Gravitational Wave Open Science Center: how to access LIGO/Virgo open data

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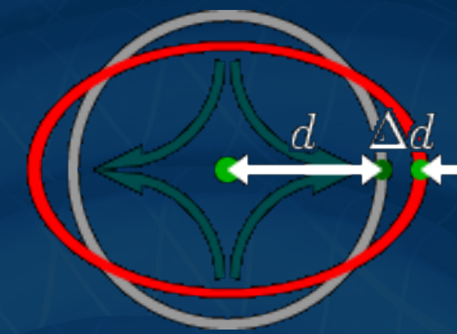
Outline

- What are LIGO/Virgo data?
- Available data sets
- Timelines and working with segment lists
- How to find tutorials and software

LIGO/Virgo data

- Main information in the Ligo/Virgo data: strain
- 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



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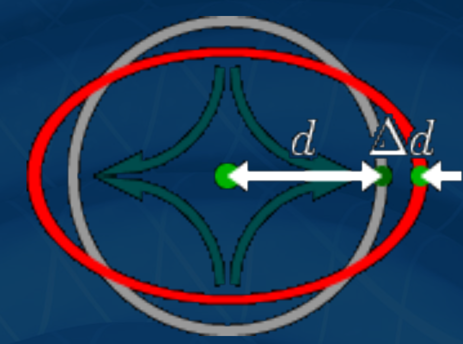
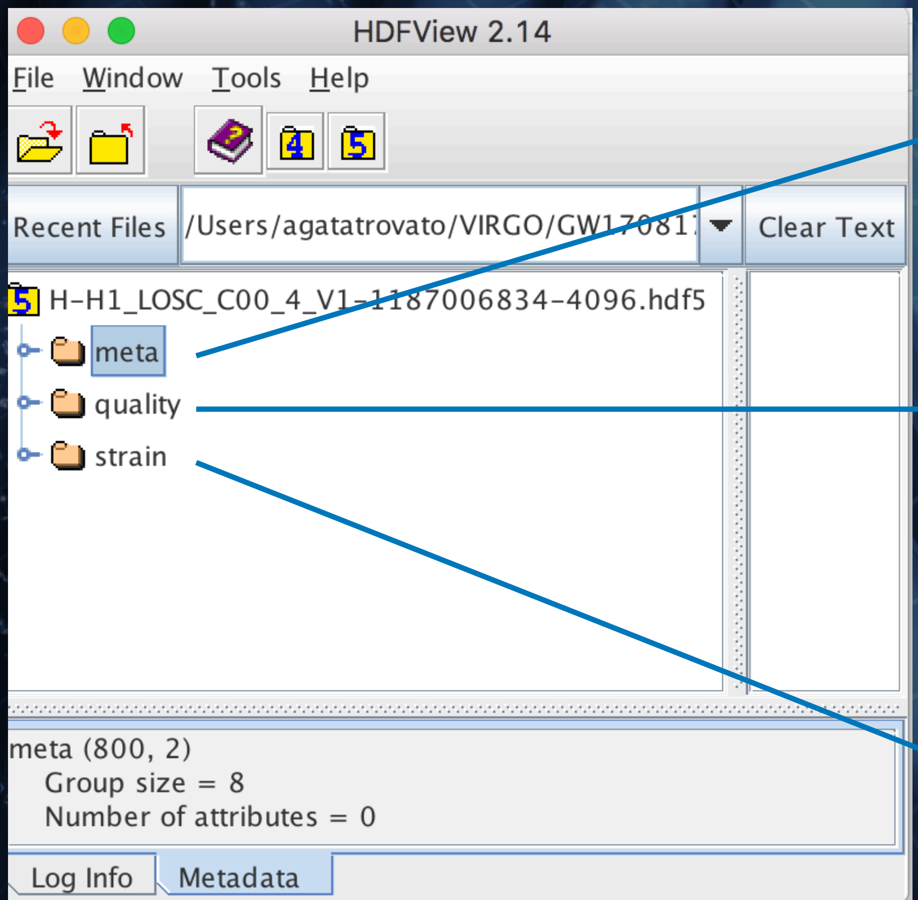


$$h = \frac{\Delta d}{d} = \frac{\mathit{change\ in\ relative\ position}}{\mathit{separation}}$$

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.

Simple python script

The content of the files can be easily read with a simple python script

https://www.gw-openscience.org/s/sample_code/plot_strain.py

```
#----------------------
# Import needed modules
#----------------------
import numpy as np
import matplotlib.pyplot as plt
import h5py

#-------------------------
# Open the File
#-------------------------
fileName = 'H-H1_LOSC_C00_4_V1-1187006834-4096.hdf5'
dataFile = h5py.File(fileName, 'r')

#----------------------
# Explore the file
#-----------------------
for key in list(dataFile.keys()):
    print(key)
```

If you execute this code the output will be:

meta
quality
strain

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dataFile = h5py.File(fileName, 'r')

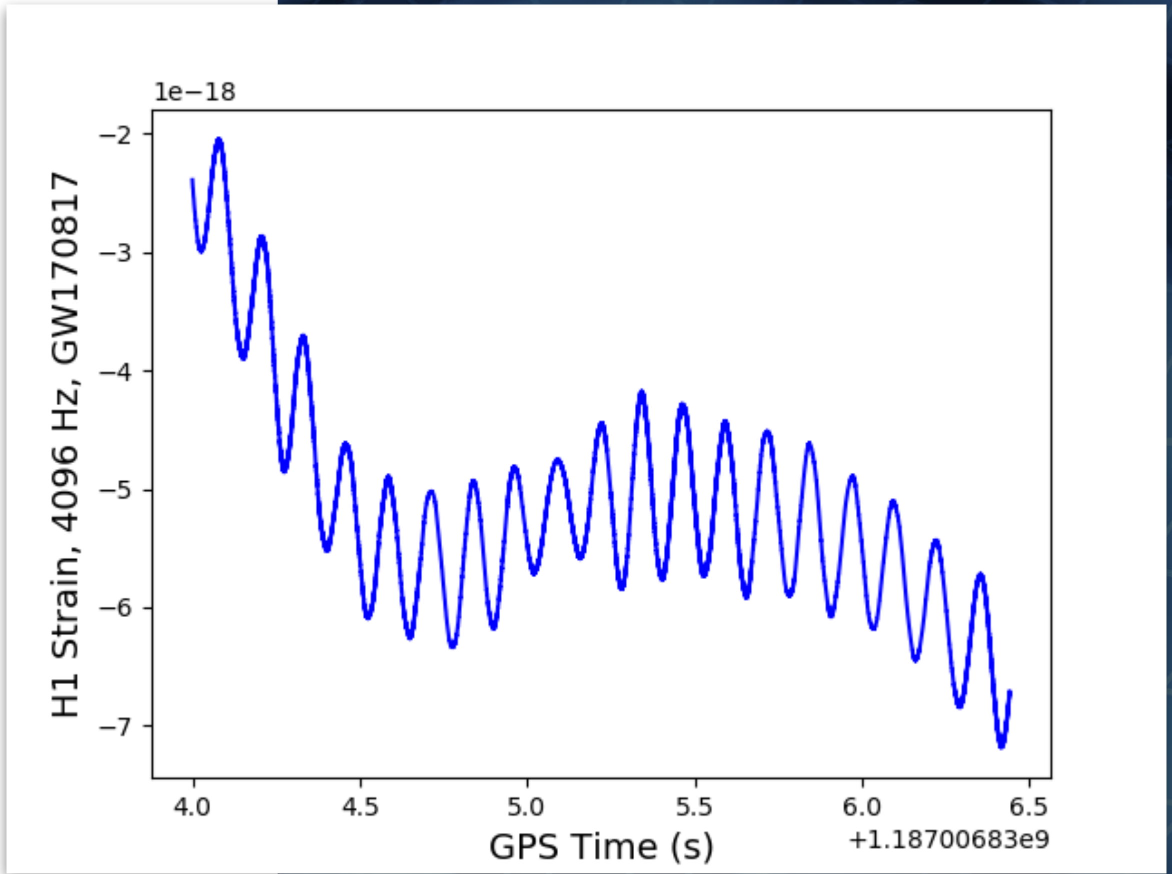
#---------------------------
# Create a time vector for
#---------------------------
meta = dataFile['meta']
gpsStart = meta['GPSstart'].value
duration = meta['Duration'].value
gpsEnd   = gpsStart + duration

strain = dataFile['strain']['Strain'].value
ts = dataFile['strain']['Strain'].attrs['Xspacing']

time = np.arange(gpsStart, gpsEnd, ts)

#----------------------
# Plot the time series
#----------------------
numSamples = 10000

plt.plot(time[0:numSamples], strainC00[0:numSamples],color='b')
plt.xlabel('GPS Time (s)’)
plt.ylabel('H1 Strain, 4096 Hz, GW170817')
plt.show()
```



How many seconds of data this plot should contain?

This file was sampled at 4096 Hz (every second you have 4096 strain measurements). We are plotting the first 10000 samples so the length in time will be 10000/4096 = 2.44 s

Available data sets

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

Gravitational wave data surrounding discoveries

Confident detections available at the moment:

Name	Detector	Type	Run
GW150914	LIGO	BBH	O1
GW151012	LIGO	Candidate BBH	O1
GW151226	LIGO	BBH	O1
GW170104	LIGO	BBH	O2
GW170608	LIGO	BBH	O2
GW170729	LIGO + VIRGO	BBH	O2
GW170809	LIGO + VIRGO	BBH	O2
GW170814	LIGO + VIRGO	BBH	O2
GW170817	LIGO + VIRGO	BNS	O2
GW170818	LIGO + VIRGO	BBH	O2
GW170823	LIGO	BBH	O2

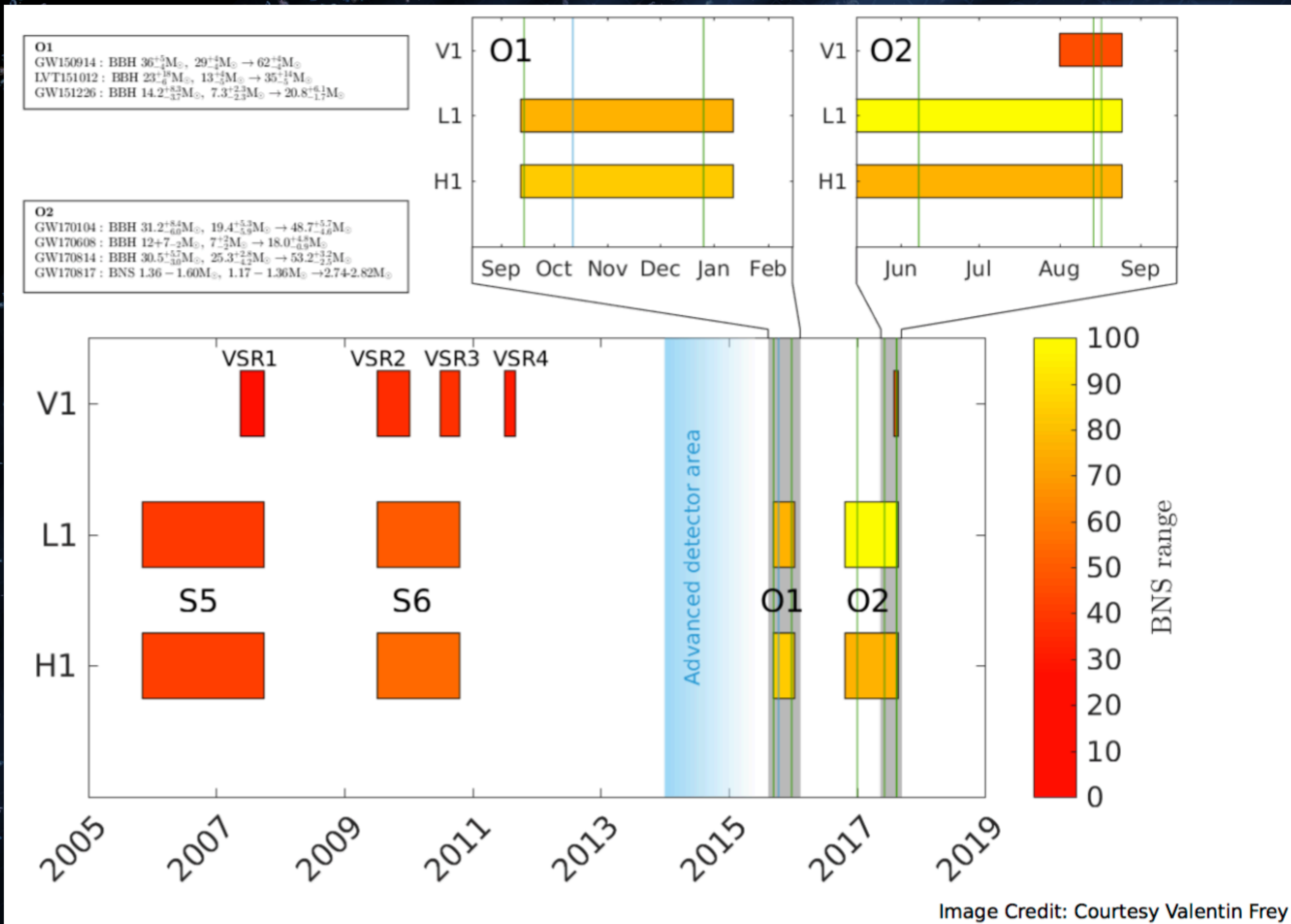
Data taken during a whole observation run

Runs available at the moment (LIGO only):

- S5 (Nov 2005 - Oct 2007)
- S6 (Jul 2009 - Oct 2010)
- O1 (Sep 2015 - Jan 2016)
- O2 to be released on Feb

BBH = Binary Black Hole
BNS = Binary Neutron Star

Science runs



GWOSC home page

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

gw-openscience.org

Gravitational Wave Open Science Center

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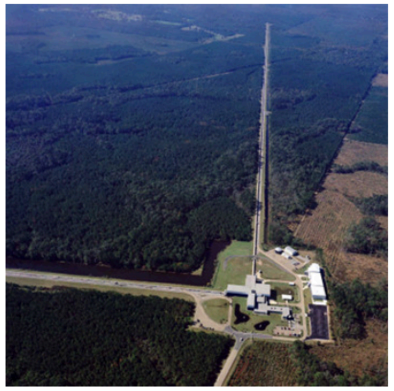
  - Catalogs
  - Bulk Data
- Tutorials
- Software
- Detector Status
- Timelines
- My Sources
- GPS ↔ UTC
- About the detectors
- Projects
- Acknowledge GWOSC

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.

Get started!

Download data

GWTC-1: Catalog of Compact Binary Mergers

Join the email list

Attend an open data workshop

Gravitational-Wave Transient Catalog of Compact Binary Mergers (GWTC-1)

gw-openscience.org

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

Available Catalogs

GWTC-1-confident

Confident detections from GWTC-1, the Gravitational-Wave Transient Catalog of Compact Binary Mergers Observed by LIGO and Virgo during the First and Second Observing Runs.
Data | Documentation

GWTC-1-marginal

Marginal triggers from GWTC-1, the Gravitational-Wave Transient Catalog of Compact Binary Mergers Observed by LIGO and Virgo during the First and Second Observing Runs.
Data | Documentation

Older event releases

Previous event releases are also available.

The DOI for this page is https://doi.org/10.7935/82H3-HH23

GWTC-1 marginal = 14 GW candidate events that have an estimated false alarm rate (FAR) less than 1 per 30 days whose astrophysical origin cannot be established nor excluded unambiguously

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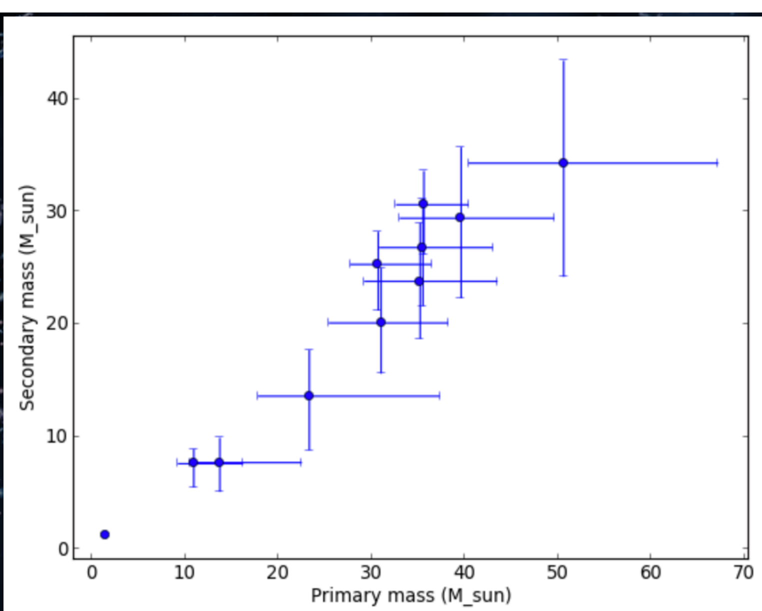
GWTC-1 Confident

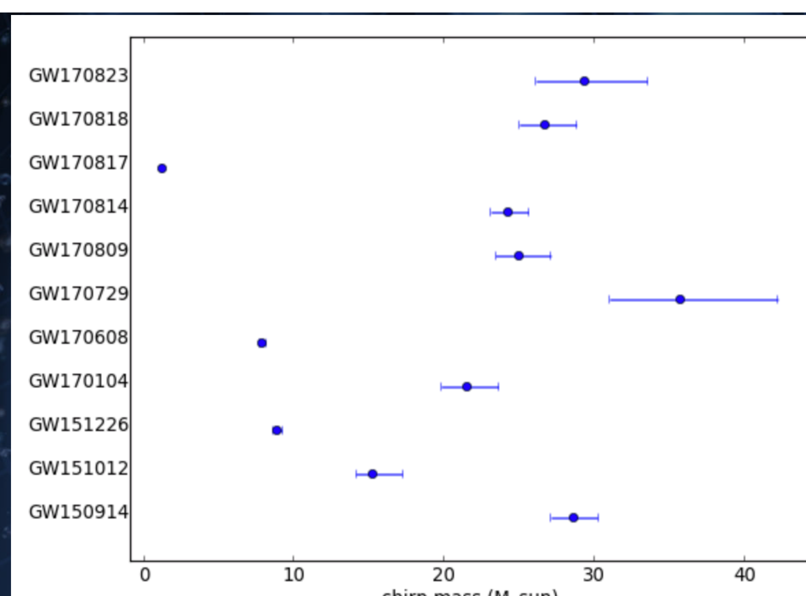
JSON Parameter Table

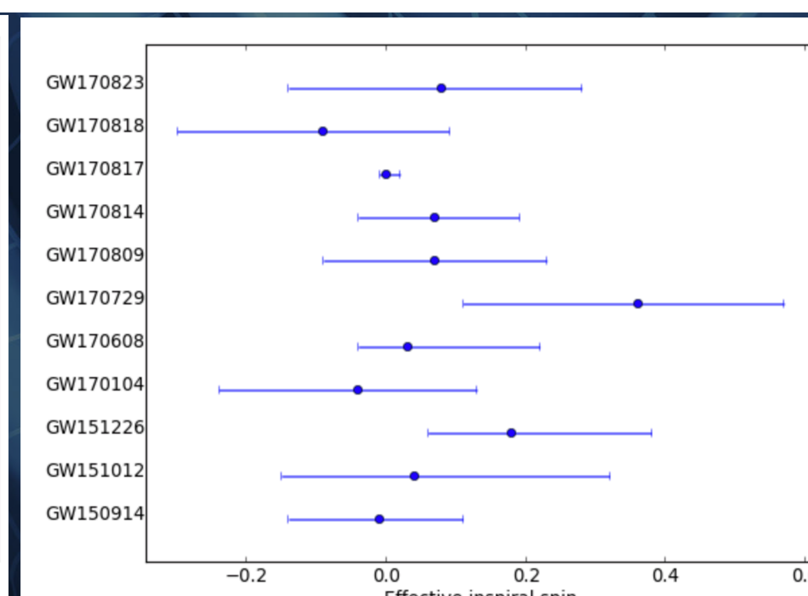
Show/hide columns

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







GWTC-1 event example

GWTC-1-confident

GW170814

Effective inspiral spin,	**0.07** $^{+0.12}_{-0.11}$
Luminosity distance, *Mpc*	**580** $^{+160}_{-210}$
Final spin,	**0.72** $^{+0.07}_{-0.05}$
Primary mass, *M_sun*	**30.7** $^{+5.7}_{-3.0}$
FAR gstLAL, *yr^-1*	**< 1.00e-07**
FAR PyCBC, *yr^-1*	**< 1.25e-05**
Secondary mass, *M_sun*	**25.3** $^{+2.9}_{-4.1}$
chirp mass, *M_sun*	**24.2** $^{+1.4}_{-1.1}$
Radiated energy, *M_sun X c^2*	**2.7** $^{+0.4}_{-0.3}$
Network SNR gstLAL,	**15.9**
Source redshift,	**0.12** $^{+0.03}_{-0.04}$
FAR cWB, *yr^-1*	**< 2.08e-04**
UTCtime,	**10:30:43.5**
Peak luminosity, *10^56 erg s^-1*	**3.7** $^{+0.4}_{-0.5}$
Sky localization, *deg^2*	**87**
Final mass, *M_sun*	**53.4** $^{+3.2}_{-2.4}$
GPS time (s),	**1186741861.5**
Network SNR PyCBC,	**16.3**
Network SNR cWB,	**17.2**

Download Data Files:

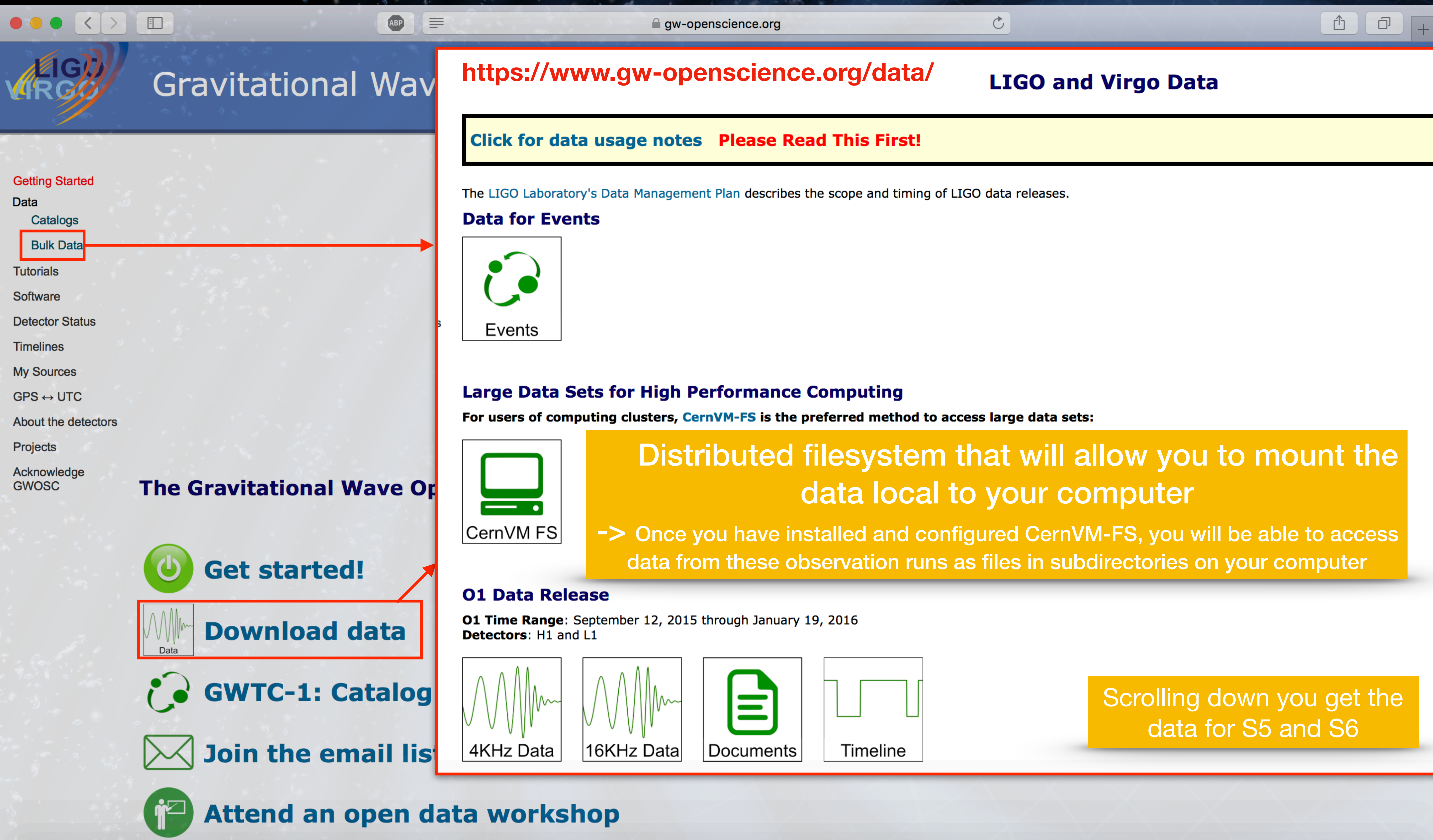
V1 4096sec 4KHz	V-V1_GWOSC_4KHZ_R1-1186739814-4096.hdf5 V-V1_GWOSC_4KHZ_R1-1186739814-4096.gwf V-V1_GWOSC_4KHZ_R1-1186739814-4096.txt.gz
V1 4096sec 16KHz	V-V1_GWOSC_16KHZ_R1-1186739814-4096.hdf5 V-V1_GWOSC_16KHZ_R1-1186739814-4096.gwf V-V1_GWOSC_16KHZ_R1-1186739814-4096.txt.gz
V1 32sec 4KHz	V-V1_GWOSC_4KHZ_R1-1186741846-32.hdf5 V-V1_GWOSC_4KHZ_R1-1186741846-32.gwf V-V1_GWOSC_4KHZ_R1-1186741846-32.txt.gz
V1 32sec 16KHz	V-V1_GWOSC_16KHZ_R1-1186741846-32.hdf5 V-V1_GWOSC_16KHZ_R1-1186741846-32.gwf V-V1_GWOSC_16KHZ_R1-1186741846-32.txt.gz
H1 4096sec 4KHz	H-H1_GWOSC_4KHZ_R1-1186739814-4096.hdf5 H-H1_GWOSC_4KHZ_R1-1186739814-4096.gwf H-H1_GWOSC_4KHZ_R1-1186739814-4096.txt.gz
H1 4096sec 16KHz	H-H1_GWOSC_16KHZ_R1-1186739814-4096.hdf5 H-H1_GWOSC_16KHZ_R1-1186739814-4096.gwf H-H1_GWOSC_16KHZ_R1-1186739814-4096.txt.gz
H1 32sec 4KHz	H-H1_GWOSC_4KHZ_R1-1186741846-32.hdf5 H-H1_GWOSC_4KHZ_R1-1186741846-32.gwf H-H1_GWOSC_4KHZ_R1-1186741846-32.txt.gz
H1 32sec 16KHz	H-H1_GWOSC_16KHZ_R1-1186741846-32.hdf5 H-H1_GWOSC_16KHZ_R1-1186741846-32.gwf H-H1_GWOSC_16KHZ_R1-1186741846-32.txt.gz
L1 4096sec 4KHz	L-L1_GWOSC_4KHZ_R1-1186739814-4096.hdf5 L-L1_GWOSC_4KHZ_R1-1186739814-4096.gwf L-L1_GWOSC_4KHZ_R1-1186739814-4096.txt.gz
L1 4096sec 16KHz	L-L1_GWOSC_16KHZ_R1-1186739814-4096.hdf5 L-L1_GWOSC_16KHZ_R1-1186739814-4096.gwf L-L1_GWOSC_16KHZ_R1-1186739814-4096.txt.gz
L1 32sec 4KHz	L-L1_GWOSC_4KHZ_R1-1186741846-32.hdf5 L-L1_GWOSC_4KHZ_R1-1186741846-32.gwf L-L1_GWOSC_4KHZ_R1-1186741846-32.txt.gz
L1 32sec 16KHz	L-L1_GWOSC_16KHZ_R1-1186741846-32.hdf5 L-L1_GWOSC_16KHZ_R1-1186741846-32.gwf L-L1_GWOSC_16KHZ_R1-1186741846-32.txt.gz

These data files are available as JSON.

Download MD5 checksums for all data files above.

Query form for timelines associated with this event.

Data from observation runs



Example: O1 page

Gravitational Wave Open Science Center https://www.gw-openscience.org/archive/O1/

Archive for O1 dataset

Each data file corresponds to 4096 seconds of GPS time, and may contain up to half a GB. The file may be downloaded in either HDF5 or Frame format. For documentation, see the tutorials.

O1 start GPS: 1126051217 UTC: 2015-09-12T00:00:00

O1 end GPS: 1137254417 UTC: 2016-01-19T16:00:00

Next choose your gravitational wave detector:

- H1
- L1

Now choose the start and end time of the data that you want, either Universal time or GPS. Change either side and the other responds immediately.

	Universal Time (ISO8601)	GPS Time	
Start Time	2015-09-12T00:00:00	1126051217	OK
End Time	2016-01-19T16:00:00	1137254417	OK

Choose your output format:

- Time series data in HDF5 and Frame files
- Time series data in HDF5 and Frame files, with data quality guide
- Includes statistics of each file: min/max, band-limited RMS, etc.
- JSON formatted table of files and data quality

Click the button to continue Continue

Archive

This page lists:

- Files that are available from the **O1** dataset
- Times from 1126051217 to 1137254417
- **L1** detector.
- Each file covers a 4096-second period, with strain data at either 16kHz or downsampled to 4 kHz.
- File sizes are shown in megabytes.
- The time of the beginning of the file is shown as 'GPS start time', and is linked to a timeline showing which parts of the tile have science-mode data.
- The last column of the table shows the percentage of each file that has data.
- For instructions on downloading many files, see the Automatic Download Tutorial.

Timeline	UTC	Mbytes	HDF5	Frame	Percent
1126068224	2015-09-12T04:43:27	6 MB	HDF5	Frame	4
1126072320	2015-09-12T05:51:43	125 MB	HDF5	Frame	100
1126076416	2015-09-12T06:59:59	126 MB	HDF5	Frame	100
1126080512	2015-09-12T08:08:15	126 MB	HDF5	Frame	100
1126084608	2015-09-12T09:16:31	66 MB	HDF5	Frame	52
1126088704	2015-09-12T10:24:47	126 MB	HDF5	Frame	100
1126092800	2015-09-12T11:33:03	127 MB	HDF5	Frame	100
1126096896	2015-09-12T12:41:19	84 MB	HDF5	Frame	65
1126100992	2015-09-12T13:49:35	127 MB	HDF5	Frame	100
1126105088	2015-09-12T14:57:51	127 MB	HDF5	Frame	100
1126109184	2015-09-12T16:06:07	61 MB	HDF5	Frame	47
1126162432	2015-09-13T06:53:35	39 MB	HDF5	Frame	29
1126232064	2015-09-14T02:14:07	66 MB	HDF5	Frame	51
1126236160	2015-09-14T03:22:23	85 MB	HDF5	Frame	67
1126244352	2015-09-14T05:38:55	12 MB	HDF5	Frame	8
1126256640	2015-09-14T09:03:43	120 MB	HDF5	Frame	95

Segment Lists

- LIGO/Virgo data are not always 'on' (in science mode)
- Data quality may not meet basic requirements
- Consequence : GW data analysis is applied to data segments (different in each detector)

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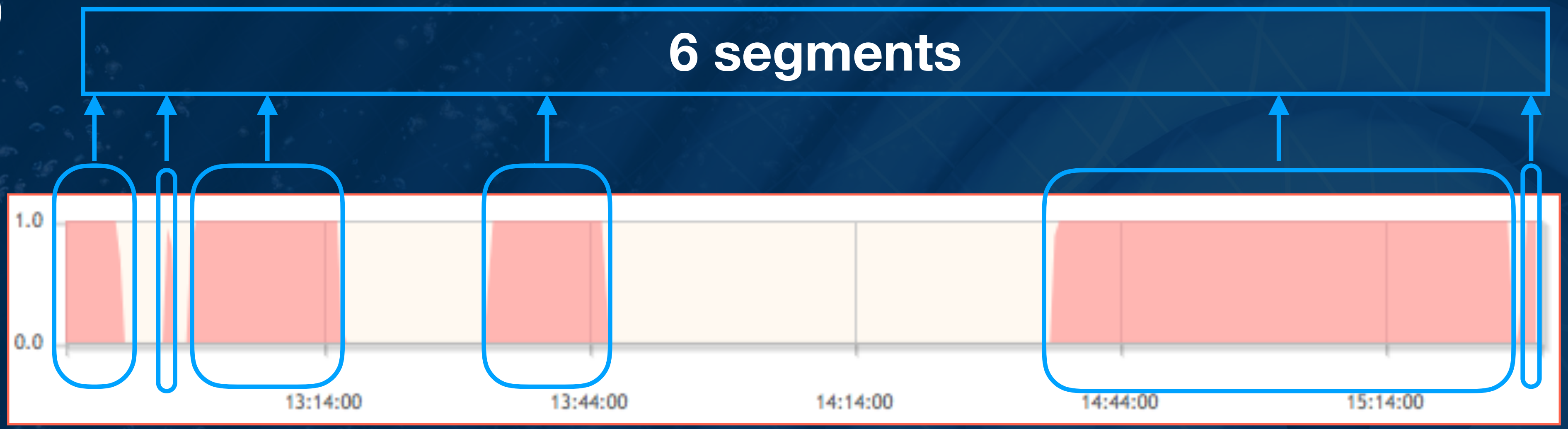
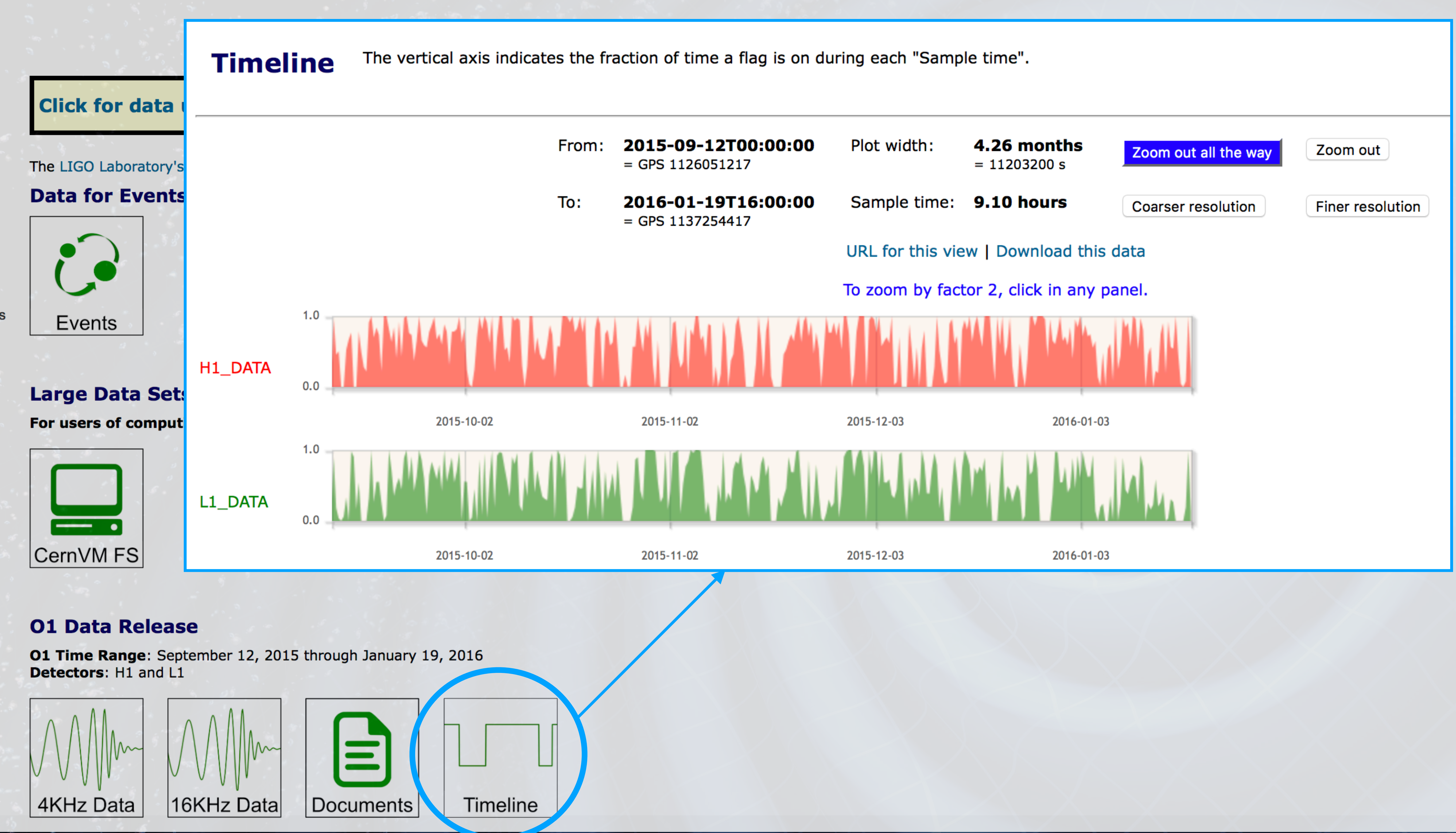
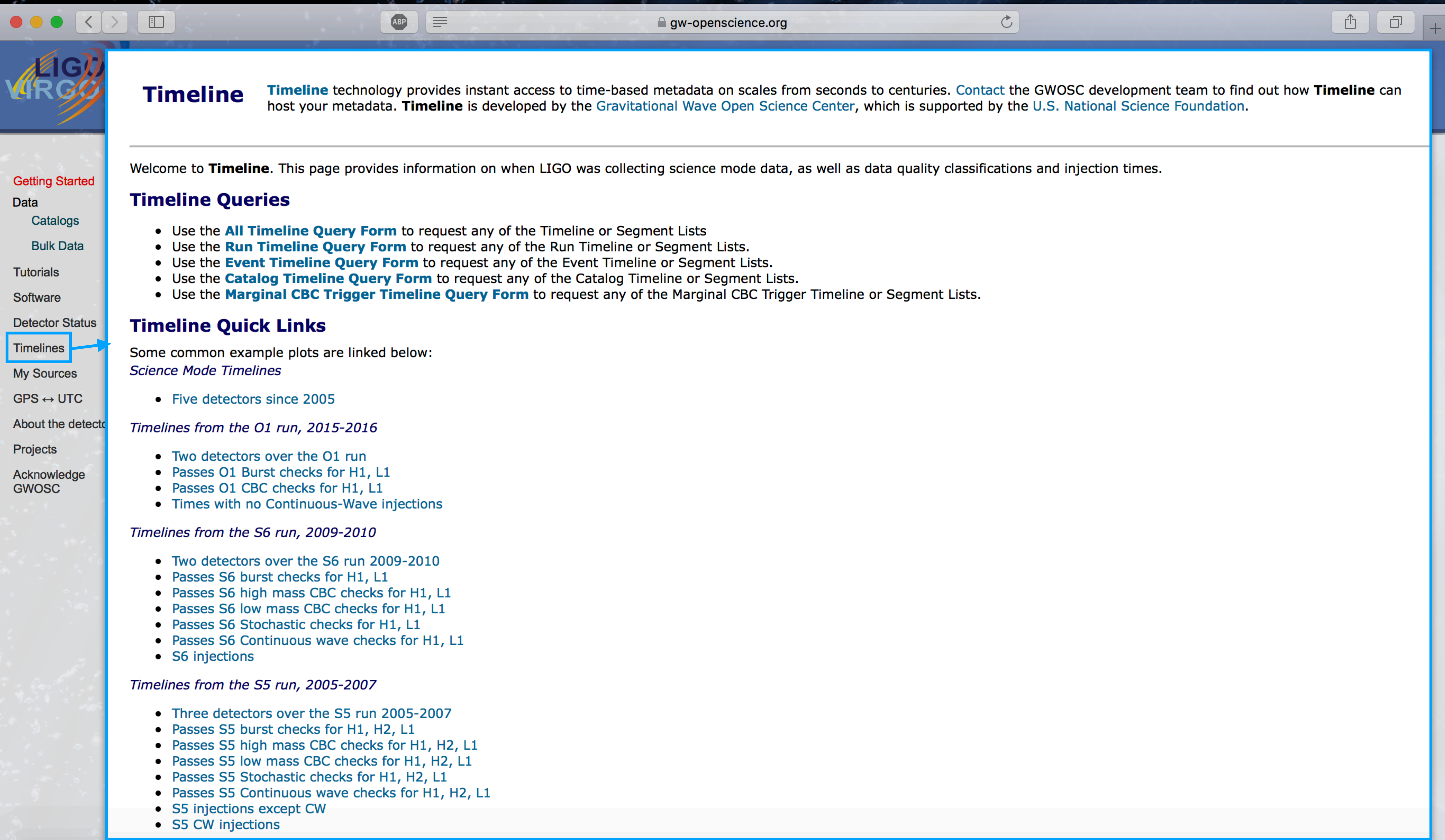


- The “Timeline” tool of the GWOSC website allows you to select segments that fulfill specific data quality checks in a time period that can be selected specifying GPS time and duration

O1 timelines



Timeline page



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Timeline

Timeline technology provides instant access to time-based metadata on scales from seconds to centuries. Contact the GWOSC development team to find out how **Timeline** can host your metadata. **Timeline** is developed by the Gravitational Wave Open Science Center, which is supported by the U.S. National Science Foundation.

Welcome to **Timeline**. This page provides information on when LIGO was collecting science mode data, as well as data quality classifications and injection times.

Timeline Queries

- Use the **All Timeline Query Form** to request any of the Timeline or Segment Lists
- Use the **Run Timeline Query Form** to request any of the Run Timeline or Segment Lists.
- Use the **Event Timeline Query Form** to request any of the Event Timeline or Segment Lists.
- Use the **Catalog Timeline Query Form** to request any of the Catalog Timeline or Segment Lists.
- Use the **Marginal CBC Trigger Timeline Query Form** to request any of the Marginal CBC Trigger Timeline or Segment Lists.

Timeline Quick Links

Some common example plots are linked below:
Science Mode Timelines

- Five detectors since 2005

Timelines from the O1 run, 2015-2016

- Two detectors over the O1 run
- Passes O1 Burst checks for H1, L1
- Passes O1 CBC checks for H1, L1
- Times with no Continuous-Wave injections

Timelines from the S6 run, 2009-2010

- Two detectors over the S6 run 2009-2010
- Passes S6 burst checks for H1, L1
- Passes S6 high mass CBC checks for H1, L1
- Passes S6 low mass CBC checks for H1, L1
- Passes S6 Stochastic checks for H1, L1
- Passes S6 Continuous wave checks for H1, L1
- S6 injections

Timelines from the S5 run, 2005-2007

- Three detectors over the S5 run 2005-2007
- Passes S5 burst checks for H1, H2, L1
- Passes S5 high mass CBC checks for H1, H2, L1
- Passes S5 low mass CBC checks for H1, H2, L1
- Passes S5 Stochastic checks for H1, H2, L1
- Passes S5 Continuous wave checks for H1, H2, L1
- S5 injections except CW
- S5 CW injections

Timeline page

gw-openscience.org

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Timeline Queries

- Use the All Timeline Query Form to request any of the Timeline or Segment Lists
- Use the **Run Timeline Query Form** to request any of the Run Timeline or Segment Lists.
- Use the Event Timeline Query Form to request any of the Event Timeline or Segment Lists.
- Use the **Catalog** ...
- Use the **Marginal** ...

Timeline Quick L...

Some common example...

Science Mode Timelines

- Five detectors sinc...

Timelines from the O1 ru...

- Two detectors ove...
- Passes O1 Burst c...
- Passes O1 CBC ch...
- Times with no Cor...

Timelines from the S6 ru...

- Two detectors ove...
- Passes S6 burst c...
- Passes S6 high ma...
- Passes S6 low ma...
- Passes S6 Stochas...
- Passes S6 Continu...
- S6 injections

Timelines from the S5 ru...

- Three detectors o...
- Passes S5 burst c...
- Passes S5 high ma...
- Passes S5 low ma...
- Passes S5 Stochas...
- Passes S5 Continu...
- S5 injections exce...
- S5 CW injections

Timelines are available to display times when a number of GW instruments were collecting data, as well as data quality and injection information. This information can be retrieved as a plot, an ASCII list of segments, or as JSON data. A simple URL pattern is all you need to find the segment information you want. To see how these URLs are constructed, fill in the information below, and see the URL that appears at the bottom of the screen.

Run Timeline Query Form

Select Data Set: S5 S6 O1

O1 dataset

GPS start: 1126051217 (2015-09-12T00:00:00)
GPS end: 1137254417 (2016-01-19T16:00:00)

Enter the **starting GPS**: 1126051217 (GPS ↔ UTC converter)

Enter the **end GPS or duration** in seconds: 1137254417

Select display type:
- **Plot**: Plot fraction of time that passes the chosen DQ level in each time bin
- **Segment List**: ASCII segment list (tutorial on segments)
- **JSON Single Segment List**: Segment list for single category in JSON format
- **JSON All Segment Lists**: Segment lists for all categories in JSON format (Takes several minutes to load.)

Select flag names. For plots and JSON, multiple selections can be made, but for segments, only one can be selected. There is more information about these flags here.

H1_BURST_CAT1	L1_BURST_CAT1
H1_BURST_CAT2	L1_BURST_CAT2
H1_BURST_CAT3	L1_BURST_CAT3
H1_CBC_CAT1	L1_CBC_CAT1
H1_CBC_CAT2	L1_CBC_CAT2
H1_CBC_CAT3	L1_CBC_CAT3
H1_DATA	L1_DATA
H1_NO_BURST_HW_INJ	L1_NO_BURST_HW_INJ
H1_NO_CBC_HW_INJ	L1_NO_CBC_HW_INJ
H1_NO_CW_HW_INJ	L1_NO_CW_HW_INJ
H1_NO_DETCHAR_HW_INJ	L1_NO_DETCHAR_HW_INJ
H1_NO_STOCH_HW_INJ	L1_NO_STOCH_HW_INJ

Get your Timeline at:

https://www.gw-osc.org/timeline/show/O1/H1_BURST_CAT1/1126051217/11203200/

Segments and data via timeline

Timeline

The vertical axis indicates the fraction of time a flag is on during each "Sample time".

From: **2016-01-14T14:40:24** = GPS 1136817641 Plot width: **1.01 days** = 87525 s

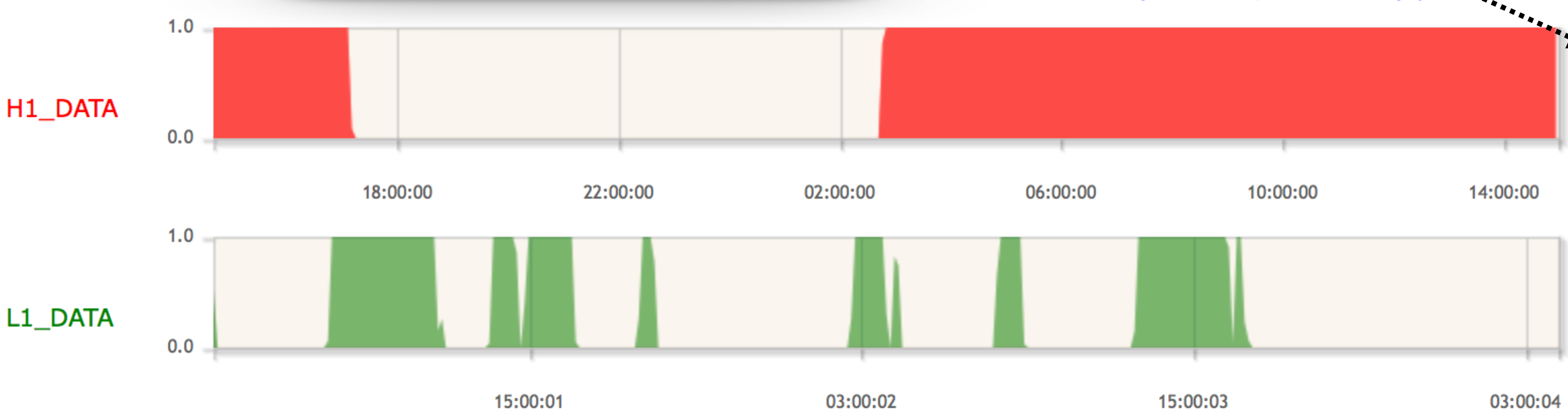
To: **2016-01-15T14:59:09** = GPS 1136905166 Sample time: **4.27 minutes**

Zoom out all the way | Zoom out | Coarser resolution | Finer resolution

URL for this view | Download this data
Download Segment Lists [?]: H1_DATA L1_DATA
This plot as JSON plot0 plot1
Get strain data [?]: H1 L1

GPSstart	GPSstop	Duration
1136817641	1136826646	9005
1136861219	1136905166	43947

To zoom by factor 2, click in any panel.



Archive

This page lists:

- Files that are available from the **O1** dataset
- Times from 1136817641 to 1136905165
- **H1** detector.
- Each file covers a 4096-second period, with strain data at either 16kHz or dow
- File sizes are shown in megabytes.
- The time of the beginning of the file is shown as 'GPS start time', and is linked
- The last column of the table shows the percentage of each file that has data.
- For instructions on downloading many files, see the Automatic Download Tutor

Timeline	UTC	Mbytes	HDF5	Frame	Percent
1136816128	2016-01-14T14:15:11	114 MB	HDF5	Frame	87
1136820224	2016-01-14T15:23:27	130 MB	HDF5	Frame	100
1136824320	2016-01-14T16:31:43	74 MB	HDF5	Frame	56
1136861184	2016-01-15T02:46:07	129 MB	HDF5	Frame	99
1136865280	2016-01-15T03:54:23	130 MB	HDF5	Frame	100
1136869376	2016-01-15T05:02:39	130 MB	HDF5	Frame	100
1136873472	2016-01-15T06:10:55	130 MB	HDF5	Frame	100
1136877568	2016-01-15T07:19:11	130 MB	HDF5	Frame	100
1136881664	2016-01-15T08:27:27	130 MB	HDF5	Frame	100
1136885760	2016-01-15T09:35:43	130 MB	HDF5	Frame	100
1136889856	2016-01-15T10:43:59	130 MB	HDF5	Frame	100
1136893952	2016-01-15T11:52:15	130 MB	HDF5	Frame	100
1136898048	2016-01-15T13:00:31	130 MB	HDF5	Frame	100
1136902144	2016-01-15T14:08:47	130 MB	HDF5	Frame	100

Segments via readligo

- On the GWOSC page you can find a lot of examples and tutorials
- The website contains also an example API *readligo.py* that easily allow you to handle HDF5 files (it has to be in the same directory of the files)
- To use the methods you have to add in the header of your program:
  - ✓ *import readligo as rl*
- To load a single file you can use the method *loaddata*
  - ✓ *strain, time, chan_dict = rl.loaddata('H-H1_LOSC…hdf5', 'H1')*

Strain time series

dictionary of all of the data quality flags in the file

GPS time series

- To get segments of data (assuming you downloaded the hdf5 files in the same folder)
  - ✓ *segList = rl.getsegs(start, stop, 'H1', flag='BURST_CAT2')*

GPS time

Detector

data quality flag

List of GPS time of the segments fulfilling the requested criteria

Segments: example code

https://www.gw-openscience.org/s/sample_code/use_readligo.py

```
import numpy as np
import matplotlib.pyplot as plt
import readligo as rl

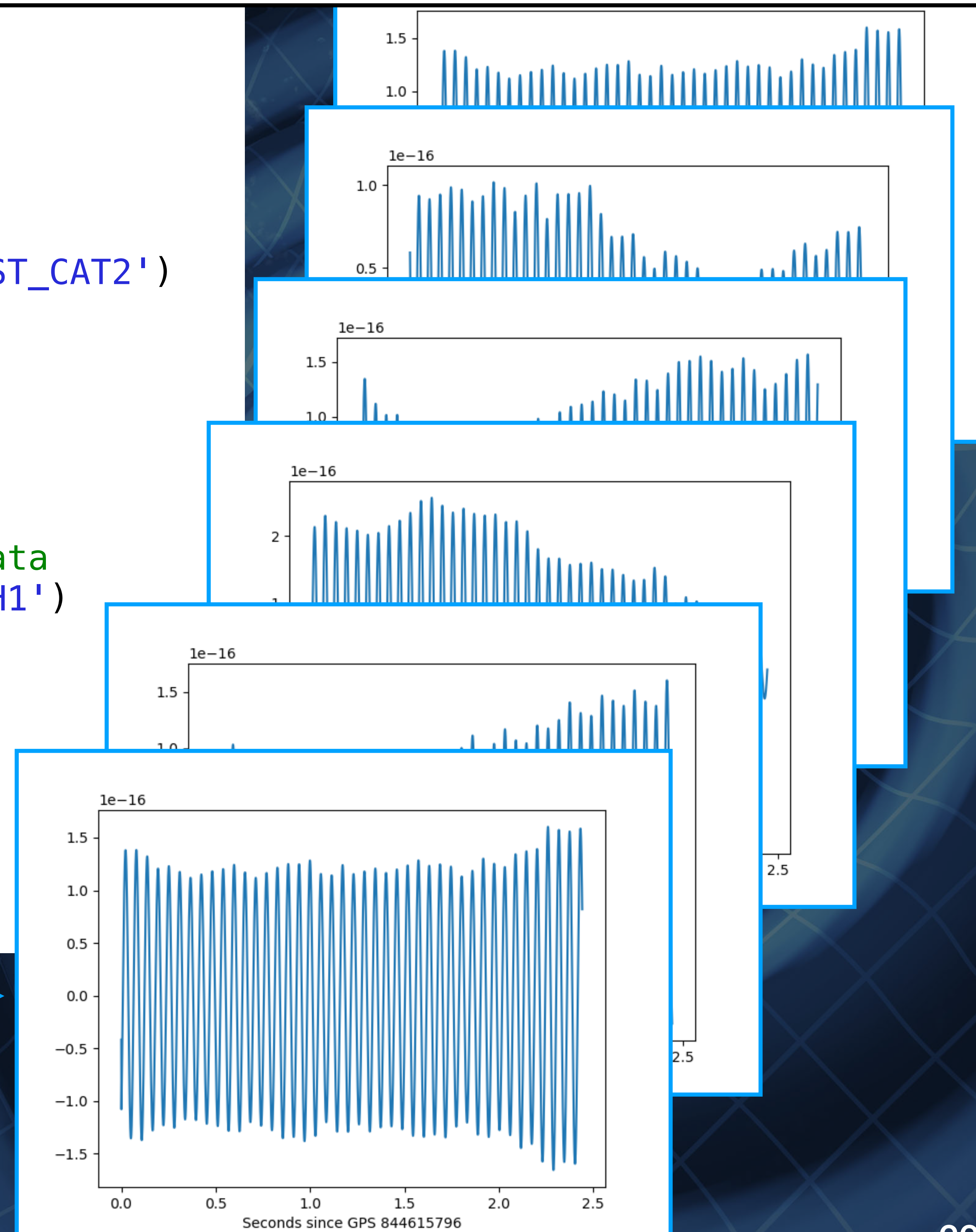
start = 844605900
stop =  844615900

segList = rl.getsegs(start, stop, 'H1', flag='BURST_CAT2')
print (segList)
#----------------------------------------
# Plot a few seconds of each "good" segment
#----------------------------------------
N = 10000
for (begin, end) in segList:
    # -- Use the getstrain() method to load the data
    strain, meta, dq = rl.getstrain(begin, end, 'H1')

    # -- Make a plot
    plt.figure()
    ts = meta['dt']
    rel_time = np.arange(0, end-begin, meta['dt'])
    plt.plot(rel_time[0:N], strain[0:N])
    plt.xlabel('Seconds since GPS ' + str(begin) )
plt.show()
```

Output:

```
SegmentList( [(844605900, 844606294), (844606594,
844606649), (844606759, 844607779), (844608784,
844609581), (844612612, 844615722), (844615796,
844615900)] )
```



GWOSC Tutorials

- The scripts I've shown are part of GWOSC tutorials that you can find at:
  - ✓ https://www.gw-openscience.org/tutorials/

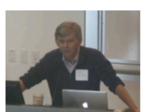
Tutorials

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 these 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)

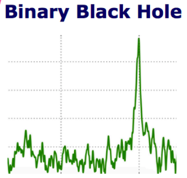


Self-paced web course on GWOSC data analysis

Course Material

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

Binary Black Hole Events



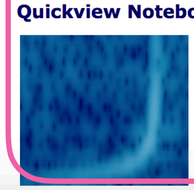
Use matched filtering to find signals hidden in noise.

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

Short tutorials about the basics of data analysis applied to the realised events

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

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

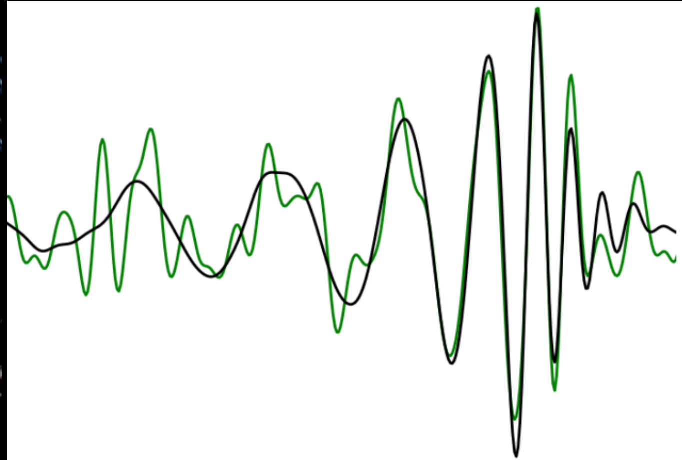
Automated Downloads

- 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

First Open Data Workshop



LIGO Scientific Collaboration

Open Data Workshop #1

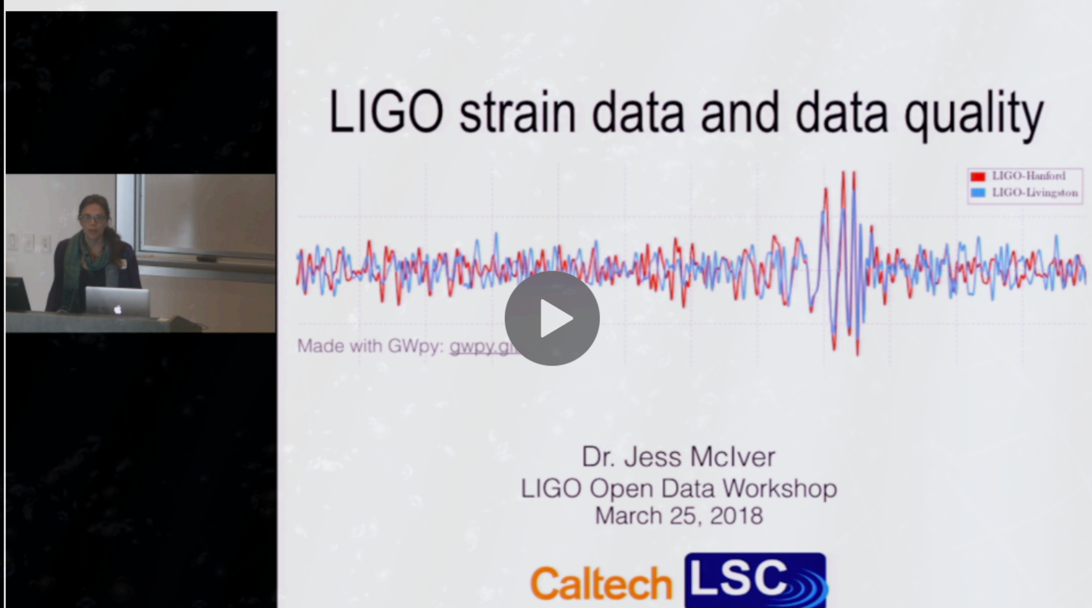
Sunday - Tuesday, March 25 - 27, 2018

Data Workshop | Location | Lodging | Transportation | Registration | Program | Lecture Videos

LIGO Strain Data and Data Quality

Lecture by Jess McIver

Slides



Exercises

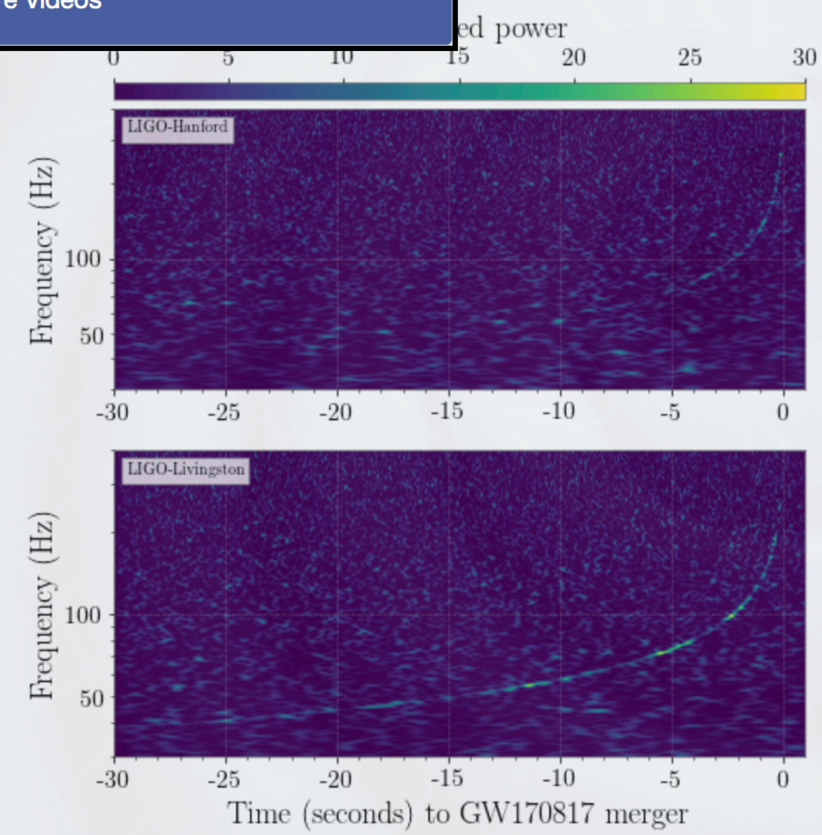
- gwpy Tutorial 2a
- gwpy Tutorial 2b
- gwpy Tutorial 3

```
n use for labelling
ford', visible=False)
dlelength=0, handletextpad=0)
ingston', visible=False)
dlelength=0, handletextpad=0)

)')

o GW170817 merger')

'Normalised power', location='top')
0x1149ee590>
```



Now we can a BNS merge all the way back to T=-25 seconds in LIGO-Livingston data!

This is basically the same procedure (and the same code) that was used to produce Figure 1 of the BNS discovery article *'Observation of Gravitational Waves from a Binary Neutron Star Inspiral'* [link]

Where to find software

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

Software for working with LIGO data

A number of software packages are useful for working with LIGO data.

GWpy

GWpy is a python package for gravitational-wave astrophysics.

- GWpy Home Page

PyCBC

PyCBC is a software package used to explore astrophysical sources of gravitational waves. It is a python package built on LALSuite, and provides functionality to analyze gravitational-wave data, detect the signatures of compact binary mergers, and estimate the parameters of a potential source.

- PyCBC Home Page
- PyCBC Online Notebooks
- Get PyCBC in a Docker container

LALSuite

The LSC Algorithm Library Suite (LALSuite) is comprised of various gravitational wave data analysis routines written in C.

- LALSuite Home Page

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.

- GstLAL Home Page

The Frame Library

The Frame Library is a software dedicated to the frame manipulation including file input/output. It is a C code and a matlab interface is also provided as part of the distribution.

- Frame Library Home Page

LDASTools

LDAS Tools provides a collection of libraries and utility programs that can be leveraged to simply tasks related to reading and writing of frames, maintain a hash of files on a file system, and to create custom frame sets.

- LDASTools Home Page

HDF5

HDF5 is a data model, library, and file format for storing and managing data.

- HDF5 Home Page

LOSC Example Python Scripts

- LOSC Tutorials
- Software Setup
- readligo.py (Example API)

LOSC Example MATLAB Script

- Read and plot a LOSC data file with MATLAB

LOSC Example C Script

Gravitation Open Science Workshop #2

https://indico.in2p3.fr/e/gw-odw2

Gravitational wave
Open Data Workshop #2
Paris, April 8-10 2019

AstroParticule & Cosmologie
Paris Diderot University

Three-day workshop to learn how to access and analyze LIGO and Virgo data

LIGO LSC VIRGO

http://www.gw-openscience.org

Gravitation Open Science Workshop #2

https://indico.in2p3.fr/e/gw-odw2

Gravitational wave
Open Data Workshop #2
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AstroParticule & Cosmologie
Paris Diderot University

Three-day workshop to learn how to access and analyze LIGO and Virgo data

LIGO LSC VIRGO http://w

A new astronomy based on gravitational waves was born with the first advanced LIGO and advanced Virgo discoveries and will develop with the third observation run, O3, that will begin in 2019.

Bulk data from past observation runs and data snippets around the discoveries are made publicly available at gw-openscience.org, along with associated software libraries. This workshop is intended for students or more senior scientists that wish to learn about these data and software in order to conduct research in the field of gravitational-wave astronomy.

The workshop will offer participants a hands-on introduction to working with software tools that allow to access and analyze open gravitational-wave data. Participants are expected to bring a laptop computer. Some previous experience with python programming and/or signal processing will be helpful, but not required.

Tentative program

The tentative program includes a mixture of lecture style presentations and hands-on programming exercises.

Git repo with the material for the hands-on sessions (in progress): https://github.com/gw-odw/odw-2019

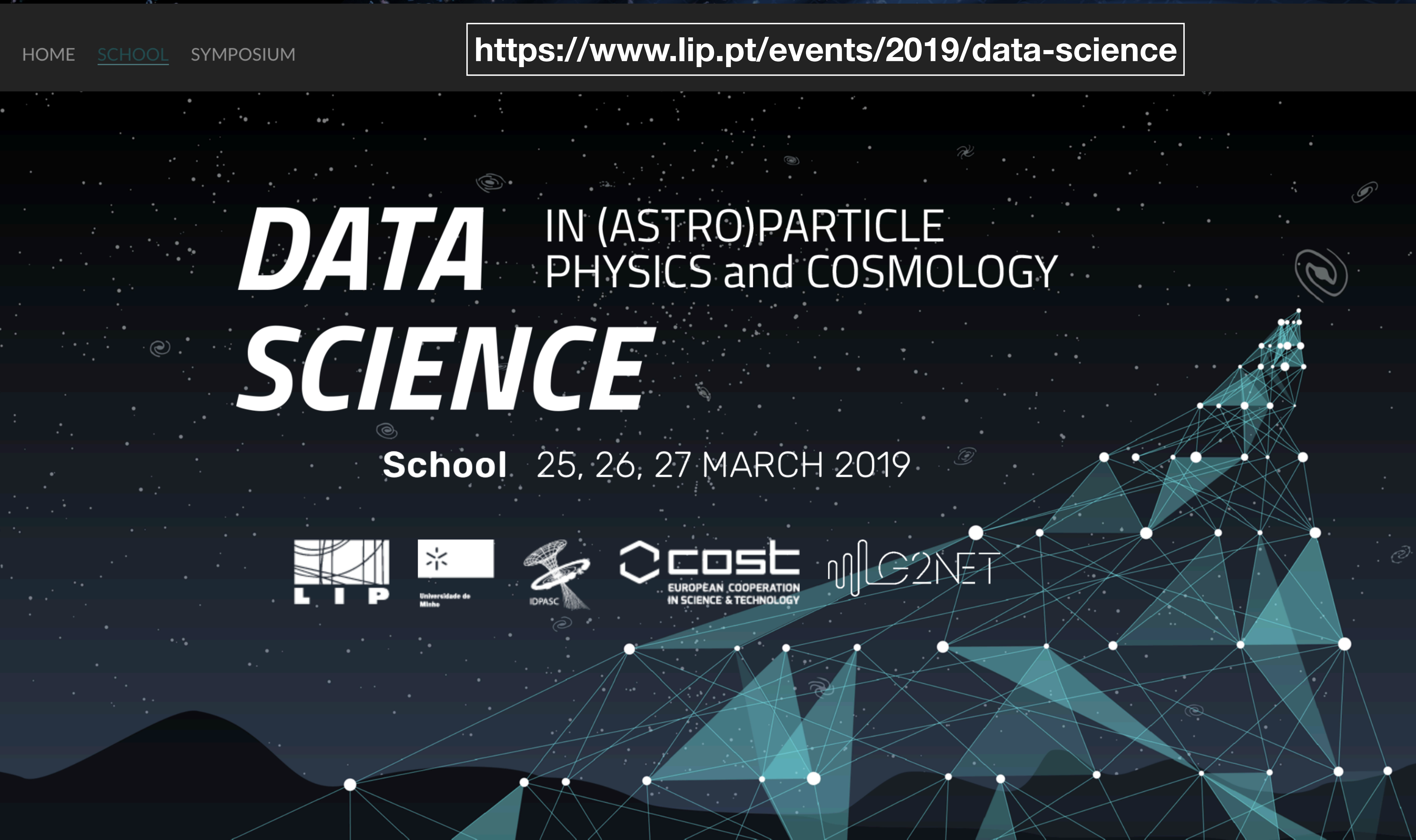
GW ODW#1 (Caltech, 3/2018): https://www.gw-openscience.org/static/workshop1

Note: you can configure the language for the website menu bar in the drop down list at the top right corner of this page.

Commence le 8 avr. 2019 à 08:30
Se termine le 10 avr. 2019 à 13:00
Europe/Paris

Université Paris Diderot
Amphi Pierre-Gilles de Gennes (Condorcet, level -1)
Université Paris Diderot – Bâtiment Condorcet
APC AstroParticule et Cosmologie
10, rue Alice Domon et Léonie Duquet
75013 Paris

Data science school




Thank you!
Questions?