LIGO

Catching Gravitational Waves in Livingston, Louisiana

Mark Coles

Observatory Head

LIGO Livingston Observatory

California Institute of Technology

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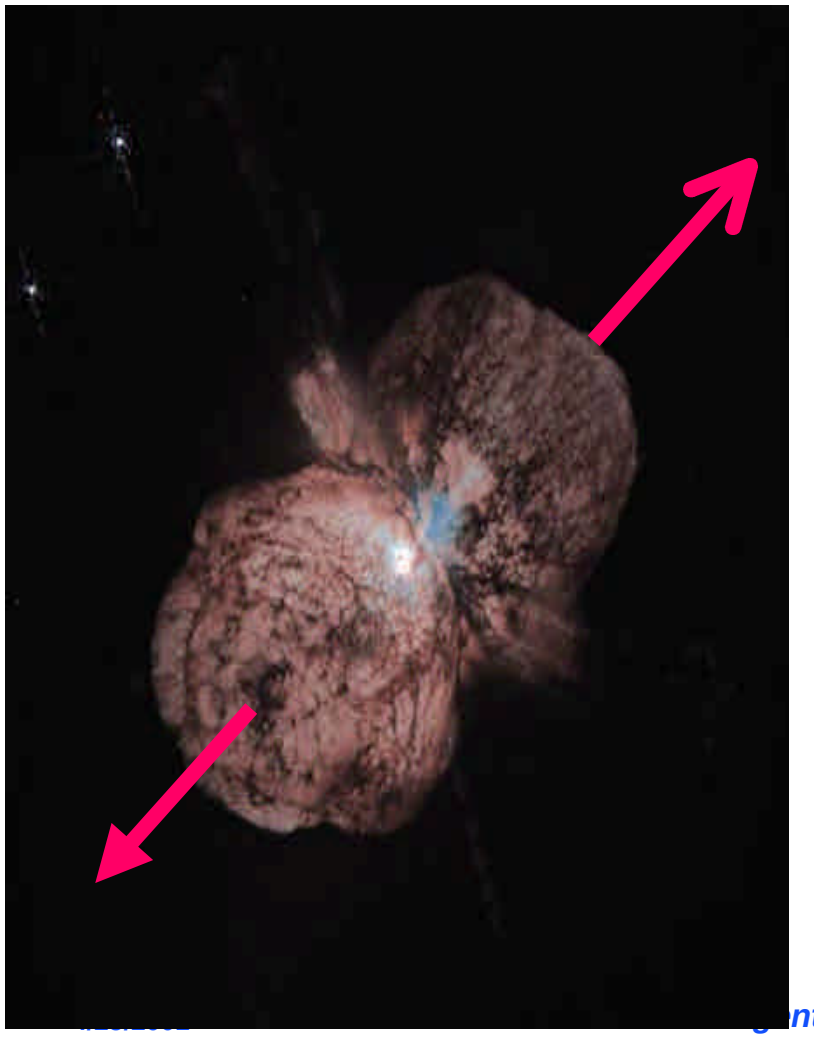
Project Overview

- LIGO: Laser Interferometer Gravitational Wave Observatory
- Operated by California Institute of Technology in partnership with Massachusetts Institute of Technology.
- Funded through cooperative agreement between National Science Foundation and Caltech
- LIGO is the result of more than 30 years of study and development of laser interferometer gravity wave antennae

Scientific Motivation

- Albert Einstein predicted the existence of gravitational waves - *ripples in the fabric of space and time* - as part of the general theory of relativity.
- LIGO is designed to detect these waves directly, opening up a new vantage point from which to study the universe.
- When operational, LIGO will allow scientists to understand the astrophysical sources of gravitational waves, including supernovae, binary neutron star systems, and the vibration of black holes.

Example: Supernova



Why does this picture look this way?

Gravity plays a critical role in shaping the way the universe looks

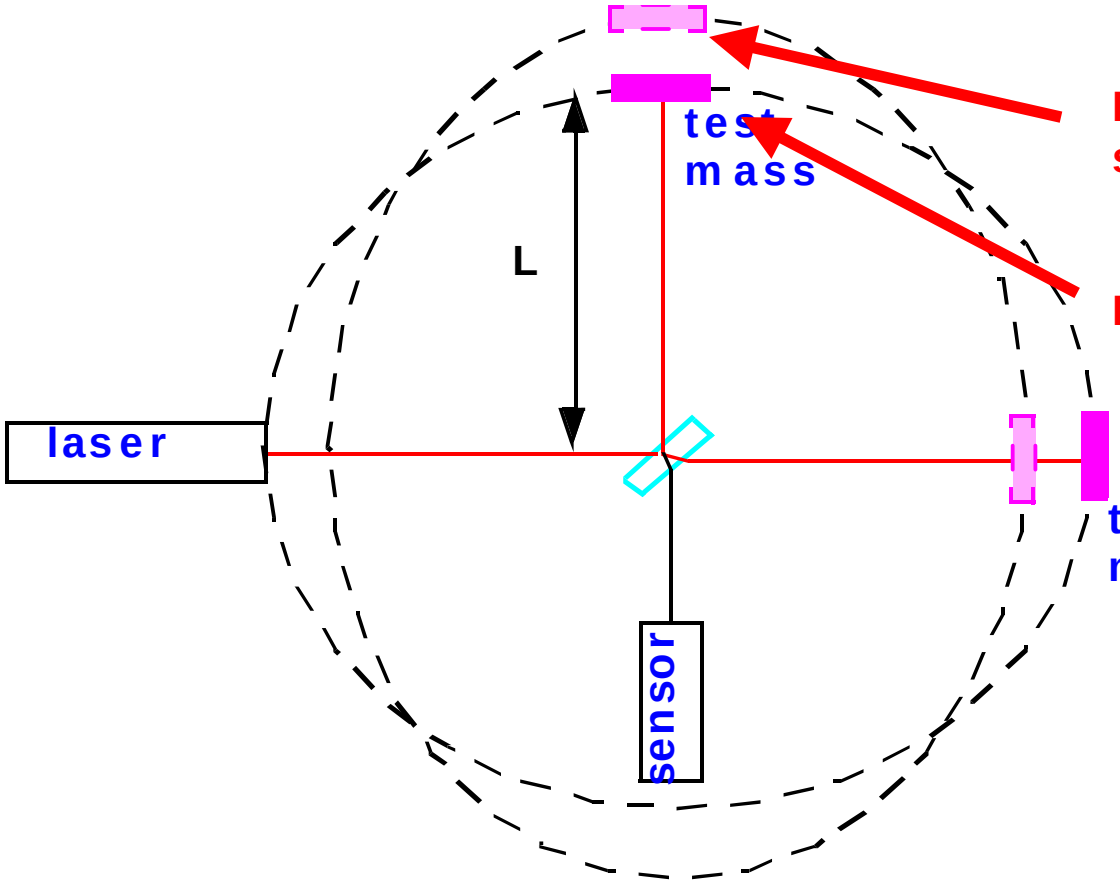
Eta Carinae –

photo from Hubble Space Telescope

How LIGO works

- LIGO measures the tiny distortions of space-time caused by the passage of gravitational waves.
  - » Gravitational waves are waves in space and time
  - » Space is stretched and compressed at the frequency of the gravitational wave
- Distances between mirrors suspended in vacuum are precisely measured using a highly stabilized laser beam

How LIGO Works

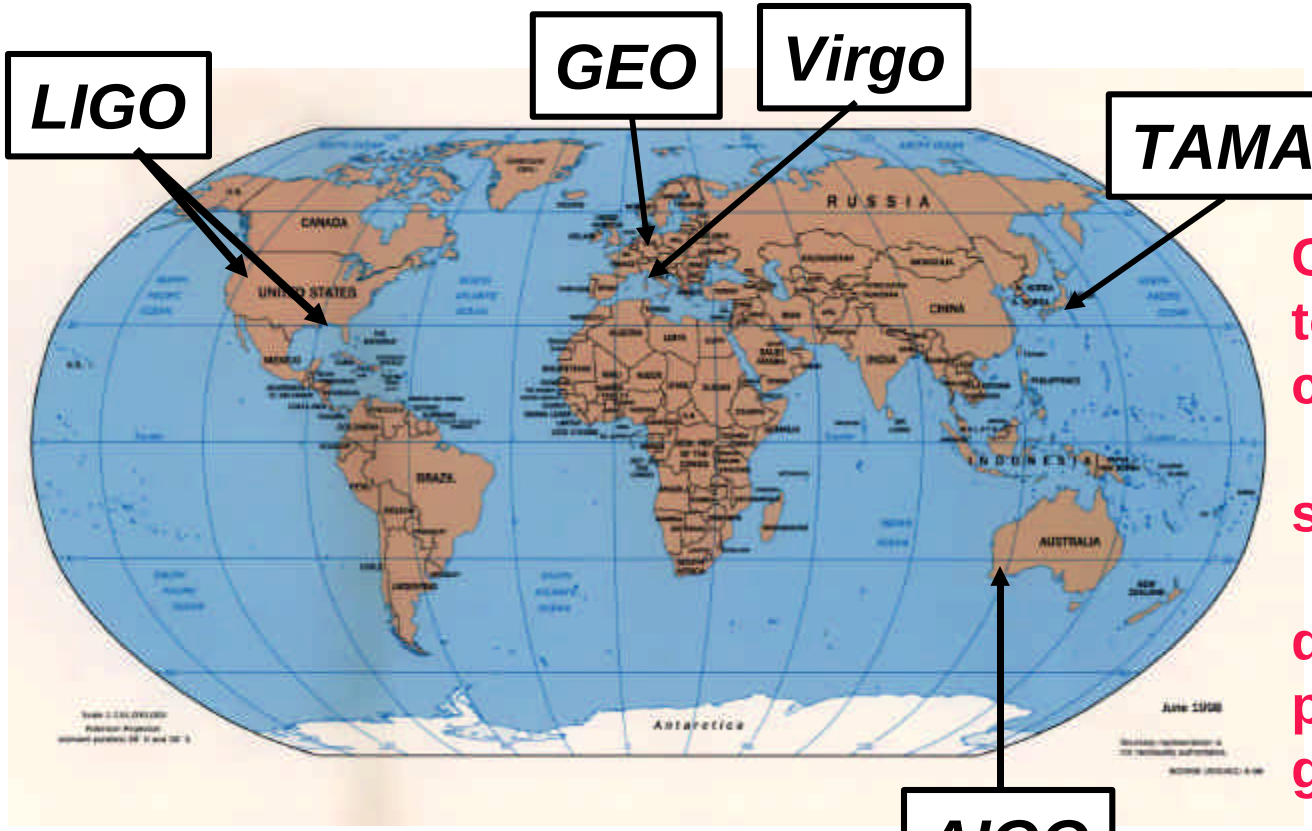


Initial position of freely suspended test mass

Displaced test mass position

Mirror displacement
~10^{-19} meters

International network of gravitational wave interferometers now being readied for operation

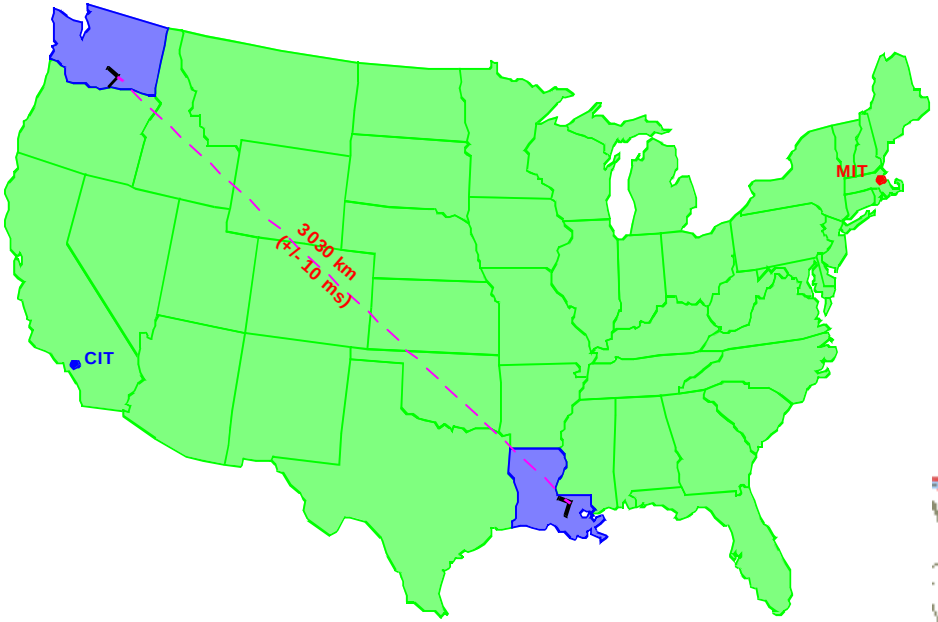


Coincident detection to enhance detection confidence

source location

decompose the polarization of gravitational waves

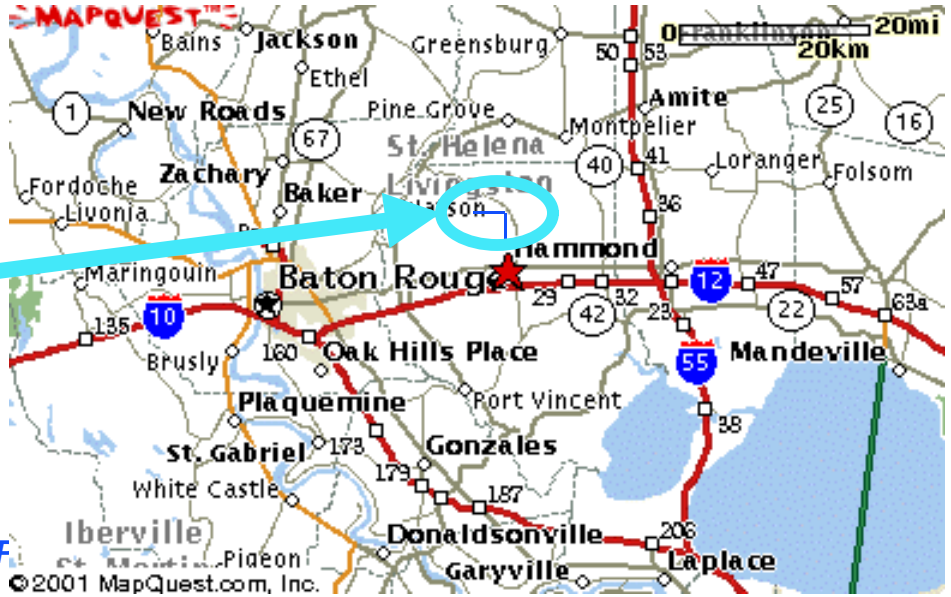
LIGO Locations



Two well separated observatory sites to minimize correlated noise:

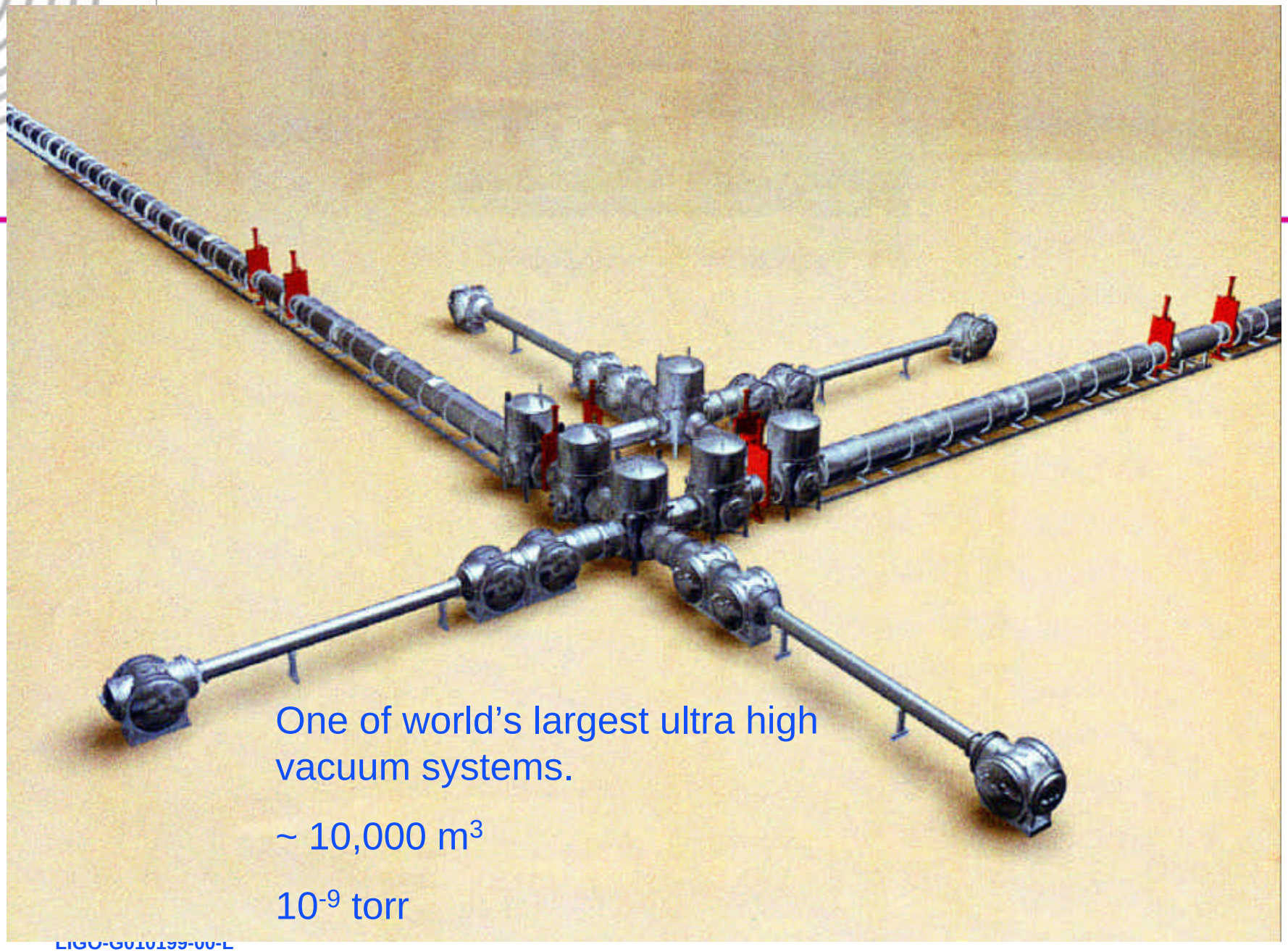
- Tri-cities area of Eastern Washington
- Livingston, Louisiana

LIGO

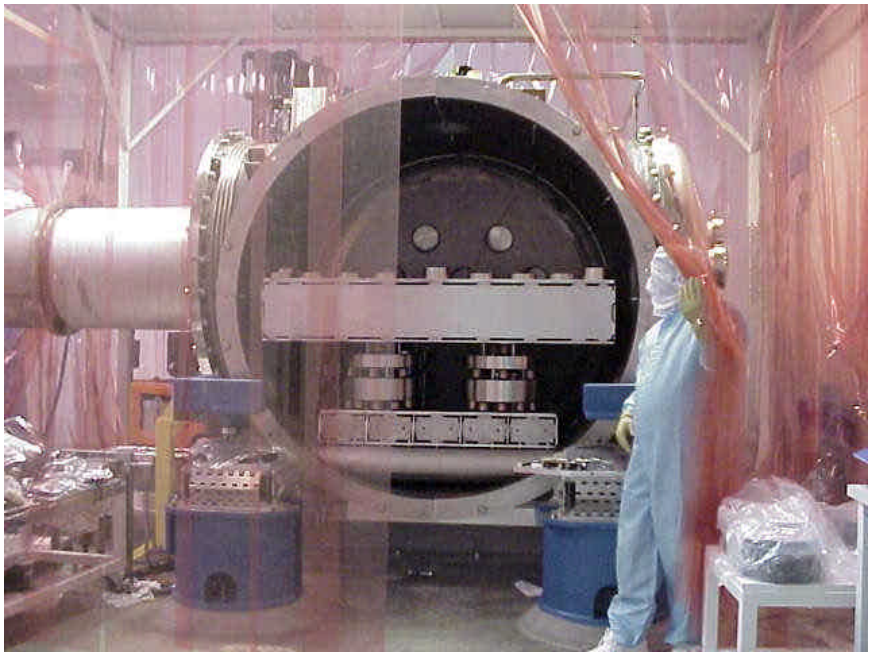


LIGO (Washington)

LIGO (Louisiana)


One of world's largest ultra high vacuum systems.
~ 10,000 m3
10-9 torr

Seismic isolation system



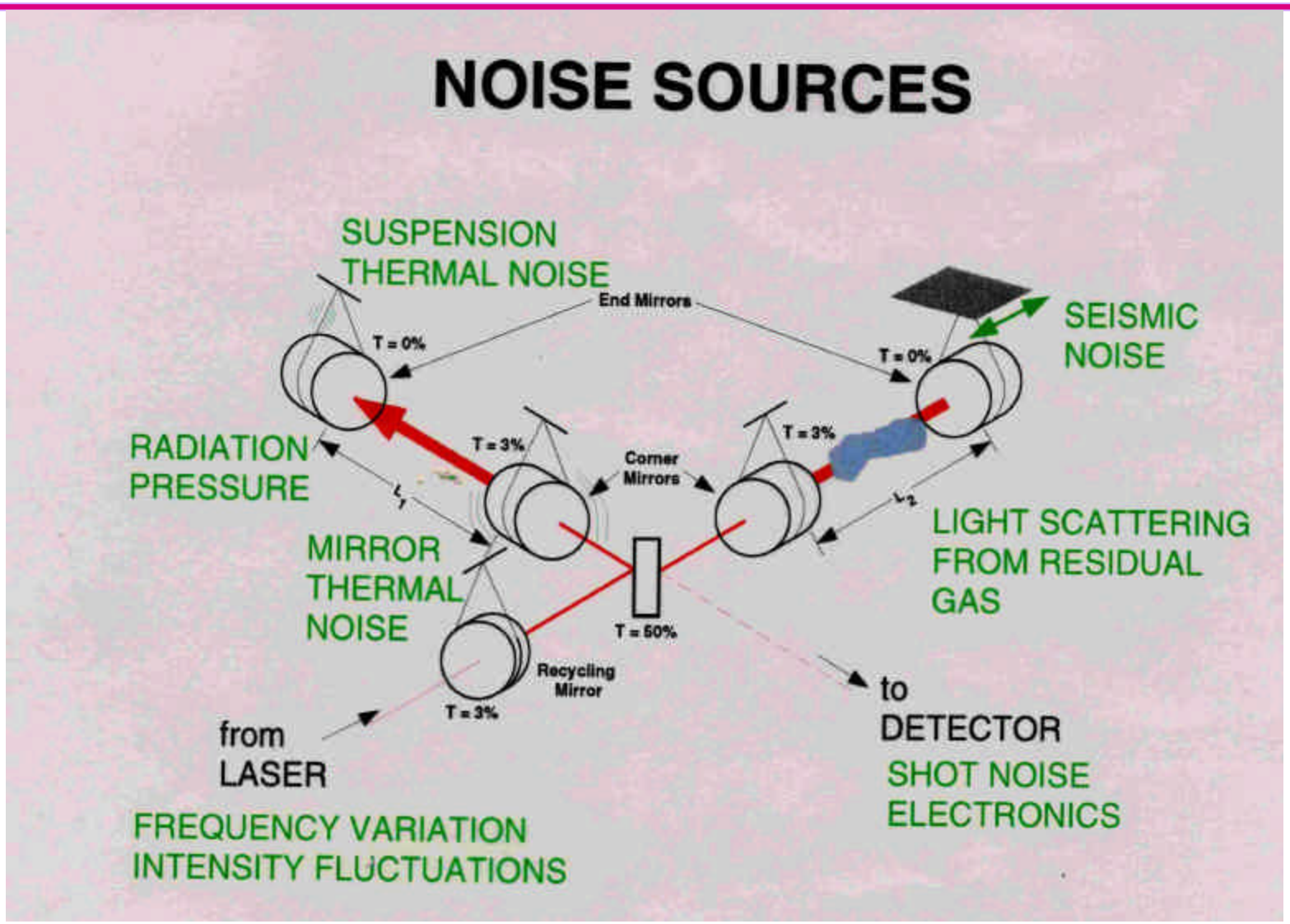
Suspended Optics

Mass	10.7 kg
Mirror diameter	25 cm
Mirror material	Fused silica
Mirror internal Q per mode	$>10^6$
Mirror internal adsorption	~5 ppm
Mirror loss	50 ppm

Single Wire Loop Suspension

Pendulum material	Steel wire, Q=200,000
Pendulum frequency	1 Hz

Limiting Factors in Operation



Design considerations to reduce noise

- Insensitivity to ground motion
  - » Seismic isolation
  - » Low vibration support equipment
  - » Active vibration isolation and servo control systems
- Brighter lasers
  - » Materials (mirrors, coatings, modulators) that can handle very high CW optical powers (up to about 1 MW at 1.06 μ)
  - » 200 Watt single mode lasers at $\lambda = 1.06\ \mu$
- Reduced thermal noise
  - » High Q suspensions
  - » High Q materials – sapphire, fused quartz, YAG, etc.

Collaborating Institutions

- Approximately 30 institutions world-wide are part of the LIGO science collaboration.
- LIGO encourages the participation of additional institutions in the science collaboration, particularly those in the regions close to each of the LIGO sites.
- Presently participating Louisiana institutions:
  - » LSU
  - » Southern Univ. of Baton Rouge
  - » Louisiana Tech Univ.
  - » Southeastern Louisiana Univ.
  - » Loyola University
- Others welcome!

Observatory Facilities and Staff

- Approximately 30 scientists and engineers resident at each LIGO site.
- Joint faculty appointments with U of Florida, SLU
- 5-10 scientific visitors from Caltech and MIT spend weeks to years
- Regular visitors from local universities
- Summer program for undergraduates
  - » This year about 20 students will work at Livingston during the summer
- Summer teacher program
  - » Strengthen science education in the region
- Laboratories and shops to conduct supporting research and development
- T1 internet (to be upgraded to OC3)

Status

- Construction complete
- All equipment installed
- Systems integration and test nearly complete
- Engineering studies continue through 2001
- Scientific data taking for 3-4 years begins in 2002
- Major upgrade planned for 2006
  - » 1000X increase in astrophysics event rate
  - » Advanced R&D and design engineering to be undertaken in parallel with scientific data taking

How Colleges and Universities Can Become Involved in LIGO

- *Join LIGO science collaboration:*
  - » Contribute intellectually to the understanding of the interferometer, instrumental and environmental sources of noise, data analysis algorithms, etc.
  - » Significant advantage in being located close to LIGO – data is dominated by instrumental signatures which need to be understood
  - » Participate in the advanced R&D program for the LIGO upgrade:
    - – Optical materials research
    - – Coatings
    - – Servo control system design
    - – High power laser systems
    - – Cryogenics
    - – Earth science too! Characterization and adaptive reduction of seismic noise environment, earth tides

Educational Outreach

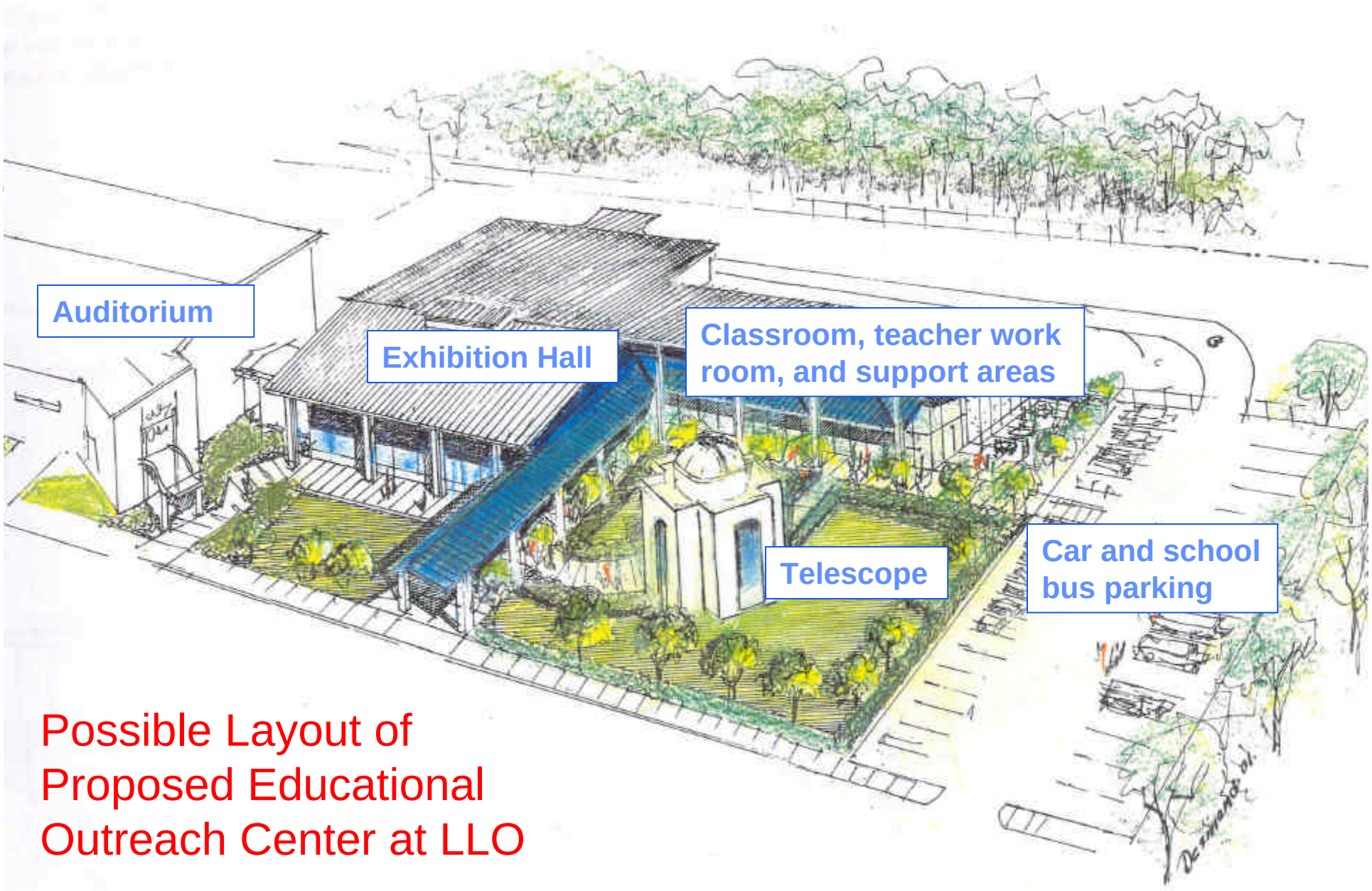
- Field trips by community and professional groups at both sites
- More than 3,000 visitors in last year at LLO (mostly school classes), 750 on one day during public open house
- Teacher open houses in summer and winter, more than 100 middle and high school science teachers in Livingston Parish have toured LIGO as part of teacher in-service
- LLO hosted more than 100 African-American high school science students participating in Southern University's Timbuktu Academy

Become an Education Partner

- We want to be an important part of regional educational infrastructure
- Strengthen K-12 science education
  - » Pilot program in place at Northwestern State Univ. to develop LIGO related school curriculum materials
  - » Strong relationship with Southern University to promote community and K-12 outreach in traditionally underserved communities
  - » Additional opportunities to partner with school systems for in-class and site visits.
  - » Opportunity to develop proposals to NSF Division of Education and Human Resources
- Lots of room for others to be involved!

Outreach Center

- Congressman Richard Baker has enthusiastically supported establishment of an outreach center at LIGO Livingston Observatory along the lines of centers at Arecibo, Lowell Observatory, MacDonald Observatory.
- Center mission:
  - » Host site visitors with hands-on exhibits and science classes (similar to NSF-funded Arecibo and Lowell Observatory centers).
  - » Teacher in-service training and support for classroom enrichment (also like Arecibo and Lowell Centers).
  - » Host a modest school-to-work program for vocational training.
- We would like to partner with other education organizations to help create, operate, and utilize the proposed center.



Possible Layout of Proposed Educational Outreach Center at LLO

Summary

- LIGO welcomes opportunities for collaborative research and development with local institutions
- LIGO is committed to strengthening science education at the K-12 and university levels and wants to partner with universities, local school systems, and regional science centers to do this
- More information is available at the LIGO website: www.ligo.caltech.edu