CITIZENS OPTIMIZE LARGE RESEARCH INFRASTRUCTURES: "GLITCH HUNTING"

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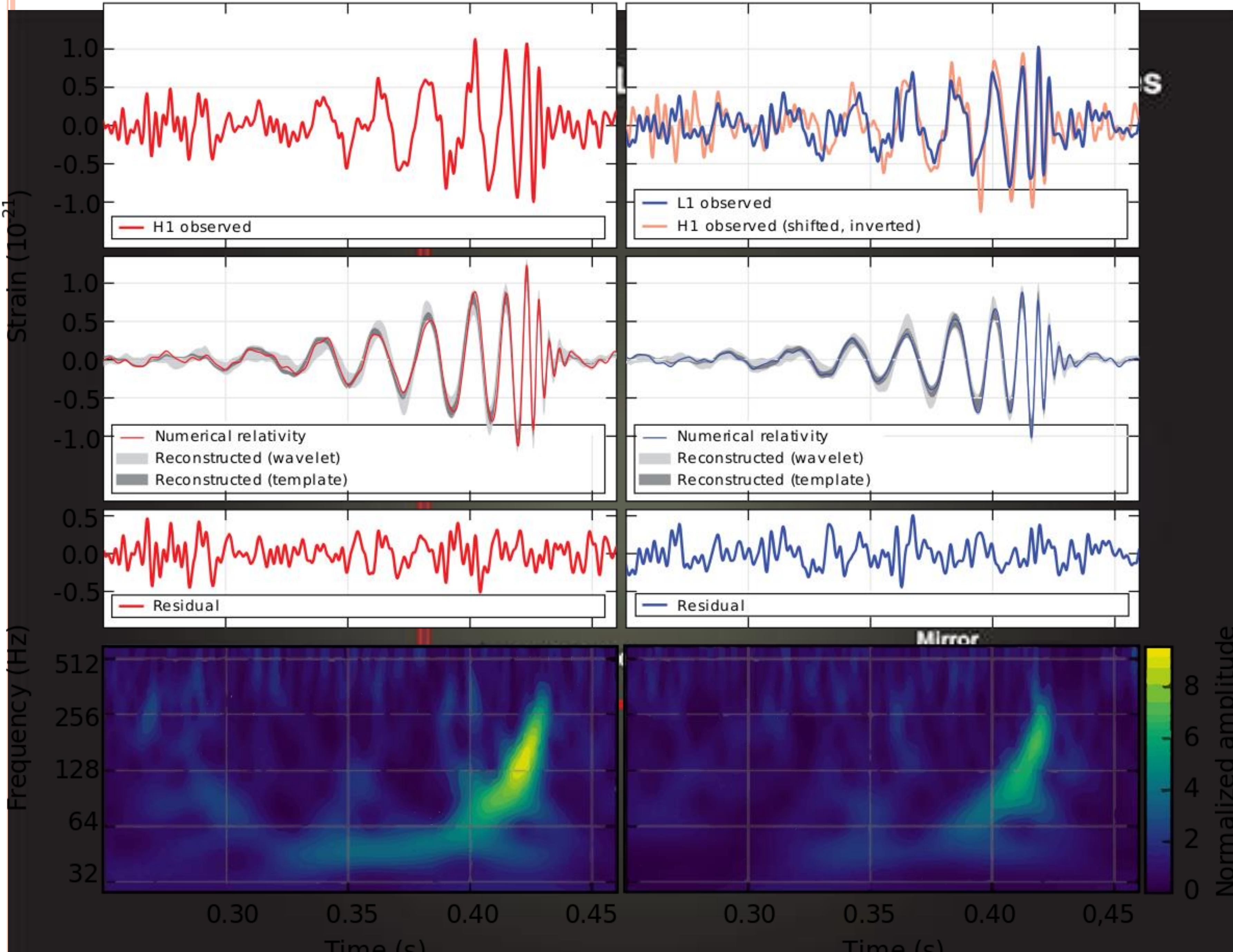
A quick reminder about gravitational waves..

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



H1 observed
L1 observed
H1 observed (shifted, inverted)
Numerical relativity
Reconstructed (wavelet)
Reconstructed (template)
Numerical relativity
Reconstructed (wavelet)
Reconstructed (template)
Residual
Residual
Strain (10^{-21})
1.0
0.5
0.0
-0.5
-1.0
Frequency (Hz)
512
256
128
64
32
0.30
0.35
0.40
0.45
Time (s)
Normalized amplitude
0
2
4
6
8

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”

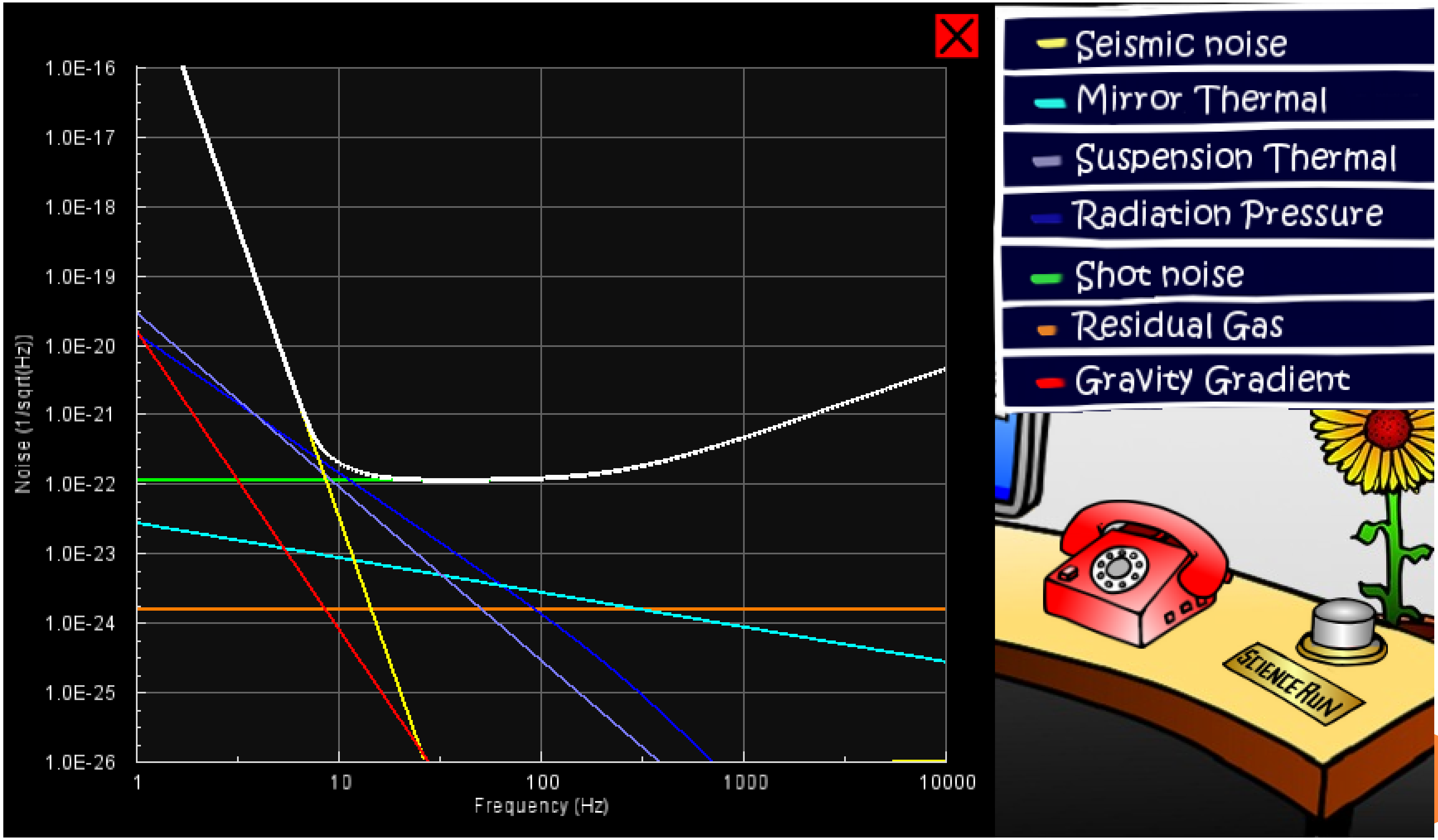
What affects a gravitational wave detector's sensitivity? Let's go back to our analogy with the ear..

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

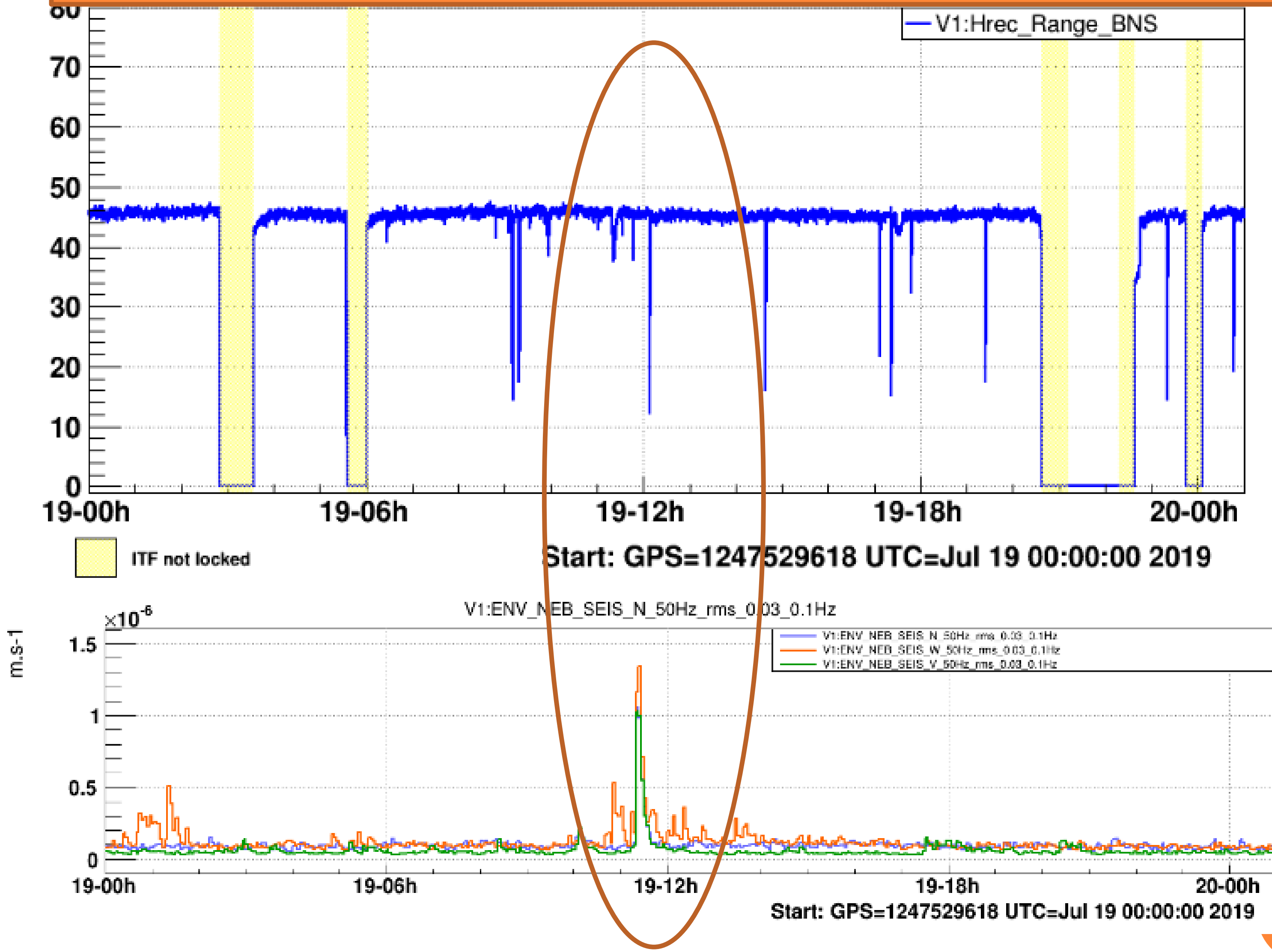


Adapted from : Laser Labs' Spacetime Quest: https://www.laserlabs.org/spacetimequest.php

A few examples of environmental noise..

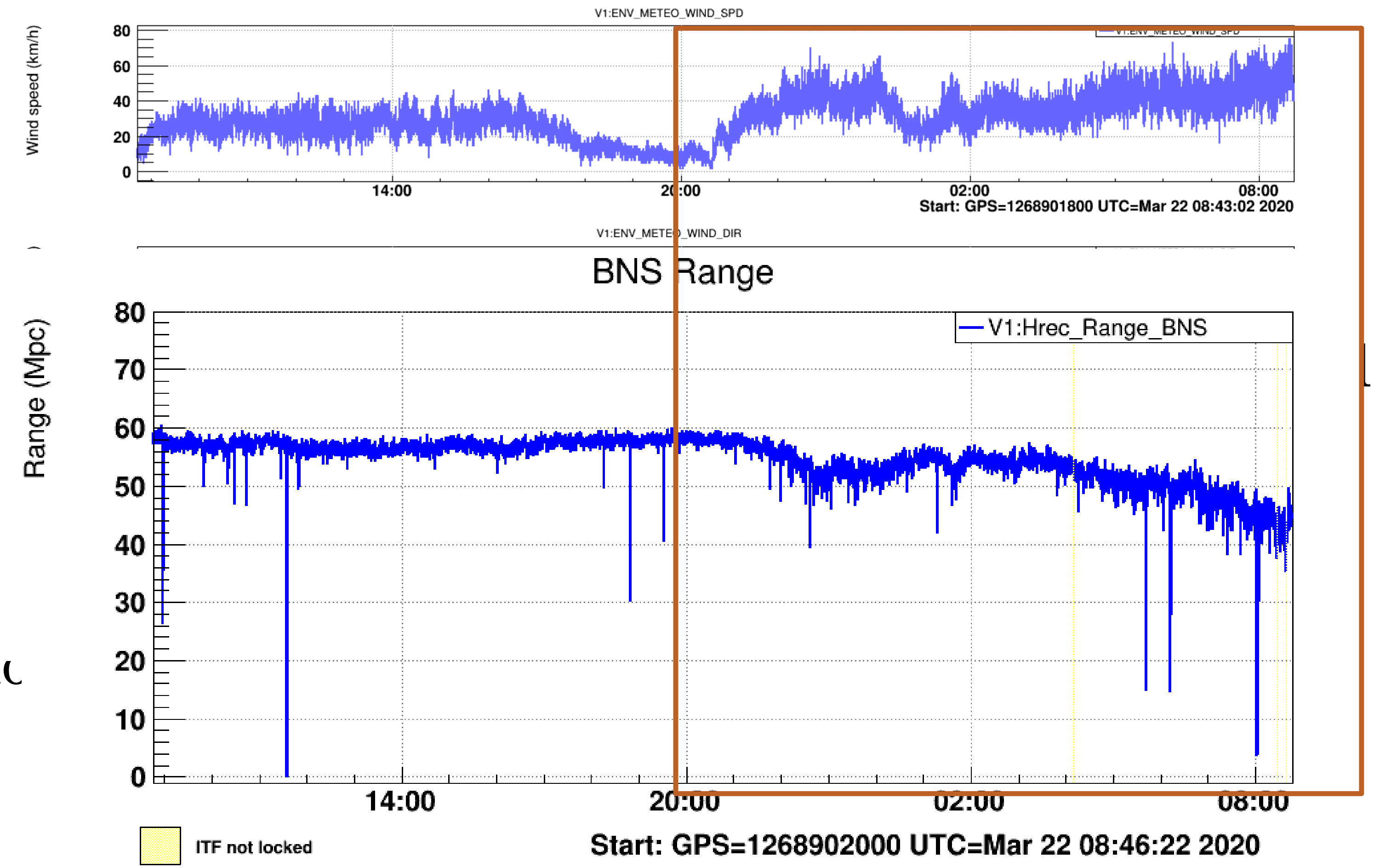
Due to the earthquake in Magoula, the horizon of the Virgo detector dropped by a factor of 3!

*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 1.4solar masses neutron stars with signal to noise ratio of 8.

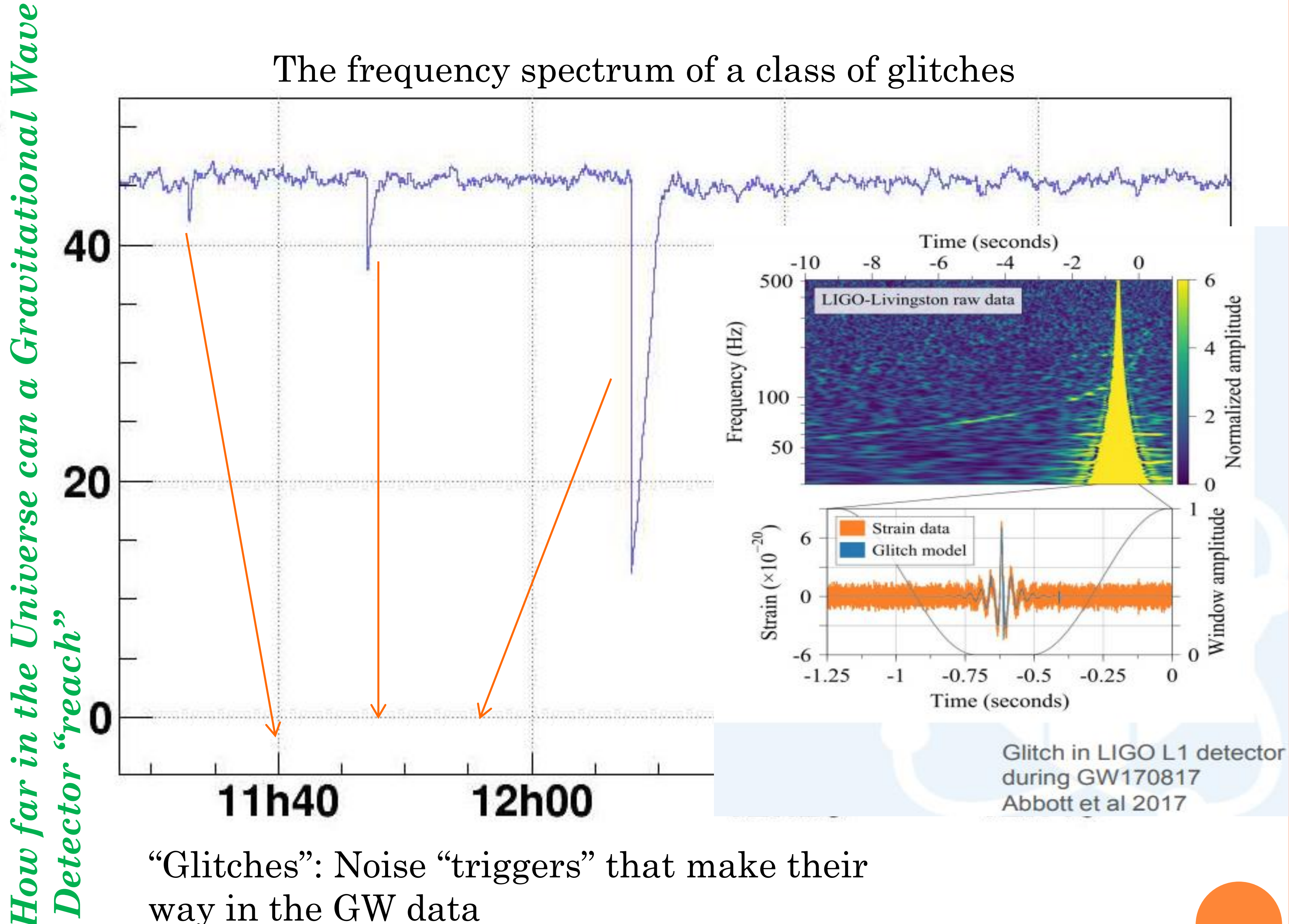
Does the wind blowing, affect a gravitational wave detector?



"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!"

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

The frequency spectrum of a class of glitches



Glitch in LIGO L1 detector during GW170817 Abbott et al 2017

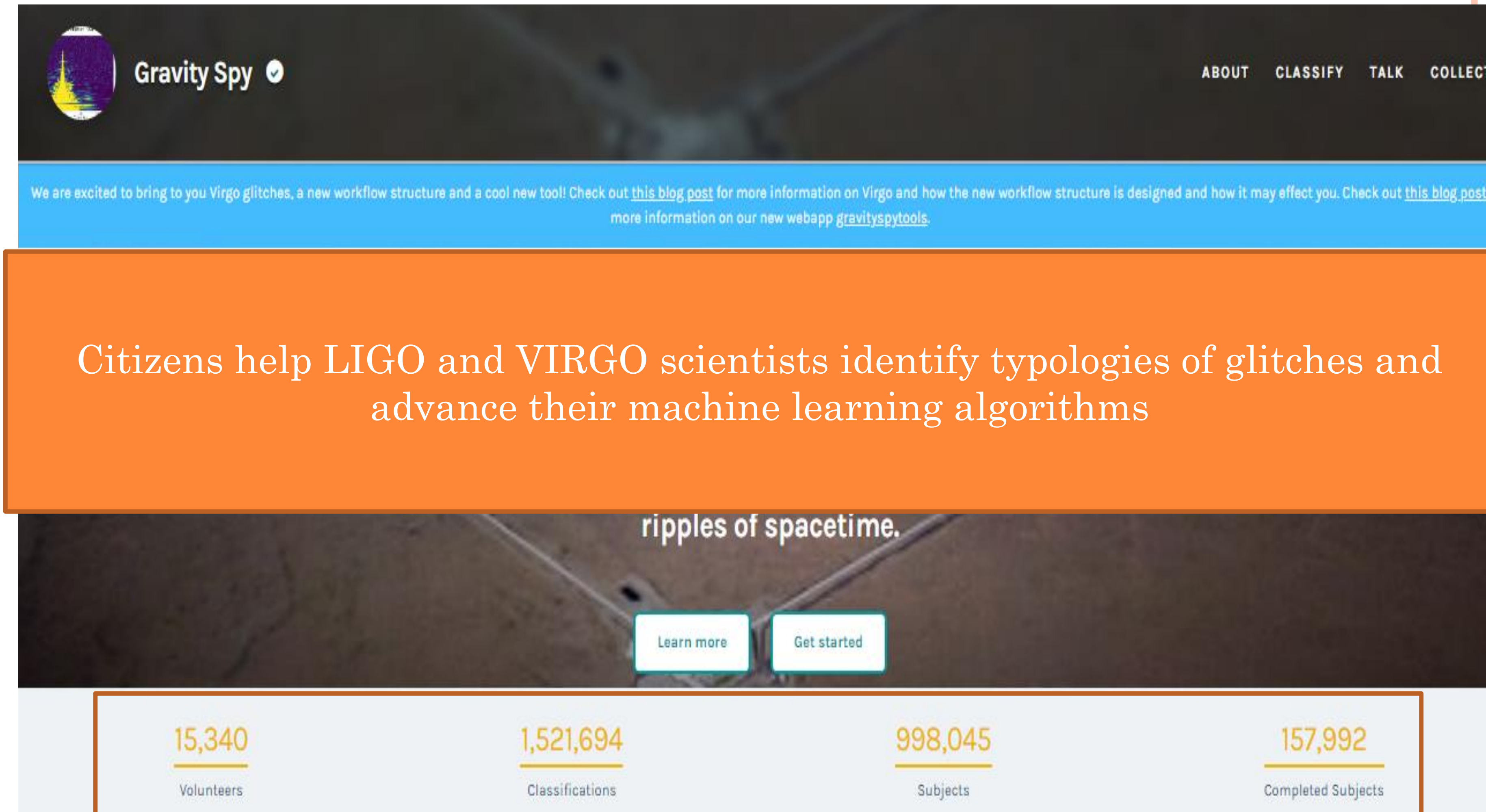
"Glitches": Noise "triggers" that make their way in the GW data
and introduce dead time in the detector and mimic GW signals.

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 citizen science comes to the rescue!

CITIZENS SUPPORT THE OPTIMIZATION OF LARGE RESEARCH INFRASTRUCTURES
CASE STUDY: 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

How does it work?

- Citizen scientists sift through the enormous amount of LIGO/Virgo data to produce a robust "gold standard" glitch dataset that can be used to seed and train machine learning algorithms.
- Machine learning algorithms will learn from this classified dataset to sort through more LIGO/Virgo data, and choose the most interesting, abnormal glitches to be sent back to the citizen scientists
- Citizen scientists further classify and characterize these glitch morphologies, determining new glitch categories to be used in the training of the machine learning algorithms.
- Utilizing the strengths of both humans and computers, this project keeps LIGO/Virgo data as clean as possible, and helps to unlock more of the gravitational wave universe.

- In Gravity Spy, citizens classify "glitches" according to their signal characteristics and communicate their findings to collaborating scientists from the GW detector team.

https://www.inverse.com/article/28729-gravity-spy-hunting-for-gravitational-waves-ligo

The Citizens' Contribution

"Without good knowledge of the noise in the detectors, it would be near impossible to make discovery of these gravitational waves," says Zevin. "Even though the Citizens aren't really searching for gravitational waves themselves, without their help and without the help of the teams that actually do the analys of all the noise, we would have no way of detecting gravitational waves in the first place."

"I chose to participate because I realized it was a great opportunity to be a part of one of the most prominent scientific projects in the world," says Téglás. "I thought that if I could do something for this, even the tiniest thing, it was worth it."

RECOGNITION OF CITIZENS' ACHIEVEMENTS

aLIGO LHO Logbook
Logbooks LHO LLO Virgo KAGRA

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Reports until 09:30, Thursday 12 May 2016

A citizen scientist identified a new source of glitches and helped scientists
optimize their detector against them, thus contributing in the optimization
of a GW detector!

Itâ€™s also not clear yet exactly how this couples in. These glitches do not look like scattering arches - they are too high in frequency, have no support at lower frequency, and also thereâ€™s no top part of an arch. So it may be jitter, or clipping. The best prediction of the glitches is the pitch position of SR2 as seen by the OSEM. One kind of glitch happens at the maxima, and one at the minima. The final attachment shows this. But we havenâ€™t looked at all channels yet.

Further work can be done by looking at other times when this kind of glitch occurs (GravitySpy can provide those), looking for the cause of the BS motion, and trying to find which of the alignment channels is the best predictor of the exact glitch times.

https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=27138

Now is your turn! Let's identify glitches together!

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