



Distributed Data and Grid Computing for Inquiry-based Science Education and Outreach

Eric Myers

LIGO Hanford Observatory

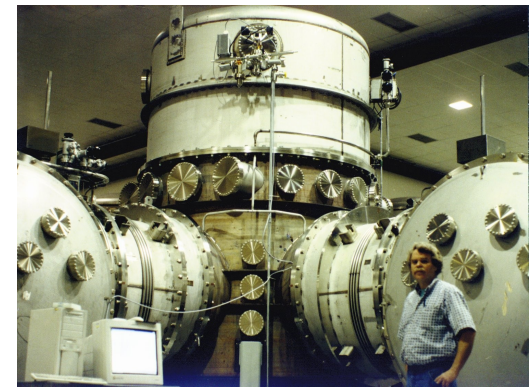
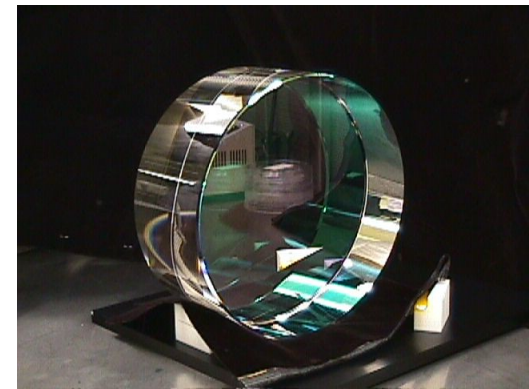
Hanford, Washington

"BOINC in Research, Science, and Education"

1st East Coast BOINC Meeting

University of Delaware

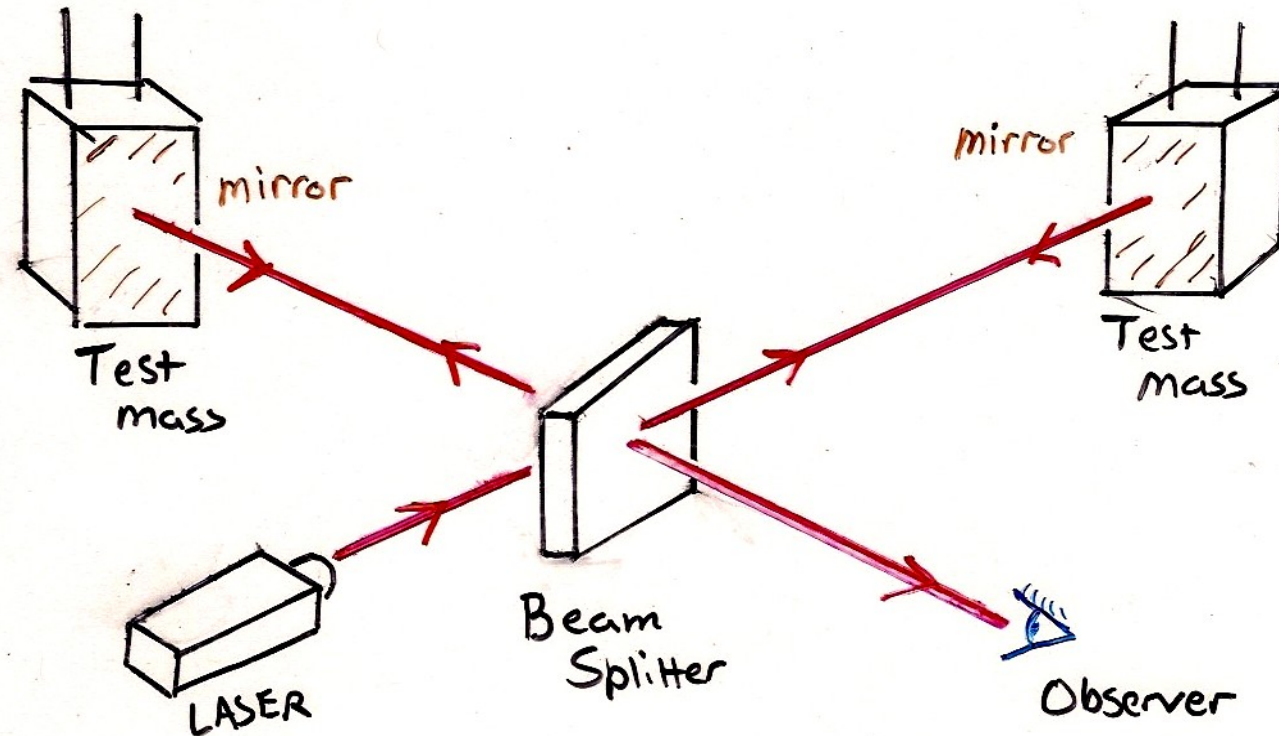
29 August 2008



Distributed Data¹ and Grid Computing²
for Inquiry-based Science Education³ and Outreach⁴

1. **Distributed Data** – real data, from LIGO, a cutting-edge physics experiment to detect gravitational waves, and (eventually) to use them for a new kind of astronomy
2. **Grid Computing** – distributed supercomputing (using VDS and Swift rather than BOINC)
3. **Inquiry-based education** – project oriented, investigative,
- 4....and outreach - informal education too

But first, a word from our sponsor....



Measuring ΔL in arms allows the measurement of the strain

$$h = \Delta L/L,$$

which is proportional to the gravitational wave amplitude $h(t)$.
(Larger L is better, and multiple reflections increase effective length.)

Laser Interferometer Gravitational wave Observatory

LIGO Livingston Observatory (LLO)

Livingston Parish, Louisiana

L1 (4km)



LIGO Hanford Observatory (LHO)

Hanford, Washington

H1 (4km) and H2 (2km)

Funded by the National Science Foundation; operated by Caltech and MIT; the research focus for ~ 500 LIGO Scientific Collaboration members worldwide.

Educational use of LIGO PEM data

- LIGO interferometers are ultra-high precision optical instruments!
- Operation requires careful monitoring of the physical environment of the instruments (including seismic activity, weather, magnetic fields...)
- PEM data (and data products derived from them, such as DMT BLRMS seismic channels) can be used by students for inquiry-based learning projects:
 - LHO/Gladstone HS SST Program (1999-2001)
 - LIGO/QuarkNet/I2U2 partnership (2005-)

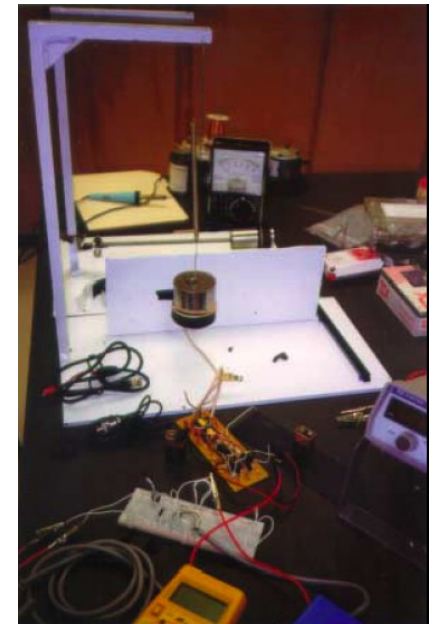
PEM = “Physics Environment Monitoring”

DMT = “Data Monitoring Tools”

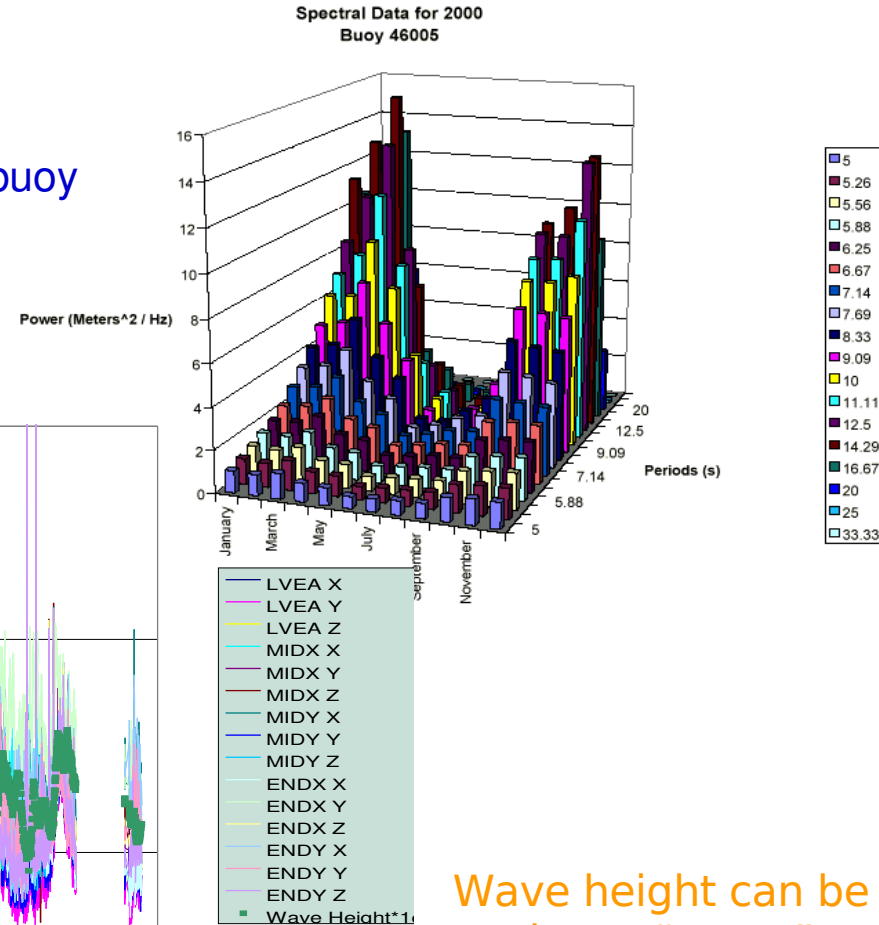
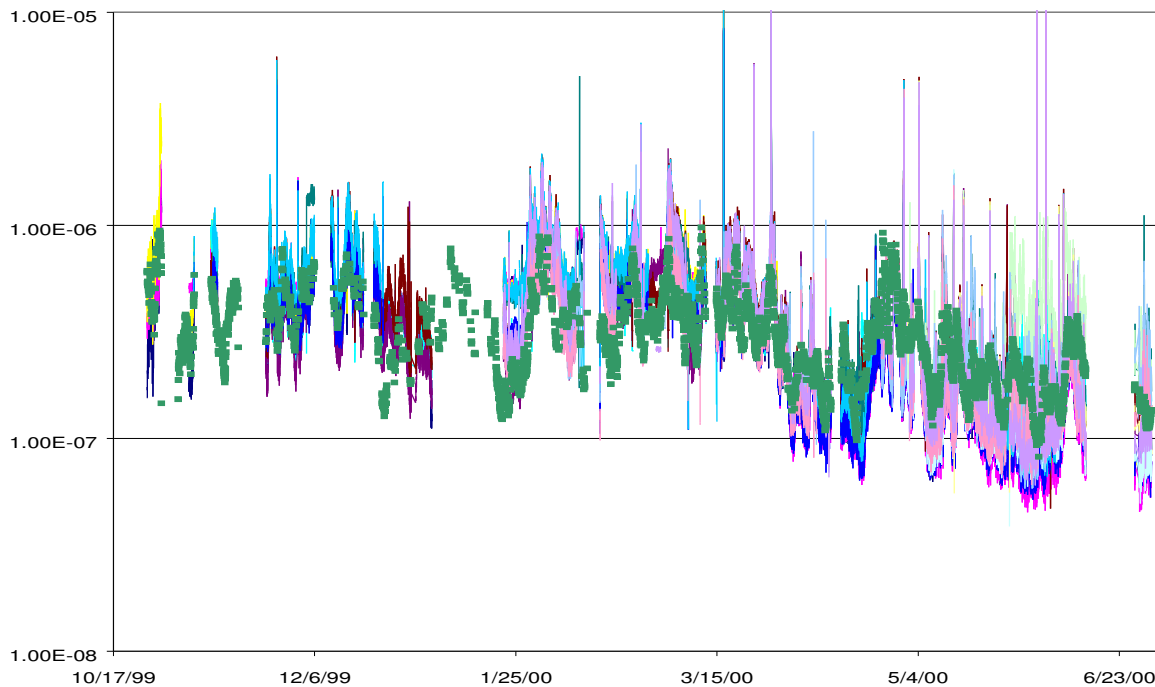
BLRMS = “Bandwidth Limited RMS”

A partnership between LIGO Hanford Observatory and Gladstone High School (near Portland, OR), supported in part by the Student, Scientist, Teacher (SST) program run by Pacific Northwest National Lab (PNNL)

- One teacher and three students spent 8 weeks at LHO in summers 1999, 2000, and 2001
- Science classes during school year involved a variety of projects aimed at understanding PEM seismic data transferred to GHS via Internet (using FTP).
- The students who had hands-on experience from the summer internship were a key resource.
- Students met with a LIGO scientist via telecon every 3 weeks, and they all visited the LHO site once during year.
- Students built “demo” instruments which gave them hands-on experience with equipment without risk of breaking something.



Seasonal trend in microseism identified in early analysis (below) agrees qualitatively with ocean-buoy wave-height data (right)



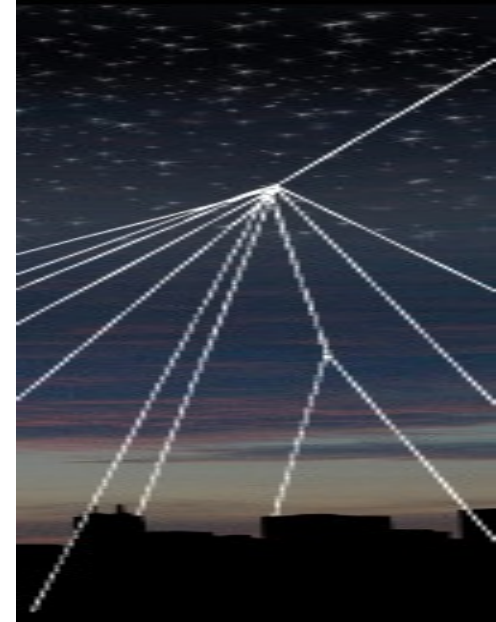
Wave height can be used as a “proxy” to predict overall long-term microseism activity at Hanford.

QuarkNet is a teacher education project, funded by NSF and DOE, and run by the *Fermilab* office of Science Education

- Provides long-term professional development for high-school physics teachers through research experience, workshops, and sustained support.
- Teachers are paired with physicist mentor from one of ~50 QuarkNet Centers at Universities and National Labs.

QuarkNet created the “*Cosmic Rays e-Lab*”:

- Distributed array of 200+ cosmic ray detectors, in classrooms
- Students manage Data Acquisition (DAQ) and upload data to a central server
- Students can use data from entire cluster in analyses, which run on The Grid (originally under VDS, now under Swift)



“Interactions In Understanding the Universe”

QuarkNet organizers sought to extend the idea, and so invited large physics experiments to join the effort:

ATLAS, CMS, LIGO, STAR, Mariachi,
with Adler Planetarium, U. Chicago

- Aimed at leveraging *Grid Computing* for educational use
- Inquiry-based education projects (called “e-Labs”) which use real data from cutting-edge physics experiments
- Title of project is *“Interactions in Understanding the Universe”* (I2U2)
- Initial pilot funding from NSF for 2005-2006, extended for 2006-2007.

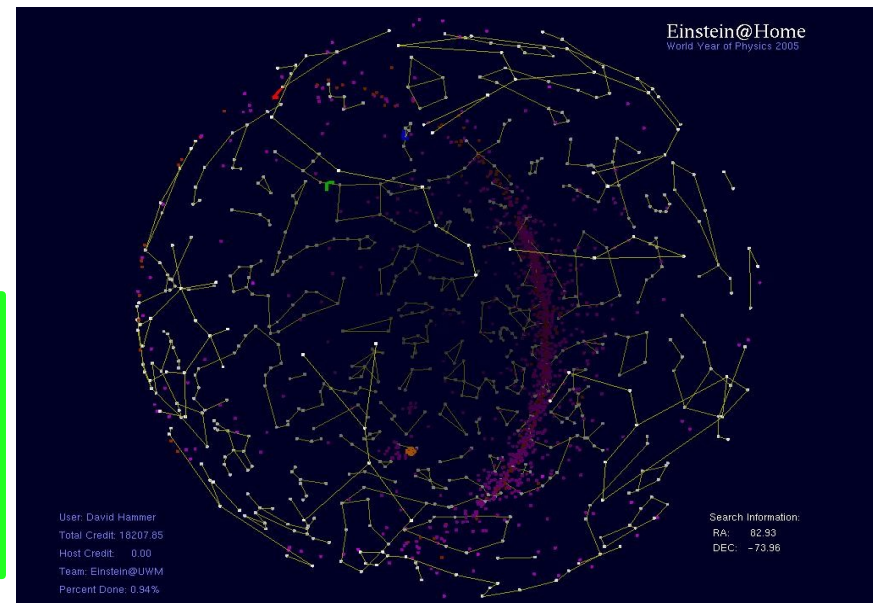
Three year grant starting 2008.

- Searching through the data streams for evidence of gravitational waves from a periodic source at an arbitrary sky position requires **an extremely large amount of computing power** - more than existing Beowulf clusters!
- *Einstein@Home* uses the Berkeley Open Infrastructure for Network Computing (BOINC) to perform the search on a “small” chunk of data on a volunteer’s PC, all while displaying a mesmerizing screensaver.

Anybody can join:

<http://einstein.phys.uwm.edu/>

Web site includes discussion “forums” for interaction between users, and with project scientists 🖱️ *“Outreach”*

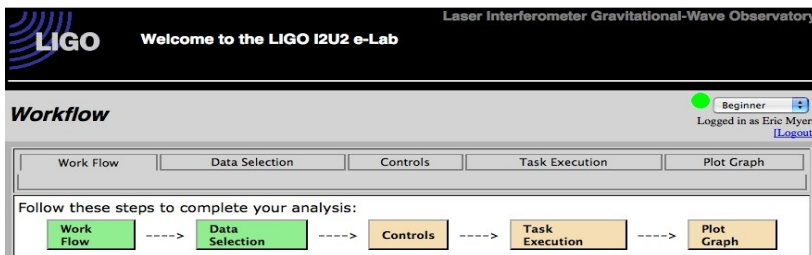
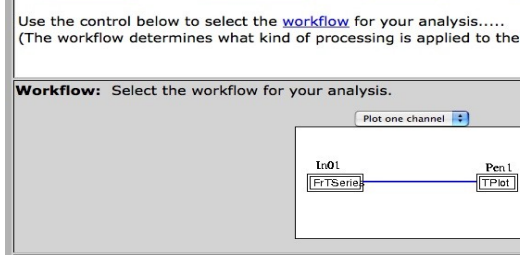
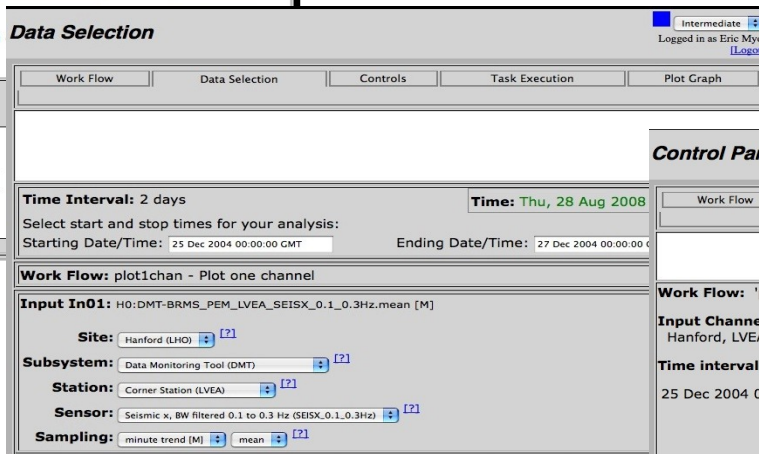
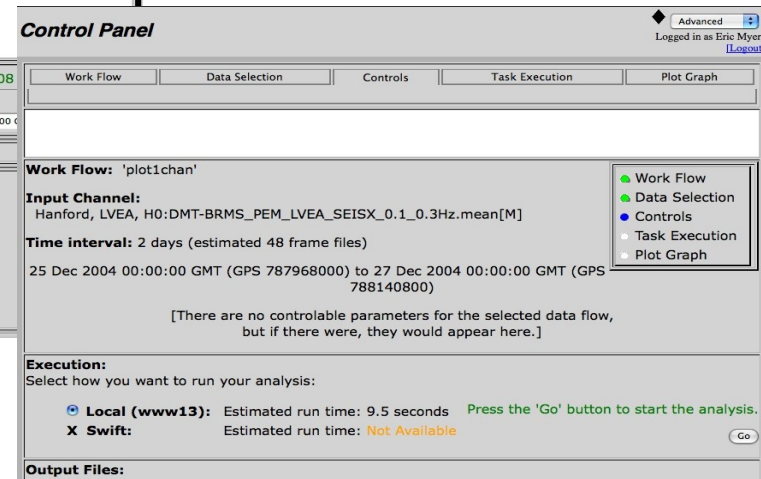


LIGO I2U2 Software Goals

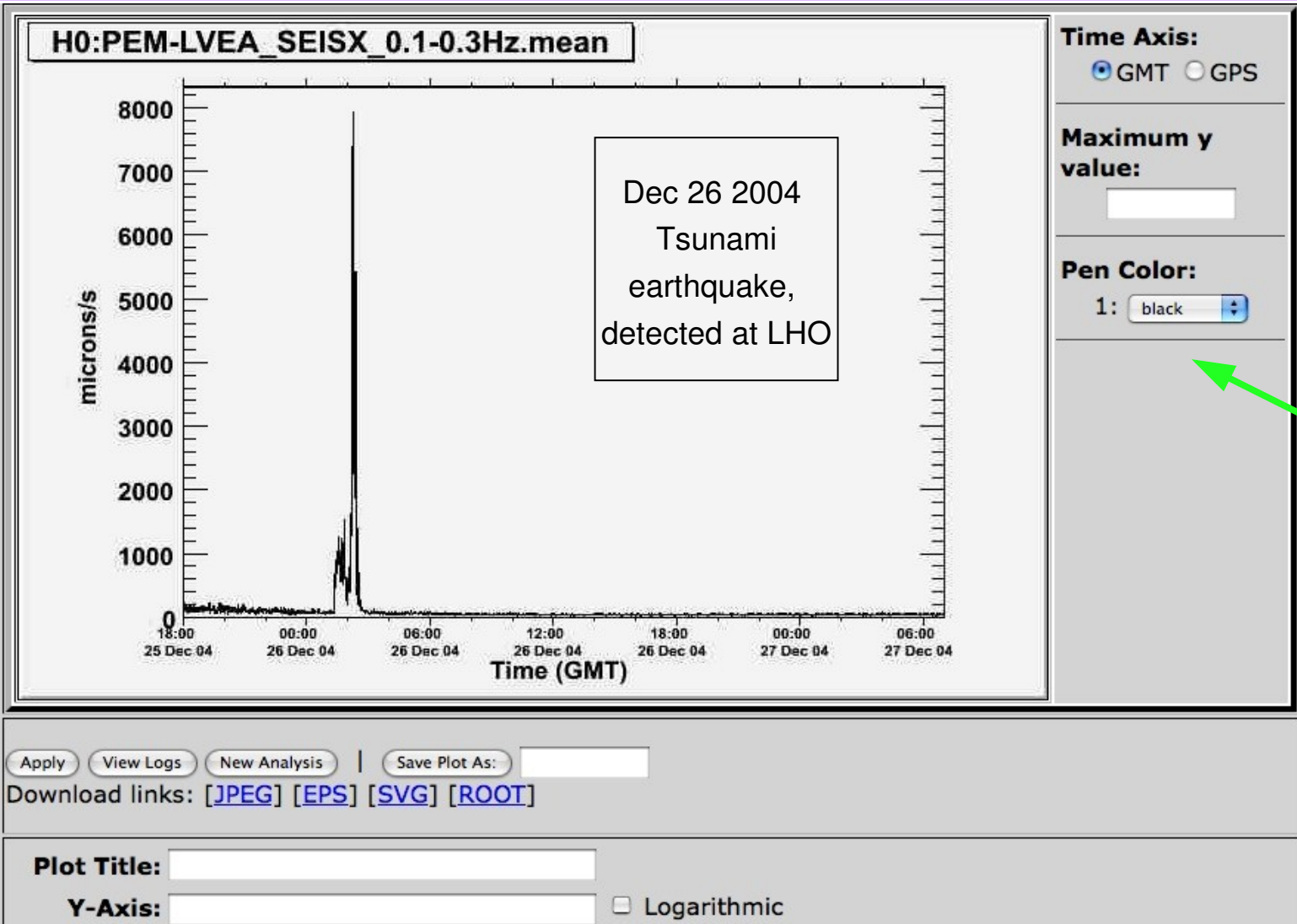
- Provide easy access to LIGO environmental data (seismometers, magnetometers, tilt-meters, and weather stations)
- Provide web-based analysis tool with functionality and feel similar to those available to scientists in the LIGO control rooms (such as DMT, DTT, DataViewer, ilog)
- Provide interface for use of “Grid” computing to analyse the data.
- Provide supporting tools for interaction and collaboration between students, teachers, e-Lab developers, and possibly LIGO scientists (vis. SST and Einstein@Home)

A web based *Analysis Tool* which has a user interface (adjustable!) similar to LIGO control room tools (DMT, DTT, & ROOT) and with the potential to provide much of the same functionality (with influences from LabView)

Try it out:
http://pirates.spy-hill.net/tla_test

Tutorial available as a PDF file



ROOT
via web
interface

Make Entry | Latest Log | Today | Previous | Next | List Past 1 3 6 Months | Calendar | Search

LIVINGSTON Detector LOG: Wednesday, Mar 16, 2005

16:02:50 Wed Mar 16 2005 (Local)

Topic: RoboMon Author: Ashfaq Khan Wed Mar 16 22:02:50 2005 UTC

RoboScifom

Figure of Merit 4

End of Day Shift

This entry automatically clogged by **ROBO SCIFOM**

<http://ilog.ligo-la.caltech> (ref.)

[- Ashfaq Khan](#)

NO_KEYWORD

17:22:16 Wed Mar 16 2005 (Local)

Topic: Commissioning Author: Brian O'Reilly Replaces the [ol](#)

A new channel L0:PEM:

During a short interruption of science mode today (for S. O'Keefe et. al. visit) connected a new PEM channel. The channel is L0:PEM-RADIO_ROOF and taken from a rooftop antenna. The idea is to monitor the 24.483 MHz radio sig which have been seen in L0:PEM-RADIO_LVEA.

The ADCUPEM processor was reconfigured and both framebuilders were re...

LIGO electronic logbook (the "ilog").
<http://ilog.ligo-wa.caltech.edu/ilog>
 (reader / readonly)

Washington LIGO Hanford ID: 269 | User ctrl: [x] | Rating: 0 | Rate: [+] / [-] [Post to thread] [Reply to THIS post]

Message 270 - Posted 3 Jan 2007 15:56:29 UTC - [delete post] - [move post]

Final Entry!

The 0.1-0.3 Hz band obviously carries a lot of earthquake information, but we saw in the group 1 plots that this band also is affected by other longer-term influences. I indulged in the luxury of running a 90-second analysis job to form the attached plot which shows the entire month of December 2006 at 0.1-0.3 Hz. At these frequencies there is more to the story seismic story than the occasional passing of earthquakes!

 1206_month_01_03.jpg

Dale Ingram
 LIGO Hanford Observatory

ID: 270 | User ctrl: [x] | Rating: 0 | Rate: [+] / [-] [Post to thread] [Reply to THIS post]

Message 287 - Posted 2 Feb 2007 18:05:11 UTC - in response to Message ID 248. - [delete post] - [move post]
 Last modified: 2 Feb 2007 18:10:51 UTC

Attached is a plot of the 0.1-0.3 Hz LVEA SEIS X channel that starts two days earlier than the previous plot. Could a single earthquake cause the activity that we see between 12/10 and 12/13? I'm inclined to say "no" because of the up-down-up pattern of the data over that time span. I think that an earthquake would produce an "up" and a "down" but not the second "up" a day later. If the seismic changes we see here are not due to an earthquake, what else could be the cause?

I agree with Mr. Ingram's inclination that this phenomenon is not earthquake related. From the fact that it rises gradually and takes about a day or so to play out in each rise/fall event, it would appear more likely to come from a weather related cause. Two candidates might be windy weather local to the observatory or perhaps a storm at sea whipping up wave action.

ID: 287 | User ctrl: [x] | Rating: 0 | Rate: [+] / [-] [Post to thread] [Reply to THIS post]

Message 288 - Posted 2 Feb 2007 18:18:12 UTC - in response to Message ID 252. - [delete post] - [move post]

Dale Ingram wrote:

Group 1, Entry 6

I2U2 Prototype site:
<http://www13.i2u2.org>
 Discussion / Logbook,
 based on BOINC forums
 + File attachments
 + Keyword classifications

RSS News subscription
for project/server status

Hello, Eric Myers! Select your e-Lab:

article annotations edit history protect delete move unwatch

LIGO e-Lab ideas

There are many interesting questions you can ask and try to answer using the data now available from LIGO. The best investigation is one you think of yourself to answer your own questions, but if you don't have any immediate ideas as to what to investigate then you might find something below which sparks your interest.

Don't feel that you have to answer the exact question listed here; Instead, think of it as a starting point for developing the question which most interests *you!*

Earthquakes

1. What happens to the tiltmeters when there is an earthquake?
2. Is there any effect on weather due to earthquakes?
3. Do the components of an earthquake at different frequencies all arrive at LIGO at the same time?
4. Do all earthquakes all have the same duration?
5. Do earthquakes look exactly alike at different stations (LVEA, EX, EY)?
6. Is there any effect on the frequency or magnitude of earthquakes due to weather?
7. Did anything interesting happen on your birthday? If so, can you reconstruct the story of what happened (as a detective reconstructs a crime from the crime scene)?
8. How long after a big earthquake does something show up at LIGO?
9. What is the smallest earthquake LIGO can detect?
10. What is the smallest earthquake which can knock the LIGO interferometers out of lock?
11. Is there any effect on the frequency or magnitude of earthquakes due to weather?
12. How does the distance to an earthquake affect the magnitude of the signal detected at Hanford?
13. How does the depth of an earthquake affect the magnitude of the signal detected at Hanford?
14. Can you use the data from LIGO to figure out the direction to an earthquake?
15. Can you use the data from LIGO to figure out the distance to an earthquake?

Seismic Activity (in general)

1. Does the weather affect the seismic activity at LIGO in ways other than just earthquakes?
2. Was anything interesting happening on your birthday?

What Else?

Anybody who has an idea for a LIGO investigation can add it to this list! You might discuss it first with your classmates and teacher. You might even find that your idea can be turned into more than a single question.

Status

DISCUSSION ROOM ASSIGNMENTS

- [The Aquarium Room](#) - General Topics
- [Cosmic Ray's Diner](#) - QuarkNet e-Lab
- [The ROOT Cellar](#) - CMS test beam e-Lab
- [The Gladstone Room](#) - LIGO e-Lab
- [The Cascade Room](#) - Adler i-Lab

News

March 6, 2007
LIGO Data now flowing
 LIGO data are now flowing again
[Click here for more information](#)

March 1, 2007 21:38 UTC
No new LIGO data
 Right now we are not getting any new data for the LIGO Analysis Tool. New data should be available after a server is upgraded at LHO.
[Click here for more information](#)

February 6, 2007 19:31 UTC
LHO Network Outage
 The primary network connection at the LIGO Hanford Observatory will be down for maintenance starting at midnight (PST) Feb 8th and lasting from 4 to 6 hours. The Analysis Tool will likely not be available during that period.
[Click here for more information](#)

January 18, 2007 23:20 UTC

PARTICIPANTS

- [Your account](#) - modify
- [Logout from your account](#)
- [School](#) - set your school

COMMUNITY

- [Meeting and Discussion](#)
- [Participant Profiles](#)
- [User Helpdesk: Questions](#)

RESOURCES

- [Glossary](#)
- [CMS e-Lab site](#)
- [LIGO e-Lab documents](#)
- Tool, LIGO Analysis (status)
 - [Production](#) [status]
 - [Testing](#) [semi-stable]
 - [Development](#)
- [LIGO Hanford Observatory](#)
- [LIGO Hanford iLogs](#)

I2U2 LINKS

- [I2U2 Home](#)
- [QuarkNet](#)
- [I2U2 Wiki](#) at U. Chicago

- [BOINC developer's notes](#)
- [BOINC wiki](#)

Project glossary, using same software that runs Wikipedia, but with single-sign-on



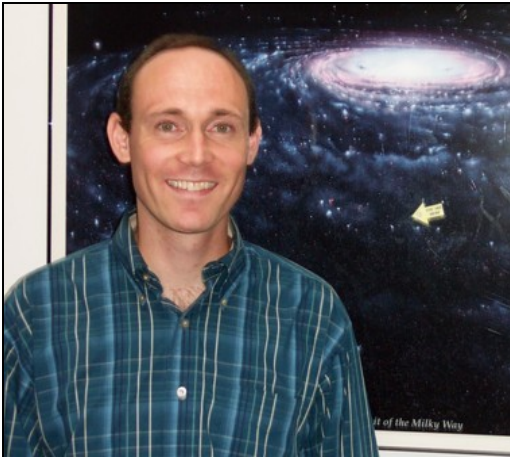
- navigation
- Discussion/Logbook
 - Glossary
 - Recent Changes
 - List of Articles
 - List of Categories
 - Random Page
 - About I2U2
 - Help

- external links
- QuarkNet
 - LIGO Hanford Observatory

search

- toolbox
- What links here
 - Related changes
 - Upload file
 - Special pages
 - Printable version
 - Permanent link

Teacher Activities





Summer 2006 intern
teacher John Kerr



Teacher workshop, August 2006

- Teacher workshops at LHO in 2006, 2007, 2008
- LIGO e-Lab in use in classrooms in Washington and Indiana

- The inquiry-based approach does not have answers in the back of the book, or rigid evaluation criteria
- Teacher is no longer in primary role as an authority
- I2U2 addresses National Science Standards (based on process), while teachers pay more attention to State standards (based on content)
- Many teachers are “*digital immigrants*” while students are “*digital natives*”
- Teachers and administrators may be afraid of Internet. (“*Wikipedia is Evil*”)
- Every school district has it's own firewall policy and whitelist (doesn't scale)
- Privacy laws may prohibit sharing of student identifying information, maybe even just names, even for scientific collaboration
- Many technical challenges in a *collaboration of collaborations...*

- Volunteer computing projects can be effective for *outreach* and *informal education*, not just computation.  **This is important!**
- BOINC projects might also play a role in formal 9-12 education.
(but you need to make it easy for teachers to do this – they are already too busy)
- Outreach and education activities can bring in more participants
 more computation!
- Maybe an overlap in our development efforts?
 - Forums: attachments, keywords, access restrictions, etc...
 - Adding a wiki: `BOINCAuthPlugin.php` for MediaWiki
 - Forums: rooms for classes or research groups (or teams)
 - Membership, ownership, roles, and permissions: generalized