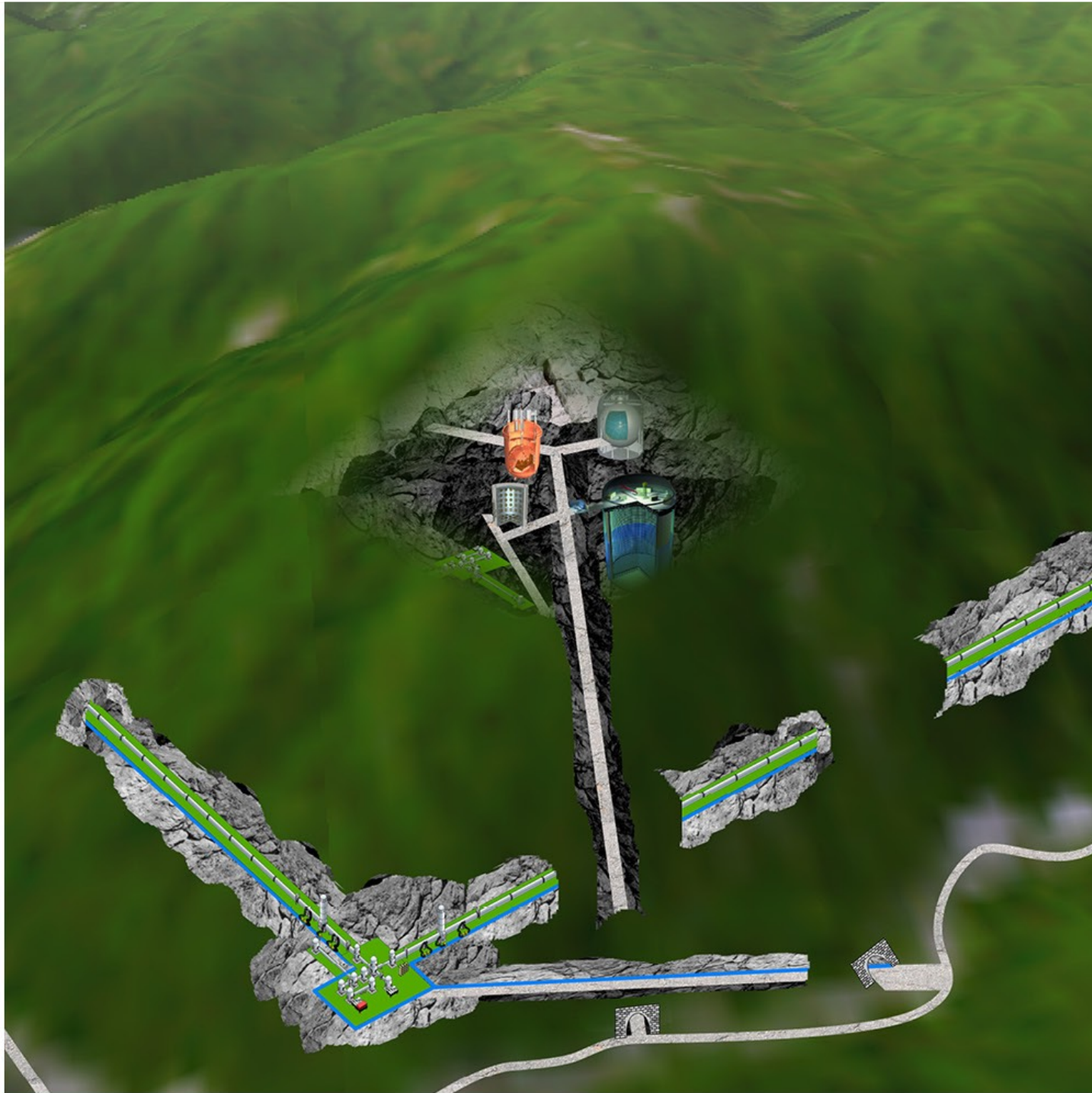
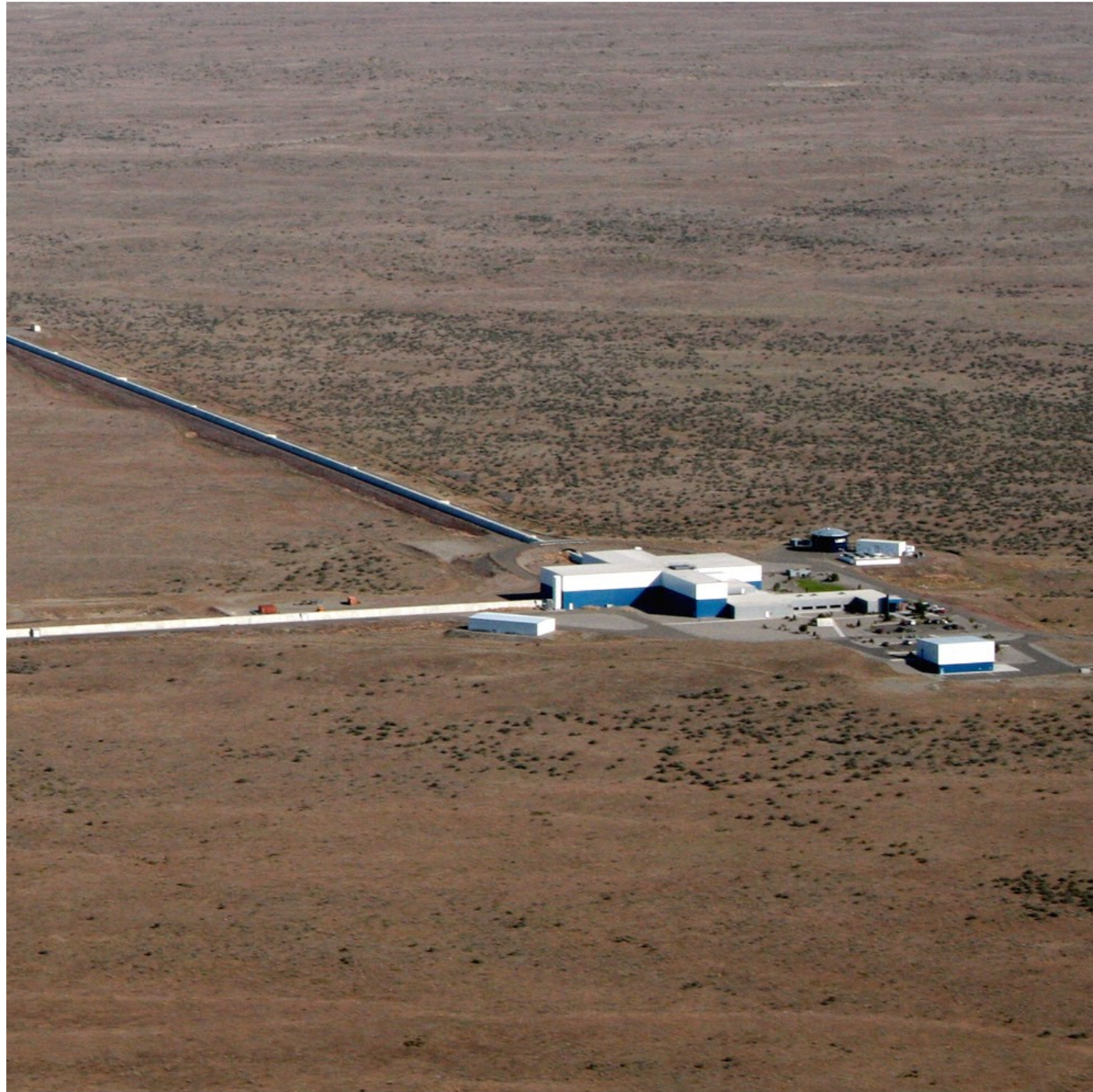


LIGO-Virgo-KAGRA Open Data

Jonah Kanner
LIGO Lab, Caltech

April 18, 2024 | LIGO-G2400876-v2





Gravitational Wave **Open Science Center**

Discover Gravitational-Wave Observatory Data,
Tutorials, and Software Tools.

Explore Data

Learn

gwosc.org

Data

Documentation

Tutorials

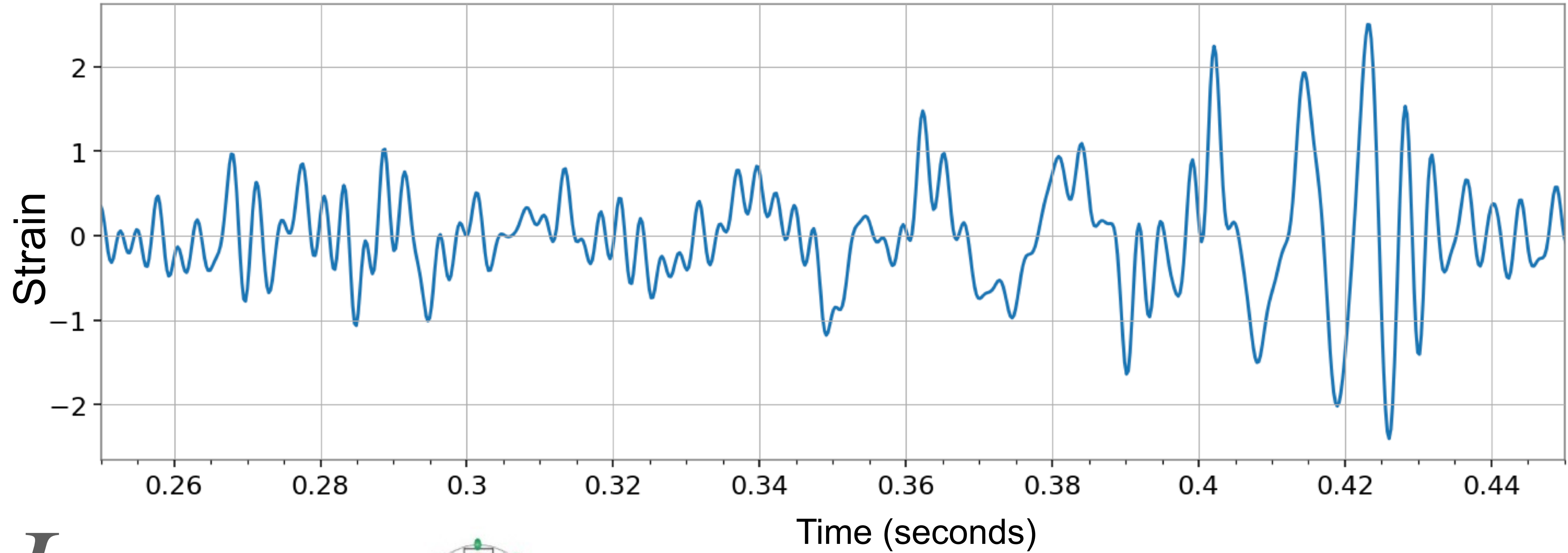
Software

Segment Lists

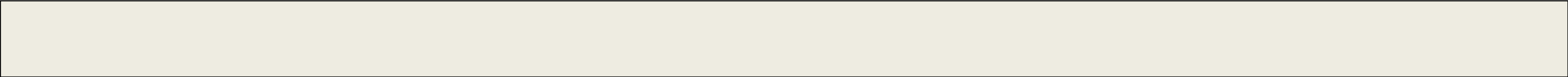
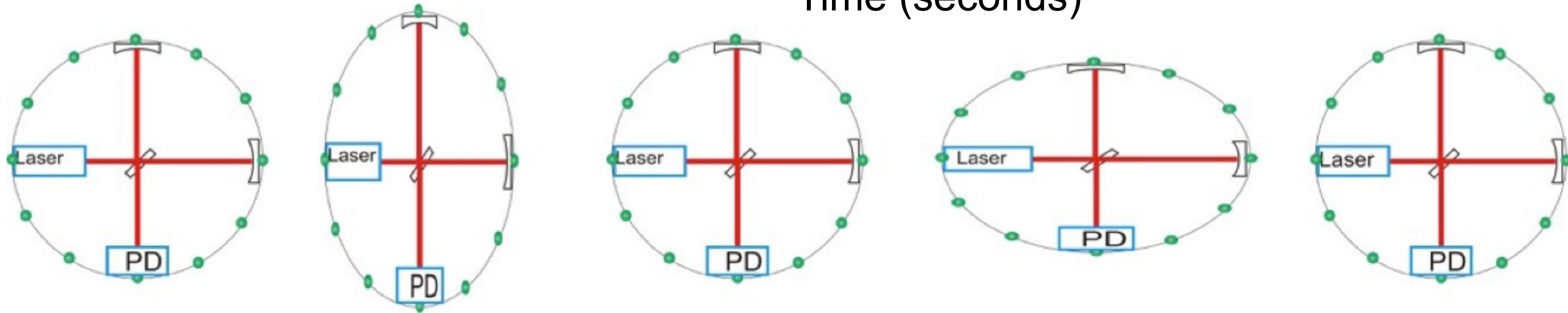
Web Apps

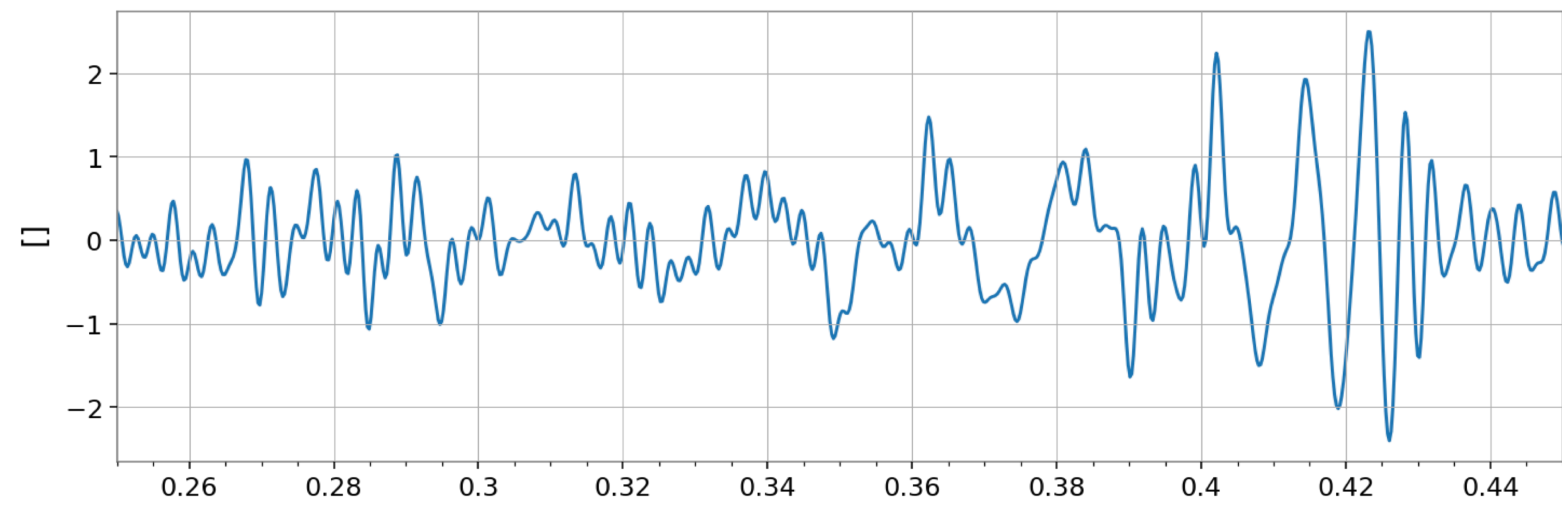
Strain data

Time Domain Strain Data



$$\frac{\Delta L}{L}$$





Time Domain Strain Data

Time-series data

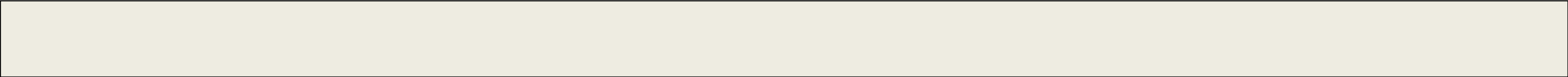
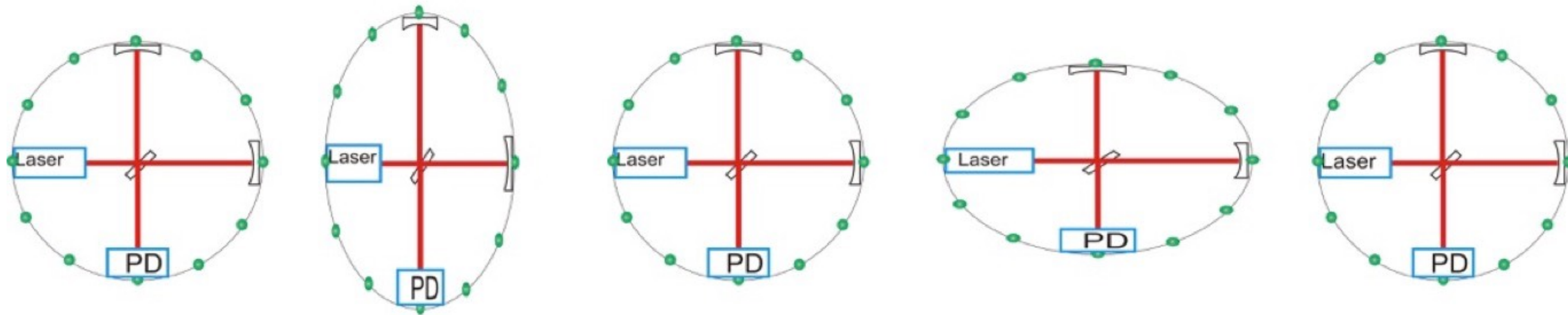
Data sets span months or years

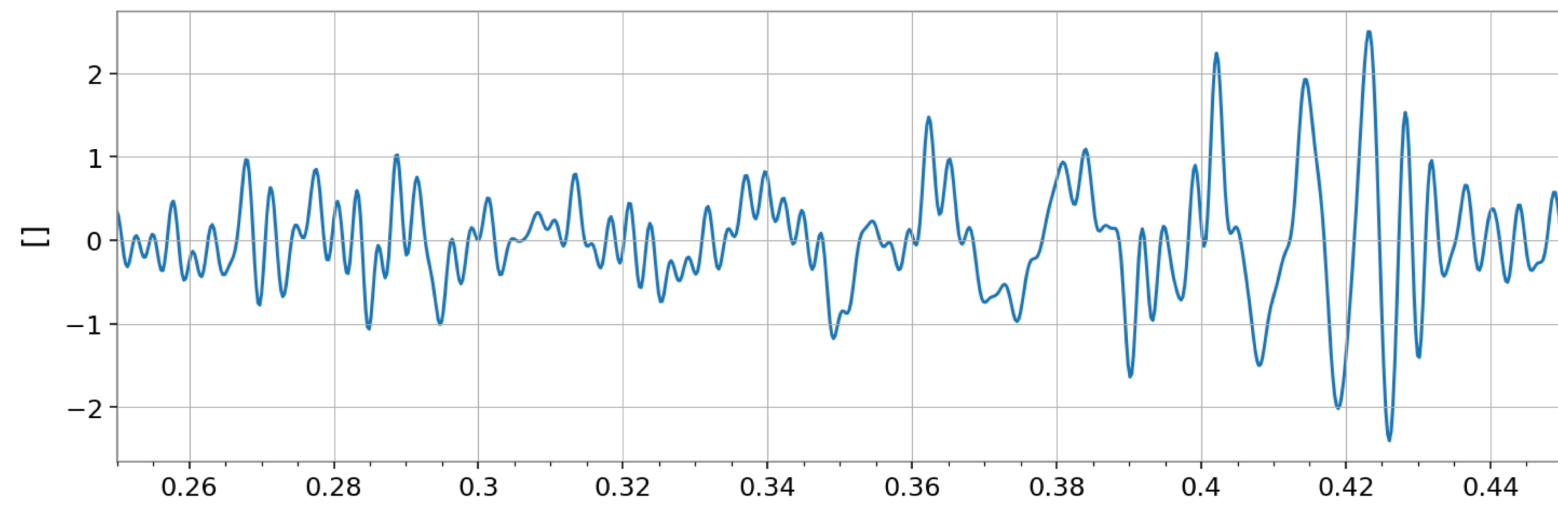
A few TB per year

Detections last for seconds or less

Detections are hidden in noise

$$\frac{\Delta L}{L}$$





Time Domain Strain Data



SoftwareX

Volume 13, January 2021, 100658



Original software publication

Open data from the first and second observing runs of Advanced LIGO and Advanced Virgo

Rich Abbott¹ [✉](#), Thomas D. Abbott², Sheelu Abraham³, Fausto Acernese^{4,5}, Kendall Ackley⁶, Carl Adams⁷, Rana X. Adhikari¹, Vaishali B. Adya⁸, Christoph Affeldt^{9,10}, Michalis Agathos^{11,12}, Kazuhiro Agatsuma¹³, Nancy Aggarwal¹⁴, Odylio D. Aguiar¹⁵, Amit Aich¹⁶, Lorenzo Aiello^{17,18}, Anirban Ain³, Ajith Parameswaran¹⁹, Gabrielle Allen²⁰, Annalisa Allocca²¹, Paul A. Altin⁸... John Zweizig¹

[Show more](#) [v](#)

THE ASTROPHYSICAL JOURNAL
SUPPLEMENT SERIES

OPEN ACCESS

Open Data from the Third Observing Run of LIGO, Virgo, KAGRA, and GEO

R. Abbott¹, H. Abe², F. Acernese^{3,4}, K. Ackley⁵ [ID](#), S. Adhicary⁶, N. Adhikari⁷ [ID](#), R. X. Adhikari¹ [ID](#), V. K. Adkins⁸, V. B. Adya⁹, C. Affeldt^{10,11} [+ Show full author list](#)

Published 2023 July 28 • © 2023. The Author(s). Published by the American Astronomical Society.

[The Astrophysical Journal Supplement Series, Volume 267, Number 2](#)

Citation R. Abbott *et al* 2023 *ApJS* 267 29

DOI 10.3847/1538-4365/acdc9f

Published papers describe
each data set

Strain data file

```
H-H1_GWOSC_4KHZ_R1-1268903496-32.txt
# Gravitational wave strain for GW200322_091133-v1 for H1
# This file has 4096 samples per second
# starting GPS 1268903496 duration 32
-7.1980900594956013e-21
-6.8433397262034073e-21
-1.7612990400426759e-20
-9.4267311704874265e-21
-6.1983141016039667e-21
-1.3240125547300500e-20
-1.2532010942962005e-20
-1.6986963728113432e-20
-1.4093840416373476e-20
-9.5227443608221438e-21
-1.9064670104960347e-20
1.6122006160160277e-20
```

Formats:

GWF
or
HDF5

Strain data file

```
H-H1_GWOSC_4KHZ_R1-1268903496-32.txt
# Gravitational wave strain for GW200322_091133-v1 for H1
# This file has 4096 samples per second
# starting GPS 1268903496 duration 32
-7.1980900594956013e-21
-6.8433397262034073e-21
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-9.4267311704874265e-21
-6.1983141016039667e-21
-1.3240125547300500e-20
-1.2532010942962005e-20
-1.6986963728113432e-20
-1.4093840416373476e-20
-9.5227443608221438e-21
-1.9064670104960347e-20
1.6122006160160277e-20
```

Sample Rate

16384 Hz

or

4096 Hz

Strain data file

```
H-H1_GWOSC_4KHZ_R1-1268903496-32.txt
# Gravitational wave strain for GW200322_091133-v1 for H1
# This file has 4096 samples per second
# starting GPS 1268903496 duration 32
-7.1980900594956013e-21
-6.8433397262034073e-21
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-1.3240125547300500e-20
-1.2532010942962005e-20
-1.6986963728113432e-20
-1.4093840416373476e-20
-9.5227443608221438e-21
-1.9064670104960347e-20
1.6122006160160277e-20
```

Start time
Time measured
in GPS seconds

Strain data file

```
H-H1_GWOSC_4KHZ_R1-1268903496-32.txt
# Gravitational wave strain for GW200322_091133-v1 for H1
# This file has 4096 samples per second
# starting GPS 1268903496 duration 32
-7.1980900594956013e-21
-6.8433397262034073e-21
-1.7612990400426759e-20
-9.4267311704874265e-21
-6.1983141016039667e-21
-1.3240125547300500e-20
-1.2532010942962005e-20
-1.6986963728113432e-20
-1.4093840416373476e-20
-9.5227443608221438e-21
-1.9064670104960347e-20
1.6122006160160277e-20
```

Strain values
at each sample time

Time between samples

$$\Delta t = 1/f_s$$

GPS

Time

- Number of seconds from Jan 6, 1980 UTC
- Used by GPS satellites
- Convenient time convention for computers
- Conversion tool: gwosc.org/gps

UTC/GPS Time Converter

Change either box and the other responds immediately.

UTC
2024-04-05T22:17:24

Universal Time [ISO8601](https://www.iso.org/standard/52083.html)

GPS Time
1396390662

OK

Current time

Explore Strain: GW Quickview App

<https://gw-quickview.streamlit.app/>

Select Data Time and Detector

How do you want to find data?

By event name ▼

Select Event

GW150914 ▼

Detector

H1 ▼

Full sample rate data

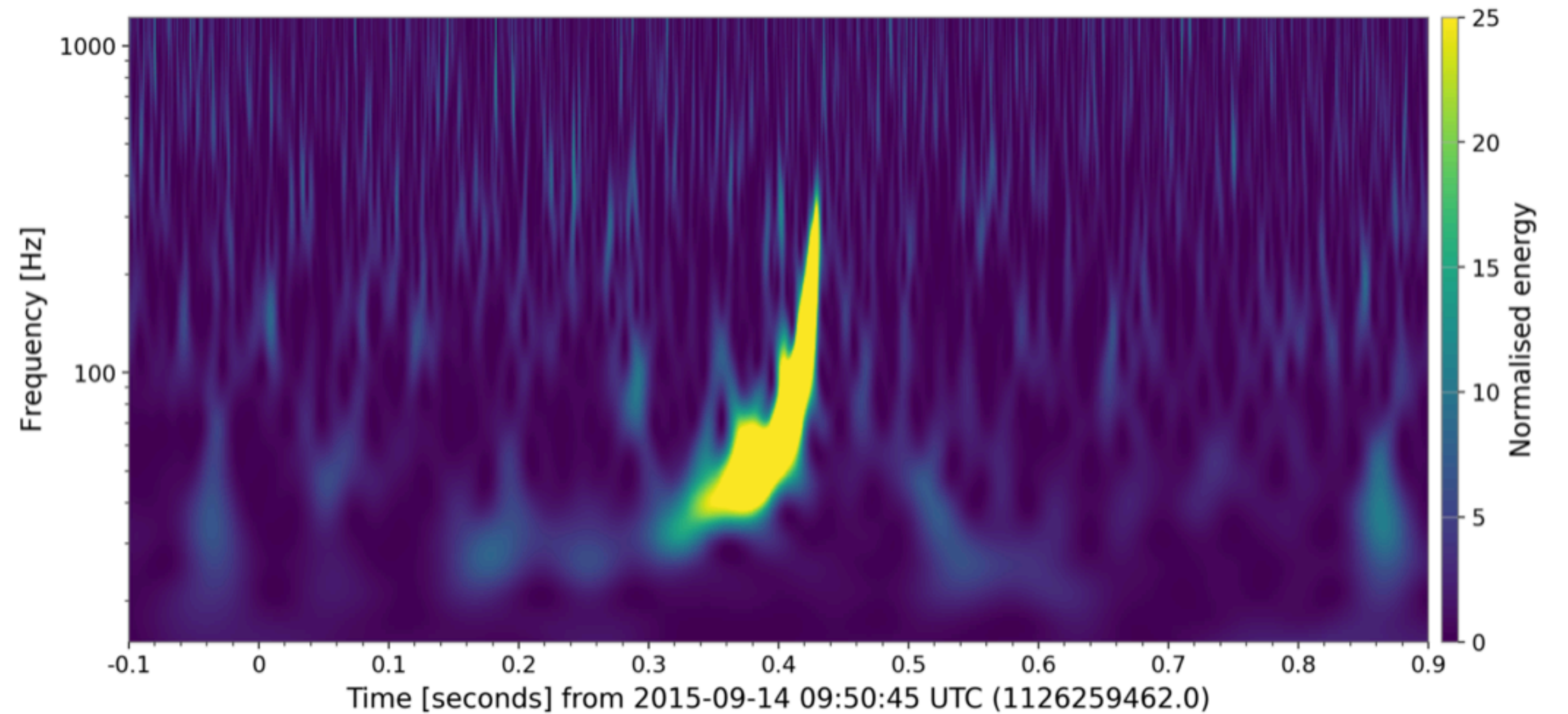
Set Plot Parameters

Time Range (seconds)

1.00

0.10 8.00

Q-transform



See notes ▼

About this app

Select Data Time and Detector

How do you want to find data?

By event name

Select Event

GW151012

Detector

H1

Full sample rate data

Set Plot Parameters

Time Range (seconds)

0.44

Gravitational Wave Quickview

- Use the menu at left to select data and set plot parameters
- Your plots will appear below

GW151012

GPS: 1128678900.4

Mass 1: 23.2 M_⊙

Mass 2: 13.6 M_⊙

Network SNR: 10

Event page: <https://gw-osc.org/eventapi/html/event/GW151012>

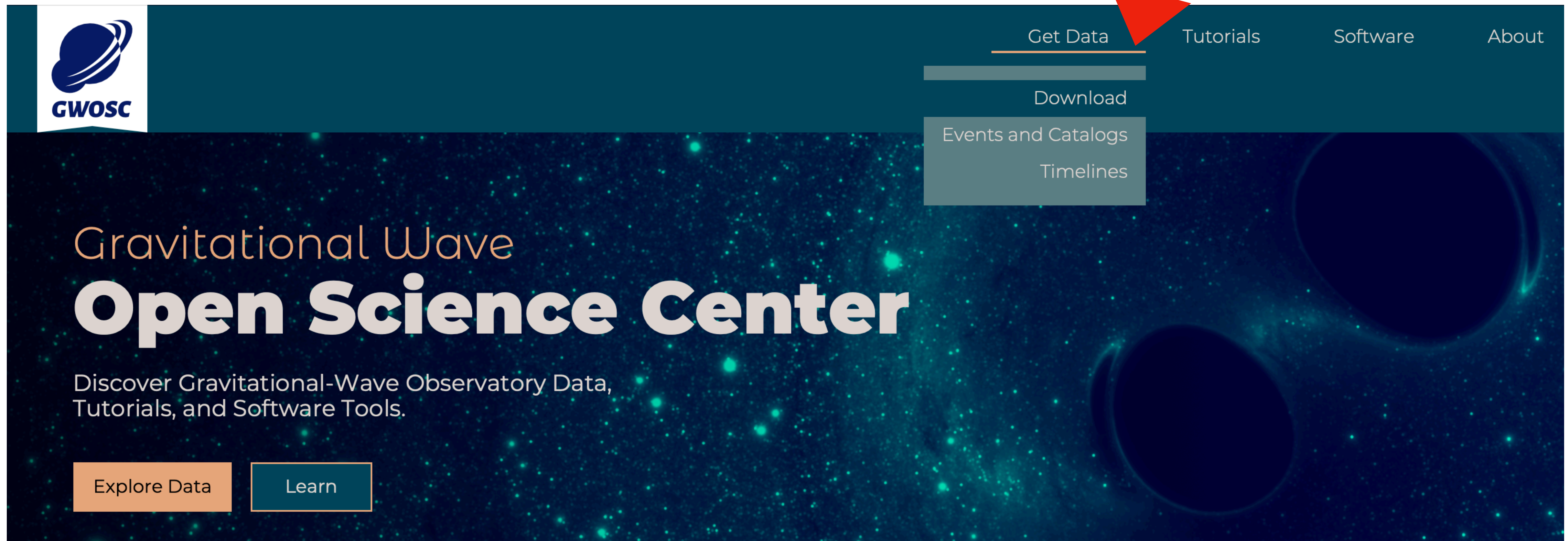
Loading data...done!

Download Strain Data

1) Point & Click

Download Strain Data

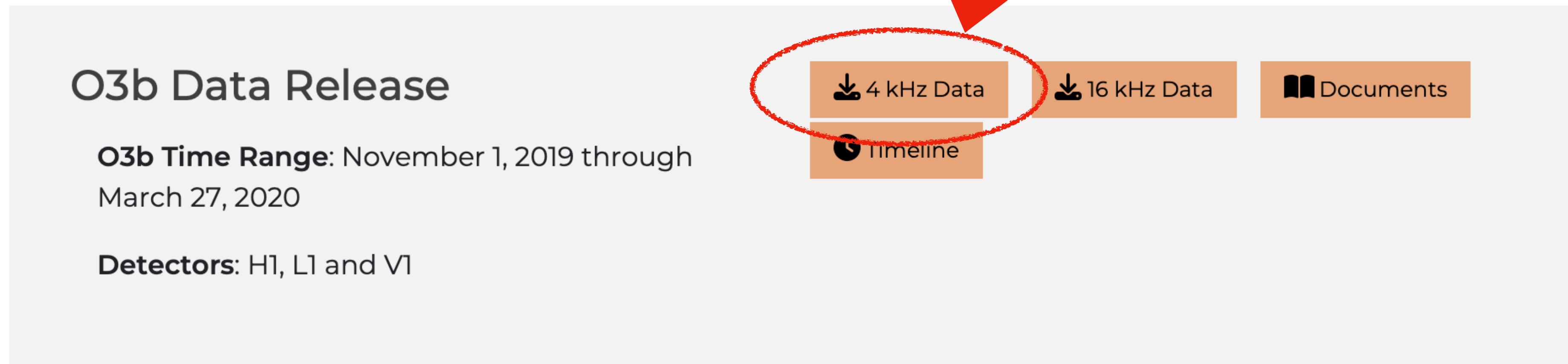
1) Point & Click



The image shows a screenshot of the Gravitational Wave Open Science Center (GWOSC) website. The top navigation bar is dark teal and contains the GWOSC logo on the left and the links 'Get Data', 'Tutorials', 'Software', and 'About' on the right. A red arrow points to the 'Get Data' link, which has a dropdown menu open. The dropdown menu contains three items: 'Download', 'Events and Catalogs', and 'Timelines'. Below the navigation bar, the main content area has a dark blue background with a starry pattern. The text 'Gravitational Wave Open Science Center' is displayed in large, bold, white letters. Below this, a smaller line of text reads 'Discover Gravitational-Wave Observatory Data, Tutorials, and Software Tools.' At the bottom left, there are two buttons: 'Explore Data' (orange) and 'Learn' (teal).

Download Strain Data


1) Point & Click





O3b Data Release


O3b Time Range: November 1, 2019 through March 27, 2020

Detectors: H1, L1 and V1

 4 kHz Data

 16 kHz Data

 Documents

 Timeline

A red arrow points to the '4 kHz Data' button, which is also circled in red.

Download Strain Data

1) Point & Click

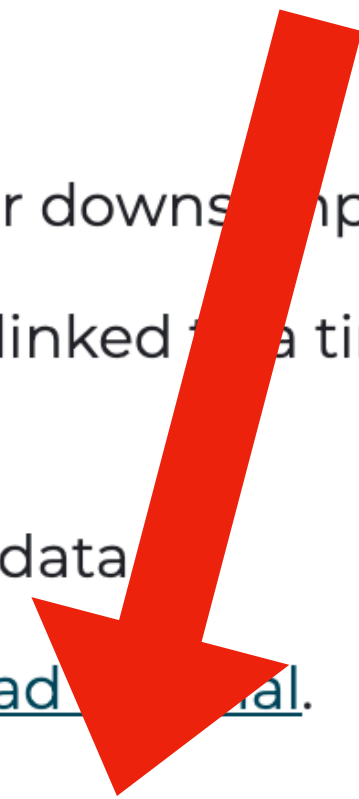
Dataset: O3b_4KHZ_R1

GPS Time Interval: [1256655618, 1269363618]

Detector: H1

Note:

- Each file covers a 4096-second period, with strain data at either 16kHz or downsampled to 4 kHz.
- 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 file 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
1256660992	2019-11-01T16:29:34	50.4 MB	HDF5	Frame	40.2
1256665088	2019-11-01T17:37:50	124.3 MB	HDF5	Frame	100.0
1256669184	2019-11-01T18:46:06	124.3 MB	HDF5	Frame	100.0

Download Strain Data

1) Point & Click

2) Python Client

Download Strain Data

1) Point & Click

2) Python Client

```
>>> from gwosc.locate import get_urls
>>> get_urls('L1', 968650000, 968660000)
['https://gwosc.org/archive/data/S6/967835648/L-L1_L0SC_4_V1-968646656-4096.hdf5',
 'https://gwosc.org/archive/data/S6/967835648/L-L1_L0SC_4_V1-968650752-4096.hdf5',
 'https://gwosc.org/archive/data/S6/967835648/L-L1_L0SC_4_V1-968654848-4096.hdf5',
 'https://gwosc.org/archive/data/S6/967835648/L-L1_L0SC_4_V1-968658944-4096.hdf5']
```

Download Strain Data

1) Point & Click

2) Python Client

3) Direct load w/ gwpy

Download Strain Data

1) Point & Click

2) Python Client

3) Direct load w/ gwpy

```
>>> from gwpy.timeseries import TimeSeries
>>> data = TimeSeries.fetch_open_data('L1', start, end)
```

Download Strain Data

1) Point & Click

2) Python Client

3) Direct load w/ gwpy

4) Extended release: NDS2 & CVMFS

Download Strain Data

```
from gwpy.timeseries import TimeSeries
data = TimeSeries.fetch('L1:ISI-GND_STS_ITMY_Z_BLRMS_30M_100M',
start=1266624018, end=1266624618, host='nds.gwosc.org')
```

4) Extended release: **NDS2** & **CVMFS**

A diagram with two ovals. The left oval is blue and contains the text 'NDS2'. The right oval is red and contains the text 'CVMFS'. A blue arrow points from the 'NDS2' oval to the 'host' parameter in the code block above. A red arrow points from the 'CVMFS' oval to the 'host' parameter in the code block above.

CVMFS available on Open Science Grid
& other computer clusters

Download Strain Data

1) Point & Click

2) Python Client

3) Direct load w/ gwpy

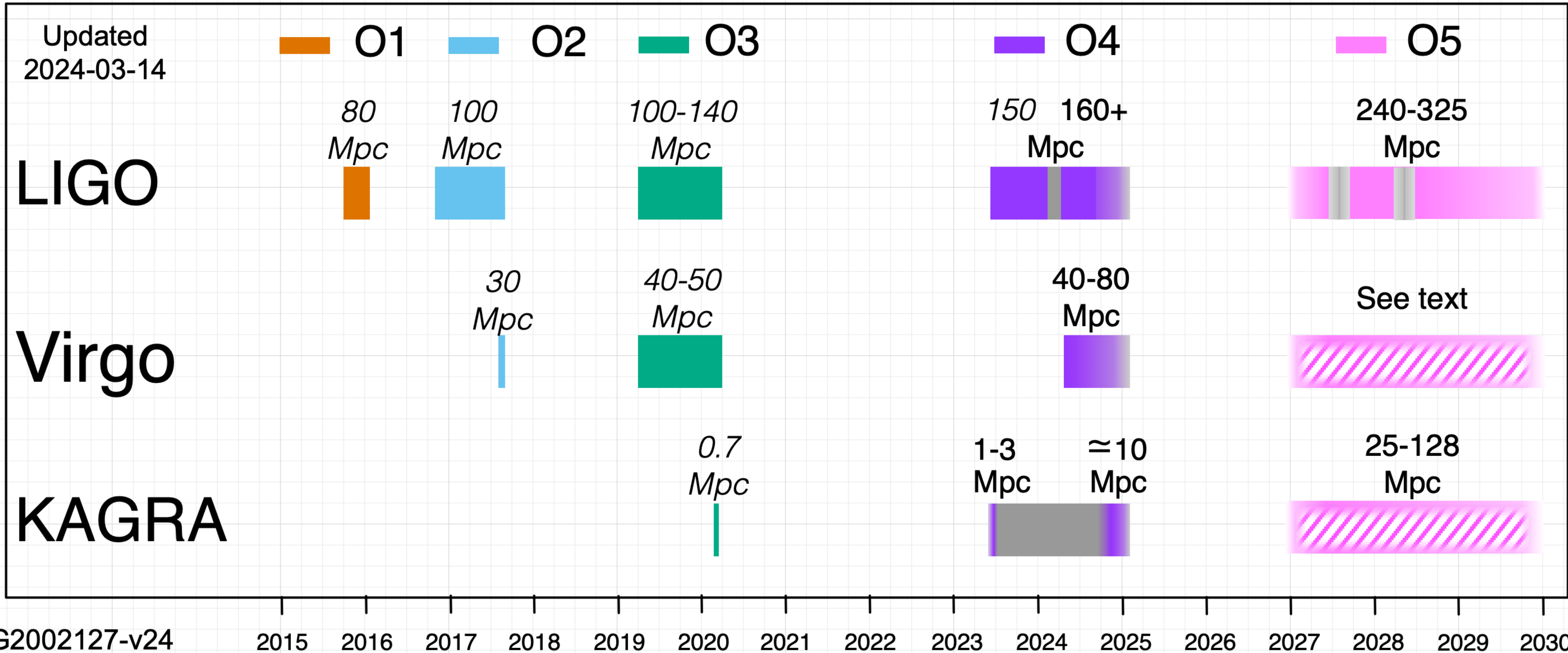
4) Extended release: NDS2 & CVMFS

Timeline App & Segments

When are data available?

Timeline App & Segments

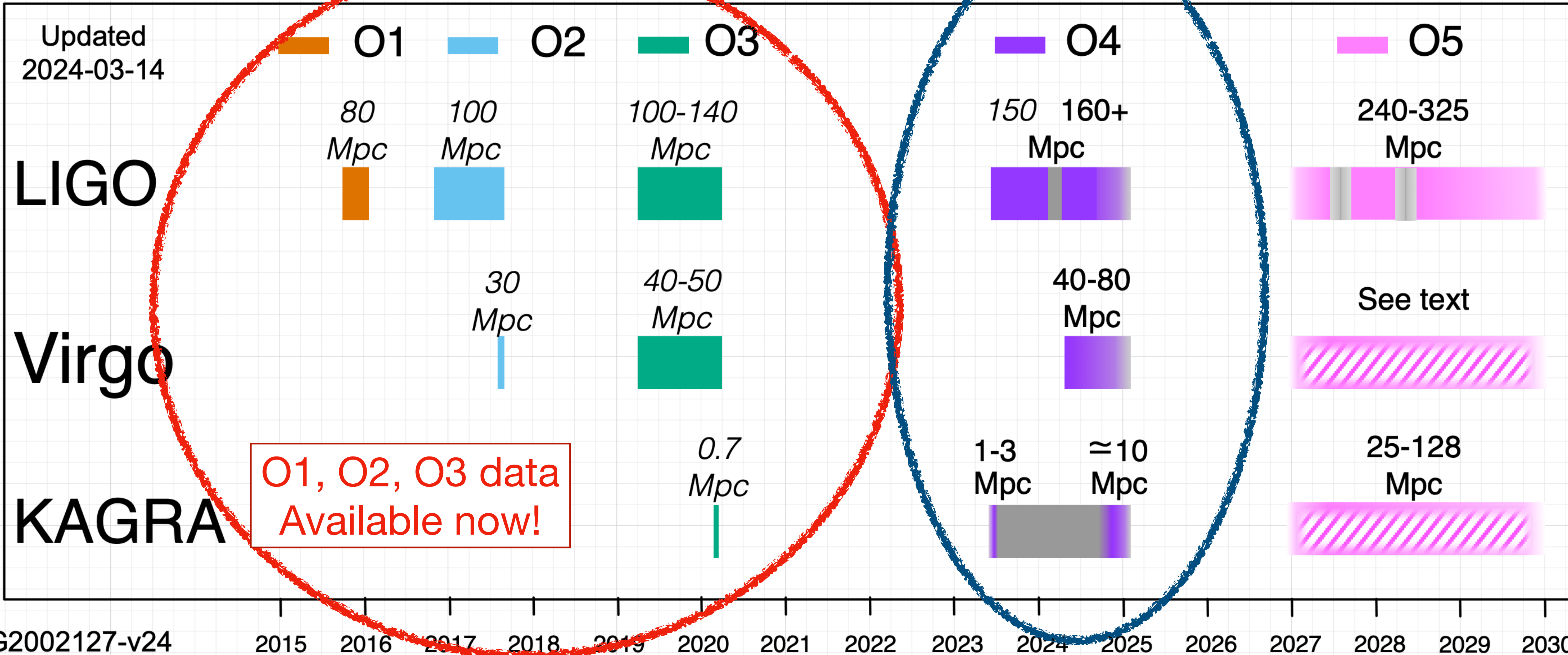
When are data available?



Timeline App & Segments

When are data available?

O4 run
in progress

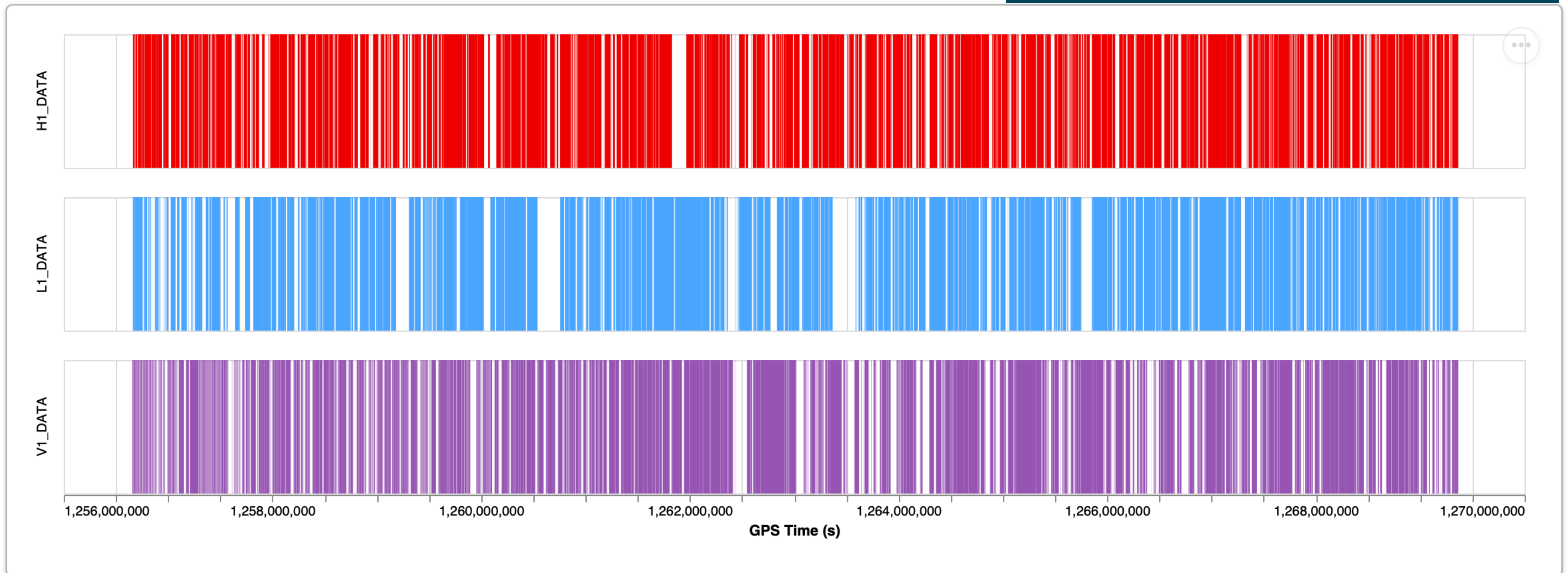


Timeline App & Segments

When are data available?

gwosc.org/timeline

Timeline O3b



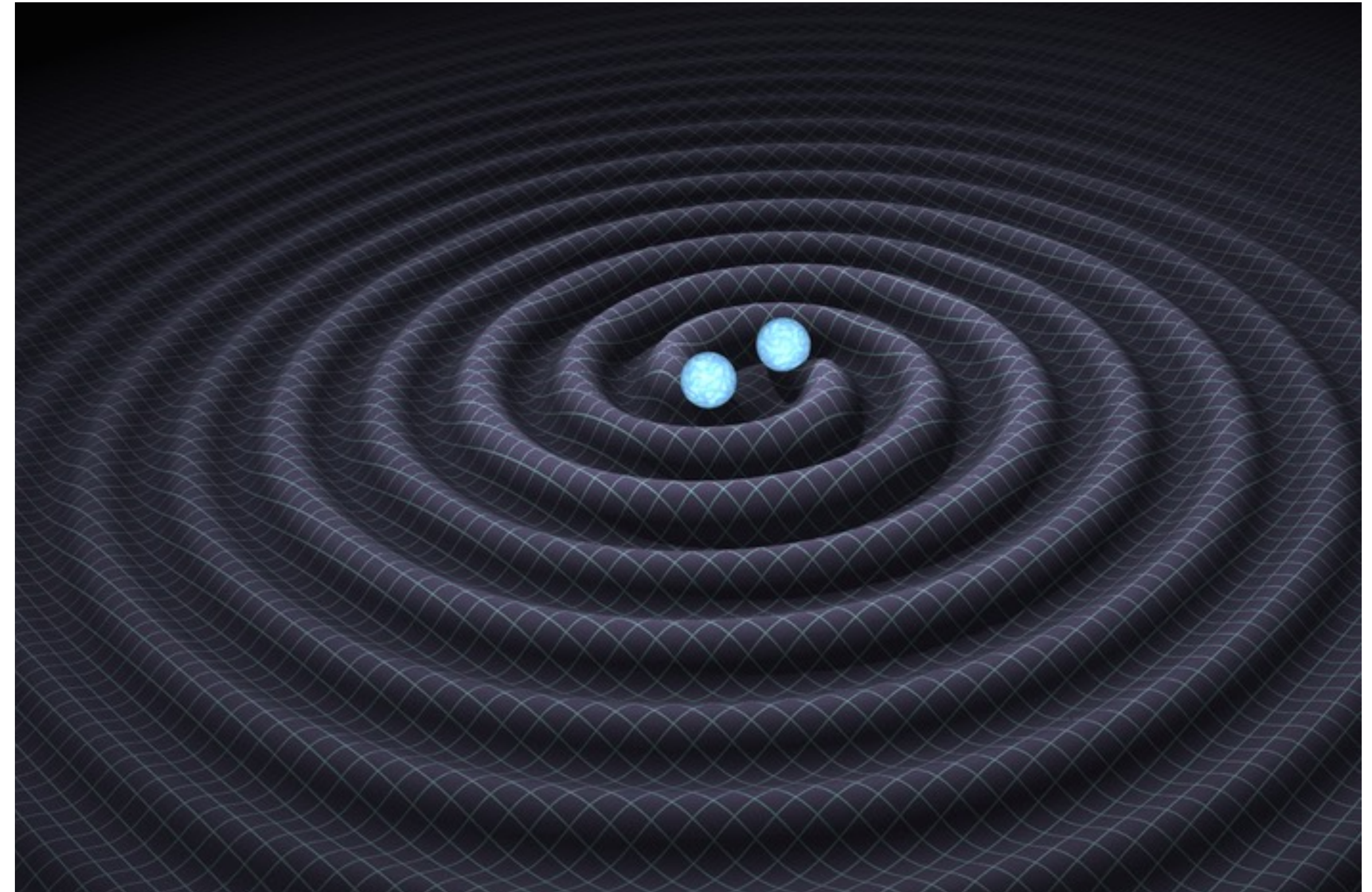
Event Catalogs

What events has LIGO/Virgo/KAGRA seen?

Event Catalogs

What events has LIGO/Virgo/KAGRA seen?

- Each “event” is a compact object merger
 - Mergers of black holes or neutron stars
- Observed for seconds or less
- Around 90 detections so far





Gravitational Wave Open Science Center



Data ▾

Software ▾

Online Tools ▾

Learning Resources ▾

About GWOSC ▾

 Help

Event Portal

GWTC Transient Catalog

Releases

Events

Query

Event Query

Event Name:

The (partial) name of the event, e.g. GW150914

Release:

GWTC-1-marginal
GWTC-1-confident
O1_O2-Preliminary
O3_Discovery_Papers

Restrict search to a Catalog Release

i Mass 1
Range:

i Mass 2
Range:

i Total Mass
Range:

i Final Mass
Range:

i Chirp Mass
Range:

i Detector
Frame Chirp
Mass Range:

i Distance
(Mpc) Range:

i Redshift
Range:

i Network
SNR Range:

i χ_{eff} Range:

i False Alarm
Rate Range:

i P_{astro} Range:

IGWN Catalogs

Event Portal

List of Events

Data Product

Name	Version	Release	GPS	Mass 1 (M_{\odot})	Mass 2 (M_{\odot})	Network SNR	Distance (Mpc)	χ_{eff}	Total Mass (M_{\odot})	Chirp M
GW200322_091133	v1	GWTC-3-confident	1268903511.3	34^{+48}_{-18}	$14.0^{+16.8}_{-8.7}$	$6.0^{+1.7}_{-1.2}$	3600^{+7000}_{-2000}	$0.24^{+0.45}_{-0.51}$	55^{+37}_{-27}	$15.5^{+15.7}_{-3.7}$
GW200316_215756	v1	GWTC-3-confident	1268431094.1	$13.1^{+10.2}_{-2.9}$	$7.8^{+1.9}_{-2.9}$	$10.3^{+0.4}_{-0.7}$	1120^{+470}_{-440}	$0.13^{+0.27}_{-0.10}$	$21.2^{+7.2}_{-2.0}$	$8.75^{+0.6}_{-0.5}$
GW200311_115853	v1	GWTC-3-confident	1267963151.3	$34.2^{+6.4}_{-3.8}$	$27.7^{+4.1}_{-5.9}$	$17.8^{+0.2}_{-0.2}$	1170^{+280}_{-400}	$-0.02^{+0.16}_{-0.20}$	$61.9^{+5.3}_{-4.2}$	$26.6^{+2.4}_{-2.0}$
GW200308_173609	v1	GWTC-3-confident	1267724187.7	$36.4^{+11.2}_{-9.6}$	$13.8^{+7.2}_{-3.3}$	$7.1^{+0.5}_{-0.5}$	5400^{+2700}_{-2600}	$0.65^{+0.17}_{-0.21}$	$50.6^{+10.9}_{-8.5}$	$19.0^{+4.8}_{-2.8}$
GW200306_093714	v1	GWTC-3-confident	1267522652.1	$28.3^{+17.1}_{-7.7}$	$14.8^{+6.5}_{-6.4}$	$7.8^{+0.4}_{-0.6}$	2100^{+1700}_{-1100}	$0.32^{+0.28}_{-0.46}$	$43.9^{+11.8}_{-7.5}$	$17.5^{+3.5}_{-3.0}$
GW200302_015811	v1	GWTC-3-confident	1267149509.5	$37.8^{+8.7}_{-8.5}$	$20.0^{+8.1}_{-5.7}$	$10.8^{+0.3}_{-0.4}$	1480^{+1020}_{-700}	$0.01^{+0.25}_{-0.26}$	$57.8^{+9.6}_{-6.9}$	$23.4^{+4.7}_{-3.0}$
GW200225_060421	v1	GWTC-3-confident	1266645879.3	$19.3^{+5.0}_{-3.0}$	$14.0^{+2.8}_{-3.5}$	$12.5^{+0.3}_{-0.4}$	1150^{+510}_{-530}	$-0.12^{+0.17}_{-0.28}$	$33.5^{+3.6}_{-3.0}$	$14.2^{+1.5}_{-1.4}$
GW200224_222234	v1	GWTC-3-confident	1266618172.4	$40.0^{+6.9}_{-4.5}$	$32.5^{+5.0}_{-7.2}$	$20.0^{+0.2}_{-0.2}$	1710^{+490}_{-640}	$0.10^{+0.15}_{-0.15}$	$72.2^{+7.2}_{-5.1}$	$31.1^{+3.2}_{-2.6}$
GW200220_124850	v1	GWTC-3-confident	1266238148.1	$38.9^{+14.1}_{-8.6}$	$27.9^{+9.2}_{-9.0}$	$8.5^{+0.3}_{-0.5}$	4000^{+2800}_{-2200}	$-0.07^{+0.27}_{-0.33}$	67^{+17}_{-12}	$28.2^{+7.3}_{-5.1}$
GW200220_061928	v1	GWTC-3-confident	1266214786.7	87^{+40}_{-23}	61^{+26}_{-25}	$7.2^{+0.4}_{-0.7}$	6000^{+4800}_{-3100}	$0.06^{+0.40}_{-0.38}$	148^{+55}_{-33}	62^{+23}_{-15}

Event Catalogs

Event Portal

GW200129_065458

Single Event Data Product

Documentation

Release: [GWTC-3-confident](#)

Event UID: [GW200129_065458-v1](#)

Names: [GW200129_065458](#)

GPS: [1264316116.4](#)

UTC Time: [2020-01-29 06:54](#)

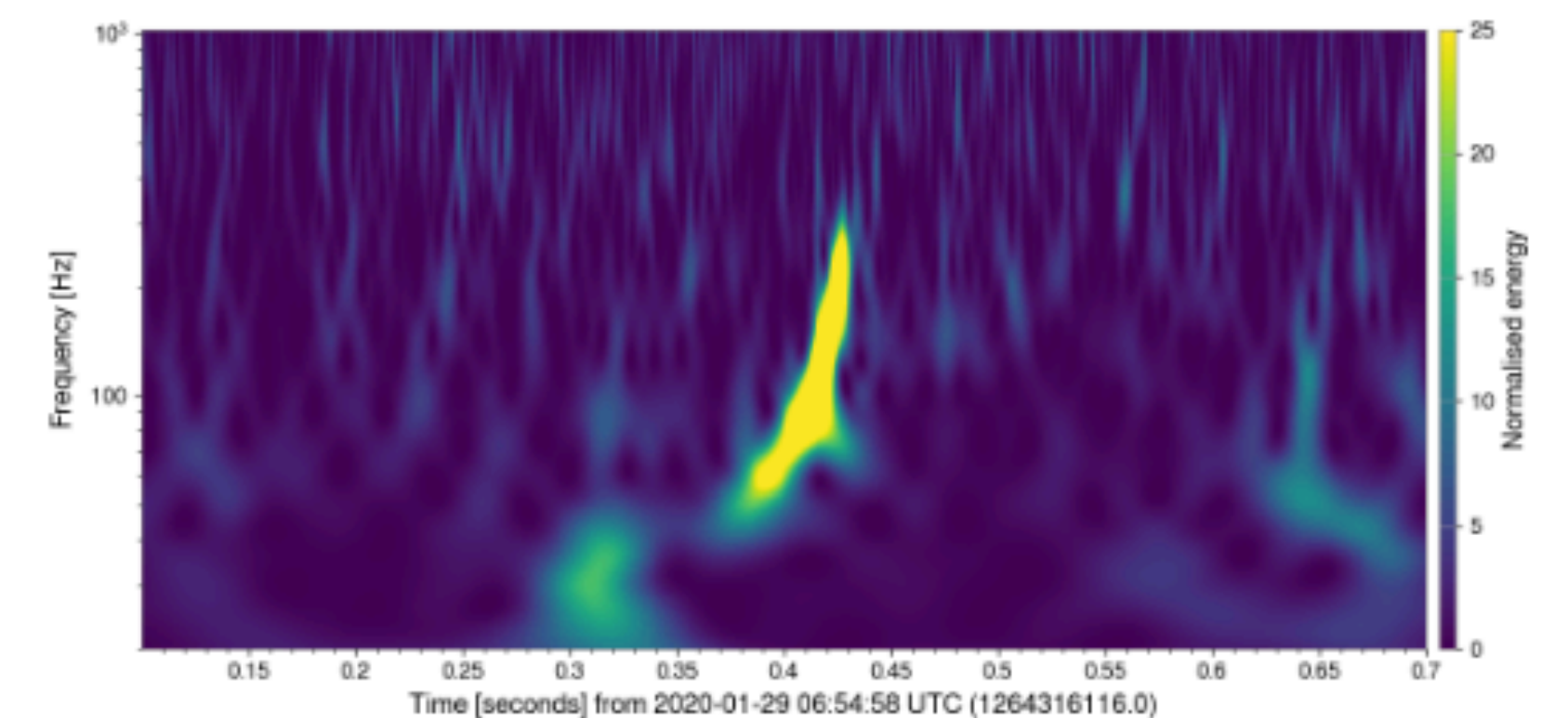
GraceDB: [S200129m](#)

GCN: [Notices · Circulars](#)

Timeline: [Query for segments](#)

DOI: <https://doi.org/10.7935/b024-1886>

H1 strain



32sec · 16KHz: [GWF](#) [HDF](#) [TXT](#)

32sec · 4KHz: [GWF](#) [HDF](#) [TXT](#)

4096sec · 16KHz: [GWF](#) [HDF](#) [TXT](#)

4096sec · 4KHz: [GWF](#) [HDF](#) [TXT](#)

Data sourced from frame channels.

FrameChannels: [H1:DCS-CALIB_STRAIN_CLEAN_SUB60HZ_C01, L1:DCS-CALIB_STRAIN_CLEAN_SUB60HZ_C01, V1:Hrec_hoft_16384Hz]

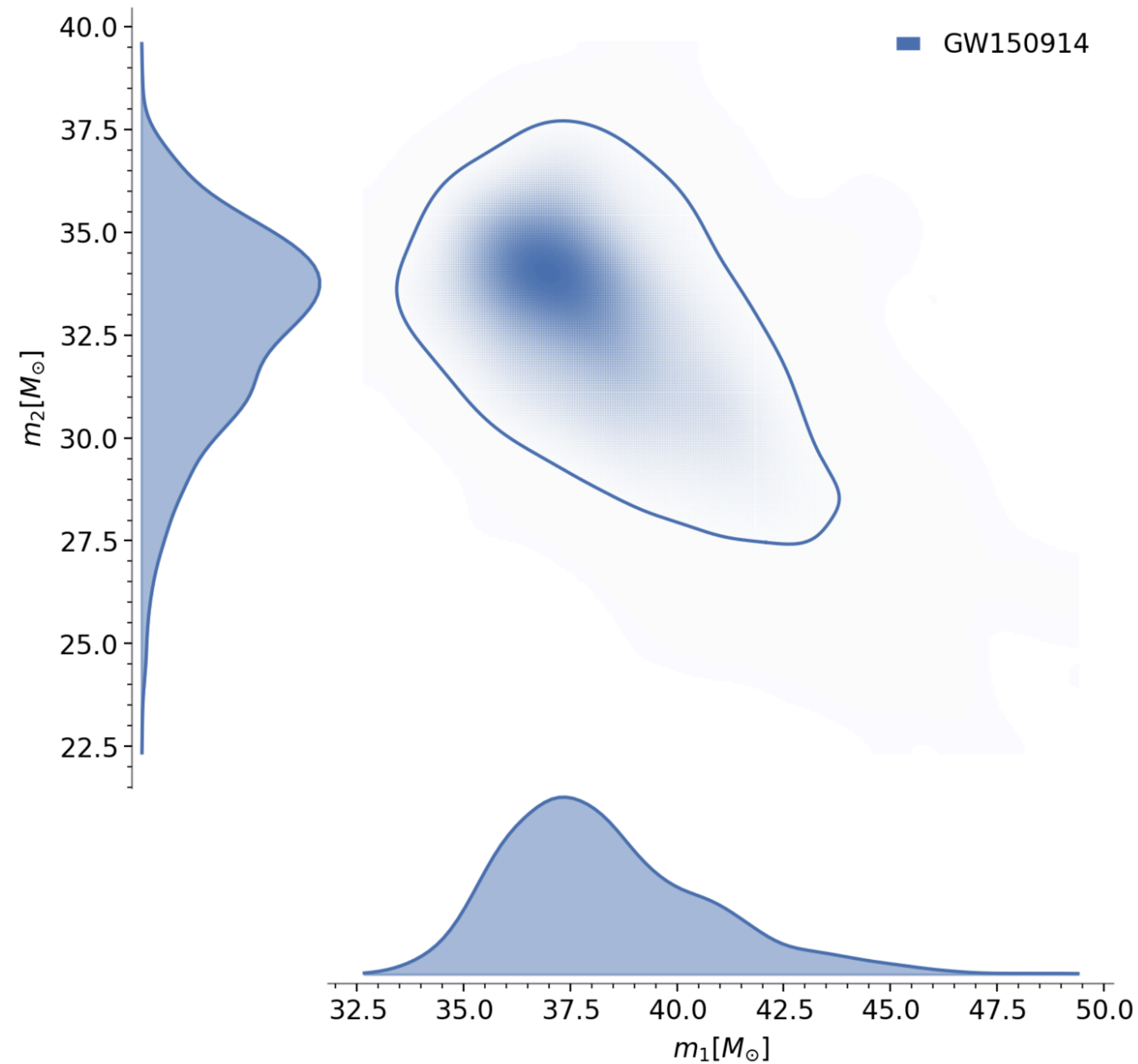
Data sourced from frame types:

FrameTypes: [H1 HOFT_CLEAN_SUB60HZ_C01 L1 HOFT_CLEAN_SUB60HZ_C01 V1Online]

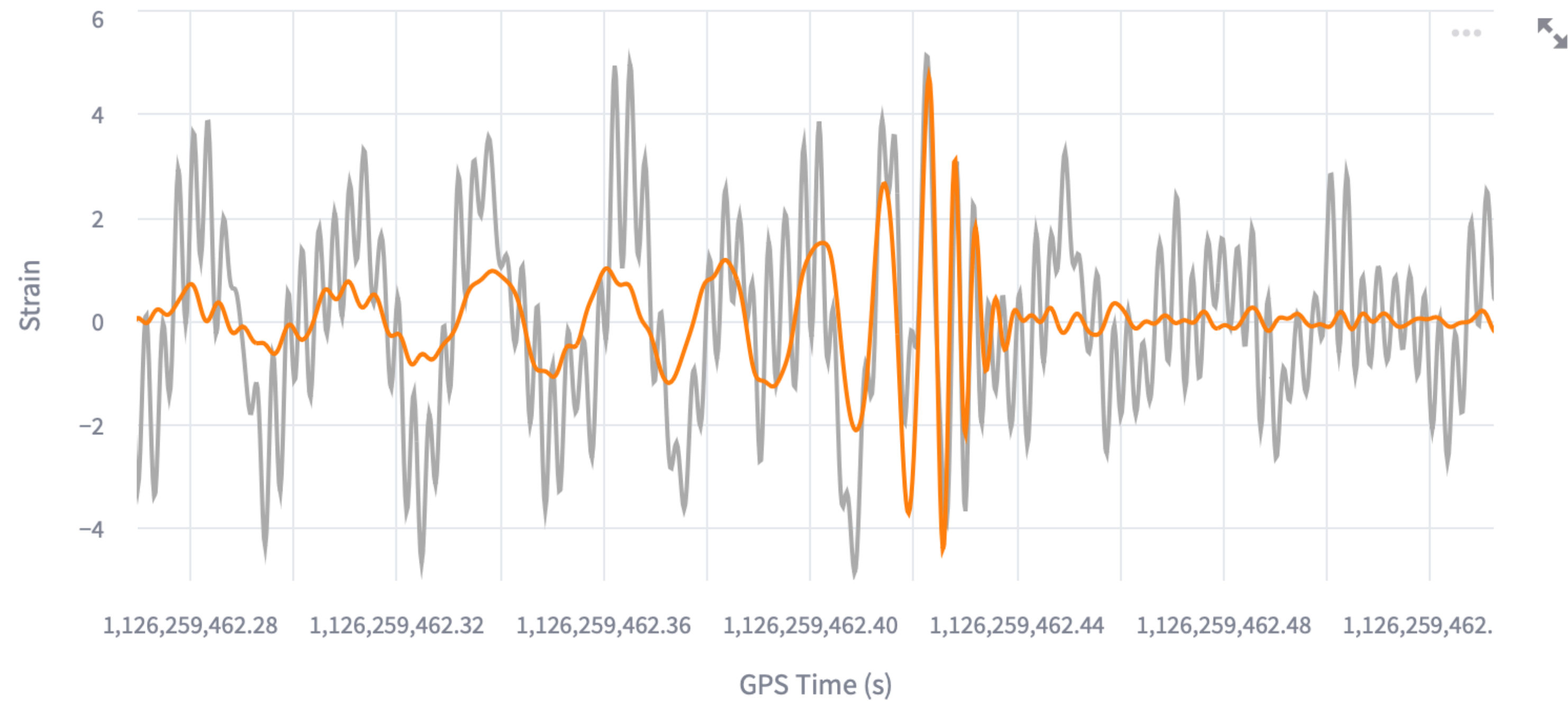
Event Viewer App

Visualize event parameters & waveforms

Triangle plot



H1



peviewer.igwn.org



Select events

Event 1

GW150914



Event 2

GW190521



Event 3

None

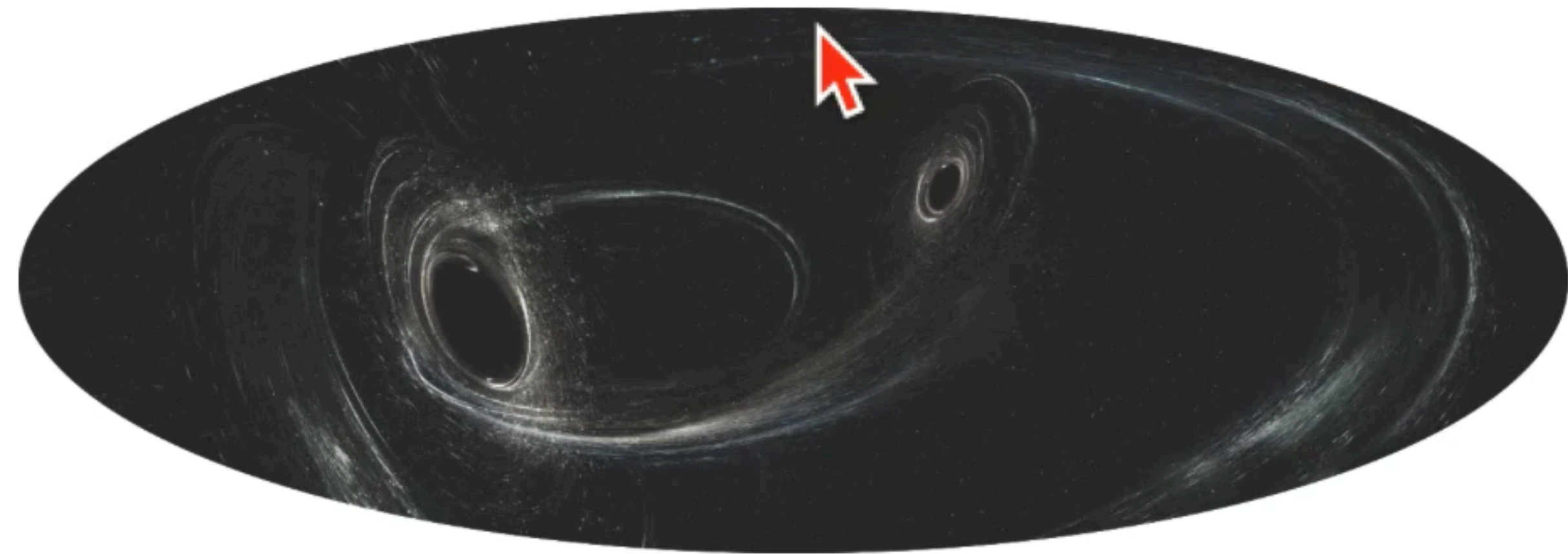


Update data



PE Viewer

Make plots of waveforms, source parameters, and skymaps for gravitational-wave events.



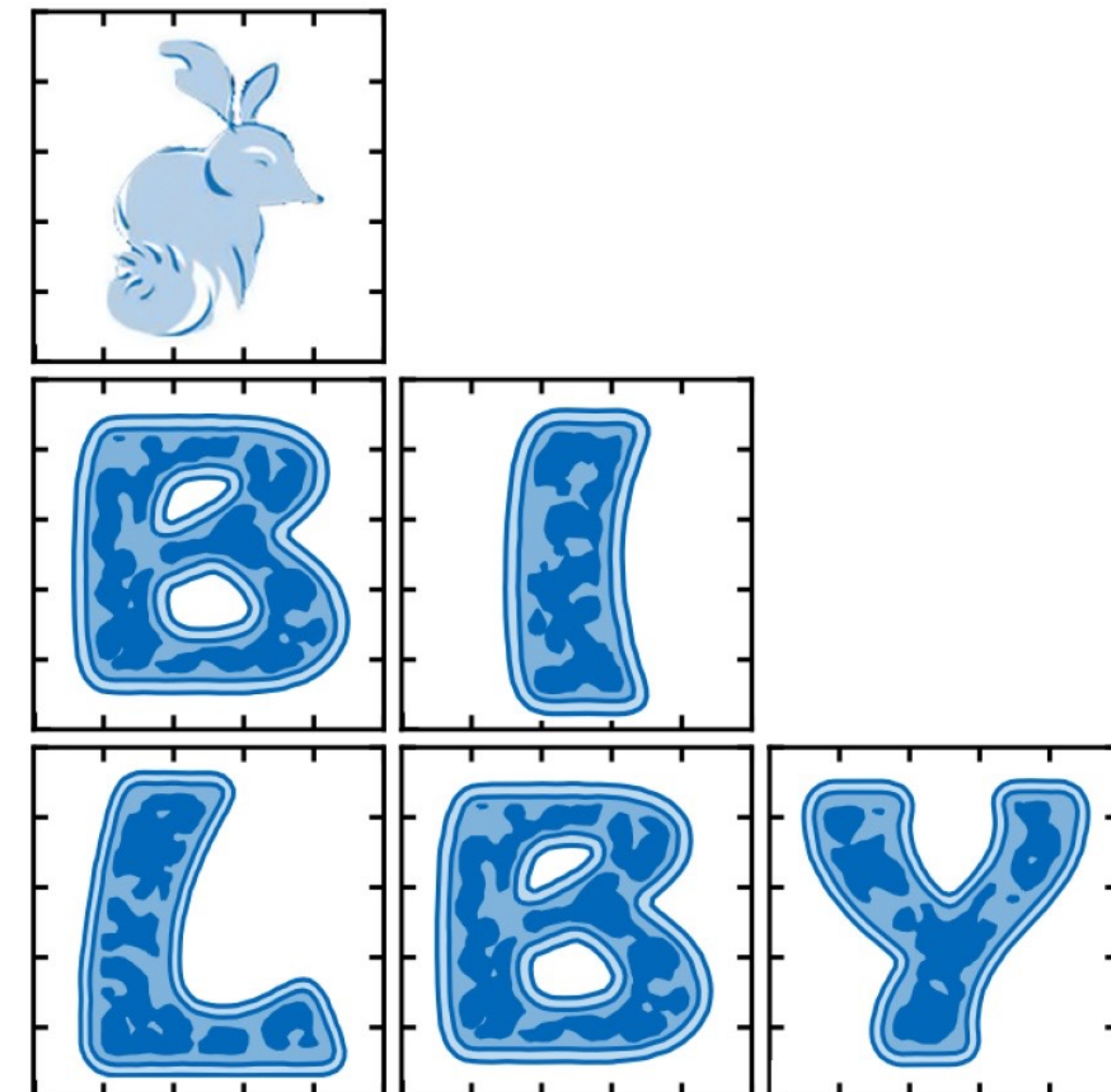
[About](#) [2-D Plots](#) [Skymaps](#) [All Parameters](#) [Waveform](#) [Config](#)

Making waveform for Event 1: GW150914

Software

gwosc.org/software

- IGWN Conda Software Distribution
 - —> install full LVK software stack
- PyPY (pip) also possible in many cases

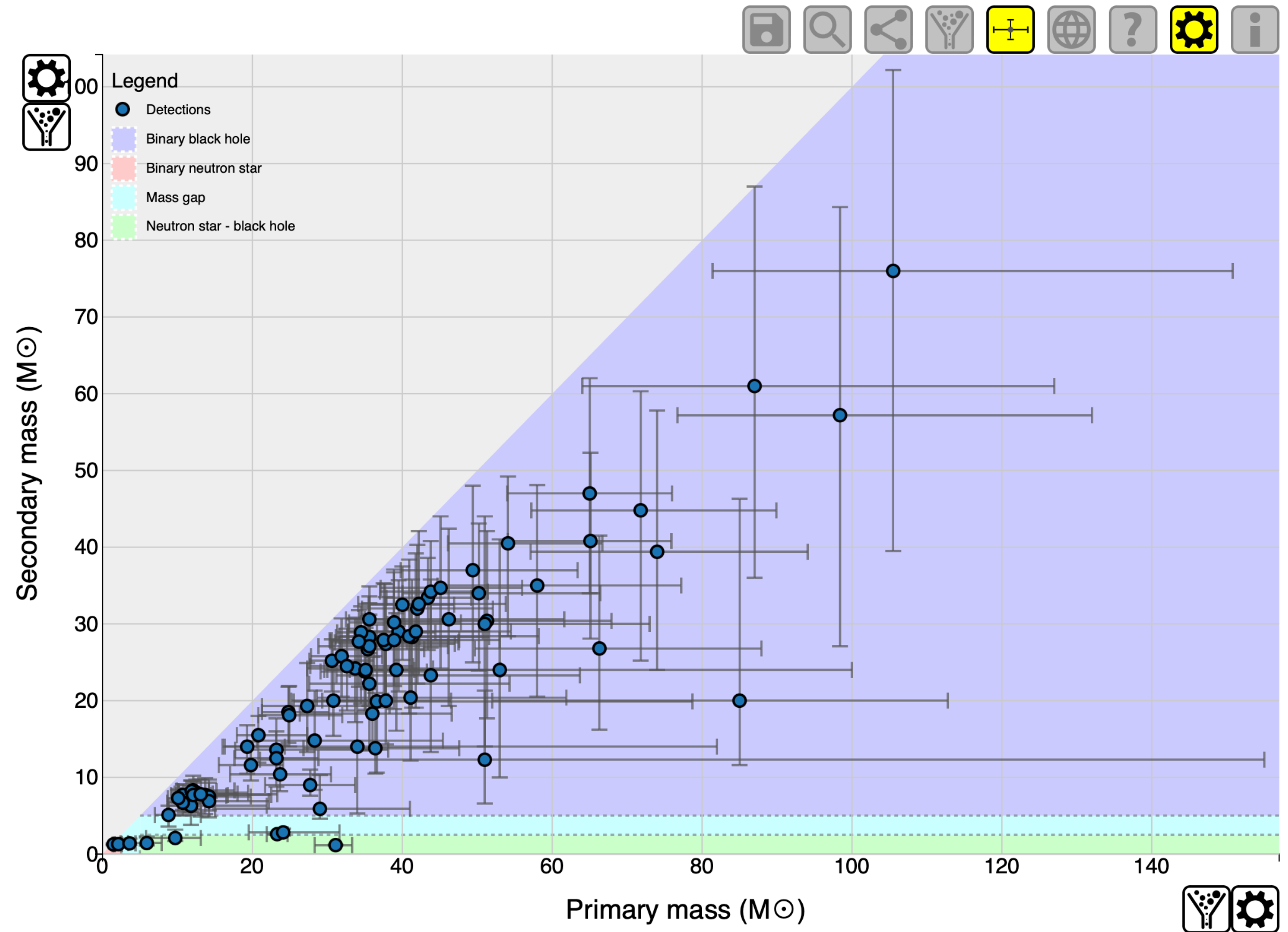


Web Apps

gwosc.org/interactive

- List of apps for GW data
- Plotting tools, games, phone apps

Cardiff University GW Catalog Plotting App



Get help!

ask.igwn.org

- Discussion forum
- Post questions (and answers!)
- Use it for this workshop!

▼

Welcome to the gravitational wave community forum

A community for discussion of gravitational wave science with LIGO, Virgo, and KAGRA.

[categories ▾](#)
[tags ▾](#)
[Categories](#)
[Latest](#)
[Unread \(3\)](#)
[Top](#)

[+ New Category](#)
[+ New Topic](#)

Category	Topics
<p>Open Data Workshop</p> <p>Discussion related to the Gravitational Wave Open Data Workshops.</p>	<p>39</p> <p>1 unread</p> <p>1 unread topic</p>
<p>Uncategorized</p> <p>Topics that don't need a category, or don't fit into any other existing category.</p>	<p>13</p>
<p>Data Analysis</p> <p>Post technical questions about working with gravitational wave data, debugging software, and signal processing.</p>	<p>61</p> <p>2 unread</p>



Summary

Gravitational Wave Open Science Center

Discover Gravitational-Wave Observatory Data,
Tutorials, and Software Tools.

Explore Data

Learn

Find times when data are available
Download strain data
Browse catalogs of events
and more

gwosc.org