LIGO and its Scientific Collaboration

Gabriela González,
Louisiana State University
LIGO Scientific Collaboration spokesperson

LIGO-G1401182

LIGO Scientific Collaboration

900+ members, 80+ institutions, 16 countries

LSC-USA

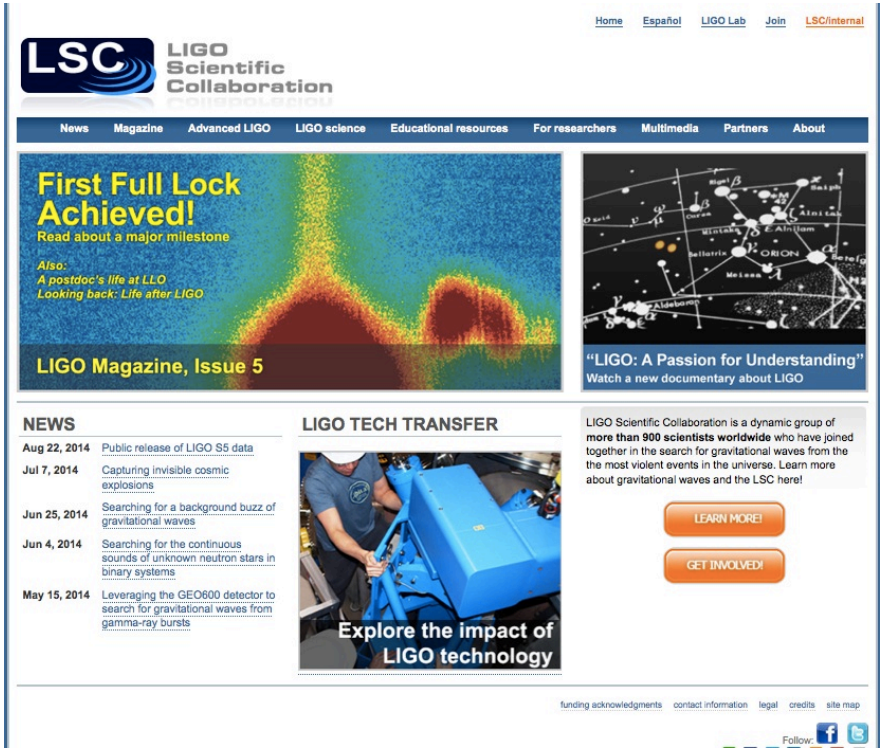
- Of LSC 900+ members, 500+ are in the USA.
- Large institutional diversity: large and small departments, graduate and undergraduate institutions, several serving large under-represented groups.
- Most US groups are supported by NSF by competitive, single investigator NSF grants. LIGO Laboratory (~25% of LSC) is supported by MRFC NSF grant to Caltech and MIT.
- Many LSC “graduates” now working in STEM industry (Intel, Synaptics, Google, SpaceX, Apple, Facebook,…), national facilities (Lincoln Labs, NASA, …) and academia.

LIGO and LSC

- **The LSC and the LIGO Laboratory together make up "LIGO".**

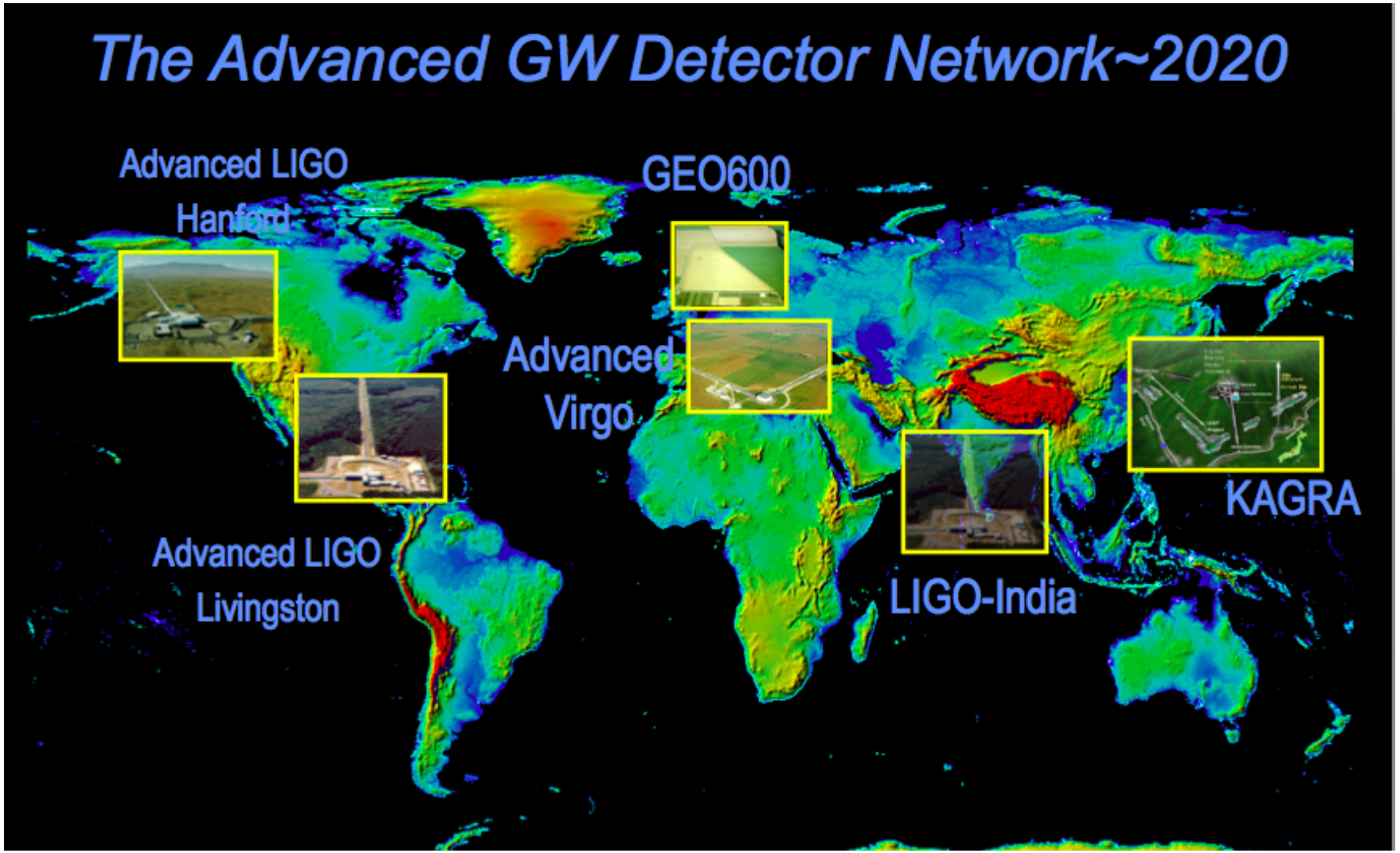
- LSC Mission: The LIGO Scientific Collaboration (LSC) is a **self-governing collaboration** seeking to detect gravitational waves, use them to explore the fundamental physics of gravity, and develop gravitational wave observations as a tool of astronomical discovery.

- LSC Responsibilities:
  - data analysis strategy, goals, and timeline, and carry out the data analysis program;
  - identify priorities for research and development, and carry out the R&D program;
  - carry out a public outreach, and provide educational opportunities for young people;
  - disseminate the results of the data analysis program and the R&D program;
  - participate in the scientific operations of the LIGO detectors;
  - perform internal evaluation of progress in data analysis and R&D.

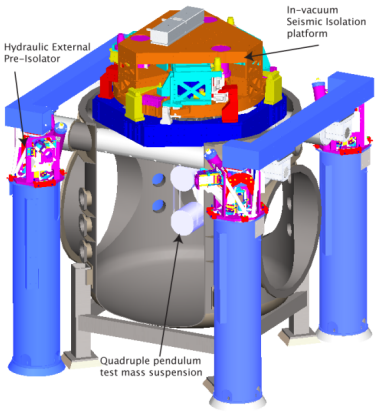


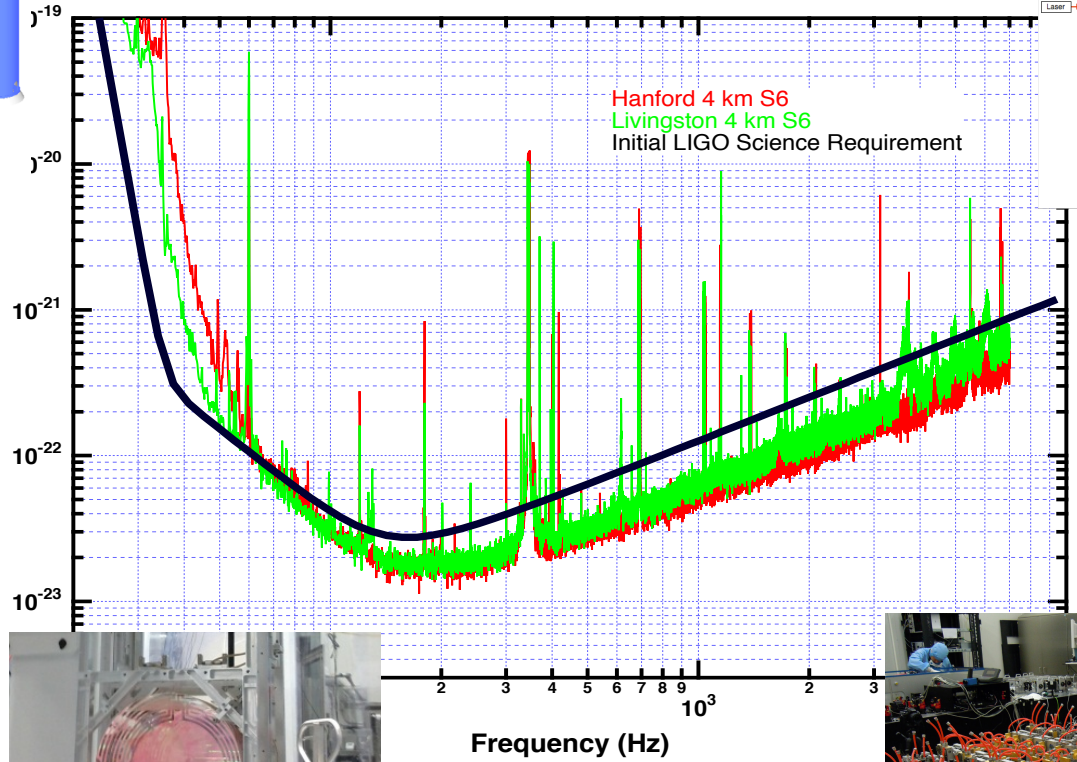
www.ligo.org

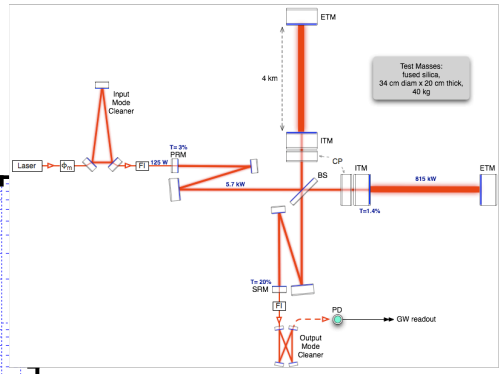
LIGO leads but it's not alone: gravitational wave network

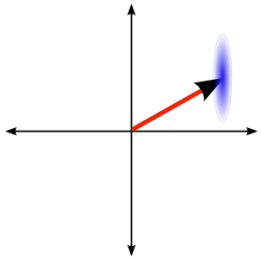


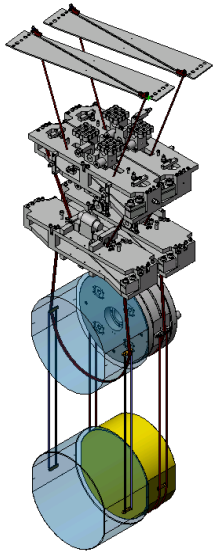
LIGO Detectors Technology

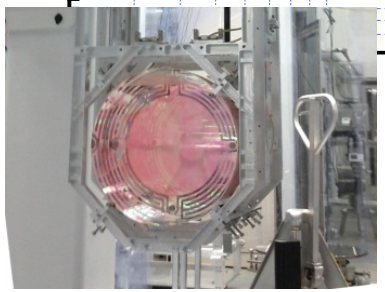


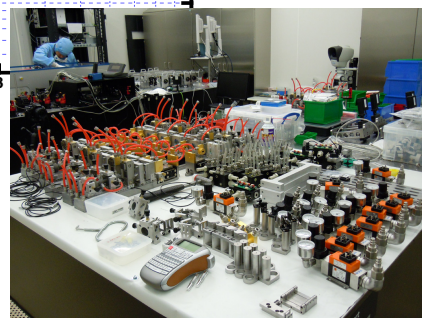






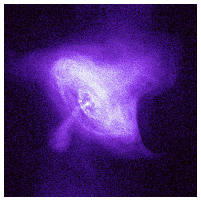




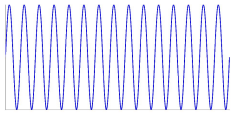


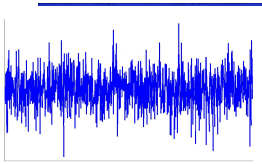
Five instrumental working groups – white paper LIGO-T1400316 (dcc.ligo.org).

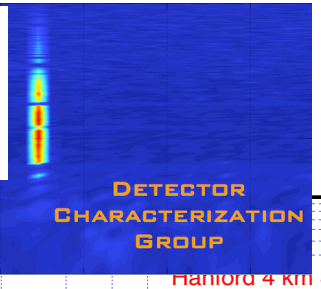
LIGO Data Analysis

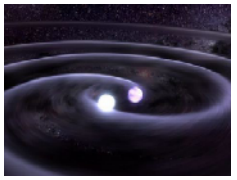


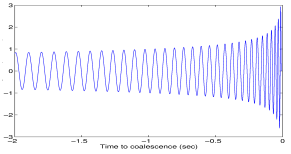
Crab pulsar (NASA, Chandra Observatory)

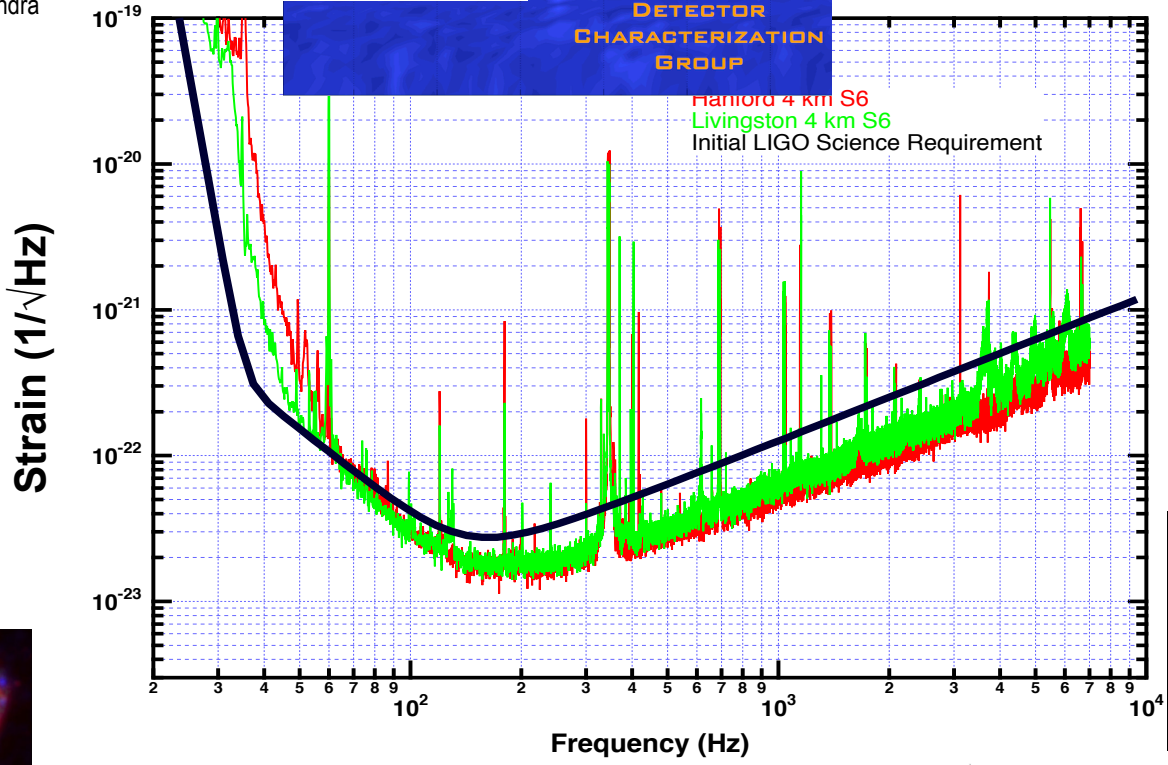


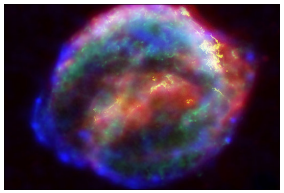


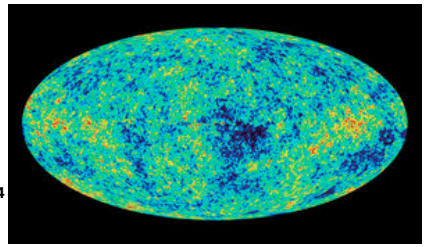




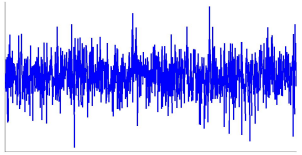


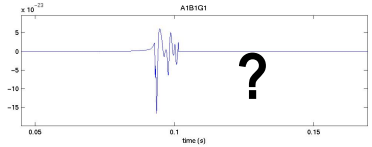






NASA, WMAP

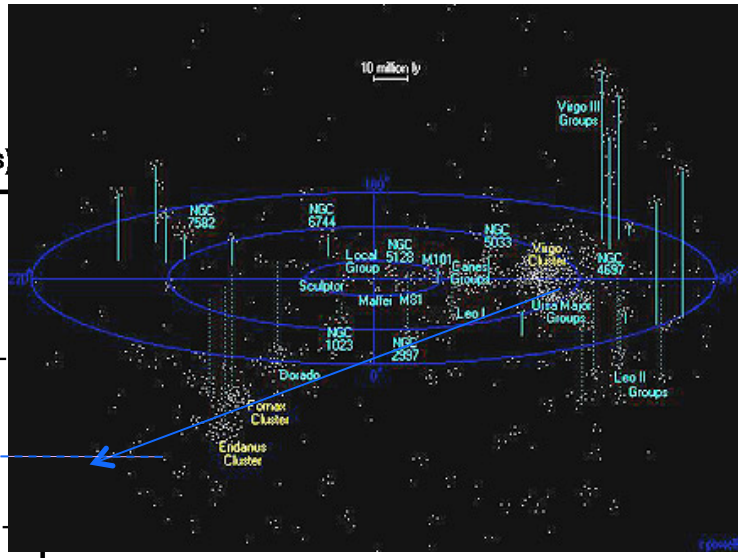


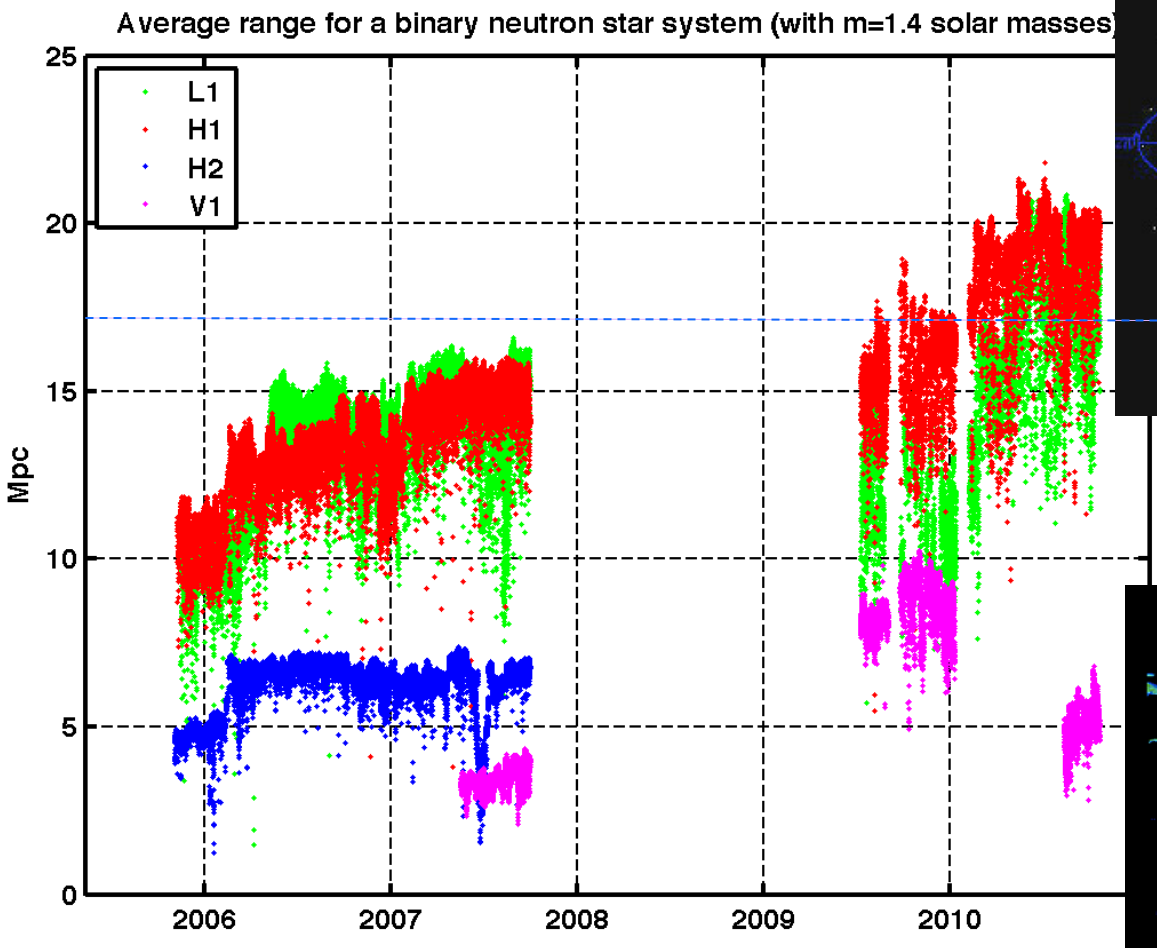


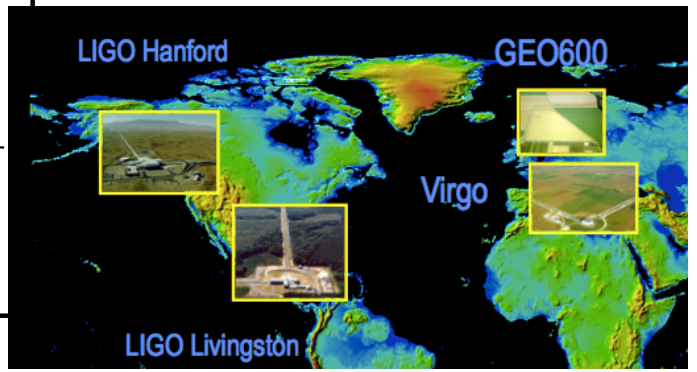
Four analysis working groups (plus detector characterization, software and computing) white paper LIGO-T1400054 (dcc.ligo.org).

LIGO-Virgo detectors 2005-2010

atlasofthe universe.com

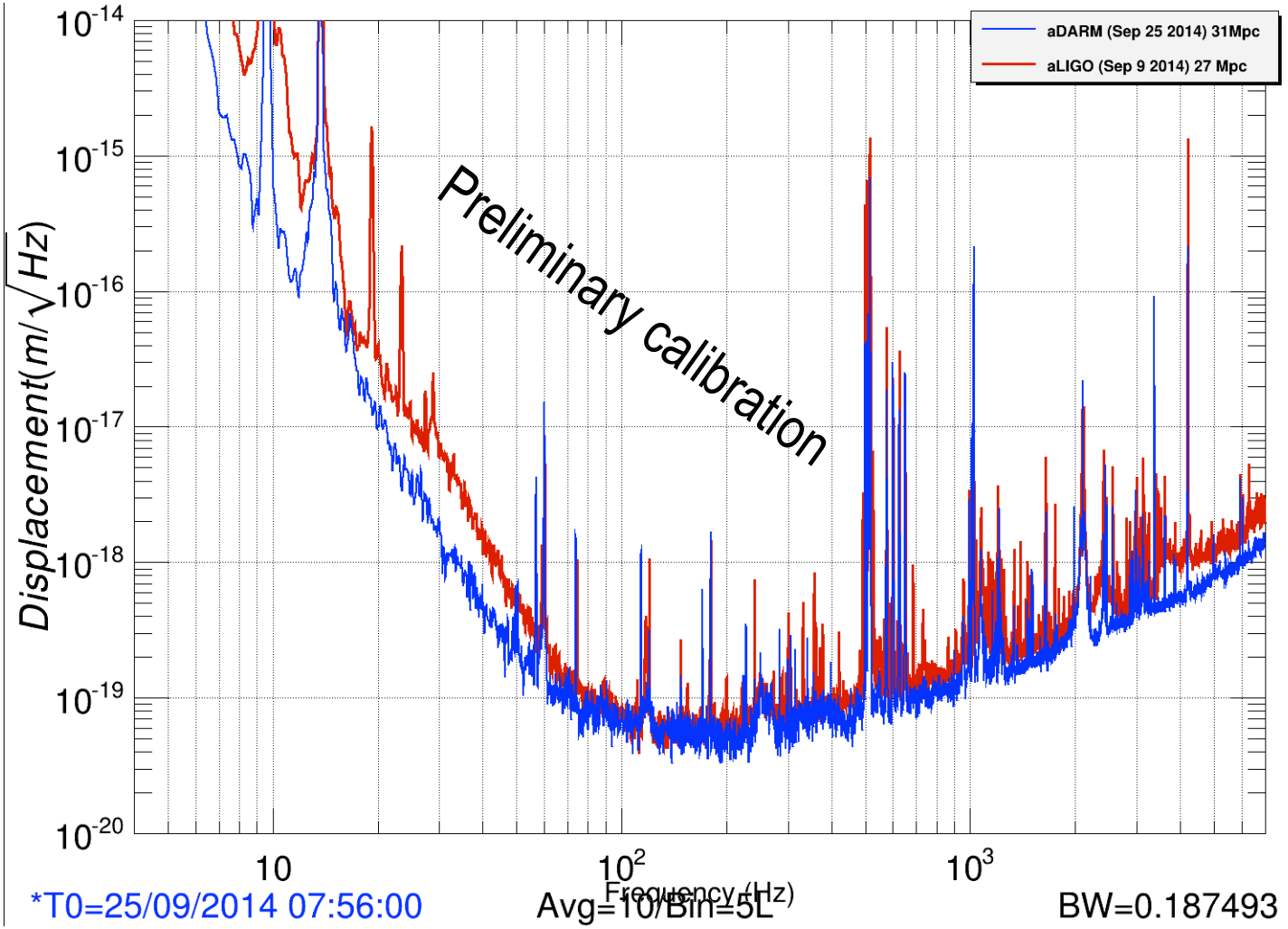






Advanced LIGO current status

Is already better than S6! L1 detector, Sept 25: 30+ Mpc!



Academic interest in LIGO

WEB OF SCIENCE™ THOMSON REUTERS

Back to Search | My Tools | Search History | Marked List

Citation Report: 1398

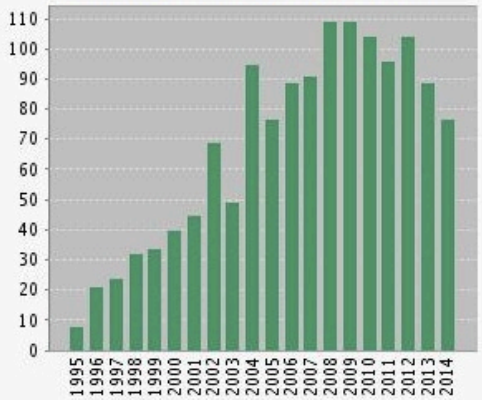
(from Web of Science Core Collection)

You searched for: **TOPIC:** (LIGO) **...More**

1000+ papers, increasing citations/year

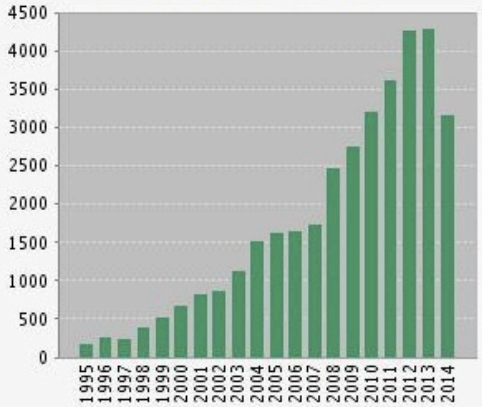
This report reflects citations to source items indexed within Web of Science Core Collection. Perform a Cited Reference Search to include citations to items not indexed within Web of Science Core Collection.

Published Items in Each Year



The latest 20 years are displayed.
View a graph with all years.

Citations in Each Year



The latest 20 years are displayed.
View a graph with all years.

Results found:	1398
Sum of the Times Cited [?] :	35890
Sum of Times Cited without self-citations [?] :	24850
Citing Articles [?] :	10851
Citing Articles without self-citations [?] :	9562
Average Citations per Item [?] :	25.67
h-index [?] :	88

September 2014

Latest LSC papers

SUMMARIES OF LSC SCIENTIFIC PUBLICATIONS

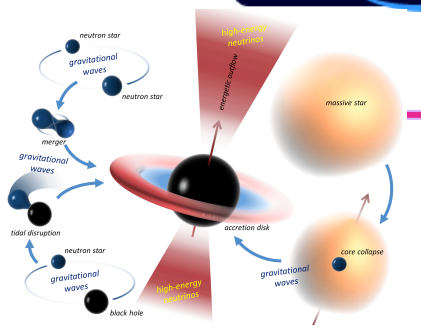
We now feature, for each new research article, a summary written for the general public with a downloadable and printable flyer in PDF format.

2014

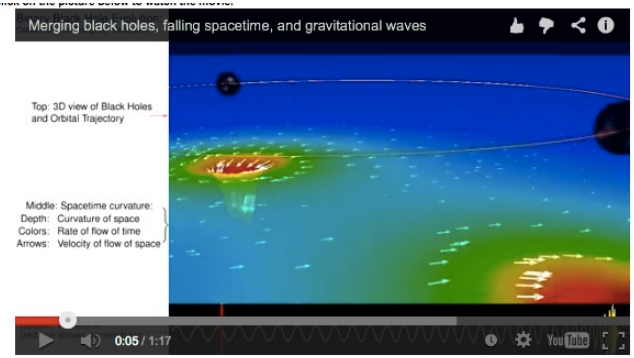
Jul 7, 2014	Capturing Invisible Cosmic Explosions [flyer]
Jun 25, 2014	Searching for a Background Buzz of Gravitational Waves [flyer]
Jun 4, 2014	Searching for the Continuous Sounds of Unknown Neutron Stars in Binary Systems [flyer]
May 15, 2014	Leveraging the GEO600 Detector to Search for Gravitational Waves from Gamma-ray Bursts [flyer]
Apr 15, 2014	Searching for Gravitational Waves Associated with Gamma-ray Bursts Detected by the InterPlanetary Network [flyer]
Apr 09, 2014	Observing the Invisible Collisions of Intermediate Mass Black Holes [flyer]
Mar 26, 2014	Ringing of the Cosmic Bells: A Search for Black Hole Vibrations [flyer]
Feb 24, 2014	All-sky Search for Continuous Gravitational Waves in the Virgo Data [flyer]
Jan 16, 2014	Can we Hear Black Holes Collide? Testing Our Search Methods using Numerically Generated Gravitational-wave Signals [flyer]

2013

Nov 14, 2013	Do Cosmic Strings Exist? [flyer]
Nov 14, 2013	Searching for Continuous Gravitational Wave Signals with the Hough Transform [flyer]



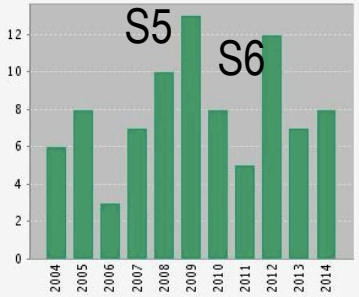
Credit: I. Bartos/Based on arXiv:1212.2289



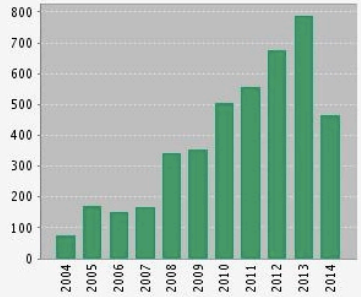
You searched for: **AUTHOR:** (Saulson AND Gonzalez AND Weiss) **...More**

This report reflects citations to source items indexed within All Databases.

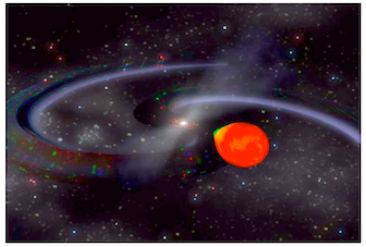
Published Items in Each Year



Citations in Each Year



Results found:	**87**
Sum of the Times Cited [?] :	**4278**
Sum of Times Cited without self-citations [?] :	**3761**
Citing Articles [?] :	**1603**
Citing Articles without self-citations [?] :	**1520**
Average Citations per Item [?] :	**49.17**
h-index [?] :	**39**



Courtesy of NASA Goddard

Find all LSC results and publications in www.ligo.org - science tab

LIGO and the National Cyberinfrastructure

- Gravitational-wave science is Big Science on Big Data - petascale data sets through massive workflows
- LIGO has driven development in
  - Computing clusters (e.g. exploration of consumer-grade GPUs for science)
  - Crowd-sourced computing (e.g. Einstein at Home)
  - Scientific workflow management (e.g. Condor and Pegasus)
  - Federated identity management (e.g. Co-manage and Shibboleth)
- Gravitational-wave science trains people with real world computing skills that are applicable to many scientific domains and to industry

LIGO open data

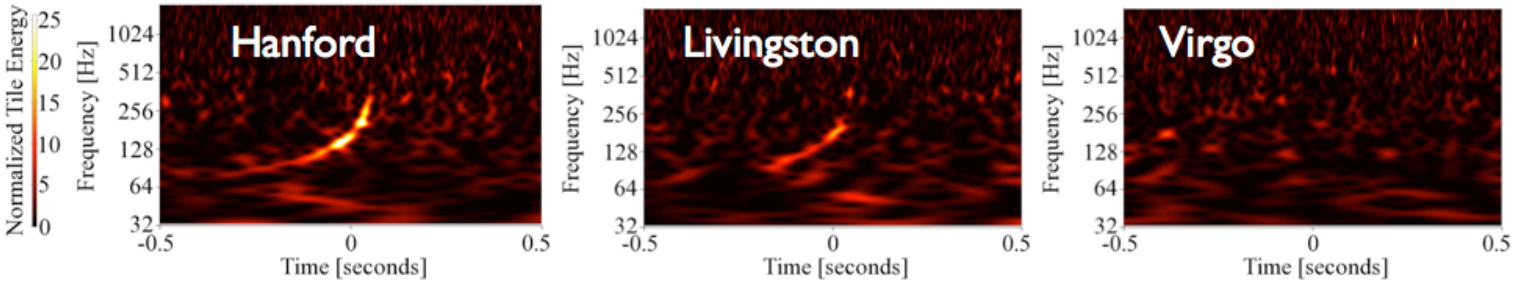
LIGO is committed to open data and prompt release of GW observations.

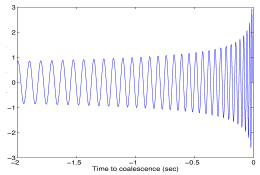
Much development is needed for releasing LIGO data - prototyping with initial LIGO data: S5 is now public.

https://losc.ligo.org/

Some S5/S6 LSC results

- Best experimental limits to cosmic GW background around 100 Hz (Nature **460** (2009) 990)
- Limits on GW radiation from known pulsars: “mountains” on Crab are less than 1m high (Astrophys. J. **785** (2014) 119)
- Multi-messenger searches for GW transients in coincidence with neutrinos, gamma ray bursts, soft gamma repeaters, pulsar glitches, magnetars, …
- We can detect GWs! Phys. Rev D**85** (2012) 082002





All publications in www.ligo.org

The future is coming – soon!

- Prospects for Localization of Gravitational Wave Transients by the Advanced LIGO and Advanced Virgo Observatories, The LIGO Scientific Collaboration and The Virgo Collaboration, arXiv:1304.0670

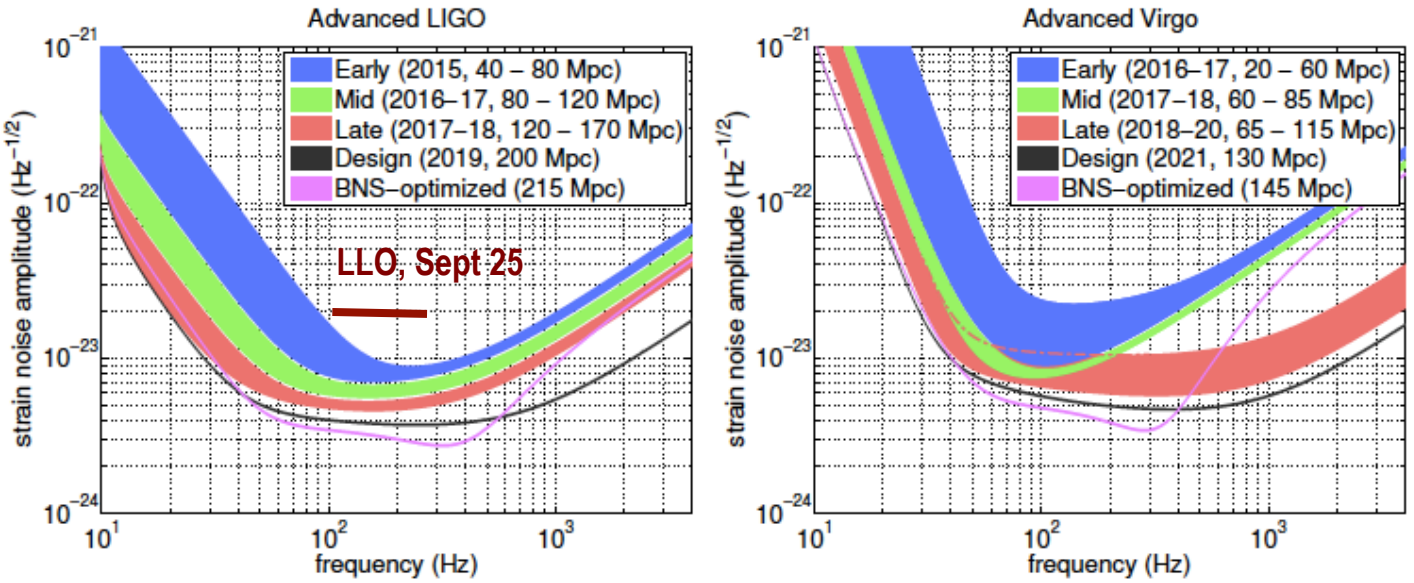


Figure 1: aLIGO (left) and AdV (right) target strain sensitivity as a function of frequency. The average distance to which binary neutron star (BNS) signals could be seen is given in Mpc. Current notions of the progression of sensitivity are given for early, middle, and late commissioning phases, as well as the final design sensitivity target and the BNS-optimized sensitivity. While both dates and sensitivity curves are subject to change, the overall progression represents our best current estimates.

Observing Scenario

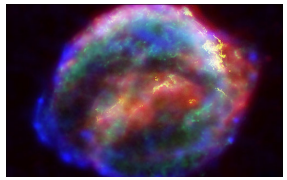
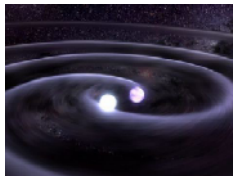
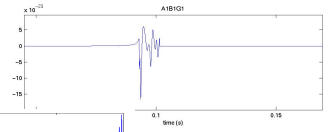
Epoch	Estimated Run Duration	$E_{GW} = 10^{-2} M_{\odot} c^2$ Burst Range (Mpc)		BNS Range (Mpc)		Number of BNS Detections	% BNS Localized within	
		LIGO	Virgo	LIGO	Virgo		$5\,\mathrm{deg}^2$	$20\,\mathrm{deg}^2$
2015	3 months	40 – 60	–	40 – 80	–	0.0004 – 3	–	–
2016–17	6 months	60 – 75	20 – 40	80 – 120	20 – 60	0.006 – 20	2	5 – 12
2017–18	9 months	75 – 90	40 – 50	120 – 170	60 – 85	0.04 – 100	1 – 2	10 – 12
2019+	(per year)	105	40 – 80	200	65 – 130	0.2 – 200	3 – 8	8 – 28
2022+ (India)	(per year)	105	80	200	130	0.4 – 400	17	48

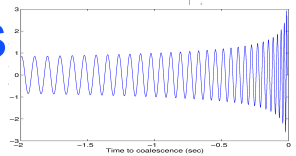
Table 1: Summary of a plausible observing schedule, expected sensitivities, and source localization with the advanced LIGO and Virgo detectors, which will be strongly dependent on the detectors' commissioning progress. The burst ranges assume standard-candle emission of $10^{-2} M_{\odot} c^2$ in GWs at 150 Hz and scale as $E_{GW}^{1/2}$. The burst and binary neutron star (BNS) ranges and the BNS localizations reflect the uncertainty in the detector noise spectra shown in Fig. 1. The BNS detection numbers also account for the uncertainty in the BNS source rate density [28], and are computed assuming a false alarm rate of $10^{-2}\,\mathrm{yr}^{-1}$. Burst localizations are expected to be broadly similar to those for BNS systems, but will vary depending on the signal bandwidth. Localization and detection numbers assume an 80% duty cycle for each instrument.

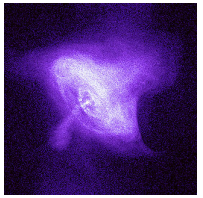
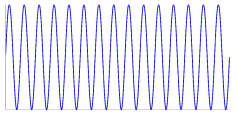
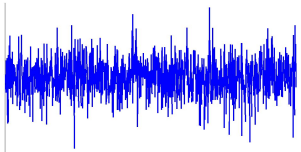
Planned O1 searches

Described in public white paper LIGO–T1400054

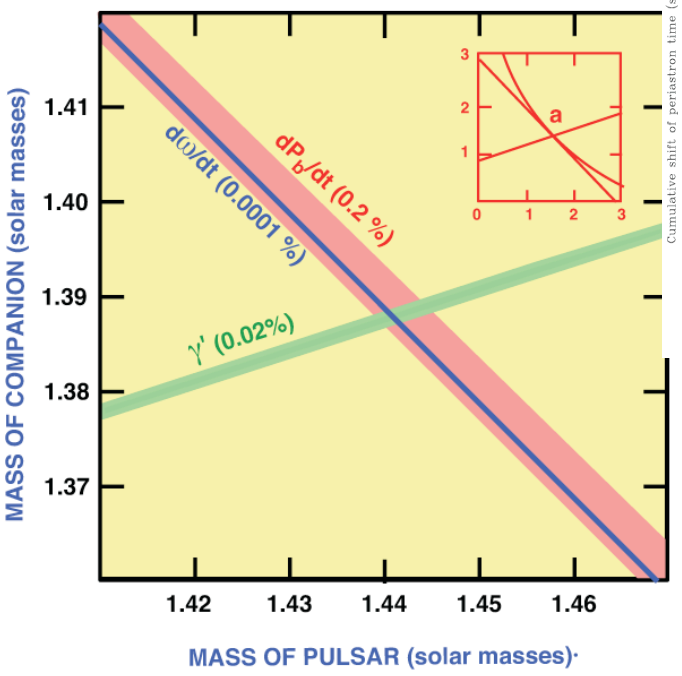
- All-sky burst search
- Binary neutron star coalescences
- Stellar-mass binary black holes coalescences
- Neutron star-black hole coalescences
- Intermediate mass black hole binary coalescences
- GRB sources of transient gravitational waves
- All-sky searches for isolated spinning neutron stars
- Targeted searches for gravitational waves from known pulsars
- Isotropic stochastic gravitational wave background
- Directional search for persistent gravitational waves
- … other plans in preparation

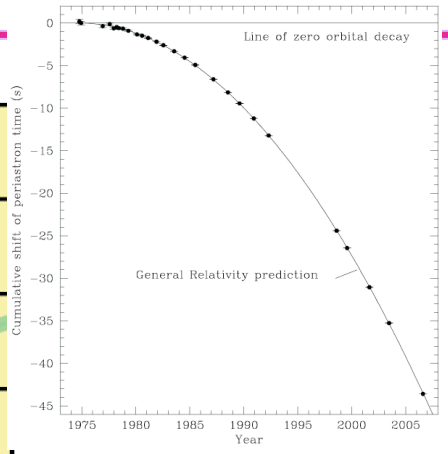




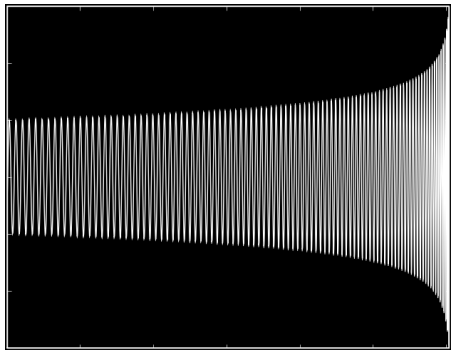


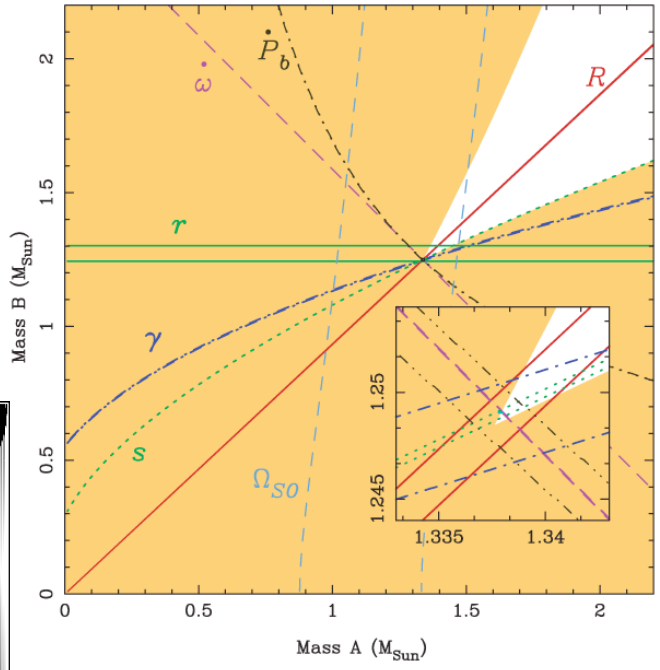




Detection and GR tests







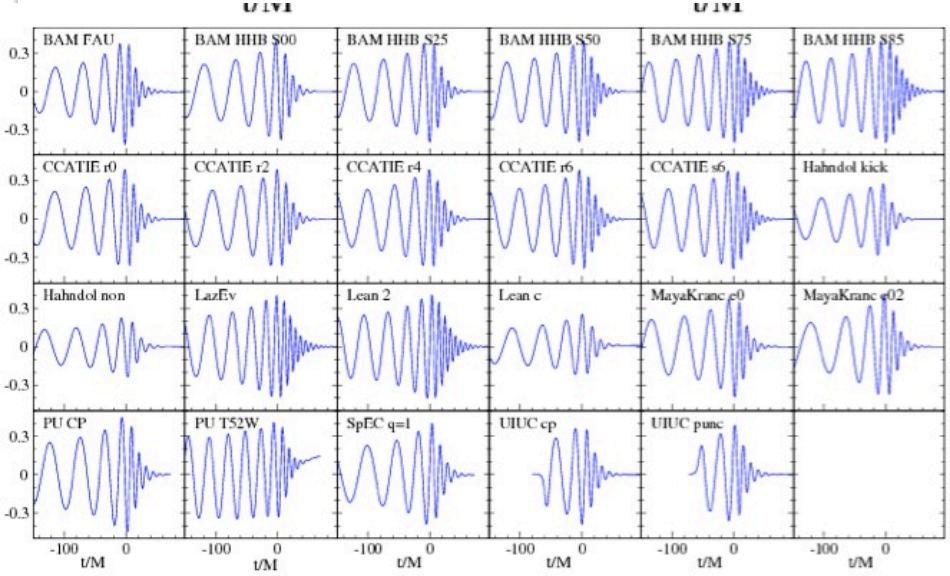


Pulsar tests measure leading orders in orbit decay.
Waveforms in GW detectors will measure the coalescence, millions of years later, in the extreme strong gravity regime: birth of black holes!

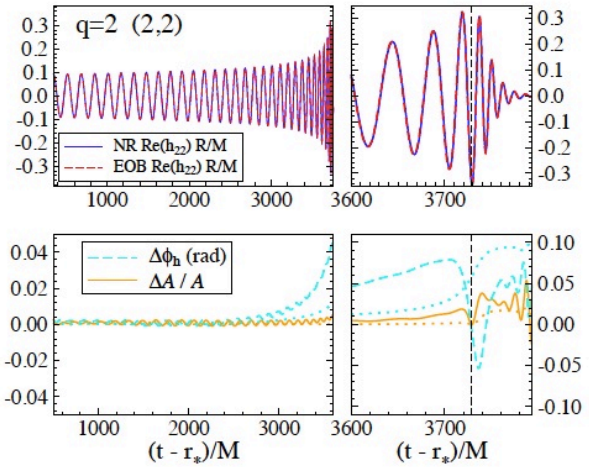
Living Rev. Relativity, 17 (2014), 4

Numerical relativity

- There are good numerical results for a given system – computationally expensive, but they are doable! (not true before ~2005)
- There are parameterized approximations that fit numerical results, and a collaboration to produce these: **"NRAR" collaboration**, numerical and analytical relativity communities.
- Efficiency of analysis methods with PN or phenomenological approximations can be tested against numerical models: **"NINJA collaboration"**: LVC and NR communities. Most useful for post-detection parameter estimation.



Class.Quant.Grav. 26 (2009) 165008

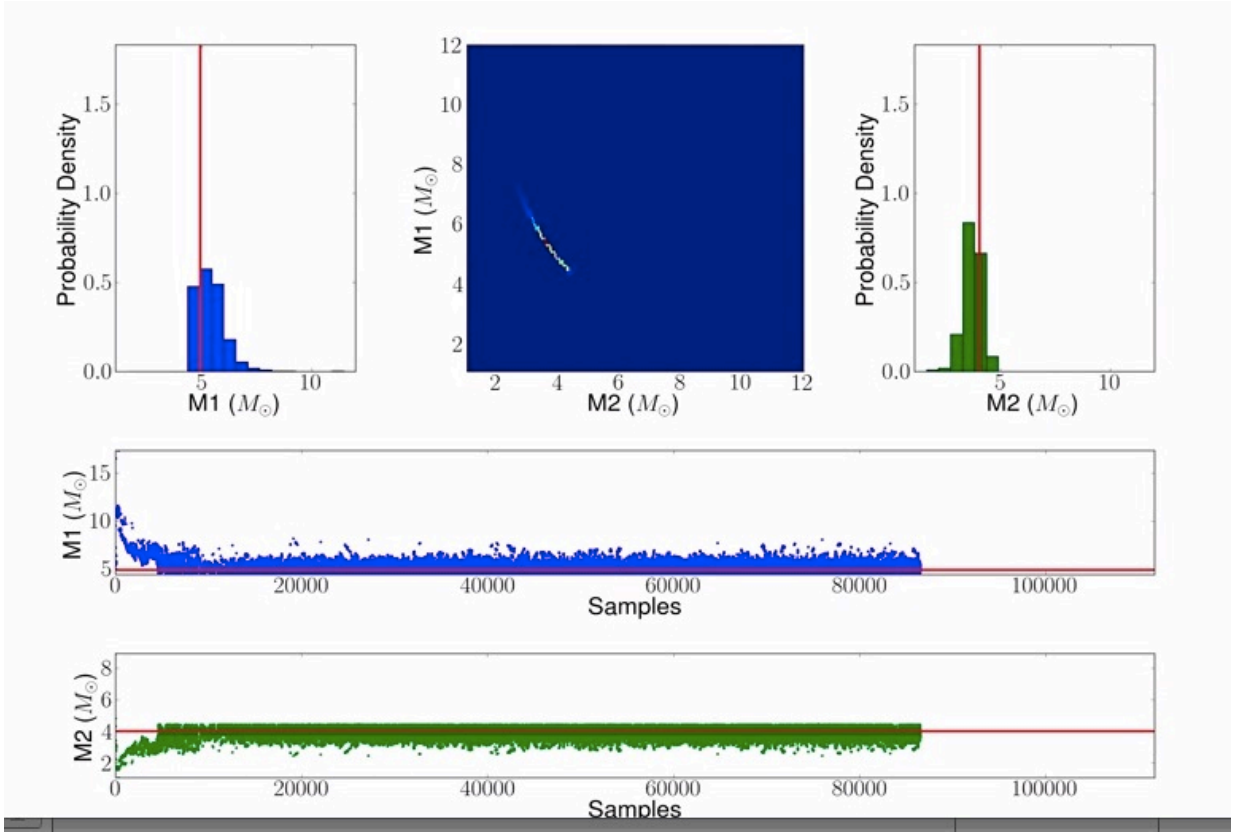


Phys.Rev. D84 124052

Astrophysics with GW detections: parameter estimation

After a search algorithm finds a candidate with some confidence, we can run (computationally expensive) parameter estimation studies, using many different models of waveforms with many possible parameters.

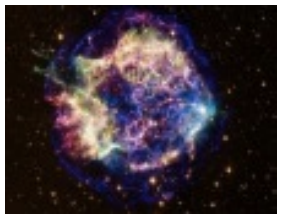
http://www.ligo.org/science/Publication-S6PE/



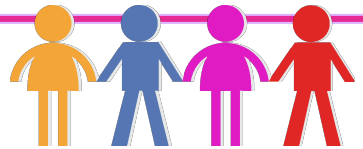
Multi-messenger astronomy: GW/EM observations

We will obtain rich astrophysics combining gravitational-wave and electromagnetic information.

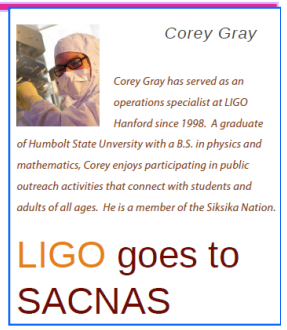
- LSC and Virgo opened a call to sign agreements for the identification of EM counterparts to GW triggers in Advanced detectors starting in 2015.
- We received and approved more than 60 applications from 19 countries, with about 150 instruments covering the full spectrum, from radio to high-energy gamma-rays!
- Shortly after a few detections, LSC/Virgo will publicly release GW triggers for follow up.



Other important LSC activities



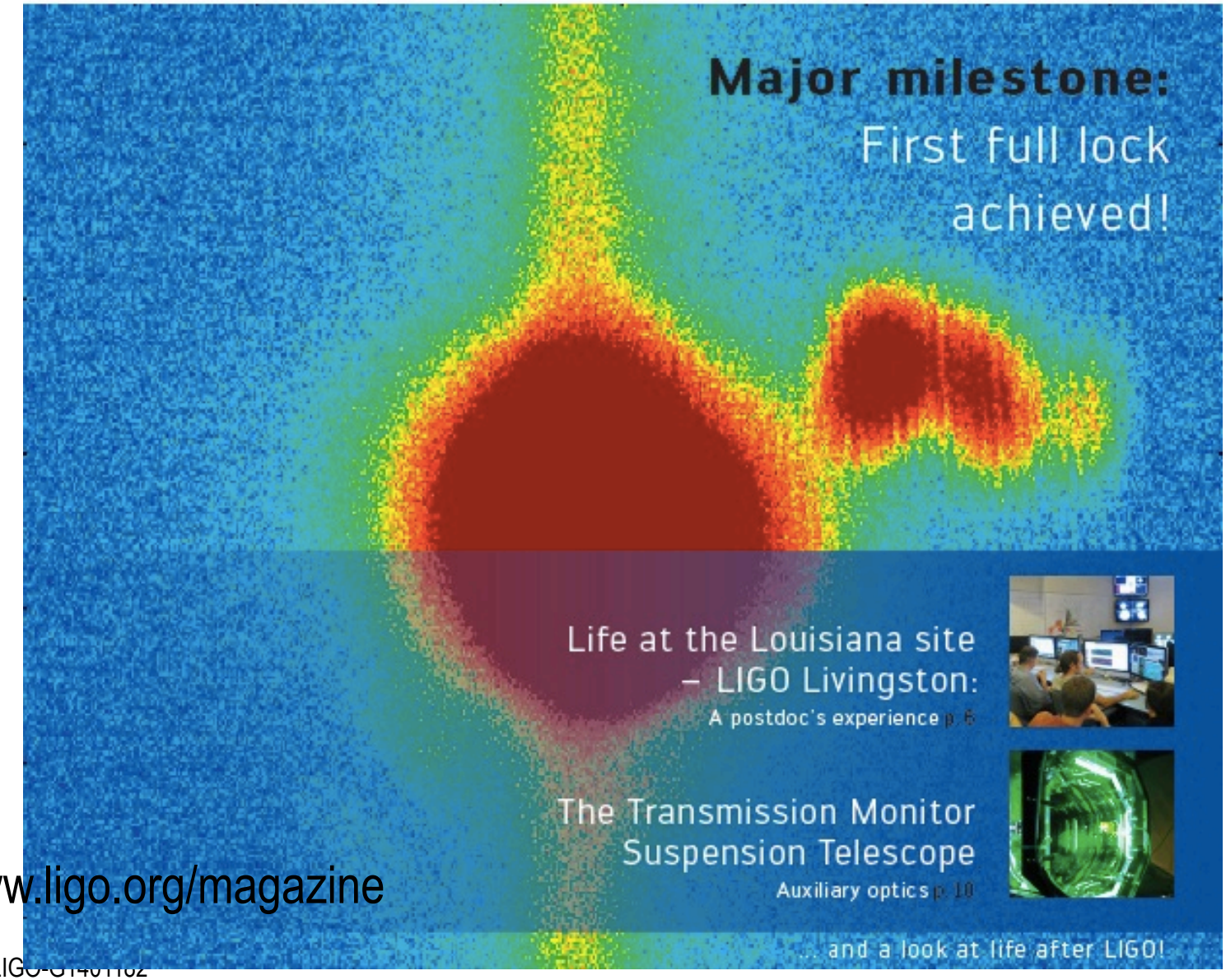
- Diversity
  - LSC has a “Diversity Committee. Some initiatives:
    - LSC Diversity statement; anti-harassment policy, LSC “best practices”
    - LSC “Ombudsperson” (former NSF program officer!)
    - LIGO summer undergraduate fellowships sponsored by NSBP and NSHP
    - “Family grants” to attend LSC meetings
    - Set up a booth and organize sessions in scientific meetings of women and minorities



- Academic mentoring
  - The LSC has an “Academic Advisory Committee” to care about mentoring of young members. Some recent activities:
    - Student and postdoc events and useful tutorials.
    - “Industry panels” with colleagues working now in industry.
    - Mentoring program: a platform for members of the LSC to form and maintain mentoring relationships.

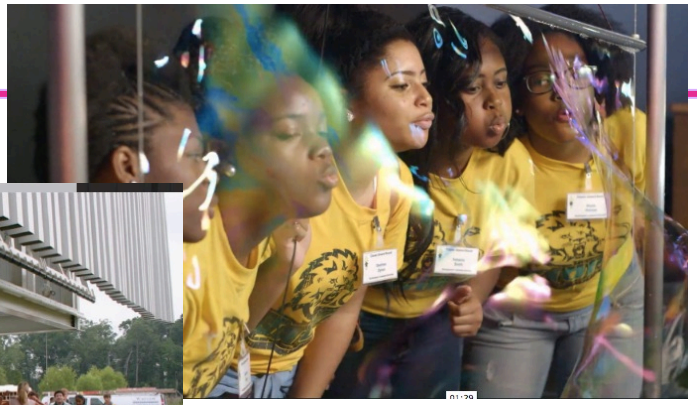
Telling our story

- Education and Public Outreach is a very active LSC working group
- www.ligo.org, LIGO magazine, science summaries, documentaries, Facebook, Twitter, and much more!



www.ligo.org/magazine

LIGO Science Education Center



An Interactive, Exhibit-Based Science and Mathematics Learning Center

GO Science Education Center has over 40 interactive, hands-on exhibits that relate to the science of LIGO. We host field trips for students, teacher training programs, and tours for the general public. Explore science conc as light, gravity, waves, and interference; learn about LIGO's search for gravitational waves; and interact with our scientists and engineers.

Follow Us on Facebook !

FIELD TRIPS:

Registration for the Fall 2014 Semester Field trips is now closed.
Registration for the Spring Semester is open. Please note that scheduling and confirmation will begin in November.

Please click on the link below to complete this form:
Field Trip Request Form

SCIENCE SATURDAY

Every third Saturday of each month; 1:00 p.m. - 5:00 p.m

Exhibit Hall Exploration	Topic Demonstrations	LIGO Videos
Topic Related Activity	Q&A with Scientist, Guest Speakers, and Science Specialist	Control Room Tours

LIGO Livingston concentrates its outreach resources on teachers and students, striving to enhance their exposure to cutting-edge physics research. Science Saturday caters to families and the general public. No reservation is required for individuals or groups less than 15. Although we encourage visits on these Saturdays, large groups may request a tour on other dates using the following link.

SCIENCE SATURDAY DATES

August 16th
Program Topic: Feels like pressure

September 20th
Program Topic: Fall into Science

October 18th
Program Topic: Appear to Disappear

November 15th
Program Topic: Cafe Style Science

December 20th
Program Topic: Year in Review

LIGO is supported by:

The National Science Foundation (NSF)

Any opinions, findings, conclusions or recommendations expressed here are those of the author(s) and do not necessarily reflect the view of the NSF.

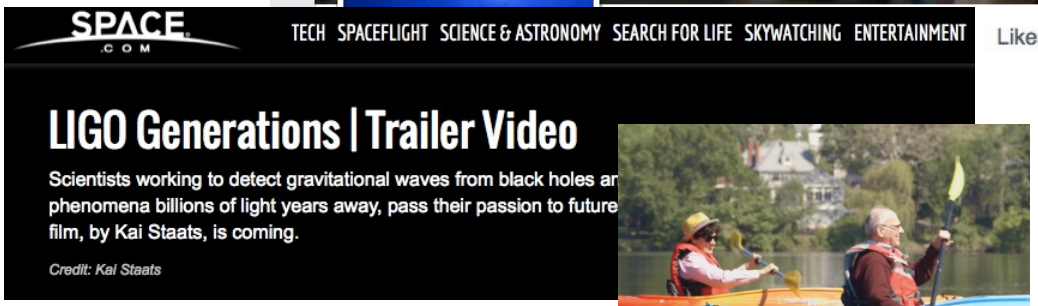
PARTNERS

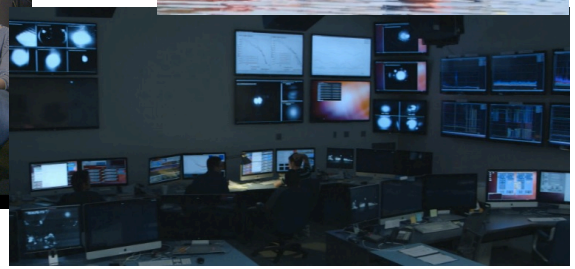
exploratorium the museum of science, art and human perception

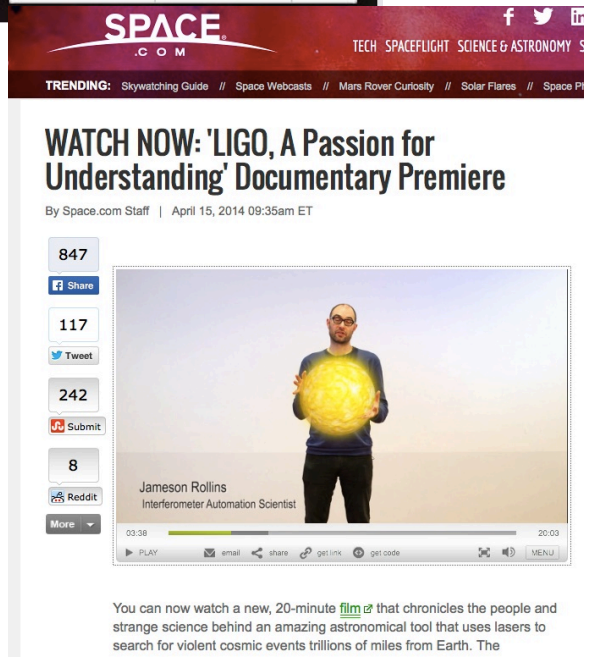
LIGO Hanford

LaSIP

Recent LIGO documentaries







World Science Festival

+Festival +Video +About +Blog Donate

FOLLOW US

The Ultimate Science Street Fair

- New York, May 29-Jun 2, 2013

INNOVATION ALLEY

CoderDojo
Coding = fun! Learn how to code and check out games made by other CoderDojo kids.

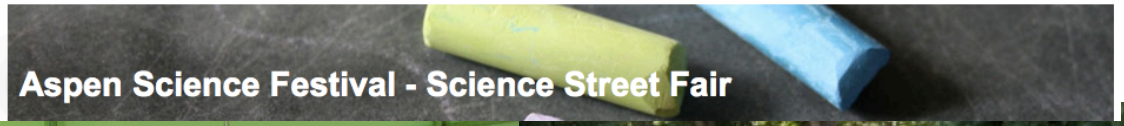
Blue Man Group
Make music and a light show on this one-of-a-kind instrument, equipped with acoustics, electronic sounds, and LED lighting.

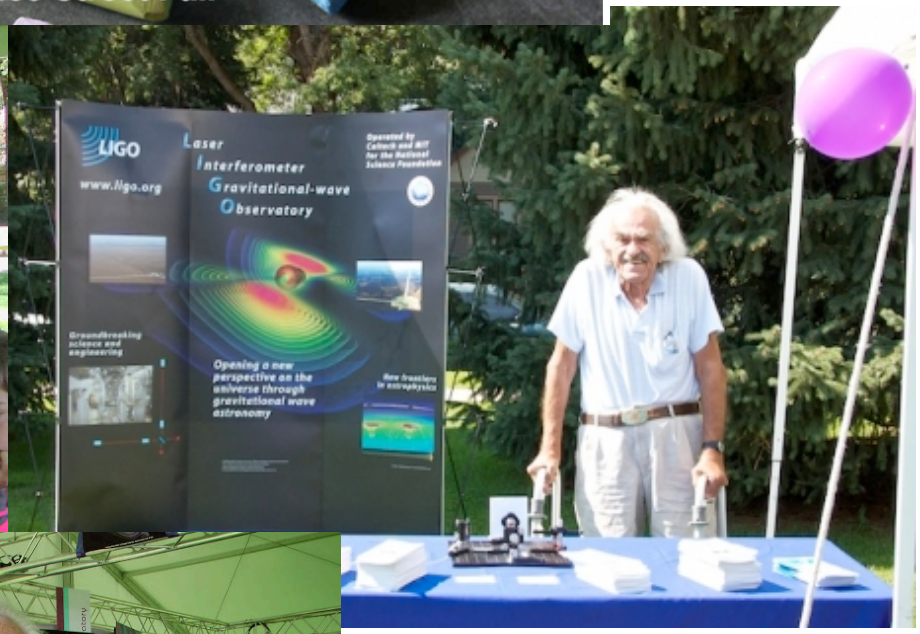
New York City/New Jersey FIRST Robotics
Robots alive! Join the New York City/New Jersey FIRST robotic team to take control of state-of-the-art robots that will keep you saying, "How *do* they do *that*?"

Listening to the Serenade of Cosmic Black Holes
Be part of a quest with Columbia Experimental Gravity group for the LIGO Scientific Collaboration and Laser Interferometer Gravitational-wave Observatory (LIGO). Black holes collide and merge violently in the Universe. We cannot see them, but we can listen to them with modern experiments. Play with a real interferometer, simulate curved space-time, try out fun computer games, and meet real scientists.

ASPEN SCIENCE CENTER

HOME | ABOUT US | PROJECTS | EDUCATION PROGRAMS | NEWS AND EVENTS | Search our site

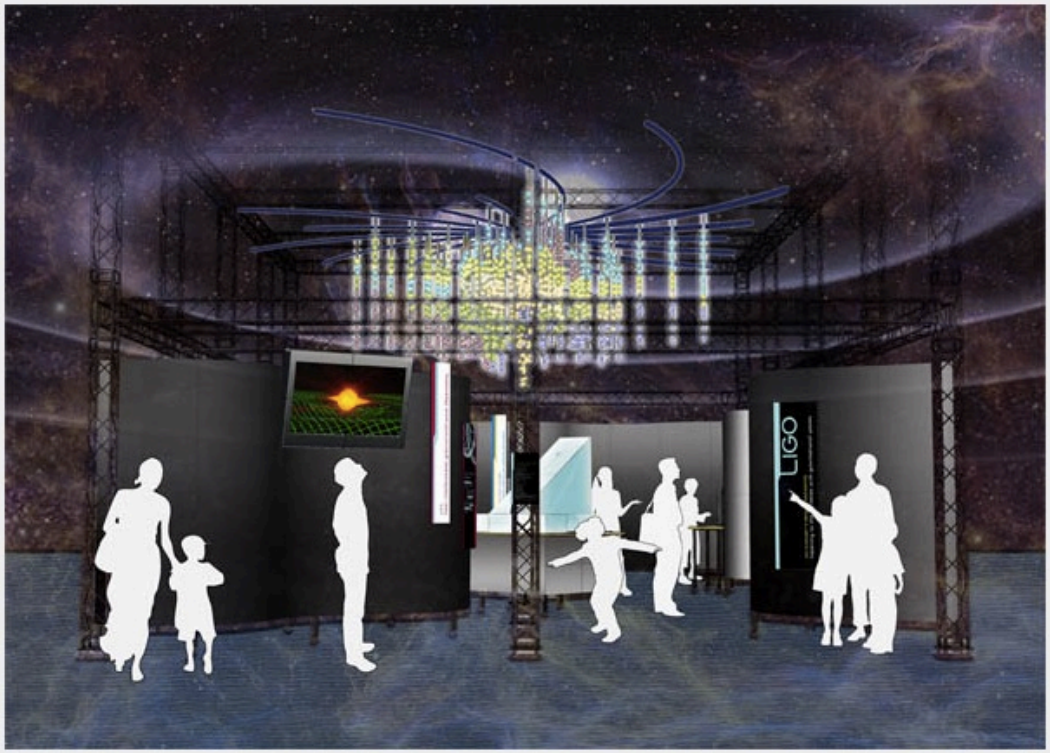




AstroDance
(Rochester Institute of Technology initiative)

LIGO traveling exhibit (University of Mississippi)

Welcome to Astronomy's New Messengers



"Astronomy's New Messengers: Listening to the Universe with Gravitational Waves" is an interactive educational experience. More...

The future is now, and is very bright!

- Decades of NSF investment in LIGO and hundreds of scientists' efforts are about to pay off.
- The convergence of gravitational-wave experiments, numerical and analytical relativity, modeling of electromagnetic counterparts, wide-field optical telescopes will revolutionize our astrophysical knowledge of the universe : "transformative science"!
- The benefits to the country will be broad, and not just in the scientific arena: also in K-12 education, public outreach, STEM resources, worldwide leadership,…