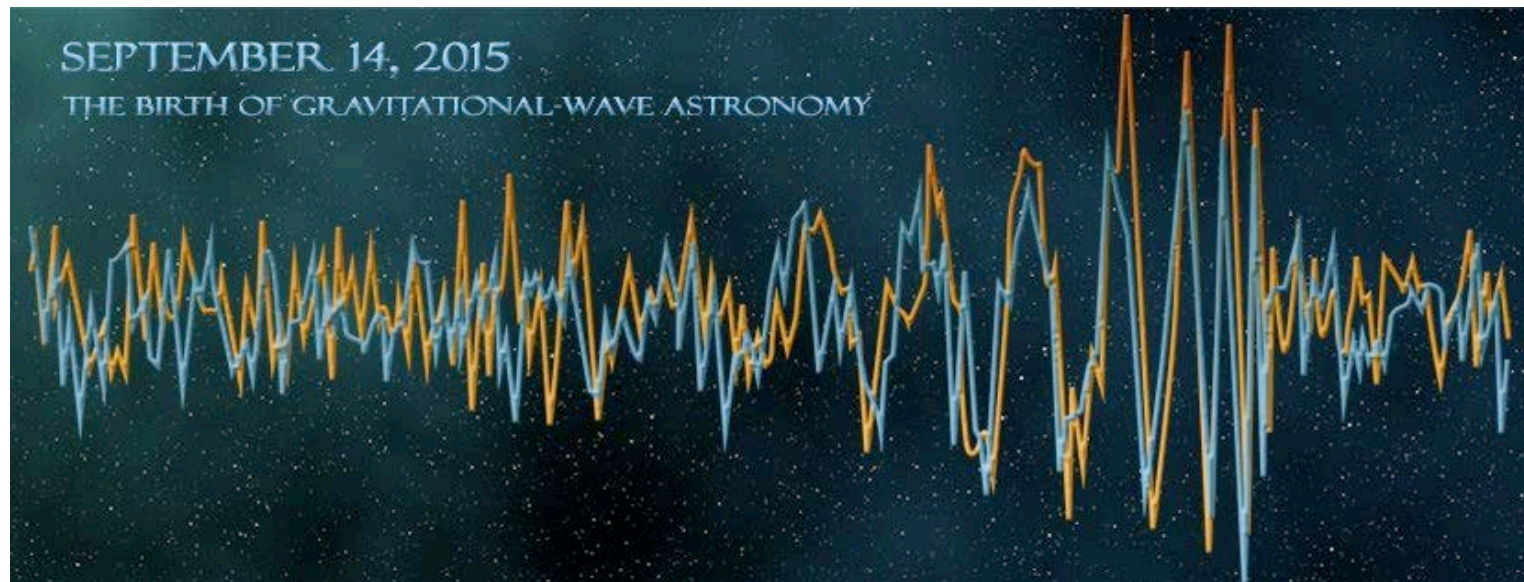
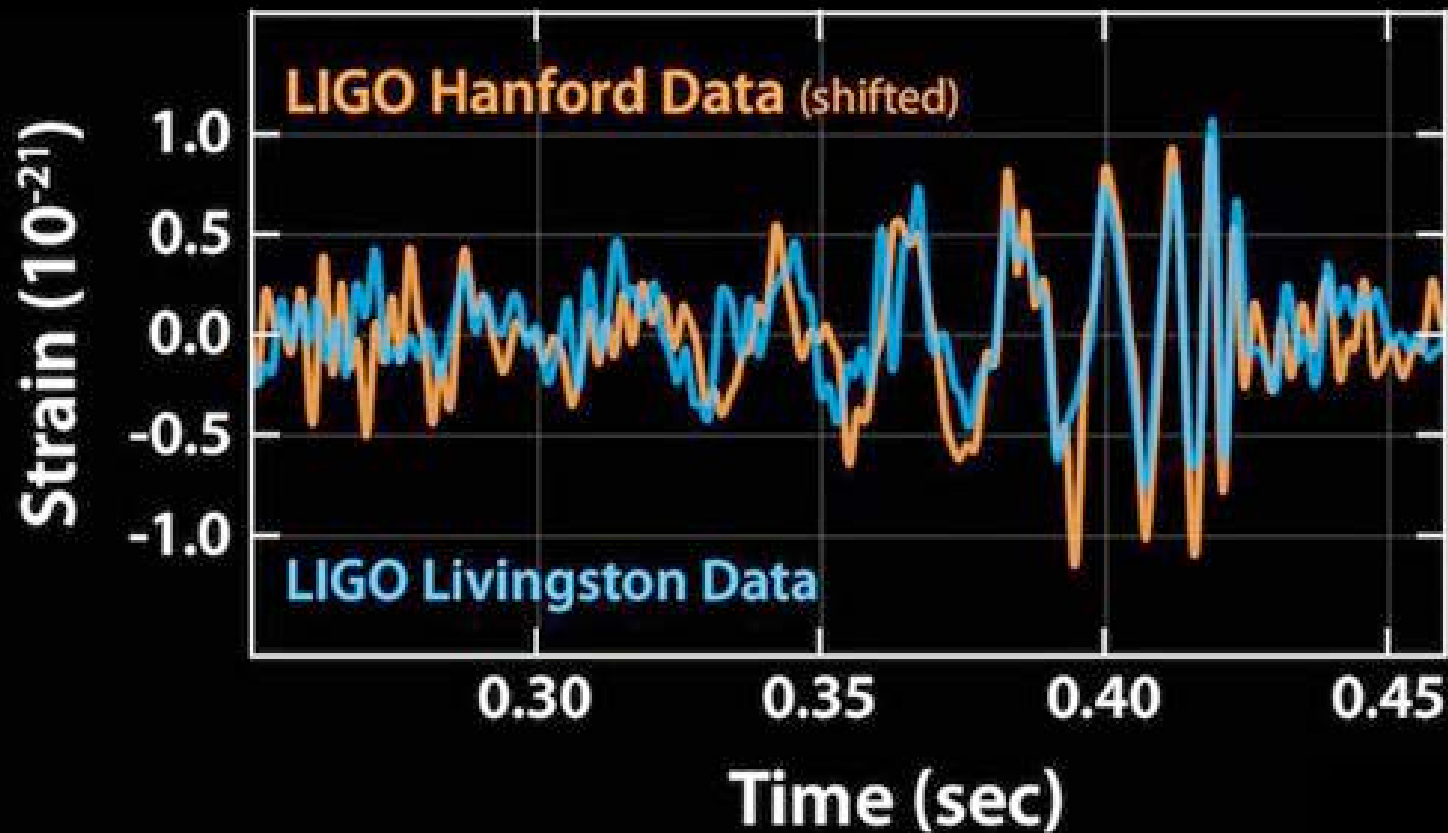


Science Done by a Global Community: The LIGO Scientific Collaboration

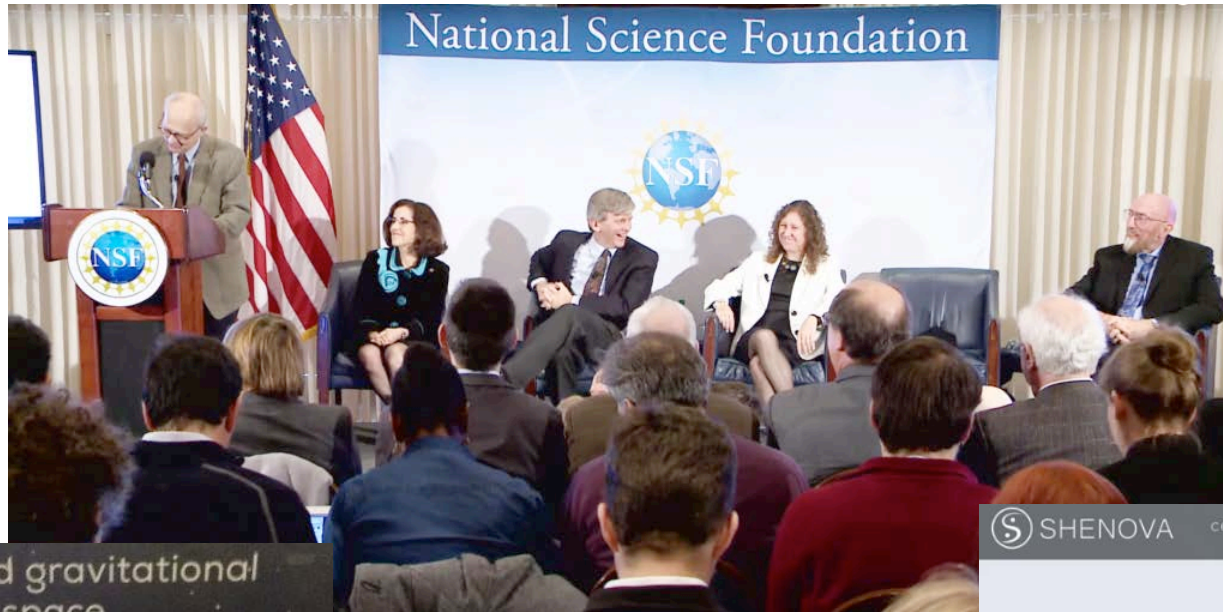
Gabriela González,
Louisiana State University



On Sept 14 2015...



February 11: We did it!



Scientists found gravitational waves in outer space.
If only it were that easy to find an apartment in NYC with a walk-in closet.

Rent your own personal closet space:
manhattanministorage.com

manhattan mini storage
212-STORAGE

we're not scientists, but we totally got space
@OurPersonalSpace



SHENOVA COLLECTIONS BLOG ABOUT HELP



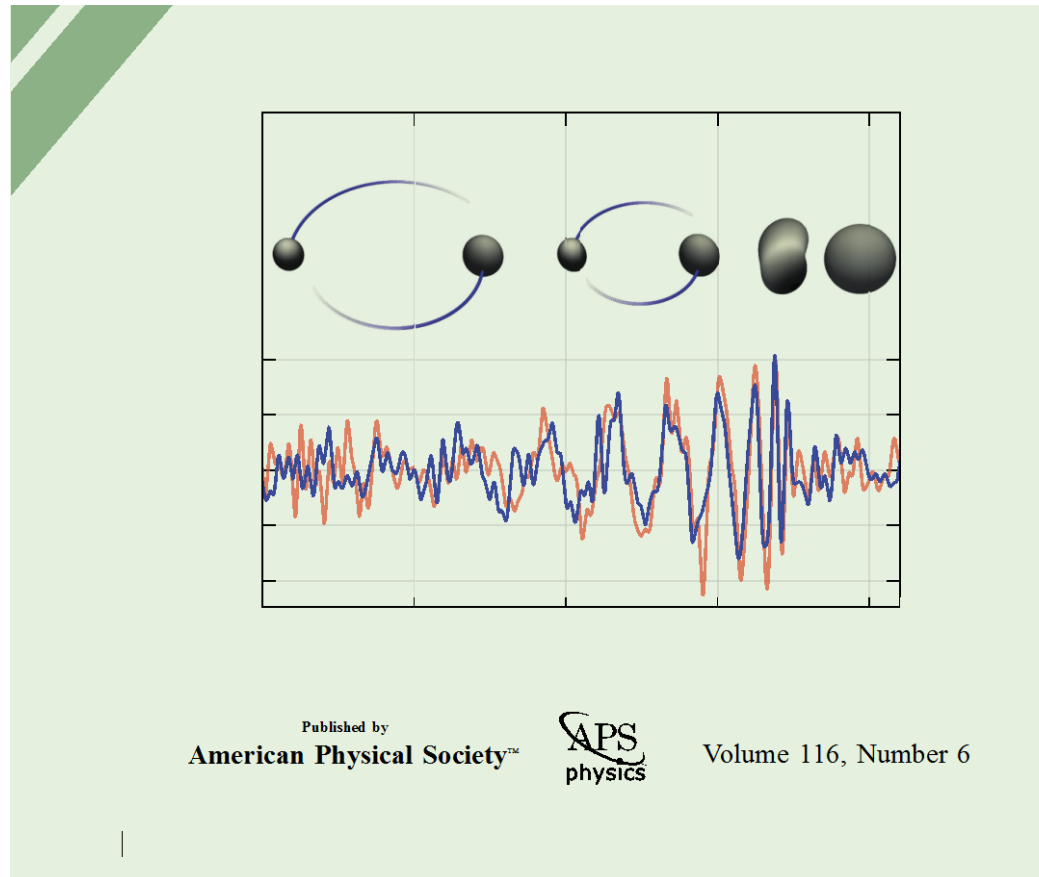


Observation of Gravitational Waves from a Binary Black Hole Merger

B. P. Abbott *et al.**

(LIGO Scientific Collaboration and Virgo Collaboration)

(Received 21 January 2016; published 11 February 2016)



Published by
American Physical Society™



Volume 116, Number 6

LIGO detectors

Hanford, WA



Livingston, LA



Advanced LIGO detectors:

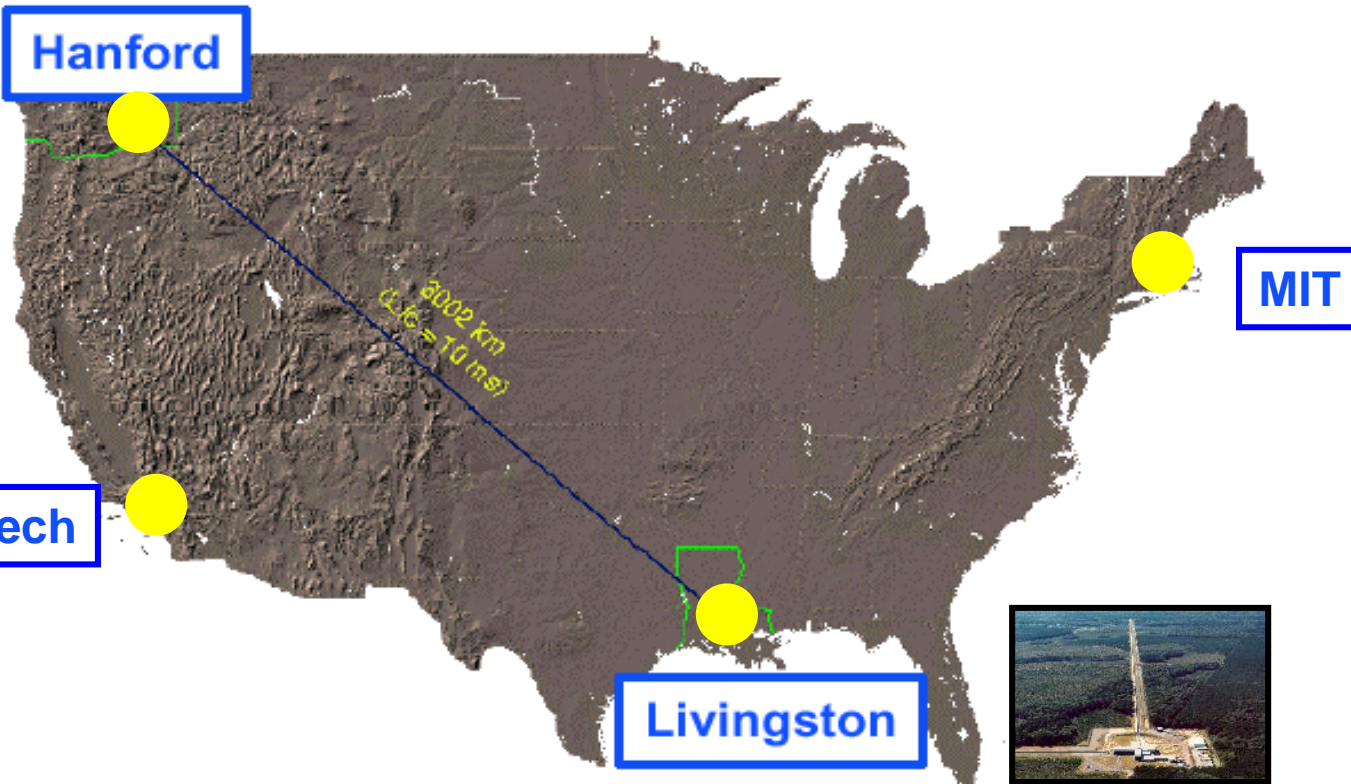


LIGO Laboratory

- Mission: Observe gravitational wave sources; operate the LIGO facilities; develop the instrument science and technology; scientific education and public outreach.
- NSF Major Research Facilities Construction LIGO grant in 1992 and in 2008; cooperative agreements since 1992, jointly managed by Caltech and MIT.
- ~170 scientists, engineer and staff; includes physicists working on instrument science and data analysis.



Hanford



MIT



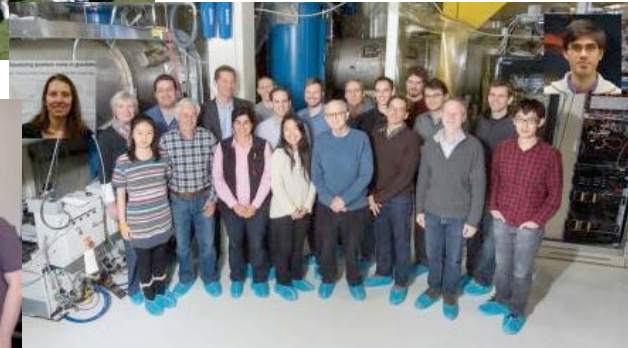
Caltech

Livingston



LIGO Scientific Collaboration

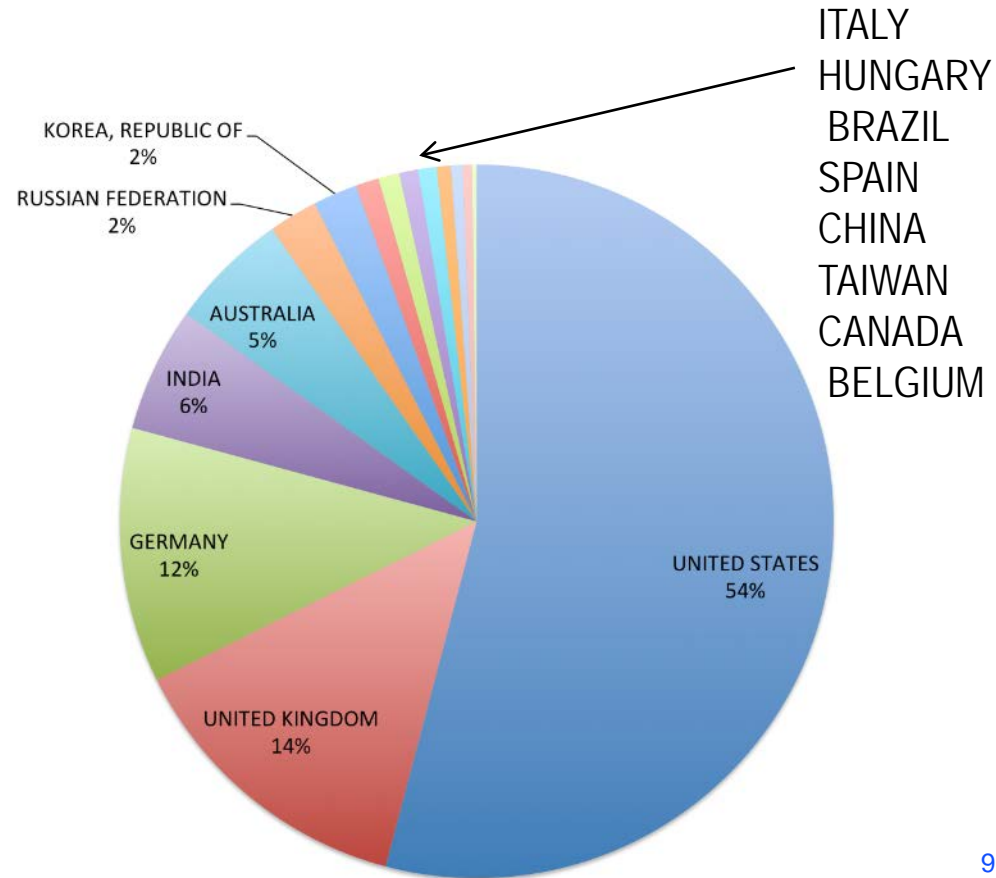




LIGO Scientific Collaboration



~1,200 members, >90 institutions,
15 countries.

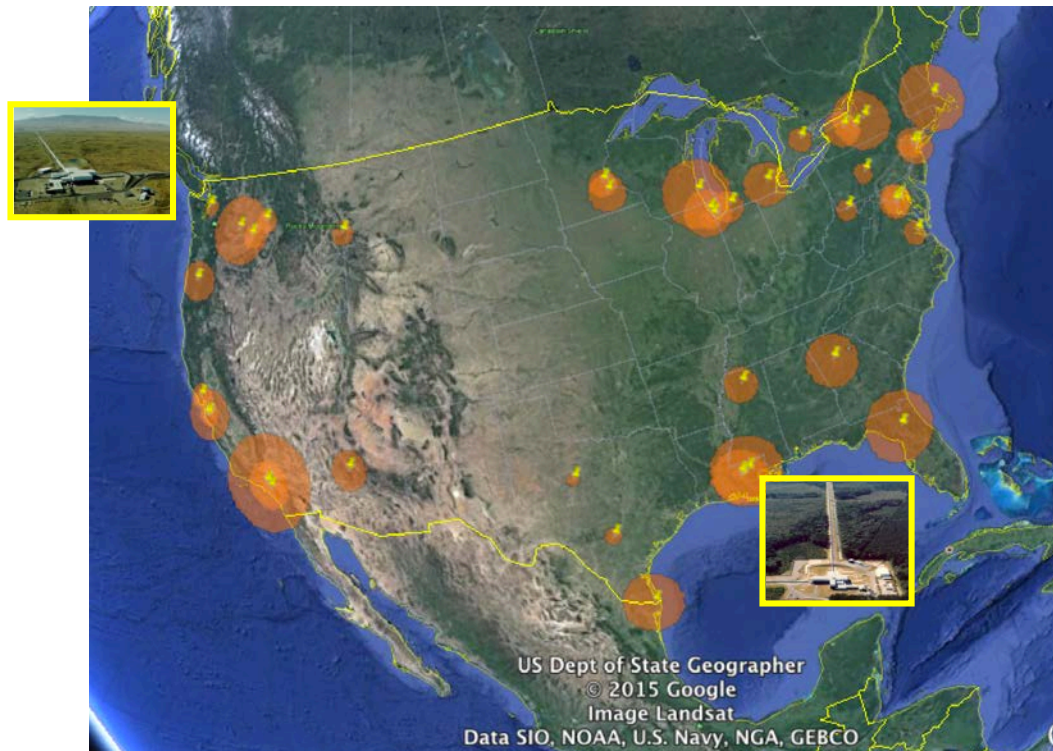


www.ligo.org

LIGO-G1700798

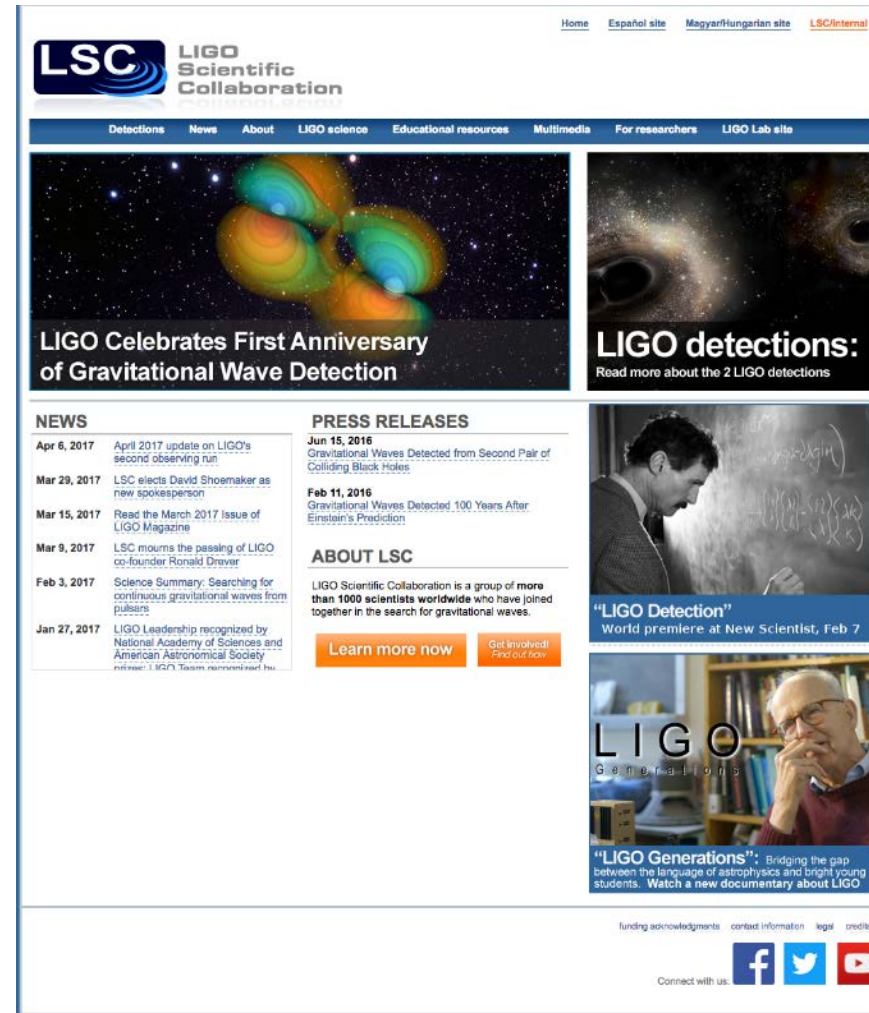
LSC-USA

- Large institutional diversity: large and small departments, graduate and undergraduate institutions, several serving large under-represented groups.
- Most US groups are supported by NSF with competitive, single investigator NSF grants. LIGO Laboratory (~30% of LSC) is supported by a cooperative agreement from NSF with Caltech and MIT.
- Many LSC “graduates” now working in STEM industries (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.



The screenshot shows the LIGO Scientific Collaboration website. At the top right, there are links for Home, Español site, MagyarHungarian site, and LSC/external. The main header features the LSC logo and the text "LIGO Scientific Collaboration". Below this is a navigation bar with links for Detections, News, About, LIGO science, Educational resources, Multimedia, For researchers, and LIGO Lab site.

The main content area is divided into several sections:

- Top Left:** A large image of gravitational wave ripples with the text "LIGO Celebrates First Anniversary of Gravitational Wave Detection".
- Top Right:** A smaller image of gravitational waves with the text "LIGO detections: Read more about the 2 LIGO detections".
- NEWS:** A list of recent news items:
 - Apr 6, 2017: April 2017 update on LIGO's second observing run
 - Mar 29, 2017: LSC elects David Shoemaker as new spokesperson
 - Mar 15, 2017: Read the March 2017 Issue of LIGO Magazine
 - Mar 9, 2017: LSC mourns the passing of LIGO co-founder Ronald Drever
 - Feb 3, 2017: Science Summary: Searching for continuous gravitational waves from pulsars
 - Jan 27, 2017: LIGO Leadership recognized by National Academy of Sciences and American Astronomical Society
- PRESS RELEASES:**
 - Jun 15, 2016: Gravitational Waves Detected from Second Pair of Colliding Black Holes
 - Feb 11, 2016: Gravitational Waves Detected 100 Years After Einstein's Prediction
- ABOUT LSC:** A paragraph stating "LIGO Scientific Collaboration is a group of more than 1000 scientists worldwide who have joined together in the search for gravitational waves." Below this are two buttons: "Learn more now" and "Get involved! Find out how".
- Bottom Right:** A section titled "LIGO Generations" featuring a photo of a man and the text "Bridging the gap between the language of astrophysics and bright young students. Watch a new documentary about LIGO".

At the bottom of the page, there are links for "funding acknowledgments", "contact information", and "legal credits". Below these are social media icons for Facebook, Twitter, and YouTube, with the text "Connect with us:".

LIGO Scientific Collaboration

- Some LSC Principles:
 - Open: “No individual or group will be denied membership on any basis except scientific merit and the willingness to participate and contribute as described in this Charter.”
 - Member agreements (MOUs) describe scientific, not financial, commitments.
 - Democratic: Spokesperson and working group leaders elected (w/2 yr terms).
 - Formal LSC/LIGO Lab interaction: “LIGO directorate” consists of the LSC spokesperson, and the Executive and Deputy Directors of the LIGO Laboratory. The LIGO Directorate will be ex officio members of all planning and evaluative bodies of the LSC. (On the ground, there are no differences between LIGO Lab LSC members and other group members, other than funding.)
- Some history:
 - Created in 1997, already international (Germany, UK, Australia, Russia).
 - Initially ~25 groups, 200 people, Rai Weiss (MIT) initial spokesperson 1997-2003
 - Peter Saulson (Syracuse University) elected spokesperson 2003-2007, David Reitze (University of Florida) 2007-2011, GG (Louisiana State University) 2011-2017
 - Current spokesperson is David Shoemaker (MIT), with Deputy spokesperson Laura Cadonati (Georgia Tech).

Education and Public Outreach



Multimedia

LIGO AMA on Reddit

- On 2/13, reddit.com/r/science hosted us in an "Ask Us Anything" event [[link](#)]
- A team of 20 answered over 60 questions from internet users. The thread turned out to be very popular:
 - Pageviews: **21,046**
 - Pageviews from unique IPs: **18,378**
 - Average time spent on page: **3:08**
 - Comments: **557**
 - Frontpage of Reddit: **yes!**
- [OutreachFAQ wiki page](#) has now been seeded with the questions and answers from the AMA, help it keep growing!

Social media



Science teachers' education

LIGO-G1700798



Science fairs, exhibits,
Science Education Center

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



Corey Gray

Corey Gray has served as an operations specialist at LIGO Hanford since 1998. A graduate of Humboldt State University with a B.S. in physics and mathematics, Corey enjoys participating in public outreach activities that connect with students and adults of all ages. He is a member of the Siksika Nation.

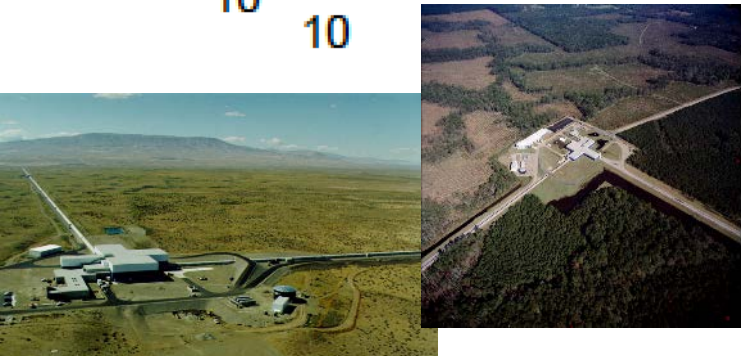
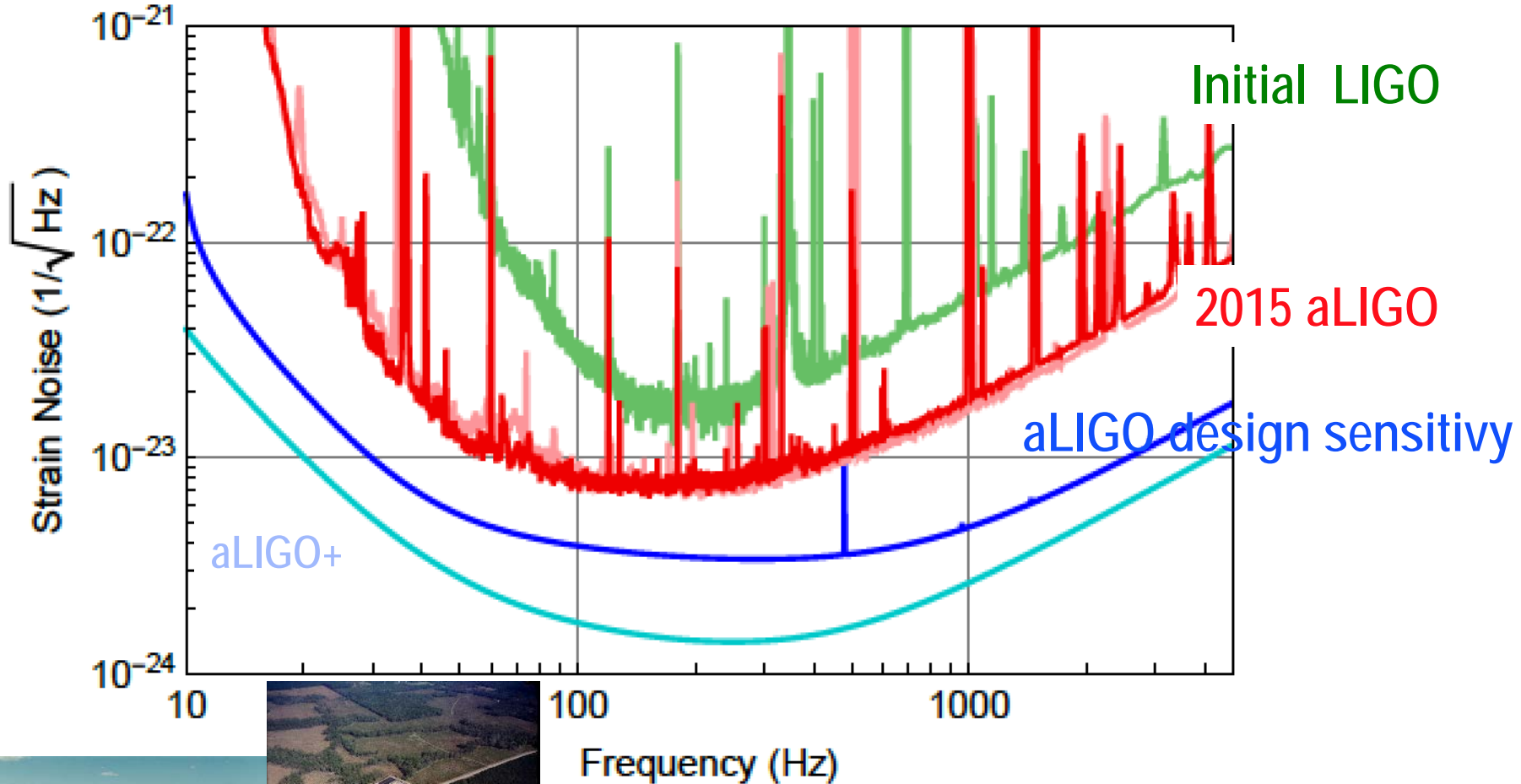
LIGO goes to SACNAS

• Academic mentoring

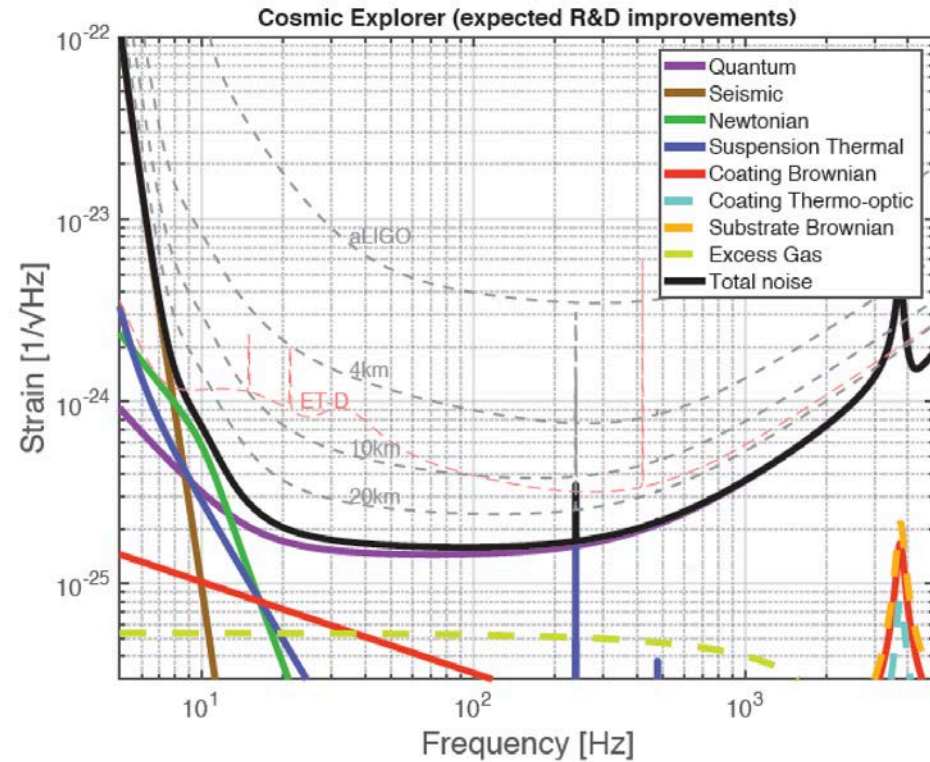
- The LSC has an “Academic Advisory Committee” to care about mentoring of young members. Some recent activities:
 - Student and postdoc events and useful tutorials.
 - “Industry panels” with colleagues working now in industry.
 - Mentoring program: a platform for members of the LSC to form and maintain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



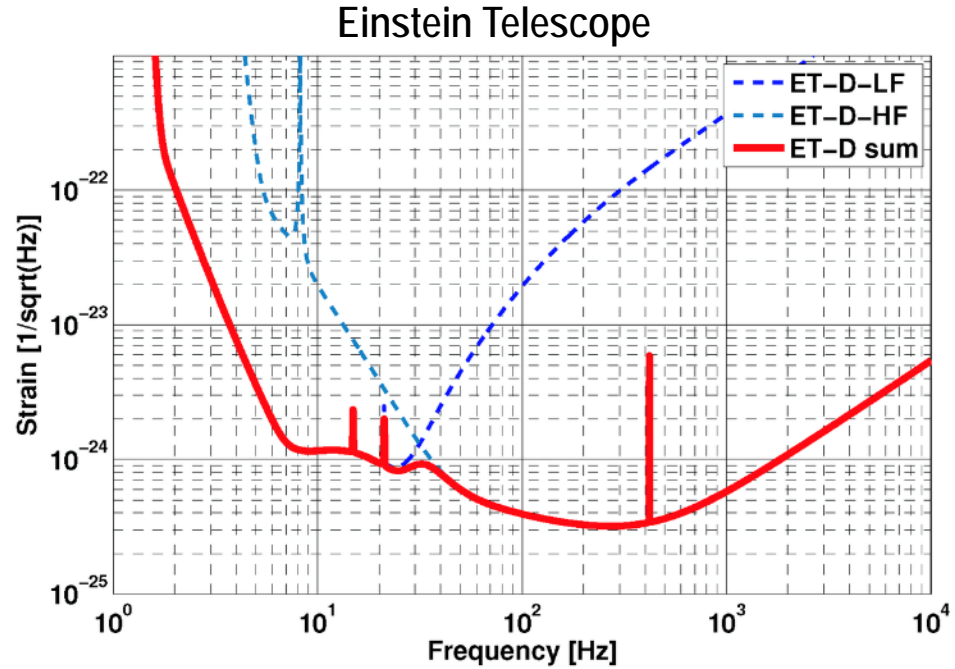
LIGO Science: GW Technology and Astrophysics



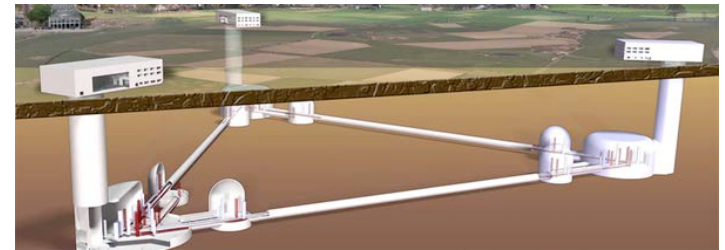
The future: 3rd generation detectors



arXiv:1607.08697

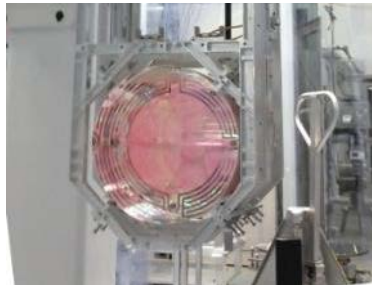
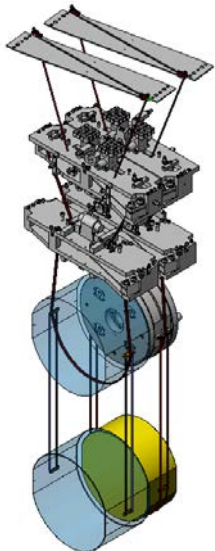
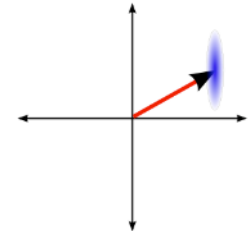
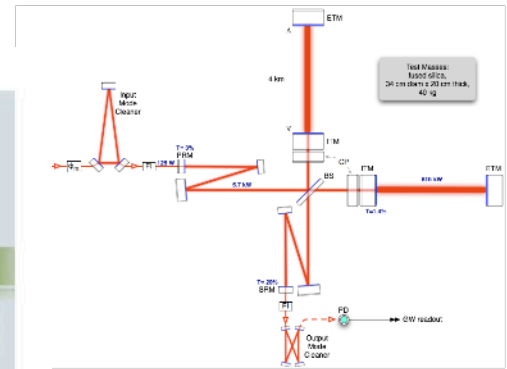
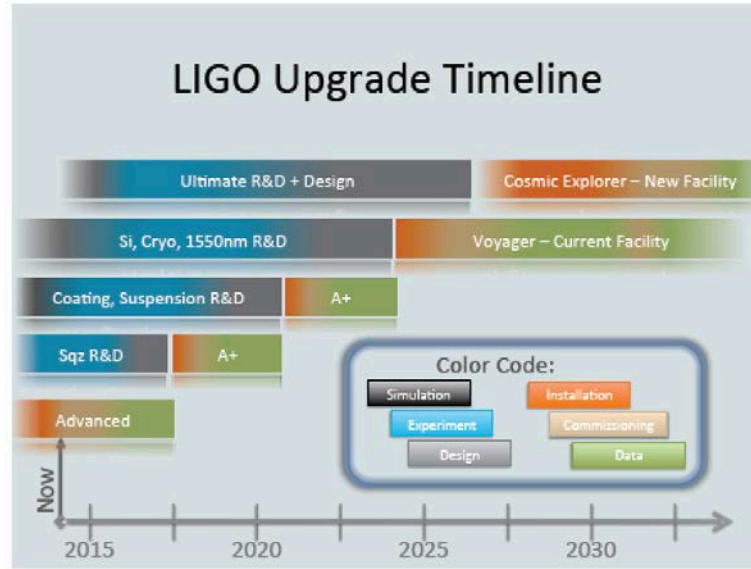
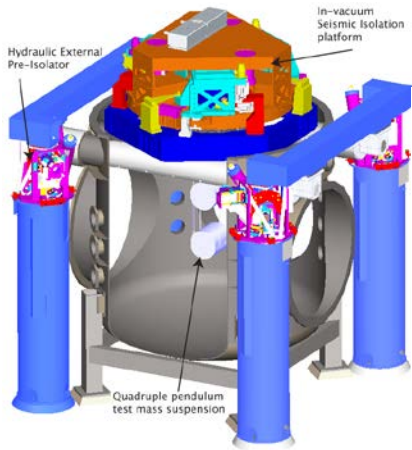


S.Hild et al., Classical and Quantum Gravity, 28 094013, 2011



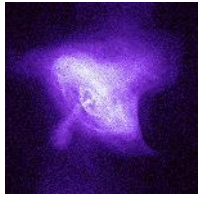
<http://www.et-gw.eu/>

LIGO Detector Technology

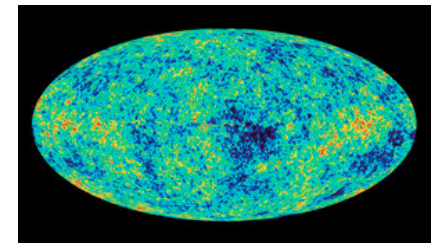
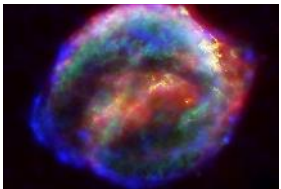
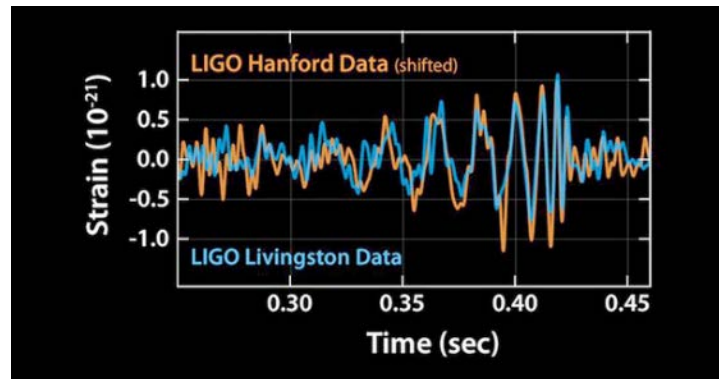
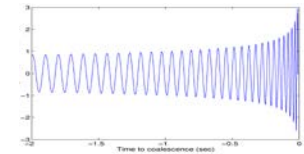
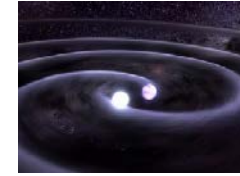
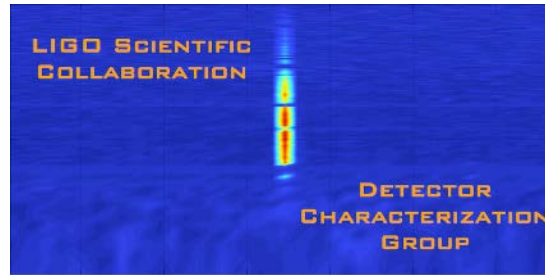
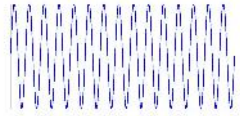


Five instrumental working groups – white paper LIGO-T1600119 (dcc.ligo.org) about R&D for future detectors with improved sensitivities

LIGO Data Analysis



Crab pulsar (NASA, Chandra Observatory)



NASA, WMAP



Four analysis working groups (plus calibration, detector characterization, software and computing) white paper LIGO-T1600115 (dcc.ligo.org) about search plans for Adv LIGO and Virgo detections

Detections in O1

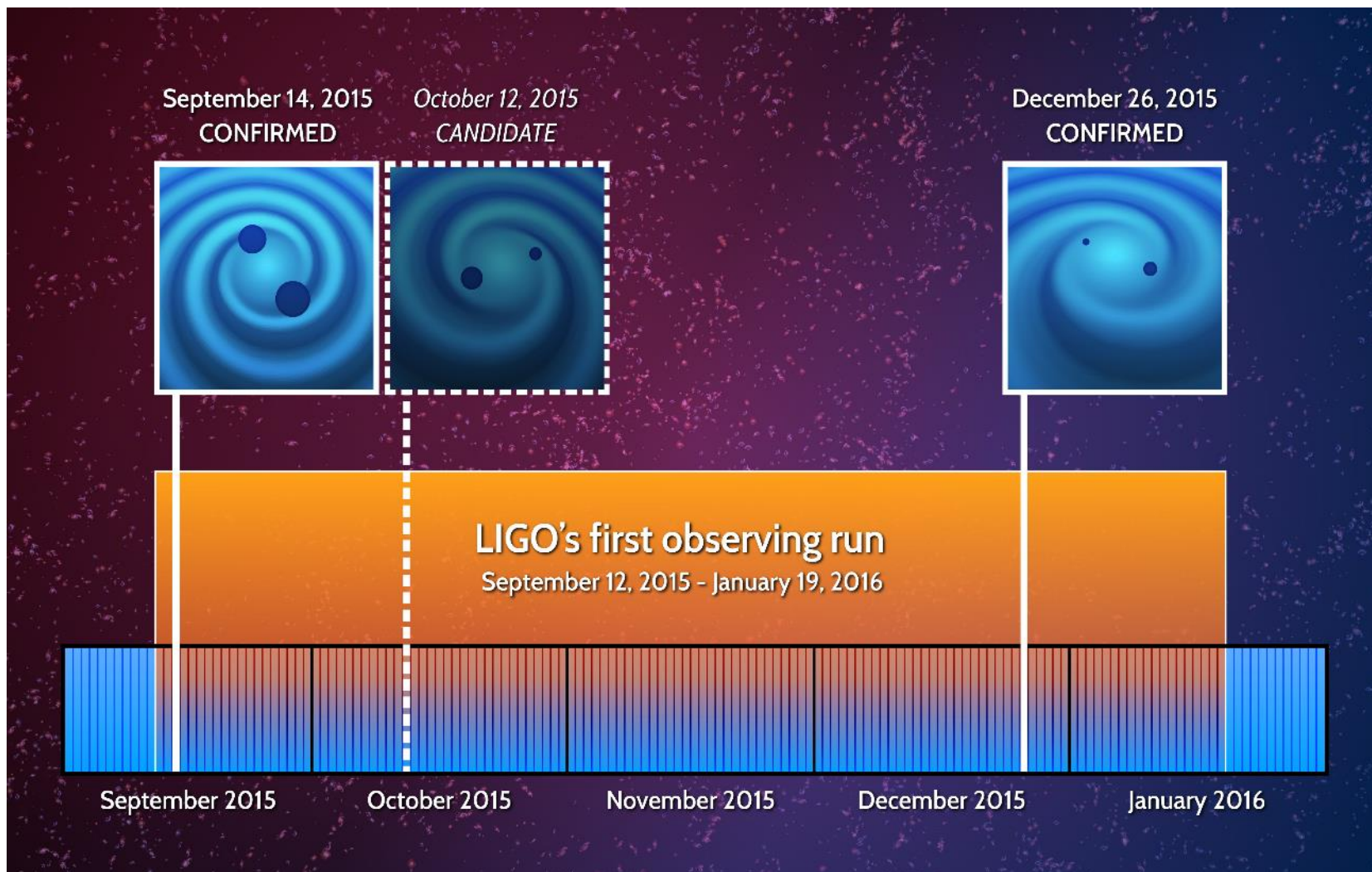
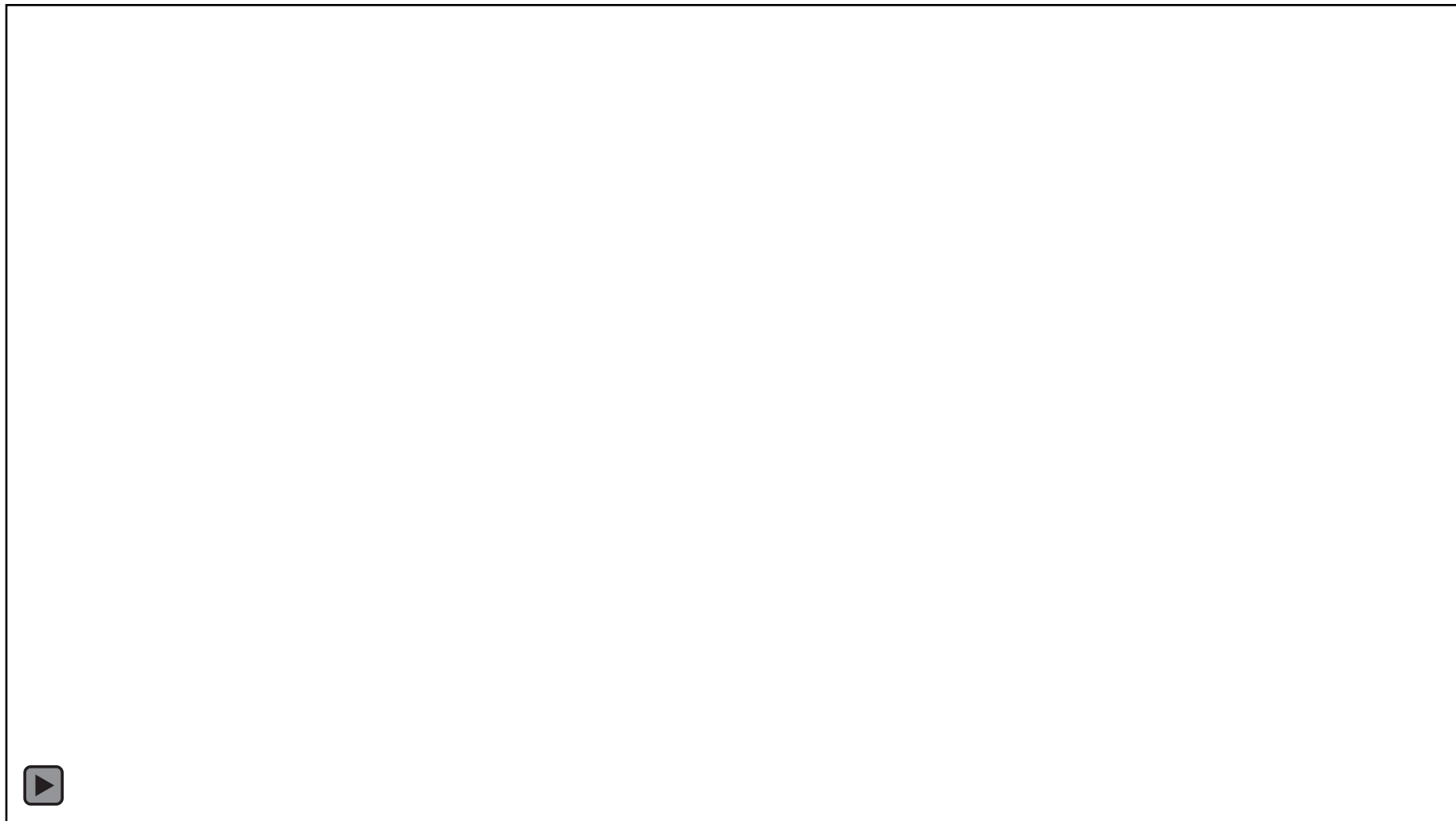


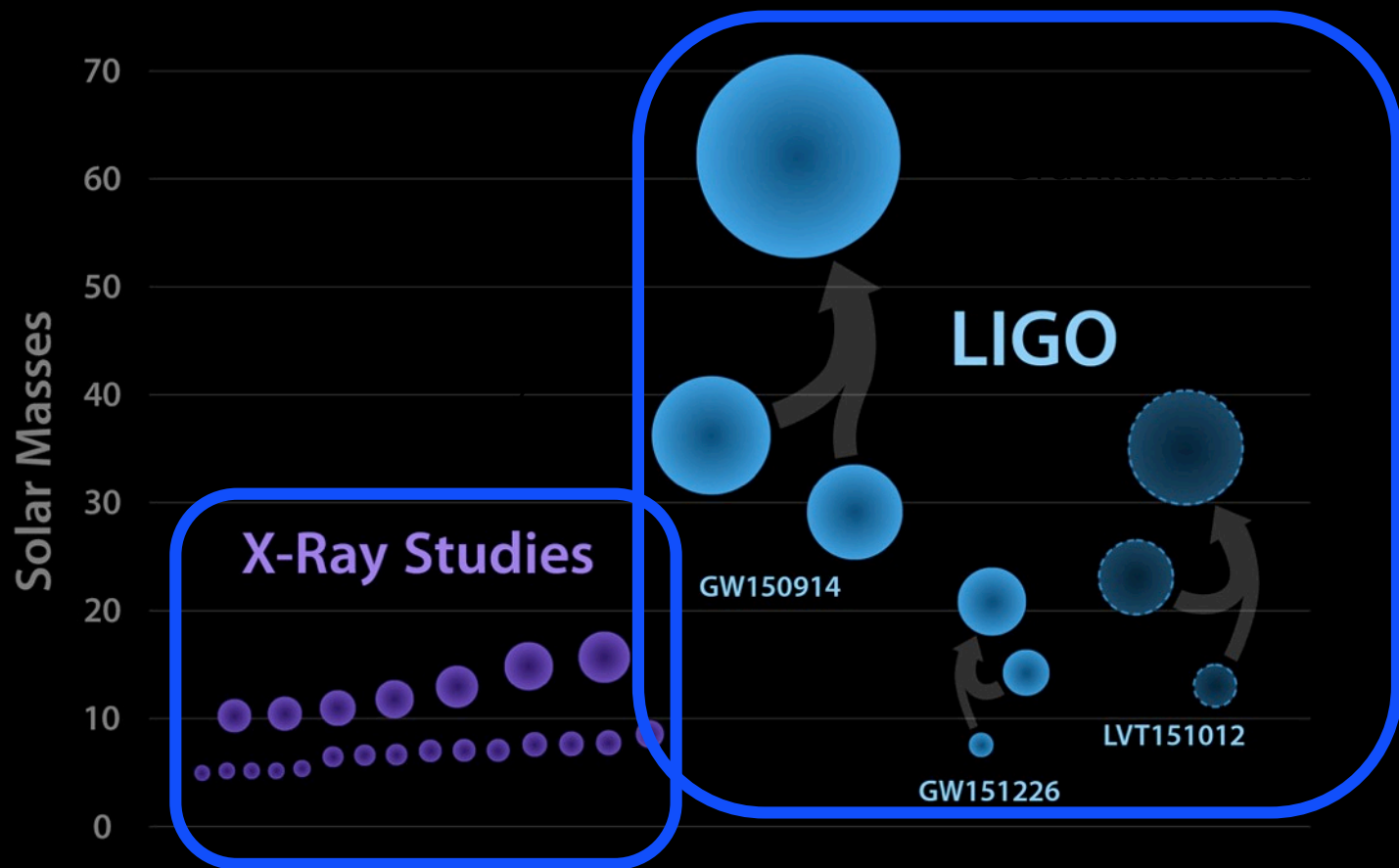
Image credit: LIGO

Gravity's music



The Black Hole Mass Menagerie

Black Holes of Known Mass

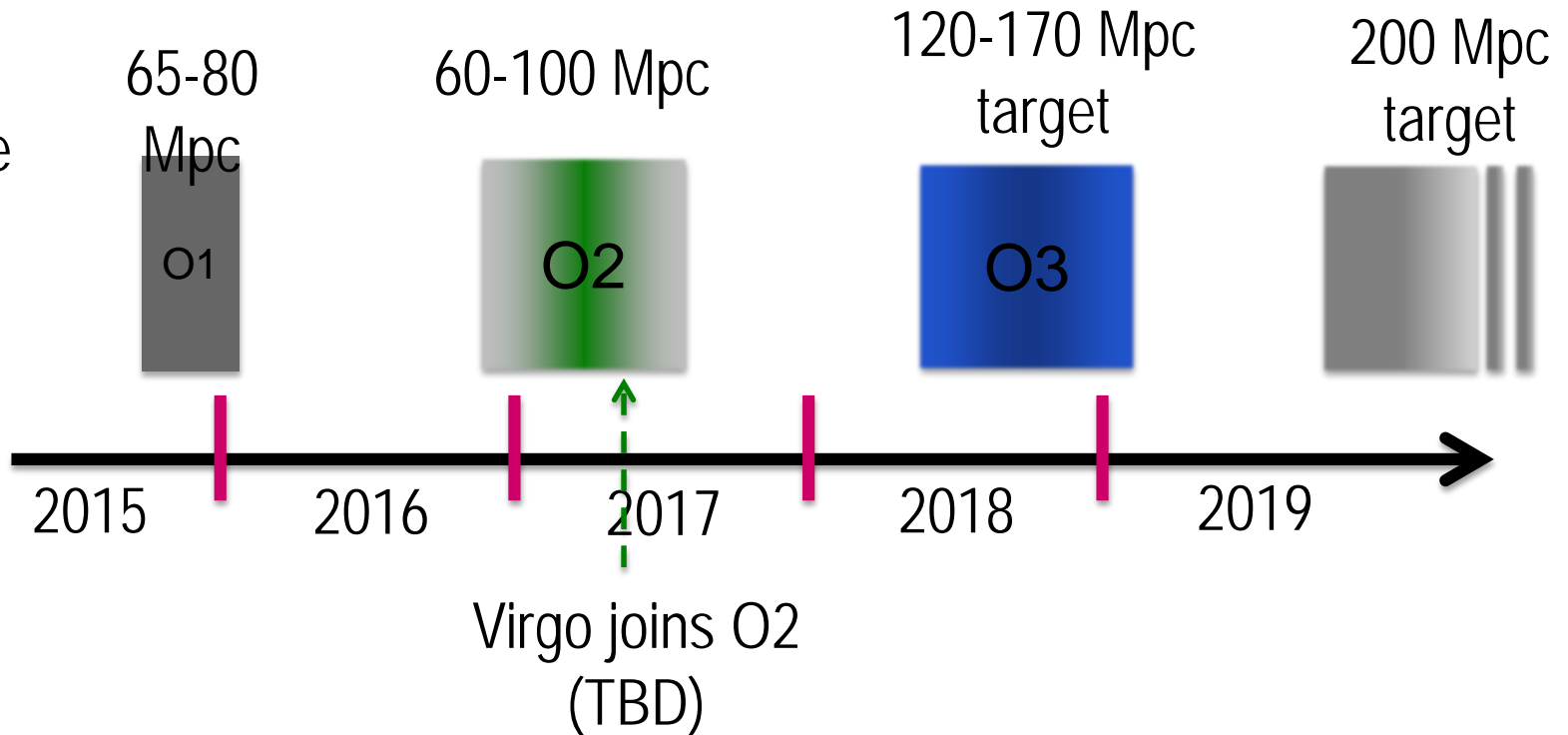


Plausible Observing Run Timeline

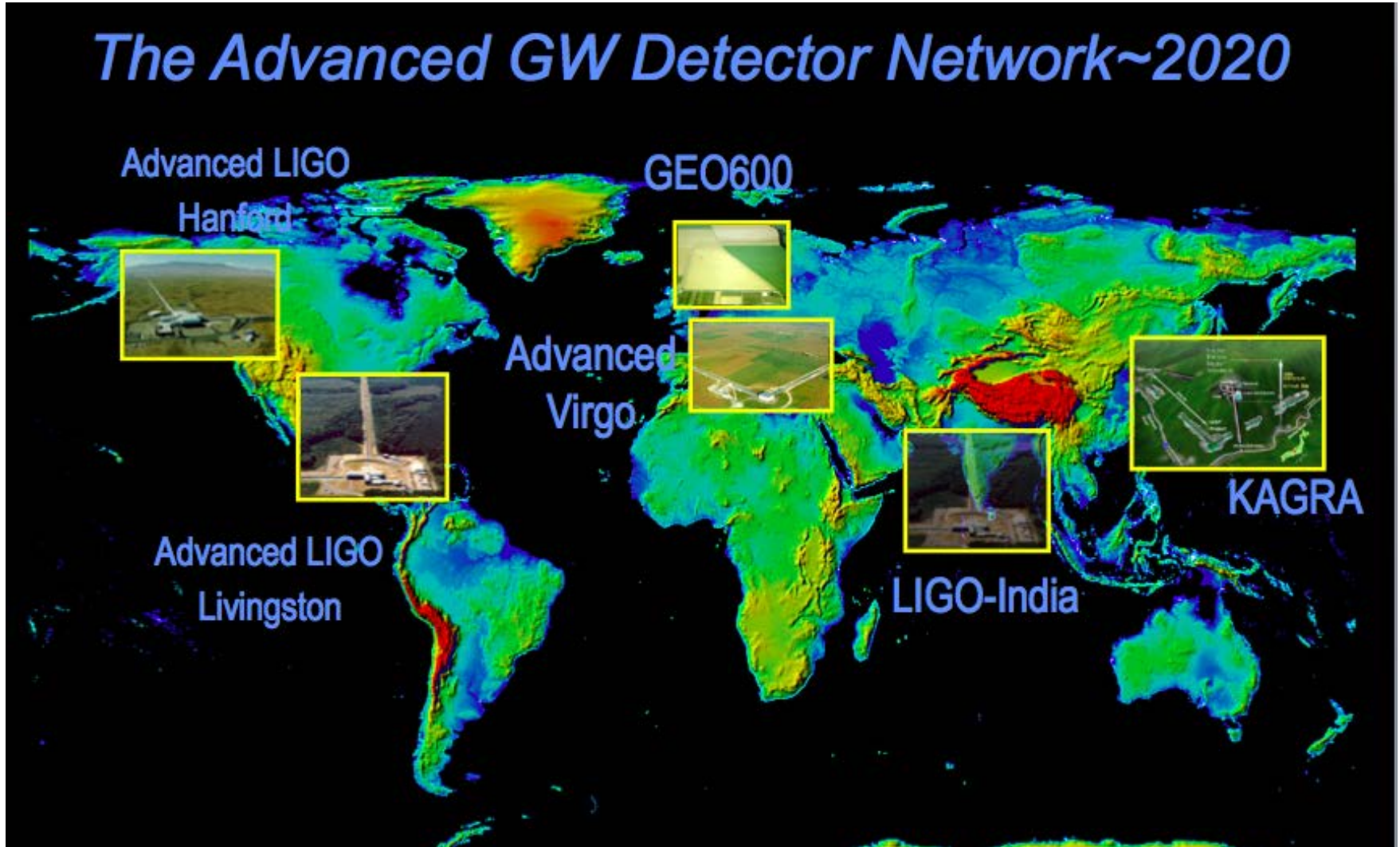


(plans still under development within the LIGO and Virgo Collaborations)

Binary
Neutron
Star range



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



Multi-messenger astronomy: GW/EM observations

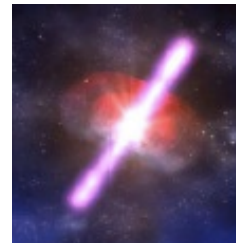
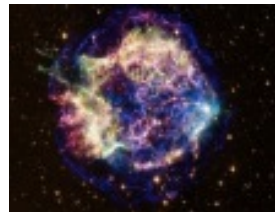


We will obtain rich astrophysics combining gravitational-wave and electromagnetic information.

- 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 have more than 60 agreements 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: dcc.ligo.org, LIGO-M1200055
- We have made initial LIGO data public (losc.ligo.org), and will make Advanced LIGO data public after curated and a proprietary period.



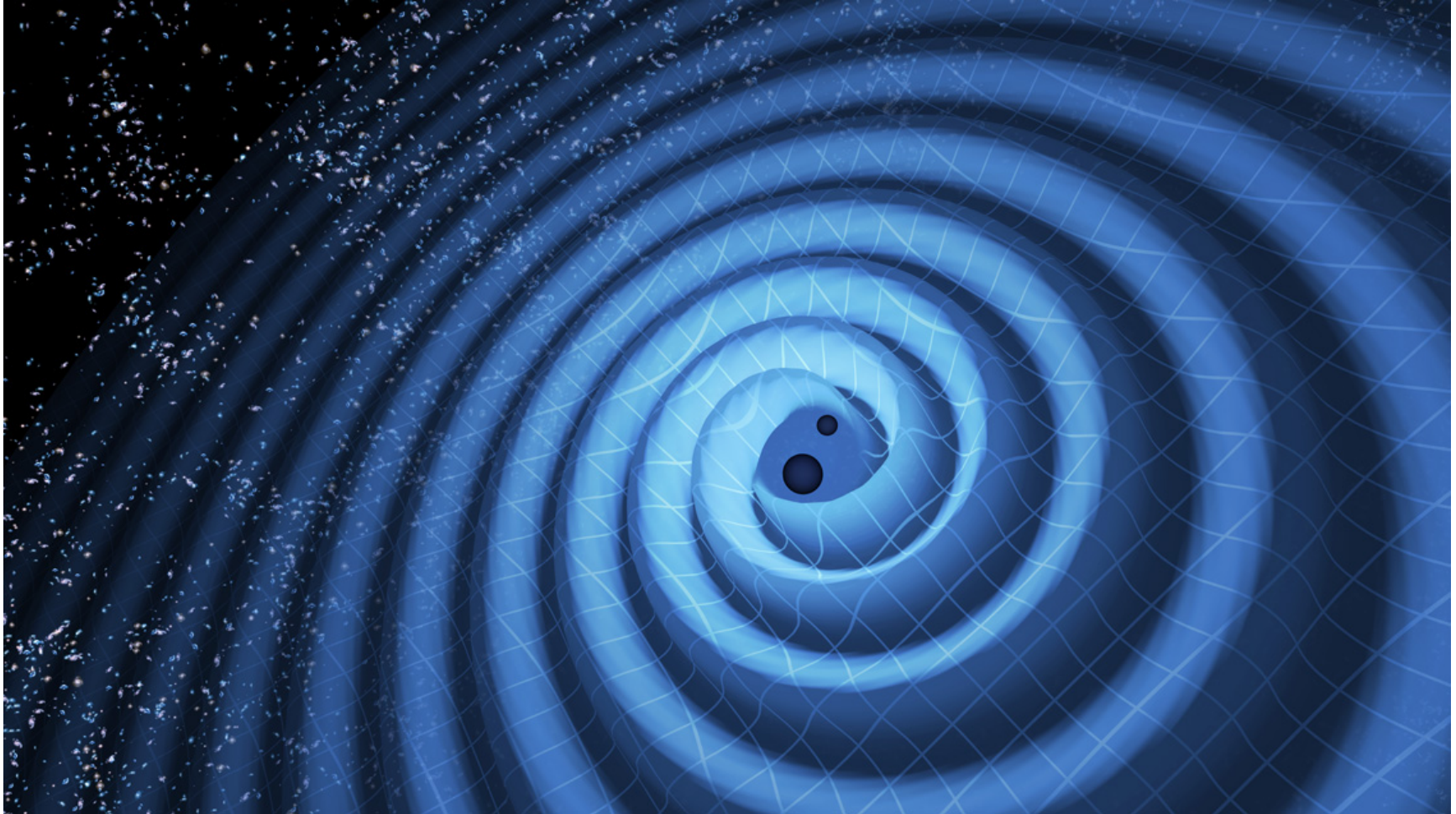
LIGO-G1700796



Conclusions

- Although atypical, the LSC model with an open and international collaboration created around a “LIGO Laboratory” has been very successful.
- Large size has already many challenges. More challenges lie ahead: collaboration model is evolving in the presence of detections and open data, funding for future detectors, ...
- The field will always need a large collaborative team working on operations, timely science analysis, and R&D ready for installation in new detectors, as well innovative methods for analysis and research on new technologies.

Gravitational waves astronomy: this is just the beginning!



www.ligo.org