I2U2 Design Workshop
-
LIGO Goals, Plans & Ideas

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Outline

I. About LIGO: background, data, people

II. Provide access to LIGO PEM data via a simple interface, and provide access to analysis and visualization tools (e.g. DMT) using those data

(Make ROOT based tools accessible via web)

III. Develop one or more prototype e-Labs

(4 candidates, and a way to "grow" more)

IV. Provide a collaborative environment for participants

(discussion forums, EVO "Virtual Institute", g-Labs)

V. Apply grid methods and philosophy of distributed computing to create a *scalable* resource for discovery-based science education.

I. LIGO Overview

- *L*aser *I*nterferometer *G*ravitational wave *O*bservatory
- An experiment to *detect* the gravitational waves (GW's) predicted by Einstein's general theory of relativity (GR).
- A facility for astronomical observation using GW's -- *opening a whole new branch of astronomy!*
- LIGO Scientific Collaboration (LSC) consists of over 400 scientists from over 40 institutions
- No detections yet, but upper limits established and analysis methods developed and refined.
- Just began year-long science run (S5) in November

Skip it

LIGO Observatories

LIGO Livingston Observatory (LLO)

Livingston Parish, Louisiana

L1 (4km)

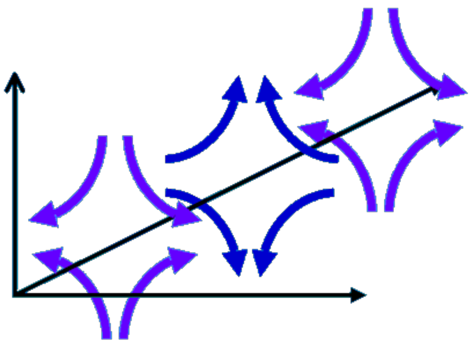
LIGO Hanford Observatory (LHO)

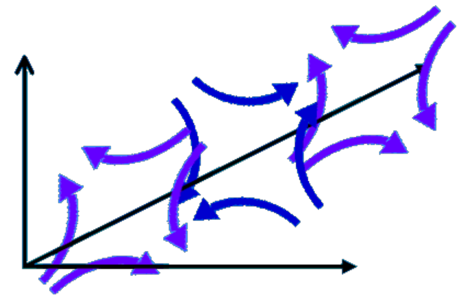
Hanford, Washington

H1 (4km) and H2 (2km)

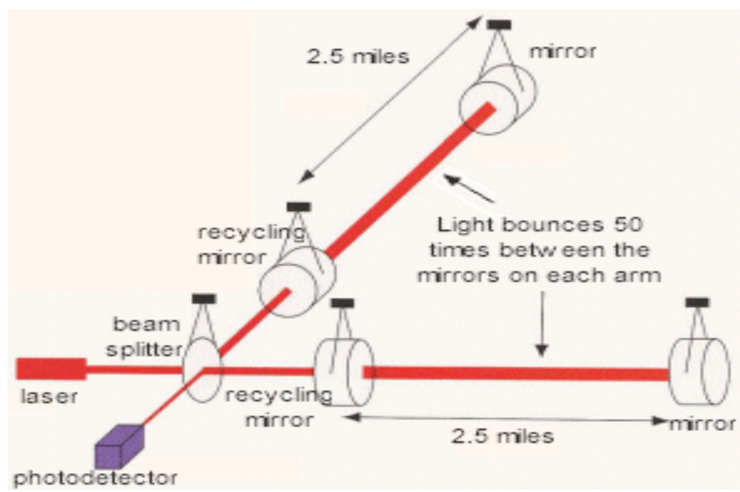
Detecting Gravitational Waves

Gravitational waves are time-varying quadrupole distortions of space-time:





These are detected as small changes in length in the arms of the Interferometers:



Sources of Gravitational Waves

LSC scientists participate in one or more upper limit/ search groups looking for signals from:

- Coalescence of binary systems: neutron stars and black holes (NS-NS, BH-BH, BH-NS) *CHIRP!*
- Continuous Wave (CW) sources, such as spinning (asymmetrical!) pulsars
- Bursts from supernovae (asymmetric!)
- A stochastic background from the early universe

In general

|h| = (2G/c^4) (1/r)(d^2/dt^2) Quv

At twice the rotational frequency of the source

LIGO PEM data

- The primary channel from LIGO is the *strain amplitude* as it varies with time:

$$h(t) = \Delta L/L$$

- Analyzing LIGO data primarily involves signal processing, both in the time domain and in the frequency domain.
- A large number of other channels are recorded to track instrument status and environment, including Physical Environment Monitoring (PEM) channels:

Seismometers	Microphones
Accelerometers	Radio receivers
Tiltmeters	Weather stations
Magnetometers	

- Analyzing LIGO PEM data have the potential for a rich variety of instructive e-Labs.

LIGO I2U2 Personnel

- Fred Raab (LIGO PI) – head of LHO, Gladstone HS project
- Dale Ingram – LIGO Education & Outreach , Gladstone HS Project
- Greg Mendell – LHO scientist and LDAS expert
- Dave Barker – LHO scientist, computer guru and LDAS expert
- Daniel Sigg – LHO scientist, DTT and DMT expert
- Eric Myers – physicist, primary I2U2 worker for planning phase
  - Theoretical physicist (GR in extra dimensions, Lattice QCD, quantum gravity, cosmic strings, gravitational waves, supercomputing)
  - with some experimental background (Fly's Eye, FNAL E570, DØ, ATLAS grid test-bed, LIGO)
  - Physics teacher (Yale, SLU, Univ. Michigan, Vassar, SUNY NP)
  - Developed Einstein@Home distributed computing project for LIGO

II. LIGO data and analysis tools

- LIGO Data flow:

  LHO and LLO → Caltech → SFT's → UWM, PSU, (also Cardiff and AEI for GEO600), etc

- LIGO analysis tools:

  LDAS, LAL, LALapps, LIGOtools, DDT and DMT

- LIGO and Grid:

  LDAS pre-dates Grid, but LIGO is 'gridified'…

  GridFTP transport, LSC DataGrid, LDR, SFT generation at LHO and Caltech, inspiral Pegasus DAG on OSG

  Participation in GriPhyN, iVDGL

III. Developing LIGO e-Labs

- What is an e-Lab? (I'm here to find out)
- How do you create an active and evolving suite of instructive and interesting lab experiments?

  (an example from Vassar Modern Physics Lab)
- Some e-Labs need to be "repeatable"

  (and some will be "new investigations")
- Need in-class data taking activities, when possible

  (physics is "physical", so make it REAL! We have some ideas)
- Need an e-Lab classification system (a' la PIRA demos)
- Candidate LIGO e-Labs:

  0) Microseism at LHO, 1) Train seismic events at LLO,

  2) Earthquake location at LHO, 3) Tracking lightning strikes at LLO
- Candidate LIGO i-Lab / exhibit

Skip it

Example: Modern Physics Lab

How do you sustain continuous development of new and existing experiments in an ongoing lab course?

Vassar Physics 201 - Spring 2003 - 10 students (5 teams)

I	II	III
Millikan's Oil Drop Michelson Inteferometer Photoelectric Effect Muon Lifetime Speed of γ Rays		

2 weeks prep, then 5x2 week experiments in "round robin", with written reports (first & second author alternating)

Example: Modern Physics Lab

How do you sustain continuous development of new and existing experiments in an ongoing lab course?

Vassar Physics 201 - Spring 2003 - 10 students (5 teams) – Last Experiment

I	II	III
Millikan's Oil Drop Michelson Inteferometer Photoelectric Effect Muon Lifetime Speed of [illegible] Rays	Acousto-Optic Effect HeNe Laser Holography	Blackbody Radiation Gravitational Constant

Added 5 "new" experiments at the end of the semester.
Final papers written individually (and using TeX)
Final presentation (10 min) on last day to rest of class.

Example: Modern Physics Lab

How do you sustain continuous development of new and existing experiments in an ongoing lab course?

Vassar Physics 201 - Spring 2004 - 14 students (7 teams)

I	II	III
Millikan's Oil Drop	Blackbody Radiation	Cosmic Ray II
Michelson Inteferometer	Gravitational Constant	Atomic Spectroscopy
Photoelectric Effect		
Muon Lifetime		**IV**
Speed of γ Rays		
Acousto-Optic Effect		Compton Effect
HeNe Laser		Franck-Hertz Effect
Holography		Zeeman Effect

Successful experiment and report moves the experiment over to the left. New experiments added in columns III or IV.

Example: Modern Physics Lab

How do you sustain continuous development of new and existing experiments in an ongoing lab course?

Vassar Physics 201 - Spring 2005 - 20 students (10 teams) – doubled!

I	II	III
Millikan's Oil Drop (x 2)	Nuclear Spectroscopy	Cosmic Ray Energies
Michelson Inteferometer	Gravitational Constant	
Photoelectric Effect	Atomic Spectroscopy	**IV**
Muon Lifetime		
Speed of γ Rays		Compton Effect
Acousto-Optic Effect		Franck-Hertz Effect
HeNe Laser		Zeeman Effect
Holography		Sonoluminescence
Blackbody Radiation		GR photon red shift

Continuous growth of a suite of both "repeatable" initial experiments and "new" investigations for the now prepared student.

Need "repeatable" labs

- Some e-Labs need to be "repeatable" projects. Even if someone else has already done them, they are new to the student, and they build skills and familiarity with methods and procedures.

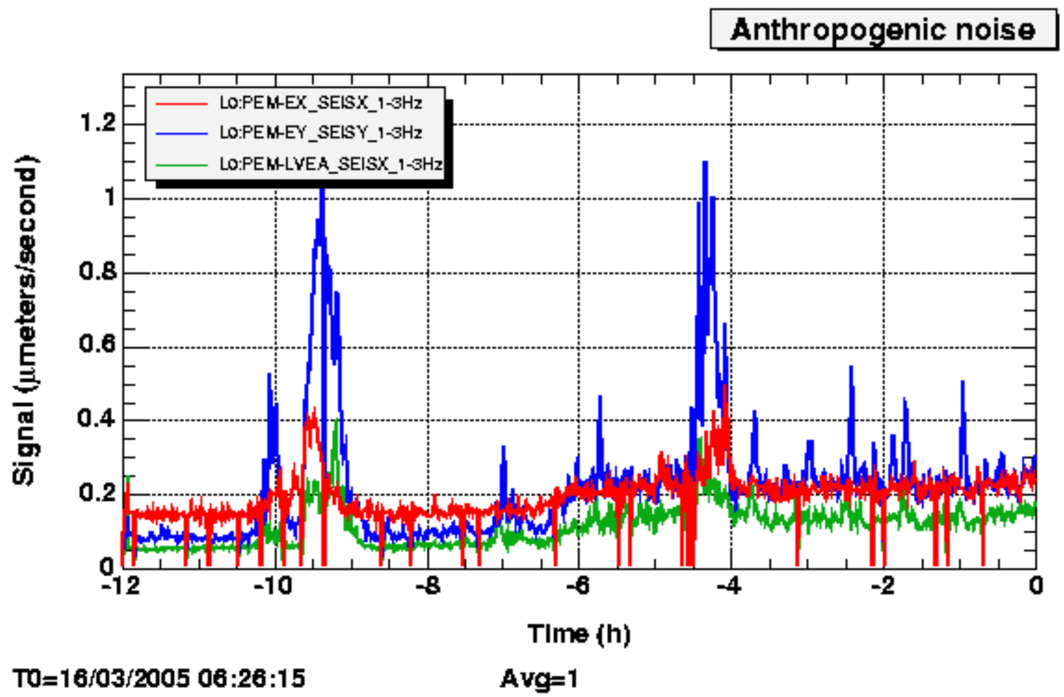
- New e-Labs will start as "new" investigations, which come from questions from existing e-Labs, or from new ideas from scientists, teachers, or students.

- My algorithm:

  Q: "What happens if I do this?"

  A. If (!dangerous) echo "Try it!"

Trains at Livingston



IV. Collaborative Tools

- Discussion forums

  Public and private "rooms", dynamically generated rooms for each "project"

- EVO "Virtual Institute"

  Outlines both roles of participants and a site plan

- g-Labs
  - An extension of the i-Labs idea to include guided e-Lab activities

- Teleconferencing

  VRVS is complicated, but getting easier. iChat/AV, Net Meeting, Skype, Polycom,… Wiki knowledge base and help forums

- Student Web Lectures at end of project

  See Web Lecture Archive Project (www.wlap.org) and FNAL Colloquia on-line

Skip it

Discussion Forums

Starting in Summer 2004 (on-line in Feb 2005), LIGO created Einstein@Home, based on the Berkeley Open Infrastructure for Network Computing (BOINC!), to use distributed volunteer computing to analyze LIGO data.

80,000 active users, 145,000 hosts, 77 Teraflops

BOINC includes software for setting up discussion forums (message boards). These have been useful for debugging the server and clients applications, for making announcements, for getting reports "from the field", for developers and scientists interacting with users, and for users interacting with each other and building team spirit and involvement.

Discussion Forum Features

Code for discussion forums could be taken directly from BOINC, with modifications. (Or use other popular packages, such as BBphp,…) Also can be used for on-line logbook.

Features:

Open source code (LGPL) written in PHP with SQL database; HTML and BBcode; Localized Language support; Avatars; Rating system; User profiles…

Desirable modifications:

Private "rooms" for teacher only discussion, developers only, etc.

Links to uploaded images (as in a logbook) or other files.

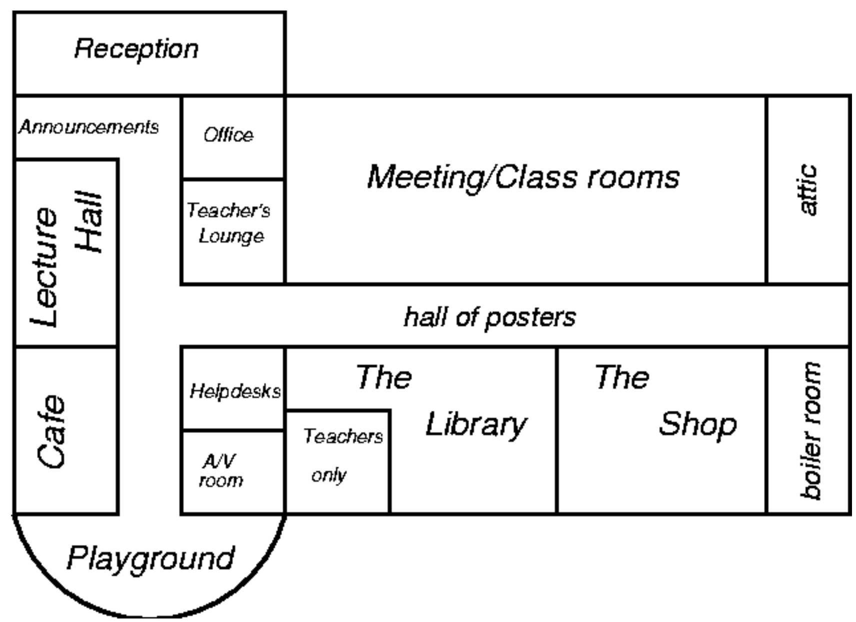
Private/Public name and Avatar.

Dynamic creation of new rooms for a new project. Attic to store old.

Virtual Institute

- EVO consists of co-PI's, advisory group, management board, institute fellows, staff, etc..
- The Virtual Institute also consists of Teachers and Students, "Project Leaders", and "Project Members", "Visitors", "Guests", and "Participants" (need to get all these roles and terms straight) and the "building" they all work in:

- In this case the "building" is the site plan for the website (portal).



g-Labs

The I2U2 proposal states that i-Labs will "*start with an appealing museum exhibit to catch a visitor's attention… inviting visitors to continue their scientific explorations via a virtual community from their home or school.*"

An extension of the idea is to get interested learners (i-Lab participants) involved in a *group* activity (usually parts of an e-Lab) while *guided* by a "Team Leader" (or *docent*).

This is not really a new component, it's just added emphasis to one of the stated goals of i-Labs.

… e, f, g, h, i, …

e-Labs: electronic (as in e-mail, e-commerce,…)

education (as in formal K-12 education),

excite (must get students *excited* about the activity)

engage (must get students *engaged* in the activity)

i-Labs: internet (as in iTunes, iPhoto, iPod,…)

introduction (tied to a museum exhibit to introduce the idea)

informal (aimed at informal learners, not students in a class)

individual, independent (go at your own pace)

interesting (or else they won't participate)

interactive (get them thinking and doing)

g-Labs: grid (as in globus, gridFTP,…)

guided (because even motivated, interested, individuals profit from some guidance and direction from someone they can interact with to discuss and ask questions)

group (because participants also profit from interactions with peers – same principle we use in undergrad education)

Teleconferencing

Teleconferencing is used by particle physicists as a useful aid for remote collaboration. The I2U2 portal could facilitate the use of teleconferencing tools without requiring any one tool. VRVS, Polycom, iChat/AV, Net Meeting, Skype, etc… all possible. The users will find the best way to use these tools.

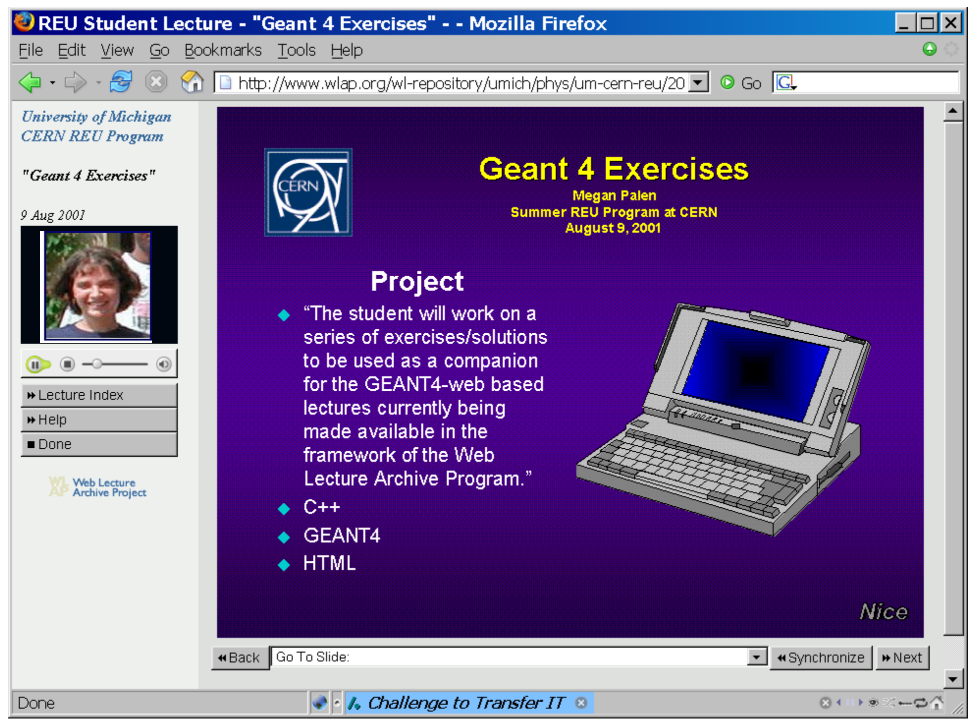
LIGO might create "Operators Office Hours" for I2U2 participants to visit the control rooms for a tour or chat with operators or Sci-Monitors, as workload allows.

Lots of other possibilities….

On-line Web Lectures

- At the end of a project, students will create an on-line poster summarizing their activities and results.
- Students could also easily record slide-based talks for presentation on the I2U2 site (in the "Lecture Hall")
- FNAL already has production facilities to generate such Web Lectures.

- Synchronized audio and video with slides changing automatically.
- See also WLAP (www.wlap.org) and especially the presentations from UM-CERN REU.



V. Grid philosophy

- I2U2 will leverage existing Grid tools, data resources and infrastructure, with some additional "middleware," for inquiry-based science education .
- But we can also apply some *<u>ideas</u>* from distributed computing!
- Grid computing is motivated by the observation that network performance (doubling every 9 months) is improving faster than computation (18 months) or storage (12 months)
  - Communications is "free" compared to computation, allowing new ways to view <u>distributed</u> computing *"talk is cheap"*
- Similar ideas can be applied to I2U2: providing interconnection and communication channels can lead to <u>distributed</u> development of a <u>distributed</u> resource: *<u>spread the work around!</u>*
- Examples: Einstein@Home translations, BOINC stats pages and tools.

Example: aligning with standards

Aligning an e-Lab with national standards is straightforward, and you do it once (per e-Lab).

But teachers also need to be assured that e-Labs are aligned with state standards. Although lots of similarities (parallelism!), these are 50+ tasks.

Solution:

- Spread the work out to 50+ teachers (distributed workload)
- Provide infrastructure to allow intercommunication between these "nodes" to lessen the work done by each.
- Make the task scale with the workload

Example: DAQ activities

Problem: LIGO e-Labs would be even better if students could also take their own data using "similar" equipment, (e.g. microphones connected to Vernier LabPro). But somebody has to figure out the best way to set up and use the equipment, create documentation, etc…

Solution: HS teachers working together via a collaborative environment could try variations and share ideas and results. The more interesting the project, the more developers it would attract. We just need to plant the seeds that get this started,

spread the work around!

Conclusions

- LIGO PEM data have the potential for a rich variety of instructive e-Labs: microseism, earthquakes, lightning,…
- Existing LIGO tools (e.g. DMT) can be used, with a new interface, to make data and analysis tools available for e-Labs, i-Labs (and g-Labs?).
- Need to create a way to share PEM data and DMT/DTT with "public" users.
- Collaborative tools can link all participants together into a “grid” of teachers and learners to create a *scalable* resource for inquiry-based science education.