```
# 1. 安装 condacolab: 这是一个专为 Colab 设计的工具。
!pip install -q condacolab
# 2. 导入 condacolab 模块，准备使用其中的方法进行环境设置。
import condacolab
# 调用 install() 方法安装 Miniconda 并自动配置环境变量，使 Conda 可在当前 Colab 环境中使用
condacolab.install()
```

Downloading https://github.com/jaimergp/miniforge/releases/download/24.11.2-1_colab/Miniforge3-colab-24.11.2-1_colab-
Installing...
Adjusting configuration...
Patching environment...
Done in 0:00:14
Restarting kernel...

```
# 安装 HEALPix、ROOT、构建工具等依赖包
!mamba install -c conda-forge -y -q healpix_cxx=3.81 root=6.26.10 cmake pkg-config
# 安装 NDS2 客户端及其 Python 接口（用于访问 LIGO 数据）
!mamba install -c conda-forge -y -q nds2-client python-nds2-client
```

Preparing transaction: ...working... done
Verifying transaction: ...working... done
Executing transaction: ...working...

done
Preparing transaction: ...working... done
Verifying transaction: ...working... done
Executing transaction: ...working... done

```
# 使用 pip 安装 pycwb
!pip install pycwb
```

```
Collecting pycwb
  Downloading pycwb-0.28.0.tar.gz (39.1 MB)
  ──────────────────────────────────────── 39.1/39.1 MB 25.0 MB/s eta 0:00:00
  Installing build dependencies ... done
  Getting requirements to build wheel ... done
  Preparing metadata (pyproject.toml) ... done
Collecting matplotlib (from pycwb)
  Downloading matplotlib-3.10.1-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (11 kB)
Collecting astropy (from pycwb)
  Downloading astropy-7.0.1-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (10 kB)
Requirement already satisfied: pyyaml in /usr/local/lib/python3.11/site-packages (from pycwb) (6.0.2)
Requirement already satisfied: jsonschema in /usr/local/lib/python3.11/site-packages (from pycwb) (4.23.0)
Collecting watchfiles (from pycwb)
  Downloading watchfiles-1.0.5-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (4.9 kB)
Requirement already satisfied: numpy in /usr/local/lib/python3.11/site-packages (from pycwb) (1.26.4)
Collecting numba (from pycwb)
  Downloading numba-0.61.2-cp311-cp311-manylinux2014_x86_64.manylinux_2_17_x86_64.whl.metadata (2.8 kB)
Collecting gwpy (from pycwb)
  Downloading gwpy-3.0.12-py3-none-any.whl.metadata (4.9 kB)
Collecting ligo-segments (from pycwb)
  Downloading ligo-segments-1.4.0.tar.gz (51 kB)
  Preparing metadata (setup.py) ... done
Collecting aiohttp (from pycwb)
  Downloading aiohttp-3.11.18-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (7.7 kB)
Collecting pycbc (from pycwb)
  Downloading pycbc-2.8.2-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (4.6 kB)
Collecting filelock (from pycwb)
  Downloading filelock-3.18.0-py3-none-any.whl.metadata (2.9 kB)
Collecting scipy (from pycwb)
  Downloading scipy-1.15.2-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (61 kB)
Collecting pillow>=9.0.0 (from pycwb)
  Downloading pillow-11.2.1-cp311-cp311-manylinux_2_28_x86_64.whl.metadata (8.9 kB)
Collecting click (from pycwb)
  Downloading click-8.1.8-py3-none-any.whl.metadata (2.3 kB)
Collecting orjson (from pycwb)
  Downloading orjson-3.10.18-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (41 kB)
Collecting dacite (from pycwb)
  Downloading dacite-1.9.2-py3-none-any.whl.metadata (17 kB)
Collecting lalsuite>=7.0.0 (from pycwb)
  Downloading lalsuite-7.25.1-cp311-cp311-manylinux_2_28_x86_64.whl.metadata (3.2 kB)
Collecting prefect (from pycwb)
  Downloading prefect-3.4.0-py3-none-any.whl.metadata (13 kB)
Collecting prefect-dask (from pycwb)
  Downloading prefect_dask-0.3.5-py3-none-any.whl.metadata (1.7 kB)
Collecting dask (from pycwb)
  Downloading dask-2025.4.1-py3-none-any.whl.metadata (3.8 kB)
Collecting dask_jobqueue (from pycwb)
  Downloading dask_jobqueue-0.9.0-py2.py3-none-any.whl.metadata (1.3 kB)
Collecting htcondor (from pycwb)
  Downloading htcondor-24.7.3-cp311-cp311-manylinux_2_28_x86_64.whl.metadata (1.4 kB)
Requirement already satisfied: psutil in /usr/local/lib/python3.11/site-packages (from pycwb) (7.0.0)
Collecting lscsoft-glue (from lalsuite>=7.0.0->pycwb)
  Downloading lscsoft_glue-4.1.0-py3-none-any.whl.metadata (1.5 kB)
Requirement already satisfied: python-dateutil in /usr/local/lib/python3.11/site-packages (from lalsuite>=7.0.0->pycwb)
Collecting aiohappyeyeballs>=2.3.0 (from aiohttp->pycwb)
  Downloading aiohappyeyeballs-2.6.1-py3-none-any.whl.metadata (5.9 kB)
Collecting aiosignal>=1.1.2 (from aiohttp->pycwb)
  Downloading aiosignal-1.3.2-py2.py3-none-any.whl.metadata (3.8 kB)
Requirement already satisfied: attrs>=17.3.0 in /usr/local/lib/python3.11/site-packages (from aiohttp->pycwb) (25.3.0)
Collecting frozenlist>=1.1.1 (from aiohttp->pycwb)
  Downloading frozenlist-1.6.0-cp311-cp311-manylinux_2_5_x86_64.manylinux1_x86_64.manylinux_2_17_x86_64.manylinux2014_x8
Collecting multidict<7.0,>=4.5 (from aiohttp->pycwb)
  Downloading multidict-6.4.3-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (5.3 kB)
Collecting propcache>=0.2.0 (from aiohttp->pycwb)
  Downloading propcache-0.3.1-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (10 kB)
Collecting yarl<2.0,>=1.17.0 (from aiohttp->pycwb)
  Downloading yarl-1.20.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (72 kB)
Collecting pyerfa>=2.0.1.1 (from astropy->pycwb)
  Downloading pyerfa-2.0.1.5-cp39-abi3-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (5.7 kB)
Collecting astropy-iers-data>=0.2025.1.31.12.41.4 (from astropy->pycwb)
  Downloading astropy_iers_data-0.2025.5.5.0.38.14-py3-none-any.whl.metadata (5.1 kB)
Requirement already satisfied: packaging>=22.0.0 in /usr/local/lib/python3.11/site-packages (from astropy->pycwb) (24.2)
Collecting cloudpickle>=3.0.0 (from dask->pycwb)
  Downloading cloudpickle-3.1.1-py3-none-any.whl.metadata (7.1 kB)
Collecting fsspec>=2021.09.0 (from dask->pycwb)
  Downloading fsspec-2025.3.2-py3-none-any.whl.metadata (11 kB)
Collecting partd>=1.4.0 (from dask->pycwb)
  Downloading partd-1.4.2-py3-none-any.whl.metadata (4.6 kB)
Requirement already satisfied: toolz>=0.10.0 in /usr/local/lib/python3.11/site-packages (from dask->pycwb) (1.0.0)
Requirement already satisfied: importlib_metadata>=4.13.0 in /usr/local/lib/python3.11/site-packages (from dask->pycwb)
Collecting distributed>=2022.02.0 (from dask_jobqueue->pycwb)
  Downloading distributed-2025.4.1-py3-none-any.whl.metadata (3.4 kB)
Collecting dateparser>=1.1.4 (from gwpy->pycwb)
  Downloading dateparser-1.2.1-py3-none-any.whl.metadata (29 kB)
Collecting dqsegdb2 (from gwpy->pycwb)
  Downloading dqsegdb2-1.3.0-py3-none-any.whl.metadata (3.6 kB)
Collecting gwdatafind>=1.1.0 (from gwpy->pycwb)
  Downloading gwdatafind-2.0.0-py3-none-any.whl.metadata (3.6 kB)
Collecting gwosc>=0.5.3 (from gwpy->pycwb)
  Downloading gwosc-0.8.0-py3-none-any.whl.metadata (6.2 kB)
```

```
Collecting h5py>=3.0.0 (from gwpy->pycwb)
  Downloading h5py-3.13.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (2.5 kB)
Collecting igwn-segments>=2.0.0 (from gwpy->pycwb)
  Downloading igwn_segments-2.1.0-cp311-cp311-manylinux_2_5_x86_64.manylinux1_x86_64.manylinux_2_28_x86_64.whl.metadata
Collecting ligotimegps>=1.2.1 (from gwpy->pycwb)
  Downloading ligotimegps-2.0.1-py2.py3-none-any.whl.metadata (2.6 kB)
Requirement already satisfied: requests>=2.20.0 in /usr/local/lib/python3.11/site-packages (from gwpy->pycwb) (2.32.3)
Requirement already satisfied: tqdm>=4.52.0 in /usr/local/lib/python3.11/site-packages (from gwpy->pycwb) (4.67.1)
Collecting contourpy>=1.0.1 (from matplotlib->pycwb)
  Downloading contourpy-1.3.2-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (5.5 kB)
Collecting cycler>=0.10 (from matplotlib->pycwb)
  Downloading cycler-0.12.1-py3-none-any.whl.metadata (3.8 kB)
Collecting fonttools>=4.22.0 (from matplotlib->pycwb)
  Downloading fonttools-4.57.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (102 kB)
Collecting kiwisolver>=1.3.1 (from matplotlib->pycwb)
  Downloading kiwisolver-1.4.8-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (6.2 kB)
Collecting pyparsing>=2.3.1 (from matplotlib->pycwb)
  Downloading pyparsing-3.2.3-py3-none-any.whl.metadata (5.0 kB)
Requirement already satisfied: jsonschema-specifications>=2023.03.6 in /usr/local/lib/python3.11/site-packages (from jso
Requirement already satisfied: referencing>=0.28.4 in /usr/local/lib/python3.11/site-packages (from jsonschema->pycwb) (
Requirement already satisfied: rpds-py>=0.7.1 in /usr/local/lib/python3.11/site-packages (from jsonschema->pycwb) (0.24.
Requirement already satisfied: six in /usr/local/lib/python3.11/site-packages (from ligo-segments->pycwb) (1.17.0)
Collecting llvmlite<0.45,>=0.44.0dev0 (from numba->pycwb)
  Downloading llvmlite-0.44.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (4.8 kB)
Collecting aiosqlite<1.0.0,>=0.17.0 (from prefect->pycwb)
  Downloading aiosqlite-0.21.0-py3-none-any.whl.metadata (4.3 kB)
Collecting alembic<2.0.0,>=1.7.5 (from prefect->pycwb)
  Downloading alembic-1.15.2-py3-none-any.whl.metadata (7.3 kB)
Requirement already satisfied: anyio<5.0.0,>=4.4.0 in /usr/local/lib/python3.11/site-packages (from prefect->pycwb) (4.9
Collecting apprise<2.0.0,>=1.1.0 (from prefect->pycwb)
  Downloading apprise-1.9.3-py3-none-any.whl.metadata (53 kB)
Collecting asgi-lifespan<3.0,>=1.0 (from prefect->pycwb)
  Downloading asgi_lifespan-2.1.0-py3-none-any.whl.metadata (10 kB)
Collecting asyncpg<1.0.0,>=0.23 (from prefect->pycwb)
  Downloading asyncpg-0.30.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (5.0 kB)
Collecting cachetools<6.0,>=5.3 (from prefect->pycwb)
  Downloading cachetools-5.5.2-py3-none-any.whl.metadata (5.4 kB)
Collecting coolname<3.0.0,>=1.0.4 (from prefect->pycwb)
  Downloading coolname-2.2.0-py2.py3-none-any.whl.metadata (6.2 kB)
Requirement already satisfied: cryptography>=36.0.1 in /usr/local/lib/python3.11/site-packages (from prefect->pycwb) (44
Collecting docker<8.0,>=4.0 (from prefect->pycwb)
  Downloading docker-7.1.0-py3-none-any.whl.metadata (3.8 kB)
Requirement already satisfied: exceptiongroup>=1.0.0 in /usr/local/lib/python3.11/site-packages (from prefect->pycwb) (1
Collecting fastapi<1.0.0,>=0.111.0 (from prefect->pycwb)
  Downloading fastapi-0.115.12-py3-none-any.whl.metadata (27 kB)
Collecting graphviz>=0.20.1 (from prefect->pycwb)
  Downloading graphviz-0.20.3-py3-none-any.whl.metadata (12 kB)
Collecting griffe<2.0.0,>=0.49.0 (from prefect->pycwb)
  Downloading griffe-1.7.3-py3-none-any.whl.metadata (5.0 kB)
Requirement already satisfied: httpcore<2.0.0,>=1.0.5 in /usr/local/lib/python3.11/site-packages (from prefect->pycwb) (
Requirement already satisfied: httpx!=0.23.2,>=0.23 in /usr/local/lib/python3.11/site-packages (from httpx[http2]!=0.23.
Collecting humanize<5.0.0,>=4.9.0 (from prefect->pycwb)
  Downloading humanize-4.12.3-py3-none-any.whl.metadata (7.8 kB)
Collecting jinja2-humanize-extension>=0.4.0 (from prefect->pycwb)
  Downloading jinja2_humanize_extension-0.4.0-py3-none-any.whl.metadata (3.6 kB)
Requirement already satisfied: jinja2<4.0.0,>=3.1.6 in /usr/local/lib/python3.11/site-packages (from prefect->pycwb) (3.
Requirement already satisfied: jsonpatch<2.0,>=1.32 in /usr/local/lib/python3.11/site-packages (from prefect->pycwb) (1.
Collecting opentelemetry-api<2.0.0,>=1.27.0 (from prefect->pycwb)
  Downloading opentelemetry_api-1.32.1-py3-none-any.whl.metadata (1.6 kB)
Collecting pathspec>=0.8.0 (from prefect->pycwb)
  Downloading pathspec-0.12.1-py3-none-any.whl.metadata (21 kB)
Collecting pendulum<4,>=3.0.0 (from prefect->pycwb)
  Downloading pendulum-3.1.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (6.8 kB)
Requirement already satisfied: prometheus-client>=0.20.0 in /usr/local/lib/python3.11/site-packages (from prefect->pycwb
Collecting pydantic!=2.10.0,<3.0.0,>=2.9 (from prefect->pycwb)
  Downloading pydantic-2.11.4-py3-none-any.whl.metadata (66 kB)
Collecting pydantic-core<3.0.0,>=2.12.0 (from prefect->pycwb)
  Downloading pydantic_core-2.34.1-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (6.8 kB)
Collecting pydantic-extra-types<3.0.0,>=2.8.2 (from prefect->pycwb)
  Downloading pydantic_extra_types-2.10.4-py3-none-any.whl.metadata (3.9 kB)
Collecting pydantic-settings!=2.9.0,<3.0.0,>2.2.1 (from prefect->pycwb)
  Downloading pydantic_settings-2.9.1-py3-none-any.whl.metadata (3.8 kB)
Collecting python-slugify<9.0,>=5.0 (from prefect->pycwb)
  Downloading python_slugify-8.0.4-py2.py3-none-any.whl.metadata (8.5 kB)
Collecting python-socks<3.0,>=2.5.3 (from python-socks[asyncio]<3.0,>=2.5.3->prefect->pycwb)
  Downloading python_socks-2.7.1-py3-none-any.whl.metadata (8.0 kB)
Requirement already satisfied: pytz<2026,>=2021.1 in /usr/local/lib/python3.11/site-packages (from prefect->pycwb) (2025
Collecting readchar<5.0.0,>=4.0.0 (from prefect->pycwb)
  Downloading readchar-4.2.1-py3-none-any.whl.metadata (7.5 kB)
Requirement already satisfied: rfc3339-validator<0.2.0,>=0.1.4 in /usr/local/lib/python3.11/site-packages (from prefect-
Collecting rich<15.0,>=11.0 (from prefect->pycwb)
  Downloading rich-14.0.0-py3-none-any.whl.metadata (18 kB)
Requirement already satisfied: ruamel-yaml>=0.17.0 in /usr/local/lib/python3.11/site-packages (from prefect->pycwb) (0.1
Requirement already satisfied: sniffio<2.0.0,>=1.3.0 in /usr/local/lib/python3.11/site-packages (from prefect->pycwb) (1
Collecting sqlalchemy<3.0.0,>=2.0 (from sqlalchemy[asyncio]<3.0.0,>=2.0->prefect->pycwb)
  Downloading sqlalchemy-2.0.40-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (9.6 kB)
Collecting toml>=0.10.0 (from prefect->pycwb)
  Downloading toml-0.10.2-py2.py3-none-any.whl.metadata (7.1 kB)
Collecting typer!=0.12.2,<0.16.0,>=0.12.0 (from prefect->pycwb)
  Downloading typer-0.15.3-py3-none-any.whl.metadata (15 kB)
Requirement already satisfied: typing-extensions<5.0.0,>=4.10.0 in /usr/local/lib/python3.11/site-packages (from prefect
```

```
Collecting ujson<6.0.0,>=5.8.0 (from prefect->pycwb)
  Downloading ujson-5.10.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (9.3 kB)
Collecting uv>=0.6.0 (from prefect->pycwb)
  Downloading uv-0.7.3-py3-none-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (11 kB)
Collecting uvicorn!=0.29.0,>=0.14.0 (from prefect->pycwb)
  Downloading uvicorn-0.34.2-py3-none-any.whl.metadata (6.5 kB)
Collecting websockets<16.0,>=13.0 (from prefect->pycwb)
  Downloading websockets-15.0.1-cp311-cp311-manylinux_2_5_x86_64.manylinux1_x86_64.manylinux_2_17_x86_64.manylinux2014_x
Collecting cython>=0.29 (from pycbc->pycwb)
  Downloading Cython-3.0.12-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (3.3 kB)
Collecting mpld3>=0.3 (from pycbc->pycwb)
  Downloading mpld3-0.5.10-py3-none-any.whl.metadata (5.1 kB)
Collecting Mako>=1.0.1 (from pycbc->pycwb)
  Downloading mako-1.3.10-py3-none-any.whl.metadata (2.9 kB)
Requirement already satisfied: beautifulsoup4>=4.6.0 in /usr/local/lib/python3.11/site-packages (from pycbc->pycwb) (4.1
Requirement already satisfied: setuptools in /usr/local/lib/python3.11/site-packages (from pycbc->pycwb) (65.6.3)
Collecting pegasus-wms.api>=5.0.8 (from pycbc->pycwb)
  Downloading pegasus-wms.api-5.0.9.tar.gz (47 kB)
  Installing build dependencies ... done
  Getting requirements to build wheel ... done
  Preparing metadata (pyproject.toml) ... done
Collecting python-ligo-lw>=1.7.0 (from pycbc->pycwb)
  Downloading python-ligo-lw-1.8.3.tar.gz (2.3 MB)
                                        ━━━━━━━━━━━━━━━━━━━━ 2.3/2.3 MB 89.9 MB/s eta 0:00:00
  Preparing metadata (setup.py) ... done
Collecting pykerr (from pycbc->pycwb)
  Downloading pykerr-0.1.0-py3-none-any.whl.metadata (5.4 kB)
Requirement already satisfied: idna>=2.8 in /usr/local/lib/python3.11/site-packages (from anyio<5.0.0,>=4.4.0->prefect->
Requirement already satisfied: certifi in /usr/local/lib/python3.11/site-packages (from apprise<2.0.0,>=1.1.0->prefect->
Collecting requests-oauthlib (from apprise<2.0.0,>=1.1.0->prefect->pycwb)
  Downloading requests_oauthlib-2.0.0-py2.py3-none-any.whl.metadata (11 kB)
Collecting markdown (from apprise<2.0.0,>=1.1.0->prefect->pycwb)
  Downloading markdown-3.8-py3-none-any.whl.metadata (5.1 kB)
Requirement already satisfied: soupsieve>1.2 in /usr/local/lib/python3.11/site-packages (from beautifulsoup4>=4.6.0->pyc
Requirement already satisfied: cffi>=1.12 in /usr/local/lib/python3.11/site-packages (from cryptography>=36.0.1->prefect
Collecting regex!=2019.02.19,!=2021.8.27,>=2015.06.24 (from dateparser>=1.1.4->gwpy->pycwb)
  Downloading regex-2024.11.6-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (40 kB)
Collecting tzlocal>=0.2 (from dateparser>=1.1.4->gwpy->pycwb)
  Downloading tzlocal-5.3.1-py3-none-any.whl.metadata (7.6 kB)
Collecting locket>=1.0.0 (from distributed>=2022.02.0->dask_jobqueue->pycwb)
  Downloading locket-1.0.0-py2.py3-none-any.whl.metadata (2.8 kB)
Collecting msgpack>=1.0.2 (from distributed>=2022.02.0->dask_jobqueue->pycwb)
  Downloading msgpack-1.1.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (8.4 kB)
Collecting sortedcontainers>=2.0.5 (from distributed>=2022.02.0->dask_jobqueue->pycwb)
  Downloading sortedcontainers-2.4.0-py2.py3-none-any.whl.metadata (10 kB)
Collecting tblib>=1.6.0 (from distributed>=2022.02.0->dask_jobqueue->pycwb)
  Downloading tblib-3.1.0-py3-none-any.whl.metadata (25 kB)
Requirement already satisfied: tornado>=6.2.0 in /usr/local/lib/python3.11/site-packages (from distributed>=2022.02.0->d
Requirement already satisfied: urllib3>=1.26.5 in /usr/local/lib/python3.11/site-packages (from distributed>=2022.02.0->
Collecting zict>=3.0.0 (from distributed>=2022.02.0->dask_jobqueue->pycwb)
  Downloading zict-3.0.0-py2.py3-none-any.whl.metadata (899 bytes)
Collecting starlette<0.47.0,>=0.40.0 (from fastapi<1.0.0,>=0.111.0->prefect->pycwb)
  Downloading starlette-0.46.2-py3-none-any.whl.metadata (6.2 kB)
Requirement already satisfied: colorama>=0.4 in /usr/local/lib/python3.11/site-packages (from griffe<2.0.0,>=0.49.0->pre
Collecting igwn-auth-utils>=0.3.1 (from gwdatafind>=1.1.0->gwpy->pycwb)
  Downloading igwn_auth_utils-1.3.1-py3-none-any.whl.metadata (4.1 kB)
Requirement already satisfied: h11>=0.16 in /usr/local/lib/python3.11/site-packages (from httpcore<2.0.0,>=1.0.5->prefec
Requirement already satisfied: h2<5,>=3 in /usr/local/lib/python3.11/site-packages (from httpx[http2]!=0.23.2,>=0.23->pr
Requirement already satisfied: zipp>=3.20 in /usr/local/lib/python3.11/site-packages (from importlib_metadata>=4.13.0->d
Requirement already satisfied: MarkupSafe>=2.0 in /usr/local/lib/python3.11/site-packages (from jinja2<4.0.0,>=3.1.6->pr
Requirement already satisfied: jsonpointer>=1.9 in /usr/local/lib/python3.11/site-packages (from jsonpatch<2.0,>=1.32->p
Collecting deprecated>=1.2.6 (from opentelemetry-api<2.0.0,>=1.27.0->prefect->pycwb)
  Downloading Deprecated-1.2.18-py2.py3-none-any.whl.metadata (5.7 kB)
Collecting pegasus-wms.common (from pegasus-wms.api>=5.0.8->pycbc->pycwb)
  Downloading pegasus-wms.common-5.0.9.tar.gz (47 kB)
  Installing build dependencies ... done
  Getting requirements to build wheel ... done
  Preparing metadata (pyproject.toml) ... done
Collecting tzdata>=2020.1 (from pendulum<4,>=3.0.0->prefect->pycwb)
  Downloading tzdata-2025.2-py2.py3-none-any.whl.metadata (1.4 kB)
Collecting annotated-types>=0.6.0 (from pydantic!=2.10.0,<3.0.0,>=2.9->prefect->pycwb)
  Downloading annotated_types-0.7.0-py3-none-any.whl.metadata (15 kB)
Collecting pydantic-core<3.0.0,>=2.12.0 (from prefect->pycwb)
  Downloading pydantic_core-2.33.2-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (6.8 kB)
Collecting typing-inspection>=0.4.0 (from pydantic!=2.10.0,<3.0.0,>=2.9->prefect->pycwb)
  Downloading typing_inspection-0.4.0-py3-none-any.whl.metadata (2.6 kB)
Collecting python-dotenv>=0.21.0 (from pydantic-settings!=2.9.0,<3.0.0,>2.2.1->prefect->pycwb)
  Downloading python_dotenv-1.1.0-py3-none-any.whl.metadata (24 kB)
Collecting text-unidecode>=1.3 (from python-slugify<9.0,>=5.0->prefect->pycwb)
  Downloading text_unidecode-1.3-py2.py3-none-any.whl.metadata (2.4 kB)
Requirement already satisfied: charset_normalizer<4,>=2 in /usr/local/lib/python3.11/site-packages (from requests>=2.20.
Collecting markdown-it-py>=2.2.0 (from rich<15.0,>=11.0->prefect->pycwb)
  Downloading markdown_it_py-3.0.0-py3-none-any.whl.metadata (6.9 kB)
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in /usr/local/lib/python3.11/site-packages (from rich<15.0,>=11.0
Requirement already satisfied: ruamel.yaml.clib>=0.2.7 in /usr/local/lib/python3.11/site-packages (from ruamel-yaml>=0.1
Collecting greenlet>=1 (from sqlalchemy<3.0.0,>=2.0->sqlalchemy[asyncio]<3.0.0,>=2.0->prefect->pycwb)
  Downloading greenlet-3.2.1-cp311-cp311-manylinux_2_24_x86_64.manylinux_2_28_x86_64.whl.metadata (4.1 kB)
Collecting shellingham>=1.3.0 (from typer!=0.12.2,<0.16.0,>=0.12.0->prefect->pycwb)
  Downloading shellingham-1.5.4-py2.py3-none-any.whl.metadata (3.5 kB)
Requirement already satisfied: pycparser in /usr/local/lib/python3.11/site-packages (from cffi>=1.12->cryptography>=36.0
```

```
Collecting wrapt<2,>=1.10 (from deprecated>=1.2.6->opentelemetry-api<2.0.0,>=1.27.0->prefect->pycwb)
  Downloading wrapt-1.17.2-cp311-cp311-manylinux_2_5_x86_64.manylinux1_x86_64.manylinux_2_17_x86_64.manylinux2014_x86_64
Requirement already satisfied: hyperframe<7,>=6.0 in /usr/local/lib/python3.11/site-packages (from h2<5,>=3->httpx[http2
Requirement already satisfied: hpack<5,>=4.0 in /usr/local/lib/python3.11/site-packages (from h2<5,>=3->httpx[http2]!=0.
Collecting safe-netrc>=1.0 (from igwn-auth-utils>=0.3.1->gwdatafind>=1.1.0->gwpy->pycwb)
  Downloading safe_netrc-1.0.1-py3-none-any.whl.metadata (1.9 kB)
Collecting scitokens>=1.8 (from igwn-auth-utils>=0.3.1->gwdatafind>=1.1.0->gwpy->pycwb)
  Downloading scitokens-1.8.1-py3-none-any.whl.metadata (12 kB)
Collecting mdurl~=0.1 (from markdown-it-py>=2.2.0->rich<15.0,>=11.0->prefect->pycwb)
  Downloading mdurl-0.1.2-py3-none-any.whl.metadata (1.6 kB)
Collecting oauthlib>=3.0.0 (from requests-oauthlib->apprise<2.0.0,>=1.1.0->prefect->pycwb)
  Downloading oauthlib-3.2.2-py3-none-any.whl.metadata (7.5 kB)
Collecting PyJWT>=1.6.1 (from scitokens>=1.8->igwn-auth-utils>=0.3.1->gwdatafind>=1.1.0->gwpy->pycwb)
  Downloading PyJWT-2.10.1-py3-none-any.whl.metadata (4.0 kB)
Downloading lalsuite-7.25.1-cp311-cp311-manylinux_2_28_x86_64.whl (40.4 MB)
                           ———————————— 40.4/40.4 MB 82.3 MB/s eta 0:00:00
Downloading pillow-11.2.1-cp311-cp311-manylinux_2_28_x86_64.whl (4.6 MB)
                           ———————————— 4.6/4.6 MB 106.8 MB/s eta 0:00:00
Downloading aiohttp-3.11.18-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (1.7 MB)
                           ———————————— 1.7/1.7 MB 75.8 MB/s eta 0:00:00
Downloading astropy-7.0.1-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (10.3 MB)
                           ———————————— 10.3/10.3 MB 148.4 MB/s eta 0:00:00
Downloading click-8.1.8-py3-none-any.whl (98 kB)
Downloading dacite-1.9.2-py3-none-any.whl (16 kB)
Downloading dask-2025.4.1-py3-none-any.whl (1.5 MB)
                           ———————————— 1.5/1.5 MB 60.3 MB/s eta 0:00:00
Downloading dask_jobqueue-0.9.0-py2.py3-none-any.whl (52 kB)
Downloading filelock-3.18.0-py3-none-any.whl (16 kB)
Downloading gwpy-3.0.12-py3-none-any.whl (1.4 MB)
                           ———————————— 1.4/1.4 MB 67.1 MB/s eta 0:00:00
Downloading matplotlib-3.10.1-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (8.6 MB)
                           ———————————— 8.6/8.6 MB 132.7 MB/s eta 0:00:00
Downloading scipy-1.15.2-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (37.6 MB)
                           ———————————— 37.6/37.6 MB 72.7 MB/s eta 0:00:00
Downloading htcondor-24.7.3-cp311-cp311-manylinux_2_28_x86_64.whl (62.0 MB)
                           ———————————— 62.0/62.0 MB 53.3 MB/s eta 0:00:00
Downloading numba-0.61.2-cp311-cp311-manylinux2014_x86_64.manylinux_2_17_x86_64.whl (3.8 MB)
                           ———————————— 3.8/3.8 MB 130.4 MB/s eta 0:00:00
Downloading orjson-3.10.18-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (132 kB)
Downloading prefect-3.4.0-py3-none-any.whl (6.0 MB)
                           ———————————— 6.0/6.0 MB 134.9 MB/s eta 0:00:00
Downloading prefect_dask-0.3.5-py3-none-any.whl (14 kB)
Downloading pycbc-2.8.2-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (9.0 MB)
                           ———————————— 9.0/9.0 MB 144.1 MB/s eta 0:00:00
Downloading watchfiles-1.0.5-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (454 kB)
Downloading aiohappyeyeballs-2.6.1-py3-none-any.whl (15 kB)
Downloading aiosignal-1.3.2-py2.py3-none-any.whl (7.6 kB)
Downloading aiosqlite-0.21.0-py3-none-any.whl (15 kB)
Downloading alembic-1.15.2-py3-none-any.whl (231 kB)
Downloading apprise-1.9.3-py3-none-any.whl (1.4 MB)
                           ———————————— 1.4/1.4 MB 66.0 MB/s eta 0:00:00
Downloading asgi_lifespan-2.1.0-py3-none-any.whl (10 kB)
Downloading astropy_iers_data-0.2025.5.5.0.38.14-py3-none-any.whl (2.0 MB)
                           ———————————— 2.0/2.0 MB 74.2 MB/s eta 0:00:00
Downloading asyncpg-0.30.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (3.1 MB)
                           ———————————— 3.1/3.1 MB 108.1 MB/s eta 0:00:00
Downloading cachetools-5.5.2-py3-none-any.whl (10 kB)
Downloading cloudpickle-3.1.1-py3-none-any.whl (20 kB)
Downloading contourpy-1.3.2-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (326 kB)
Downloading coolname-2.2.0-py2.py3-none-any.whl (37 kB)
Downloading cycler-0.12.1-py3-none-any.whl (8.3 kB)
Downloading Cython-3.0.12-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (3.6 MB)
                           ———————————— 3.6/3.6 MB 34.4 MB/s eta 0:00:00
Downloading dateparser-1.2.1-py3-none-any.whl (295 kB)
Downloading distributed-2025.4.1-py3-none-any.whl (1.0 MB)
                           ———————————— 1.0/1.0 MB 51.2 MB/s eta 0:00:00
Downloading docker-7.1.0-py3-none-any.whl (147 kB)
Downloading fastapi-0.115.12-py3-none-any.whl (95 kB)
Downloading fonttools-4.57.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (4.9 MB)
                           ———————————— 4.9/4.9 MB 128.4 MB/s eta 0:00:00
Downloading frozenlist-1.6.0-cp311-cp311-manylinux_2_5_x86_64.manylinux1_x86_64.manylinux_2_17_x86_64.manylinux2014_x86_
Downloading fsspec-2025.3.2-py3-none-any.whl (194 kB)
Downloading graphviz-0.20.3-py3-none-any.whl (47 kB)
Downloading griffe-1.7.3-py3-none-any.whl (129 kB)
Downloading gwdatafind-2.0.0-py3-none-any.whl (39 kB)
Downloading gwosc-0.8.0-py3-none-any.whl (32 kB)
Downloading h5py-3.13.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (4.5 MB)
                           ———————————— 4.5/4.5 MB 123.5 MB/s eta 0:00:00
Downloading humanize-4.12.3-py3-none-any.whl (128 kB)
Downloading igwn_segments-2.1.0-cp311-cp311-manylinux_2_5_x86_64.manylinux1_x86_64.manylinux_2_28_x86_64.whl (128 kB)
Downloading jinja2_humanize_extension-0.4.0-py3-none-any.whl (4.8 kB)
Downloading kiwisolver-1.4.8-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (1.4 MB)
                           ———————————— 1.4/1.4 MB 59.9 MB/s eta 0:00:00
Downloading ligotimegps-2.0.1-py2.py3-none-any.whl (19 kB)
Downloading llvmlite-0.44.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (42.4 MB)
                           ———————————— 42.4/42.4 MB 77.0 MB/s eta 0:00:00
Downloading lscsoft_glue-4.1.0-py3-none-any.whl (50 kB)
Downloading mako-1.3.10-py3-none-any.whl (78 kB)
Downloading mpld3-0.5.10-py3-none-any.whl (202 kB)
Downloading multidict-6.4.3-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (223 kB)
Downloading opentelemetry_api-1.32.1-py3-none-any.whl (65 kB)
```

```
Downloading partd-1.4.2-py3-none-any.whl (18 kB)
Downloading pathspec-0.12.1-py3-none-any.whl (31 kB)
Downloading pendulum-3.1.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (353 kB)
Downloading propcache-0.3.1-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (232 kB)
Downloading pydantic-2.11.4-py3-none-any.whl (443 kB)
Downloading pydantic_core-2.33.2-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (2.0 MB)
                         ━━━━━━━━━━━━━━━━━ 2.0/2.0 MB 81.7 MB/s eta 0:00:00
Downloading pydantic_extra_types-2.10.4-py3-none-any.whl (37 kB)
Downloading pydantic_settings-2.9.1-py3-none-any.whl (44 kB)
Downloading pyerfa-2.0.1.5-cp39-abi3-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (738 kB)
                         ━━━━━━━━━━━━━━━━━ 738.7/738.7 kB 32.2 MB/s eta 0:00:00
Downloading pyparsing-3.2.3-py3-none-any.whl (111 kB)
Downloading python_slugify-8.0.4-py2.py3-none-any.whl (10 kB)
Downloading python_socks-2.7.1-py3-none-any.whl (54 kB)
Downloading readchar-4.2.1-py3-none-any.whl (9.3 kB)
Downloading rich-14.0.0-py3-none-any.whl (243 kB)
Downloading sqlalchemy-2.0.40-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (3.2 MB)
                         ━━━━━━━━━━━━━━━━━ 3.2/3.2 MB 107.5 MB/s eta 0:00:00
Downloading toml-0.10.2-py2.py3-none-any.whl (16 kB)
Downloading typer-0.15.3-py3-none-any.whl (45 kB)
Downloading ujson-5.10.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (53 kB)
Downloading uv-0.7.3-py3-none-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (17.4 MB)
                         ━━━━━━━━━━━━━━━━━ 17.4/17.4 MB 158.1 MB/s eta 0:00:00
Downloading uvicorn-0.34.2-py3-none-any.whl (62 kB)
Downloading websockets-15.0.1-cp311-cp311-manylinux_2_5_x86_64.manylinux1_x86_64.manylinux_2_17_x86_64.manylinux2014_x86
Downloading yarl-1.20.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (358 kB)
Downloading dqsegdb2-1.3.0-py3-none-any.whl (27 kB)
Downloading pykerr-0.1.0-py3-none-any.whl (48.1 MB)
                         ━━━━━━━━━━━━━━━━━ 48.1/48.1 MB 63.6 MB/s eta 0:00:00
Downloading annotated_types-0.7.0-py3-none-any.whl (13 kB)
Downloading Deprecated-1.2.18-py2.py3-none-any.whl (10.0 kB)
Downloading greenlet-3.2.1-cp311-cp311-manylinux_2_24_x86_64.manylinux_2_28_x86_64.whl (583 kB)
                         ━━━━━━━━━━━━━━━━━ 583.9/583.9 kB 21.4 MB/s eta 0:00:00
Downloading igwn_auth_utils-1.3.1-py3-none-any.whl (34 kB)
Downloading locket-1.0.0-py2.py3-none-any.whl (4.4 kB)
Downloading markdown_it_py-3.0.0-py3-none-any.whl (87 kB)
Downloading msgpack-1.1.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (403 kB)
Downloading python_dotenv-1.1.0-py3-none-any.whl (20 kB)
Downloading regex-2024.11.6-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (792 kB)
                         ━━━━━━━━━━━━━━━━━ 792.7/792.7 kB 33.5 MB/s eta 0:00:00
Downloading shellingham-1.5.4-py2.py3-none-any.whl (9.8 kB)
Downloading sortedcontainers-2.4.0-py2.py3-none-any.whl (29 kB)
Downloading starlette-0.46.2-py3-none-any.whl (72 kB)
Downloading tblib-3.1.0-py3-none-any.whl (12 kB)
Downloading text_unidecode-1.3-py2.py3-none-any.whl (78 kB)
Downloading typing_inspection-0.4.0-py3-none-any.whl (14 kB)
Downloading tzdata-2025.2-py2.py3-none-any.whl (347 kB)
Downloading tzlocal-5.3.1-py3-none-any.whl (18 kB)
Downloading zict-3.0.0-py2.py3-none-any.whl (43 kB)
Downloading markdown-3.8-py3-none-any.whl (106 kB)
Downloading requests_oauthlib-2.0.0-py2.py3-none-any.whl (24 kB)
Downloading mdurl-0.1.2-py3-none-any.whl (10.0 kB)
Downloading oauthlib-3.2.2-py3-none-any.whl (151 kB)
Downloading safe_netrc-1.0.1-py3-none-any.whl (10 kB)
Downloading scitokens-1.8.1-py3-none-any.whl (31 kB)
Downloading wrapt-1.17.2-cp311-cp311-manylinux_2_5_x86_64.manylinux1_x86_64.manylinux_2_17_x86_64.manylinux2014_x86_64.w
Downloading PyJWT-2.10.1-py3-none-any.whl (22 kB)
Building wheels for collected packages: pycwb, ligo-segments, pegasus-wms.api, python-ligo-lw, pegasus-wms.common
  Building wheel for pycwb (pyproject.toml) ... done
  Created wheel for pycwb: filename=pycwb-0.28.0-cp311-cp311-linux_x86_64.whl size=5231391 sha256=a7093d57906e921d5d4c0f
  Stored in directory: /root/.cache/pip/wheels/ca/7a/f4/8ae7d6ed0809707c997723db714f80fa1bf26804c0d22e4633
  Building wheel for ligo-segments (setup.py) ... done
  Created wheel for ligo-segments: filename=ligo_segments-1.4.0-cp311-cp311-linux_x86_64.whl size=51012 sha256=282f04022
  Stored in directory: /root/.cache/pip/wheels/02/2b/93/c2ee2b6f4ea9572ee4f5ade0115c4bd0887be6228328740dae
  Building wheel for pegasus-wms.api (pyproject.toml) ... done
  Created wheel for pegasus-wms.api: filename=pegasus_wms.api-5.0.9-py3-none-any.whl size=50501 sha256=b6e24b07374d652ad
  Stored in directory: /root/.cache/pip/wheels/0a/bd/57/326d054073a07633fd57cf57b2bafe2da52e807dda321d3762
  Building wheel for python-ligo-lw (setup.py) ... done
  Created wheel for python-ligo-lw: filename=python_ligo_lw-1.8.3-cp311-cp311-linux_x86_64.whl size=132756 sha256=b6a075
  Stored in directory: /root/.cache/pip/wheels/dc/3a/a1/2400e079ce9e36a572fa67ccd3645e87b9abba772b6a7dfe98
  Building wheel for pegasus-wms.common (pyproject.toml) ... done
  Created wheel for pegasus-wms.common: filename=pegasus_wms.common-5.0.9-py3-none-any.whl size=50839 sha256=bbabf5d0b62
  Stored in directory: /root/.cache/pip/wheels/a8/2d/ae/5e5b9e2ff0179596560483395ada98c369fa972a8dd6892a85
Successfully built pycwb ligo-segments pegasus-wms.api python-ligo-lw pegasus-wms.common
Installing collected packages: text-unidecode, sortedcontainers, htcondor, coolname, zict, wrapt, websockets, uv, ujson,
Successfully installed Mako-1.3.10 PyJWT-2.10.1 aiohappyeyeballs-2.6.1 aiohttp-3.11.18 aiosignal-1.3.2 aiosqlite-0.21.0
WARNING: The following packages were previously imported in this runtime:
  [PIL,cycler,kiwisolver]
You must restart the runtime in order to use newly installed versions.
```

[RESTART SESSION]

```
# 使用 pip3 安装指定版本的 packaging（版本为 24.2）
# packaging 是 Python 中用于处理版本号、依赖关系等的标准库，常被许多工具依赖
!pip3 install "packaging==24.2"
```

⇄ Requirement already satisfied: packaging==24.2 in /usr/local/lib/python3.11/site-packages (24.2)

```
# 安静模式安装 healpy、tensorflow 和 basemap 这三个 Python 库
# – healpy: 用于处理 HEALPix 格式的天文球面数据（Python 接口）
# – tensorflow: Google 提供的机器学习/深度学习框架
# – basemap: matplotlib 的地图绘图库插件，常用于地理/球面数据可视化
!pip3 install -q healpy tensorflow basemap
```

⇄ ──────────────────────────────── 8.9/8.9 MB 89.4 MB/s eta 0:00:00
   ──────────────────────────────── 644.9/644.9 MB 31.8 MB/s eta 0:00:00
   ──────────────────────────────── 942.4/942.4 kB 38.7 MB/s eta 0:00:00
   ──────────────────────────────── 30.5/30.5 MB 142.8 MB/s eta 0:00:00
   ──────────────────────────────── 5.9/5.9 MB 107.9 MB/s eta 0:00:00
   ──────────────────────────────── 1.3/1.3 MB 62.6 MB/s eta 0:00:00
   ──────────────────────────────── 24.5/24.5 MB 163.2 MB/s eta 0:00:00
   ──────────────────────────────── 11.6/11.6 MB 150.8 MB/s eta 0:00:00
   ──────────────────────────────── 4.7/4.7 MB 118.6 MB/s eta 0:00:00
   ──────────────────────────────── 8.6/8.6 MB 140.5 MB/s eta 0:00:00
   ──────────────────────────────── 5.5/5.5 MB 130.6 MB/s eta 0:00:00
   ──────────────────────────────── 5.1/5.1 MB 121.5 MB/s eta 0:00:00
   ──────────────────────────────── 6.6/6.6 MB 13.7 MB/s eta 0:00:00
   ERROR: pip's dependency resolver does not currently take into account all the packages that are installed. This behaviou
   gwpy 3.0.12 requires packaging>=24.1, but you have packaging 23.2 which is incompatible.

```
# 使用 pip3 安装 ligo.gracedb 库，用于与 LIGO（激光干涉引力波天文台）的 GraceDB 系统进行交互
# GraceDB 是 LIGO 数据库，用于存储和管理引力波事件及其元数据
!pip3 install ligo.gracedb
```

⇄ Collecting ligo.gracedb
   Downloading ligo_gracedb-2.14.2-py3-none-any.whl.metadata (3.0 kB)
   Requirement already satisfied: cryptography>=1.7.2 in /usr/local/lib/python3.11/site-packages (from ligo.gracedb) (44.0.
   Requirement already satisfied: requests>=2.6.0 in /usr/local/lib/python3.11/site-packages (from ligo.gracedb) (2.32.3)
   Requirement already satisfied: igwn-auth-utils>=1.0.0 in /usr/local/lib/python3.11/site-packages (from ligo.gracedb) (1.
   Requirement already satisfied: cffi>=1.12 in /usr/local/lib/python3.11/site-packages (from cryptography>=1.7.2->ligo.gra
   Requirement already satisfied: safe-netrc>=1.0 in /usr/local/lib/python3.11/site-packages (from igwn-auth-utils>=1.0.0->
   Requirement already satisfied: scitokens>=1.8 in /usr/local/lib/python3.11/site-packages (from igwn-auth-utils>=1.0.0->l
   Requirement already satisfied: charset_normalizer<4,>=2 in /usr/local/lib/python3.11/site-packages (from requests>=2.6.0
   Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.11/site-packages (from requests>=2.6.0->ligo.grace
   Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.11/site-packages (from requests>=2.6.0->ligo
   Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.11/site-packages (from requests>=2.6.0->ligo
   Requirement already satisfied: pycparser in /usr/local/lib/python3.11/site-packages (from cffi>=1.12->cryptography>=1.7.
   Requirement already satisfied: PyJWT>=1.6.1 in /usr/local/lib/python3.11/site-packages (from scitokens>=1.8->igwn-auth-u
   Downloading ligo_gracedb-2.14.2-py3-none-any.whl (2.5 MB)
   ──────────────────────────────── 2.5/2.5 MB 40.6 MB/s eta 0:00:00
   Installing collected packages: ligo.gracedb
   Successfully installed ligo.gracedb-2.14.2

```
# 使用 pip3 安装指定版本的 matplotlib（版本为 3.10）
# matplotlib 是一个广泛使用的 Python 数据可视化库，主要用于创建静态、动态和交互式图表
!pip3 install "matplotlib==3.10"
```

⇄ Collecting matplotlib==3.10
   Downloading matplotlib-3.10.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (11 kB)
   Requirement already satisfied: contourpy>=1.0.1 in /usr/local/lib/python3.11/site-packages (from matplotlib==3.10) (1.3.
   Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.11/site-packages (from matplotlib==3.10) (0.12.1)
   Requirement already satisfied: fonttools>=4.22.0 in /usr/local/lib/python3.11/site-packages (from matplotlib==3.10) (4.5
   Requirement already satisfied: kiwisolver>=1.3.1 in /usr/local/lib/python3.11/site-packages (from matplotlib==3.10) (1.4
   Requirement already satisfied: numpy>=1.23 in /usr/local/lib/python3.11/site-packages (from matplotlib==3.10) (1.26.4)
   Requirement already satisfied: packaging>=20.0 in /usr/local/lib/python3.11/site-packages (from matplotlib==3.10) (23.2)
   Requirement already satisfied: pillow>=8 in /usr/local/lib/python3.11/site-packages (from matplotlib==3.10) (11.2.1)
   Requirement already satisfied: pyparsing>=2.3.1 in /usr/local/lib/python3.11/site-packages (from matplotlib==3.10) (3.2.
   Requirement already satisfied: python-dateutil>=2.7 in /usr/local/lib/python3.11/site-packages (from matplotlib==3.10) (
   Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.11/site-packages (from python-dateutil>=2.7->matplotli
   Downloading matplotlib-3.10.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (8.6 MB)
   ──────────────────────────────── 8.6/8.6 MB 78.2 MB/s eta 0:00:00
   Installing collected packages: matplotlib
   Attempting uninstall: matplotlib
     Found existing installation: matplotlib 3.8.4
     Uninstalling matplotlib-3.8.4:
       Successfully uninstalled matplotlib-3.8.4
   ERROR: pip's dependency resolver does not currently take into account all the packages that are installed. This behaviou
   basemap 1.4.1 requires matplotlib<3.9,>=1.5; python_version >= "3.5", but you have matplotlib 3.10.0 which is incompatib
   gwpy 3.0.12 requires packaging>=24.1, but you have packaging 23.2 which is incompatible.
   Successfully installed matplotlib-3.10.0

```
# 使用 pip 安装 gwpy 库，这是一个专为引力波数据分析设计的 Python 库
# gwpy 提供了处理和可视化 LIGO 和 Virgo 引力波探测数据的工具
!pip install gwpy
```

⇶ Requirement already satisfied: gwpy in /usr/local/lib/python3.11/site-packages (3.0.12)
Requirement already satisfied: astropy>=4.3.0 in /usr/local/lib/python3.11/site-packages (from gwpy) (7.0.1)
Requirement already satisfied: dateparser>=1.1.4 in /usr/local/lib/python3.11/site-packages (from gwpy) (1.2.1)
Requirement already satisfied: dqsegdb2 in /usr/local/lib/python3.11/site-packages (from gwpy) (1.3.0)
Requirement already satisfied: gwdatafind>=1.1.0 in /usr/local/lib/python3.11/site-packages (from gwpy) (2.0.0)
Requirement already satisfied: gwosc>=0.5.3 in /usr/local/lib/python3.11/site-packages (from gwpy) (0.8.0)
Requirement already satisfied: h5py>=3.0.0 in /usr/local/lib/python3.11/site-packages (from gwpy) (3.13.0)
Requirement already satisfied: igwn-segments>=2.0.0 in /usr/local/lib/python3.11/site-packages (from gwpy) (2.1.0)
Requirement already satisfied: ligotimegps>=1.2.1 in /usr/local/lib/python3.11/site-packages (from gwpy) (2.0.1)
Requirement already satisfied: matplotlib>=3.3.0 in /usr/local/lib/python3.11/site-packages (from gwpy) (3.10.0)
Requirement already satisfied: numpy>=1.19.5 in /usr/local/lib/python3.11/site-packages (from gwpy) (1.26.4)
Collecting packaging>=24.1 (from gwpy)
  Using cached packaging-25.0-py3-none-any.whl.metadata (3.3 kB)
Requirement already satisfied: python-dateutil in /usr/local/lib/python3.11/site-packages (from gwpy) (2.9.0.post0)
Requirement already satisfied: requests>=2.20.0 in /usr/local/lib/python3.11/site-packages (from gwpy) (2.32.3)
Requirement already satisfied: scipy>=1.6.0 in /usr/local/lib/python3.11/site-packages (from gwpy) (1.15.2)
Requirement already satisfied: tqdm>=4.52.0 in /usr/local/lib/python3.11/site-packages (from gwpy) (4.67.1)
Requirement already satisfied: pyerfa>=2.0.1.1 in /usr/local/lib/python3.11/site-packages (from astropy>=4.3.0->gwpy) (2
Requirement already satisfied: astropy-iers-data>=0.2025.1.31.12.41.4 in /usr/local/lib/python3.11/site-packages (from a
Requirement already satisfied: PyYAML>=6.0.0 in /usr/local/lib/python3.11/site-packages (from astropy>=4.3.0->gwpy) (6.0
Requirement already satisfied: pytz>=2024.2 in /usr/local/lib/python3.11/site-packages (from dateparser>=1.1.4->gwpy) (2
Requirement already satisfied: regex!=2019.02.19,!=2021.8.27,>=2015.06.24 in /usr/local/lib/python3.11/site-packages (fr
Requirement already satisfied: tzlocal>=0.2 in /usr/local/lib/python3.11/site-packages (from dateparser>=1.1.4->gwpy) (5
Requirement already satisfied: igwn-auth-utils>=0.3.1 in /usr/local/lib/python3.11/site-packages (from gwdatafind>=1.1.0
Requirement already satisfied: contourpy>=1.0.1 in /usr/local/lib/python3.11/site-packages (from matplotlib>=3.3.0->gwpy
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.11/site-packages (from matplotlib>=3.3.0->gwpy) (0
Requirement already satisfied: fonttools>=4.22.0 in /usr/local/lib/python3.11/site-packages (from matplotlib>=3.3.0->gwp
Requirement already satisfied: kiwisolver>=1.3.1 in /usr/local/lib/python3.11/site-packages (from matplotlib>=3.3.0->gwp
Requirement already satisfied: pillow>=8 in /usr/local/lib/python3.11/site-packages (from matplotlib>=3.3.0->gwpy) (11.2
Requirement already satisfied: pyparsing>=2.3.1 in /usr/local/lib/python3.11/site-packages (from matplotlib>=3.3.0->gwpy
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.11/site-packages (from python-dateutil->gwpy) (1.17.0)
Requirement already satisfied: charset_normalizer<4,>=2 in /usr/local/lib/python3.11/site-packages (from requests>=2.20.
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.11/site-packages (from requests>=2.20.0->gwpy) (3.
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.11/site-packages (from requests>=2.20.0->gwp
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.11/site-packages (from requests>=2.20.0->gwp
Requirement already satisfied: click>=6.7 in /usr/local/lib/python3.11/site-packages (from dqsegdb2->gwpy) (8.1.8)
Requirement already satisfied: cryptography>=44.0.1 in /usr/local/lib/python3.11/site-packages (from igwn-auth-utils>=0.
Requirement already satisfied: safe-netrc>=1.0 in /usr/local/lib/python3.11/site-packages (from igwn-auth-utils>=0.3.1->
Requirement already satisfied: scitokens>=1.8 in /usr/local/lib/python3.11/site-packages (from igwn-auth-utils>=0.3.1->g
Requirement already satisfied: cffi>=1.12 in /usr/local/lib/python3.11/site-packages (from cryptography>=44.0.1->igwn-au
Requirement already satisfied: PyJWT>=1.6.1 in /usr/local/lib/python3.11/site-packages (from scitokens>=1.8->igwn-auth-u
Requirement already satisfied: pycparser in /usr/local/lib/python3.11/site-packages (from cffi>=1.12->cryptography>=44.0
Using cached packaging-25.0-py3-none-any.whl (66 kB)
Installing collected packages: packaging
  Attempting uninstall: packaging
    Found existing installation: packaging 23.2
    Uninstalling packaging-23.2:
      Successfully uninstalled packaging-23.2
ERROR: pip's dependency resolver does not currently take into account all the packages that are installed. This behaviou
basemap 1.4.1 requires matplotlib<3.9,>=1.5; python_version >= "3.5", but you have matplotlib 3.10.0 which is incompatib
basemap 1.4.1 requires packaging<24.0,>=16.0; python_version >= "3.5", but you have packaging 25.0 which is incompatible
Successfully installed packaging-25.0

```python
# 从 google.colab 导入 drive 模块，并挂载 Google Drive
# 这使得 Colab 能够访问用户的 Google Drive 文件夹，在 /content/drive 路径下进行读写
from google.colab import drive
drive.mount('/content/drive')
```

⇶ Mounted at /content/drive

```python
# 设置 Google Drive 中文件的路径，将路径指定为变量 `drive_path`
# 这个路径指向的是 Google Drive 中的 "MyDrive/Colab Notebooks/时频分析与波形重构/data/user_parameters.yaml" 文件
drive_path = "/content/drive/MyDrive/Colab Notebooks/时频分析与波形重构/data/user_parameters.yaml"
```

```python
# 将多行字符串 `user_parameters` 写入指定的文件路径 `drive_path`
# 该字符串包含了用于时频分析和波形重构的配置参数

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
"""

# 打开并写入文件，将配置内容写入指定路径的 YAML 文件
with open(drive_path, 'w') as fp:
    fp.write(user_parameters)


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

# 检查环境变量 'HOME_WAT_FILTERS' 是否已设置，如果没有设置，则设置为 pycwb 库的 vendor 文件夹路径
if not os.environ.get('HOME_WAT_FILTERS'):
    # 获取 pycwb 库的安装路径
    pyburst_path = os.path.dirname(os.path.abspath(pycwb.__file__))
    # 设置环境变量 HOME_WAT_FILTERS, 指向 pycwb 的 vendor 目录
    os.environ['HOME_WAT_FILTERS'] = f"{os.path.abspath(pyburst_path)}/vendor"

# 初始化日志记录器，通常用于记录应用的运行日志
logger_init()

# 使用 drive_path 创建配置对象
config = Config(drive_path)
```

```
Welcome to JupyROOT 6.26/10
Loading wavelet library
Trying to load wavelet library from /usr/local/lib/python3.11/site-packages/lib/wavelet.so
/usr/local/lib/python3.11/site-packages/ROOT/_facade.py:153: UserWarning: Wswiglal-redir-stdio:

SWIGLAL standard output/error redirection is enabled in IPython.
This may lead to performance penalties. To disable locally, use:

with lal.no_swig_redirect_standard_output_error():
```

```
            ...

      To disable globally, use:

      lal.swig_redirect_standard_output_error(False)

      Note however that this will likely lead to error messages from
      LAL functions being either misdirected or lost when called from
      Jupyter notebooks.

      To suppress this warning, use:

      import warnings
      warnings.filterwarnings("ignore", "Wswiglal-redir-stdio")
      import lal

        return _orig_ihook(name, *args, **kwds)
      25-05-08 05:57:34 - logger_init - INFO - Logging initialized
      25-05-08 05:57:34 - logger_init - INFO - Logging level: INFO
      25-05-08 05:57:34 - logger_init - INFO - Logging file: None
      File OverlapCatalog16-1024.bin is available on https://github.com/PycWB/xtalk-data/raw/main.
      Downloading https://github.com/PycWB/xtalk-data/raw/main/OverlapCatalog16-1024.bin...
      File saved as /usr/local/lib/python3.11/site-packages/pycwb/vendor/wdmXTalk/OverlapCatalog16-1024.bin
      25-05-08 05:57:46 - check_MRA_catalog - INFO - Checking MRA catalog
      25-05-08 05:57:47 - load_MRA - INFO - Loading catalog of WDM cross-talk coefficients: /usr/local/lib/python3.11/site-pac
```

```python
import os
import requests
from gwosc.locate import get_urls
from gwpy.timeseries import TimeSeries


# GW190521_074359 的 GPS 触发时间
t0 = 1242442967.4
ifo_list = ["H1", "L1"]


data = []
for ifo in ifo_list:
    # 获取与触发时间 t0 相关的 URL 列表
    urls = get_urls(ifo, t0, t0)

    # 如果没有找到数据，跳过该干涉仪
    if not urls:
        print(f"No data found for {ifo} at t0 = {t0}")
        continue

    # 选择列表中的最后一个 URL（通常为最新数据）
    url = urls[-1]
    print('Downloading:', url)

    # 获取文件名并下载数据文件
    fn = os.path.basename(url)
    with open(fn, 'wb') as strainfile:
        strainfile.write(requests.get(url).content)

    # 使用 gwpy 的 TimeSeries 来读取并处理数据
    strain = TimeSeries.read(fn, format='hdf5.gwosc')

    # 将数据裁剪到 t0 前后 150 秒范围内
    d = strain.crop(t0 - 150, t0 + 150)

    # 重新采样数据到 2048 Hz
    d_resampled = d.resample(2048)

    # 将处理后的数据添加到列表中
    data.append(d_resampled)
```

```
Downloading: https://gwosc.org/eventapi/json/GWTC-2.1-confident/GW190521/v4/H-H1_GWOSC_4KHZ_R1-1242440920-4096.hdf5
Downloading: https://gwosc.org/eventapi/json/GWTC-2.1-confident/GW190521/v4/L-L1_GWOSC_4KHZ_R1-1242440920-4096.hdf5
```

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

# 对数据进行预处理（滤波、归一化等）
# 返回处理后的数据 strains 和噪声 RMS（均方根）值 nRMS
strains, nRMS = data_conditioning(config, data)

# 让 matplotlib 图表嵌入在 notebook 中显示
%matplotlib inline

# 绘制第一个干涉仪（如 L1）的频谱图
plt = plot_spectrogram(strains[0], gwpy_plot=True)

# 获取当前图的坐标轴，并设置频率显示范围为 15 Hz 到 1024 Hz
```
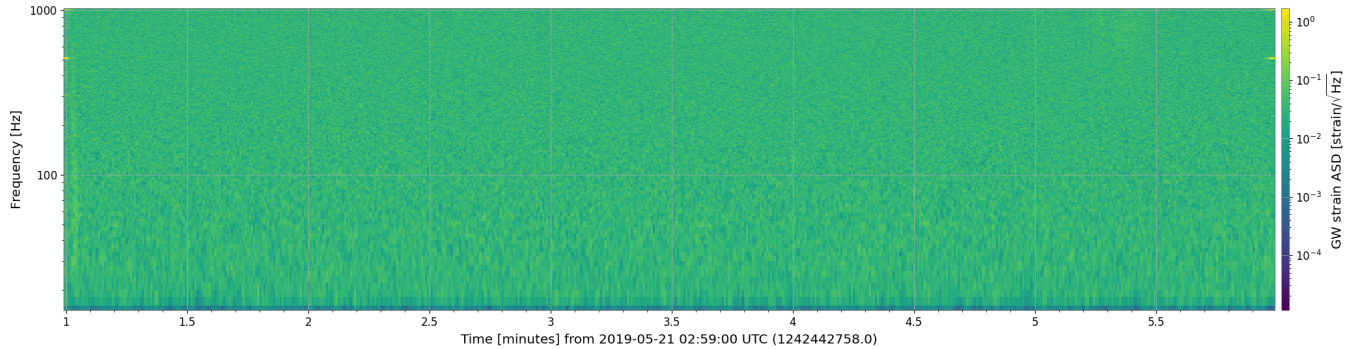
```
ax = plt.gca()
ax.set_ylim(15,1024)
```

```
# 输出处理后的数据 strains 和噪声指标 nRMS
strains, nRMS
```

```
25-05-08 05:58:24 - whitening - INFO - WDM filter max length = 6.00048828125 (sec)
25-05-08 05:58:24 - whitening - INFO - WDM filter max length = 6.00048828125 (sec)
25-05-08 05:58:25 - data_conditioning - INFO - ----------------------------------------------------
25-05-08 05:58:25 - data_conditioning - INFO - Data Conditioning Time: 4.45 seconds
25-05-08 05:58:25 - data_conditioning - INFO - ----------------------------------------------------
((<pycwb.types.time_frequency_series.TimeFrequencySeries at 0x7903b5888400>,
  <pycwb.types.time_frequency_series.TimeFrequencySeries at 0x7903b5888640>),
 (<pycwb.types.time_frequency_series.TimeFrequencySeries at 0x7903b5888580>,
  <pycwb.types.time_frequency_series.TimeFrequencySeries at 0x7903b5888a60>))
```



```
from pycwb.modules.coherence import coherence
```

```
# 计算各干涉仪之间的信号相干性，提取候选事件片段
fragment_clusters = coherence(config, strains, nRMS)
```

```
max energy in units of noise variance: 8.70647
thresholds in units of noise variance: Eo=8.83555 Emax=17.6711
live time in zero lag: 280
lag | clusters | pixels
  0 |     10 |    92
Coherence time for single level: 13.465187 slevel : 9    rate(hz) : 4    layers : 512    df(hz) : 2.000000        dt(ms)
max energy in units of noise variance: 8.7577
thresholds in units of noise variance: Eo=8.69875 Emax=17.3975
live time in zero lag: 280
lag | clusters | pixels
  0 |     14 |   153
Coherence time for single level: 13.373896 s

level : 8        rate(hz) : 8    layers : 256    df(hz) : 4.000000        dt(ms) : 125.000000
max energy in units of noise variance: 8.9794
thresholds in units of noise variance: Eo=8.71665 Emax=17.4333
live time in zero lag: 280
lag | clusters | pixels
  0 |     14 |   182
Coherence time for single level: 13.238476 s
level : 5        rate(hz) : 64    layers : 32    df(hz) : 32.000000        dt(ms) : 15.625000
max energy in units of noise variance: 12.6813
thresholds in units of noise variance: Eo=9.39361 Emax=18.7872
live time in zero lag: 280
lag | clusters | pixels
  0 |     17 |   197
Coherence time for single level: 9.145655 s
level : 6        rate(hz) : 32    layers : 64    df(hz) : 16.000000        dt(ms) : 31.250000
max energy in units of noise variance: 10.4908
thresholds in units of noise variance: Eo=8.86842 Emax=17.7368
live time in zero lag: 280
lag | clusters | pixels
  0 |     13 |   181
Coherence time for single level: 9.325707 s
level : 4        rate(hz) : 128    layers : 16    df(hz) : 64.000000        dt(ms) : 7.812500
max energy in units of noise variance: 16.3244
thresholds in units of noise variance: Eo=9.77316 Emax=19.5463
live time in zero lag: 280
```

```
  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
```

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

# 创建网络对象，表示多个干涉仪协同分析的网络
network = Network(config, strains, nRMS)

# 基于相干事件片段进行聚类，生成候选事件列表
pwc_list = supercluster(config, network, fragment_clusters, strains)
```

```
25-05-08 05:59:42 - set_time_shift - INFO - lag step: 1.0
25-05-08 05:59:42 - set_time_shift - INFO - number of time lags: 1
25-05-08 05:59:44 - sparse_table_from_fragment_clusters - INFO - ----------------------------------------
25-05-08 05:59:44 - sparse_table_from_fragment_clusters - INFO - Sparse series time: 1.70 s
25-05-08 05:59:44 - sparse_table_from_fragment_clusters - INFO - ----------------------------------------
25-05-08 05:59:46 - supercluster - INFO - -> Processing lag=0 ...
25-05-08 05:59:46 - supercluster - INFO -    ----------------------------------------
25-05-08 05:59:46 - supercluster - INFO -    coher clusters|pixels    :    101|1161
25-05-08 05:59:46 - supercluster - INFO -    super clusters|pixels    :     79|1161
25-05-08 05:59:46 - supercluster - INFO -    defrag clusters|pixels   :     74|1161
25-05-08 05:59:46 - supercluster - INFO -    subnet clusters|pixels   :      1|144
25-05-08 05:59:46 - supercluster - INFO - Supercluster done
25-05-08 05:59:46 - supercluster - INFO - total  clusters|pixels :       1|144
25-05-08 05:59:47 - supercluster - INFO - ----------------------------------------
25-05-08 05:59:47 - supercluster - INFO - Supercluster time: 4.67 s
25-05-08 05:59:47 - supercluster - INFO - ----------------------------------------
lag       ifoL1        ifoH1
  0      0.00000      0.00000
```

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

# 遍历第一个候选事件中的所有子簇
for cluster in pwc_list[0].clusters:
    # 获取该簇的稀疏似然图及其时间/频率分辨率信息
    merged_map, start, dt, df = cluster.get_sparse_map("likelihood")

    # 绘制似然图（Spectrogram）
    plt = Spectrogram(merged_map, t0=start, dt=dt, f0=0, df=df).plot()
    plt.colorbar()   # 添加颜色条以显示强度
```
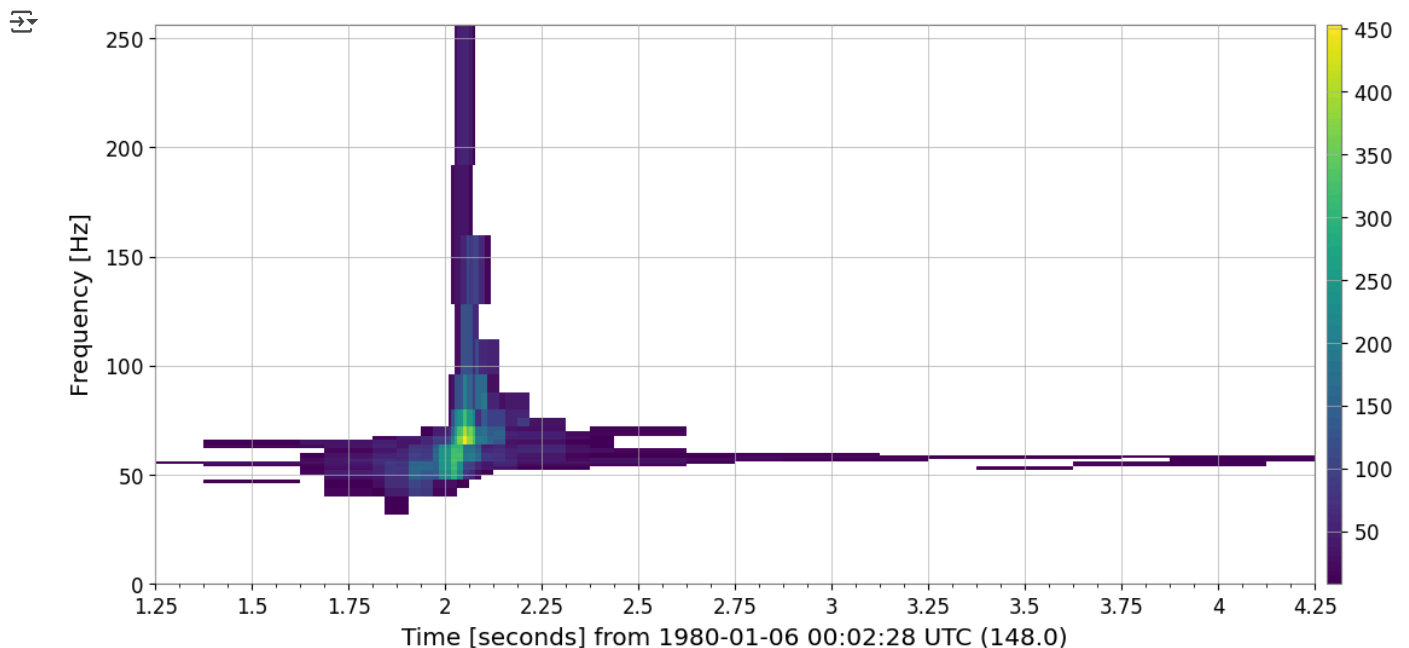


```python
from pycwb.modules.likelihood import likelihood
```
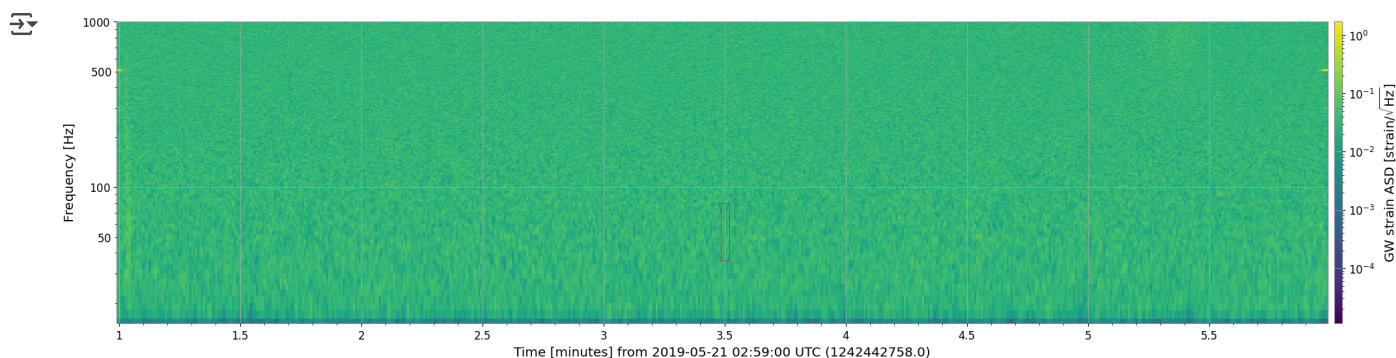
```
25-05-08 06:00:26 - likelihood - WARNING - The support of list type is only for backward compatibility. It will be depre
25-05-08 06:00:26 - likelihood - INFO - --------------------------------------------------------
25-05-08 06:00:26 - likelihood - INFO - -> Processing 1 clusters in lag=0
25-05-08 06:00:26 - likelihood - INFO -    --------------------------------------------------------
Selected core pixels: 1
    cluster-id|pixels:      1|144
          -> SELECTED !!!
------------------------------------------------------
Total events: 1
Total time: 4.05 s
------------------------------------------------------
mchirp_2g : 1 1 2.62e+01 2.033 150.101 0.000 0.809
```

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

```python
# 在频谱图上标出检测到的事件位置（如时间、频率范围）
plt = plot_event_on_spectrogram(strains[0], events)
plt.show()
```



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

```python
# 遍历似然分析后得到的所有信号簇
for cluster in clusters:
    # 提取每个簇的稀疏似然图及其时间和频率信息
    merged_map, start, dt, df = cluster.get_sparse_map("likelihood")

    # 绘制似然图（用于显示信号强度在时频空间的分布）
    plt = Spectrogram(merged_map, t0=start, dt=dt, f0=0, df=df).plot()
    plt.colorbar()  # 添加颜色条，表示信号强度
```