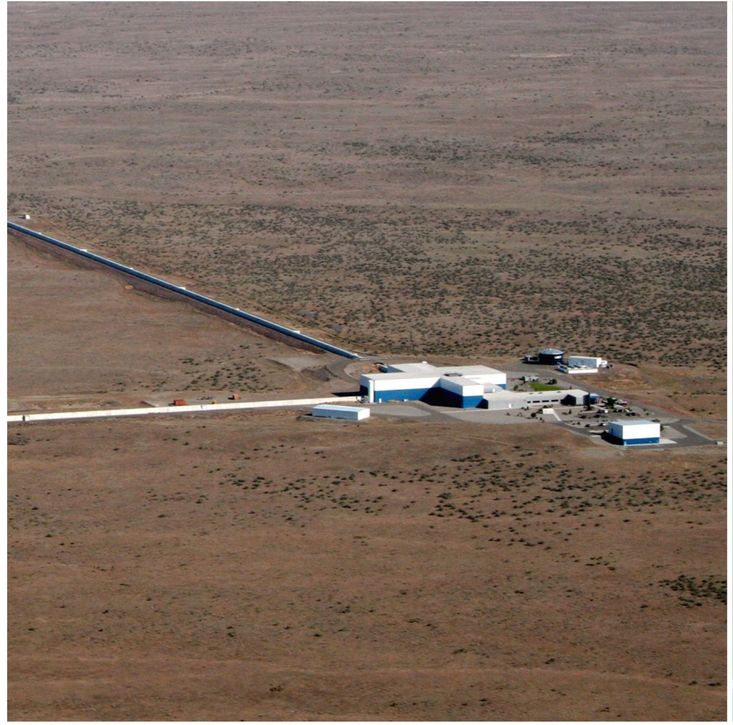
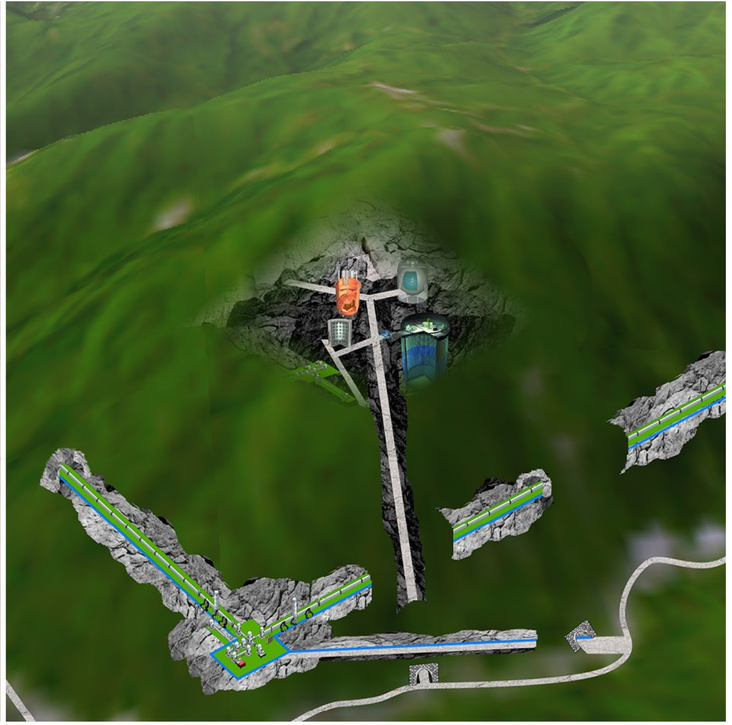
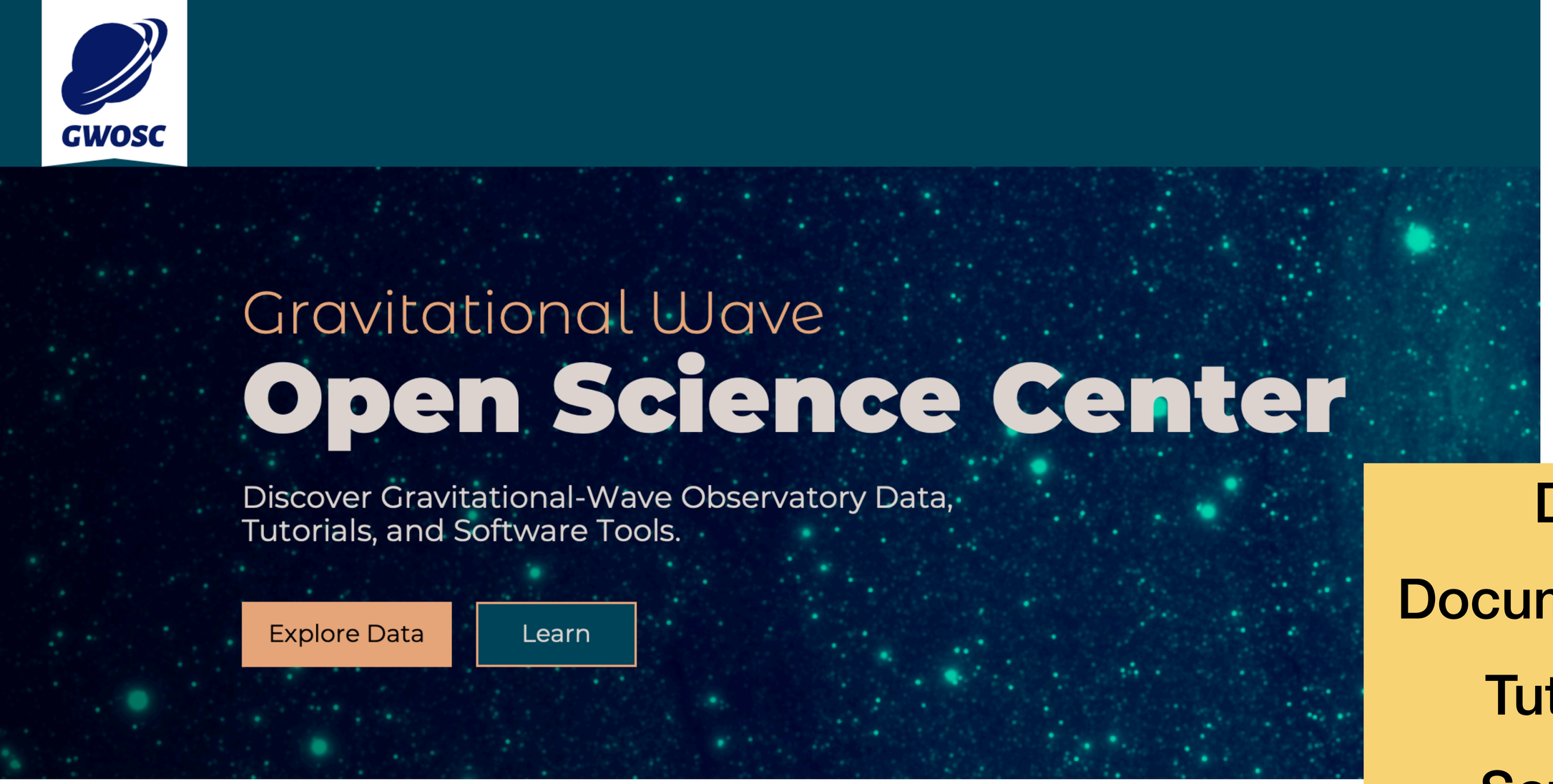
LIGO-Virgo-KAGRA Open Data

Jonah Kanner
LIGO Lab, Caltech

April 18, 2024 | LIGO-G2400876-v2







Data

Documentation

Tutorials

Software

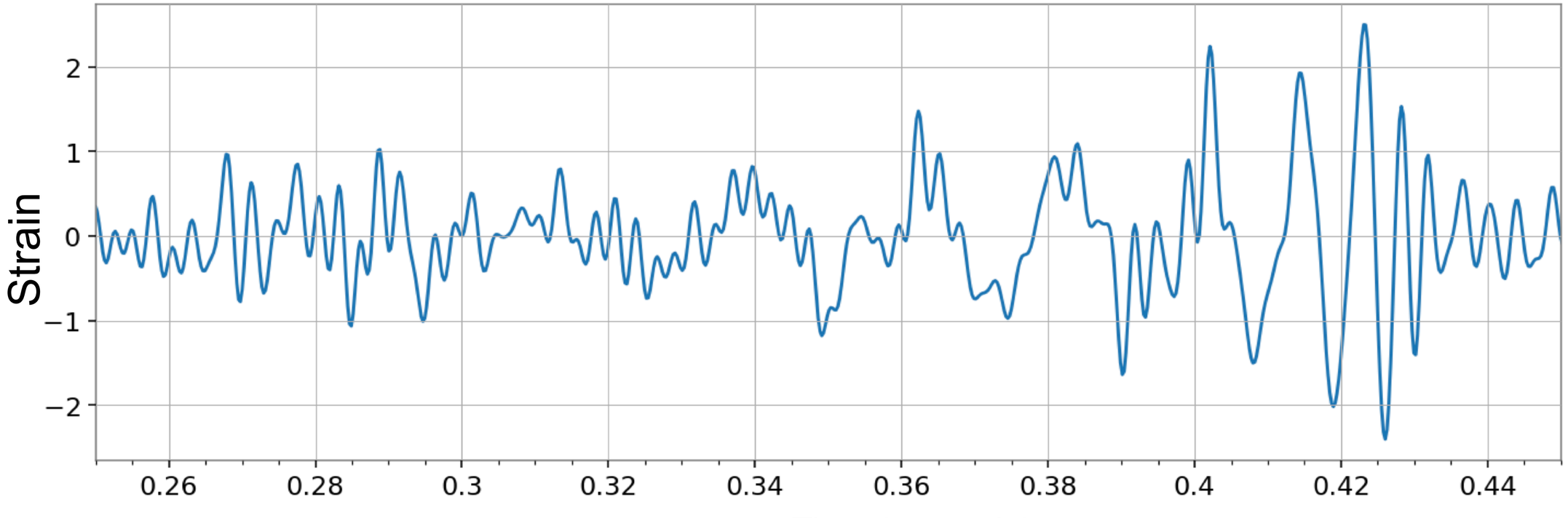
Segment Lists

Web Apps

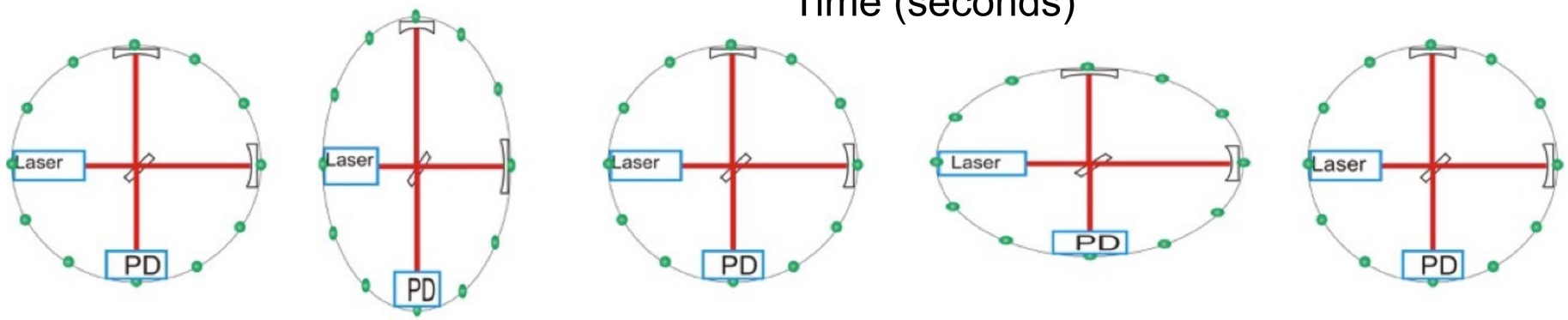
gwosc.org

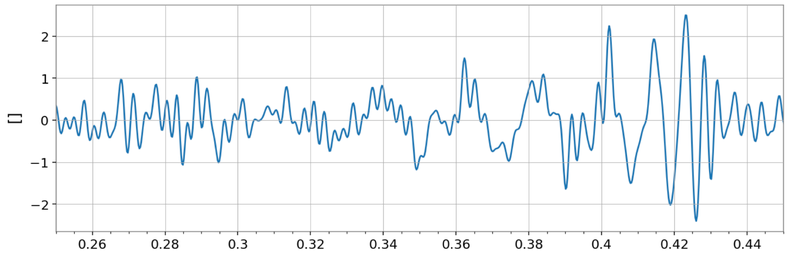
Strain data

Time Domain Strain Data



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





Time Domain Strain Data

Time-series data

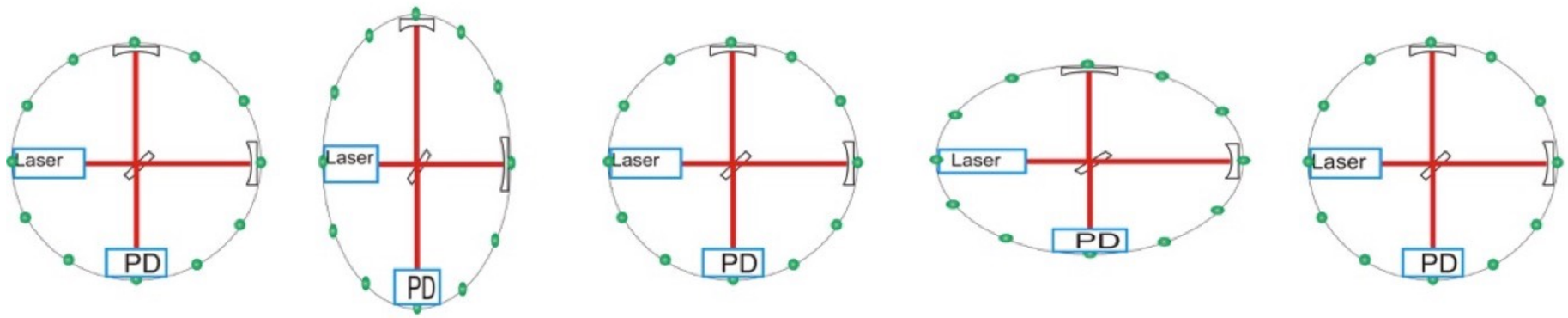
Data sets span months or years

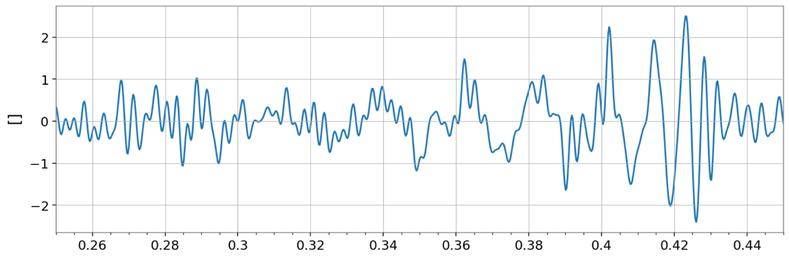
A few TB per year

Detections last for seconds or less

Detections are hidden in noise

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





Time Domain Strain Data

ELSEVIER

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 Abbott [1] ✉, Thomas D. Abbott [2], Sheelu Abraham [3], Fausto Acernese [4 5], Kendall Ackley [6], Carl Adams [7], Rana X. Adhikari [1], Vaishali B. Adya [8], Christoph Affeldt [9 10], Michalis Agathos [11 12], Kazuhiro Agatsuma [13], Nancy Aggarwal [14], Odylio D. Aguiar [15], Amit Aich [16], Lorenzo Aiello [17 18], Anirban Ain [3], Ajith Parameswaran [19], Gabrielle Allen [20], Annalisa Allocca [21], Paul A. Altin [8]... John Zweizig [1]

Show more

THE ASTROPHYSICAL JOURNAL

SUPPLEMENT SERIES

OPEN ACCESS

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

R. Abbott[1], H. Abe[2], F. Acernese[3,4], K. Ackley[5], S. Adhicary[6], N. Adhikari[7], R. X. Adhikari[1], V. K. Adkins[8], V. B. Adya[9], 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
```

Formats:

GWF
or
HDF5

Strain data file

H-H1_GWOSC_4KHZ_R1-1268903496-32.txt

```
# Gravitational wave strain for GW200322_091133-v1 for H1
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-1.3240125547300500e-20
-1.2532010942962005e-20
-1.6986963728113432e-20
-1.4093840416373476e-20
-9.5227443608221438e-21
-1.9064670104960347e-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
-7.198090059495601 3e-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
```

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
-7.198090059495601 3e-21
-6.8433397262034073e-21
-1.7612990400426759e-20
-9.426731170487426 5e-21
-6.1983141016039667e-21
-1.3240125547300500e-20
-1.2532010942962005e-20
-1.6986963728113432e-20
-1.4093840416373476e-20
-9.5227443608221438e-21
-1.9064670104960347e-20
```

Strain values
at each sample time

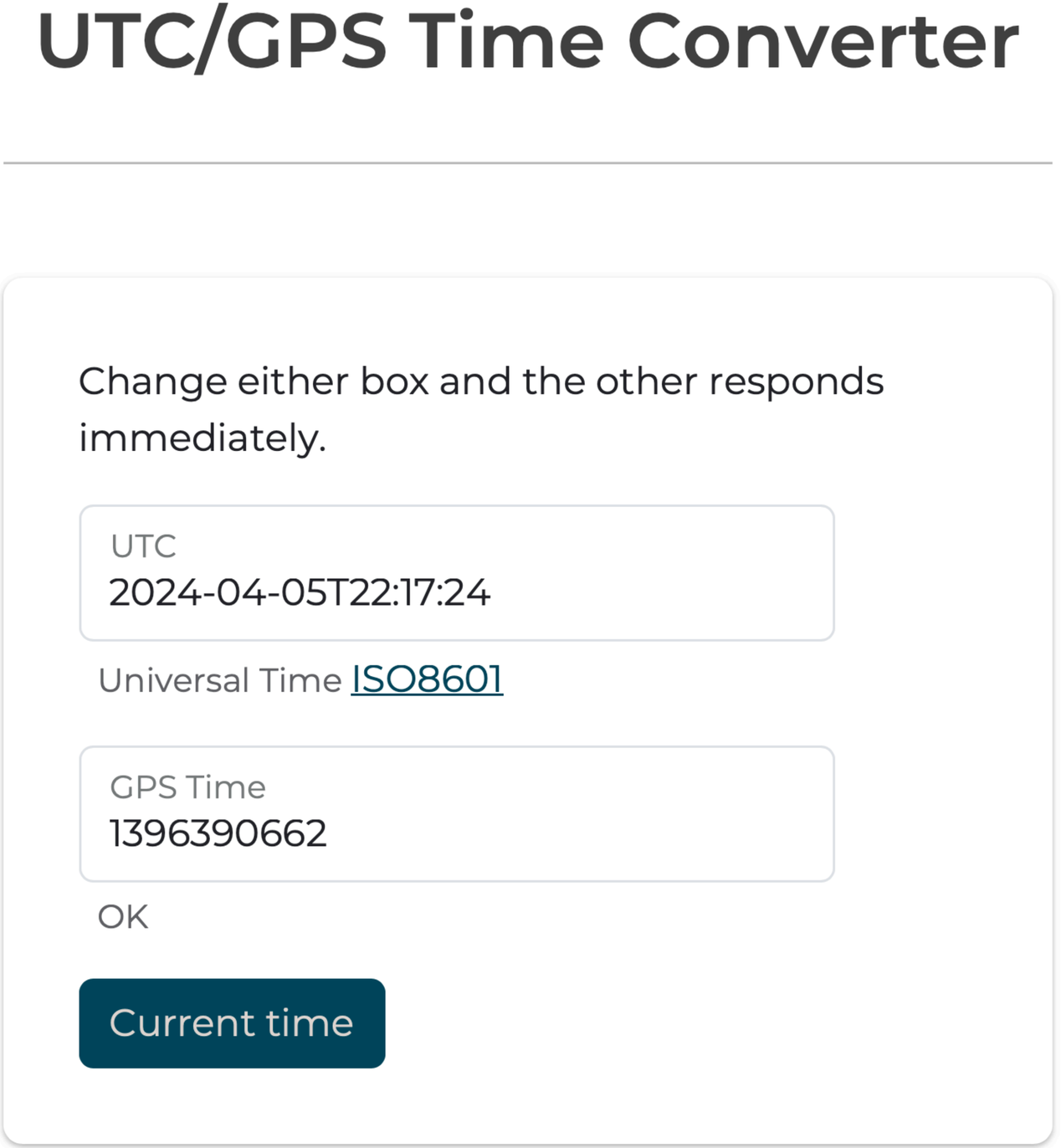
Time between samples

$$\Delta t = 1/f_s$$

GPS

Time

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



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

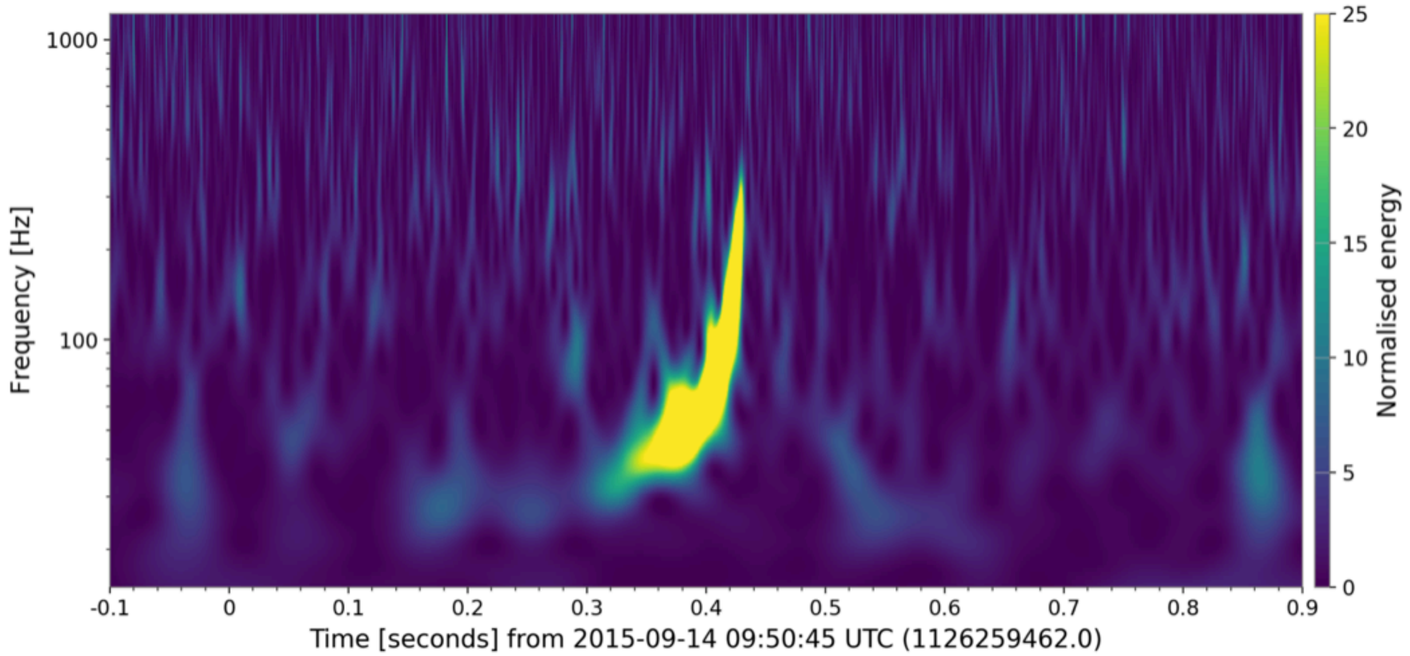
Set Plot Parameters

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` $M_\odot$

Mass 2: `13.6` $M_\odot$

Network SNR: `10`

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

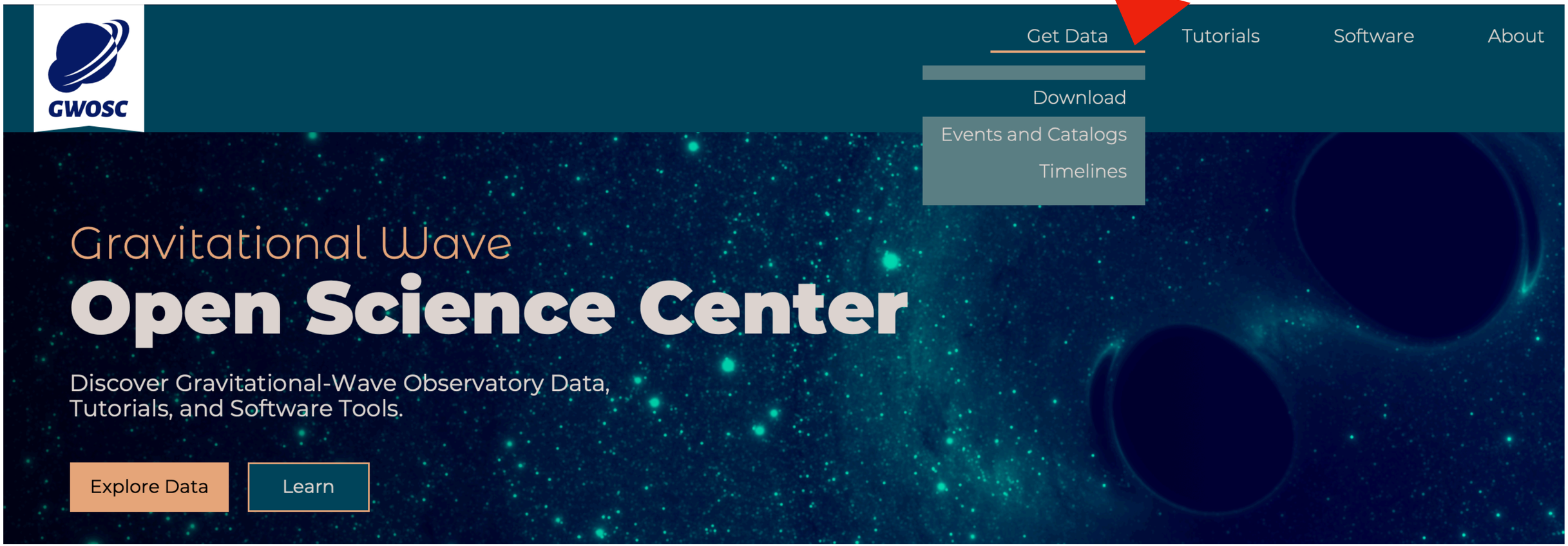
```
Loading data...done!
```

Download Strain Data

1) Point & Click

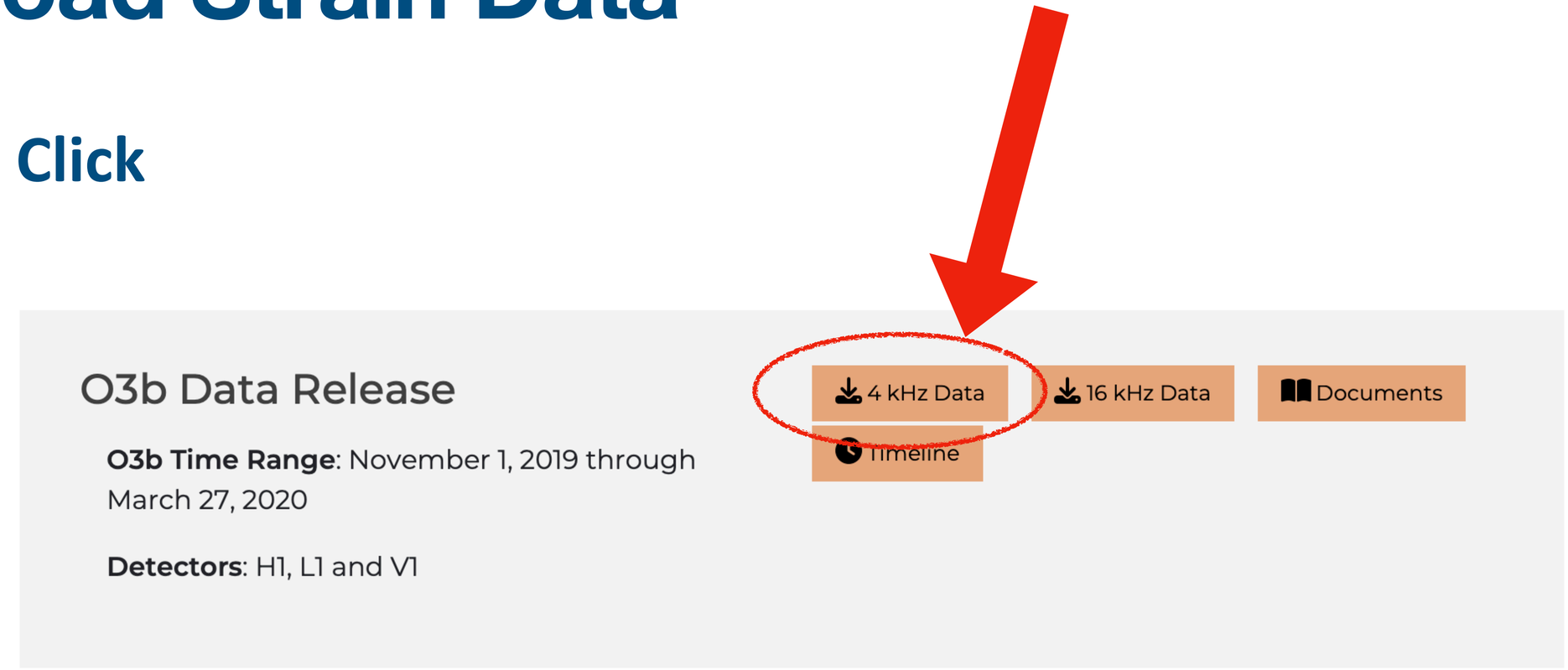
Download Strain Data

1) Point & Click



Download Strain Data

1) Point & Click



Download Strain Data

1) Point & Click

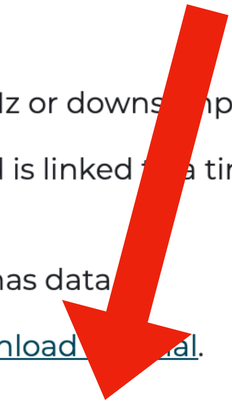
Dataset: O3b_4KHZ_R1

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 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
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_LOSC_4_V1-968646656-4096.hdf5',
 'https://gwosc.org/archive/data/S6/967835648/L-L1_LOSC_4_V1-968650752-4096.hdf5',
 'https://gwosc.org/archive/data/S6/967835648/L-L1_LOSC_4_V1-968654848-4096.hdf5',
 'https://gwosc.org/archive/data/S6/967835648/L-L1_LOSC_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

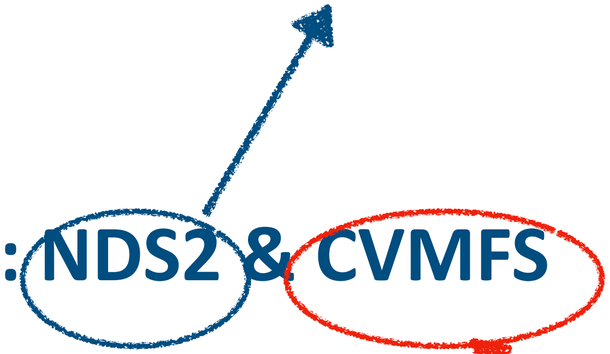
2) Python Client

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

CVMFS available on Open Science Grid
& other computer clusters

Download Strain Data

1) Point & Click

2) Python Client

3) Direct load w/ gwpy

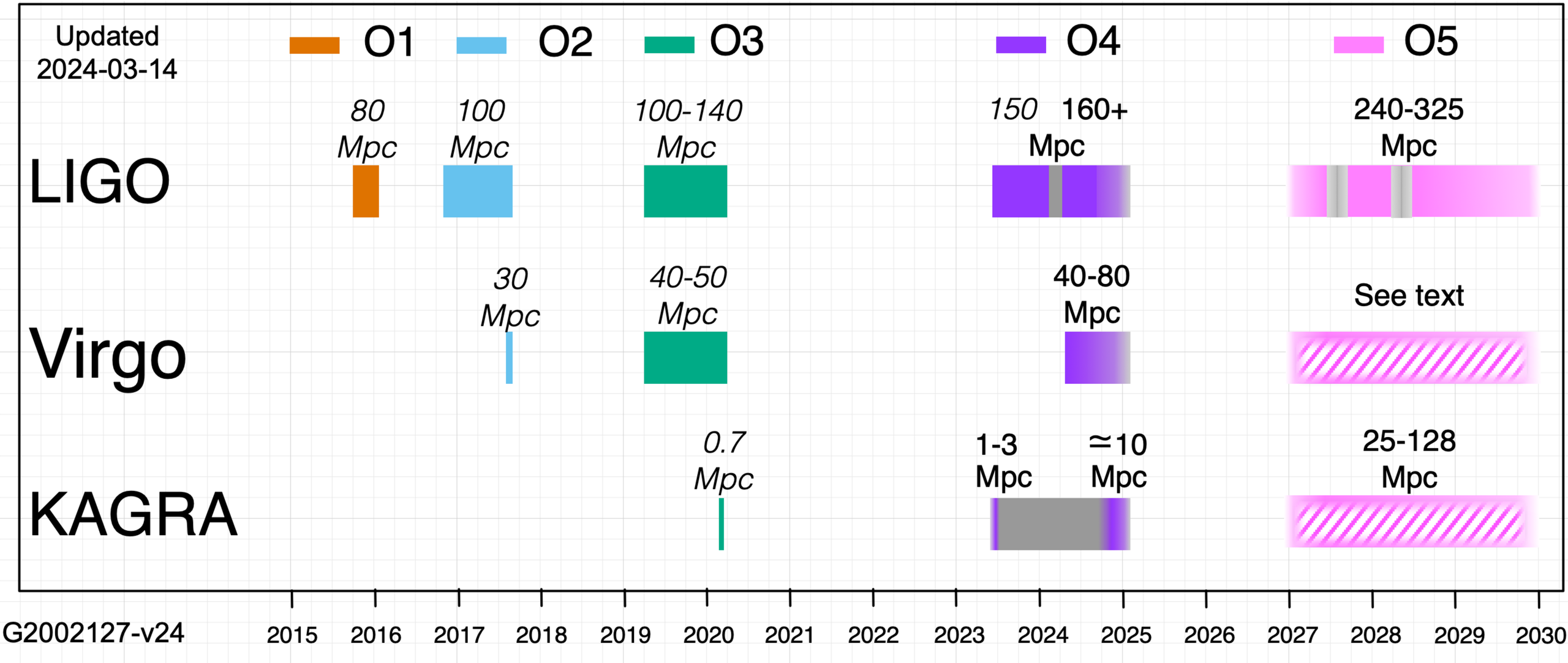
4) Extended release: NDS2 & CVMFS

Timeline App & Segments

When are data available?

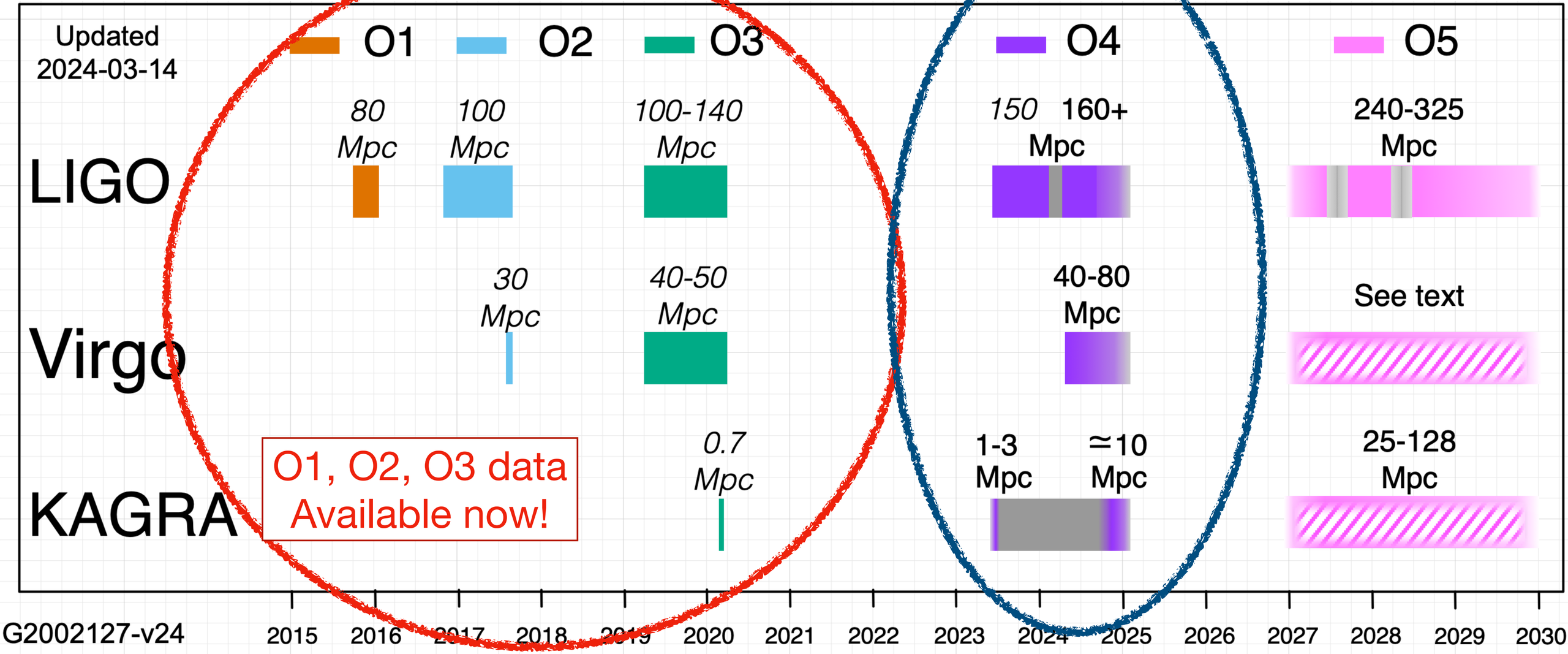
Timeline App & Segments

When are data available?



Timeline App & Segments

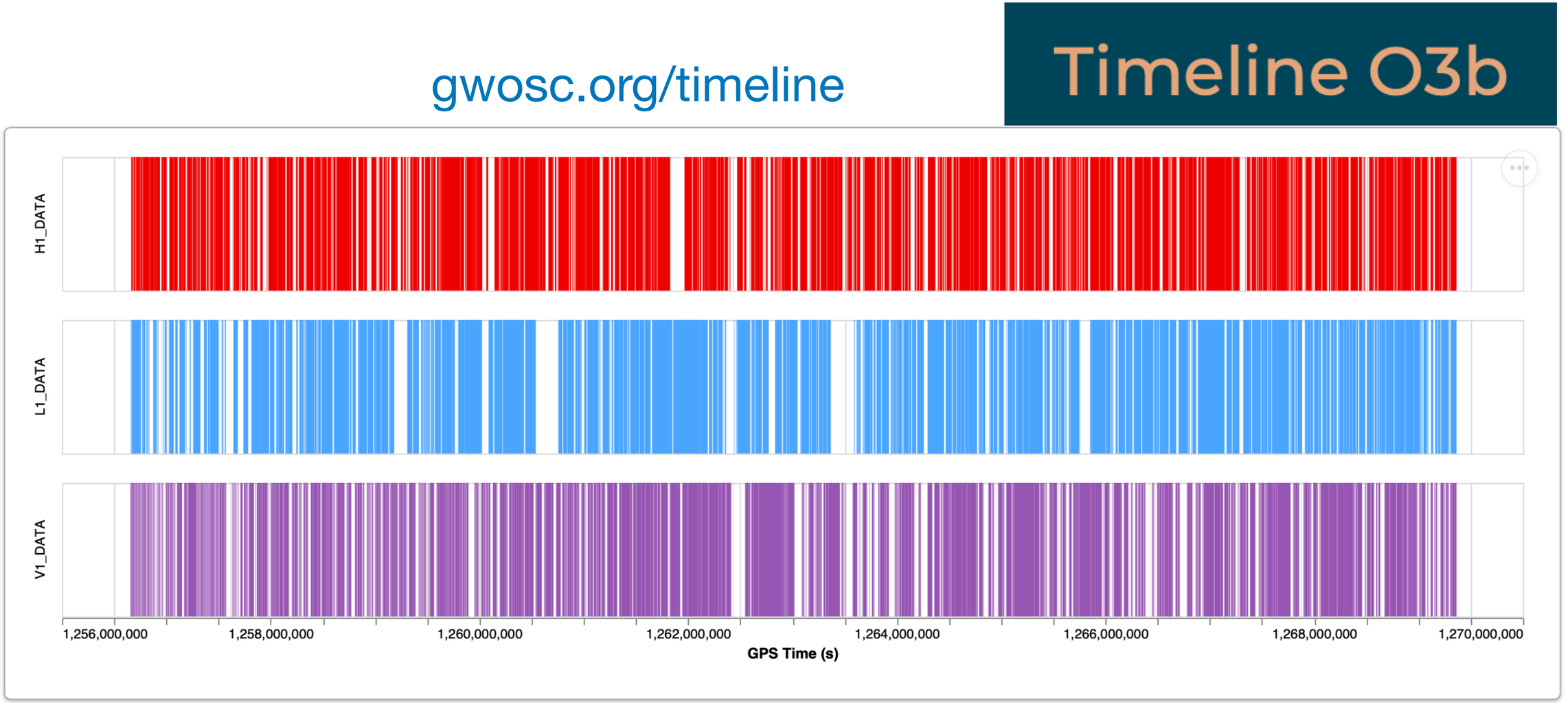
When are data available?



Timeline App & Segments

When are data available?

gwosc.org/timeline



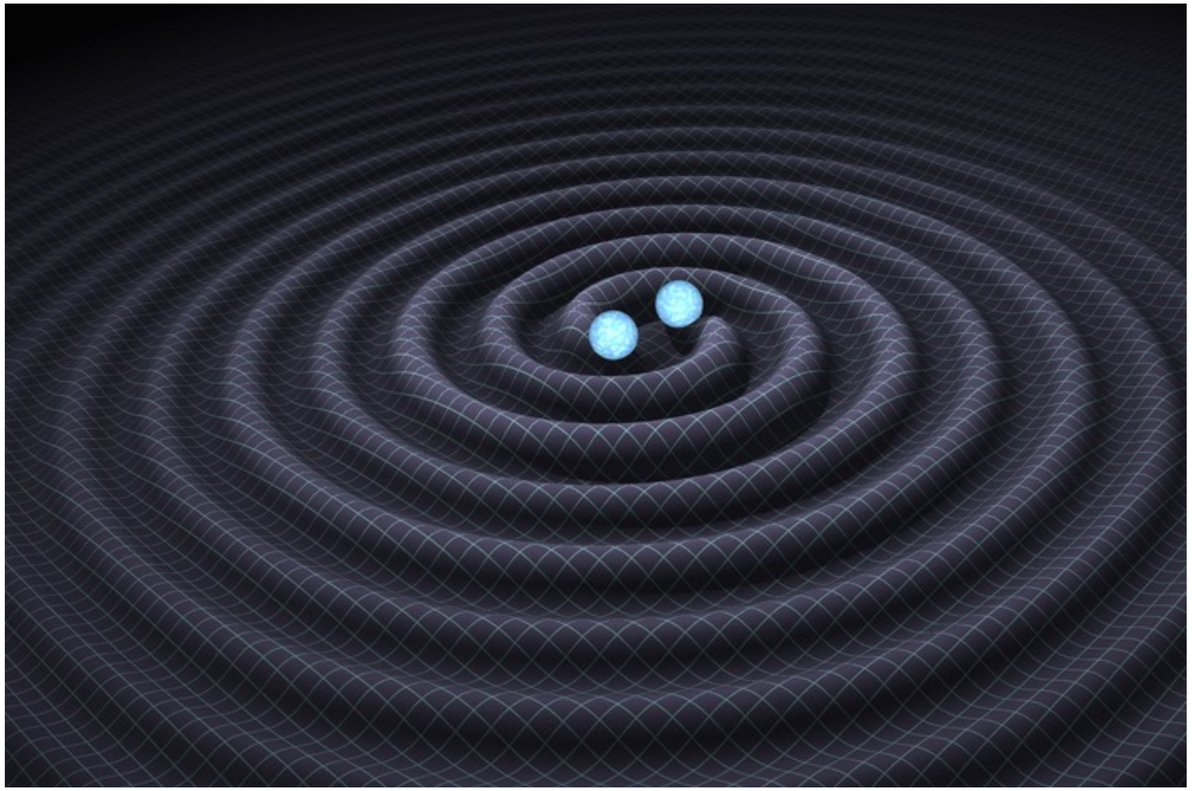
Event Catalogs

What events has LIGO/Virgo/KAGRA seen?

Event Catalogs

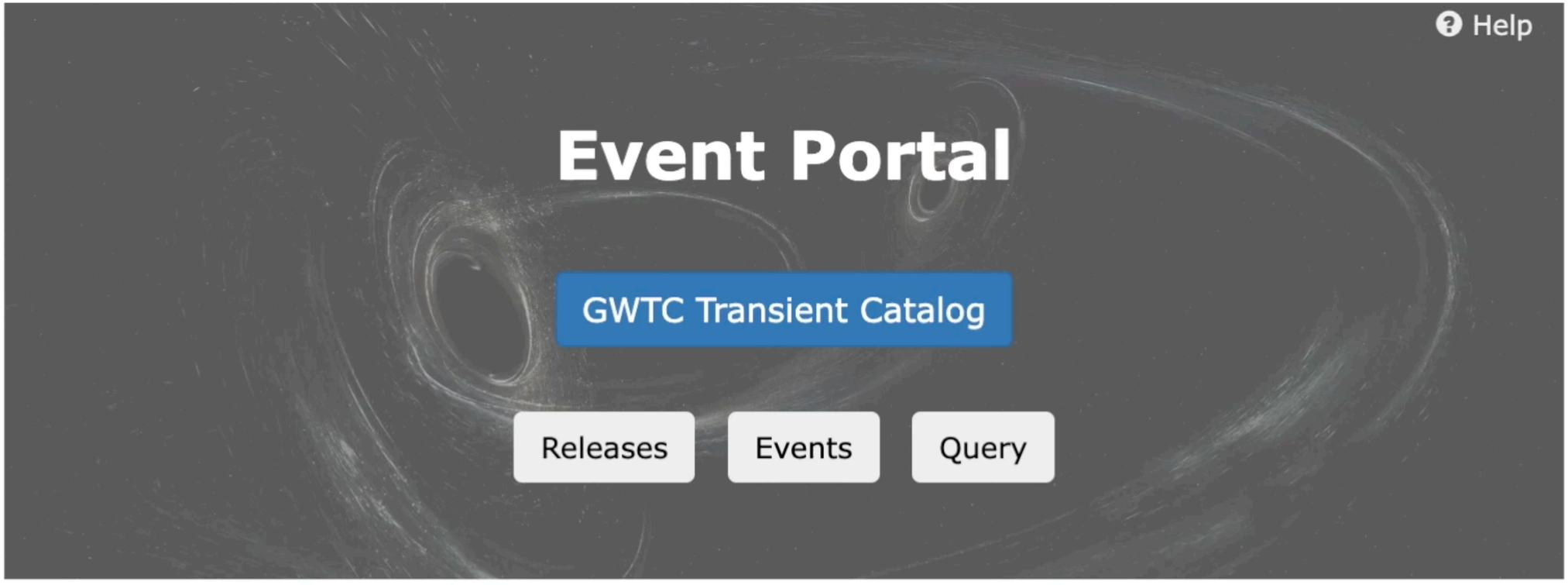
What events has LIGO/Virgo/KAGRA seen?

- 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



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

Mass 1 Range:	0	∞	Mass 2 Range:	0	∞
Total Mass Range:	0	∞	Final Mass Range:	0	∞
Chirp Mass Range:	0	∞	Detector Frame Chirp Mass Range:	0	∞
Distance (Mpc) Range:	0	∞	Redshift Range:	0	∞
Network SNR Range:	0	∞	χ_{eff} Range:	-1	1
False Alarm Rate Range:	0	∞	P_{astro} Range:	0	1

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

Single Event Data Product

GW200129_065458

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

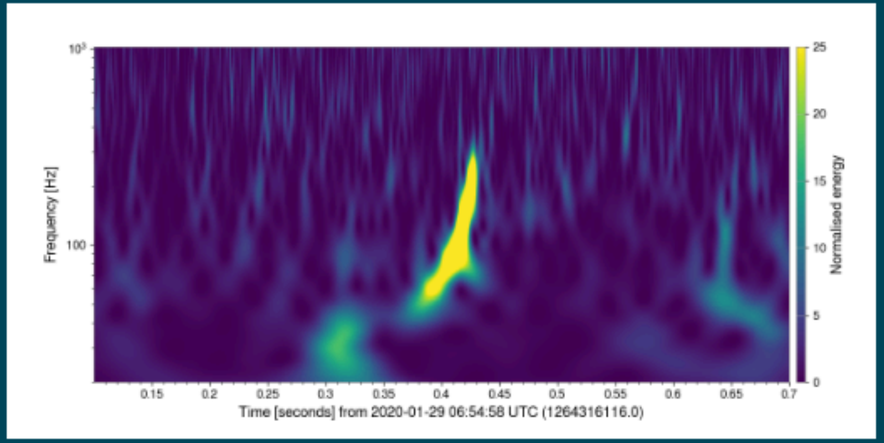
Data sourced from frame channels.

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]

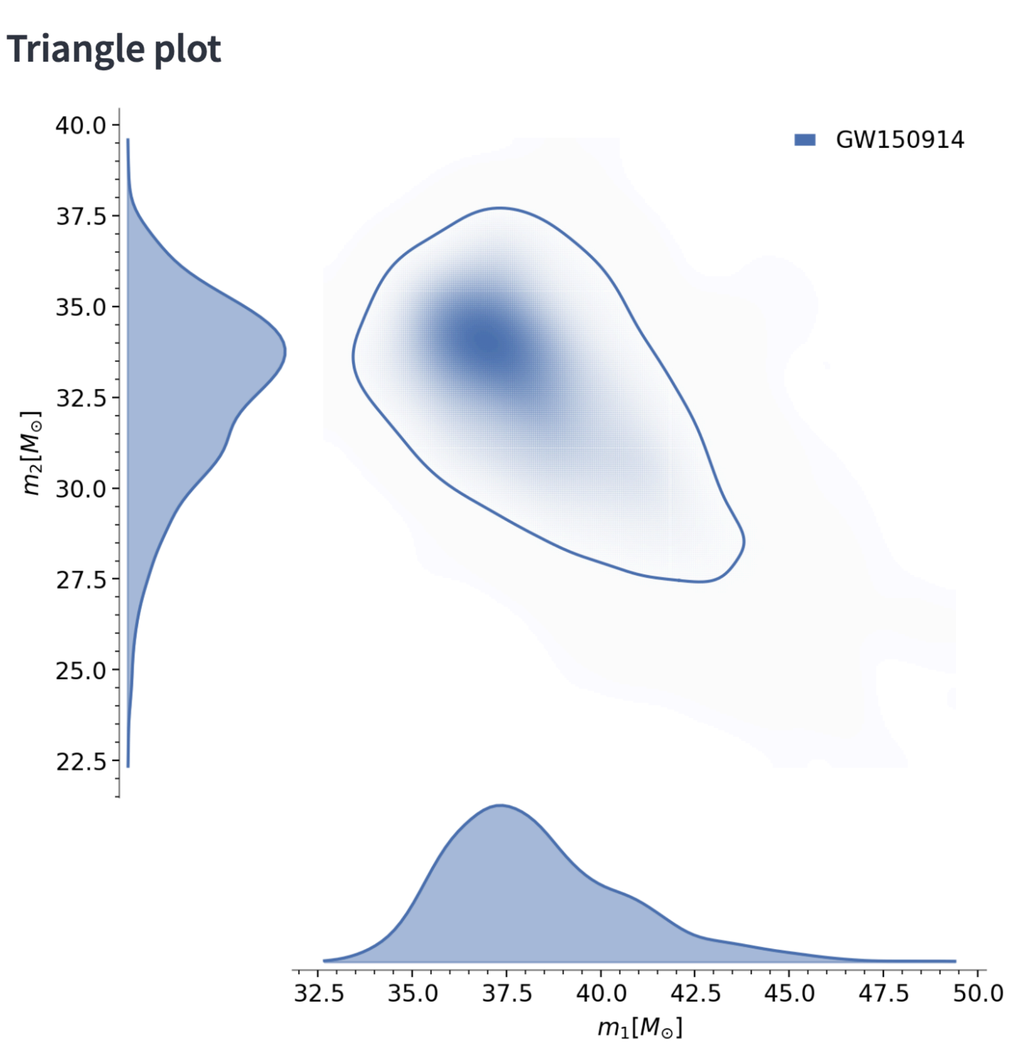
H1 strain

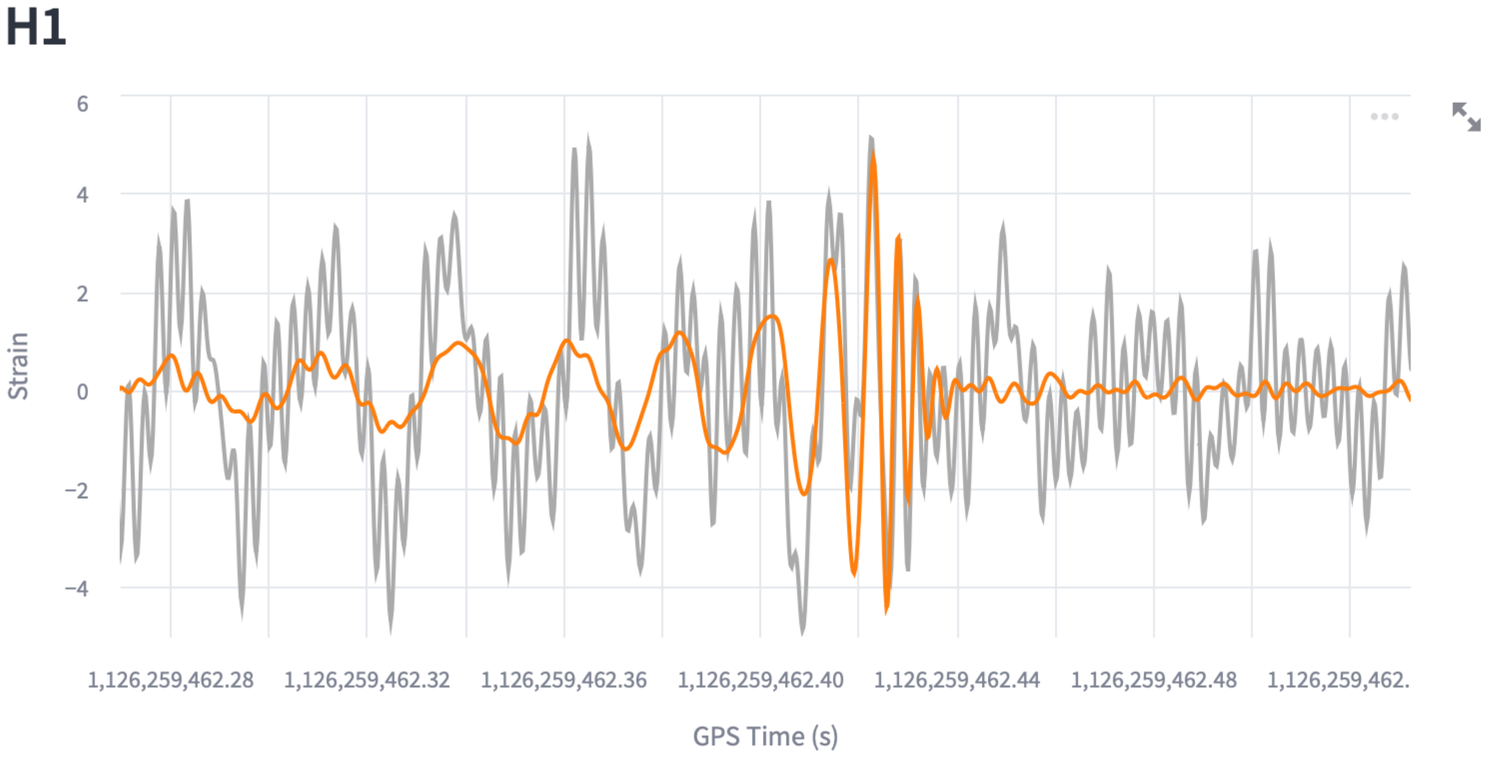


32sec · 16KHz:	GWF	HDF	TXT
32sec · 4KHz:	GWF	HDF	TXT
4096sec · 16KHz:	GWF	HDF	TXT
4096sec · 4KHz:	GWF	HDF	TXT

Event Viewer App

Visualize event parameters & waveforms





peviewer.igwn.org

Select events

Event 1

GW150914

Event 2

GW190521

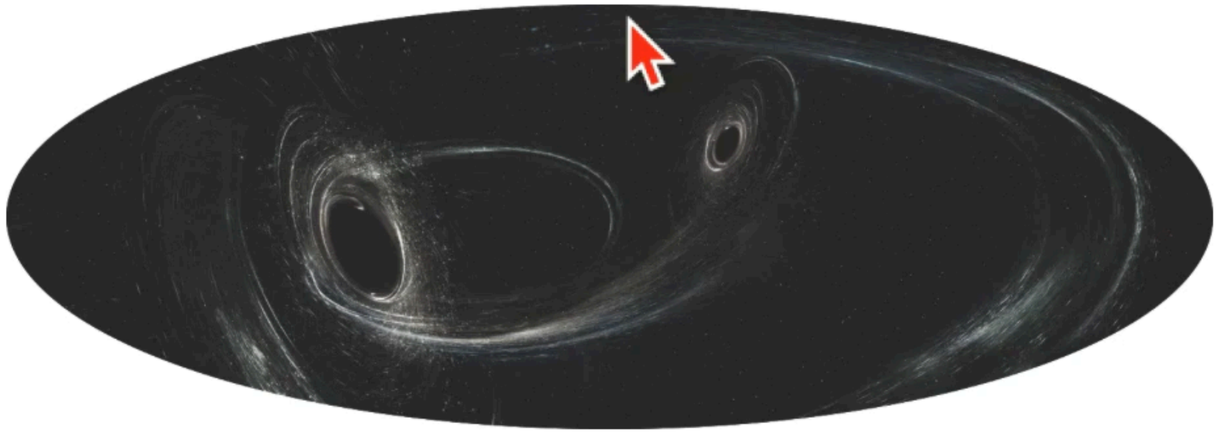
Event 3

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

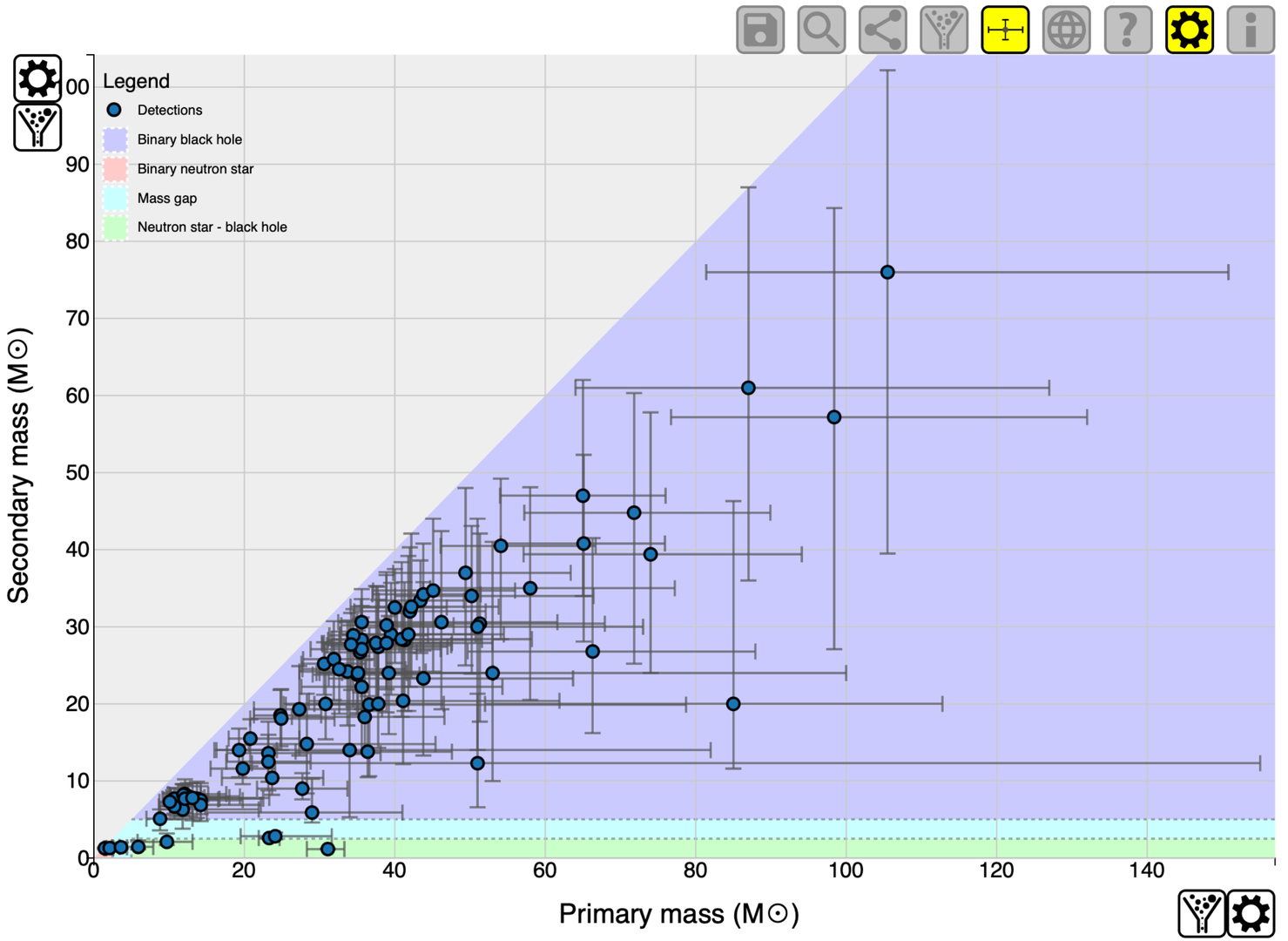
PyCBC

Gwpy

Web Apps

gwosc.org/interactive

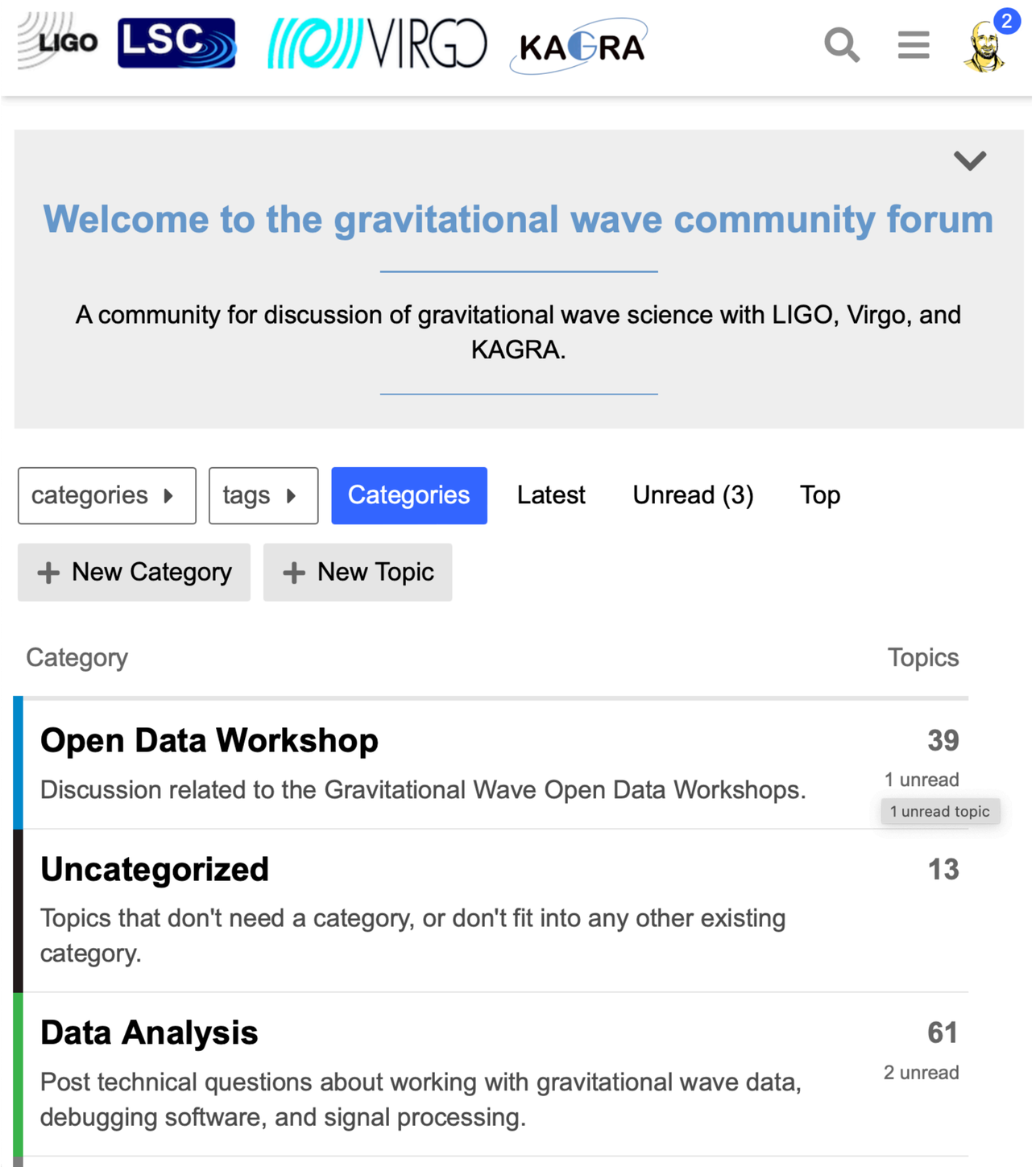
- List of apps for GW data
- Plotting tools, games, phone apps



Get help!

ask.igwn.org

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



Summary

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