
# *LIGO*

## *Laser Interferometer Gravitational Wave Observatory*

Briefing for PMA Visiting Committee

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# LIGO's mission

- Directly detect the gravitational waves predicted by General Relativity
- Pioneer the new field of gravitational wave astrophysics and astronomy

Hanford, Washington
4 km & 2 km interferometers

Livingston Louisiana
4 km interferometer

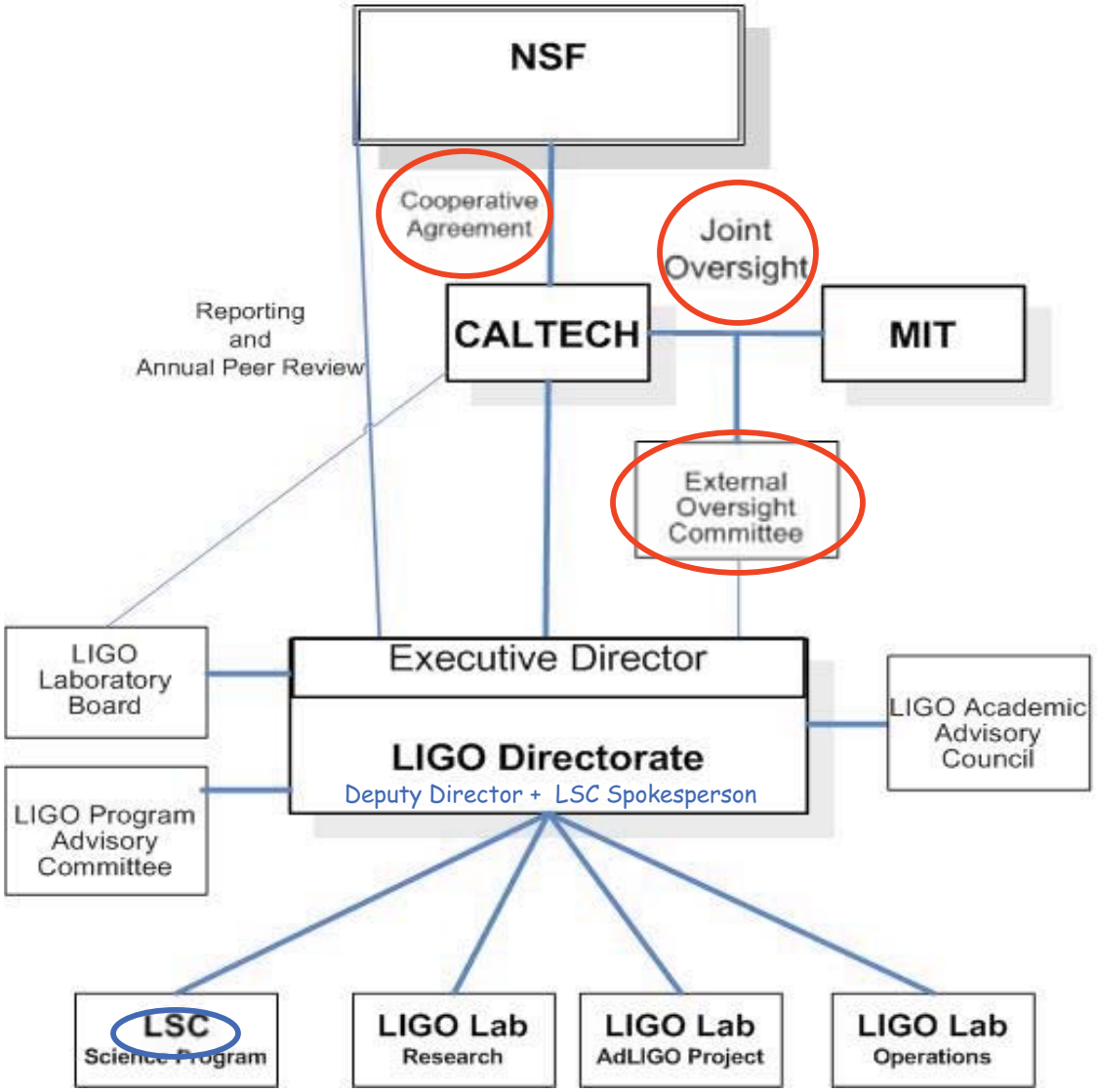

# *LIGO is Big Science*

- **LIGO = LIGO Laboratory + the LIGO Scientific Collaboration**

- **LIGO Laboratory**
  - ~180 people, headquartered at Caltech with observatories in Louisiana and Washington State & a group at MIT
  - Annual operating budget ~$33M
  - Operates the observatories, does R&D, analyses data and publishes science results, manages and executes LIGO projects

- **LIGO Scientific Collaboration**
  - ~500 scientists from 45 institutions (including Caltech)
  - With LIGO Lab, does R&D, analyses data and publishes science results
  - LSC has been integrated into the LIGO Lab management structure

# LIGO Organization



# *How much has/will NSF invest in LIGO?*

- Since start of construction start in 1995: $490M
- Expected funding FY08-FY15: $480M[1]

  (operations under new Cooperative Agreement and Advanced LIGO construction)

1--Commitments will be formalized by Cooperative Agreements with Caltech in place during the next year

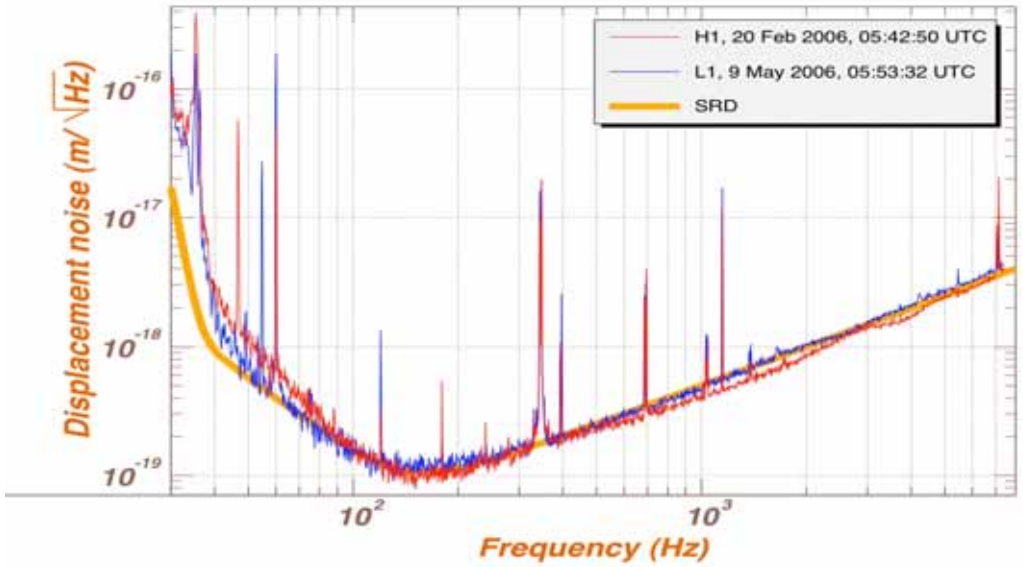
# *The challenge of measuring gravitational waves*

- Gravitational waves from even the strongest sources are very weak when they reach earth (strain ~ $10^{-22}$)

LIGO must be *sensitive to differential change in arm length of ~ $10^{-18}$ m*

- (1/1000 the size of a proton) over 4 km!!!
- Like measuring distance to nearby stars with accuracy of a hair's width

- After 5 years of intense effort to reduce noise by ~ 3 orders of magnitude, LIGO's design sensitivity was reached in 2005--a great achievement




# *Current search for gravitational waves with LIGO*

- A gravitational wave search *at design sensitivity* began in November 2005; continue into fall 2007

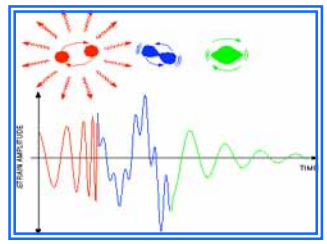
- Searching for signals in audio band (~50 Hz to few kHz) from
  - inspiraling neutron star and black hole pairs,
  - collapsing supernovae,
  - pulsars,
  - stochastic sources including the big bang,
  - the unknown.

- How far can we "see?"--
  - Range for "golden" source --inspiraling pair of 1.4 $M_o$ neutron stars-- is now ~50 million light-years

# *Sample of recent science results from LIGO*

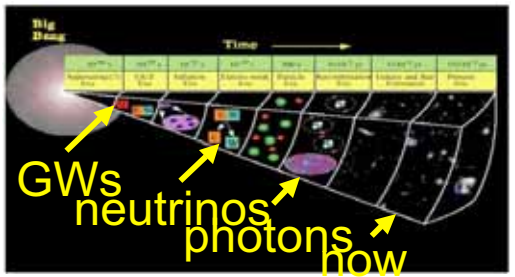
- **No GW observed yet**--data from current run sets some interesting limits

- **Binary neutron stars or black holes** coalescing
  - » In Milky Way sized galaxy
    - – for 1.4 $M_o$ NS-NS happens less often than once every 50 years
    - – for 5.0 $M_o$ BH-BH happens less often than once every 250 years



- **Pulsars--**Look for GW signal from ~100 known pulsars
  - » Limits on pulsar ellipticity ~ $10^{-6}$ (1 cm bump on 10 km size object)
  - » For Crab pulsar determine that < 60% of energy lost in spindown goes into GWs

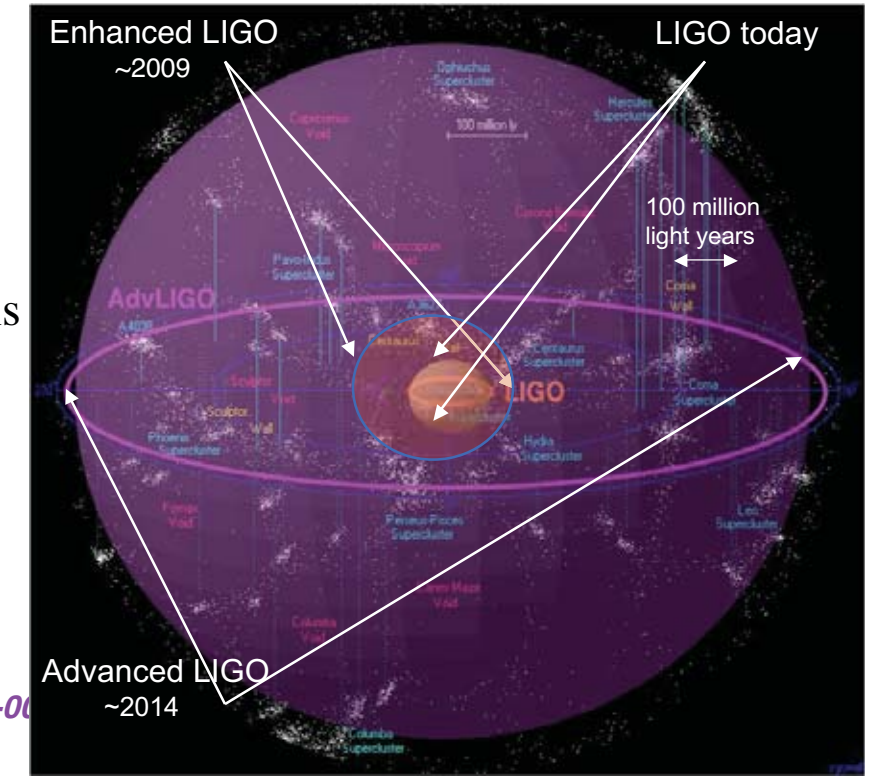
- **GWs from the Big Bang** (data from previous run)
  - » Fraction of the energy density in the universe in GW (in 50-150Hz frequency band) is less than 65 parts per million



# *The scientific evolution of LIGO*

- **Current science run** is ~65% complete
  - » Hundreds of galaxies now in range
  - » No discovery yet--possible but not highly probable
- **Enhancement program** (~2x sensitivity; 8x volume of universe)
  - » Lead by Rana Adhikari, new Caltech Asst. Professor
  - » In **2009** ~8 times more galaxies in range; discovery probability-moderate
- **Advanced LIGO project**

  (~10x sensitivity; 1000x volume of universe)
  - » ~$205M from NSF + overseas contributions
  - » Construction start expected in FY08
  - » 1000 times more galaxies in range
  - » Expect ~1 signal/day or /week in ~**2014**
  - » Will usher in era of gravitational wave astrophysics



# *LIGO at Caltech--people, space & computing*

- **People**-- Healthy balance between faculty, staff, students, postdocs
  - » ~60 Caltech employees and 28 contractors
    - – includes 10 postdocs
    - – ~ 10 grad students and ~20 summer students (SURF and REU)
  - » 6 members of professorial faculty and 3 members of research faculty are involved with LIGO
- **Space**-- significant issue with solution a few years away
  - » Staff currently in 4 different buildings on campus- a serious efficiency problem
    - – Will be resolved when Cahill Center frees space in Bridge Laboratory
    - – Commitment from PMA to consolidate in Bridge ~early 2009
- **Computing**- will need more space and infrastructure
  - » Advanced LIGO will increase need for data analysis computational capabilities
  - » Will need more space on campus for computers and increased power and cooling
    - – Working with appropriate Caltech officials to resolve


# *Bottom-line*

- LIGO is the world-leading program in Gravitational Wave science-- Caltech led and nurtured
- The current science run at design sensitivity is going very well & science results are being published
- With Enhanced and then Advanced LIGO, LIGO will observe GW and then pioneer the new field of GW astronomy
- A coordinated international network is evolving under LIGO's leadership
  - » Agreement for data sharing & coordinated operations with Virgo (French/Italian funded GW observatory near Pisa) just approved