EOSC Future

Analyzing gravitational wave data with EOSC

Extreme Universe and Gravitational Waves

A. Iess

Use cases from the EOSC Community, 16 May 2023

SCUOLA NORMALE SUPERIORE

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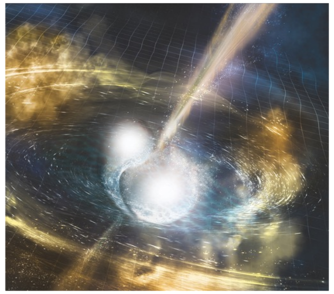
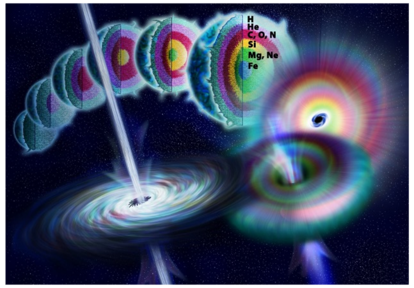
The Scientific case in a nutshell

- Detectable Gravitational waves are emitted by extreme events in the Universe involving massive objects (black holes, neutron stars…).
- Provide alerts to other observatories (such as GRB)
- Couple to eletromagnetic and neutrino observations in a *multi-messenger framework*



NSF/Ligo/Sonoma State University/ A.Simonnet



NSF/N.Rager Fuller

In the context of ESCAPE and EOSC Future we are developing a real-time analysis pipeline for multi-messenger data called **Wavefier.**

The GW data analysis part is carried out by a specific library integrated in the Wavefier framework, which is the object of this EOSC Community use case, the **Wavelet Detection Filter**.

IN COLLABORATION WITH:
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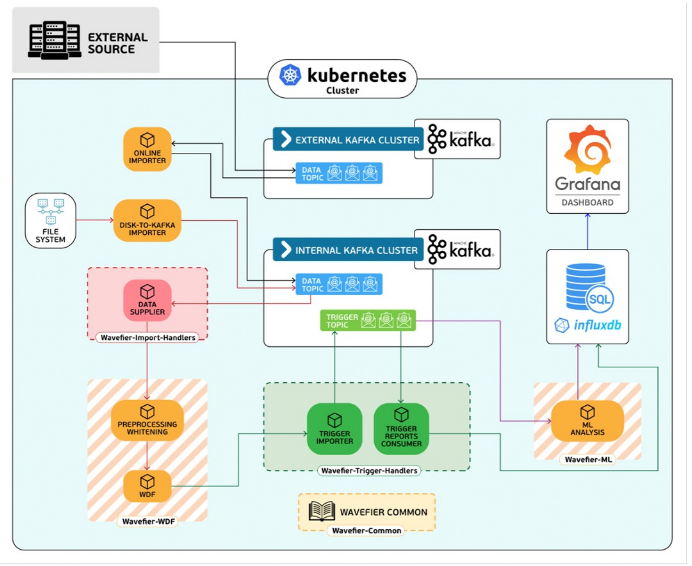
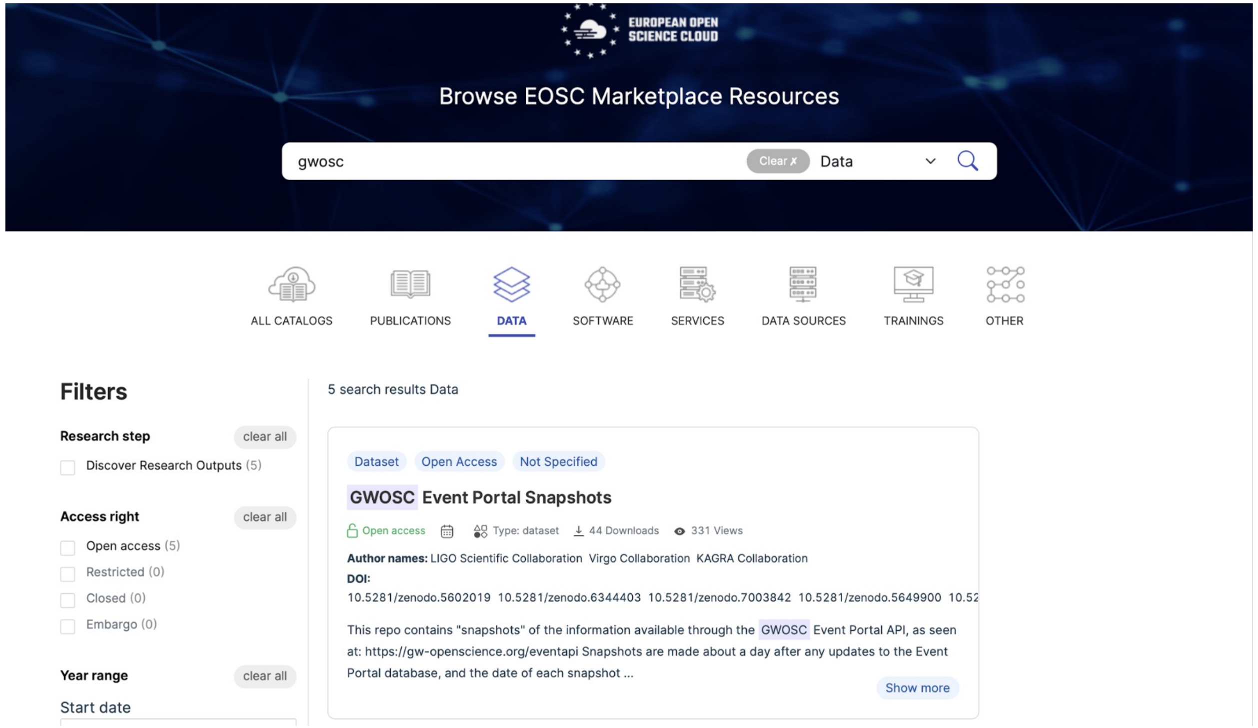


Leveraging EOSC Future: EOSC Marketplace

For this use case we started from an "agnostic" perspective searching for data on the EOSC Marketplace with simple search queries ("gw", "gravitational waves", "LIGO", "Virgo" etc):



Interesting resource:
"GWOSC Event Portal Snapshots"

(collection of data characterizing gravitational wave events found during LIGO/Virgo science runs)

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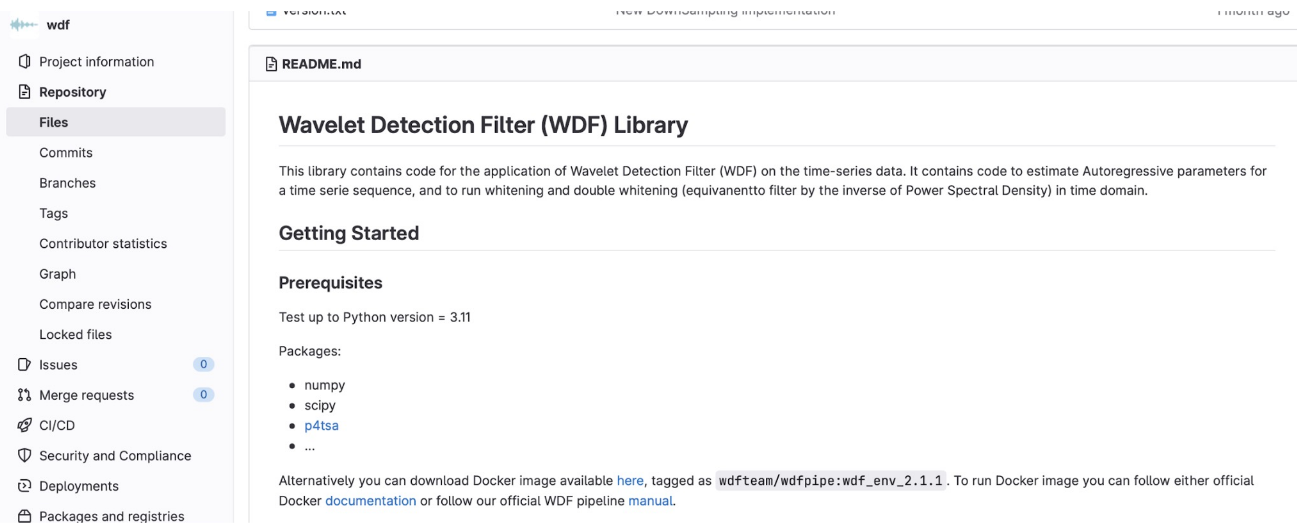
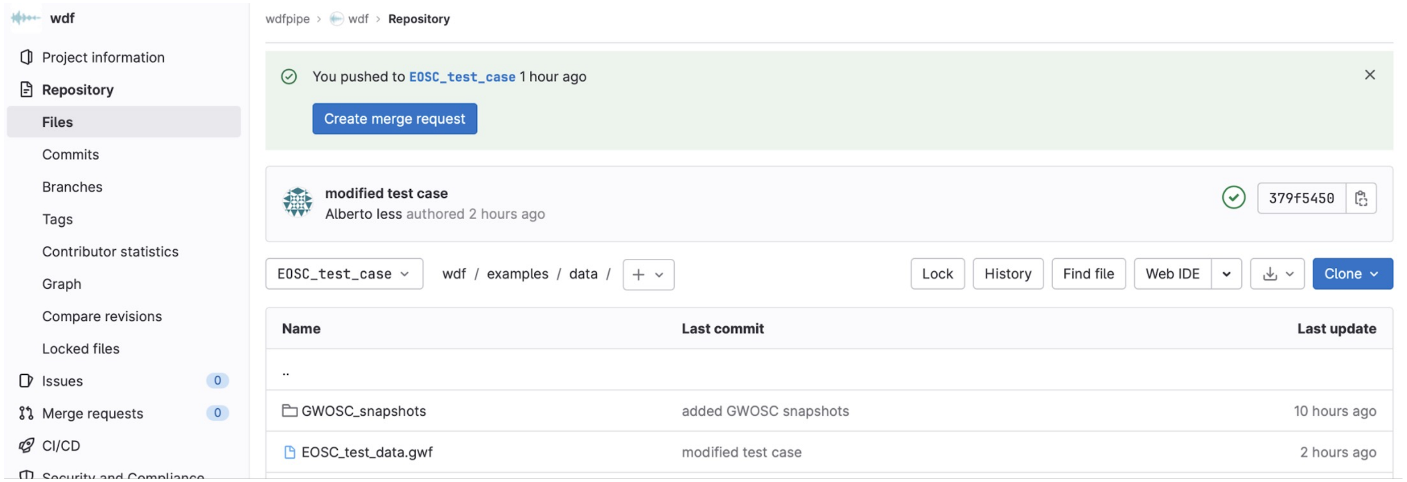
Gitlab Set Up

- We use a custom branch of the WDF python library, hosted as a gitlab project at: https://gitlab.com/wdfpipe/wdf/-/tree/EOSC_test_case?ref_type=heads

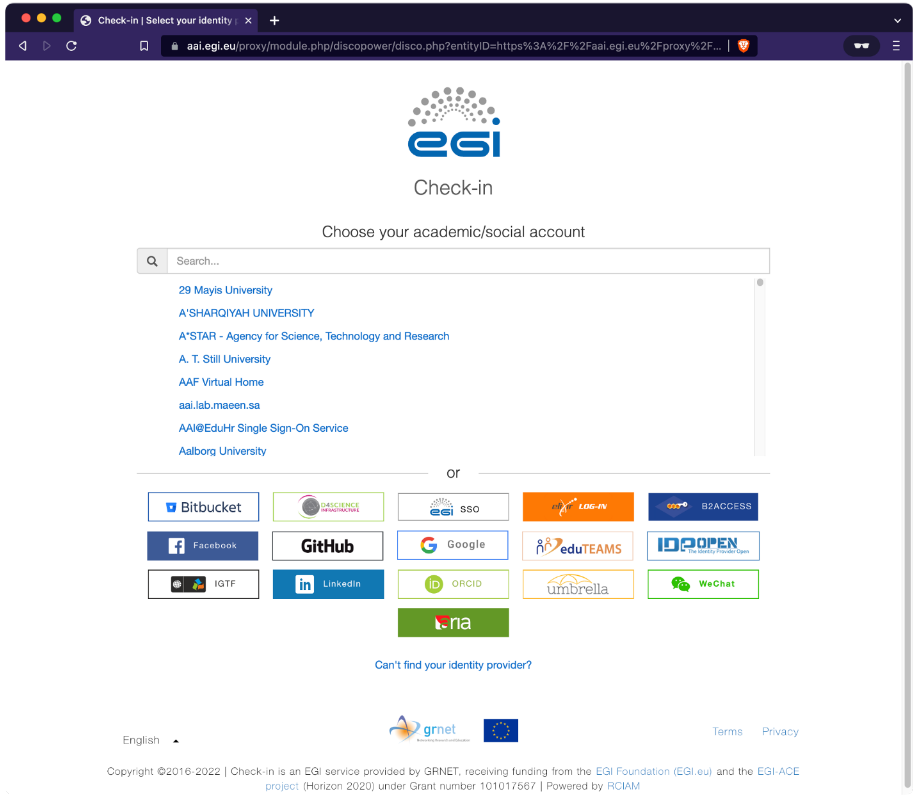


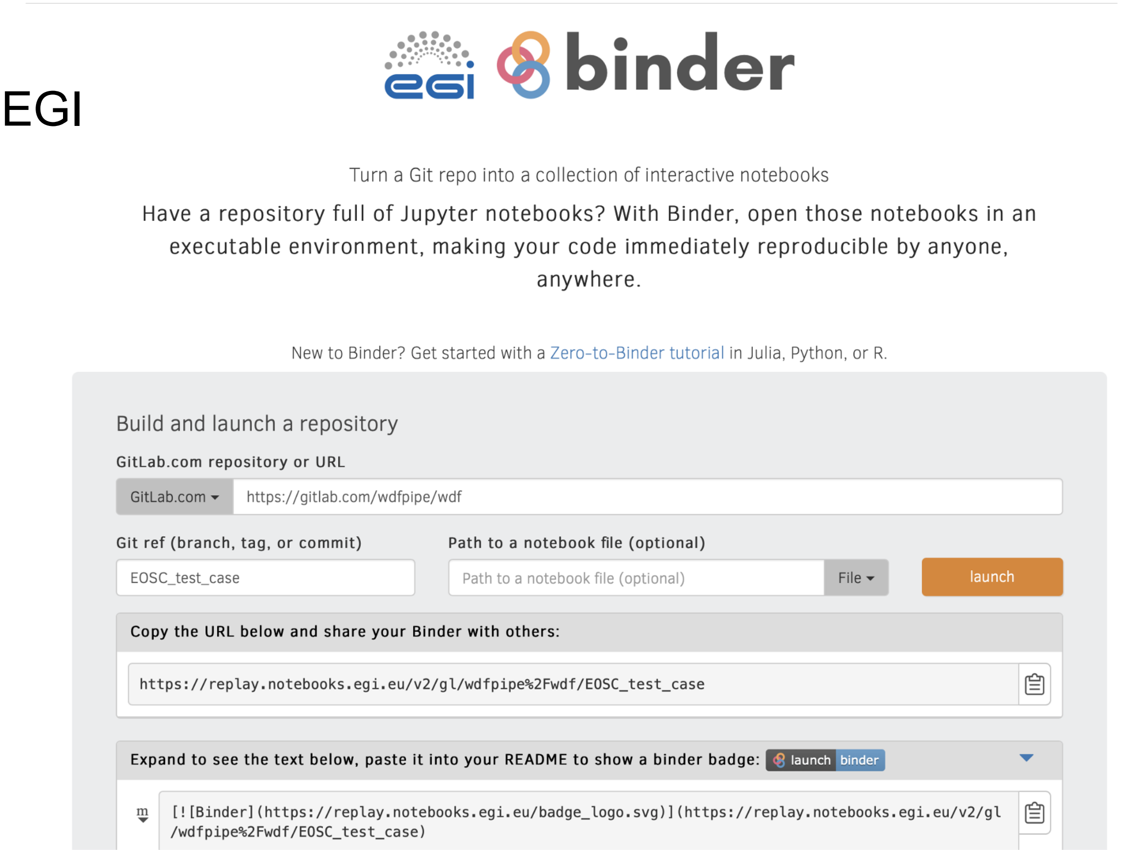
- Get the resource found on EOSC Marketplace (indexed in Zenodo) *“GWOSC Event Snapshots”*
- Added to repo for demo purpose.



Using the EGI-Notebooks

- EGI check-in with academic account
- Obtained membership for specific VO (Virtual Organisations) *vo.notebooks.egi.eu* in order to use EGI Notebooks **(~ minutes)**





Performing The Analysis

Notebook to run analysis starting from the GWOSC Event Snapshots (using GPS times)

- Binder to easily reproduce environment and notebook through github, gitlab and other repositories.

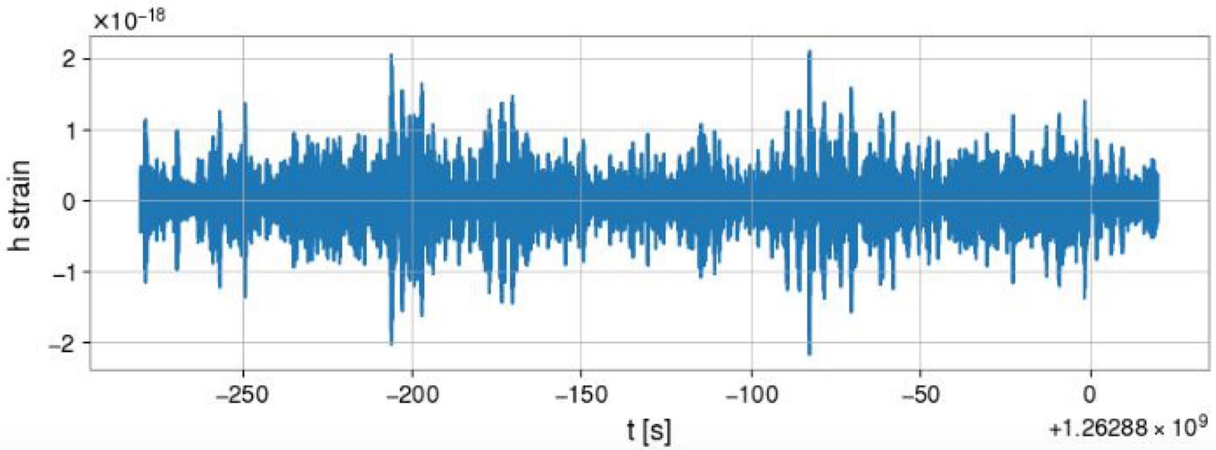
In [94]:
```
event['events']['GW200112_155838-v1']['strain'][0] #['GPSstart']
```

Out[94]:

```
{'GPSstart': 1262879920,
 'detector': 'L1',
 'duration': 32,
 'format': 'gwf',
 'sampling_rate': 16384,
 'url': 'https://www.gw-openscience.org/eventapi/json/GWTC-3-confident/GW200112_155838/v1/L-L1_GWOSC_16KHZ_R1-126
2879920-32.gwf'}
```


We use the data stored in the event snapshot to fecth **open data** from the GWOSC platform (using gwpy installed in the environment, details at https://gwpy.github.io/docs/stable/timeseries/opendata/)

In [198]:
```
gps_event = event['events']['GW200112_155838-v1']['strain'][12]['GPSstart']
start = int(gps_event) - 200
end = int(gps_event) + 100
data_L1 = TimeSeries.fetch_open_data('L1', start, end)
plt.figure(figsize=(10,3))
plt.plot(data_L1), plt.xlabel('t [s]'), plt.ylabel('h strain');
```



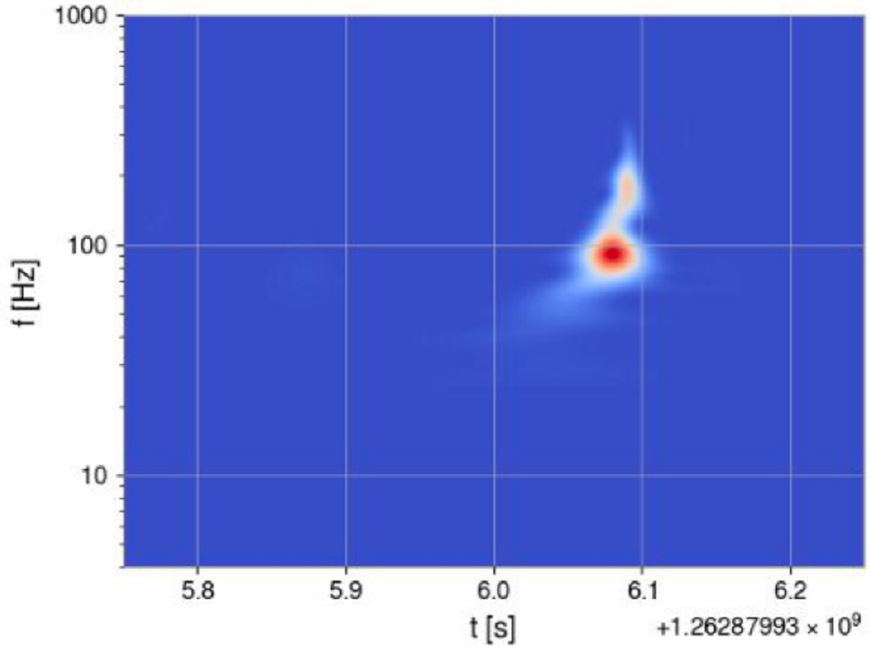
Performing The Analysis

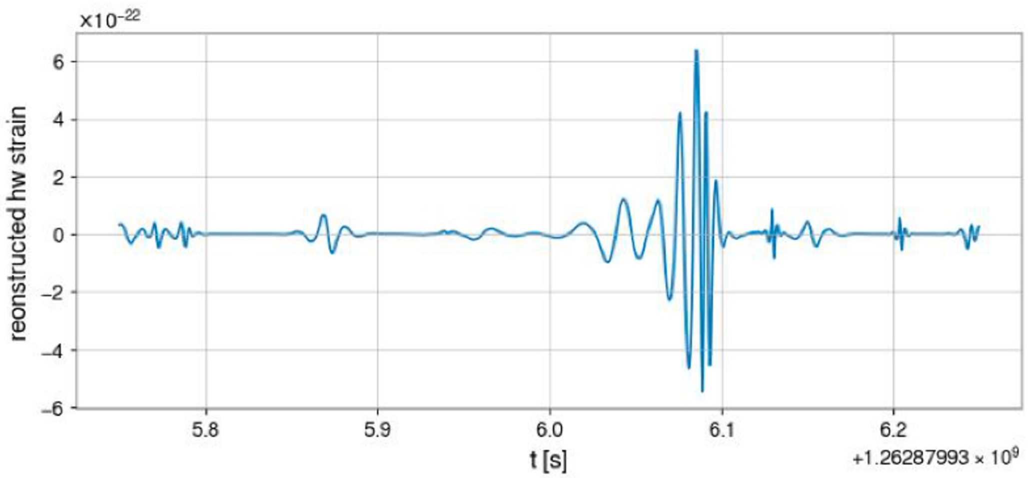
- Transient event list in .csv file
- Reconstructed whitened chirp signal as a time series and in the time-frequency domain

```
In [145]:
wdf=wdfUnitDSWorker(par,fullPrint=2)
wdf.segmentProcess(par.segment)

2023-05-15 20:14:52 hal2022 root[20277] INFO Analyzing segment: 1262879720-1262880020 for channel L1:GWOSC-16KHZ_R1_STRAIN downsampled at 2048Hz
2023-05-15 20:14:52 hal2022 root[20277] INFO Start AR parameter estimation
2023-05-15 20:15:47 hal2022 root[20277] INFO Estimated sigma= 2.204710935695034e-22
2023-05-15 20:16:14 hal2022 root[20277] INFO Starting detection loop
2023-05-15 20:23:08 hal2022 root[20277] INFO analyzed 300 seconds in 495.7170033454895 seconds
```

	gps	gpsPeak	duration	EnWDF	snrMean	snrPeak	freqMin	freqMean	freqMax	freqPeak	...	rw1014	rw1015	rw1016	rw1017
0	1262879725.125	1262879725.447	0.500	0.206	0.160	0.794	46.000	105.500	200.000	72.000	...	0.000	0.000	0.000	0.000
1	1262879727.625	1262879727.749	0.500	0.208	0.180	1.380	46.000	150.692	340.000	140.000	...	0.000	-0.000	-0.000	-0.000
2	1262879727.875	1262879728.122	0.493	0.203	0.161	1.033	44.000	121.000	248.000	56.000	...	0.000	-0.000	-0.000	0.000
3	1262879735.375	1262879735.800	0.488	0.236	0.197	1.509	76.000	169.385	258.000	152.000	...	-0.000	-0.000	-0.000	-0.000
4	1262879735.500	1262879735.800	0.298	0.223	0.183	1.509	98.000	170.577	252.000	128.000	...	0.000	0.000	0.000	0.000
5	1262879735.625	1262879735.800	0.411	0.214	0.179	1.502	98.000	170.654	252.000	128.000	...	0.000	-0.000	-0.000	-0.000
6	1262879735.750	1262879735.800	0.315	0.211	0.165	1.512	98.000	174.346	272.000	158.000	...	-0.000	-0.000	0.000	0.000
7	1262879739.625	1262879739.903	0.492	0.225	0.180	1.101	54.000	141.000	274.000	72.000	...	0.000	0.000	0.000	0.000
8	1262879739.750	1262879739.903	0.472	0.247	0.199	1.108	54.000	139.615	260.000	126.000	...	-0.000	-0.000	-0.000	-0.000
9	1262879739.875	1262879739.903	0.480	0.293	0.222	1.155	54.000	140.192	280.000	130.000	...	-0.000	-0.000	-0.000	-0.000





Use case story in a nutshell

- Used EOSC Marketplace to find a resource indexed in the EOSC portal, through Zenodo.
- Downloaded resource to find astrophysical event GPS time.
- Tested accessing EGI resources through identity check
- Tested EGI notebook to reproduce analysis.
- Used resource to download existing open source data from the Gravitational Wave Open Science Center.
- Carried-out simple gravitational wave data analysis using Wavelet Detection Filter (gitlab, soon on Zenodo visible from the Marketplace)

Added value by EOSC

- Data found through Marketplace
- Computing resources EGI-Notebook
- Reproducibility through Binder
- Student Training