LIGO -- Studying the Fabric of the Universe

Barry C. Barish
National Science Board
LIGO Livingston, LA
4-Feb-04
A Conceptual Problem is solved!

Newton’s Theory
“instantaneous action at a distance”

Einstein’s Theory
information carried by gravitational radiation at the speed of light
Einstein theorized that smaller masses travel toward larger masses, not because they are "attracted" by a mysterious force, but because the smaller objects travel through space that is warped by the larger object.

- Imagine space as a stretched rubber sheet.
- A mass on the surface will cause a deformation.
- Another mass dropped onto the sheet will roll toward that mass.
Einstein’s Theory of Gravitation

- A necessary consequence of Special Relativity with its finite speed for information transfer.

- Gravitational waves come from the acceleration of masses and propagate away from their sources as a space-time warp at the speed of light.

Gravitational radiation of binary inspiral of compact objects.
Detecting Gravitational Waves

Gravitational Wave Astrophysical Source

Terrestrial detectors
Virgo, LIGO, TAMA, GEO, AIGO

Detectors in space
LISA

Detecting Gravitational Waves
Electromagnetic waves

- over ~16 orders of magnitude
- Ultra Low Frequency radio waves to high energy gamma rays
Gravitational waves
- over ~8 orders of magnitude
- Terrestrial + space detectors

Frequency range of GW Astronomy

Audio band

Space

Terrestrial
Detecting a passing wave ....

Free masses
Detecting a passing wave ....

Interferometer
Interferometer Concept

- Laser used to measure relative lengths of two orthogonal arms
- Arms in LIGO are 4 km
- Measure difference in length to one part in $10^{21}$ or $10^{-18}$ meters
- As a wave passes, the arm lengths change in different ways causing the interference pattern to change at the photodiode
- Suspended Masses change in different ways….
Simultaneous Detection

LIGO

Hanford Observatory

Caltech

Livingston Observatory

3082 km
(L/c = 10 ms)
Gravitational Wave Astronomy

LIGO will provide a new way to view the dynamics of the Universe