PycWB Tutorial

0. Install dependencies

```
!pip install -q condacolab
import condacolab
condacolab.install()
```

```
WARNING: Running pip as the 'root' user can result in broken permissions and conflicting behaviour with the system package manager. It is recomme
✨🍰✨ Everything looks OK!
```

```
!mamba install -c conda-forge -y -q healpix_cxx=3.81 root=6.26.10 cmake pkg-config
!mamba install -c conda-forge -y -q nds2-client python-nds2-client
```

Install pycwb package

```
!git clone https://github.com/PycWB/pycwb.git
```

```
fatal: destination path 'pycwb' already exists and is not an empty directory.
```

```
!cd pycwb && git reset --hard d1d26df && pip install .
```

```
Successfully installed Mako-1.3.3 PyJWT-2.8.0 PycWB-0.18.5.dev2+gd1d26df aiohttp-3.9.5 aiosignal-1.3.1 astropy-6.0.1 astropy-iers-data-0.2024.4
WARNING: Running pip as the 'root' user can result in broken permissions and conflicting behaviour with the system package manager. It is reco
```

```
# !pip install pycwb
# !pip install "astropy<5.3" "matplotlib<3.7.0"
```

Install deps for modules

```
!pip install -q basemap healpy tensorflow
```

```
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 589.8/589.8 MB 2.7 MB/s eta 0:00:00
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━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 294.6/294.6 kB 16.8 MB/s eta 0:00:00
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━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 46.5/46.5 kB 2.3 MB/s eta 0:00:00
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━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 105.4/105.4 kB 6.8 MB/s eta 0:00:00
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 6.6/6.6 MB 30.6 MB/s eta 0:00:00
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━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 311.2/311.2 kB 14.8 MB/s eta 0:00:00
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━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 87.5/87.5 kB 5.2 MB/s eta 0:00:00
WARNING: Running pip as the 'root' user can result in broken permissions and conflicting behaviour with the system package manager. It is recomme
```

1. Run your first example

First, we download the example user parameter file

```
user_parameters = """
analysis: "2G"
cfg_search: "r"

optim: False

###### network configuration ######
ifo: ["L1","H1"]
refIFO: "L1"

inRate: 16384
# lags
lagSize: 1
lagStep: 1.
lagOff: 0
lagMax: 0

# superlags
slagSize: 0 # number of super lags (simulation=1) - if slagSize=0 -> Standard Segments
slagMin: 0
slagMax: 0
slagOff: 0

# job
segLen: 1200
segMLS: 600
segTHR: 200
segEdge: 10

# frequency
fLow: 16.
fHigh: 1024.


levelR: 3
l_low: 4 # low frequency resolution level            // std (sthr = 2)
l_high: 10 # high frequency resolution level       // std (sthr = 8)

wdmXTalk: "wdmXTalk/OverlapCatalog16-1024.bin"

healpix: 7

###### cWB production thresholds & regulators ######

bpp: 0.001
subnet: 0.5
subcut: 0.0
netRHO: 5.5
# cedRHO: 5.0
netCC: 0.5
Acore: 1.7
Tgap: 0.2
Fgap: 128.0
delta: 0.5
cfg_gamma: -1.0
LOUD: 300

pattern: 5

iwindow: 30

nSky: 196608

# simulation
# simulation: None
nfactor: 1
"""

with open('user_parameters.yaml', 'w') as fp:
        fp.write(user_parameters)
```

```
import os

import pycwb
from pycwb.config import Config
from pycwb.modules.logger import logger_init

if not os.environ.get('HOME_WAT_FILTERS'):
        pyburst_path = os.path.dirname(os.path.abspath(pycwb.__file__))
        os.environ['HOME_WAT_FILTERS'] = f"{os.path.abspath(pyburst_path)}/vendor"

logger_init()

config = Config('./user_parameters.yaml')
```

```
24-04-24 12:56:56 - logger_init - INFO - Logging initialized
24-04-24 12:56:56 - logger_init - INFO - Logging level: INFO
24-04-24 12:56:56 - logger_init - INFO - Logging file: None
24-04-24 12:56:56 - check_MRA_catalog - INFO - Checking MRA catalog
24-04-24 12:56:56 - load_MRA - INFO - Loading catalog of WDM cross-talk coefficients: /usr/local/lib/python3.10/site-packages/pycwb/vendor/wdmXTa
```

generate injected data for each detector with given parameters in config

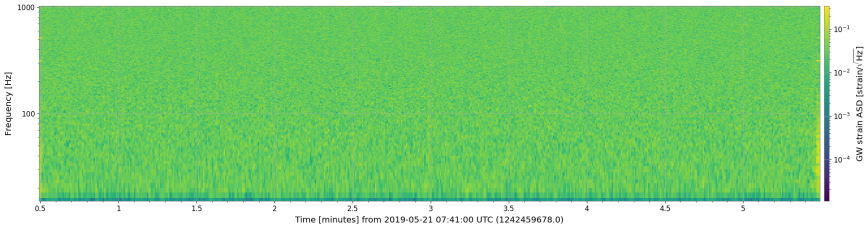
```
from pycwb.modules.read_data import read_from_catalog, read_from_online
from gwpy.timeseries import TimeSeries

import requests
from gwosc.locate import get_urls
t0 = 1242459857.5

data = []
for ifo in config.ifo:
    url = get_urls(ifo, t0, t0)[-1]

    print('Downloading: ', url)
    fn = os.path.basename(url)
    with open(fn,'wb') as strainfile:
            straindata = requests.get(url)
            strainfile.write(straindata.content)

    strain = TimeSeries.read(fn,format='hdf5.gwosc')
    d = strain.crop(t0-150, t0+150)
    d_resampled = d.resample(2048)
    data.append(d_resampled)
```

```
Downloading: http://gwosc.org/eventapi/json/GWTC-2.1-confident/GW190521_074359/v2/L-L1_GWOSC_4KHZ_R1-1242457810-4096.hdf5
Downloading: http://gwosc.org/eventapi/json/GWTC-2.1-confident/GW190521_074359/v2/H-H1_GWOSC_4KHZ_R1-1242457810-4096.hdf5
```

apply data conditioning to the data

```
from pycwb.modules.data_conditioning import data_conditioning
from pycwb.modules.plot import plot_spectrogram

strains, nRMS = data_conditioning(config, data)

# plot the spectrogram for L1
plt = plot_spectrogram(strains[0], gwpy_plot=True)
ax = plt.gca()
ax.set_ylim(15,1024)

strains, nRMS
```

```
24-04-24 12:51:18 - data_conditioning - INFO - Start data conditioning in parallel
24-04-24 12:51:25 - data_conditioning - INFO - ------------------------------------------------
24-04-24 12:51:25 - data_conditioning - INFO - Data Conditioning Time: 6.91 seconds
24-04-24 12:51:25 - data_conditioning - INFO - ------------------------------------------------
((<pycwb.types.time_frequency_series.TimeFrequencySeries at 0x7dcb22d58520>,
  <pycwb.types.time_frequency_series.TimeFrequencySeries at 0x7dcb22d58760>),
 (<pycwb.types.time_frequency_series.TimeFrequencySeries at 0x7dcb22d586a0>,
  <pycwb.types.time_frequency_series.TimeFrequencySeries at 0x7dcb22d58880>))
```



calculate coherence

```
from pycwb.modules.coherence import coherence

# calculate coherence
fragment_clusters = coherence(config, strains, nRMS)
```

```
max energy in units of noise variance: 8.19392
thresholds in units of noise variance: Eo=8.47861 Emax=16.9572
live time in zero lag: 280
lag | clusters | pixels
  0 |        4 |     29
Coherence time for single level: 14.322297 s
24-04-24 12:52:37 - _coherence_single_res - INFO - level : 8     rate(hz) : 8    layers : 256    df(hz) : 4.000000       dt(ms) : 125.000000
max energy in units of noise variance: 8.71556
thresholds in units of noise variance: Eo=8.49242 Emax=16.9848
live time in zero lag: 280
lag | clusters | pixels
  0 |        5 |    151
Coherence time for single level: 14.193154 s
24-04-24 12:52:38 - _coherence_single_res - INFO - level : 7     rate(hz) : 16   layers : 128    df(hz) : 8.000000       dt(ms) : 62.500000
max energy in units of noise variance: 9.11623
thresholds in units of noise variance: Eo=8.55191 Emax=17.1038
live time in zero lag: 280
lag | clusters | pixels
  0 |       10 |    177
Coherence time for single level: 14.687993 s
24-04-24 12:52:45 - _coherence_single_res - INFO - level : 6     rate(hz) : 32   layers : 64     df(hz) : 16.000000      dt(ms) : 31.250000
max energy in units of noise variance: 10.1297
thresholds in units of noise variance: Eo=8.7107 Emax=17.4214
live time in zero lag: 280
lag | clusters | pixels
  0 |       11 |    138
Coherence time for single level: 8.517567 s
24-04-24 12:52:45 - _coherence_single_res - INFO - level : 5     rate(hz) : 64   layers : 32     df(hz) : 32.000000      dt(ms) : 15.625000
max energy in units of noise variance: 12.1488
thresholds in units of noise variance: Eo=8.99028 Emax=17.9806
live time in zero lag: 280
lag | clusters | pixels
  0 |       18 |    184
Coherence time for single level: 7.973651 s
24-04-24 12:52:45 - _coherence_single_res - INFO - level : 4     rate(hz) : 128  layers : 16     df(hz) : 64.000000      dt(ms) : 7.812500
max energy in units of noise variance: 14.4034
```

```
0        0.00000       0.00000
lag          ifoL1         ifoH1
0        0.00000       0.00000
lag          ifoL1         ifoH1
0        0.00000       0.00000
lag          ifoL1         ifoH1
0        0.00000       0.00000
lag          ifoL1         ifoH1
0        0.00000       0.00000
lag          ifoL1         ifoH1
0        0.00000       0.00000
lag          ifoL1         ifoH1
0        0.00000       0.00000
```

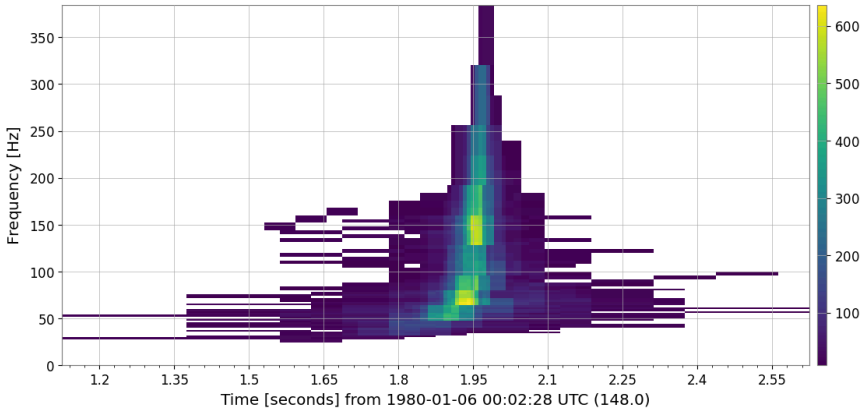
```
# # %matplotlib inline
# from gwpy.spectrogram import Spectrogram
# for fragment_cluster in fragment_clusters:
#     for cluster in fragment_cluster.clusters:
#             merged_map, start, dt, df = cluster.get_sparse_map("likelihood")

#             plt = Spectrogram(merged_map, t0=start, dt=dt, f0=0, df=df).plot()
#             plt.colorbar()
```

supercluster

```
from pycwb.modules.super_cluster import supercluster
from pycwb.types.network import Network

network = Network(config, strains, nRMS)

pwc_list = supercluster(config, network, fragment_clusters, strains)
```

```
24-04-24 12:52:47 - set_time_shift - INFO - lag step: 1.0
24-04-24 12:52:47 - set_time_shift - INFO - number of time lags: 1
24-04-24 12:52:48 - sparse_table_from_fragment_clusters - INFO - ----------------------------------------
24-04-24 12:52:48 - sparse_table_from_fragment_clusters - INFO - Sparse series time: 1.77 s
24-04-24 12:52:48 - sparse_table_from_fragment_clusters - INFO - ----------------------------------------
24-04-24 12:52:51 - supercluster - INFO - -> Processing lag=0 ...
24-04-24 12:52:51 - supercluster - INFO -    ------------------------------------------------
24-04-24 12:52:51 - supercluster - INFO -     coher clusters|pixels      :     75|1006
24-04-24 12:52:51 - supercluster - INFO -     super clusters|pixels      :      6|486
24-04-24 12:52:51 - supercluster - INFO -    defrag clusters|pixels      :      6|486
24-04-24 12:52:51 - supercluster - INFO -    subnet clusters|pixels      :      1|381
24-04-24 12:52:51 - supercluster - INFO - Supercluster done
24-04-24 12:52:51 - supercluster - INFO - total  clusters|pixels|frac :      1|381|1.000000
24-04-24 12:52:52 - supercluster - INFO - ----------------------------------------
24-04-24 12:52:52 - supercluster - INFO - Supercluster time: 5.83 s
24-04-24 12:52:52 - supercluster - INFO - ----------------------------------------
    lag          ifoL1         ifoH1
      0        0.00000       0.00000
```

```
%matplotlib inline
from gwpy.spectrogram import Spectrogram

for cluster in pwc_list[0].clusters:
        merged_map, start, dt, df = cluster.get_sparse_map("likelihood")

        plt = Spectrogram(merged_map, t0=start, dt=dt, f0=0, df=df).plot()
        plt.colorbar()
```



Likelihood

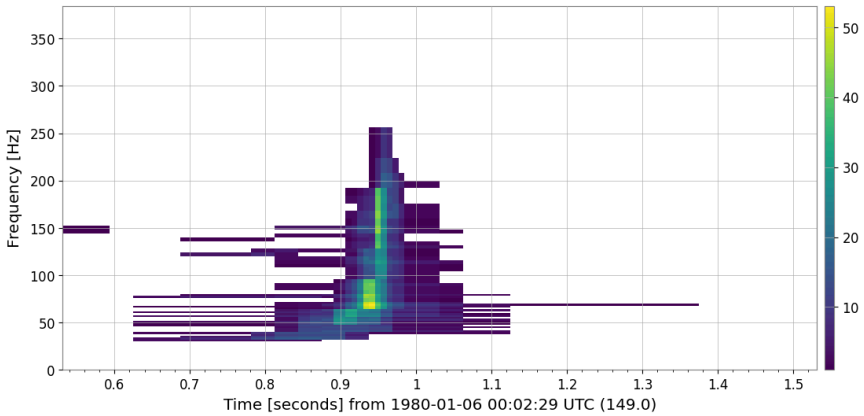
```
from pycwb.modules.likelihood import likelihood

events, clusters, skymap_statistics = likelihood(config, network, pwc_list)
```

```
24-04-24 12:53:41 - likelihood - INFO - ------------------------------------------------------------
24-04-24 12:53:41 - likelihood - INFO - -> Processing 1 clusters in lag=0
24-04-24 12:53:41 - likelihood - INFO -    ------------------------------------------------------------
24-04-24 12:53:49 - _likelihood - INFO - Selected core pixels: 1
24-04-24 12:53:49 - _likelihood - INFO -    cluster-id|pixels:     1|381
24-04-24 12:53:49 - _likelihood - INFO -         -> SELECTED !!!
24-04-24 12:53:51 - likelihood - INFO - ------------------------------------------------------------
24-04-24 12:53:51 - likelihood - INFO - Total events: 1
24-04-24 12:53:51 - likelihood - INFO - Total time: 10.09 s
24-04-24 12:53:51 - likelihood - INFO - ------------------------------------------------------------
mchirp_2g : 1 1 3.78e+01 2.480 149.961 0.000 0.965
```

plot statistics

```
%matplotlib inline
from pycwb.modules.plot import plot_event_on_spectrogram

plt = plot_event_on_spectrogram(strains[0], events)
plt.show()
```

```
%matplotlib inline
from gwpy.spectrogram import Spectrogram

for cluster in clusters:
    merged_map, start, dt, df = cluster.get_sparse_map("likelihood")

    plt = Spectrogram(merged_map, t0=start, dt=dt, f0=0, df=df).plot()
    plt.colorbar()
```




```
%matplotlib inline
from gwpy.spectrogram import Spectrogram

for cluster in clusters:
    merged_map, start, dt, df = cluster.get_sparse_map("null")

    plt = Spectrogram(merged_map, t0=start, dt=dt, f0=0, df=df).plot()
    plt.colorbar()
```