The LIGO project's quest for gravitational waves

Presenting LIGO to the students of the
Lycee Internationalde Ferney Voltaire, academy de Lyon

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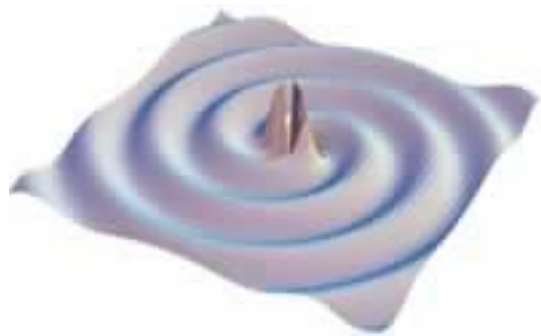
LIGO-G020512-00-D

LIGO

Gravitational Waves

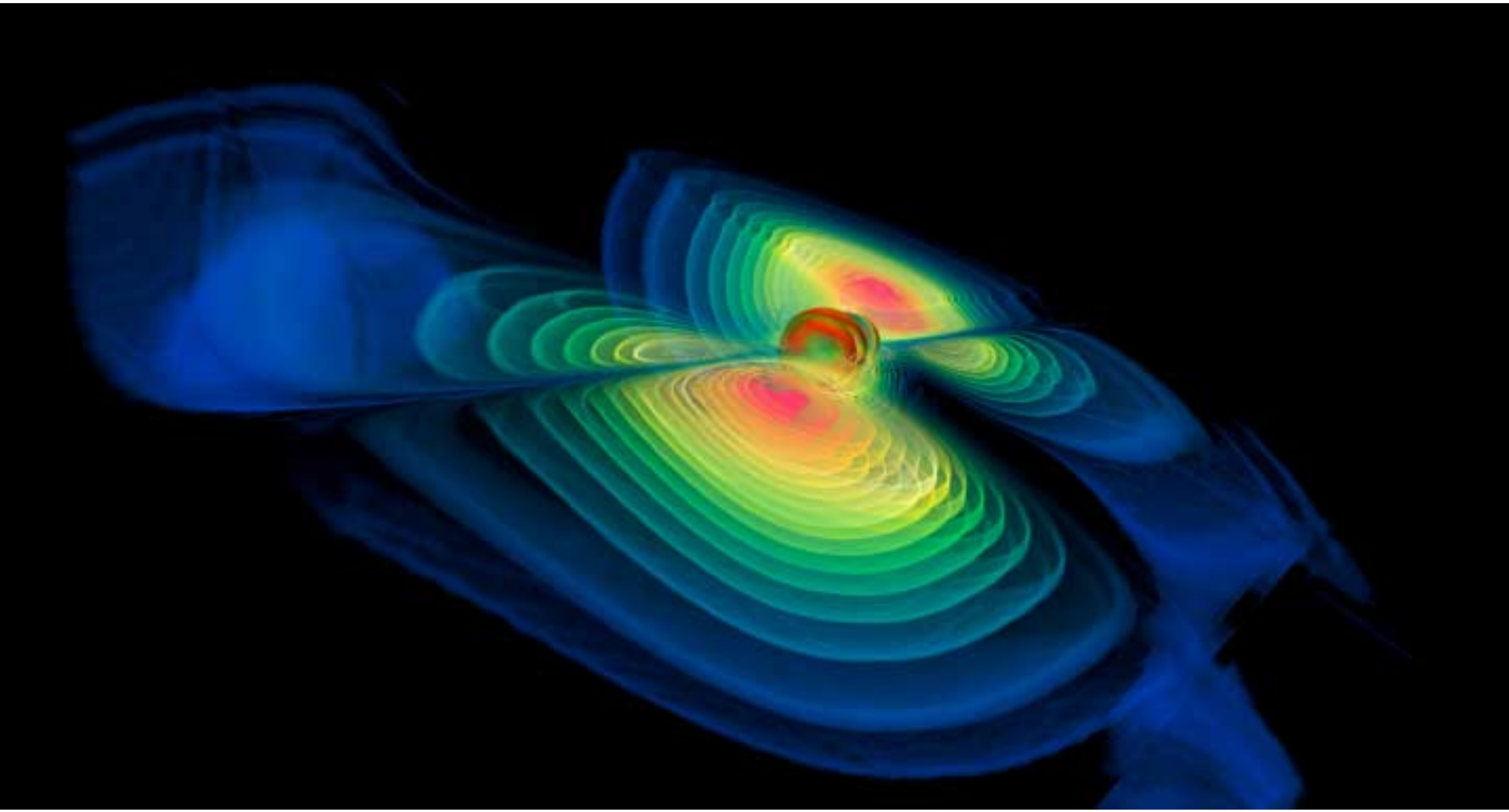
Gravitational waves are disturbances in the curvature of space-time caused by the motions of matter, traveling at the speed of light.

- Where may they come from?
  - » Supernovae explosions
  - » Neutron Star collisions
  - » Black hole cannibalism
  - » Black Holes vibrations



- What can we learn form them?
  - » Information about the sources (normally invisible)
  - » Information about the nature of gravity itself.
  - » Mapping of condensed dark matter

Coalescence of two Neutron Stars



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Gravitational Waves

- Two types of GW polarization
  - » Horizontal-vertical (+)
  - » 45 degrees (x)

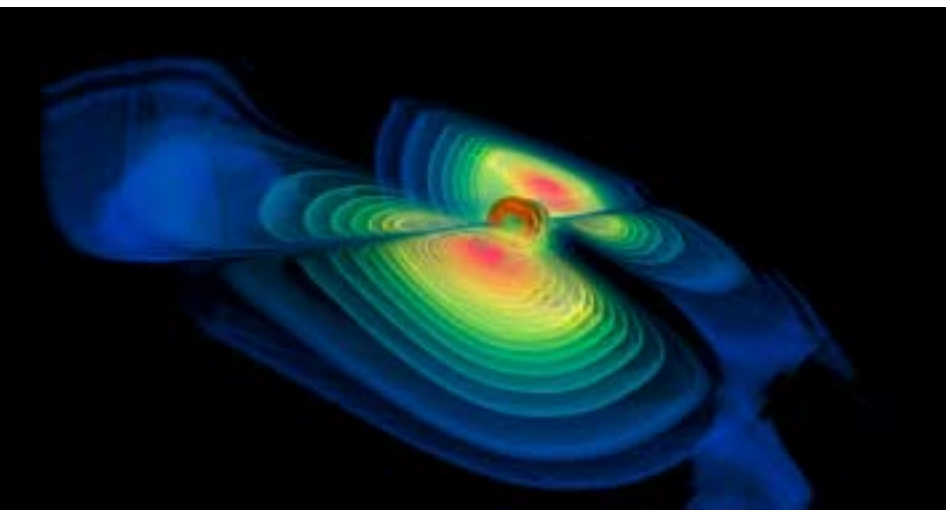
- Effect of an Electromagnetic and a Gravitational Wave on Professor Einstein

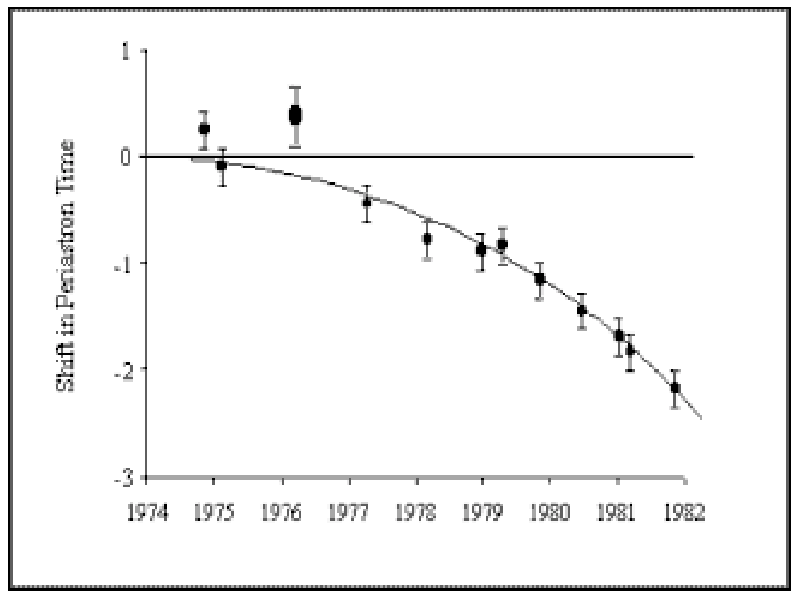
Electromagnetic wave

Gravitational Wave

Gravitational Waves

- The effects of gravitational radiation have already been observed indirectly.





Match between the changes of several orbital parameters to those predicted as a consequence of the emission of gravitational radiation

(Russell Hulse and Joseph Taylor).

Gravitational Waves

- But what about a direct observation?

Optical picture*

Radio waves mapping- different picture

GW picture

*galaxy Centaurus A

LIGO

Gravitational Waves and LIGO

- **LIGO** = **L**aser **I**nterferometer **G**ravitational wave **O**bservatory
- Operated by CalTech in partnership with MIT through a cooperative agreement with the National Science Foundation.
- Consists of two sites, separated by 3000 km.

Livingston (Louisiana)

Hanford (Washington)

LIGO

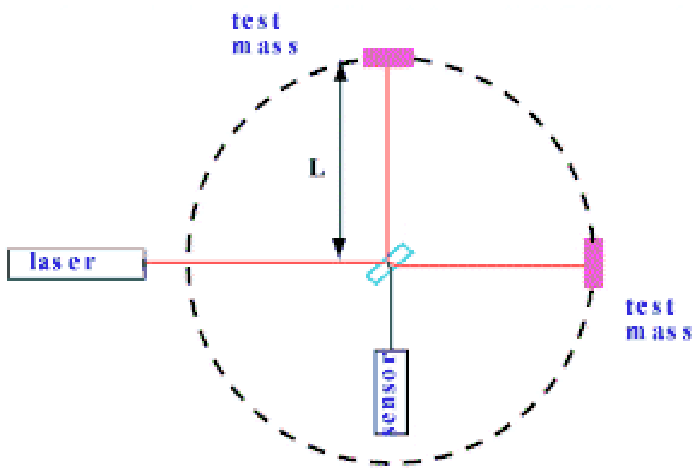
How does LIGO work?

- A GW arriving on Earth will alternately stretch and shrink distances, on an incredibly small scale - by a factor of 10^{-22} for very strong sources.

- Equivalent to detecting the motion of Saturn if it were to move closer to the sun by the diameter of a single hydrogen atom!!!

How does LIGO work?

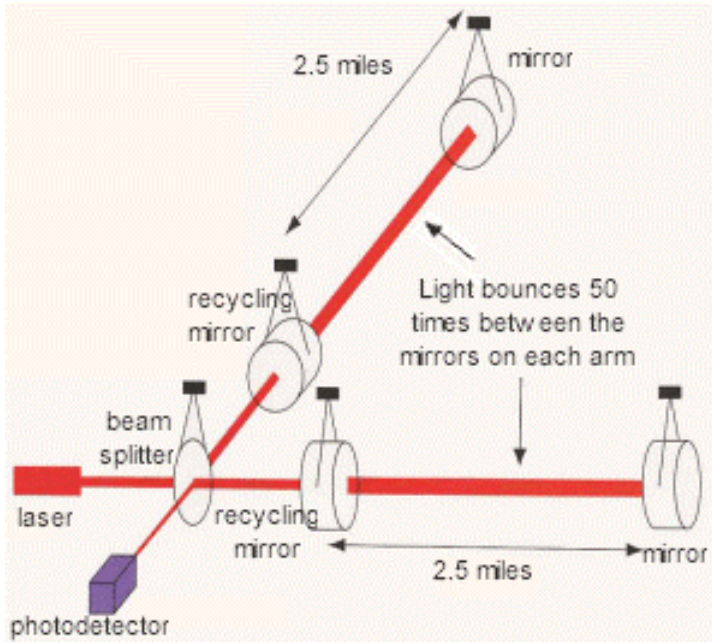
- **Detecting a GW requires the construction of an L-shaped antenna aligned with the polarization of the wave so that it is capable of detecting the squeezing of space along one arm of the antenna and the simultaneous stretching of space along the other arm.**



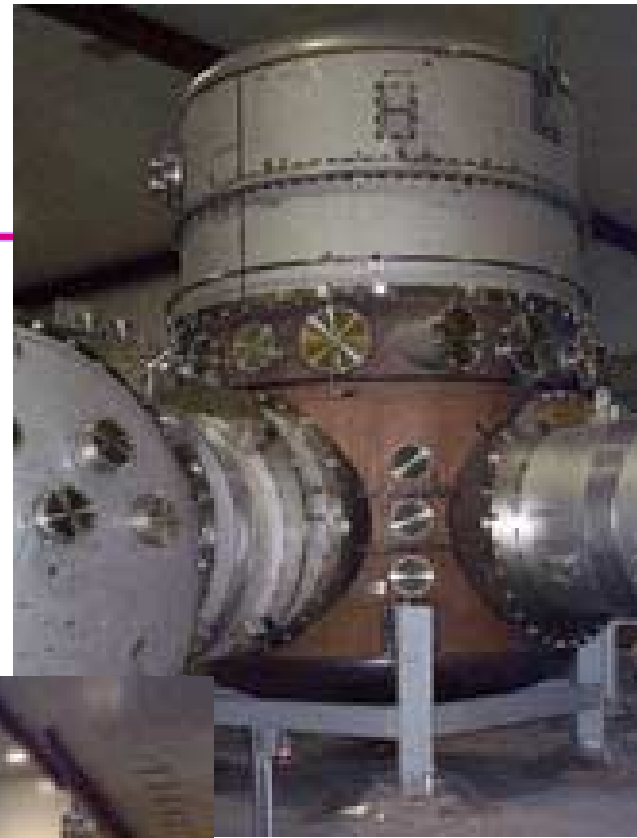
How does LIGO work?

- The “ruler” with which the stretching and squeezing of space is detected is laser light with perfectly known wavelength.
- The "strain" of space-time causes differences in the arrival times of the light from each arm.

INTERFERENCES

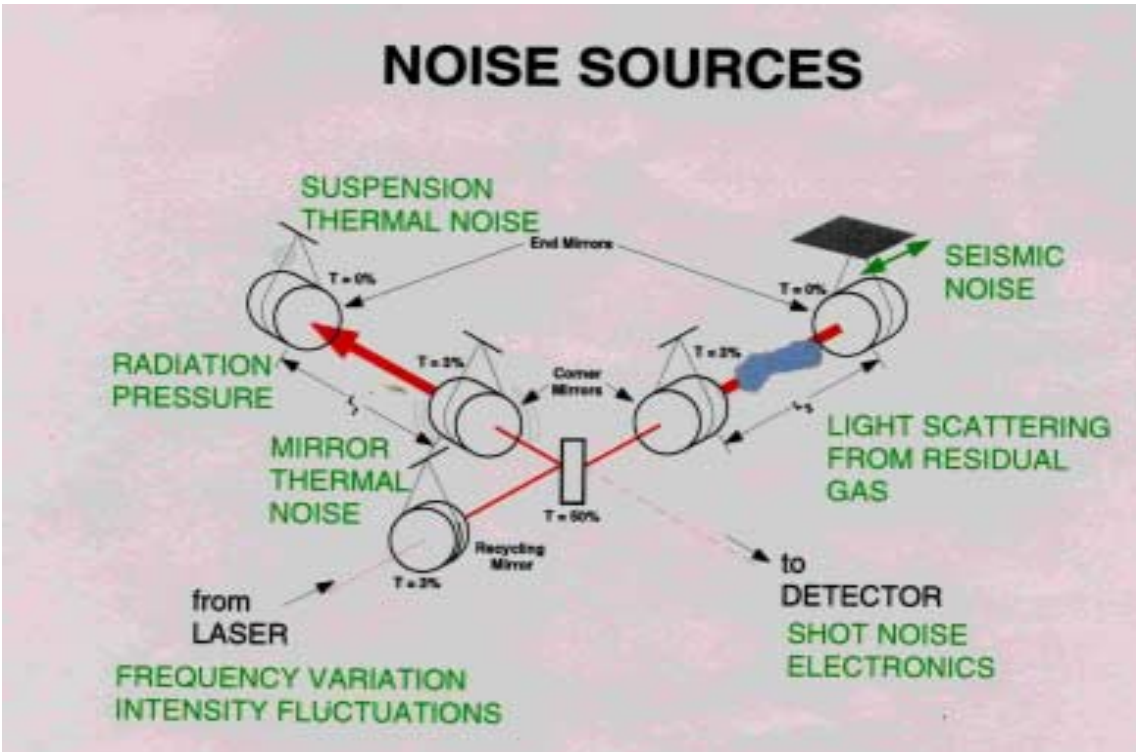


LIGO

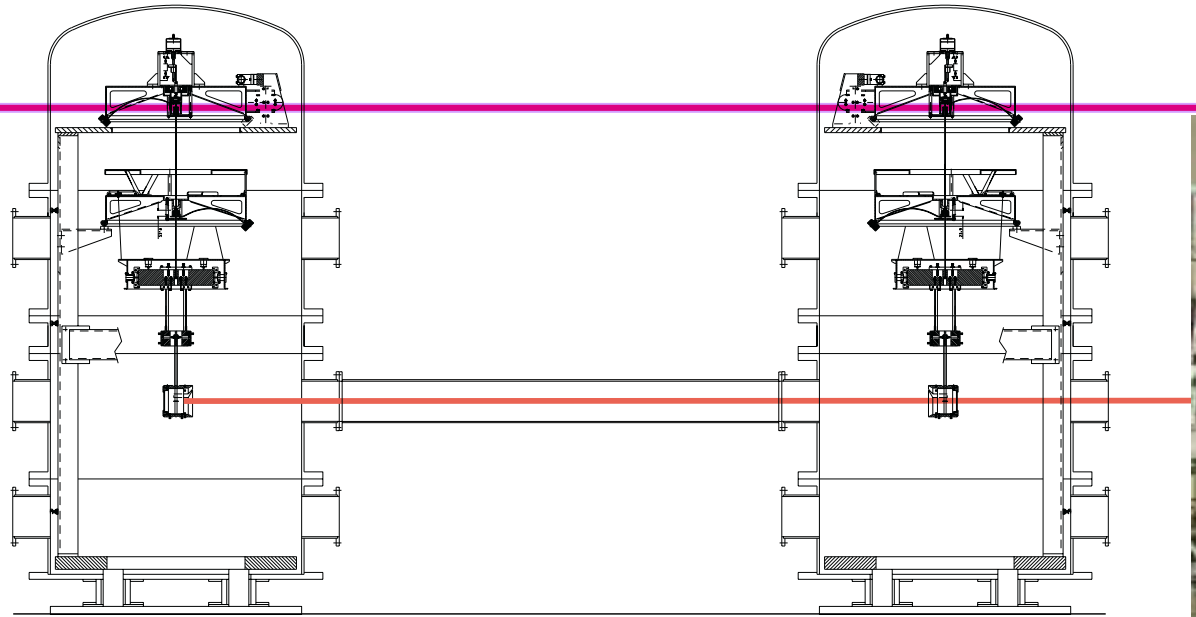


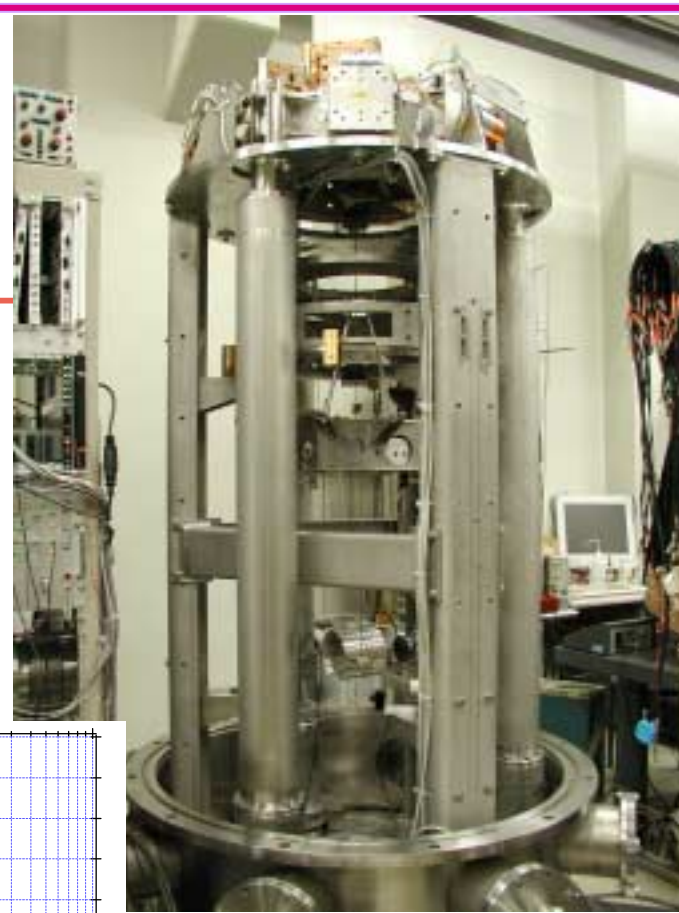
LIGO enemies

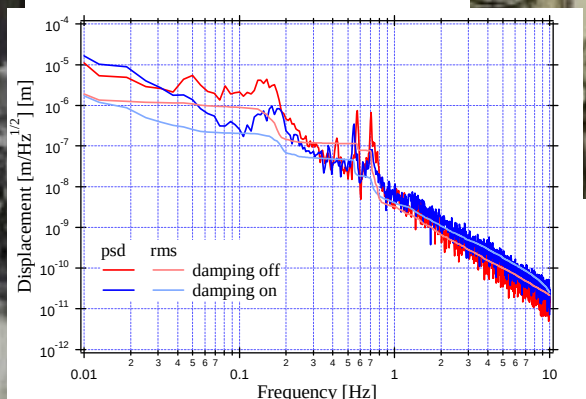
- The effects of GW are very tiny and very difficult to measure. They must be distinguished from background noise sources, which is not an easy task!



Fighting seismic motion

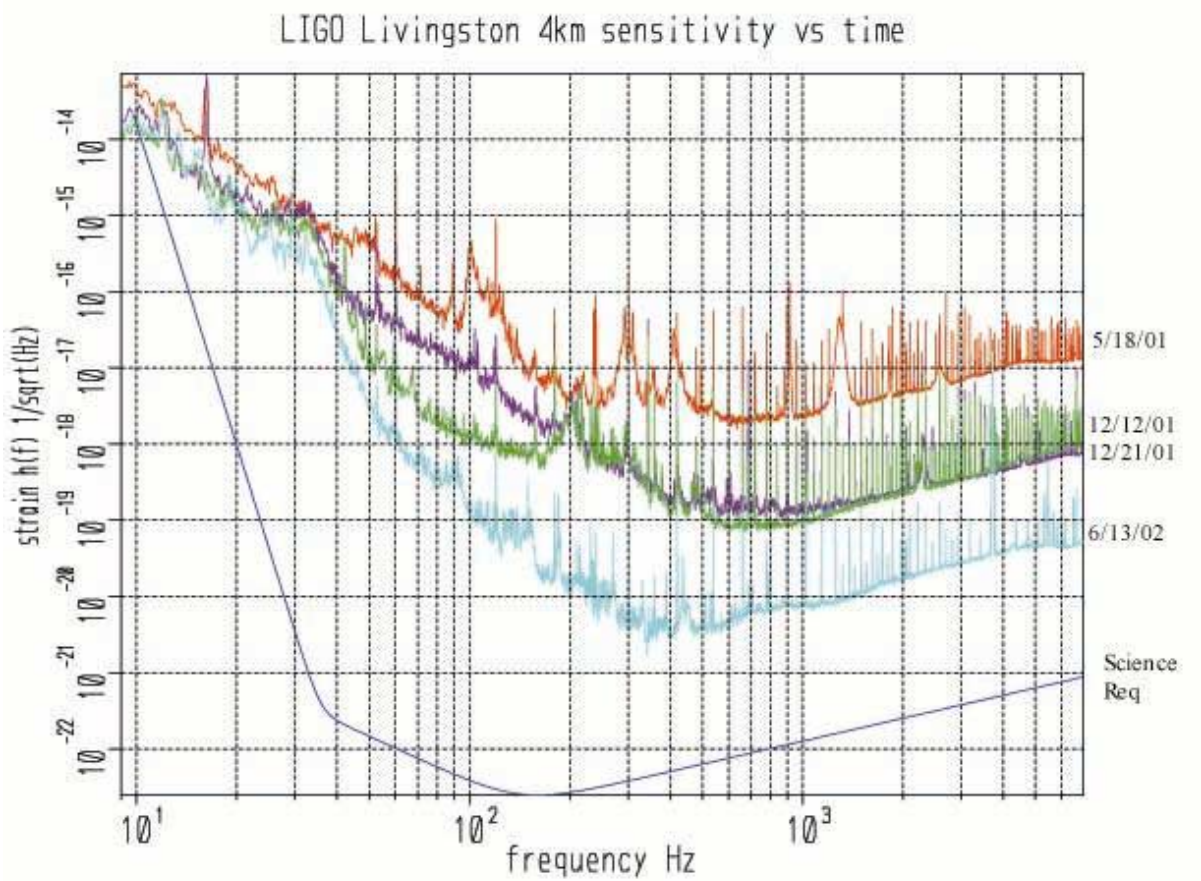






LIGO friends

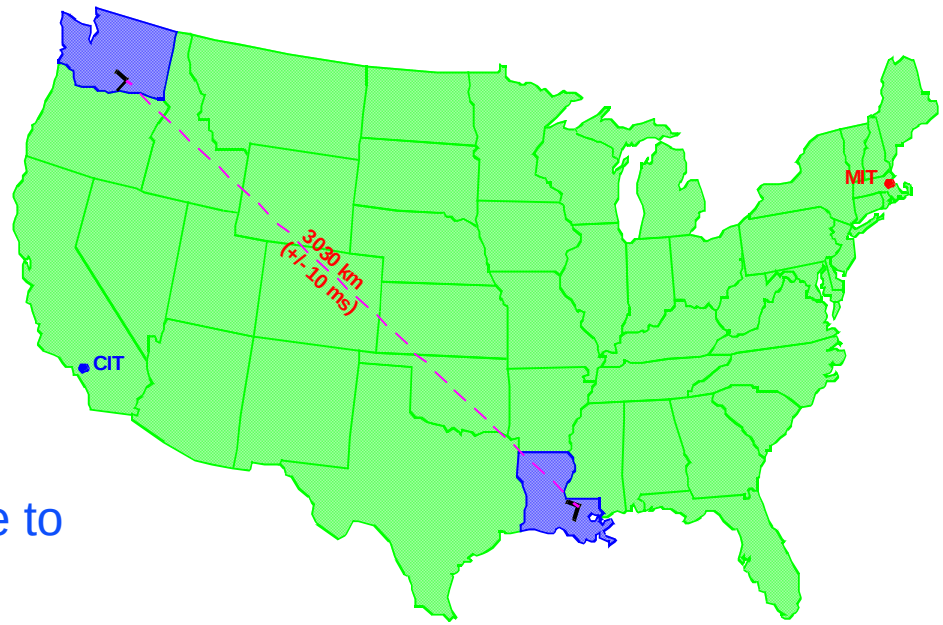
- LIGO scientists “fight” the sources of noise and improve the performances continuously.



LIGO Correlated Observations

- The outputs from the two LIGO observatories will be compared to look for coincident signals
  - » with same frequency
  - » same amplitude
  - » and detected within 10 msec.

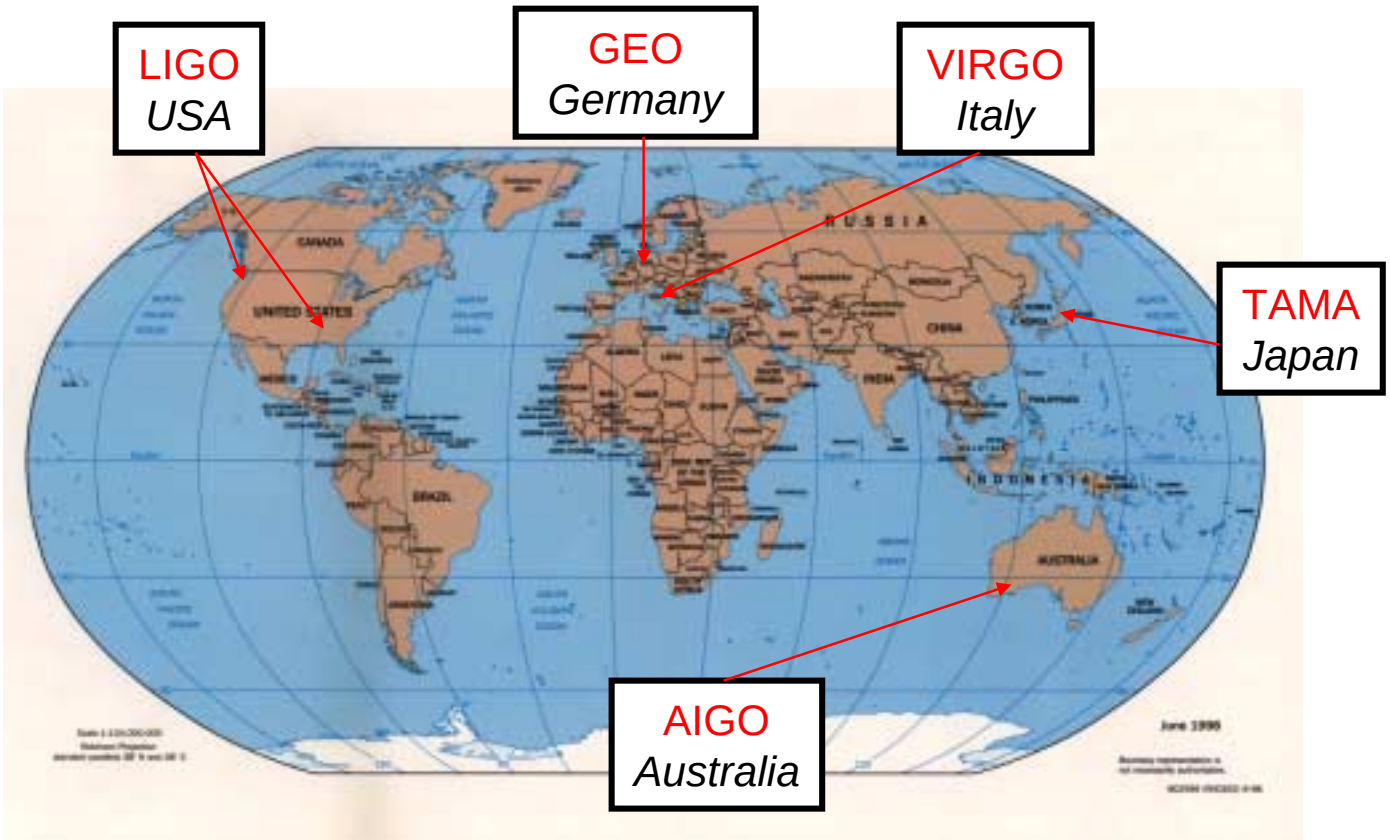
  of each other at both LIGO sites.



Those signals can truly be due to Gravitational radiation.

LIGO

International network - Even better!



International network - VIRGO

- **A collaboration between Italian and French research teams.**
- **Located at Cascina, near Pisa on the Arno plain.**
- **One of the largest ultra high vacuum vessels in the world**
- **Expected very high sensitivity. Detection of GW produced by supernovae and coalescence of binary systems in the milky way and in outer galaxies, for instance from the Virgo cluster.**

LIGO

Your program today

- Split in 4 groups (15 minutes stops)
  - » Riccardo, Xavier, Stoyan, Charles
- Visit to the labs: **hands in your pockets**
  - » 40 m
  - » Synchrotron
  - » Keck metallurgical lab
  - » Cryo lab
- Regroup at Synchrotron for walk around the campus
- Walk for dinner at Hamburger Hamlet
- Walk back to your bus