

GRAVITATIONAL WAVE NOISE HUNTING IN THE CLASSROOM

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AGOGI**

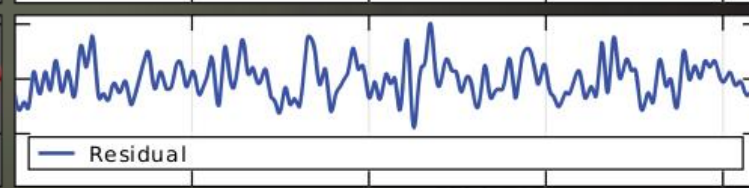
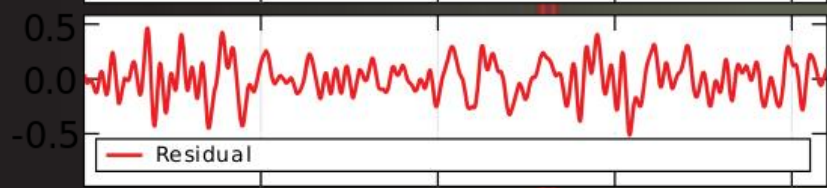
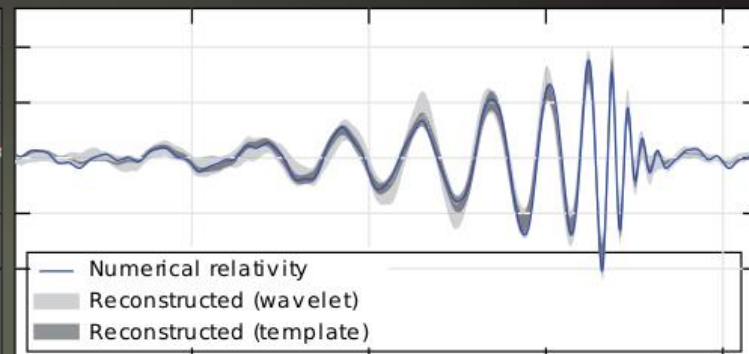
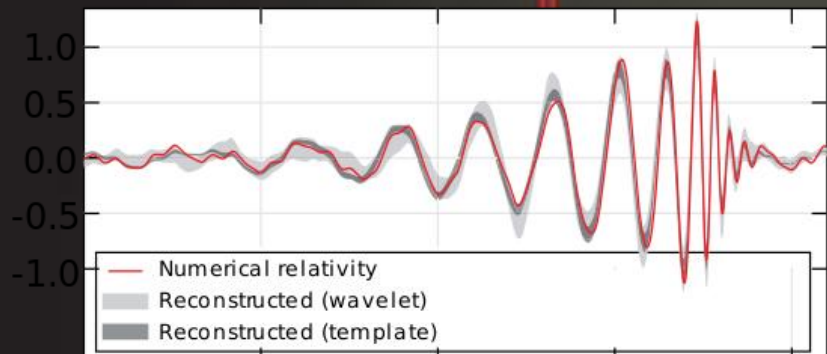
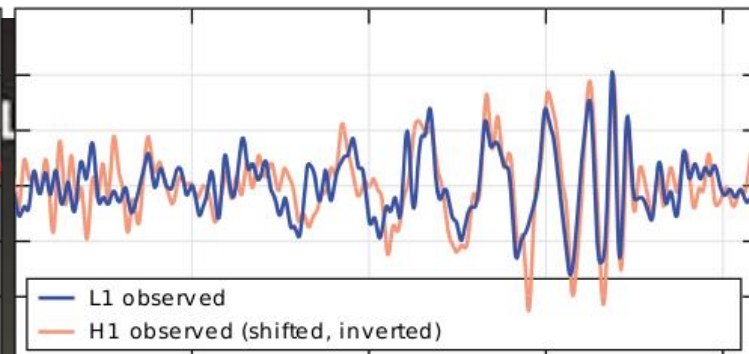
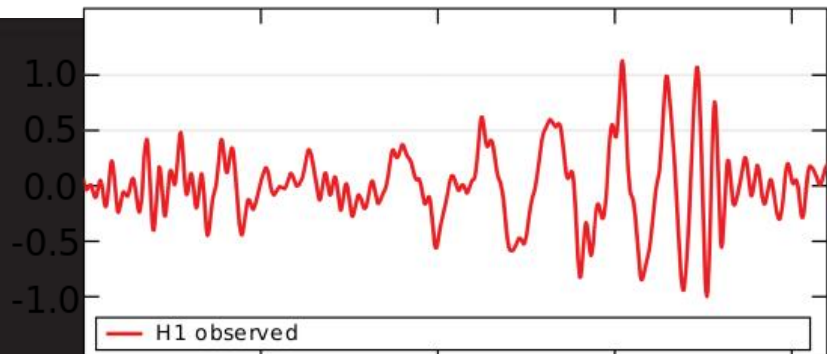


A QUICK REMINDER ABOUT GRAVITATIONAL WAVES..

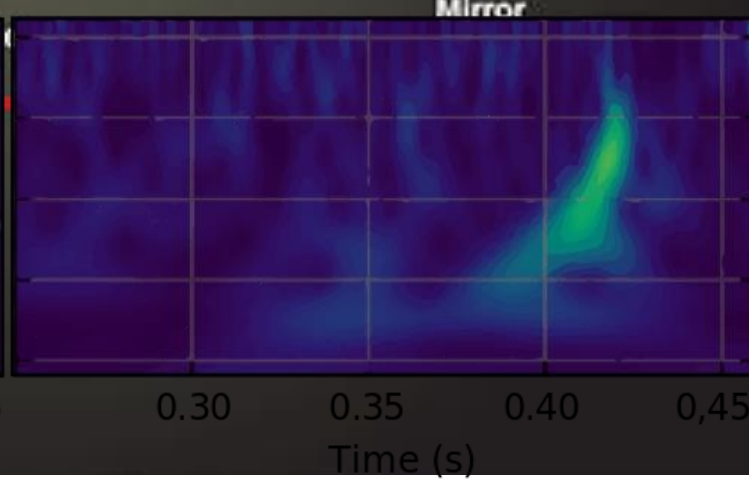
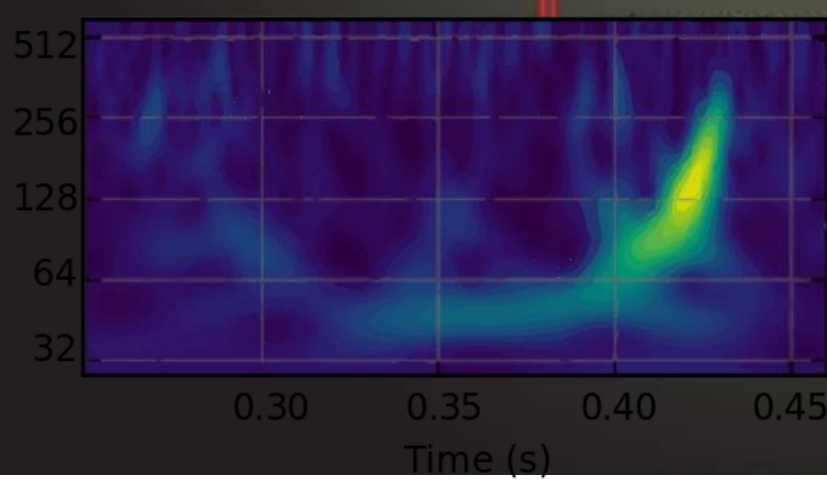
<https://www.youtube.com/watch?v=4GbWfNHtHRg>



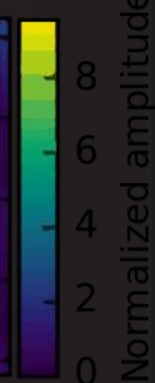
Strain (10^{-21})



Frequency (Hz)



Mirror

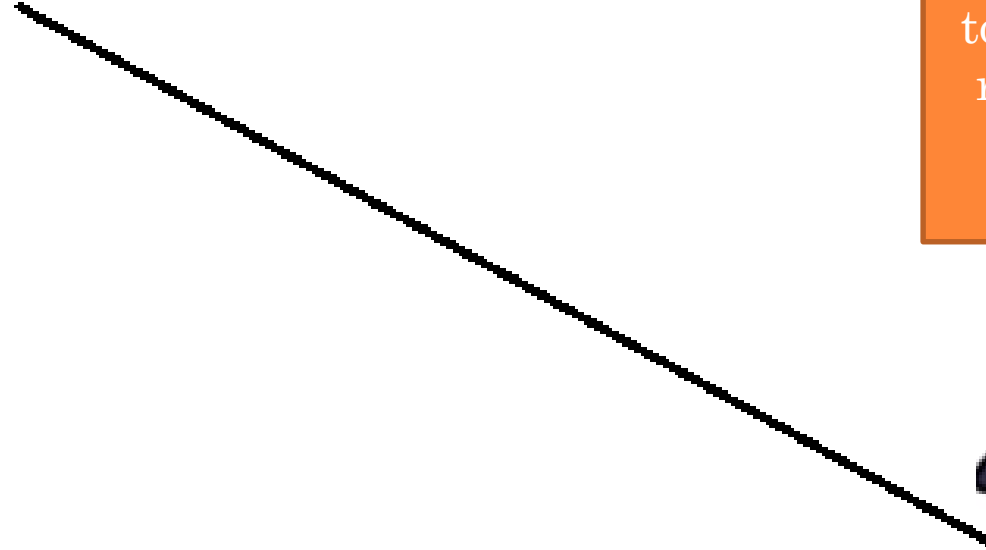


LET'S FOLLOW AN ANALOGY

Imagine a gravitational wave detector as an “ear”



Your friend is humming a tune at some distance from your “ear”. The ear will listen to the tune.



Similarly, a gravitational wave detector's sensitivity corresponds to how far in the universe it can reach and thus to its discovery potential!

Your friend keeps his voice level the same. The farther he is, the weaker the sound you hear. A more sensitive ear will be able to listen to your friend humming from a greater distance.

Therefore: “more sensitive ears” → “can identify signals from larger distances”



WHAT AFFECTS A GRAVITATIONAL WAVE DETECTOR'S SENSITIVITY? LET'S GO BACK TO OUR ANALOGY WITH THE EAR..



To detect gravitational waves even from the strongest events in the Universe, VIRGO needs to be able to know when the length of its 3-kilometer arms change by a distance 10,000 times smaller than the diameter of a proton! This makes VIRGO susceptible to a great deal of instrumental and environmental sources of noise.

These sources of noise need to be understood and controlled.

There are sources of noise that are understood...



DIFFERENT SOURCES OF “NOISE” AFFECT THE GRAVITATIONAL WAVE DETECTOR’S SENSITIVITY



Adapted from : Laser Labs’ Spacetime Quest: <https://www.laserlabs.org/spacetimequest.php>

LET'S PLAY WITH NOISE IN GRAVITATIONAL WAVE DETECTORS! A SCHOOL ACTIVITY

<https://cloud.graasp.eu/en/pages/5bd9b6190d7f5d27ca8c339f/subpages/5bd9b61b0d7f5d27ca8c33aa>

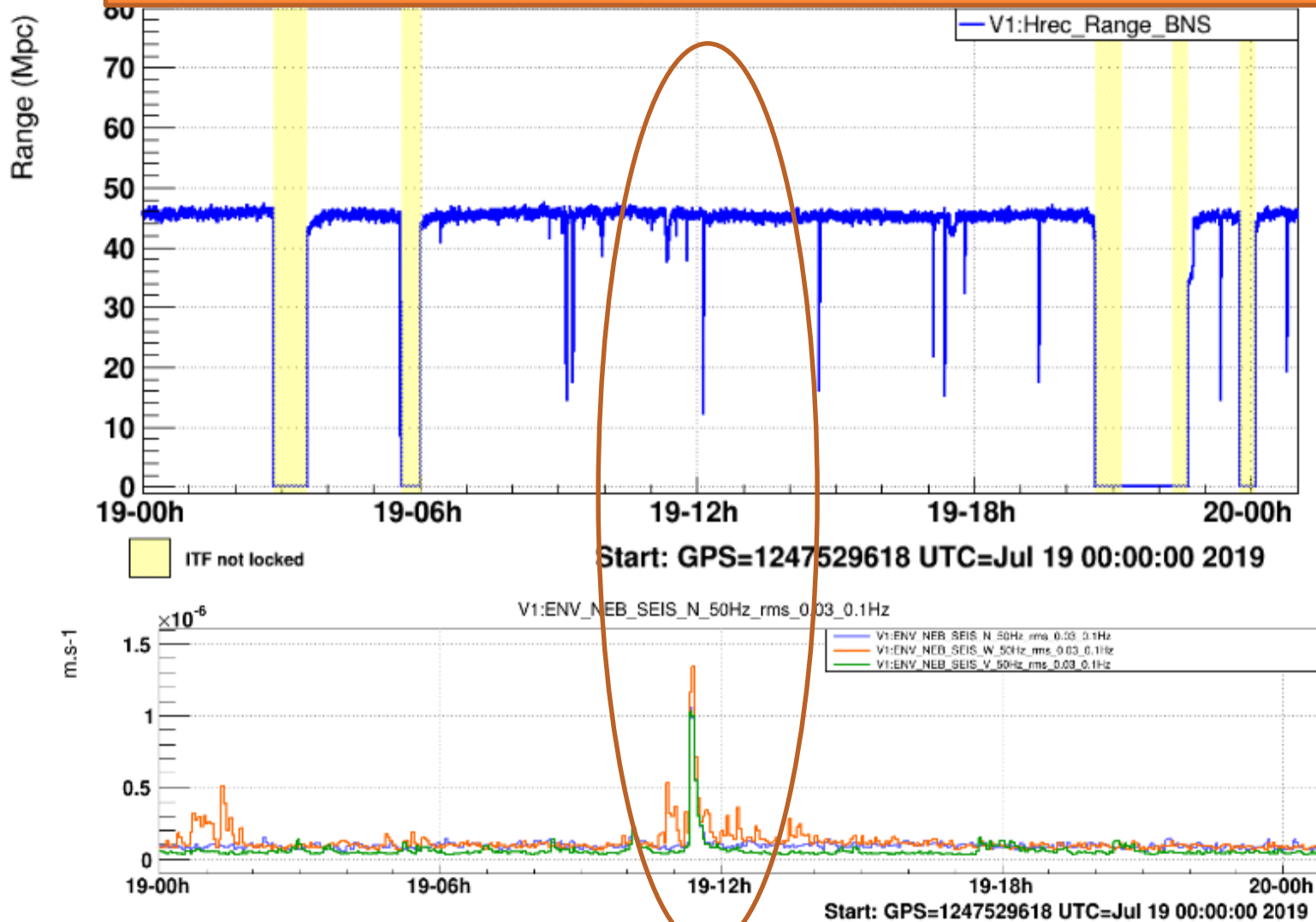


A FEW EXAMPLES OF ENVIRONMENTAL NOISE..



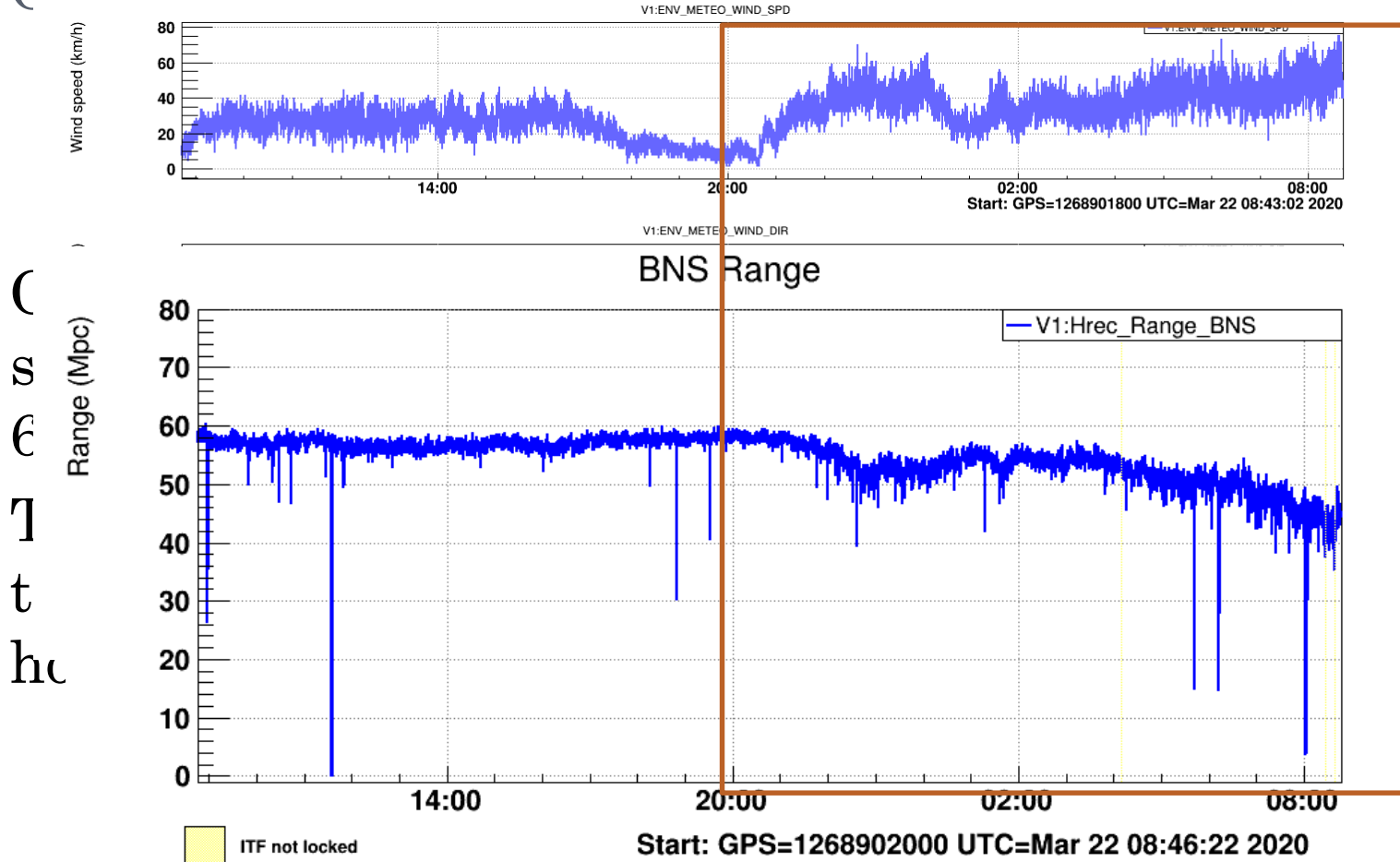
Due to the earthquake in Magoula, the horizon of the Virgo detector dropped by a factor of 3!

*A measure of How far in the Universe can the detector “hear”



* BNS range is defined as the distance up to which a single detector could observe the coalescence of a pair of 1.4 solar masses neutron stars with signal to noise ratio of 8.

DOES THE WIND BLOWING, AFFECT A GRAVITATIONAL WAVE DETECTOR?



"If two neutron stars with mass equal to 1.4 solar masses merged in distance higher than 50 Mpc and a signal arrived to our detector around 08.00 A.M, we wouldn't be able to detect it because the wind was blowing furiously!"

GLITCH HUNTING!



INTRODUCING SPECTROGRAMS..

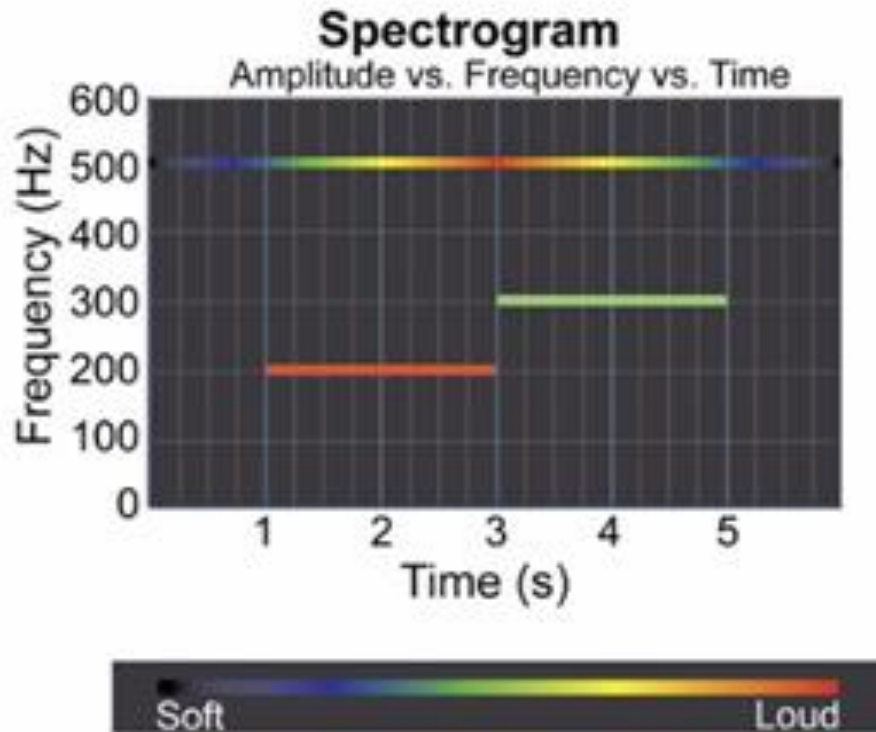
- As we said, gravitational wave detectors resemble very sensitive “ears”. One of our most important visualizations

Connecting gravitational wave noise hunting with sound!!

contribute in different proportions over time. In order to visualize this attribute, we use the spectrogram. The spectrogram shows both frequency and amplitude with respect to time.

- A spectrogram is essentially a 3D plot: It is a graph with x-axis representing time, y-axis representing frequency and the z-axis representing amplitude. Usually, the z-axis is replaced by a color code.



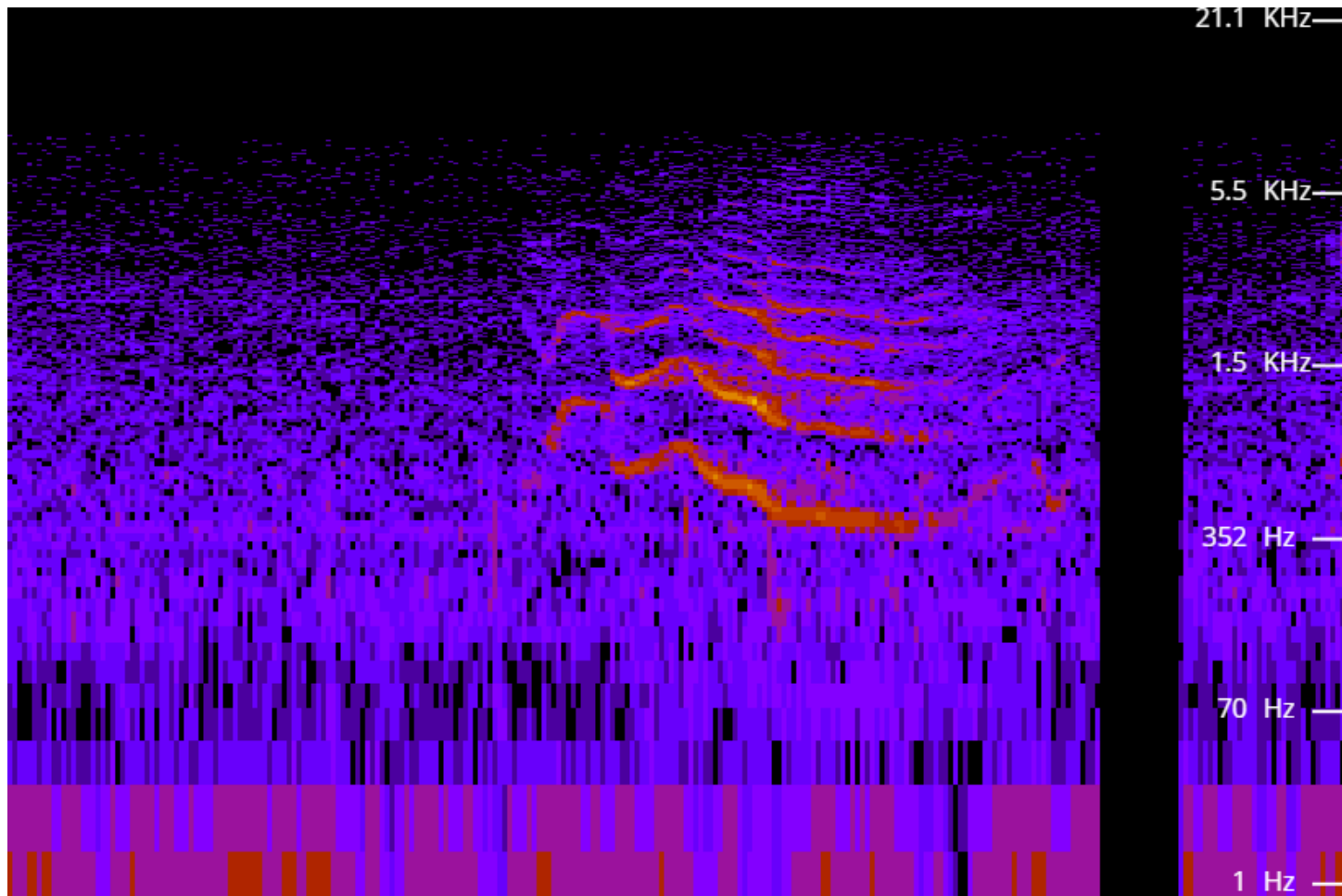


This picture shows the spectrogram of a sound consisting of three frequencies. Can you say which frequency sounds the loudest at $t=2s$? At which time does frequency equal to 500 Hz sound louder than the others?



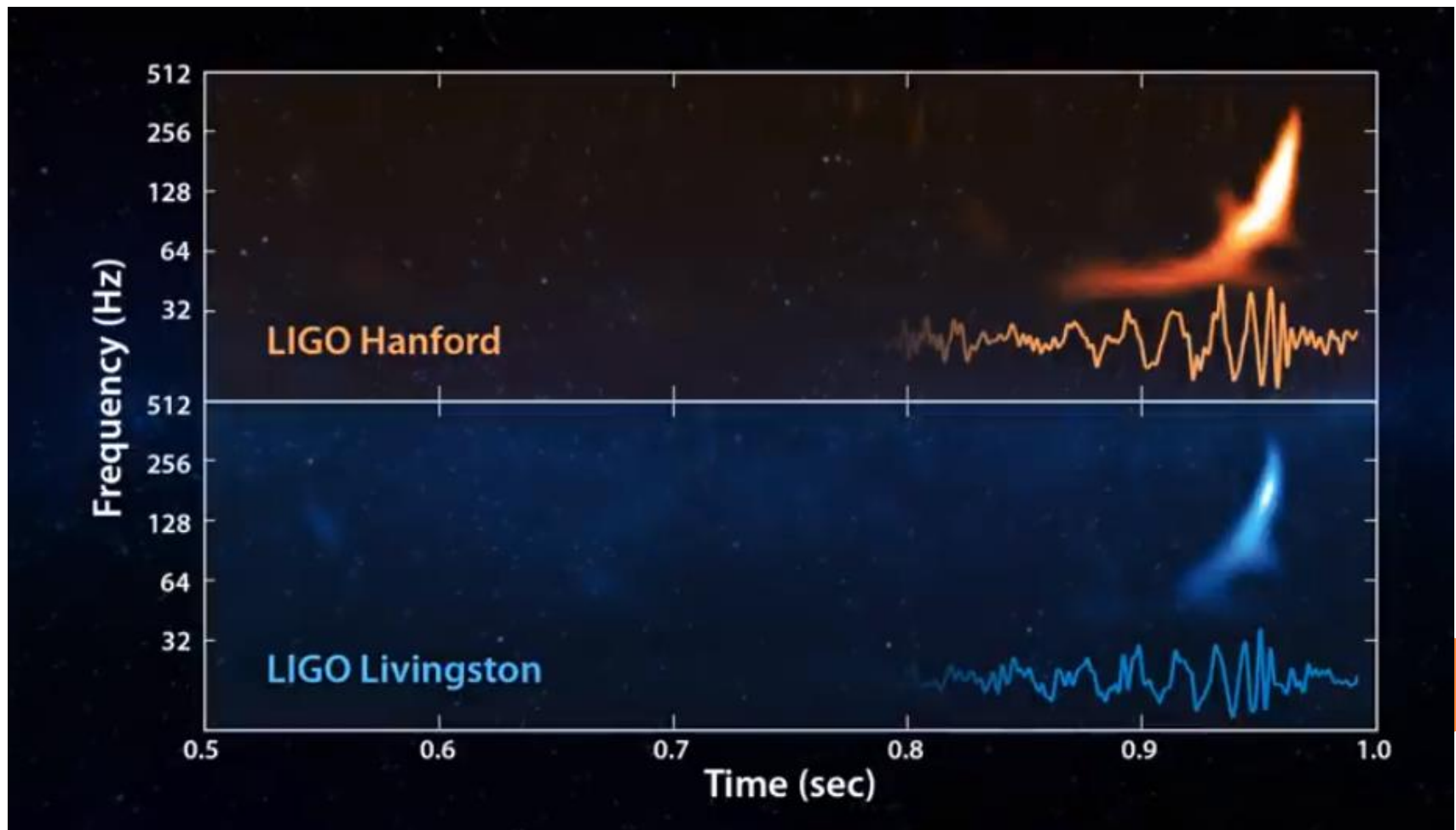
LET'S PLAY WITH SPECTROGRAMS

<https://academo.org/demos/spectrum-analyzer/>



THE SOUND OF A GRAVITATIONAL WAVE

<https://www.youtube.com/watch?v=TWqhUANNFxw>



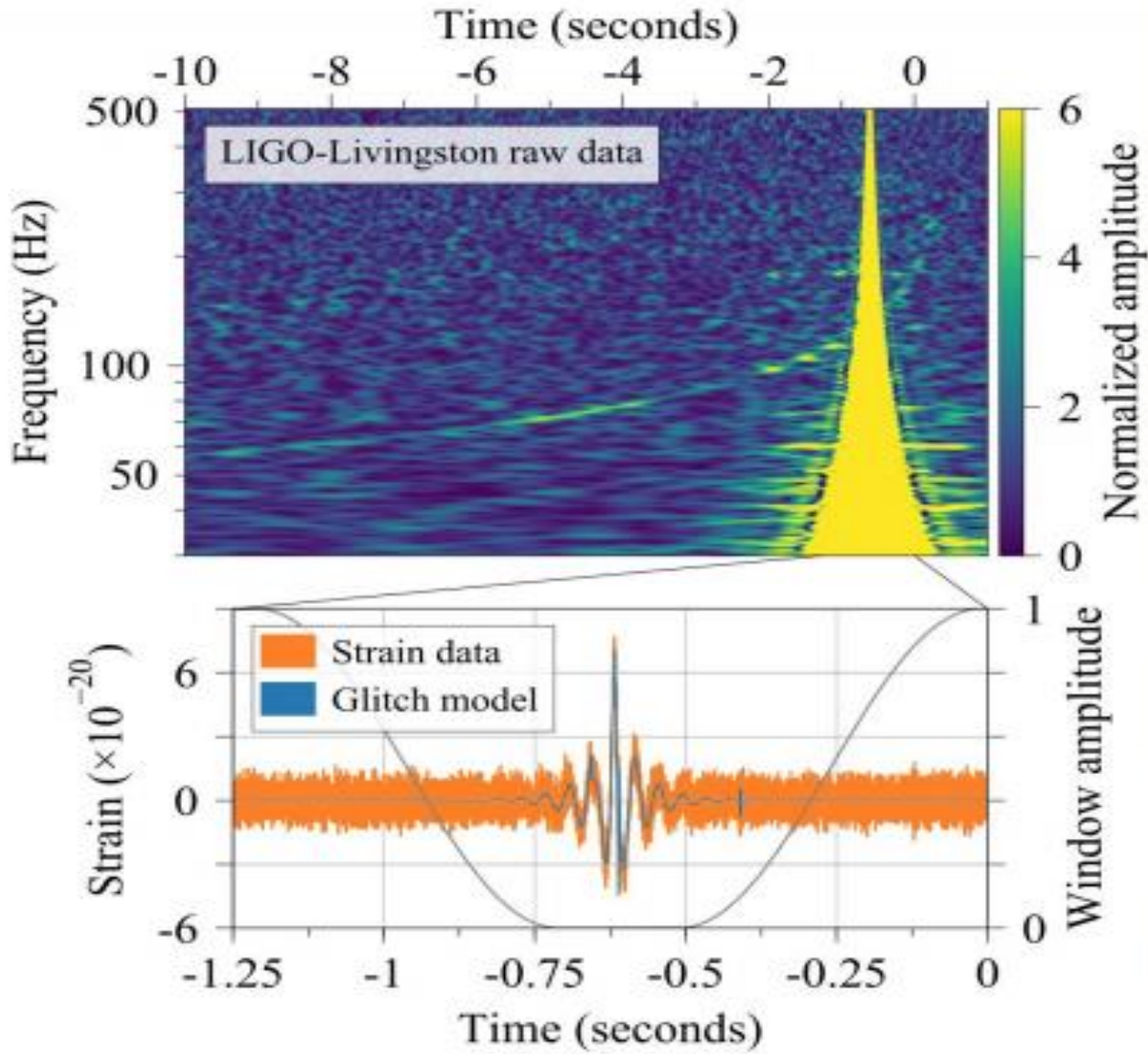
There are sources of “noise” in Gravitational Wave detectors that are poorly understood.. The so called “Glitches”!



Mpc

How far in the Universe can a Gravitational Wave Detector "reach"

40
20
0



Glitch in LIGO L1 detector during GW170817
Abbott et al 2017



Classifying glitches using computers has proven to be an exceedingly difficult task. A family of data analysis algorithms known as *machine learning* have made huge strides over the past decade in classification problems, though they usually require a large pre-classified dataset to operate effectively. However, human intuition has proven time and time again to be a useful tool in pattern recognition problems such as this.

This is where your help is needed!



LET'S DO SOME GLITCH HUNTING WITH: *GRAVITY SPY*

<https://www.zooniverse.org/projects/zooniverse/gravity-spy>



Citizens help LIGO and VIRGO scientists identify typologies of glitches and advance their machine learning algorithms



15,340

Volunteers

1,521,694

Classifications

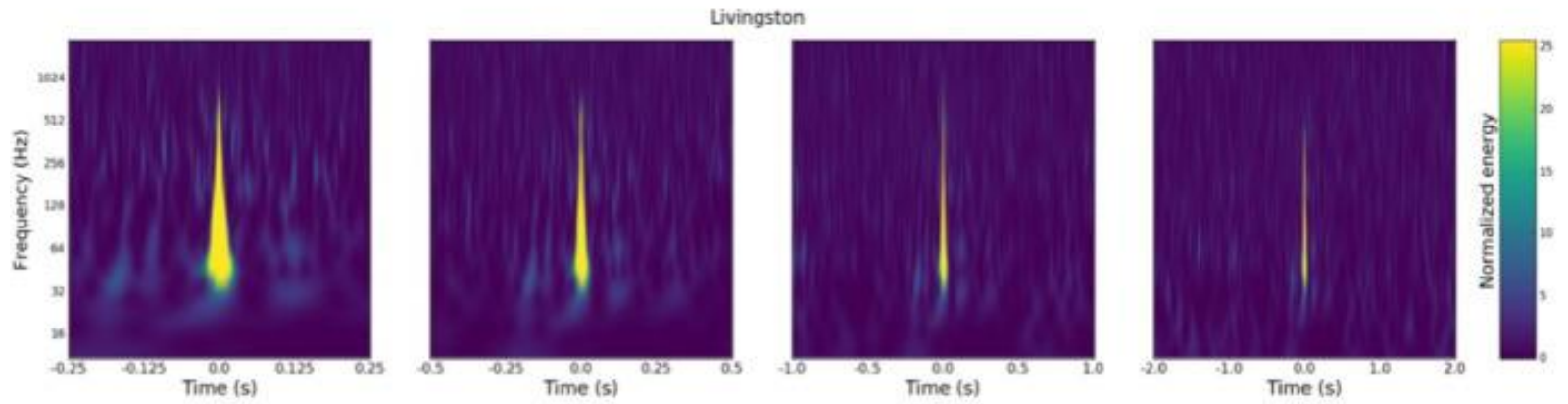
998,045

Subjects

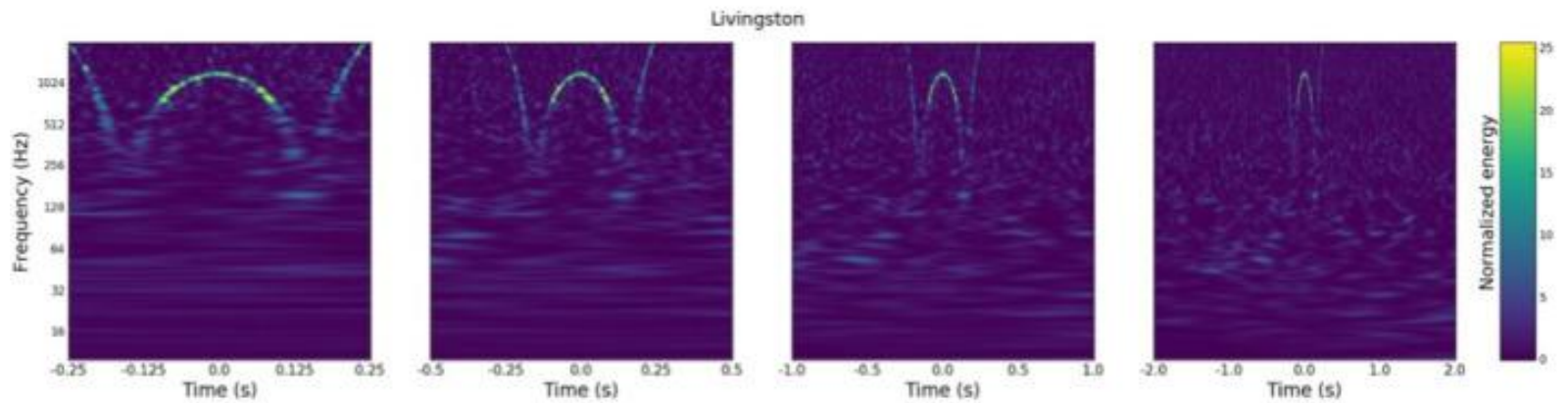
157,992

Completed Subjects

(a) Blip glitch



(b) Whistle glitch



LET'S HUNT SOME GLITCHES!

