# LIGO:

# Connecting the Excitement of Cutting Edge Research in Experimental Gravity-wave Physics to the Classroom Environment

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# Abstract:


- **LIGO – the Laser Interferometer Gravitational Wave Observatory - is the most ambitious project ever undertaken to directly detect gravitational waves from astrophysical sources. LIGO is a national research facility designed by a team of scientists and engineers from the California Institute of Technology and the Massachusetts Institute of Technology through support from the National Science Foundation. This direct observation may lead to profound new insights about the dynamics of the universe. As part of LIGO's mission, we are attempting to share the excitement of this scientific adventure with K-12 educators. LIGO consists of two observatory sites: on the Department of Energy's Hanford Nuclear Reservation near Richland, Washington, and in rural Louisiana near the town of Livingston. RET programs at each site have created partnerships between teachers and researchers involving students in LIGO-related collaborative research. There are unique opportunities and challenges associated with the establishment of RET programs at each site due to site-specific population density and composition differences, local educational resources, and other factors. Through the RET program, new LIGO related curriculum materials and hands-on activities for the classroom were developed. LIGO's initial experience participating in the RET program, the materials that have resulted, and plans for dissemination of the materials will be described.**

# LIGO

## Laser Interferometer Gravitational-wave Observatory

- LIGO consists of three laser interferometers located at two sites separated by 3000 km.
  - In eastern Washington, on the Department of Energy's Hanford Nuclear Reservation,
  - Near New Orleans, Louisiana
- LIGO is operated by Caltech in partnership with MIT through a cooperative agreement with the National Science Foundation.
- LIGO Science Collaboration is the scientific body of LIGO which defines science goals and supports their achievement.

# LIGO Scientific Collaboration

## *Member Institutions*

## LSC Membership

**35 institutions > 350 collaborators**

| | |
|---|---|
| University of Adelaide ACIGA | LIGO Livingston LIGOLA |
| Australian National University ACIGA | LIGO Hanford LIGOWA |
| California State Dominquez Hills | Louisiana State University |
| Caltech LIGO | Louisiana Tech University |
| Caltech Experimental Gravitation CEGG | Loyola Univ of New Orleans |
| Caltech Theory CART | MIT LIGO |
| University of Cardiff GEO | Max Planck (Garching) GEO |
| Carleton College | Max Planck (Potsdam) GEO |
| Cornell University | University of Michigan |
| University of Florida @ Gainesville | Moscow State University |
| Glasgow University GEO | NAOJ - TAMA |
| University of Hannover GEO | University of Oregon |
| Harvard-Smithsonian | Pennsylvania State University Exp |
| India-IUCAA | Pennsylvania State University Theory |
| IAP Nizhny Novgorod | Southern University |
| Iowa State University | Stanford University |
| Joint Institute of Laboratory Astrophysics | University of Texas@Brownsville |
| | University of Western Australia ACIGA |
| | University of Wisconsin@Milwaukee |

## International

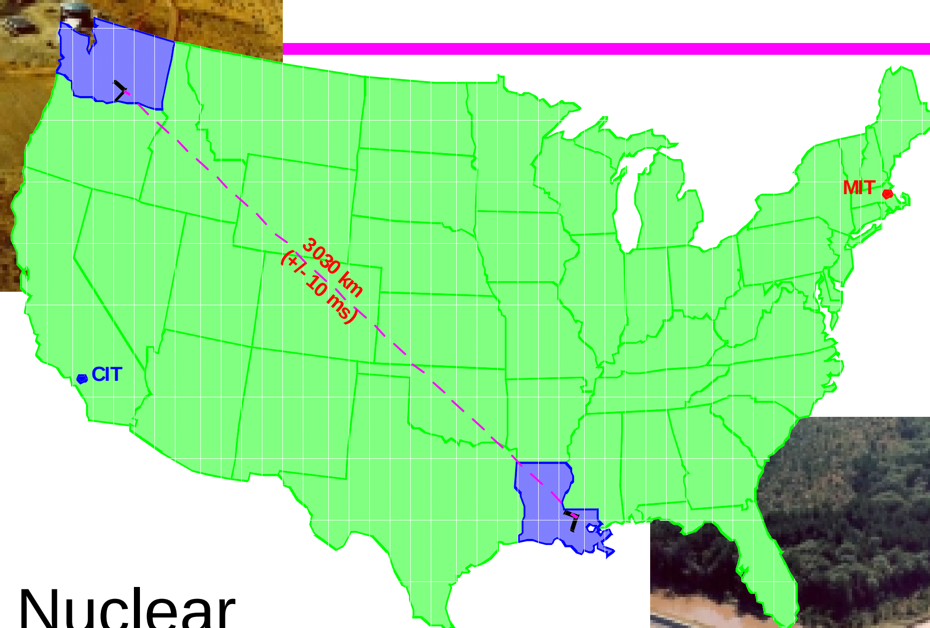
**India, Russia, Germany, U.K, Japan and Australia.**

**The international partners are involved in all aspects of the LIGO research program.**

## GWIC

**Gravitational Wave International Committee**

# LIGO Locations




DOE Hanford Nuclear Reservation – eastern WA

Near New Orleans, LA

# Some History...

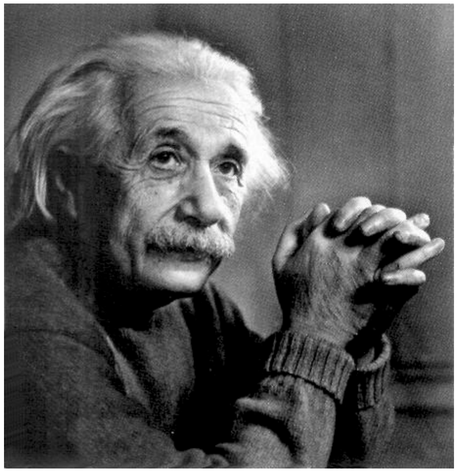
- Electromagnetic observation of the universe with photons:
  - Visible radiation:
    - atoms near surface of stars,
    - surrounding gas clouds
    - reflected radiation from planets and moons
  - Other frequencies: radio, x-ray, gamma ray
- Particle astrophysics
  - cosmic rays
  - neutrinos (solar neutrinos, SN1987 A)

What about gravity as a messenger of astrophysical information?

# Gravitational Waves

- Gravitational radiation predicted in 1916 by Einstein as a consequence of general relativity.
- LIGO is the most ambitious attempt so far to directly observe gravitational waves

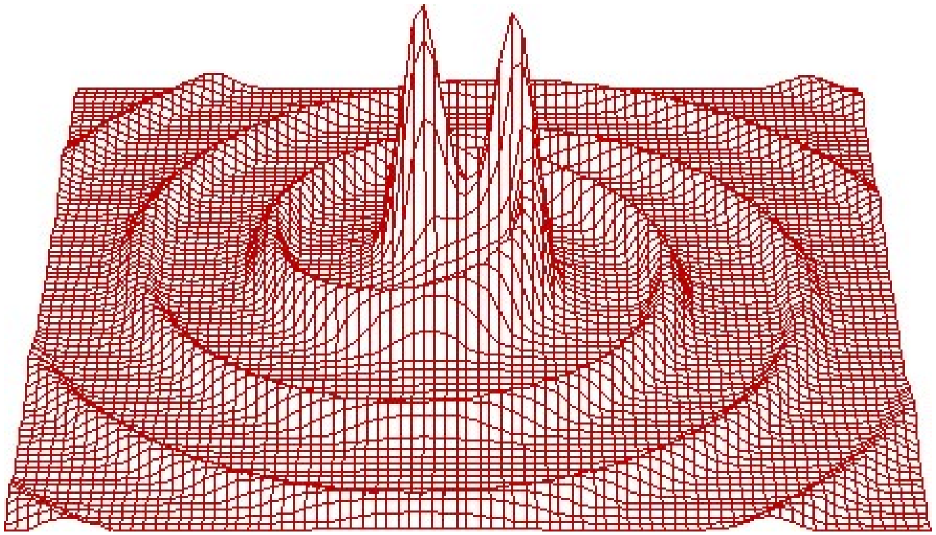
  *Extremely* weak – very hard to detect!



***information carried by gravitational radiation at the speed of light***

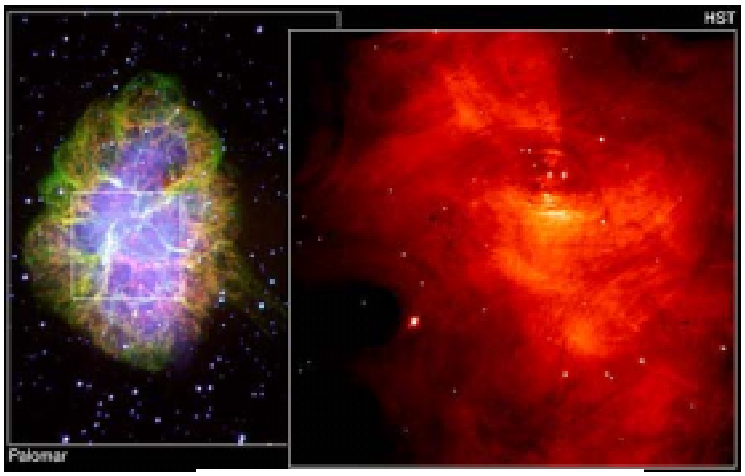
# Einstein's Theory of Gravitation
## *gravitational waves*

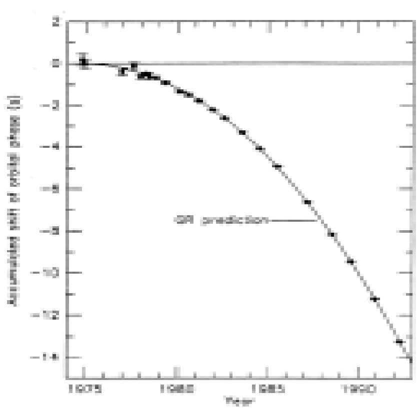
- **a necessary consequence of Special Relativity with its finite speed for information transfer**
- **Einstein in 1916 and 1918 put forward the formulation of gravitational waves in General Relativity**
- **time dependent gravitational fields come from the acceleration of masses and propagate away from their sources as a space-time warpage at the speed of light**



**gravitational radiation**
**binary inspiral of compact objects**

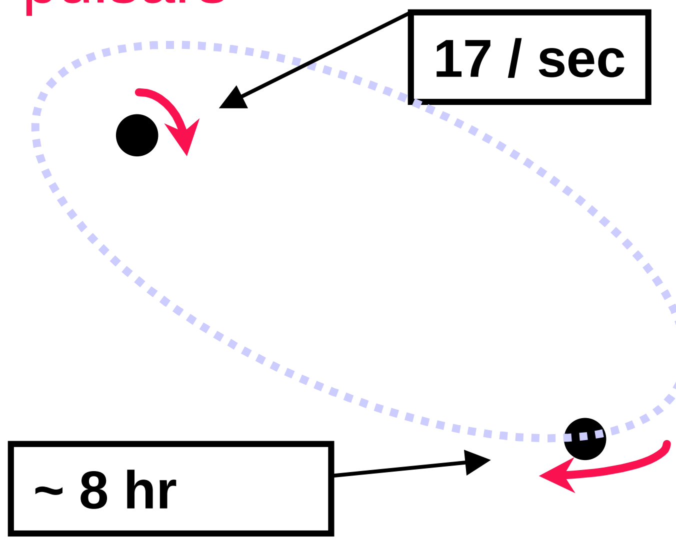
# Indirect evidence of gravitational waves: Hulse-Taylor binary pulsar



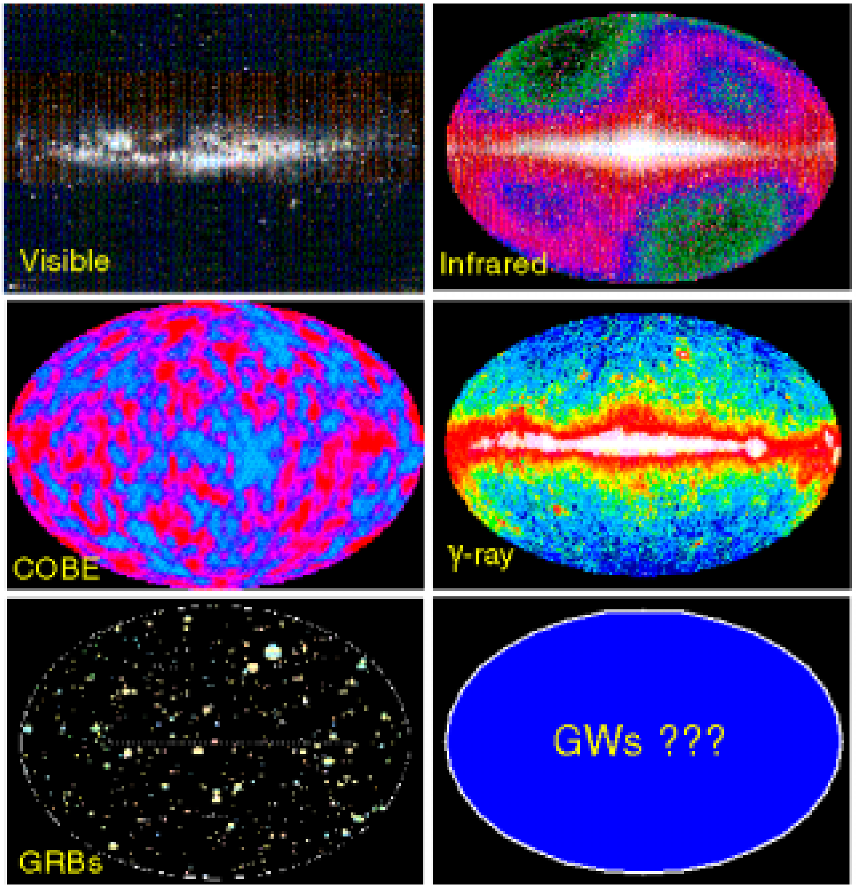

## Neutron Binary System

PSR 1913 + 16 -- Timing of pulsars



## A new vantage point to study the universe

Each time we observe the sky utilizing a new messenger, we enhance our understanding of the universe

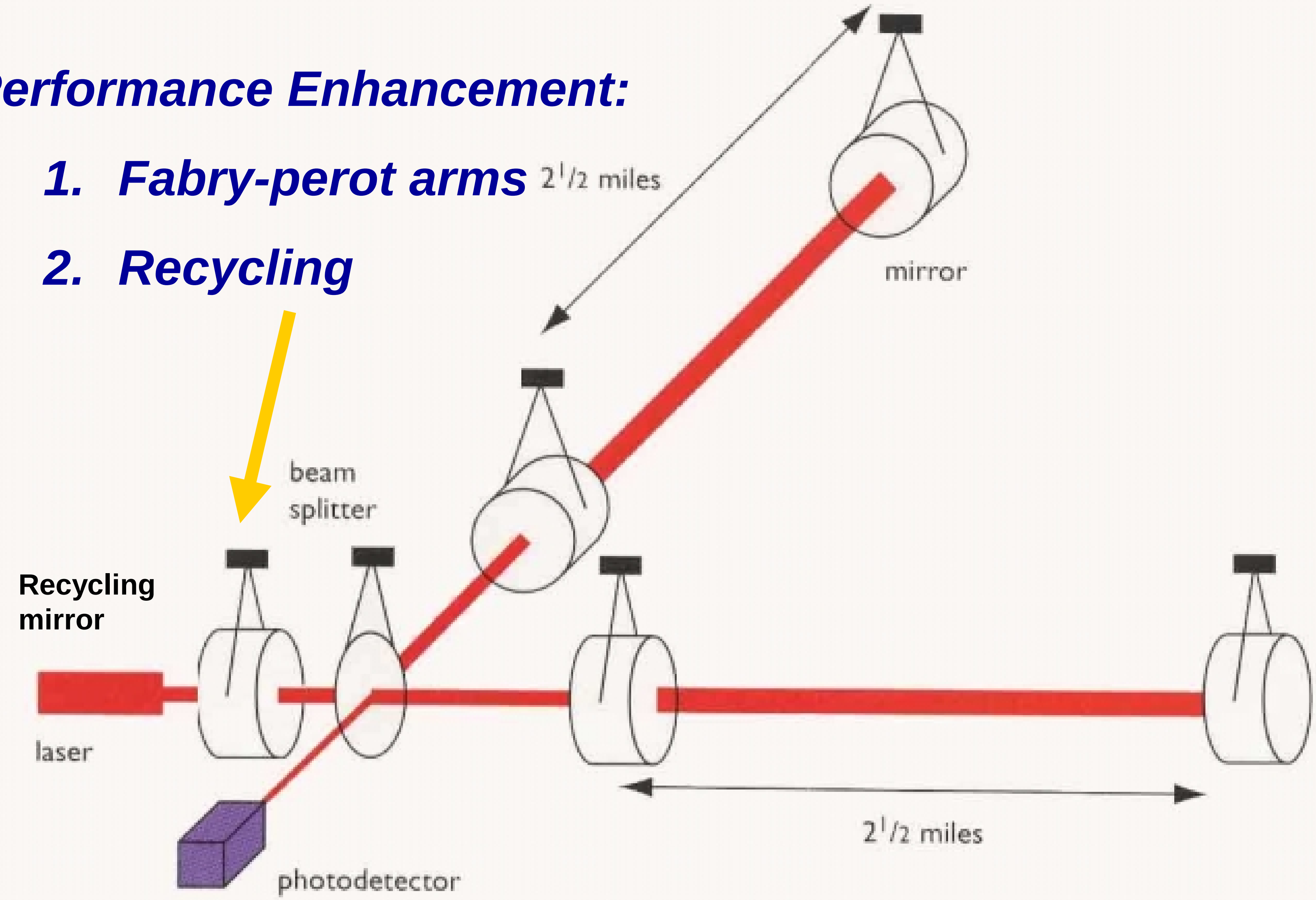


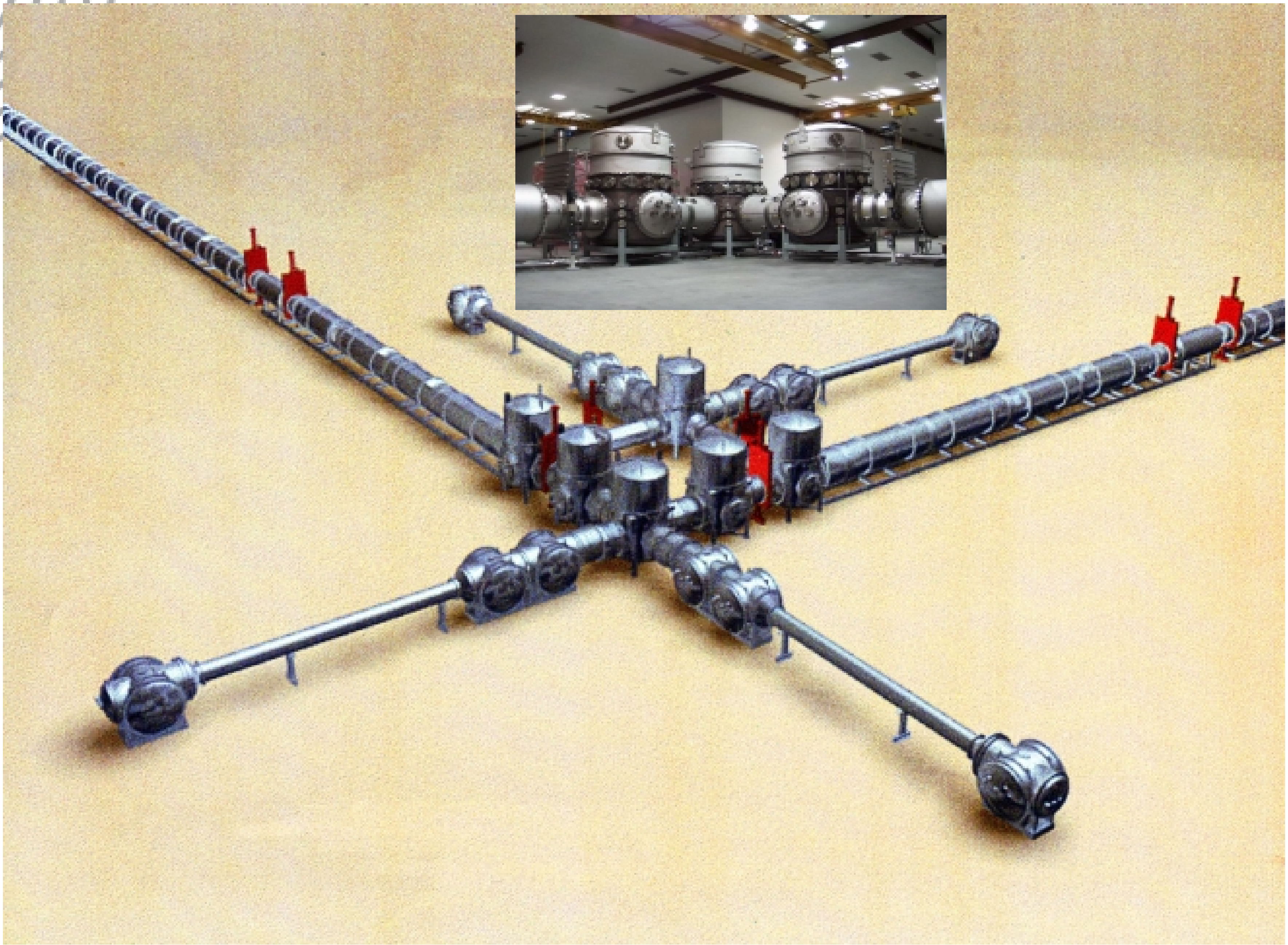
# EM vs Gravitational Waves

| | EM Wave | Grav Wave |
|---|---|---|
| Nature | Oscillation of EM fields propagating thru spacetime | Oscillations of the fabric of spacetime |
| Source | Acceleration of charge | Acceleration of mass |
| Interaction with matter | Adsorption, scattering | Essentially none! |
| Astrophysically relevant frequencies | > 10 MHz | < 10 KHz |
| Polarization | Transverse, J=1 | Transverse, quadrupole |

## *Performance Enhancement:*

1. ***Fabry-perot arms***
2. ***Recycling***





# LIGO Education Goals

- LIGO is exciting science!
- We want to utilize that excitement to stimulate student interest in science
- Where practical, we want to develop opportunities to promote student and teacher participation in research

# Educational Outreach Partnership Programs with K-12 Education

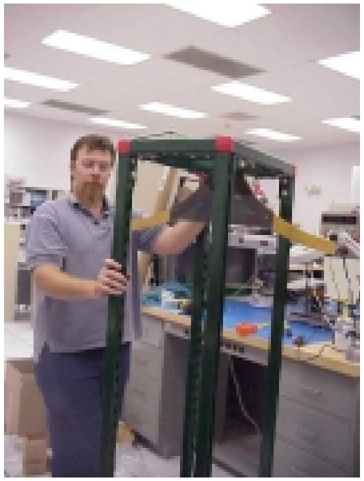
- At Hanford:
  - K-12 programs in collaboration with Pacific Northwest National Laboratory and Educational Service District 123 in southeast Washington.
- At Livingston:
  - RET program began in 2001 with 2 teachers from East Baton Rouge Parish and Livingston Parish

# At Hanford

- Collaborative research – remote monitoring of seismic sensors and wave height sensors to determine spectral content of low frequency ground motion
- With Gladstone High School in Portland, Oregon
- 2 HS teachers, 6 students in summer w/ ~30 students each academic year

# At Livingston

- Two teachers participated in summer research with interferometer commissioning and development enrichment materials to use in classroom
- Materials are web based so that they can be shared over the internet.
- See http://www.ligo-la.caltech.edu/teach.htm
- Use LIGO to reinforce classical concepts – wave motion, harmonic motion, Galilean relativity, properties of light, etc.



# Future Goals

- Expand participation in collaborative research to more high schools and more sites throughout nation via LSC.
- Expanded partnerships with formal educators to develop curriculum enrichment materials
- Interest in successful models developed elsewhere