GWOSC: Gravitational Wave Open Science Center

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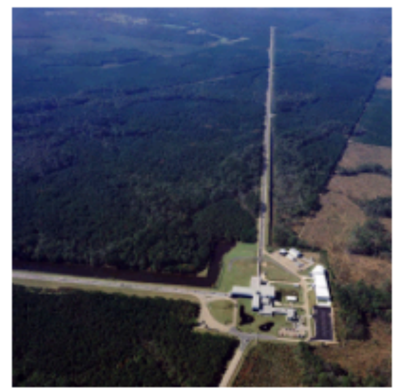
GWOSC

https://www.gw-openscience.org/

Gravitational Wave Open Science Center

- Getting Started
- Data
  - Catalogs
  - Bulk Data
- Tutorials
- Software
- Detector Status
- Timelines
- My Sources
- GPS ↔ UTC
- About the detectors
- Projects
- Acknowledge GWOSC


LIGO Hanford Observatory, Washington
(Credits: C. Gray)


LIGO Livingston Observatory, Louisiana
(Credits: J. Giaime)


Virgo detector, Italy
(Credits: Virgo Collaboration)

The Gravitational Wave Open Science Center provides data from gravitational-wave observatories, along with access to tutorials and software tools.

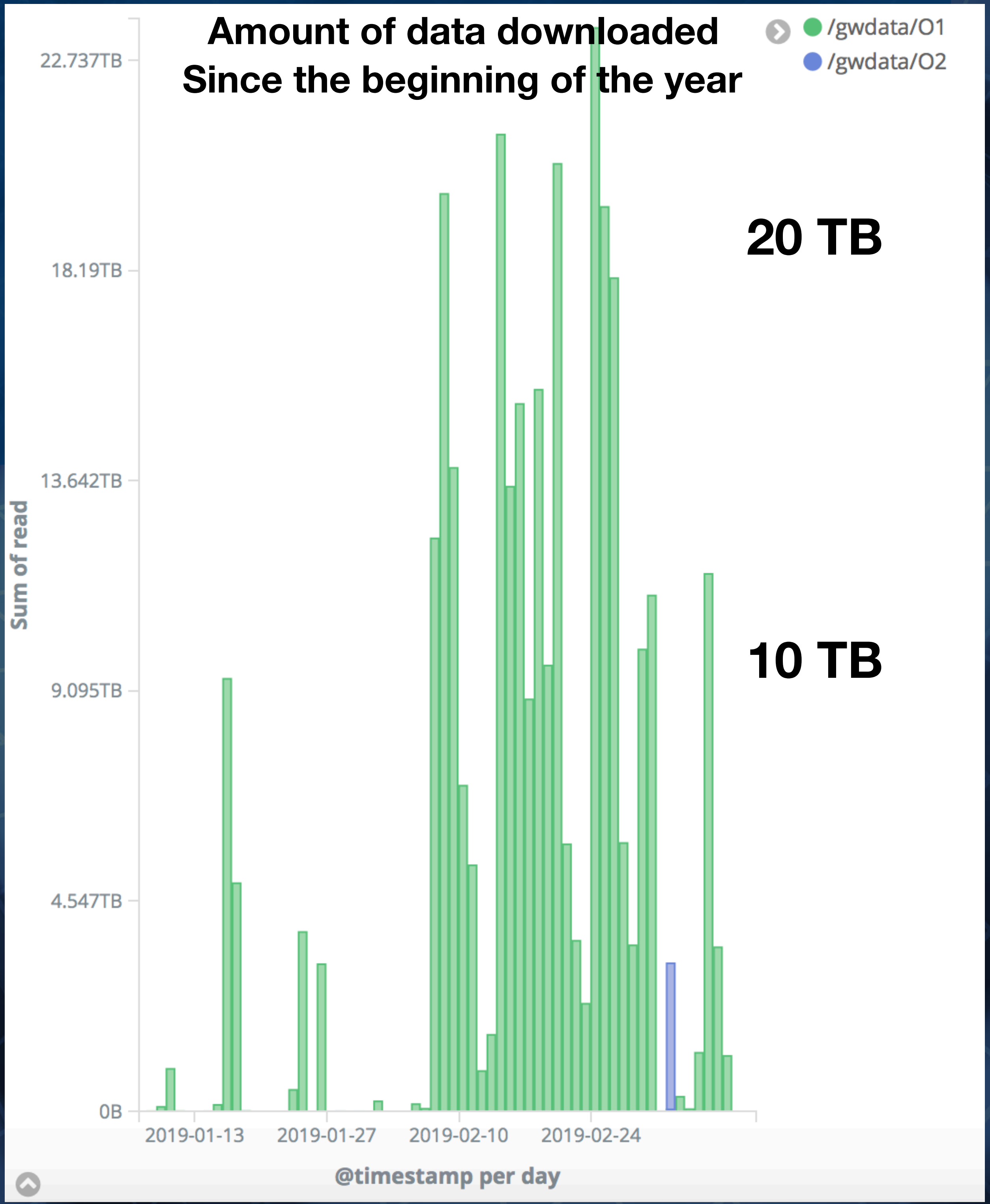
- NEW **O2 Bulk Data Release!**
- **Get started!**
- **Download data**
- **GWTC-1: Catalog of Compact Binary Mergers**
- **Join the email list**
- **Attend an open data workshop**

Importance of Open Science:

- Public owns the data
- Maximize discovery
- Multi-messenger astronomy
- Wider community

GWOSC Impact

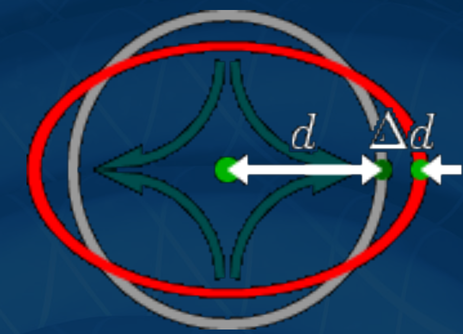
- Examples of projects using GWOSC data: https://www.gw-openscience.org/projects/
  - ✓ Scientific papers (about 50 at the moment)
  - ✓ Pioneer Academics student projects
  - ✓ iPhone App: Gravitational Wave Events
  - ✓ Online Course
  - ✓ Art installation



LIGO/Virgo data

- LIGO/Virgo data: strain, data quality and hardware injections
- LIGO/Virgo data are arranged in files provided in different formats:
    - HDF5: easily readable in python, MATLAB, C/C++, and IDL
    - Frame format (.gwf)
    - Text file

Reminder: strain



$$h = \frac{\Delta d}{d} = \frac{\textit{change in relative position}}{\textit{separation}}$$

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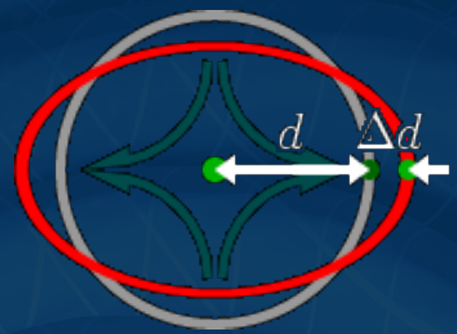
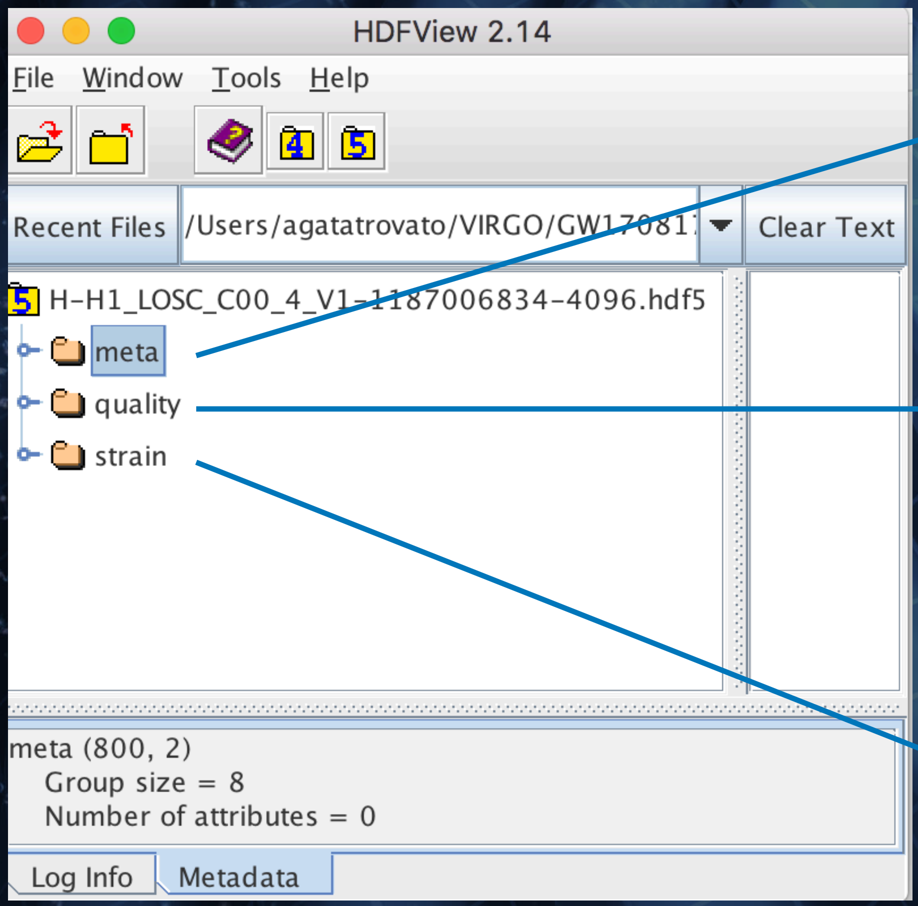


$$h = \frac{\Delta d}{d} = \frac{\textit{change in relative position}}{\textit{separation}}$$

You can use HDFView to quickly see what is inside the file



Meta-data for the file. This is basic information such as the GPS times covered, which instrument, etc.

Refers to data quality. The main item here is a 1 Hz time series describing the data quality for each second of data.

Strain data from the interferometer. In some sense, this is "the data", the main measurement performed by LIGO/Virgo.

GWOSC releases

- Open data can be found at https://www.gw-openscience.org
- Two different types of data release:

Gravitational wave data surrounding discoveries

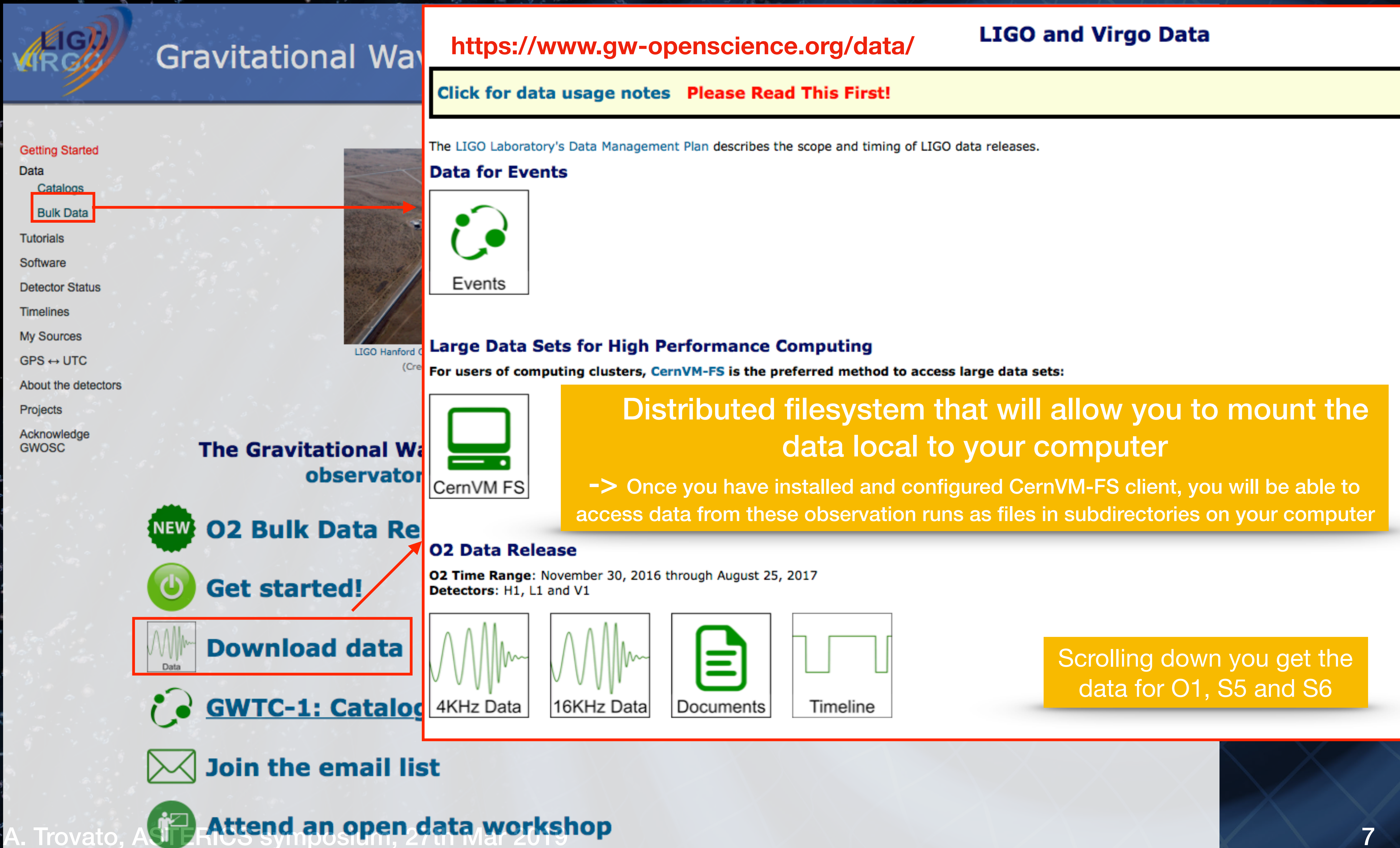
Data taken during a whole observation run

- Some releases:

**BBH = Binary Black Hole*
***BNS = Binary Neutron Star*

Data	Date of release
GW150914: First Observed BBH*	Feb 2016
GW170817: First Observed BNS**	Oct 2017 (about 60 days after the discovery)
First Observing run, **O1** (Sep 2015 - Jan 2016)	Jan 2018
GWTC-1 Catalog (O1 + O2 detections)	Dec 2018
Second Observing run, **O2** (Nov 2016 - Aug 2017)	Feb 2019

GWOSC bulk data



GWTC-1: Gravitational-Wave Transient Catalog of Compact Binary Mergers

- https://www.gw-openscience.org/catalog/
- 11 confident detection + 14 marginal triggers
- Strain data + documentation + auxiliary data products (Skymaps, Parameter Estimation Samples,…)

JSON Parameter Table | Show/hide columns

SORT: PRIMARY MASS (M_SUN) ↑

Event	Primary mass (M_sun)	Secondary mass (M_sun)	Effective inspiral spin	chirp mass (M_sun)	Final spin	Final mass (M_sun)	Luminosity distance (Mpc)	GPS time (s)
GW150914	$35.6^{+4.8}_{-3.0}$	$30.6^{+3.0}_{-4.4}$	$-0.01^{+0.12}_{-0.13}$	$28.6^{+1.6}_{-1.5}$	$0.69^{+0.05}_{-0.04}$	$63.1^{+3.3}_{-3.0}$	430^{+150}_{-170}	1126259462.4
GW151012	$23.3^{+14.0}_{-5.5}$	$13.6^{+4.1}_{-4.8}$	$0.04^{+0.28}_{-0.19}$	$15.2^{+2.0}_{-1.1}$	$0.67^{+0.13}_{-0.11}$	$35.7^{+9.9}_{-3.8}$	1060^{+540}_{-480}	1128678900.4
GW151226	$13.7^{+8.8}_{-3.2}$	$7.7^{+2.2}_{-2.6}$	$0.18^{+0.20}_{-0.12}$	$8.9^{+0.3}_{-0.3}$	$0.74^{+0.07}_{-0.05}$	$20.5^{+6.4}_{-1.5}$	440^{+180}_{-190}	1135136350.6
GW170104	$31.0^{+7.2}_{-5.6}$	$20.1^{+4.9}_{-4.5}$	$-0.04^{+0.17}_{-0.20}$	$21.5^{+2.1}_{-1.7}$	$0.66^{+0.08}_{-0.10}$	$49.1^{+5.2}_{-3.9}$	960^{+430}_{-410}	1167559936.6
GW170608	$10.9^{+5.3}_{-1.7}$	$7.6^{+1.3}_{-2.1}$	$0.03^{+0.19}_{-0.07}$	$7.9^{+0.2}_{-0.2}$	$0.69^{+0.04}_{-0.04}$	$17.8^{+3.2}_{-0.7}$	320^{+120}_{-110}	1180922494.5
GW170729	$50.6^{+16.6}_{-10.2}$	$34.3^{+9.1}_{-10.1}$	$0.36^{+0.21}_{-0.25}$	$35.7^{+6.5}_{-4.7}$	$0.81^{+0.07}_{-0.13}$	$80.3^{+14.6}_{-10.2}$	2750^{+1350}_{-1320}	1185389807.3
GW170809	$35.2^{+8.3}_{-6.0}$	$23.8^{+5.2}_{-5.1}$	$0.07^{+0.16}_{-0.16}$	$25.0^{+2.1}_{-1.6}$	$0.70^{+0.08}_{-0.09}$	$56.4^{+5.2}_{-3.7}$	990^{+320}_{-380}	1186302519.8
GW170814	$30.7^{+5.7}_{-3.0}$	$25.3^{+2.9}_{-4.1}$	$0.07^{+0.12}_{-0.11}$	$24.2^{+1.4}_{-1.1}$	$0.72^{+0.07}_{-0.05}$	$53.4^{+3.2}_{-2.4}$	580^{+160}_{-210}	1186741861.5
GW170817	$1.46^{+0.12}_{-0.10}$	$1.27^{+0.09}_{-0.09}$	$0.00^{+0.02}_{-0.01}$	$1.186^{+0.001}_{-0.001}$	≤ 0.89	≤ 2.8	40^{+10}_{-10}	1187008882.4
GW170818	$35.5^{+7.5}_{-4.7}$	$26.8^{+4.3}_{-5.2}$	$-0.09^{+0.18}_{-0.21}$	$26.7^{+2.1}_{-1.7}$	$0.67^{+0.07}_{-0.08}$	$59.8^{+4.8}_{-3.8}$	1020^{+430}_{-360}	1187058327.1
GW170823	$39.6^{+10.0}_{-6.6}$	$29.4^{+6.3}_{-7.1}$	$0.08^{+0.20}_{-0.22}$	$29.3^{+4.2}_{-3.2}$	$0.71^{+0.08}_{-0.10}$	$65.6^{+9.4}_{-6.6}$	1850^{+840}_{-840}	1187529256.5

GWOSC Tutorials

- GWOSC tutorials:
  - ✓ https://www.gw-openscience.org/tutorials/

Tutorials

Each tutorial will lead you step-by-step through some common data analysis tasks. While GWOSC data can be analyzed using libraries in many software languages (C, C++, Matlab, etc.), most of th tutorials use Python. See also the software page for more examples.

See the tutorial setup page for help installing software to run these tutorials.

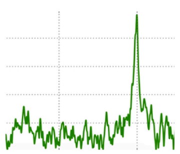
Tutorials shown here are not used to produce published results. For gravitational-wave software analysis packages that are used to produce LSC and Virgo Collaboration publications, see software page.

Gravitational Wave Open Data Workshop Web Course (2018)

Self-paced web course on GWOSC data analysis

Course Material

Binary Black Hole Events



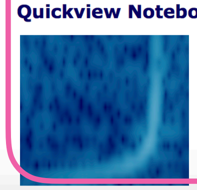
Use matched filtering to find signals hidden in noise.

Run: Azure | mybinder (Beta)

View: GW150914| LVT151012| GW151226| GW170104

Download: file with data | Jupyter notebook | Python script

Quickview Notebook



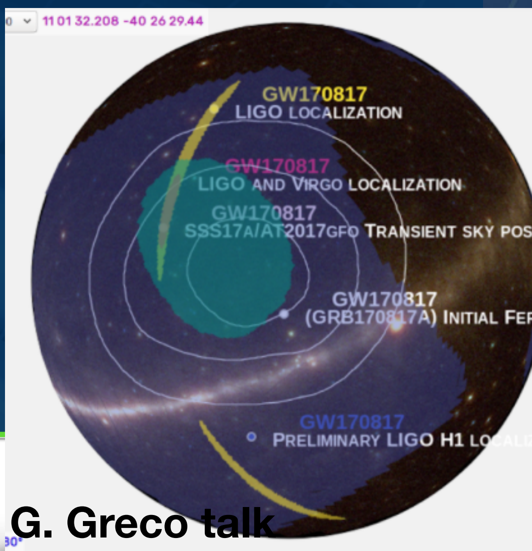
Make summary plots for any short segment of GWOSC data.

Run: Azure | mybinder (Beta)

Download: IPython 4

Next Open Data Workshop:
Paris, April 8 -10 2019
(Materials will be made available on GWOSC shortly after workshop)

First Open Data Workshop (March 2018):
slides + videos of the presentations + Jupiter notebook for hands-on sessions



G. Greco talk

Introduction to LIGO Data Files

[**Run:** workspace]

- Step 0) Software Setup
- Step 1) Download LIGO Data
- Step 2) What's in a LIGO Data File?
- Step 3) Working with Data Quality
- Step 4) Using the example API (readligo)

Working with Data

[**Run:** workspace]

- LOSC Example API
- Working with Segment Lists
- FFTs, PSDs, and Spectrograms:
  - Lots of Plots tutorial
  - Browse the plot gallery
- LSC software stack and frame reading software
- See the structure of an HDF5 file
- Plot GW150914 data [**Now superseded by the BBH Event tutorial**]
  - HTML | zip file with data

Searching for astrophysical sources

- Find an Inspiral
- Find an Inspiral Hardware Injection
- Find a Burst Injection: Slides | Script

Automated Downloads

- Discover and download LIGO data
- Automatically discover and download LIGO data
- Automatically download and process ALL the data

LIGO and Virgo Collaboration Members

- Get data on the LIGO Data Grid: Quickstart | Tutorial

Short tutorials about the basics of data analysis applied to some detected events

More specific tutorials on the data structure and how to read them

Software for GW data

- Software for working with Gravitational Wave Data available to the public: https://www.gw-openscience.org/software/
- Part of the software developed by LIGO/Virgo and open-source

GWpy

a python package for gravitational-wave astrophysics.

PyCBC

Free and open software to study gravitational waves.

Bilby

Bilby: a user-friendly Bayesian inference library.

ligo.skymap

The ligo.skymap package provides tools for reading, writing, generating, and visualizing gravitational-wave probability maps from LIGO and Virgo. It includes the rapid sky localization code BAYESTAR, tools for making sky maps from MCMC samples, observation planning utilities, and tools for making beautiful astronomical maps.

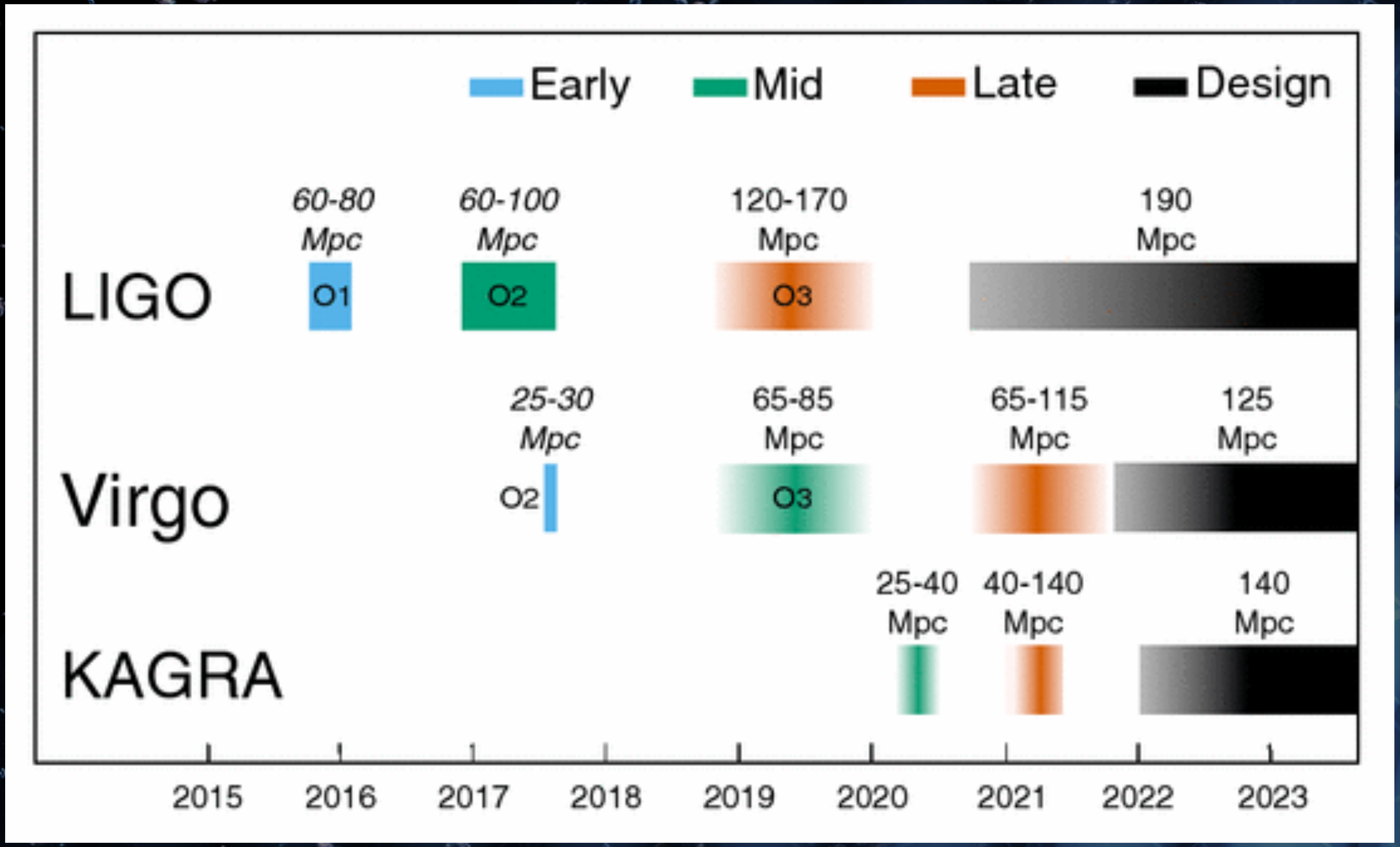
LALSuite

The LSC Algorithm Library Suite (LALSuite) is a collection of component packages, each of which is tagged, packaged, and released separately.

GstLAL

gstlal provides a suite of GStreamer elements that expose gravitational-wave data analysis tools from the LALSuite library for use in GStreamer signal-processing pipelines.

Near future



Next Observing run (O3) starts next week

- ✓ Binary neutron stars: 1 - 10
- ✓ Binary black holes: few tens to hundreds
- ✓ Neutron-star black-hole binaries?
- ✓ Other transient sources not detected so far?

✓ Releases will occur every 6 months, in blocks of 6 months of data, with a latency of 18 months from the end of acquisition of each observing block. (Data Management Plan=>https://dcc.ligo.org/LIGO-M1000066/public)

> Apr 2019-Sept 2020, Release: Apr 2021 (first 6-month block)

Thank you!

Questions?