



The LIGO Scientific Collaboration

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NSB Site Visit

LIGO Livingston Observatory

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Outline

- What is the LIGO Scientific Collaboration?
- The LSC in LIGO operations
- The LSC in data analysis
- The LSC's role in advanced R&D

What is the LSC?

The LSC is the group of scientists that sets the scientific program of LIGO and carries it out.

It has 501 members. They come from the LIGO Lab and from 35 other institutions (including 19 single-investigator groups.)

76 members are postdocs, 96 are grad students. More than 20 are undergrads.

Most are from the U.S., but we have GEO members from the U.K. and Germany, and from Australia, India, Japan, Russia and Spain.



LIGO-G040019-00-7



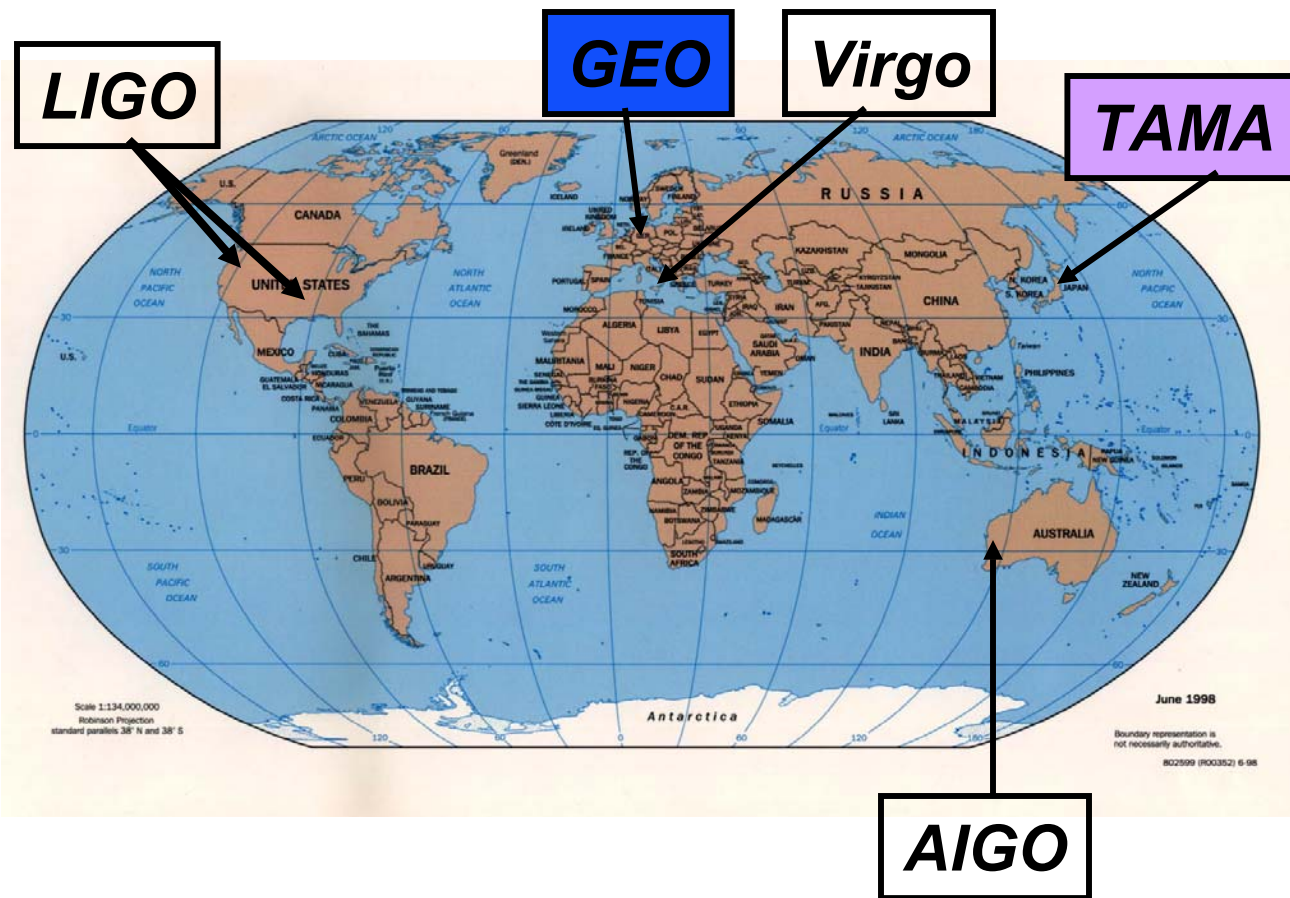
LIGO Anchors an International Network of Interferometers

Rare events require *coincident* detections.

LIGO's three interferometers were designed to emphasize obtaining good coincidences.

This makes LIGO the anchor of the worldwide network of interferometers

GEO and LIGO have a special link: all GEO members are also members of the LSC. Joint data analysis is routine.

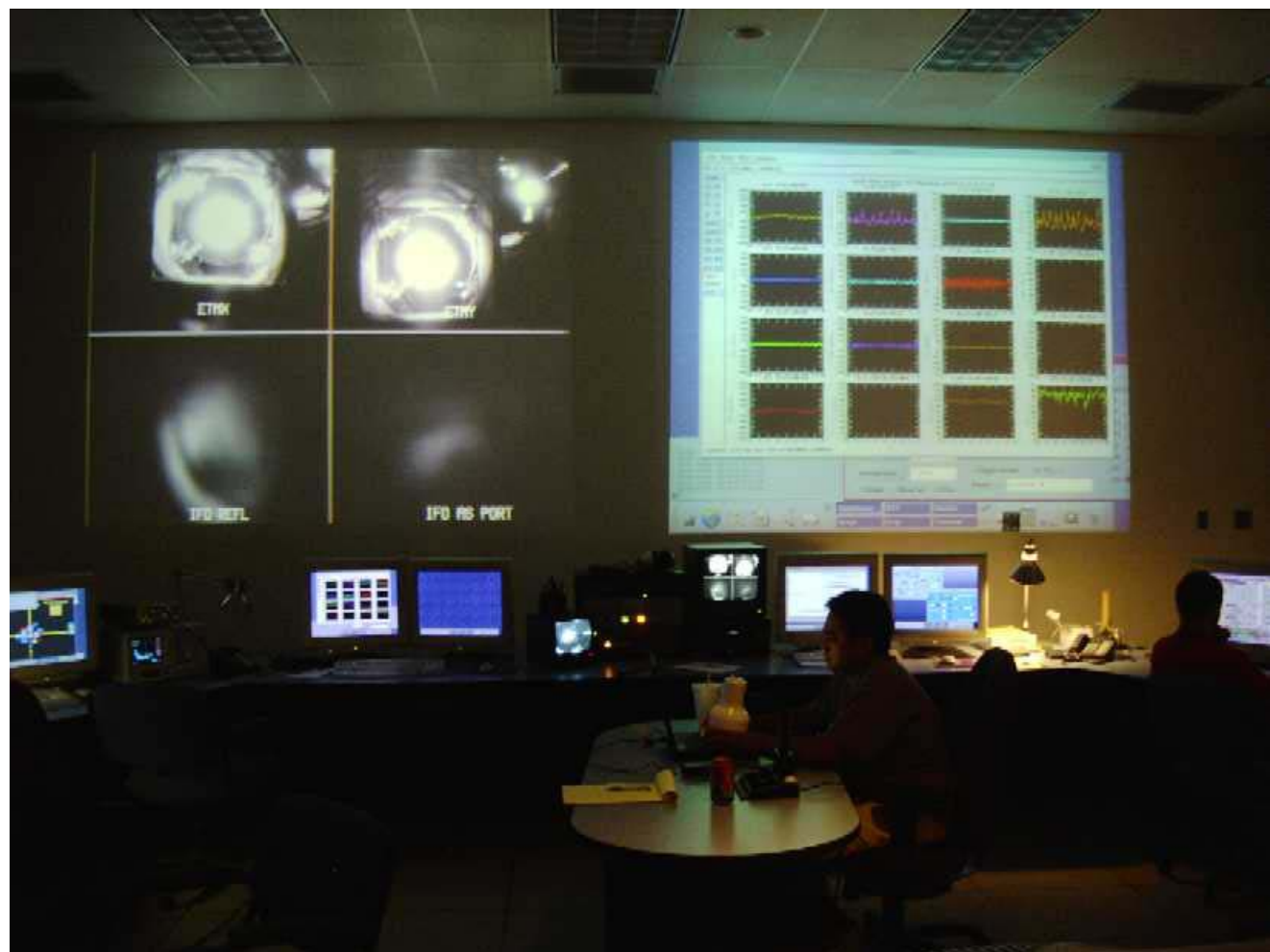


Organization of the LIGO Scientific Collaboration

- **Governance:**
 - » LSC Council, representative of all member groups, meets twice/yr.
 - » Executive Committee meets monthly by telecon
 - » Spokesperson
 - Rai Weiss (MIT), 1997 – 2003
 - Peter Saulson (Syracuse), 2003 – 2005
- **Technical Working Groups:**
 - » Carry out advanced R&D aimed at improving performance of subsystems or entire interferometer system.
 - » 2 of 6 chairs are from GEO.
- **Data Analysis Groups:**
 - » One for each of four major signal classes
 - » Two co-chairs, one experimentalist and one theorist

The LSC in LIGO Operations

Scientists examine interferometer performance during a data run.

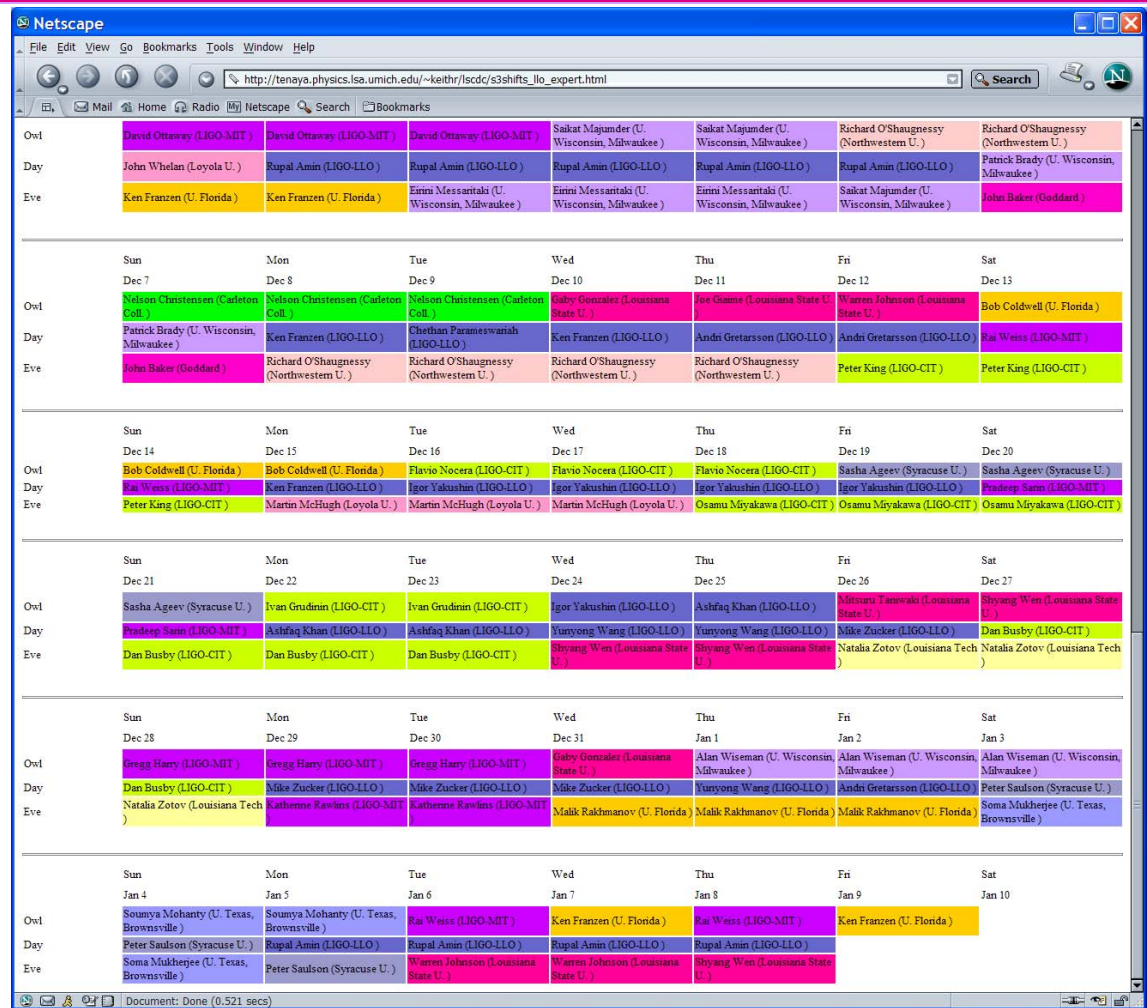


Scientific Monitoring Shifts

Part of the SciMon shift schedule during the S3 run, that just ended 9 Jan 2004.

Participation in shifts is a responsibility of all groups with authors on LIGO observational results papers.

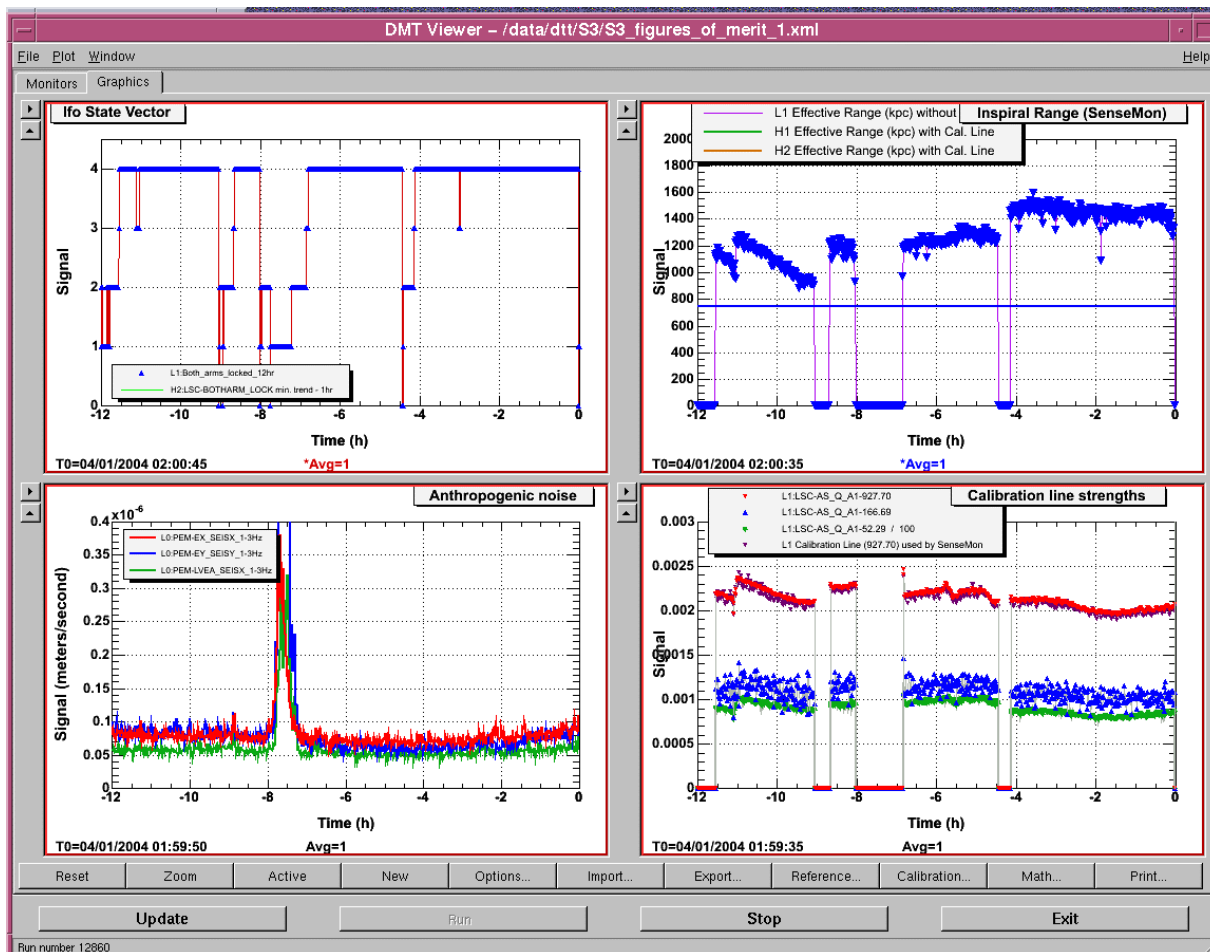
GEO members take shifts at GEO600, but we have LIGO SciMons from Australia and India.



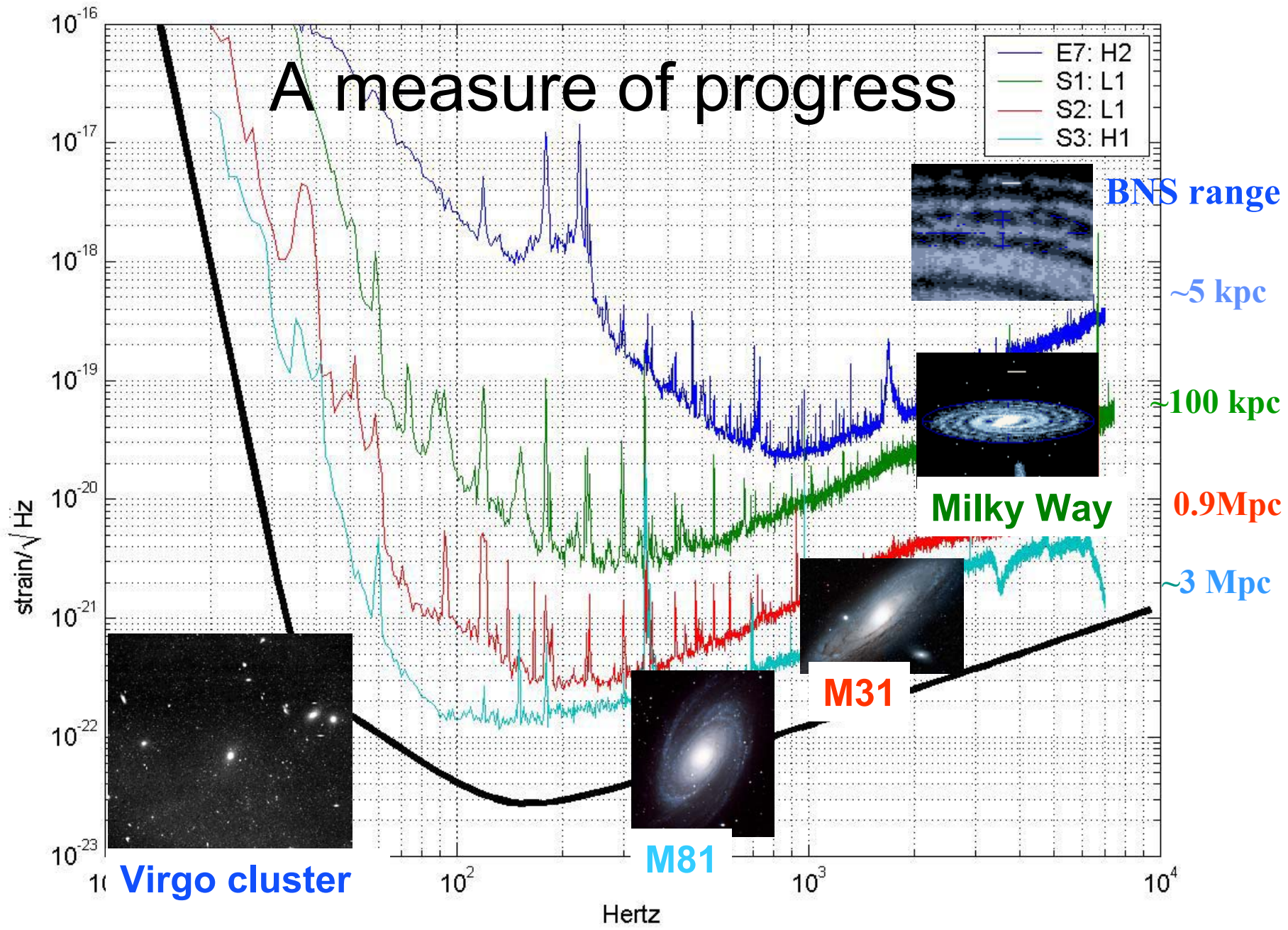
	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Owl	David Ottaway (LIGO-MIT)	David Ottaway (LIGO-MIT)	David Ottaway (LIGO-MIT)	Saikat Majumder (U. Wisconsin, Milwaukee)	Saikat Majumder (U. Wisconsin, Milwaukee)	Richard O'Shaughnessy (Northwestern U.)	Richard O'Shaughnessy (Northwestern U.)
Day	John Whelan (Loyola U.)	Rupal Anm (LIGO-LLO)	Rupal Anm (LIGO-LLO)	Rupal Anm (LIGO-LLO)	Rupal Anm (LIGO-LLO)	Rupal Anm (LIGO-LLO)	Patrick Brady (U. Wisconsin, Milwaukee)
Eve	Ken Franzen (U. Florida)	Ken Franzen (U. Florida)	Einni Messantaki (U. Wisconsin, Milwaukee)	Einni Messantaki (U. Wisconsin, Milwaukee)	Einni Messantaki (U. Wisconsin, Milwaukee)	Saikat Majumder (U. Wisconsin, Milwaukee)	John Baker (Goddard)
	Sun Dec 7	Mon Dec 8	Tue Dec 9	Wed Dec 10	Thu Dec 11	Fri Dec 12	Sat Dec 13
Owl	Nelson Christensen (Carleton Coll.)	Nelson Christensen (Carleton Coll.)	Nelson Christensen (Carleton Coll.)	Baby Gonzalez (Louisiana State U.)	Joe Glame (Louisiana State U.)	Warren Johnson (Louisiana State U.)	Bob Coldwell (U. Florida)
Day	Patrick Brady (U. Wisconsin, Milwaukee)	Ken Franzen (LIGO-LLO)	Chethan Parameswath (LIGO-LLO)	Ken Franzen (LIGO-LLO)	Andri Gretarsson (LIGO-LLO)	Andri Gretarsson (LIGO-LLO)	Rai Wess (LIGO-MIT)
Eve	John Baker (Goddard)	Richard O'Shaughnessy (Northwestern U.)	Richard O'Shaughnessy (Northwestern U.)	Richard O'Shaughnessy (Northwestern U.)	Richard O'Shaughnessy (Northwestern U.)	Peter King (LIGO-CIT)	Peter King (LIGO-CIT)
	Sun Dec 14	Mon Dec 15	Tue Dec 16	Wed Dec 17	Thu Dec 18	Fri Dec 19	Sat Dec 20
Owl	Bob Coldwell (U. Florida)	Bob Coldwell (U. Florida)	Flavio Nocera (LIGO-CIT)	Flavio Nocera (LIGO-CIT)	Flavio Nocera (LIGO-CIT)	Sasha Ageev (Syracuse U.)	Sasha Ageev (Syracuse U.)
Day	Rai Wess (LIGO-MIT)	Ken Franzen (LIGO-LLO)	Igor Yakushin (LIGO-LLO)	Igor Yakushin (LIGO-LLO)	Igor Yakushin (LIGO-LLO)	Igor Yakushin (LIGO-LLO)	Pradise Sami (LIGO-MIT)
Eve	Peter King (LIGO-CIT)	Martin McHugh (Loyola U.)	Martin McHugh (Loyola U.)	Martin McHugh (Loyola U.)	Osamu Miyakawa (LIGO-CIT)	Osamu Miyakawa (LIGO-CIT)	Osamu Miyakawa (LIGO-CIT)
	Sun Dec 21	Mon Dec 22	Tue Dec 23	Wed Dec 24	Thu Dec 25	Fri Dec 26	Sat Dec 27
Owl	Sasha Ageev (Syracuse U.)	Ivan Grudinin (LIGO-CIT)	Ivan Grudinin (LIGO-CIT)	Igor Yakushin (LIGO-LLO)	Ashfaq Khan (LIGO-LLO)	Miharu Tanigaki (Louisiana State U.)	Shiyang Wen (Louisiana State U.)
Day	Pradise Sami (LIGO-MIT)	Ashfaq Khan (LIGO-LLO)	Ashfaq Khan (LIGO-LLO)	Yuryong Wang (LIGO-LLO)	Yuryong Wang (LIGO-LLO)	Mike Zucker (LIGO-LLO)	Dan Busby (LIGO-CIT)
Eve	Dan Busby (LIGO-CIT)	Dan Busby (LIGO-CIT)	Dan Busby (LIGO-CIT)	Shiyang Wen (Louisiana State U.)	Shiyang Wen (Louisiana State U.)	Natalia Zotov (Louisiana Tech)	Natalia Zotov (Louisiana Tech)
	Sun Dec 28	Mon Dec 29	Tue Dec 30	Wed Dec 31	Thu Jan 1	Fri Jan 2	Sat Jan 3
Owl	Gregg Harry (LIGO-MIT)	Gregg Harry (LIGO-MIT)	Gregg Harry (LIGO-MIT)	Baby Gonzalez (Louisiana State U.)	Alan Wiseman (U. Wisconsin, Milwaukee)	Alan Wiseman (U. Wisconsin, Milwaukee)	Alan Wiseman (U. Wisconsin, Milwaukee)
Day	Dan Busby (LIGO-CIT)	Mike Zucker (LIGO-LLO)	Mike Zucker (LIGO-LLO)	Mike Zucker (LIGO-LLO)	Yuryong Wang (LIGO-LLO)	Andri Gretarsson (LIGO-LLO)	Peter Saulson (Syracuse U.)
Eve	Natalia Zotov (Louisiana Tech)	Katherine Rawlins (LIGO-MIT)	Katherine Rawlins (LIGO-MIT)	Malik Rakhmanov (U. Florida)	Malik Rakhmanov (U. Florida)	Malik Rakhmanov (U. Florida)	Soma Mukherjee (U. Texas, Brownsville)
	Sun Jan 4	Mon Jan 5	Tue Jan 6	Wed Jan 7	Thu Jan 8	Fri Jan 9	Sat Jan 10
Owl	Soumya Mohanty (U. Texas, Brownsville)	Soumya Mohanty (U. Texas, Brownsville)	Rai Wess (LIGO-MIT)	Ken Franzen (U. Florida)	Rai Wess (LIGO-MIT)	Ken Franzen (U. Florida)	
Day	Peter Saulson (Syracuse U.)	Rupal Anm (LIGO-LLO)	Rupal Anm (LIGO-LLO)	Rupal Anm (LIGO-LLO)	Rupal Anm (LIGO-LLO)	Rupal Anm (LIGO-LLO)	
Eve	Soma Mukherjee (U. Texas, Brownsville)	Peter Saulson (Syracuse U.)	Warren Johnson (Louisiana State U.)	Warren Johnson (Louisiana State U.)	Shiyang Wen (Louisiana State U.)		

On-line Figures of Merit

Figure of Merit displays, shown on the walls of the Control Rooms, were developed by LSC members participating in the Detector Characterization Working Group.



A measure of progress



The LSC in Data Analysis

Leadership of data analysis is distributed across the LSC. (GEO members in red.)

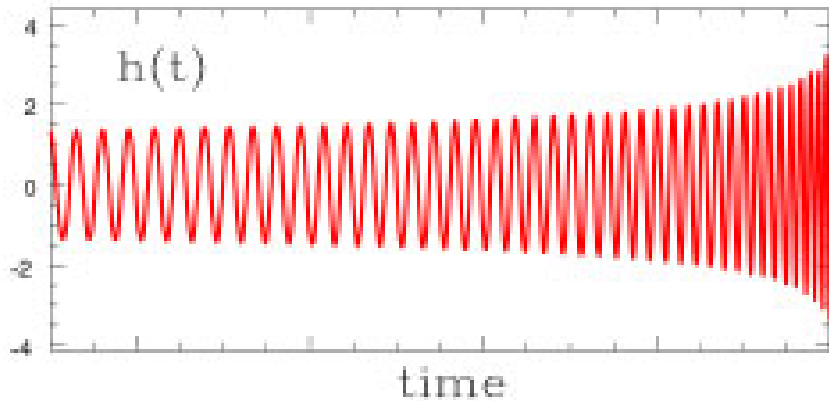
- » Inspiral Group: Gonzalez (LSU) and Brady (UWM)
- » Burst Group: Whitcomb (LIGO-Caltech) and Katsavounidis (LIGO-MIT)
- » Stochastic Group: Fritschel (LIGO-MIT) and Romano (Cardiff)
- » Pulsar Group: Landry (LIGO-Hanford) and Papa (AEI)

Four papers from S1 Science Run are submitted to PRD (two already accepted.)

S1 paved the way on methodology. Subsequent runs will push down our upper limits, or better yet, might detect signals.

Six Ph.D. theses expected from the S2 run.

Results from S1: Upper Limits on Neutron Star Binary Inspirals



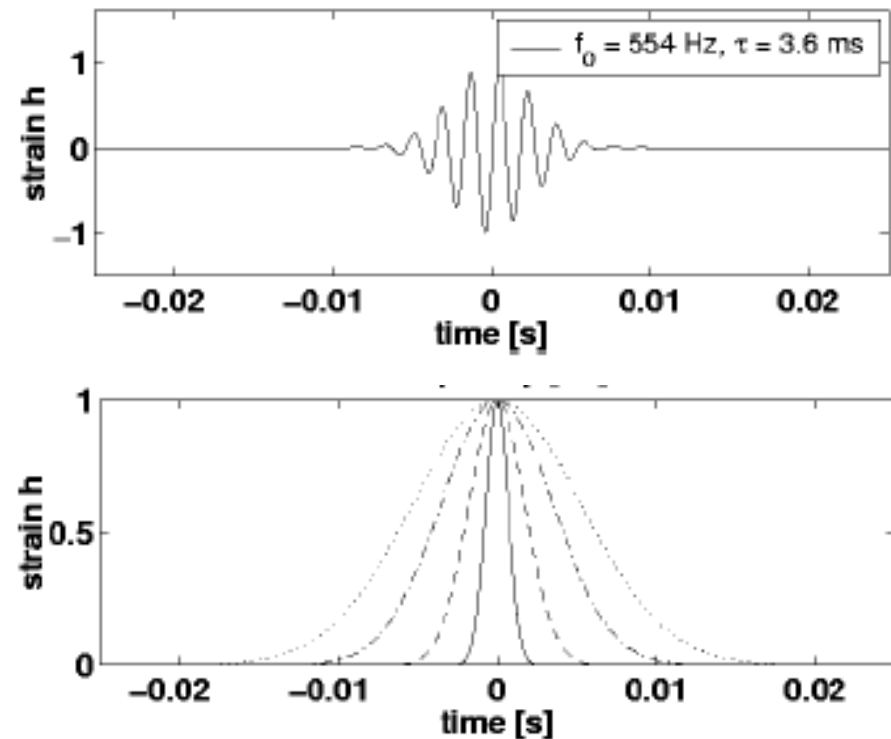
We carried out a *matched-filter* search for chirp waveforms associated with neutron star binaries between 1 and 3 solar masses.

S1 upper limit: fewer than 170/yr per Milky Way

Subsequent runs have pushed far beyond our galaxy. Stronger limits coming soon.



Results from S1: Upper Limits on Burst Signals

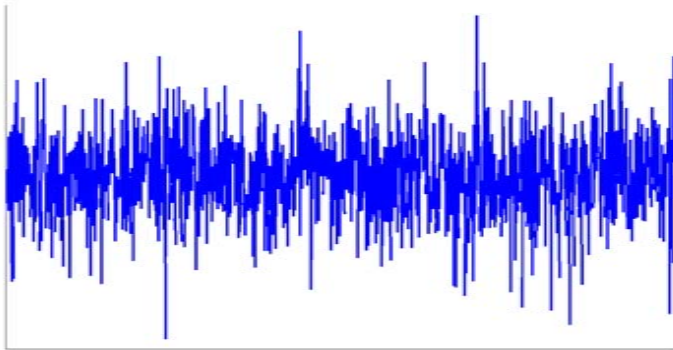


We performed a *robust* search for *coincident* transient waveforms of any shape, with durations between 4 and 100 ms and frequencies between 150 and 3000 Hz.

S1 upper limit: fewer than 1.6/day with strains large enough to see.
(root sum square strain $> 10^{-18} / \sqrt{\text{Hz}}$.)

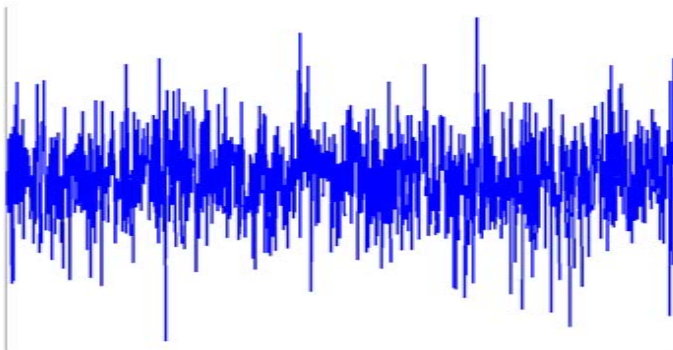
S2 analysis also being carried out in collaboration with TAMA (Japan.)
Future runs will use a global network including not only GEO but also Virgo, and perhaps some bars.

Results from S1: Upper Limits on a Stochastic Background



We searched for correlated noise in the three LIGO interferometers.

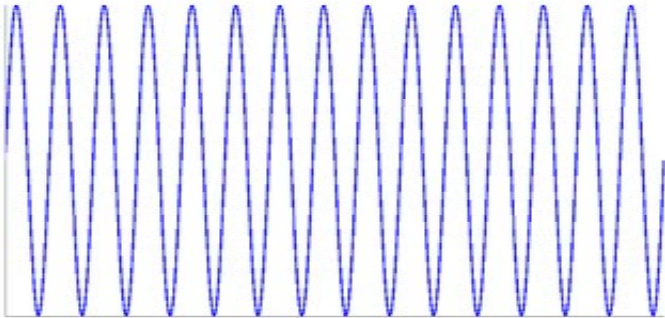
(Internal noises wouldn't be correlated. All external noises should be shielded or incoherent, except a gravitational background.)



S1 upper limit is the best yet made by direct observation.

(This limit improves rapidly as noise drops. For S2, should be ~1000 times better.)

Preliminary S2 result from Pulsar Search



We examined LIGO/GEO data for nearly pure sinusoids, but with the amplitude- and phase-modulation that would come from the earth's rotation and motion.

During S2, we set upper limits on the radiation from 28 known pulsars.

For the Crab pulsar, the limit is within a factor of ~ 35 of what is allowed by other measurements. This gap should be bridged in the data from the S3 run.

This search has an especially strong contribution from GEO.

LSC R&D toward Advanced LIGO

- Beyond the LIGO Lab, 19 other LSC groups carry out R&D aimed at the proposed Advanced LIGO.
- The concept and basic design of Advanced LIGO came out of the first few years of LSC work.
- This work has a strong international flavor. GEO contributions are key, but also very important contributions from ACIGA (Australia), as well as NOAJ-TAMA (Japan) and IAP-Nizhny Novgorod (Russia.)
- A few highlights follow.

External Pre-isolator

Since before the LSC was formed, there was work on active seismic isolation for low frequencies.

Groups at Colorado, LSU, and Stanford led this effort.

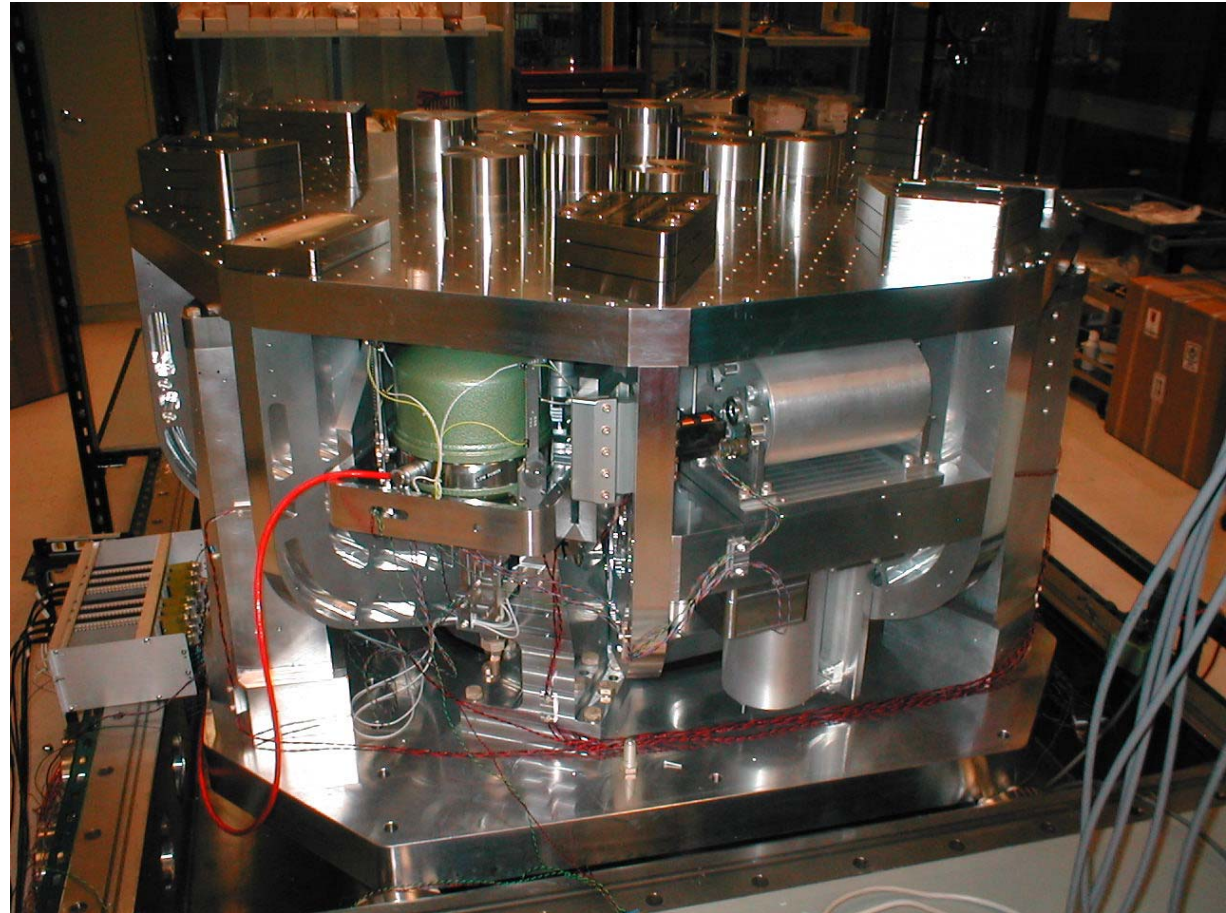
Blue structures at right show parts prepared for installation at LLO this month, to deal with excess noise in the 1 – 3 Hz band.



Two-stage active isolation platform

Low frequency noise will need to be attenuated further.

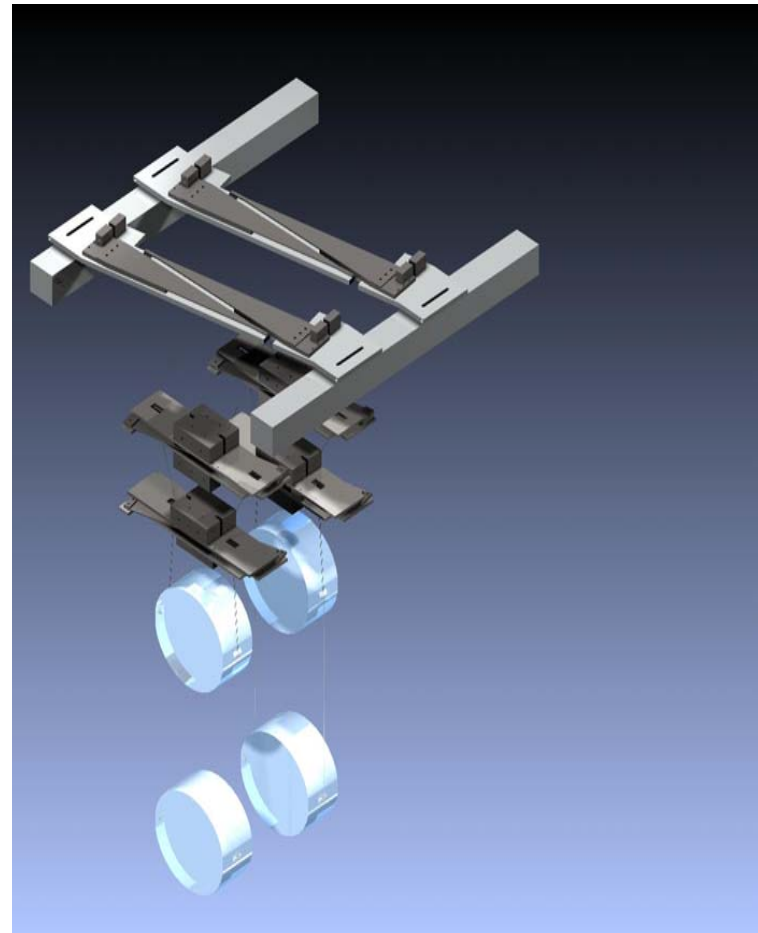
This structure at Stanford shows a prototype of in-vacuum low noise active seismic isolation.



Advanced Suspensions

Better sensitivity will require substantially greater attenuation of seismic noise, and also much lower thermal noise (Brownian motion of mirrors.)

This schematic shows the test mass suspension design developed by GEO (Glasgow).



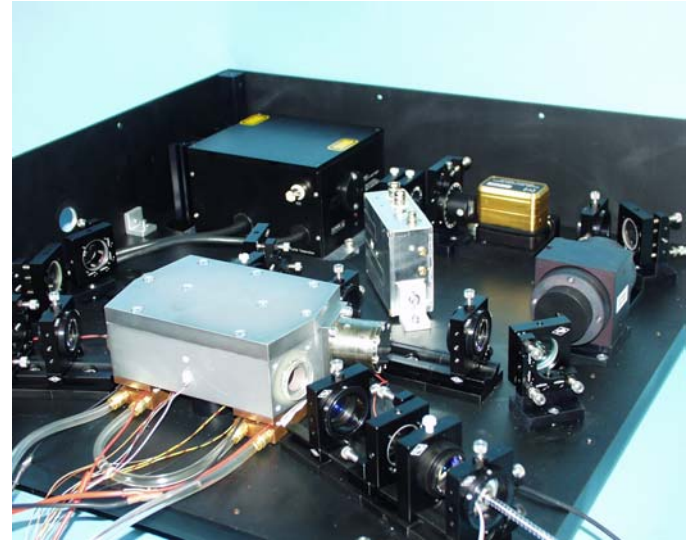
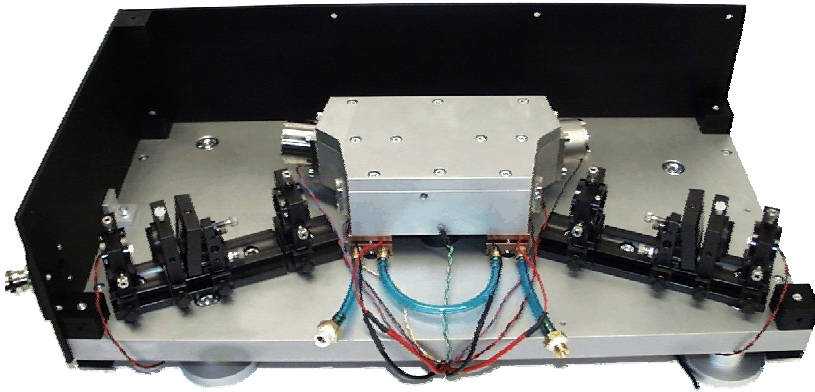
Prototype advanced suspension

An engineering prototype of one of the GEO suspensions, similar to the schematic on previous slide.

Designed in Glasgow, it is being tested at LIGO's full-scale test facility at MIT.



Laser Zentrum Hannover leads development of high power lasers



To reduce shot noise, one needs more powerful lasers. These solid-state lasers, developed for GEO and Virgo, are the foundation for new work that already has demonstrated ~ 100 W output.

A thriving scientific collaboration

- The LSC is an open collaboration with a strong international character and a large population of students.
- Our first round of papers are all with the journals. A new round of papers from the S2 and S3 runs is being prepared now.
- Advanced R&D has found practical ways to push sensitivity by an order of magnitude beyond the present LIGO design, as embodied in the Advanced LIGO proposal.
- LSC research is full of the excitement of a growing discovery field of science.