsars which radiate in the range from 500-1000 Hertz.
- Reducing background noise.

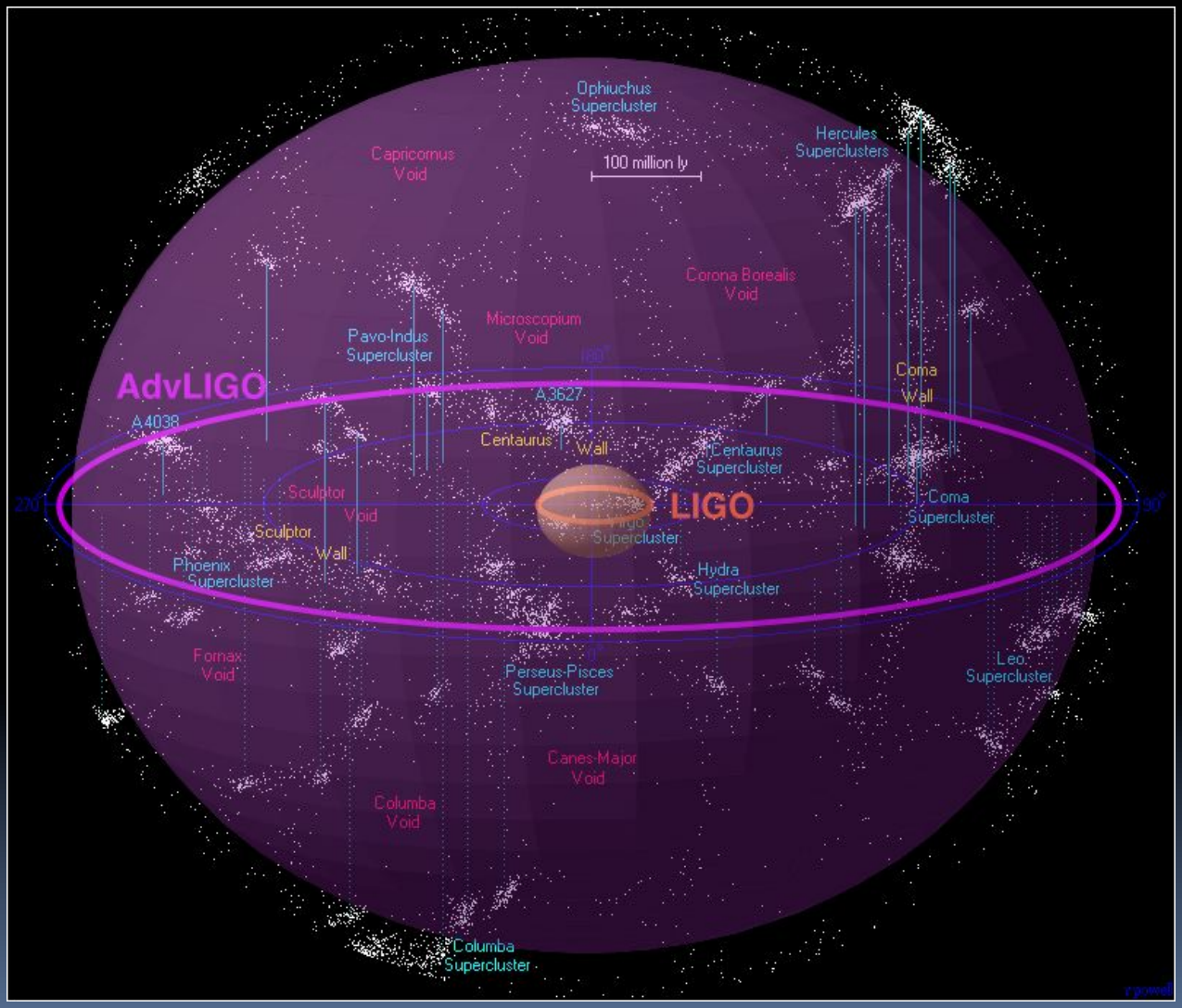


Image from LIGO Caltech

Overview

- No outstanding observation from the current LIGO.
- Money vs. Progress.
- Worth it?
- Know the universe better.
- Able to test Einstein's general relativity.
- Potential use?

Future

- Advanced LIGO
- Interferometer in the space – LISA.
- Einstein@Home.