Demystifying Gravitational Waves: A Sweet of App Utilities

Maryam A. Abchouyeh, Maurice van Putten

Department of Physics and Astronomy, Sejong University

Workshop for Korea-UK AI/ML Research in fundamental science

3 Nov. 2022



Gravitational waves introduction

Generally, gravitational waves originate from the acceleration of massive bodies. We now routinely observe gravitational waves from compact binary mergers.

Maryam A. Abchouyeh

3 Nov. 2022





Gravitational waves sources



www.sciencecircle.org

astronomynow.com



zhuanlan.zhihu.com

Maryam A. Abchouyeh

3 Nov. 2022





www.scitechdaily.com



phys.org

How do gravitational waves propagate in the Universe?

GWs stretch space-time in one direction and squeeze it in the other direction, while traveling in a third direction - a transverse wave just like EM but with spin-2.



Maryam A. Abchouyeh



Laser Interfeometer Gravitational-wave Observatory (LIGO)



Maryam A. Abchouyeh

3 Nov. 2022



Laser Interfeometer Gravitational-wave Observatory (LIGO)

LIGO is configured to detect spin-2 gravitational-waves by interferometry in a kmscale Michelson-Morley type experiment



www.ligo.org

Maryam A. Abchouyeh

3 Nov. 2022



Laser Interfeometer Gravitational-wave Observatory (LIGO)



Maryam A. Abchouyeh

3 Nov. 2022

LIGO is configured to detect spin-2 gravitational-waves by interferometry in a kmscale Michelson-Morley type experiment

Ground Based Gravitational waves observatories

LIGO started its mission in 1995, with six scientific runs and three observational runs up to now.



www.ligo.caltech.edu

Maryam A. Abchouyeh

3 Nov. 2022



Maryam A. Abchouyeh

3 Nov. 2022



Maryam A. Abchouyeh

3 Nov. 2022

Beginning of the amazing story: GW170817 (O2)

It is not a silent event like 150914, but a festival of radiations: GW, GRB, Kilonova, x-ray, optical, radio, even a post-merger signal.



Maryam A. Abchouyeh

3 Nov. 2022

DNS M1=1.46 solar mass M2=1.27 solar mass Total Mass=2.7 solar mass Frequency=350 Hz Distance=40 Mpc





But it is not the full story.....





Maryam A. Abchouyeh

3 Nov. 2022

Masses in the Stellar Graveyard



LIGO-Virgo-KAGRA Black Holes LIGO-Virgo-KAGRA Neutron Stars

LIGO-Virgo-KAGRA | Aaron Geller | Northwestern





Important factors in event detection

Raw data are provided in the form of frames of 4096 seconds of data in 4KHz frequency. And there are multiple pipelines in LVK collaboration working on different aspects and sources of gravitational waves

Maryam A. Abchouyeh

3 Nov. 2022

tota rue to sis method detector sensitivity event orientation cycl Ð



O1-O3ab.....what's next for O4-O5?

| Run | S 5 | S 6 | 01 | 02 | O3a | O3b |
|-------------------|------------|------------|------|------|-----|-----|
| number of days | 697 | 471 | 130 | 269 | 184 | 148 |
| duty cycle | ~70% | ~ 50% | ~55% | ~65% | 75% | 75% |

Maryam A. Abchouyeh

3 Nov. 2022



LIGO pipelines and software





Un-modeled search CWB oLIB LALApps

Even the open data itself is not easily accessible







Maryam A. Abchouyeh

3 Nov. 2022

www.gw-openscience.org

Automation is inevitable!

Convert data to a desired extension

check the consistency of data in two detectors

set the data to the users desired time interval

FFT windowing

Bandpass filtering

Smoothing the ends

Calculating the Spectrum :)

First steps in search of unknown signals

Accessing the data

Downloading the data

Check for data

Store the data in an easily accessible extension

Second Step to get the Spectrum

Loading the data

Select the frame rate



Automation is inevitable!

Time interval

Spectrogram

Detecting the signal, if exists

Congrats!

Making the audio

Maryam A. Abchouyeh

3 Nov. 2022

Third step to get the spectrogram

Bandpass filtering again

Whitening and whitening band width

color theme



| | | | | | | Frame Dust Spectrogram Detectors putput Spectrum Movie of Spectrum Audio | | |
|---|---------------------------------------|-------------------------------|---|---------------|---|--|--|--|
| | | | | | (c)2022 GWkplarer.com | | | |
| | | | | | | Frame Duet | | |
| | ur Sweet Ar | n. scor | he and use | | Detector 1 H1 Detector 2 11 | I know the event name I know the central GPS time Event Name 170617 T Central Time 1.187e+09 | | |
| | | p. scol | | | | Time Interval (s) 22 💌 | | |
| | | | | | Frames | | | |
| | | | MATLAB App | | | ✓ Raw Download Starting GPS Time 0 | | |
| | | Frame Duet Spectrogram Delect | tors output Spectrum Movie of Spectrum Audio | | F2 hdf5(4kl tz) 👻 | Check Ending GPS Time a | | |
| | | Detectors | Spec | ctrogram | | Cleanup Run | | |
| | | Detector 1 H1 💌 | Interval adjustment | | Compose Frame Duet | Progress Report | | |
| | | Spectrogram parameter | e.0 e.0 | | | | | |
| opectrogram para | | opeeregramparameter | -0.8 | | | MATLAB App | | |
| | | F1 hd/5(4kHz) = | -0.7 -0.7 | | ectrogram Detectors output Spectrum Movie of Spec | tum Audio | | |
| | | | | Automatic and | | | | |
| | | FFT Window Size 1024 V | - 0.4 = 0.4 | Automatic and | S | pectrum | | |
| Frame Duet Spectrogram Detectors output Spectrum Movie of Spectrogram (c)2022 GWxplorer.com | MATLAB App cectrum Audio | Color Theme | 0.3 0.2 0.1 Left = 0 Plott = 0 | user-friendly | ectors Sampling rate | Bandpass filtering DFT Spectra | | |
| | Audio | es | | | L1 • F2 hof5(4KHz) • | High pass (Hz) 1700 Window 4 🔻 | | |
| Detectors Detector 1 H1 Detector 2 L1 F hd%(4kH2) Pand pass filtering | Listen | • | Bandpass filtering Low pass (Hz) 10 High pass (Hz) 1700 | | h Resolution Figure parate figures for detectors | | | |
| Low case (Hz) 30 | φ | | | | Progress Report | | | |
| High pase (Hz) 350 | | | | s | art FrXSpectra | | | |
| Whitening | Choose one option | | | | | | | |
| Whitening | Stereo Audio Audio for Detector 1 | | | | | | | |
| Sound properties | Audio for Detector 2 | | | | | | | |
| Amplifying factor 200 | | | | | | | | |
| Speed 8 Progr | iress Report | | | | | | | |
| The Audio is already stored in GWX/FrXSpectra/Audio in your | ir home directory. | | | | | | | |
| | | | | | | | | |

Maryam A. Abchouyeh

3 Nov. 2022



Our Sweet App: scope and use



Maryam A. Abchouyeh

3 Nov. 2022



Our Sweet App: scope and use

-In our App, we use FFT as the most common time-symmetric matched-filtering method, -You need only four clicks to hear the signal (and of course a stable internet connection), -It stores all the outputs and figures on your machine, -One important characteristic of this App is its outreach factor....even high school students Installation is easy and straight forward, -By considering the standard deviation of Spectrum it gives a well defined measure of high quality data, in search of unknown signals, -No need for MATLAB installation, -It is open source,

-It will be extended.....,

Maryam A. Abchouyeh

3 Nov. 2022

