REINFORCE

REsearch INfrastructures FOR Citizens in Europe

GWitchHunters

Updates and results

on Virgo data

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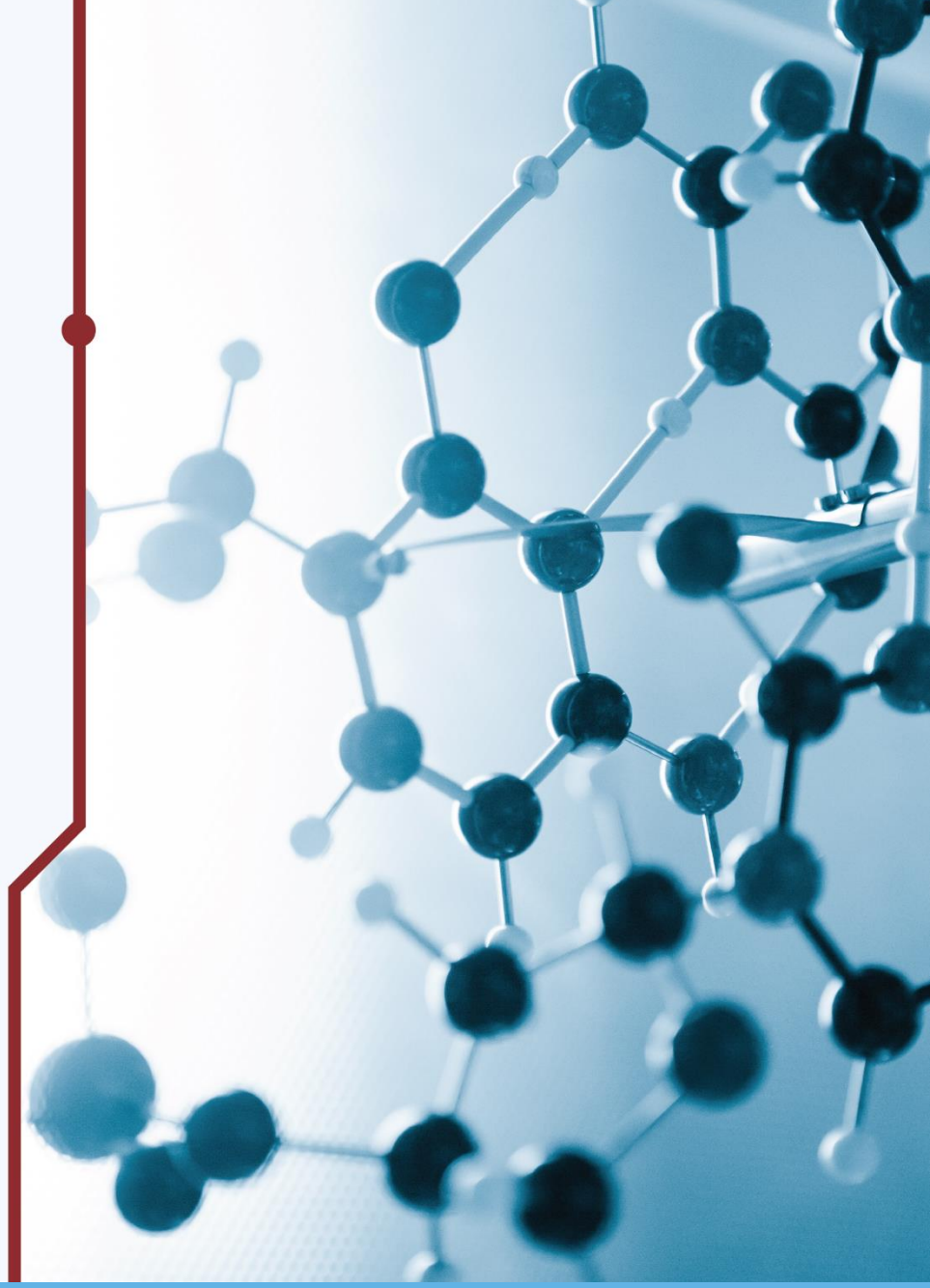
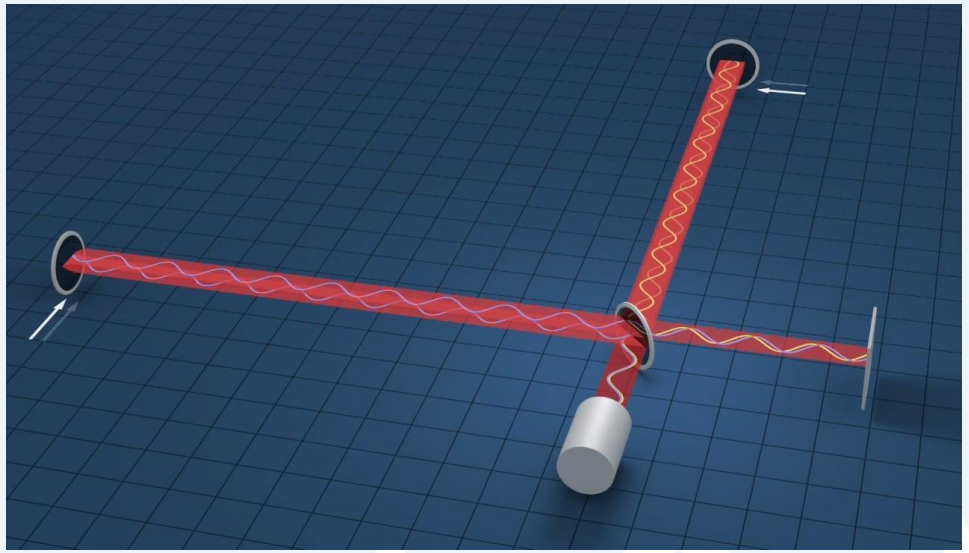
On behalf of the GWitchHunters REINFORCE team

Fostering citizens' role in the advance of ground-breaking research in fundamental physics

EGO, Sep 1-2, 2022

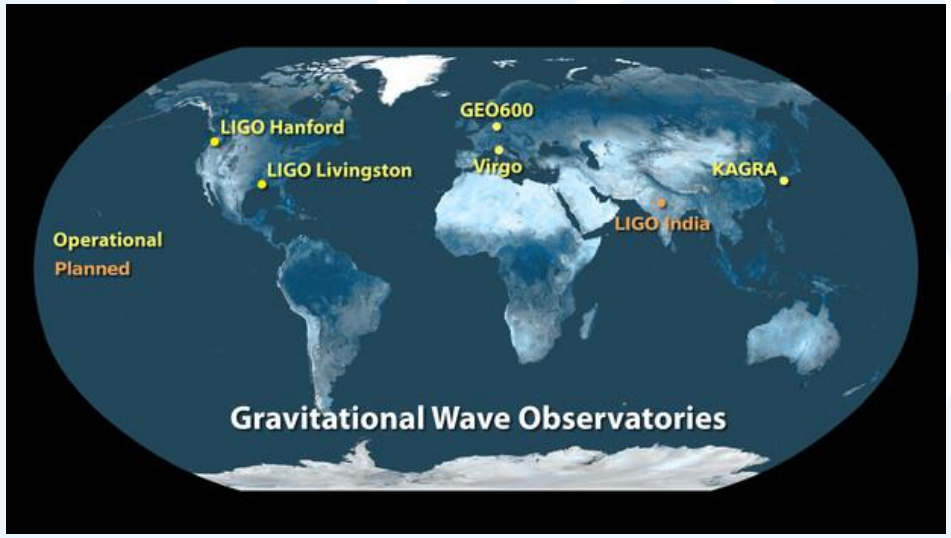


How to detect gravitational waves



- **Extremely tiny signals**
  - Typical GW sources induce a deformation of 10^{-18} m over a length of ~ few km
  - High background noise!

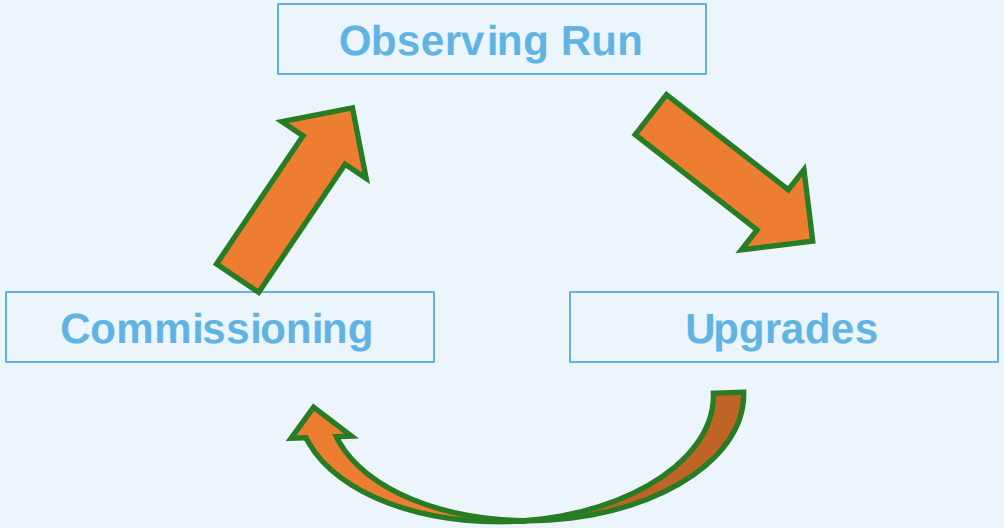
- **Laser interferometers**
  - Exploiting interference between orthogonal laser beams
  - Typical km-long scale + Fabry-Perot cavities
  - Frequency range ~20-20000 Hz
  - Advanced methods to reduce noise
  - Detectors working as a network



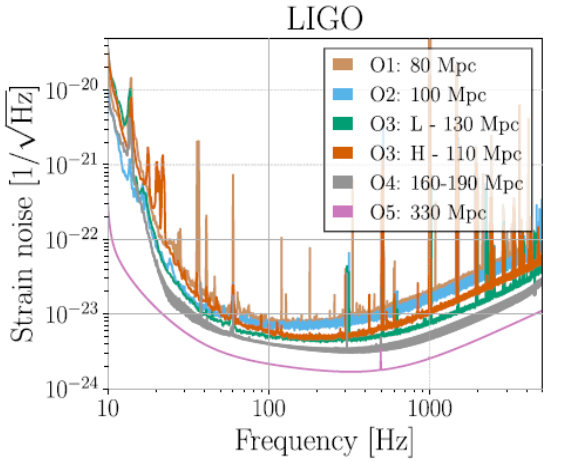
Credits: LIGO/T Pyle; Caltech/MIT/

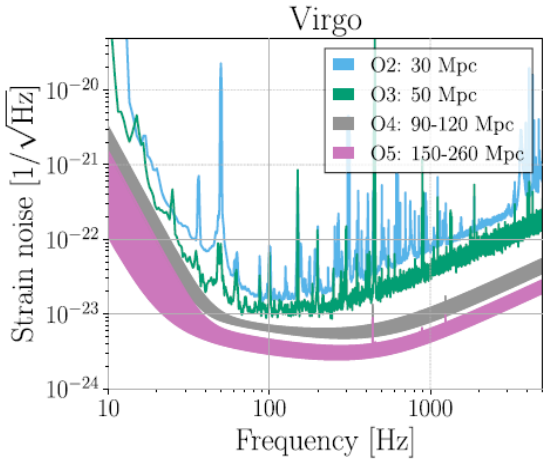
Detecting Gravitational Waves

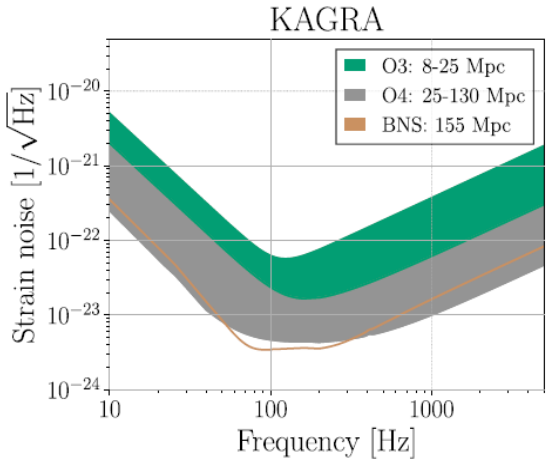
- **Sensitivity varies with frequency: main noise sources**
  - Low frequencies: Newtonian, seismic
  - Mid frequencies: thermal processes
  - High frequencies: quantum noise



Detector Characterization "noise hunting" & Data Quality





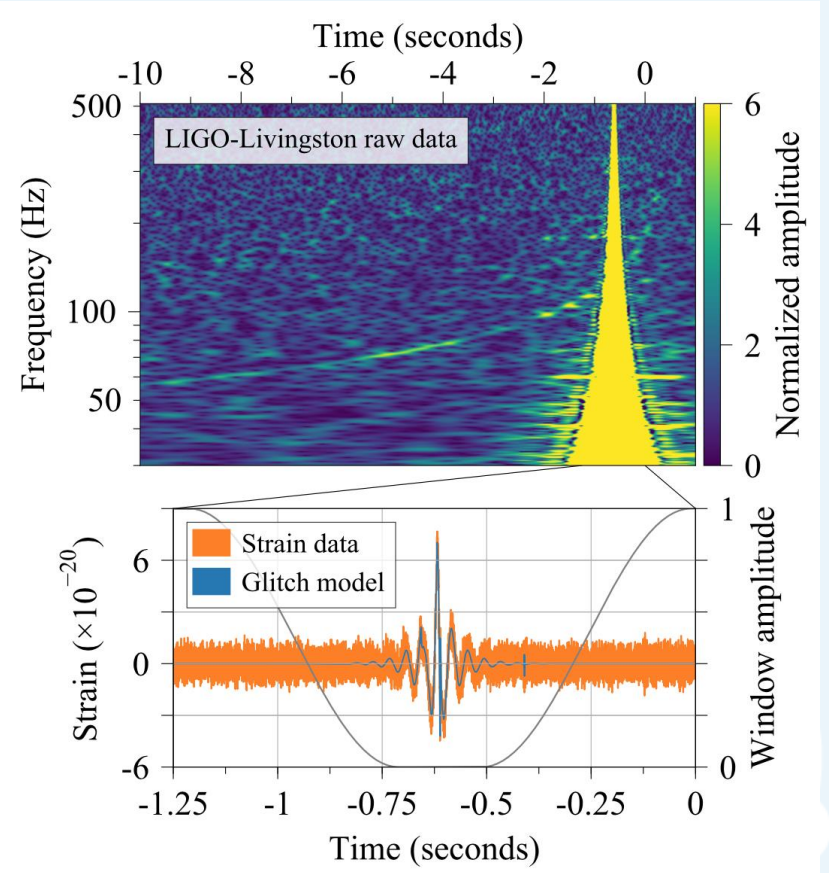


"Observing Scenario" paper
Abbott et al, (LVK collaborations) 2020, LRR, 23, 3

Noise glitches

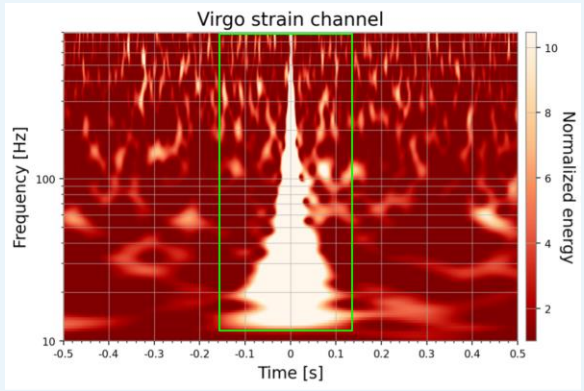
- **Noise is not stationary**
  - Transient noise events can happen
  - Not related to astrophysical source, but local disturbances
  - Different timescales/frequency ranges
  - Affect data quality, stability and GW detection

- **Noise hunting & characterization is critical**
  - Detect and classify glitches to find their origin and remove them
  - Hardware/software origin
  - Data from auxiliary sensors important to understand origin
  - Machine learning offers promising approach (e.g. George&Huerta2017, Razzano&Cuoco 2018)
  - Glitches have complex time-frequency morphologies !

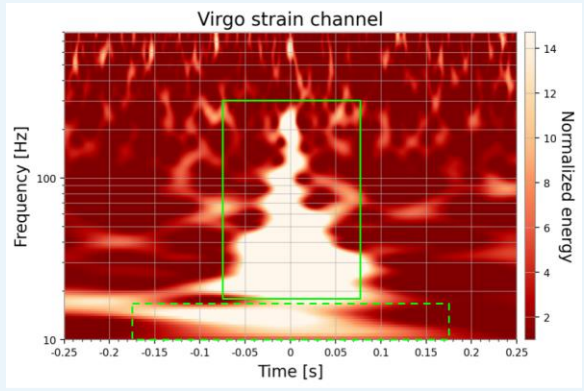


Glitch in LIGO L1 detector during GW170817
Abbott et al 2017

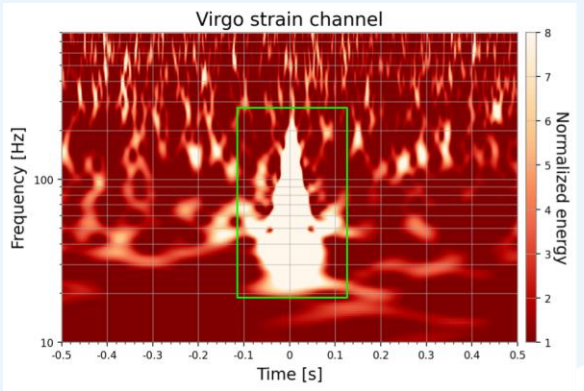
Glitch morphologies



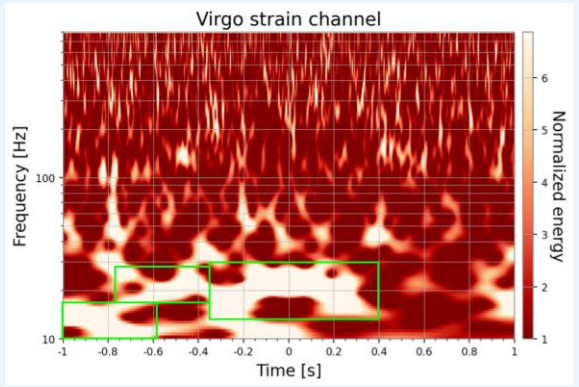
Blip



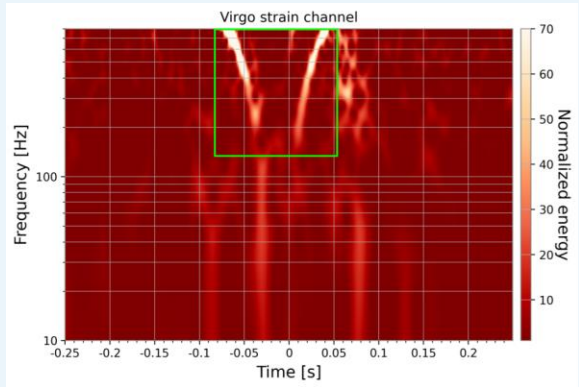
Helix



Koi Fish

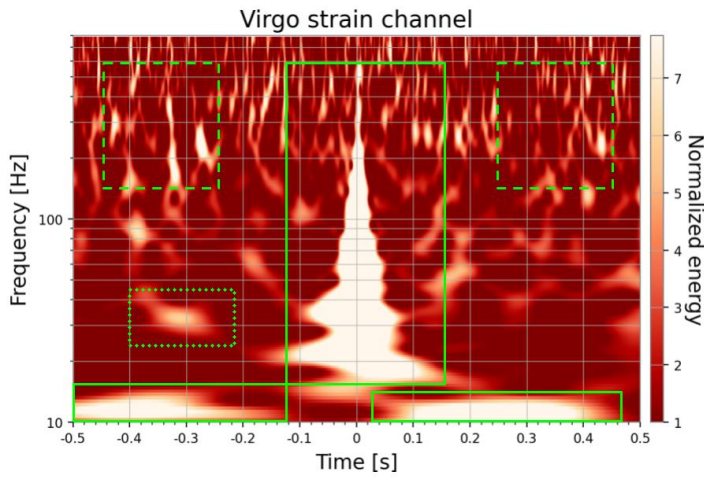


Scattered Light



Whistle

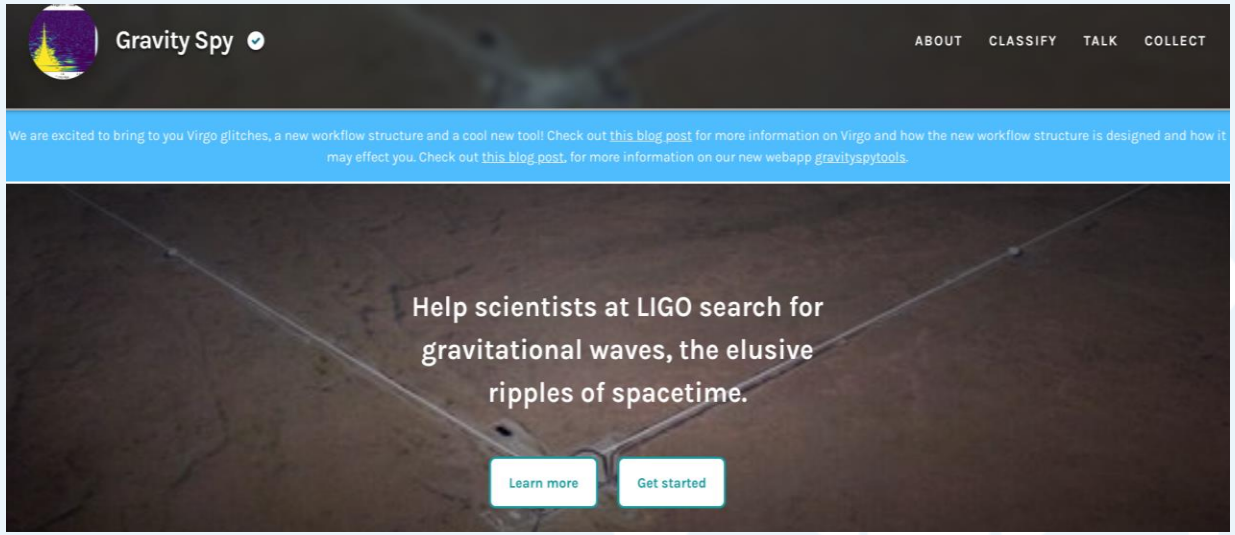
Many Glitches



Glitches and citizen science

- **Machine Learning approach**
  - Promising to classify complex time-frequency patterns of glitches (timeseries/images)
  - Large input required to train machine learning models
  - Not only for detector characterization. Various ML works for GW data analysis
  - Mostly supervised approach

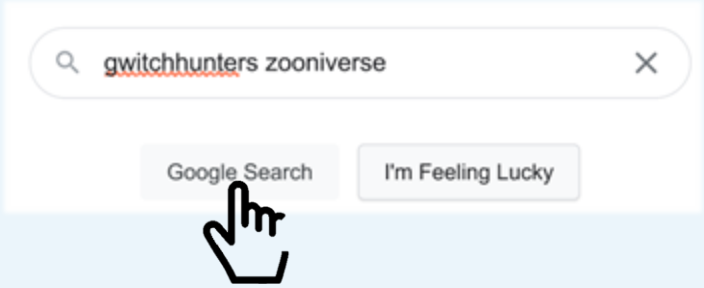
- **Citizen scientists can help**
  - Preparing labeled dataset (à la GalaxyZoo)
  - Time-frequency spectrograms (images)
  - Look at glitches & other noise sources and help characterizing them
  - Unveil novel glitch classes
  - Success story: Gravity Spy on Zooniverse (2016) by LIGO team and NSF

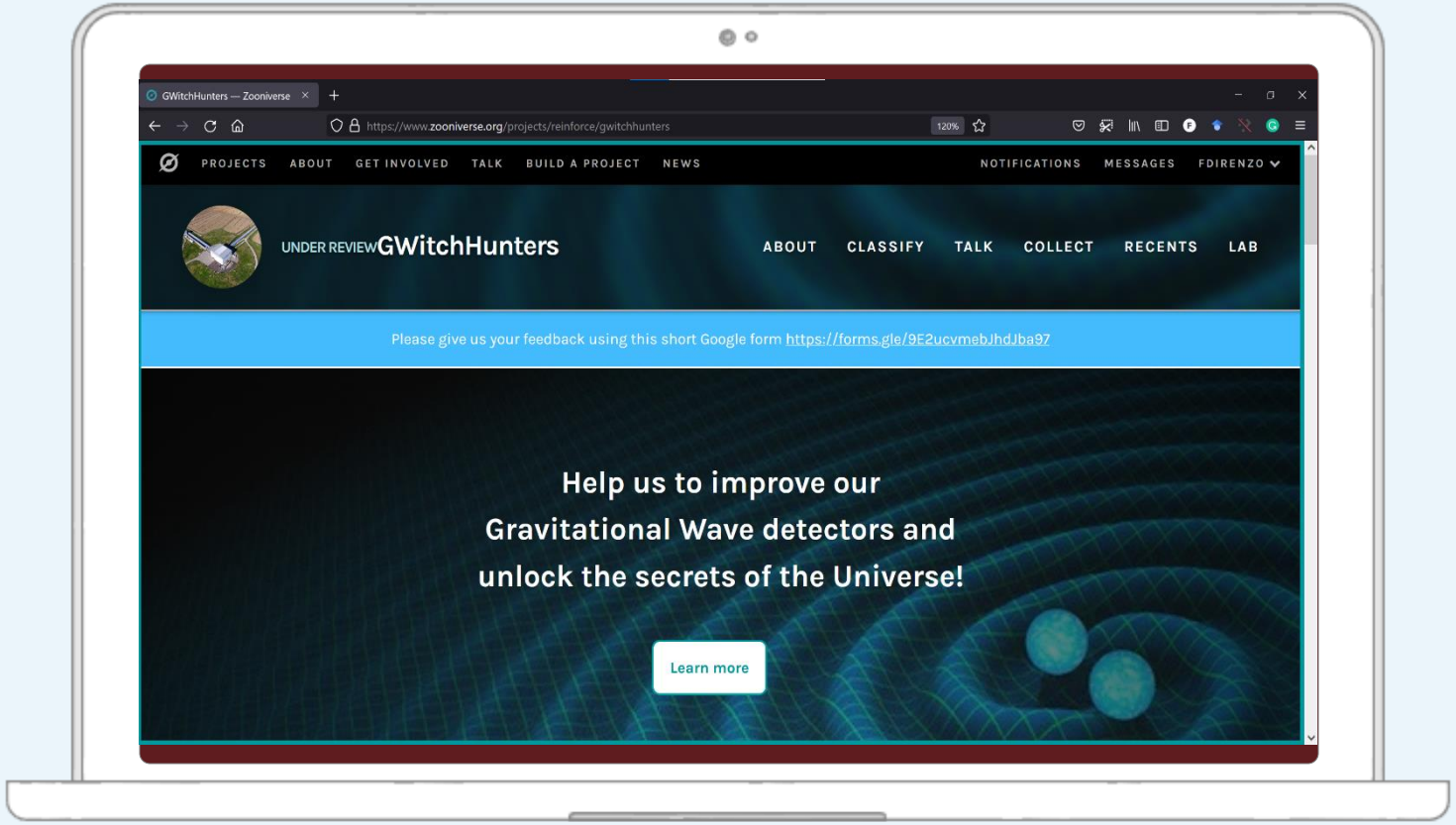


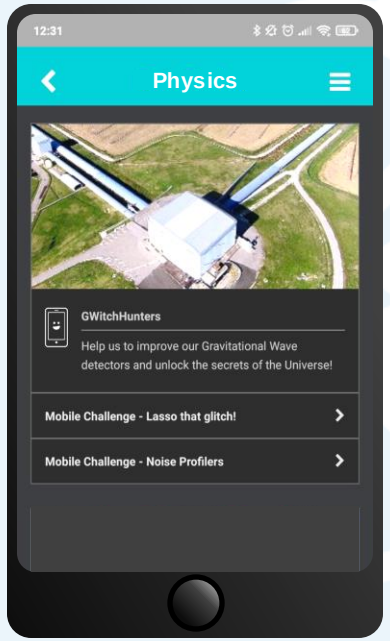
https://www.zooniverse.org/projects/zooniverse/gravity-spy

GWitchHunters: Anyone can contribute to GW Research

https://www.zooniverse.org/projects/reinforce/gwitchhunters, or just







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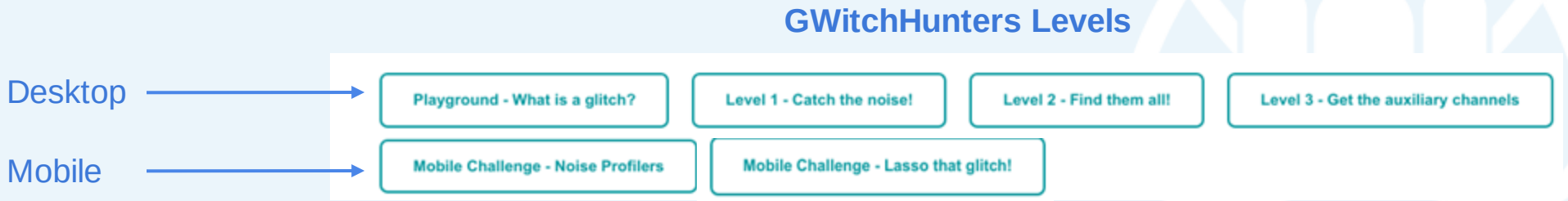
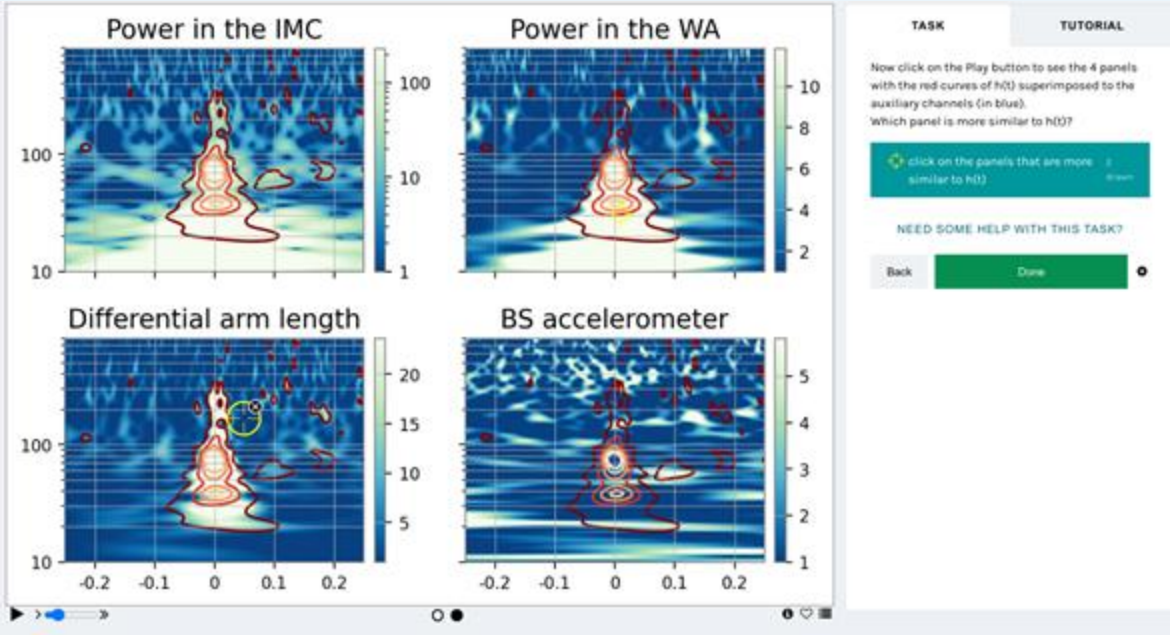
Highlights of GWitchHunters

- Introduce a **new, original** way to power GW research with citizen science
  - *GravitySpy* as a success story
  - Can we complement this approach?

- New frontiers
  - Go beyond classification tasks → **Noise hunting**
  - Include signals from sensors in the detector (“**auxiliary channels**”)
  - Run on mobile **devices**



Our Challenges



- **Be engaging and innovative**
  - **Attract** GravitySpy fans and more
  - Offer **new challenges** in GW science

- **More data, more fun!**
  - Auxiliary channels offer new insights into **how detectors work**
  - Auxiliary channels are not public. Prepared **ad hoc REINFORCE-EGO MoA**
  - As a result, an **updated & more rich dataset** than first dataset

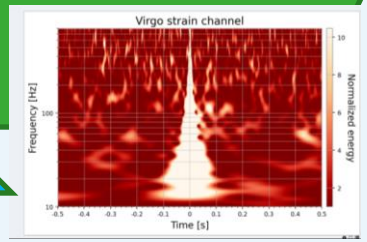
- **Go beyond glitches**
  - **Flexible workflow**, can accomodate other noise features (lines/slowly-varying noise)

Few words on data

- **Source data**
  - Real data from Advanced Virgo O3 (for the launch, next steps we plan to include LIGO)
  - Main "strain" channel (aka h(t)), also publicly available
  - Auxiliary channels, not public but available thanks to Virgo-EGO-REINFORCE MoA
- **Datasets**
  - Timeseries (+ preprocessing, whitening) to Time-Frequency image maps
  - Two Data Releases so far
    - DR01 (2021, launch) - 2000 glitches from O3a + 8 aux channels
    - DR02 (2022, follow-up) - +4000 glitches from O3b + 8 aux channels

GWitchHunters: The big picture

- Glitch triggers
- Noise features



Virgo Glitch Database

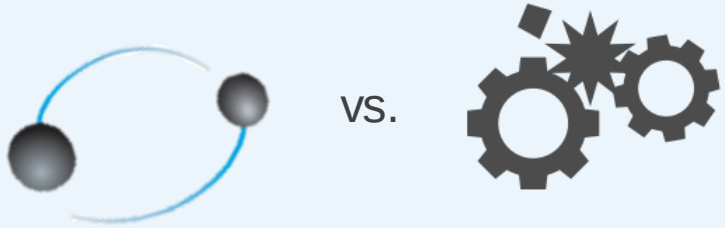
GWitchHunters
(labeling and characterization)

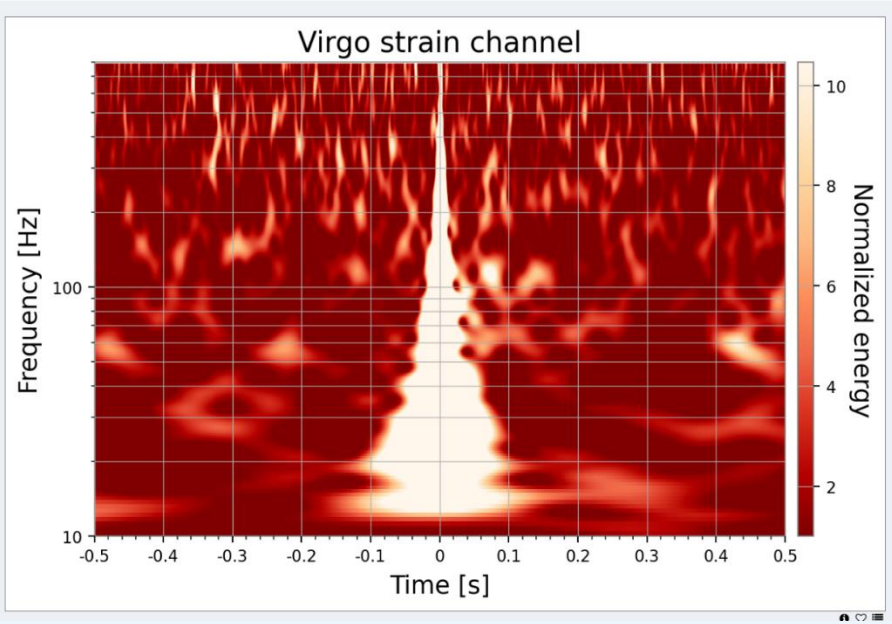
Process & ML training

Classes, aux channels
(i.e., Virgo detchar input)

Citizen Tasks: classification

- **Classify glitch morphology**
- **Similar noise features** are likely to share **similar origin**: learn to recognize them;
- Dedicated **Playground Level** for self-training
- **Get familiar** with the kind of data produced by G detectors and its noise features;
- **Distinguish transient noise** from **transient astrophysical signals** (coalescence of compact binaries)

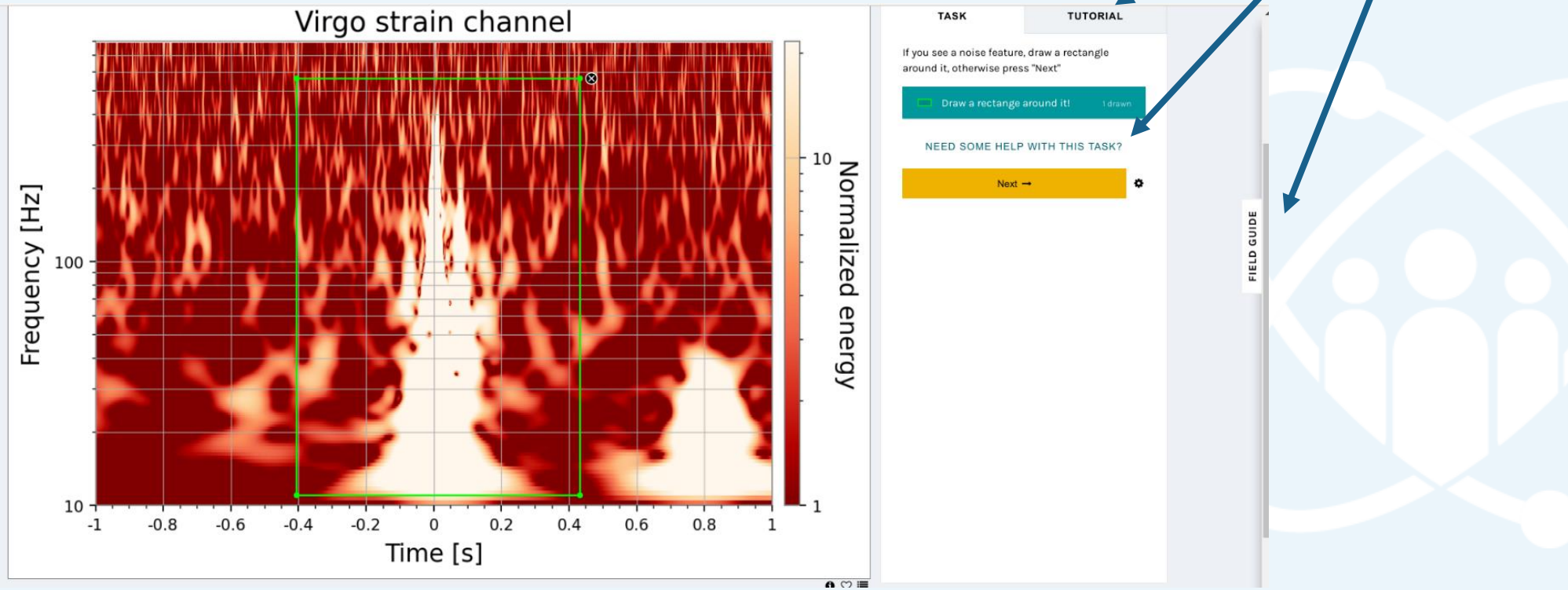




Citizen Tasks: identify noise features

- Draw rectangles around noise features

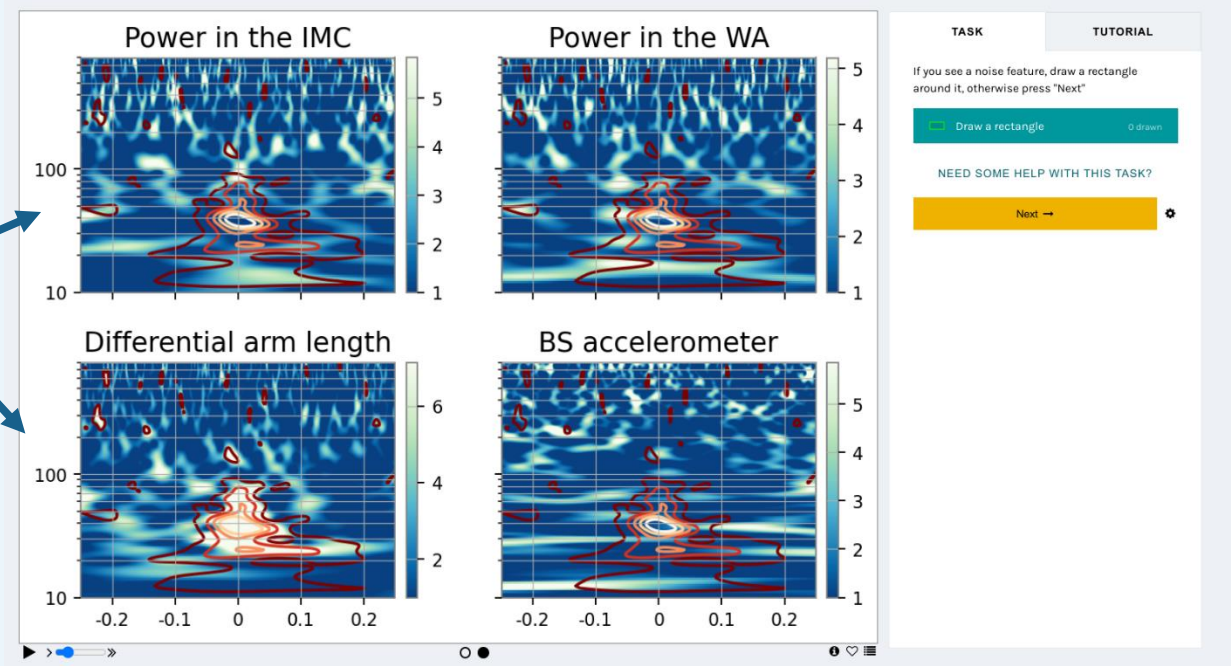
For each task
Tutorial, Help section,
and Field Guide



Citizen Tasks: correlations

- Check similar morphology between main physics channel (h(t) and auxiliary channels
- Big picture on the detector functioning;
- **Find similarities** in noise features and **discover the origin** of such disturbances;
- Help researchers get rid of the noise and improve detector sensitivity.

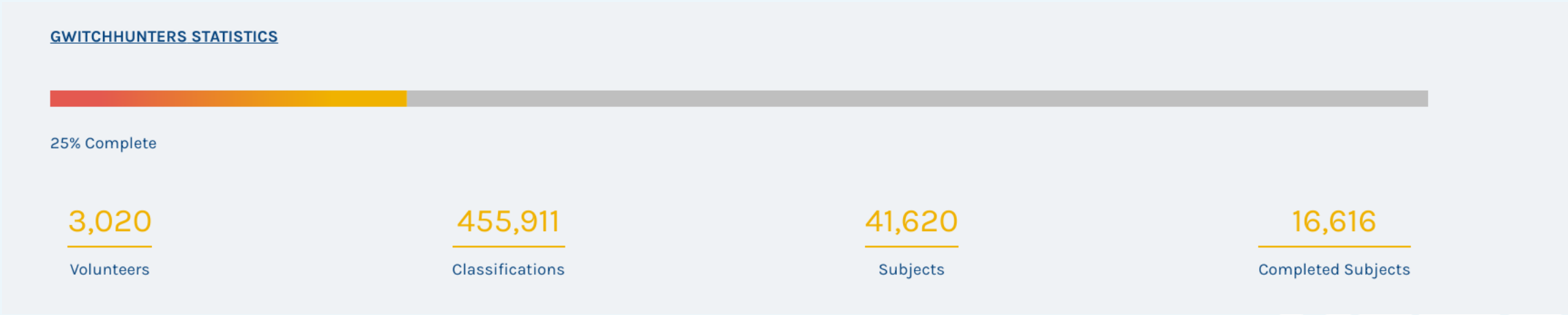
Auxiliary channels monitoring the detector and its environment



Where we are

Launched in Nov 2021, very good feedback from the citizens community

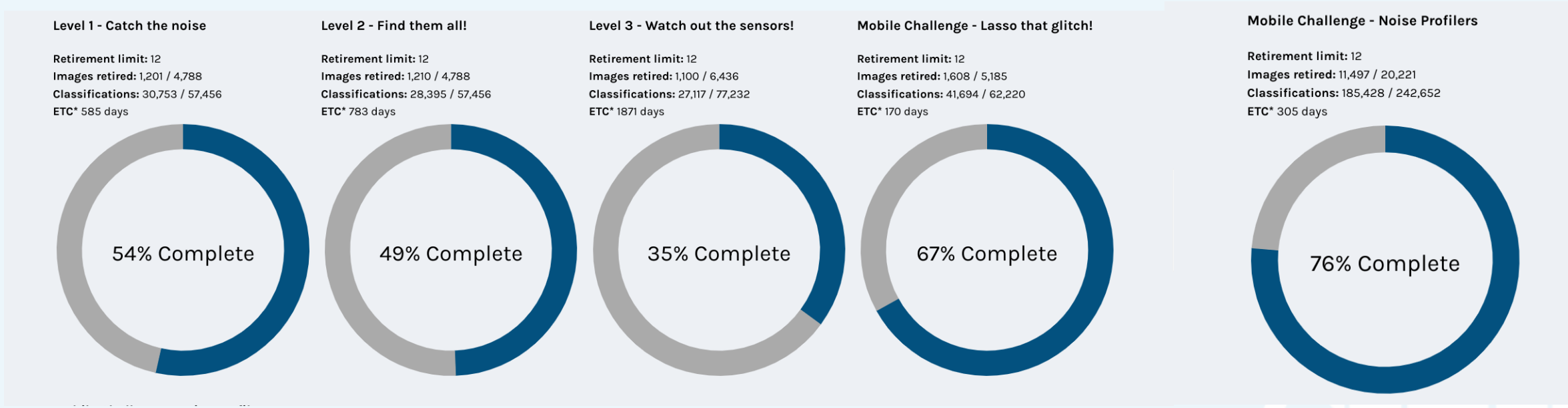
Some numbers (Aug 30,2022):



Mobile Challenges done quickly: first data release completed in mid Feb

Status of the tasks

Some tasks are in a very good stage

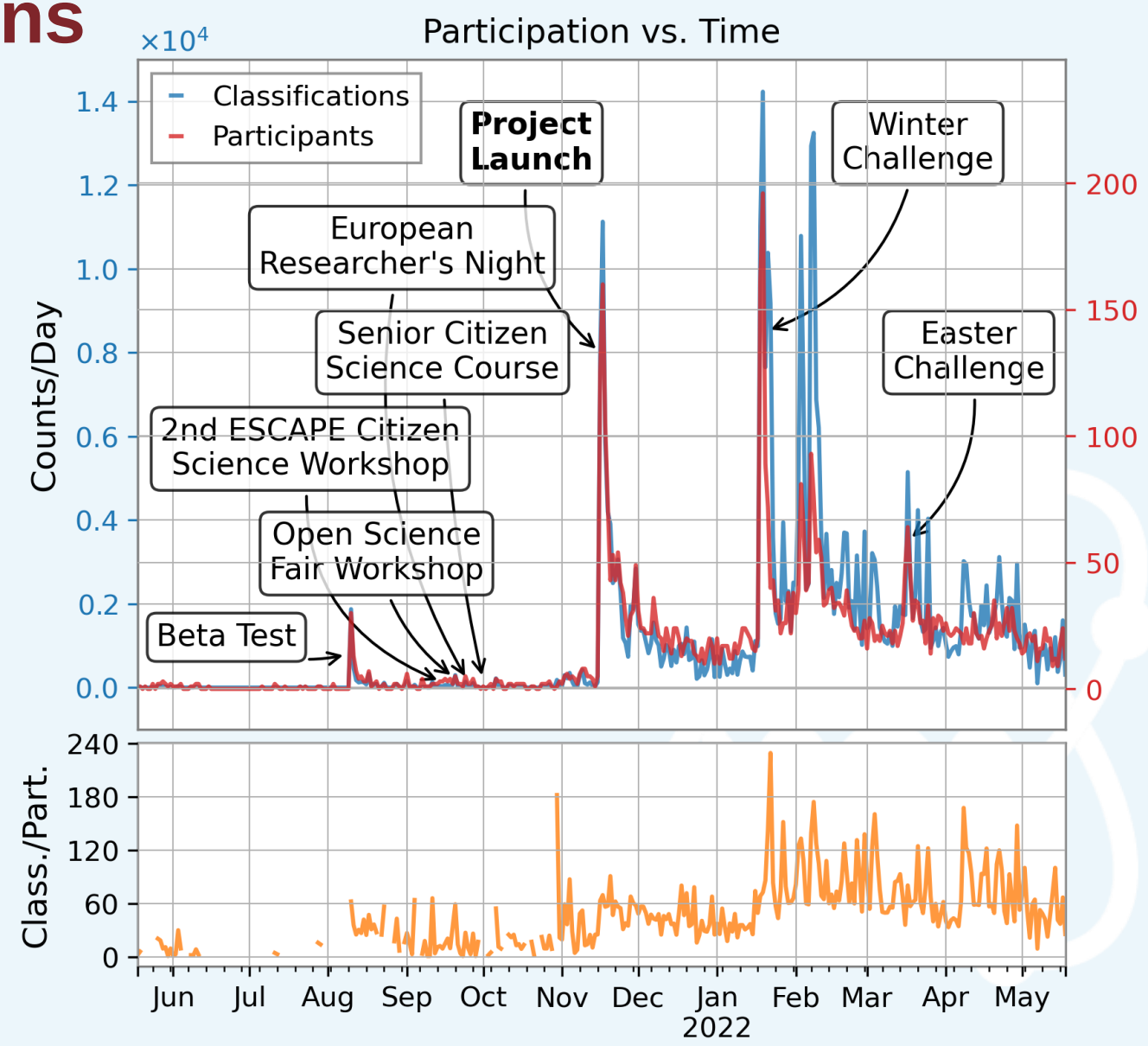


https://www.zooniverse.org/projects/reinforce/gwitchhunters

Engaging citizens

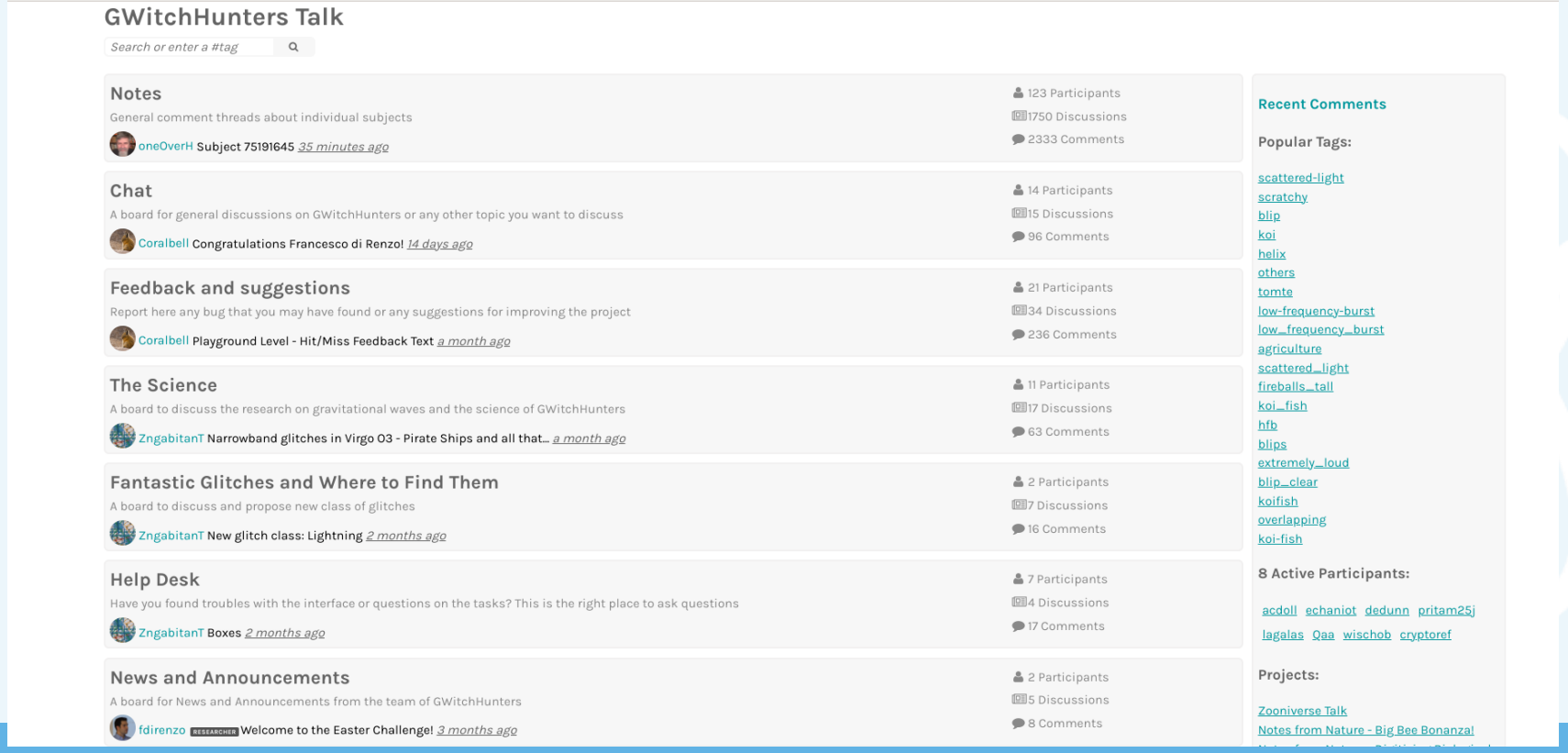
Many initiatives to promote the project

- Winter/Easter challenges
- Dedicated Workshops
- Events
- Course
- International Summer School



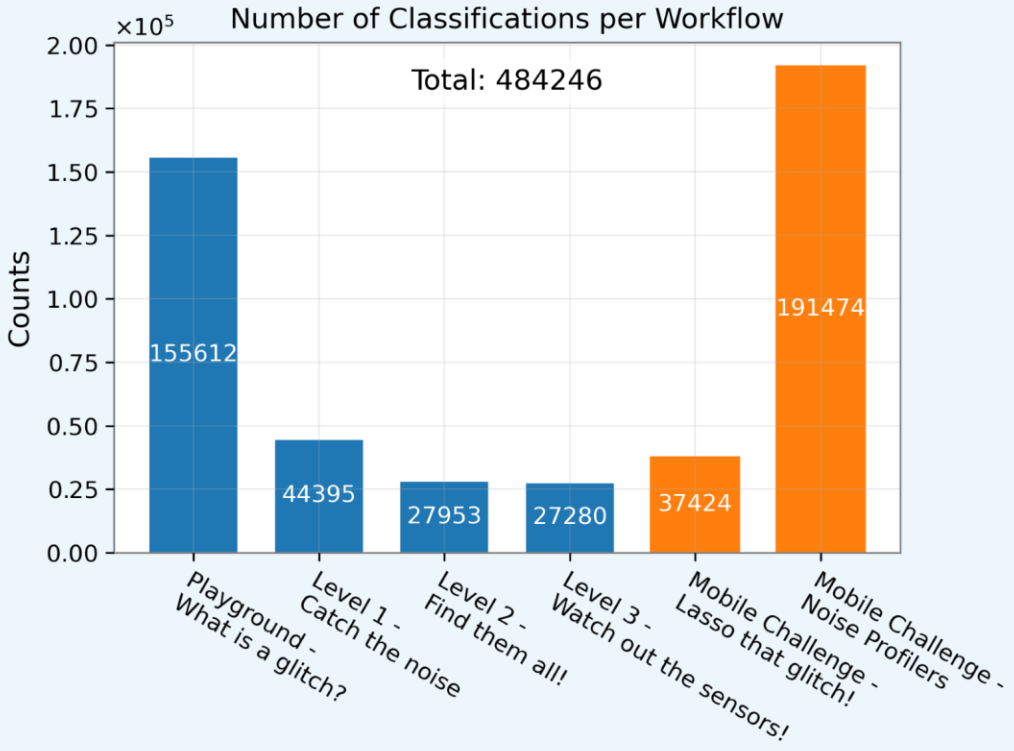
Interaction with citizens

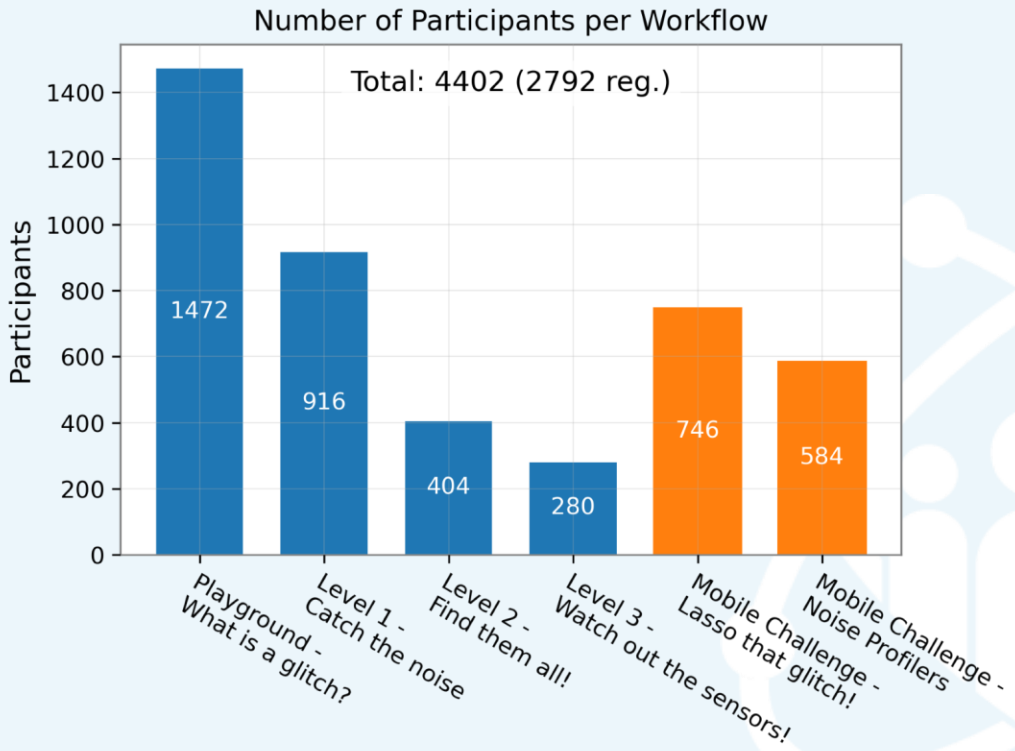
- Discussion forum very active! (>100 active participants, >1700 discussions)
- New Challenges launched: "Fantastic Glitches and where to find them"
- (6 new classes proposed, under discussion)



Highlights of results

- Detailed study of distributions of efforts among levels
- Mobile levels very effective (as expected)

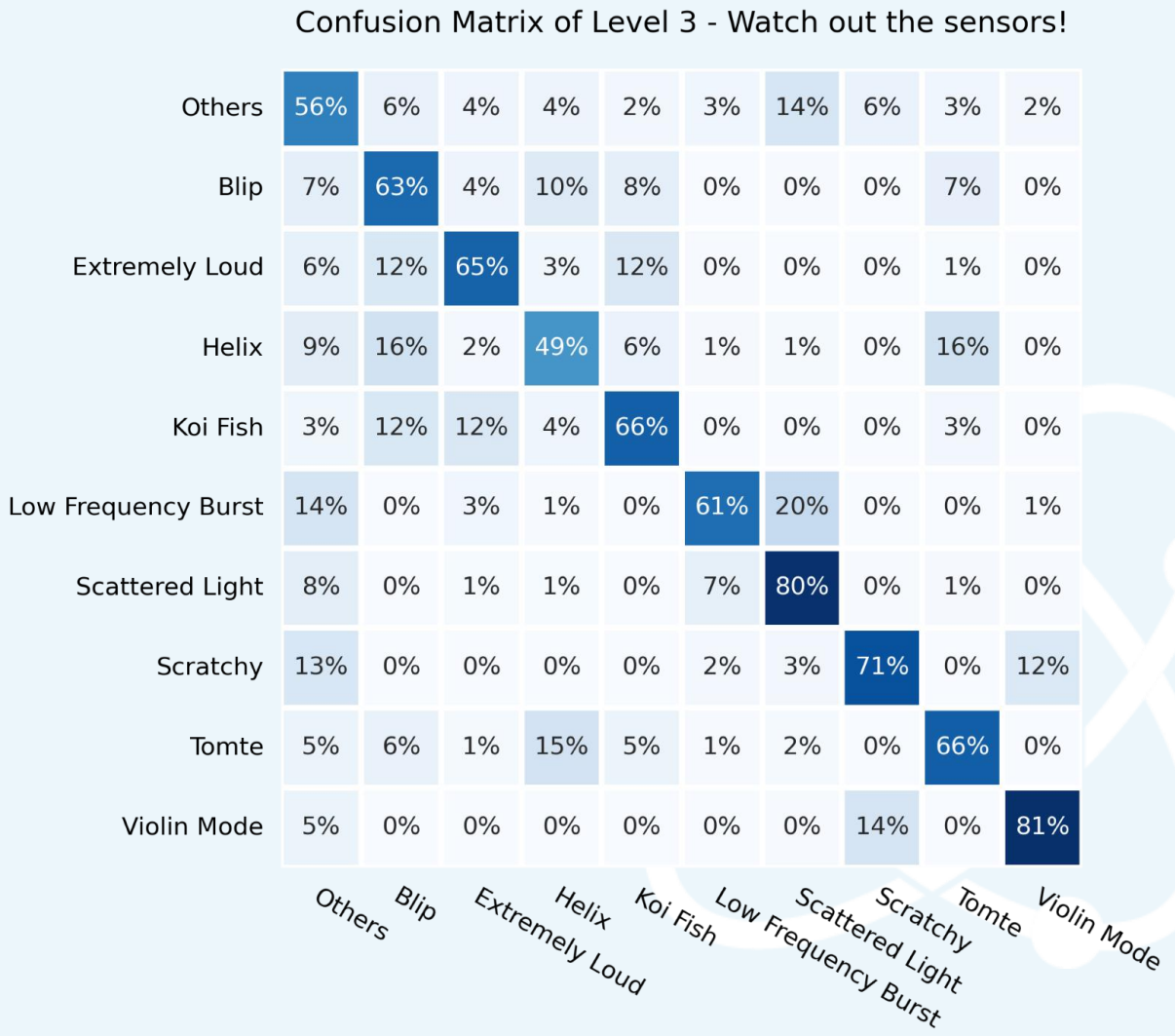




Data from May 18,2021 to Jul 15 2022

Highlights of results

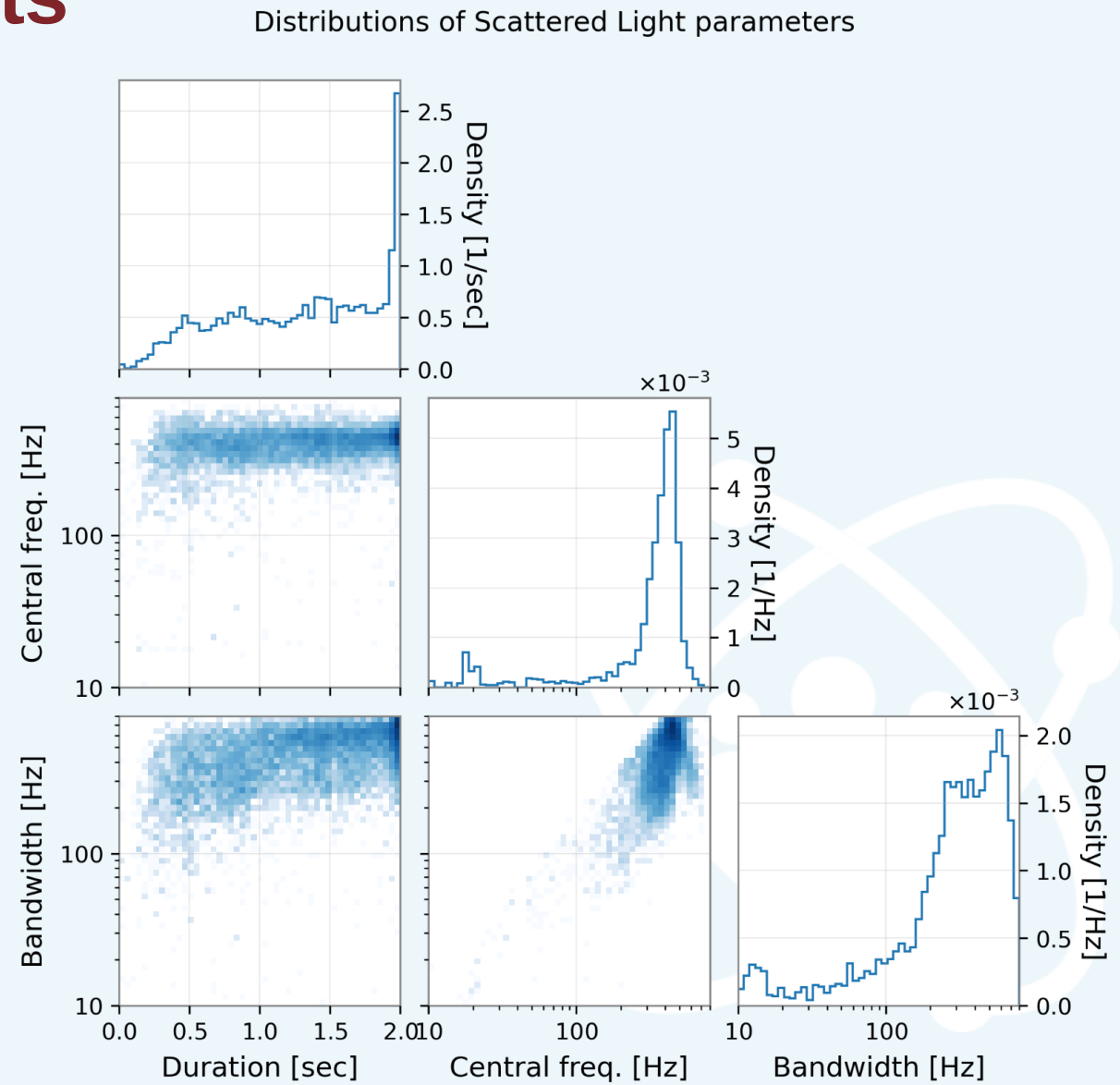
- Putative class assigned on majority vote
- Results good for some classes, for other requires more data



Data from May 18,2021 to Jul 15 2022

Highlights of results

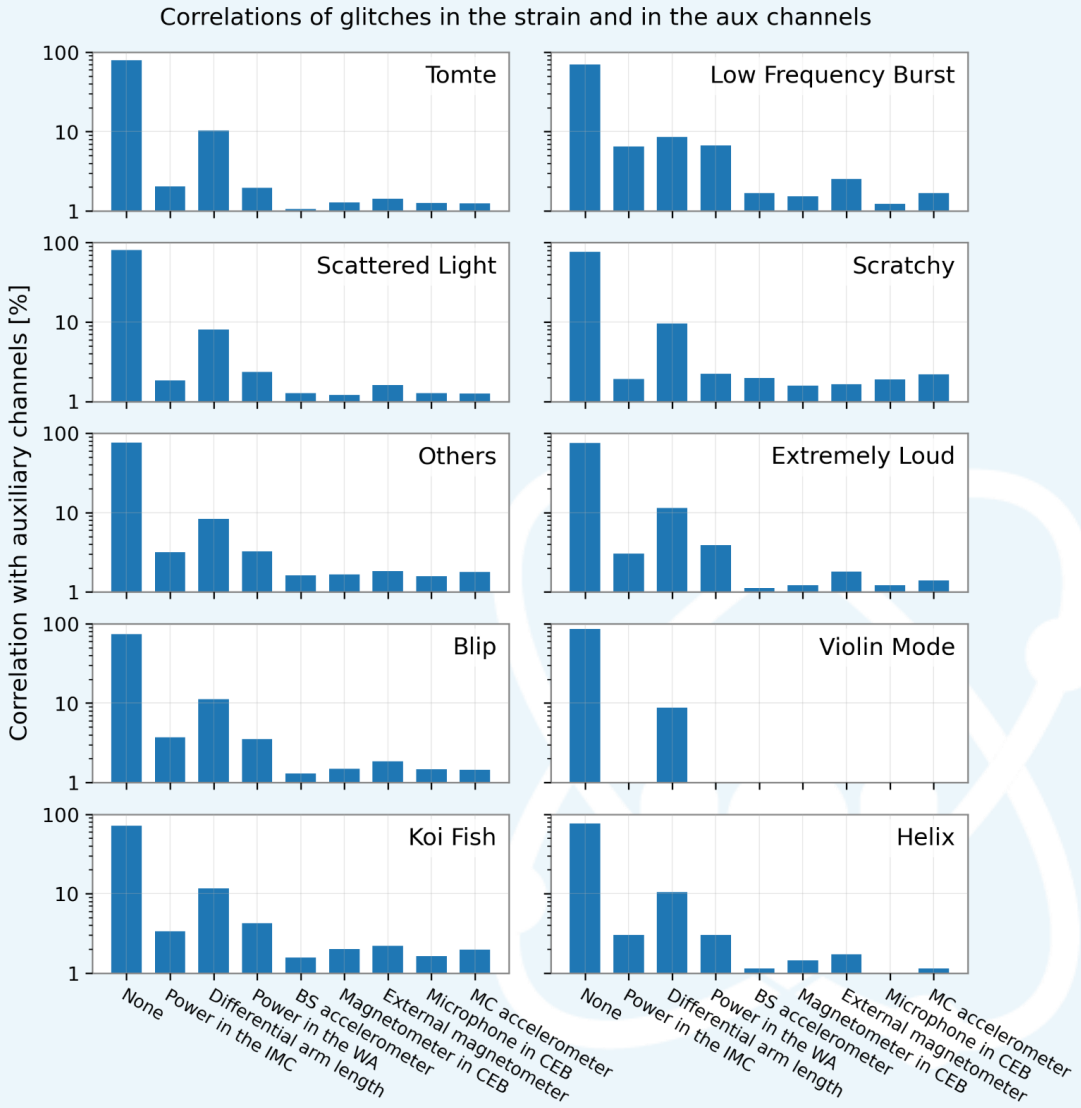
- Useful to find glitch parameter distribution
- Better discrimination among glitch classes



Data from May 18,2021 to Jul 15 2022

Highlights of results

- Only 8 channels, many info already
- DARM correlation is a known fact
- Useful to show how glitch with similar morphology correlate with different aux channels (e.g. Scattered Light and Low Frequency Bursts)



Data from May 18,2021 to Jul 15 2022

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The road ahead

- **GWitchHunters project on Zooniverse**
  - Successfully launched: we keep monitoring the data inflow
  - New datasets included
  - New challenges for citizens (e.g. find new glitches)

- **Data Analysis**
  - We have started the first analysis using the data collected so far
  - Development based on simulations
  - Comparison CNN/human in progress
  - Not only classifications, processing regression and localization

- **Next steps**
  - Add new glitch datasets & new auxiliary channels
  - Offer novel challenges for data exploration & noise hunting
  - Project is growing! Involve more people interested, etc...

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