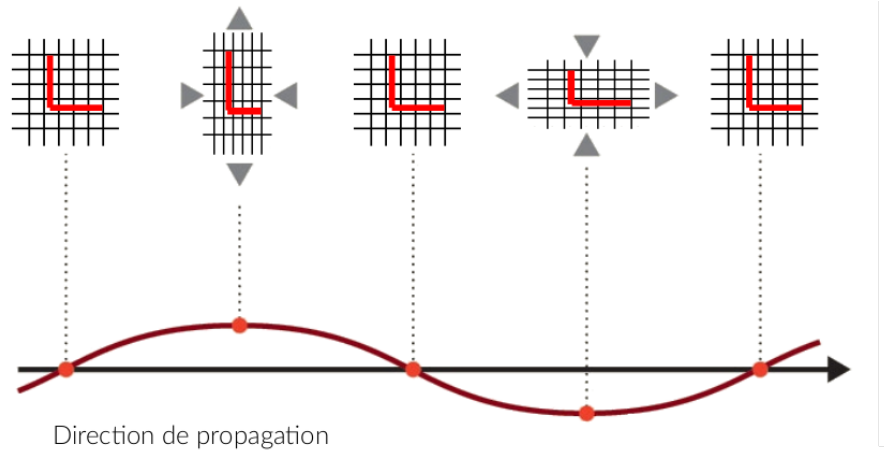


# LIGO/Virgo open data



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Gravitational wave strain  
(space-time deformation)

$$h(t) = \frac{\delta \ell}{L}$$

Time series – 16 kHz sampling (“audio” band)

Continuous observation for ~1 yr typ.  
With many on/off interruptions





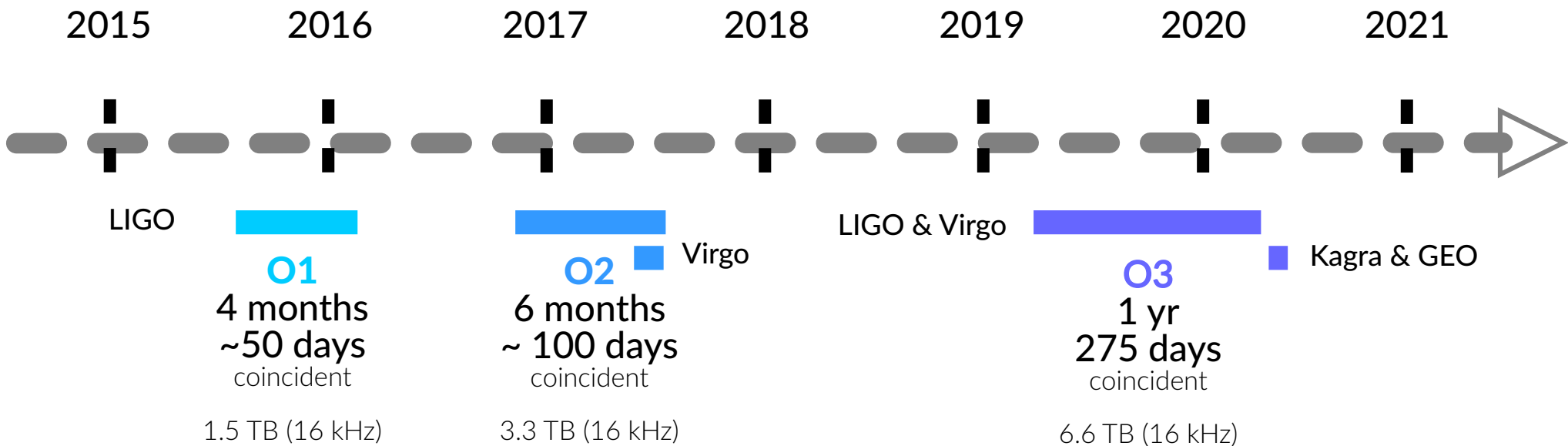
LIGO Handford H1



LIGO Livingston L1

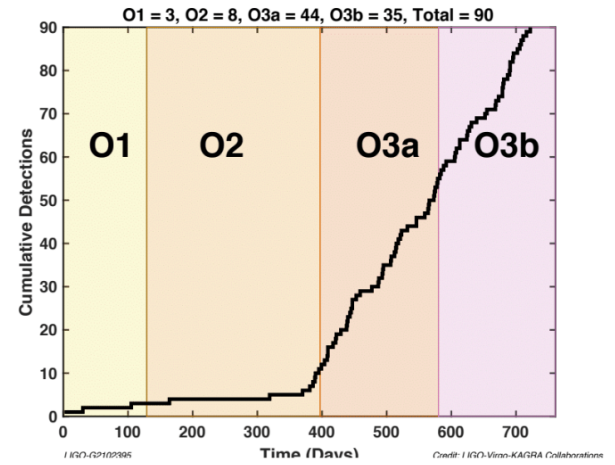


Virgo V1



April 12 2022

Action Spécifique Observatoires Virtuels



2015

2016

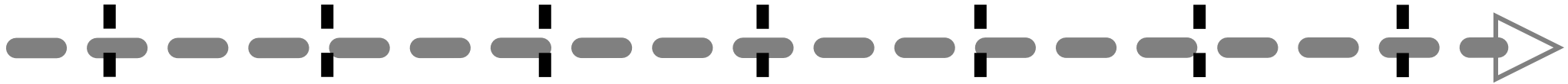
2017

2018

2019

2020

2021



LIGO

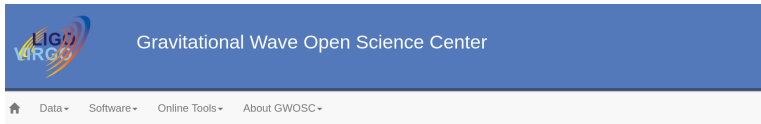
**O1**  
3 detections

**O2** Virgo  
8 detections  
GWTC-1

LIGO & Virgo

**O3**  
**O3a** 44 detections  
GWTC-2.1  
**O3b** 35 detections  
GWTC-3

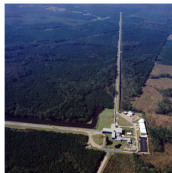
# gw-openscience.org



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









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



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



Virgo detector, Italy  
(Credits: Virgo Collaboration)

-  [O3 Bulk Data Now Available \(O3a+O3b+O3GK\)](#)
-  [GWTC-3 Catalog Data Now Available](#)
-  [Start with a Learning Path](#)
-  [Browse the Event Portal](#)
-  [Join the email list](#)
-  [Attend an Open Data Workshop](#)

- **GW Open Science Center**

- Started in 2011 by Caltech under NSF impulse

- **Public release policy – Cadence & proprietary period**

- Data Management Plan – <https://dcc.ligo.org/LIGO-M1000066/public>
- LIGO Virgo MOU – <https://dcc.ligo.org/LIGO-M060038/public>

*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*

- So far data from LIGO, Virgo, GEO and KAGRA have been release according to this schedule

O1: released in 2018

O2: released in Feb 2019

O3: released in Apr 2021 and Oct 2021

# User sociology

## Typical traffic: 100-200 users/day

- **Profile 1: Scientists (in and outside LIGO/Virgo)**
  - A. *Independent searches for GW signals*  
*need:* “bulk” data, data quality information, calibration systematics
  - B. *GW event-based analyses (collective)*  
→ interpretation of the detected sources, populations of compact objects, ...  
*need:* event catalogs, parameter estimates with uncertainties  
*GW event-based analyses (single)*  
→ waveform consistency, test of general relativity  
*need:* data around the detected events
- **Profile 2: Education at universities and high-schools**
  - Exercises and hands-on for classes
  - Science projects for undergrads  
*need:* data analysis tools and tutorials

# User profile 1A: “independent” searches

## Auxiliary Data Release

**Time Range:** 3 hours around event GW170814 (August 14, 2017)

**Detectors:** H1 and L1

**Description:** Around 1,000 channels that monitor the LIGO instruments and surrounding environment.

Auxiliary Data

## O3GK Data Release

**O3GK Time Range:** April 7, 2020 through April 21, 2020

**Detectors:** G1 and K1

4 kHz Data

16 kHz Data

Documents

Timeline

## 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

## O3a Data Release

**O3a Time Range:** April 1, 2019 through October 1, 2019

**Detectors:** H1, L1 and V1

4 kHz Data

16 kHz Data

Documents

Timeline

## O2 Data Release

**O2 Time Range:** November 30, 2016 through August 25, 2017

**Detectors:** H1, L1 and V1

4 kHz Data

16 kHz Data

Documents

Timeline

## O1 Data Release

**O1 Time Range:** September 12, 2015 through January 19, 2016

**Detectors:** H1 and L1

4 kHz Data

16 kHz Data

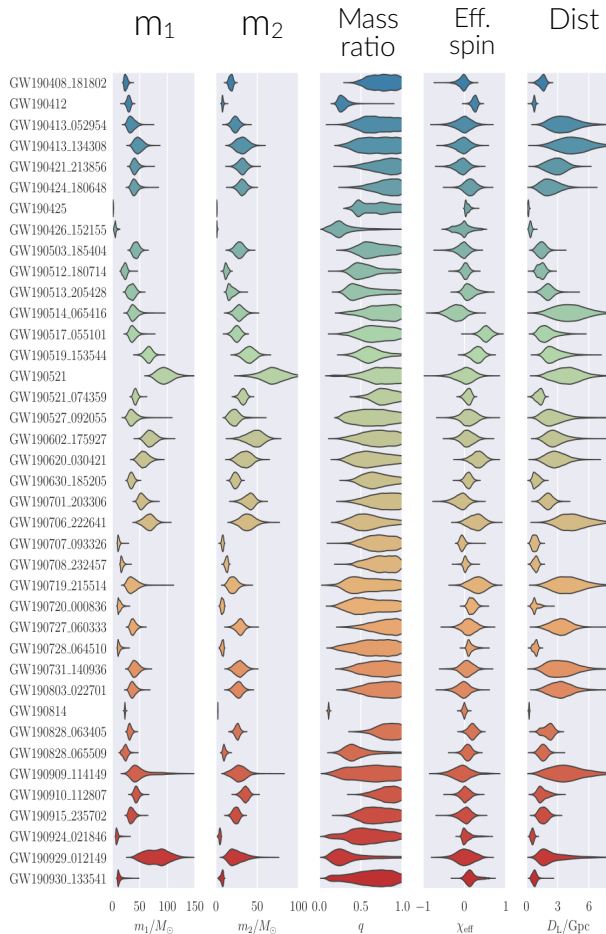
Documents

Timeline

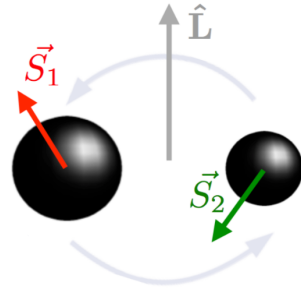
- All you need to reproduce LIGO Virgo Kagra searches
  - “Bulk” data (various formats) and data quality
  - Online documentation and through [data paper](#)
  - Mass transfer made easier with CVMFS (distributed file sys)
- Notable usages
  - Reproducibility study D Brown et al, [arXiv:2010.07244](#)
  - [OGC catalog](#) (Nitz et al)
  - [IAS pipeline](#) (Zaldarriaga et al)


*Note: Announcement today at APS meeting!*

# User profile 1B: event related physics



## GWTC 2



- Event catalogs and related science data products
  - Four catalogs released so far
    - Can be queried! 
  - Data products published for each event
    - Strain data snippets around event (various formats)
    - Confidence intervals
    - Posterior samples
    - Localization skymaps
    - Related alert (if any)
  - Other data products
    - Population properties
    - Cosmology
    - Test of general relativity



# User profile 1B: event related physics

event list

GW200129\_065458

data snippet

search pipelines

- Toggle columns on/off with widget at right.
- Click an event name for more information.
- Values in the table below are from the **Default SEARCH** and **Default PE** cases found in the individual event's page.
- See [Event Portal Usage Notes](#) for more details.

New Search Help

SORT: GPS

Name	GPS	Mass 1 (M <sub>⊙</sub> )	Mass 2 (M <sub>⊙</sub> )	Distance (Mpc)	χ <sub>eff</sub>
GW200322_091133	1268903511.3	+48 34 -18	+16.8 14.0 -8.7	+7000 3600 -2000	+0.45 0.24 -0.51
GW200316_215756	1268431094.1	+10.2 13.1 -2.9	+1.9 7.8 -2.9	+470 1120 -440	+0.27 0.13 -0.10
GW200210_092254	1265361792.9	+7.5 24.1 -4.6	+0.47 2.83 -0.42	+430 940 -340	+0.22 0.02 -0.21
GW200209_085452	1265273710.1	+10.5 35.6 -6.8	+7.8 27.1 -7.8	+1900 3400 -1800	+0.24 -0.12 -0.30
GW200208_222617	1265235995.9	+104 51 -30	+9.0 12.3 -5.7	+4400 4100 -1900	+0.43 0.45 -0.44
GW200208_130117	1265202095.9	+9.2 37.8 -6.2	+6.1 27.4 -7.4	+1000 2230 -850	+0.22 -0.07 -0.27
GW200202_154313	1264693411.5	+3.5 10.1 -1.4	+1.1 7.3 -1.7	+150 410 -160	+0.13 0.04 -0.06
GW200201_203549	1264624567.0	--	--	--	--
GW200129_065458	1264316116.4	+9.9 34.5 -3.2	+3.4 28.9 -9.3	+290 900 -380	+0.11 0.11 -0.16
GW200128_022011	1264213229.9	+11.6 42.2 -8.1	+9.5 32.6 -9.2	+2100 3400 -1800	+0.24 0.12 -0.25
200121_031748	1263611886.9	--	--	--	--
GW200115_042309	1263097407.7	+2.0 5.9 -2.5	+0.85 1.44 -0.29	+150 290 -100	+0.24 -0.15 -0.42
GW200115_042309	1263097407.7	+1.8 5.7 -2.1	+0.7 1.5 -0.3	+150 300 -100	+0.23 -0.19 -0.35
200114_020818	1263002916.2	--	--	--	--
GW200112_155838	1262879936.0	+6.7 35.6 -4.5	+4.4 28.3 -5.9	+430 1250 -460	+0.15 0.06 -0.15
GW200105_162426	1262276684.0	+1.7 9.0 -1.7	+0.33 1.91 -0.24	+120 270 -110	+0.13 0.00 -0.18
GW200105_162426	1262276684.0	+1.2 8.9 -1.4	+0.3 1.9 -0.2	+110 280 -110	+0.11 -0.01 -0.14

## 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.

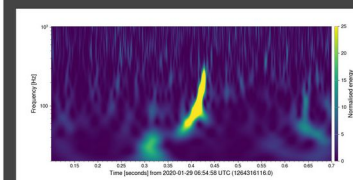
FrameChannels: [ H1:DCS-CALIB\_STRAIN\_CLEAN\_SUB60HZ\_C01, L1:DCS-CALIB\_STRAIN\_CLEAN\_SUB60HZ\_C01, V1:Hrec\_hoft\_16384Hz ]

## Data sourced from frame types:

FrameTypes: [ H1\_HOFT\_CLEAN\_SUB60HZ\_C01, L1\_HOFT\_CLEAN\_SUB60HZ\_C01, V1Online ]

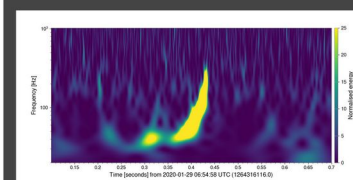
To open GWF files, use channels names as shown for GWTC-1:  
<https://doi.org/10.7935/82H3-HH23>

## H1 strain



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

## L1 strain



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

## pycbc\_bbh Search Pipeline

Date added: Sept. 13, 2021

[show / hide parameters](#)

## pycbc\_broad Search Pipeline

Date added: Sept. 13, 2021

[show / hide parameters](#)

## gstlal Search Pipeline

Date added: Sept. 13, 2021

[show / hide parameters](#)

Default SEARCH

## GWTC-3 PE for GW200129\_065458

Date added: Nov. 1, 2021

[show / hide parameters](#)

Source File

Posterior Samples in Zenodo

Skymap for GW200129\_065458

Default PE

data provenance

res Virtuels

params estimation

April 12 2022

# User profile 2: learning resources



GW Open Data Workshop

May 23 - 25, 2022




<https://www.gw-openscience.org/odw/odw2022/>

Distributed workshop with a worldwide network of study hubs

To join Paris' hub: <https://s.42l.fr/odw2022-paris>

Hands-on sessions

<https://github.com/gw-odw/odw-2022>

- **Software utilities** for data access, simulation and analysis
  - Including <https://pypi.org/project/gwosc/> for easy access to data
  - GWOSC public API
  - Documentation and usage recommendations
- **Tutorials – Jupyter notebooks**
- **Communication with users**
  - Q&A: [gwosc@igwn.org](mailto:gwosc@igwn.org)
  - “Office hours”: meet a scientist 
  - User forum: <http://ask.igwn.org>
- **Training through workshops**
  - At University level: 5 editions so far – ~1000 students overall
  - High-school level: online course [[Learning path](#)]

# Conclusions

**CERN COURIER** | Reporting on international high-energy physics



POLICY | FEATURE



**Preserving the legacy of particle physics**



11 March 2019

“Only days after they announced the first observation of gravitational waves, the LIGO and Virgo collaborations made public their data.”

- **GWOSC cited as a model for open science**
  - Service to a large community of users
  - 220+ papers using GWOSC data contributed by groups around the globe
- **Development plans for the coming year**
  - Improve accessibility and infrastructure
  - Prepare O4 release (catalog scalability!)
  - Experimenting with IVAO tools to disseminate catalog data (TAP server) – Happy to discuss with experts!