Doing outreach with the first direct observation of gravitational waves

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Outline

- The first two direct detections of gravitational waves (GWs)
  - GW150914
  - GW151226
- Discovery announcement
  - Players
  - Audiences
  - Strategy
  - Means & difficulties
  - Results
- Outreach resources
- Activities
- Outlook

Caveat: **many E&O actions are done at the institution level: they are not covered here.**

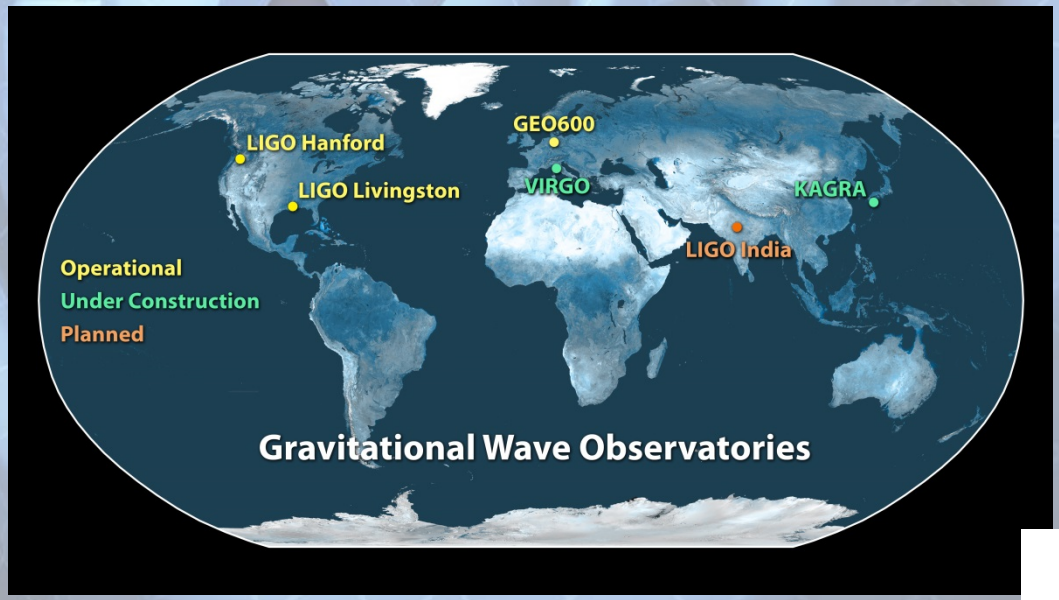
NATURE PHYSICS | VOL 12 | JUNE 2016 | www.nature.com/naturephysics

commentary

Defining gravity

Joey Shapiro Key and Martin Hendry

The announcement confirming the discovery of gravitational waves created sensational media interest. But educational outreach and communication must remain high on the agenda if the general public is to understand such a landmark result.

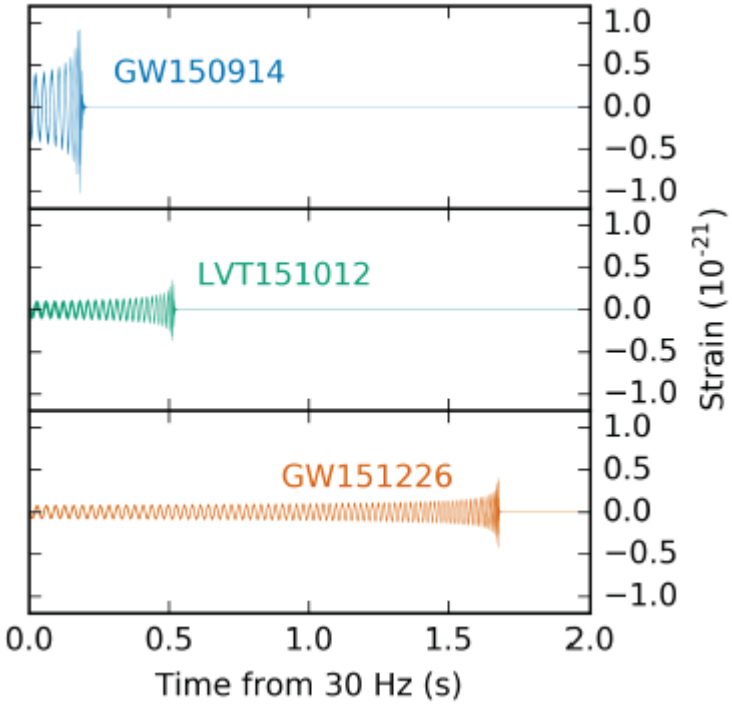


First direct detections of gravitational waves

- Two binary black hole (BBH) coalescences
  - Recorded by the two Advanced LIGO detectors
  - Announced by the LIGO Scientific Collaboration and the Virgo Collaboration

Event	Recorded	Announced
GW150914	2015/09/14	2016/02/11
GW151226	2015/12/26	2016/06/15

- Plus a BBH candidate, LVT151012



- First direct detection of GWs
- First direct detection of BHs
- First detection of BHs in this mass range
- First detection of BBHs

- More information
  - Astro-particle Physics and Cosmology parallel session
    "Gravitational Wave Detection: Present and Future" [This morning]
  - Plenary talk [Monday morning]
  - Public lecture [Tuesday night]

Preparing the discovery announcement

- GW150914
  - 3 minutes after data recorded: event identified online as promising
  - Within a day: strong BBH candidate

    Extensive data analysis to make the detection case rock-solid
    Communication & outreach: all hands on deck!
    → Education and Public Outreach (EPO) working group
  - 5 months later: detection announcement

- Many players involved
  - LIGO Observatories
    GEO600 Collaboration
    LIGO Scientific Collaboration
  - Virgo Collaboration
    European Gravitation Observatory (EGO)

1000+ scientists
→ LVC: LIGO-Virgo Collaboration (MOU, 2007)

- Funding agencies (USA, UK, Germany, Spain, France, Italy, etc.)
- Labs & universities

Discovery announcement strategy

- Keep everything secret/internal to the LVC
  - Any analysis/check could turn the promising GW candidate into a false alarm
    → Hope for no (major) leak
    If any, use the (true!) reply:
    analysis in progress, results to be made public when analysis complete
  - In the end: minor annoyance, no change of plan needed
- Target different audiences
  - Scientific community
    → GW discovery = completion of a century-long quest
  - General audience
    → Little or no scientific knowledge
  - High-school teachers and students
- Develop a wide set of educational resources
  - From basic schematics and analogies, to science summaries of publications
- Use social media to promote the scientific results and the associated E&O
  - Twitter, Facebook, Reddit
- Reference: announcement of the H boson discovery by the LHC experiments

Discovery announcement strategy

- Write a discovery article
  - Have it accepted by PRL prior to annoucing the discovery

  → Target date: February 11, first day of the AAAS Annual Meeting in D.C. (American Association for the Advancement of Science)
- Plus several « companion papers » focusing on the various aspects of the analysis

- Simultaneous announcements worldwide
  - Two main press conferences: Washington D.C. (LIGO) & Cascina (Virgo site)
  - Several satellite press briefings – e.g. CNRS headquarters, Paris

- At what time?
  - Beware of time zone differences! Compromise: 10.30 US EST

  → Early on the West Coast (07:30), quite late in Europe (16:30) for evening news

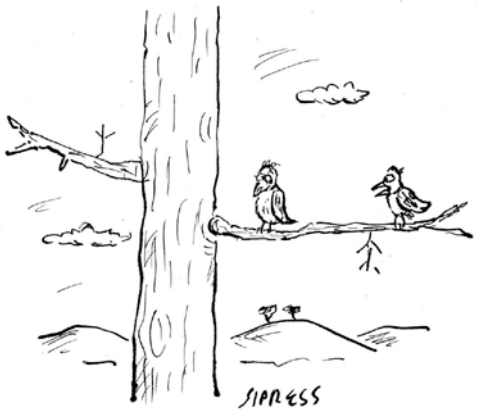
- Coordinated press releases
  - Compulsory parts, which must be included in all press releases

    → In particular: common start for all releases
  - Additional text written at the discretion of the organization issuing the release

  → Translation in as many languages as possible

GW150914 announcement: facts and figures

- Among the Newseum front page archives http://www.newseum.org
  - One of the few positive events listed…
- 200+ journalists followed the announcement
  - Either in person or through webcasts
- O(5,000) press articles in the world
  - From daily newspapers to magazines
- > 500,000 internet users watched webcasts



"Was that you I heard just now, or was it two black holes colliding?"

© The New Yorker 2016/02/12

Orlando Nightclub Shooting

June 14, 2016

June 13, 2016

Muhammad Ali, 1942-2016

June 11, 2016

June 5, 2016

Journalists Memorial Rededication

June 6, 2016

June 8, 2015

Prince Dies

April 22, 2016

Terrorists Attack Brussels

March 23, 2016

Ronald (1911-2004) and Nancy (1921-2016) Reagan

March 7, 2016

June 6, 2004

Justice Antonin Scalia Dies

Feb. 14, 2016

Discovery of Gravitational Waves

Feb. 12, 2016

San Bernardino Shooting

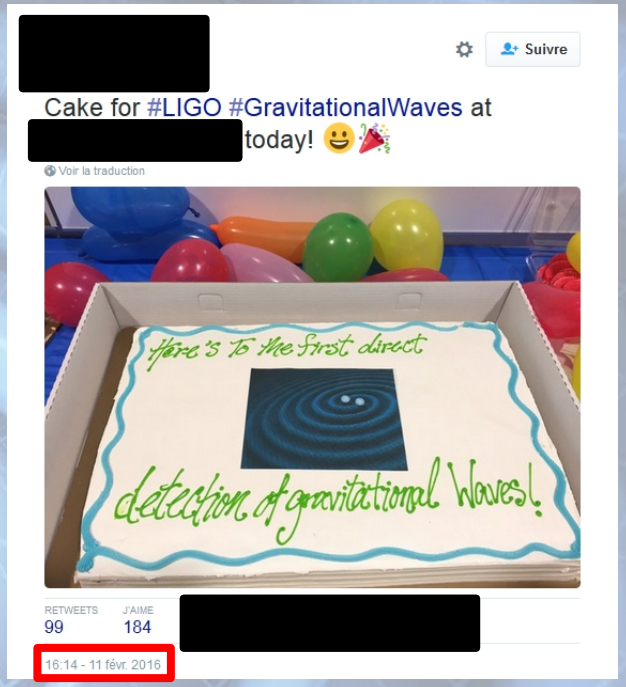
Dec. 4, 2015

Dec. 3, 2015

961 front pages

GW150914 announcement: facts and figures

- Twitter
  - 70 million impressions for #gravitationalwaves, #LIGO, and #EinsteinWasRight
  - 10 million for #ondesgravitationnelles
  - Followers!
    @ligo: < 3,000 → 25,000+ (after GW151226)
    @ego_virgo: < 100 → 1,000+
  - Mentions/retweets/likes from celebrities
    → e.g. @POTUS
- Facebook
  - New followers as well: 9K for LIGO, 1K for Virgo
- Reddit
  - AMA (Ask Me Anything) live sessions following both announcements
- Astronomy Picture of the Day
  - 1M+ views in the week following GW150914
- No Google doodle (yet!?)



GW150914 announcement: facts and figures

- Press release translated into 18 languages
- Multilingual science summaries

LSC LIGO Scientific Collaboration VIRGO

OBSERVATION OF GRAVITATIONAL WAVES FROM A BINARY BLACK HOLE MERGER

Albert Einstein's general theory of relativity, first published a century ago, was described by physicist Max Born as "the greatest feat of human thinking about nature". We report on two major scientific breakthroughs involving key predictions of Einstein's theory: the first direct detection of **gravitational waves** and the first observation of the collision and merger of a pair of **black holes**.

This cataclysmic event, producing the gravitational-wave signal **GW150914**, took place in a distant galaxy more than one billion light years from the Earth. It was observed on September 14, 2015 by the two detectors of the **Laser Interferometer Gravitational-wave Observatory** (LIGO), arguably the most sensitive scientific instruments ever constructed. LIGO estimated that the peak gravitational-wave power radiated during the final moments of the black hole merger was more than ten times greater than the combined light power from all the stars and galaxies in the observable Universe. This remarkable discovery marks the beginning of an exciting new era of astronomy as we open an entirely new, gravitational-wave, window on the Universe.

INTRODUCTION AND BACKGROUND

Gravitational waves are 'ripples' in space-time produced by some of the most violent events in the cosmos, such as the collisions and mergers of massive compact stars. Their existence was predicted by Einstein in 1916, when he showed that accelerating massive objects would shake space-time so much that waves of distorted space would radiate from the source. These ripples travel at the speed of light through the Universe, carrying with them information about their cataclysmic origins, as well as invaluable clues to the nature of gravity itself.

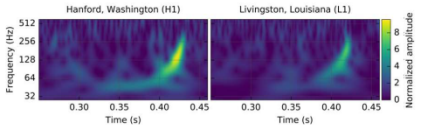


Figure 1. *(Adapted from Figure 1 of our publication). The gravitational wave event GW150914 observed by the LIGO Hanford (H1, left panel) and LIGO Livingston (L1, right panel) detectors. The two plots show how the gravitational wave strain (see below) produced by the event in each LIGO detector varied as a function of time (in seconds) and frequency (in hertz, or number of wave cycles per second). Both plots show the frequency of GW150914 sweeping sharply upwards, from 35 Hz to about 150 Hz over two tenths of a second. GW150914 arrived first at L1 and then at H1 about seven thousandths of a second later – consistent with the time taken for light, or gravitational waves, to travel between the two detectors.*

Over the past few decades astronomers have amassed strong supporting evidence that gravitational waves exist, chiefly by studying their effect on the motions of tightly orbiting pairs of stars in our Galaxy. The results of these indirect studies agree extremely well with Einstein's theory – with their orbits shrinking, exactly as predicted, due to the emission of gravitational wave energy. Nevertheless the *direct* detection of gravitational waves as they reach the Earth has been hugely anticipated by the scientific community as this breakthrough would provide new and more stringent ways to test general relativity under the most extreme conditions and open up an entirely novel way to explore the Universe.

In the same year that Einstein predicted gravitational waves, the physicist Karl Schwarzschild showed that Einstein's work permitted the existence of **black holes**: bizarre objects which are so dense and so compact that not even light can escape their gravitational field. Although by definition we cannot directly 'see' light from a black hole, astronomers have gathered a great deal of circumstantial evidence for their existence by studying the effects of black hole candidates on their immediate surroundings. For example, it is thought that most galaxies in the Universe, including the Milky Way, contain a **supermassive black hole** at their center – with masses millions or even billions of times that of the Sun. There is also evidence of many black hole candidates with much lower masses (ranging from a few, to a few dozen, times the Sun's mass), believed to be the remnants of dead stars that have undergone a cataclysmic explosion known as a **core-collapse supernova**.

Alongside this substantial progress in the indirect *observation* of black holes, there have been dramatic improvements in our *theoretical* understanding of these bizarre objects – including, over the past decade, some remarkable advances in modeling a pair of black holes (referred to as a binary) through several close orbits before they finally merge. These computer models have allowed us to construct precise **gravitational waveforms** – i.e. the pattern of gravitational waves emitted by the black holes as they approach ever closer and finally merge into a single, larger black hole – in accordance with the predictions of general relativity. The direct observation of a binary black hole merger would therefore provide a powerful cosmic laboratory for testing Einstein's theory.

Visit our website at http://www.ligo.org/

#GravitationalWaves
#BinaryBlackHole
#EinsteinWasRight

GRAVITATIONAL WAVES DETECTED 100 YEARS AFTER EINSTEIN'S PREDICTION
LIGO Opens New Window on the Universe with Observation of Gravitational Waves from Colliding Black Holes

WASHINGTON, DC/Cascina, Italy

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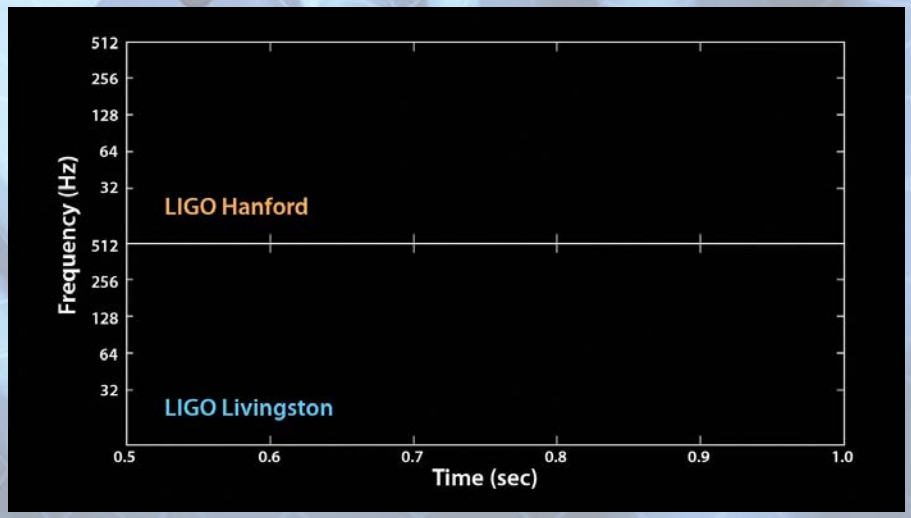
LIGO neegIyinnim maani xistsiiguumsdan amuu spoohts essatsimyaa Abuduuxbiisiiya o?bigimskAAsts muustsk nAbuutsbiiya sigooxgiya

Washington, DC/Cascina Italy

Siksika (Blackfoot Indians, Canada)

- Graphical and multimedia resources



Educational resources & activities

- A variety of projects
  - Developed either before the detections, or to go along with them
    → Only a sample presented in this talk
  - New projects in preparation as well

- For more information
  - LIGO labs: https://www.ligo.caltech.edu/page/educational-resources
  - LSC: http://www.ligo.org/public.php
  - Virgo: http://public.virgo-gw.eu/language/en

- question@ligo.org: forum to ask questions
  - Hundreds of questions answered so far

- LOSC : LIGO Open Science Center
- Educational activities
- Site visits
- Magazines & medias
- Online resources
- Citizen science
- Serious games & apps

LOSC: LIGO Open Science Center

- https://losc.ligo.org/about

- 1 hour of data released for both events
  - The GW channel « h(t) »
  - Along with the discovery announcement

- Tutorials
  - Python-based
  - Technical difficulty adapted to the user

More discoveries from LIGO!

Data Releases from two events and a candidate event

released 2016 June 15:
Event of December 26, GW151226: Chirp mass 9

released 2016 June 15:
Candidate event of October 12, LVT151012: Chirp mass 15

released 2016 Feb 11:
Event of September 14, GW150914: Chirp mass 30

The LIGO Laboratory's Data Management Plan describes the scope and timing of LIGO data releases.

Jupyter notebook
See the new tutorial on signal processing with LIGO data, as a Jupyter (iPython) notebook.
Tutorial on Binary Black Hole Signals in LIGO Open Data

Data release for event GW150914

This page has been prepared by the LIGO Scientific Collaboration (LSC) and the Virgo Collaboration to inform the broader community about a confirmed astrophysical event observed by the gravitational-wave detectors, and to make the data around that time available for others to analyze. There is also a **technical details** page about the data linked below, and feel free to **contact us**. This dataset has the Digital Object Identifier (doi) http://dx.doi.org/10.7935/K5MW2F23

Summary of Observation

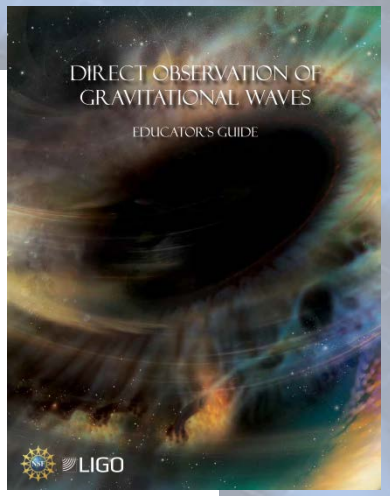
The event occurred at GPS time 1126259462 == September 14 2015, 09:50:45 UTC. The false alarm rate is estimated to be less than 1 event per **203,000 years**, equivalent to a significance of **5.1 sigma**. The event was detected in data from the LIGO Hanford and LIGO Livingston observatories.

- There are Science Summaries, covering the information below in ordinary language.
- There is a one page factsheet about GW150914, summarizing the event.

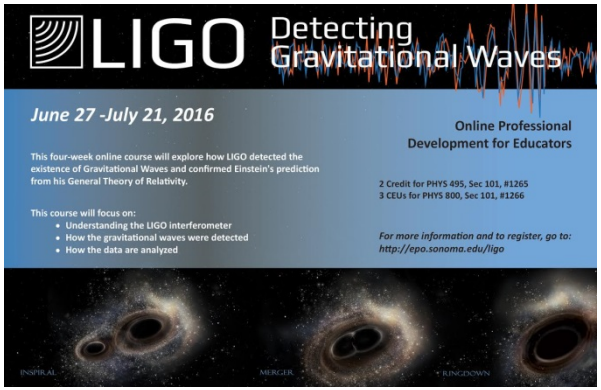
How to Use this Page

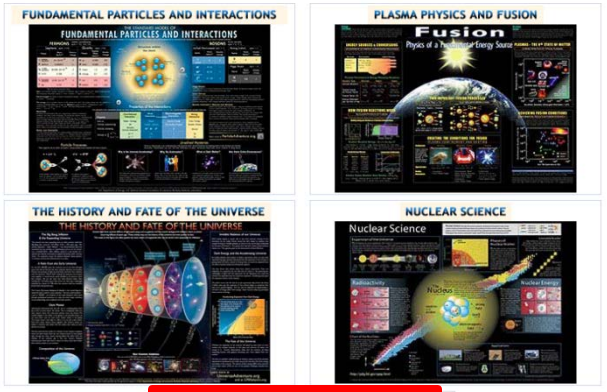
- **Click on the section headings below to show available data files.**
  - (click to Open/Close all sections)
- There are lots of data files available in the sections below, look for the word **DATA**.
- Click on each thumbnail image for larger image.
- See the papers linked below for full information, references, and meaning.
- Many of the data files linked below have heterogeneous formatting; if you have any questions, please contact us.

Educational activities



- Many resources available through ligo.org and the Observatory websites
  - See URLs on slide 10
- GW Educator's guide
  - http://www.cpepphysics.org/images/LIGOEdGuide_Final.pdf
  - Updated to include the GW detection
- 4-week online course [last month]
  - 2015 course: https://universe.sonoma.edu/cosmo/course/view.php?id=3

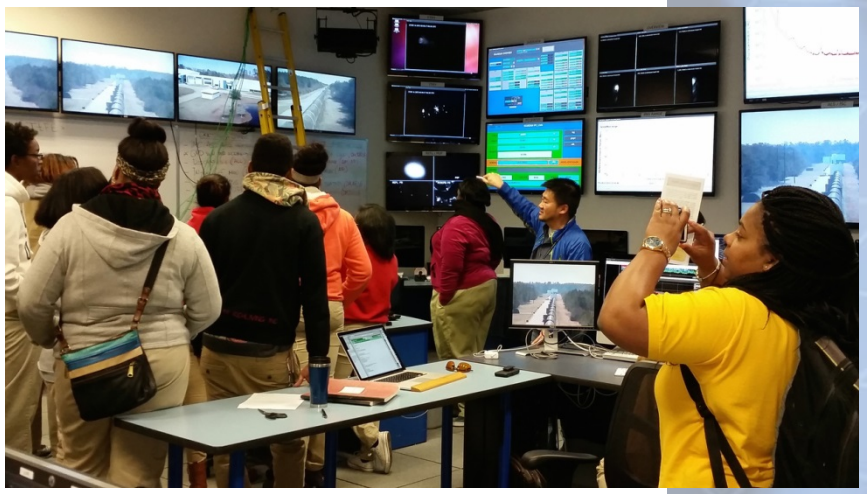




- CPEP poster to be released soon
  - http://www.cpepphysics.org/gravitation.html
  - Gravitation + GW detection

Site visits

- GW Observatories can be visited
  - LIGO Hanford: https://www.ligo.caltech.edu/WA/page/lho-tours
  - LIGO Livingston: https://www.ligo.caltech.edu/LA/page/Tours
    → https://www.ligo.caltech.edu/LA/page/Science-Education-Center
  - EGO / Virgo: http://public.virgo-gw.eu/visit-us



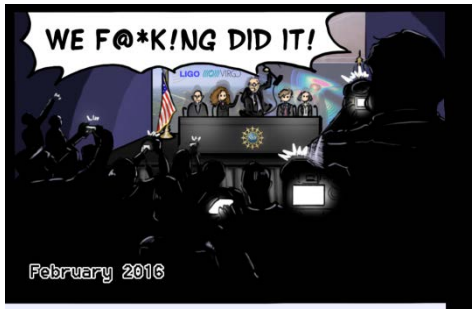
- Constraints
  - Site locations – countryside
  - Limited manpower available
  - Seismic vibrations!

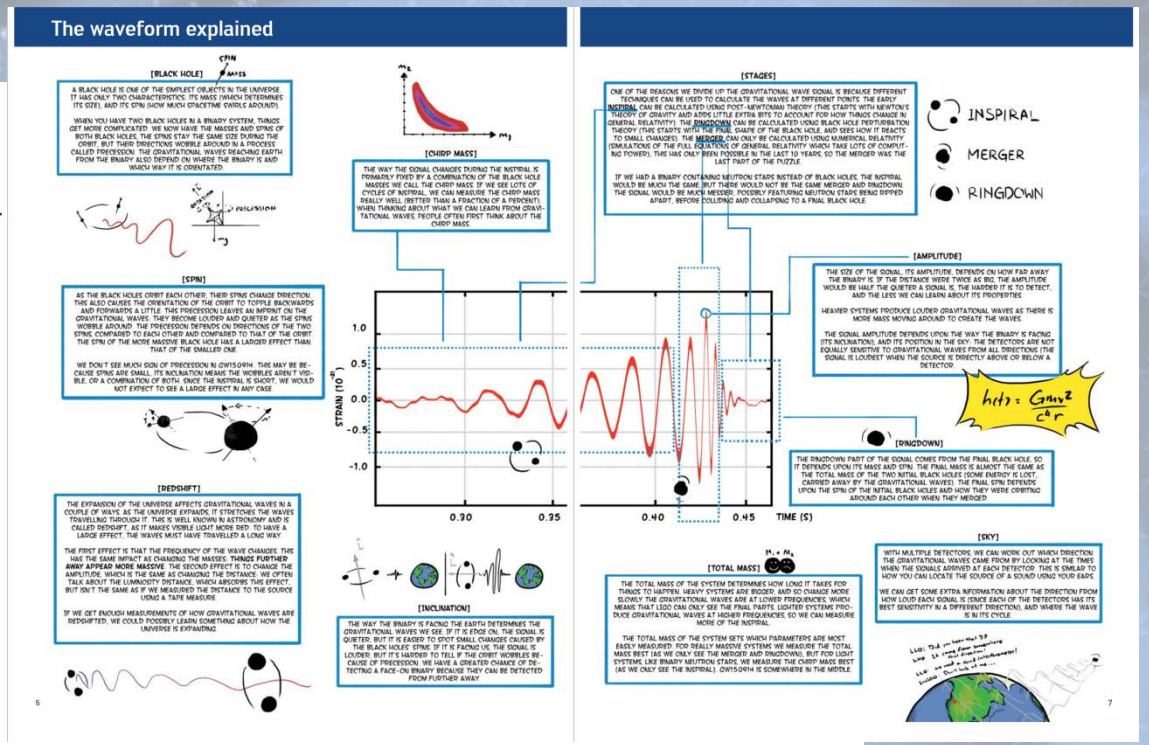
→ Defined timeslots for visits
  - ~Monthly opening days
  - School fied trips and private tours to be booked in advance
  - Special events – e.g. Researchers Night

- Much more requests and larger attendances since discoveries announced
  → Projects to develop virtual visits – both standalone and live

Magazines & medias

- LIGO magazine
  - http://www.ligo.org/magazine
  - Latest issue (8) : March 2016
  - Next issue available soon





- h the gravitational voice

News from EGO and VIRGO

  - http://www.ego-gw.it/public/hletter/hletter.aspx
  - Latest issue (30): April 2016

- Youtube channel
  - https://www.youtube.com/channel/UCMATJmzibndbcdY8s9Prhjg
  - Explainer videos, talks, GW events, sources & simulations

Online resources

- GW150914 and GW151226
  - LIGO: http://ligo.org/detections.php
  - Virgo: https://owncloud.ego-gw.it/index.php/s/WGB7jLJvU9tW7sF

- Well-known online medias
  - Minute physics: https://www.youtube.com/watch?v=YHS9g72npqA
  - PhD comics: http://phdcomics.com/comics/archive.php?comicid=1853

- Misc.
  - Known stellar-mass black holes: https://gravity.astro.cf.ac.uk/plotgw/bhbubble.html
    → Basic information (mass, discovery, etc.) + visual comparison of their « sizes »
  - Gravoscope: http://astrog80.astro.cf.ac.uk/Gravoscope
    → Combine electromagnetic and GW sky maps
  - GWplotter : http://rhcole.com/apps/GWplotter
    → Detector sensitivities and sources
  - Inside Advanced Virgo: https://www.youtube.com/watch?v=6raomYII9P4
  - Sounds of spacetime: http://www.soundsofspacetime.org

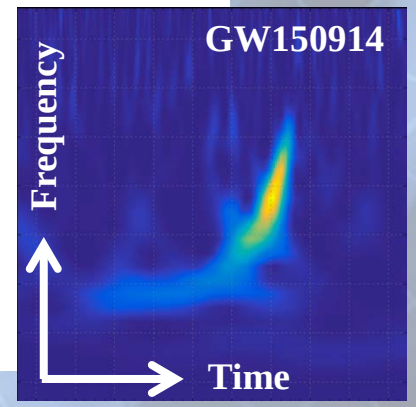
Citizen science

- Einstein@Home project
  - https://www.einsteinathome.org
  - Use computer idle time to look for GW signals coming from pulsars
  - BOINC framework

http://boincstats.com/en/stats/projectStatsInfo

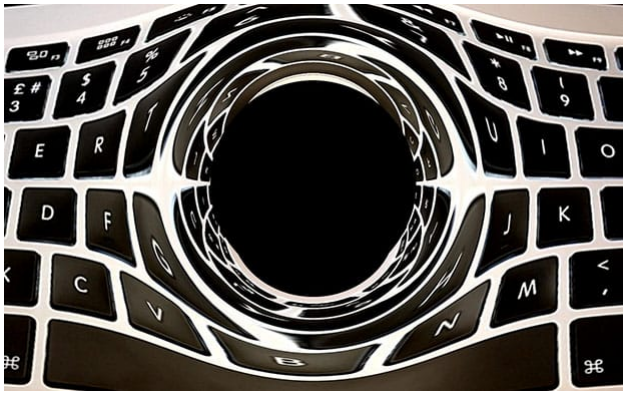
Project name	Users	last day	Hosts	last day	Teams	last day	Countries	last day	Total credit	last day	Last update
BOINC combined	3,859,708	2,505	14,368,301	5,829	105,031	2	277	0	24,001,926,536,329	26,131,517,261	2016-07-24 08:30:41
Bitcoin Utopia	2,645	0	6,862	3	336	0	98	0	20,542,116,997,637	24,043,653,301	2016-07-24 07:10:15
Collatz Conjecture	59,716	11	397,015	34	1,652	1	179	0	584,541,452,909	871,575,986	2016-07-24 06:10:21
PrimeGrid	91,671	9	268,691	31	2,954	1	197	0	498,712,754,118	233,456,859	2016-07-24 06:10:16
GPUGRID	30,780	4	62,466	0	1,523	1	155	0	416,156,950,753	200,691,350	2016-07-24 05:10:11
SETI@Home	1,636,237	166	4,026,091	443	63,705	1	233	0	351,564,716,811	144,054,215	2016-07-23 22:14:06
MilkyWay@home	203,497	16	459,228	46	4,169	0	214	0	271,971,023,377	42,529,640	2016-07-24 06:10:38
Einstein@Home	435,566	69	1,550,014	174	11,398	1	226	0	251,169,301,879	172,851,162	2016-07-24 08:10:56
World Community Grid	509,398	41	2,651,820	411	24,900	2	225	0	216,115,277,893	100,945,150	2016-07-24 01:11:12
POEM@HOME	57,018	13	1,273,374	1,986	1,816	0	183	0	135,236,001,800	131,143,710	2016-07-24 07:10:15

- Gravity Spy [*coming soon!*]
  - https://daily.zooniverse.org/2016/02/19/coming-soon-gravity-spy
  - Users will help classifying instrumental noise transients using time-frequency maps of the glitches
    → Background identification and removal is a key task to improve the detector sensitivity to real GW signal
  - Zooniverse portal



Serious games & apps

- Black hole hunter: http://www.blackholehunter.org
  - Listen to audio files, look for compact binary coalescence signals buried in noise
- Space time quest: http://www.gwoptics.org/processing/space_time_quest
  - Simulation game to design a GW detector
- Black Hole Pong: http://www.gwoptics.org/processing/blackhole_pong
  - Use black hole gravity to deflect a ball and score
- Pocket Black Hole: https://www.laserlabs.org/pocketblackhole.php
  - Distort pictures by mimicking light-bending effects of a black hole



- Stretch and squash: https://www.laserlabs.org/stretchandsquash.php
  - Shows how GW distort space-time

Outlook

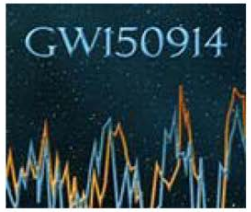
- A wide range of E&O activities related to GW and GW detection by giant interferometric detectors

- First two discoveries changed everything
  - K. Thorne, 1983:
    "*That the quest ultimately will succeed seems almost assured. The only question is when and with how much further effort .*"
  - D. Reize, 2016/02/11:
    "*Ladies and gentlemen. We have detected gravitational waves. We did it!*"
  - More audience
  - Real data (and excitement) to share

- More observation runs to come
  - Improved detector sensitivity
  - Global network of instruments
    + electromagnetic follow-up
    → Source sky localization

→ Dawn of the GW astronomy

Visit the Cafepress online shop:
http://www.cafepress.com/ligosc
A way to raise funds for E&O



GW150914
GW150914 accessories and gifts

LSC and LIGO

LIGO Virgo