Analysing Gravitational Wave Observation

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LIGO

Figure: LIGO Livingston Observatory

Objectives

- Detect cosmic gravitational waves
- Make them an observation tool

Achievement

- Detected multiple binary black hole mergers
- Detected binary neutron star

Why are we doing this project

- Pilot project to learn about scientific software
- Well documented HPC project
- Intro to statistical analysis
- Opportunity to document and suggest improvements

Jupyter Notebook

Definition

The Jupyter Notebook is an open-source web application that allows you to create and share documents that contain live code, equations, visualizations and narrative text.

Usage

Data cleaning and transformation, numerical simulation, statistical modeling, data visualization, machine learning, and much more.

Jupyter Notebook

Anaconda

Regardless of OS types, Anaconda supports Jupyter notebook including python and scientific packages such as numpy, Scipy and pandas.
This way is highly recommended.

pip

User can install Jupyter by just pip like below
python3 -m pip install –upgrade pip
python3 -m pip install jupyter

Jupyter Notebook

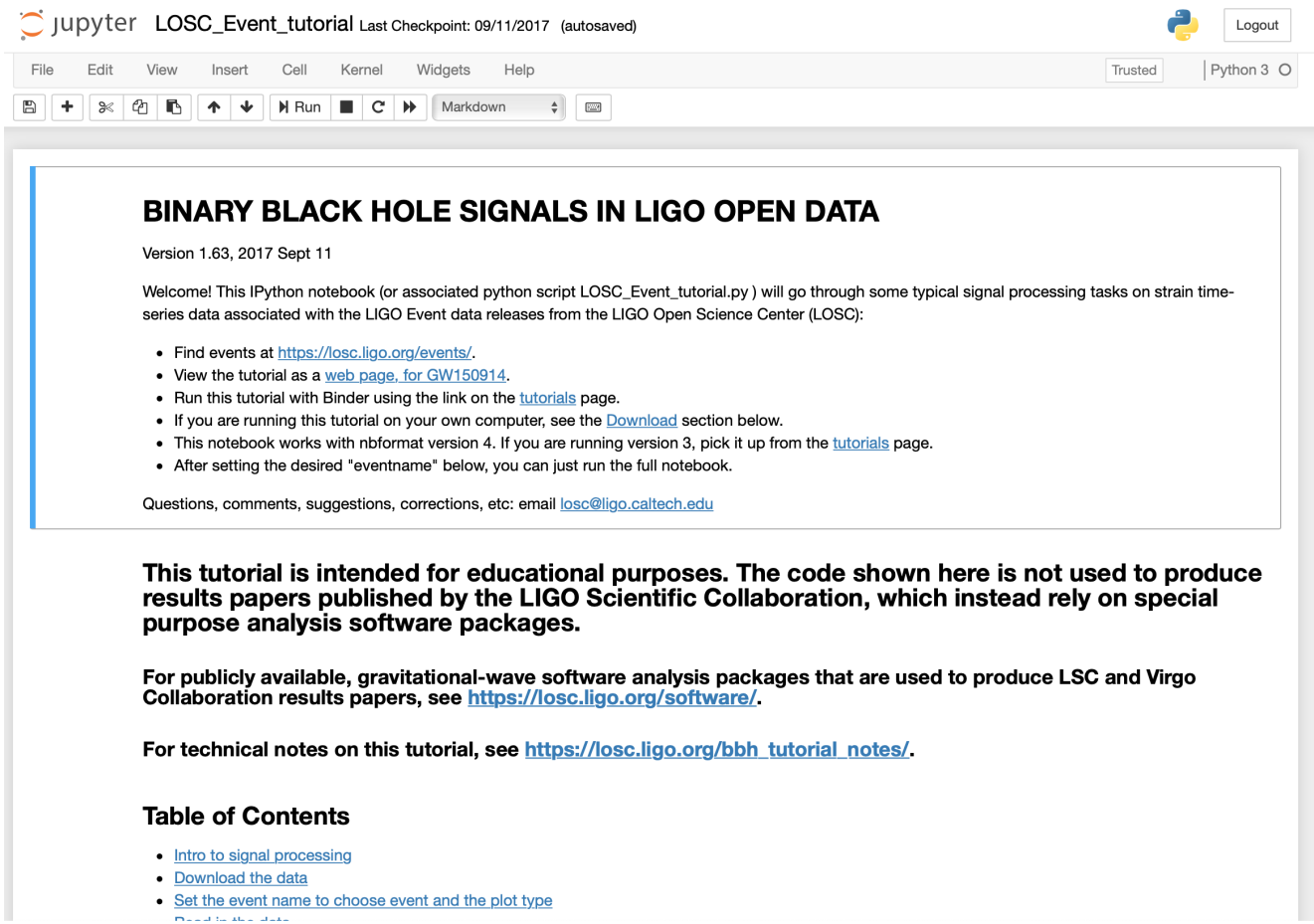

Figure: Applying project to Jupyter Notebook

Jupyter Notebook

Plot the Amplitude Spectral Density (ASD)

Plotting these data in the Fourier domain gives us an idea of the frequency content of the data. A way to visualize the frequency content of the data is to plot the amplitude spectral density, ASD.

The ASDs are the square root of the power spectral densities (PSDs), which are averages of the square of the fast fourier transforms (FFTs) of the data.

They are an estimate of the "strain-equivalent noise" of the detectors versus frequency, which limit the ability of the detectors to identify GW signals.

They are in units of strain/rt(Hz). So, if you want to know the root-mean-square (rms) strain noise in a frequency band, integrate (sum) the squares of the ASD over that band, then take the square-root.

There's a signal in these data! For the moment, let's ignore that, and assume it's all noise.

In [19]:
```
make_psds = 1
if make_psds:
    # number of sample for the fast fourier transform:
    NFFT = 4*fs
    Pxx_H1, freqs = mlab.psd(strain_H1, Fs = fs, NFFT = NFFT)
    Pxx_L1, freqs = mlab.psd(strain_L1, Fs = fs, NFFT = NFFT)

    # We will use interpolations of the ASDs computed above for whitening:
    psd_H1 = interp1d(freqs, Pxx_H1)
    psd_L1 = interp1d(freqs, Pxx_L1)

    # Here is an approximate, smoothed PSD for H1 during O1, with no lines. We'll use it l
    Pxx = (1.e-22*(18./(0.1+freqs))**2)**2+0.7e-23**2+((freqs/2000.)*4.e-23)**2
    psd_smooth = interp1d(freqs, Pxx)

if make_plots:
    # plot the ASDs, with the template overlaid:
    f_min = 20.
    f_max = 2000.
    plt.figure(figsize=(10,8))
    plt.loglog(freqs, np.sqrt(Pxx_L1),'g',label='L1 strain')
    plt.loglog(freqs, np.sqrt(Pxx_H1),'r',label='H1 strain')
    plt.loglog(freqs, np.sqrt(Pxx),'k',label='H1 strain, O1 smooth model')
    plt.axis([f_min, f_max, 1e-24, 1e-19])
    plt.grid('on')
    plt.ylabel('ASD (strain/rtHz)')
    plt.xlabel('Freq (Hz)')
    plt.legend(loc='upper center')
    plt.title('Advanced LIGO strain data near '+eventname)
    plt.savefig(eventname+'_ASDs.'+plottype)
```

```
/anaconda3/lib/python3.6/site-packages/matplotlib/cbook/deprecation.py:107: MatplotlibDe
precationWarning: Passing one of 'on', 'true', 'off', 'false' as a boolean is deprecated
; use an actual boolean (True/False) instead.
  warnings.warn(message, mplDeprecation, stacklevel=1)
```

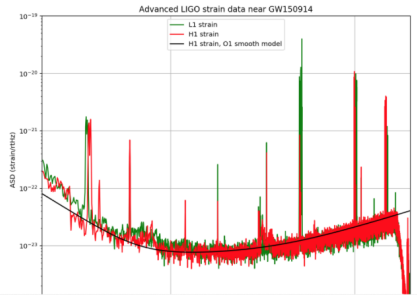

Figure: Applying project to Jupyter Notebook

What we are going to

the direction of our study

We're going to go through the process of detecting gravitational waves and converting them into audio files through some sample data from the paper.

the point of our attention..

Hypothesis

Parameters required for frequency analysis for gravitational wave detection will affect the results in certain directions.

proof process

1. Compare the magnitude of gravitational waves between different samples
2. Get the relationship of gravitational waves according to parameters.

Sample data parameters

we have 4 BBH events

parameters

example of GW150914

Estimated Source Parameters

Quantity	Value	Unit
UTC time	**2017-01-04T10:11:58.6**	
GPS time	**1167559936.6**	
Primary mass	**31.2** +8.4 -6.0	Msun
Secondary mass	**19.4** +5.3 -5.9	Msun
Chirp mass	**21.1** +2.4 -2.7	Msun
Total mass	**50.7** +5.9 -5.0	Msun
Final mass	**48.7** +5.7 -4.6	Msun
Radiated energy	**2.0** +0.6 -0.7	Msun c^2
Peak luminosity	**3.1** +0.7 -1.3	10^56 erg s^-1
Effective inspiral spin	**-0.12** +0.21 -0.30	
Final spin	**0.64** +0.09 -0.20	
Luminosity distance	**880** +450 -390	Mpc
Source redshift	**0.18** +0.08 -0.07	
False alarm rate	**< 1.4e-05**	yr^-1
Signal to Noise Ratio	**13**	
Sky localization	**1200**	deg^2

Questions