COSMIC MUON IMAGES: REINFORCE MUON TOMOGRAPHY CITIZEN SCIENCE DEMONSTRATOR

Theodore Avgitas[1] & Jacques Marteau[2]

Institut de Physique des deux Infinis de Lyon (IP2I), Villeurbanne, France

[1]avgitas@ipnl.in3p3.fr, [2]marteau@ipnl.in2p3.fr

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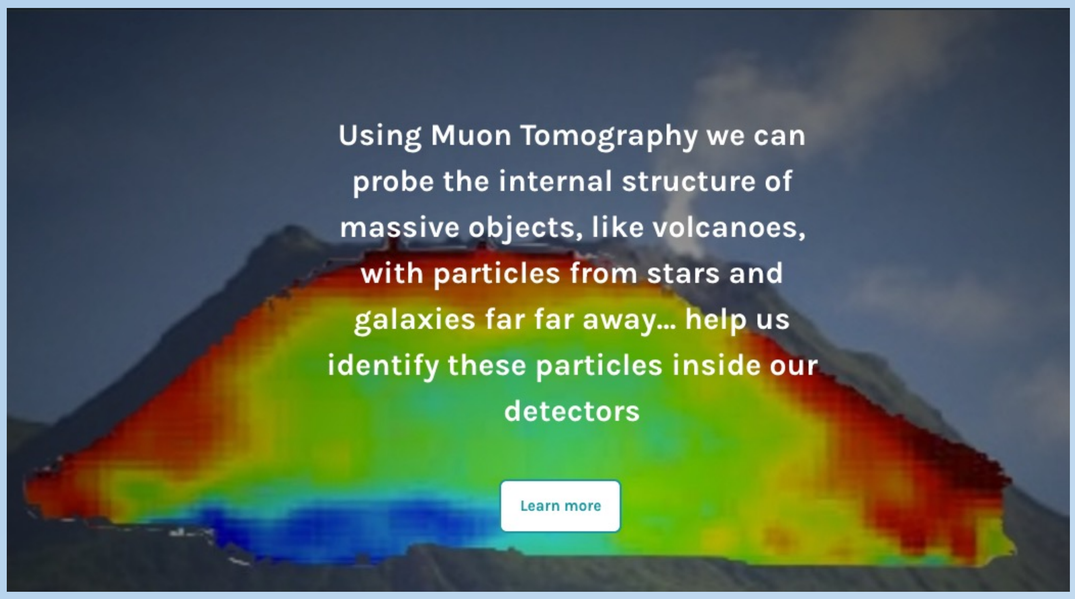
MUON TOMOGRAPHY

is an imaging technique that uses secondary cosmic rays, specifically **muons**, to probe the internal density distribution of massive objects. It has proved very successful especially in **Volcanology** but also in other fields like **Archaeology** and **civil engineering**. A particle detector is placed behind the object under study (target) and measures the incoming cosmic muon flux. The comparison of this experimental flux with the theoretical **muon spectrum**, in the absence of the target, is used to calculate the mass distribution within the detector's field of view. Given the dimensions of the object this mass distribution can be converted to a **density histogram** for the internal structure of the object. Furthermore, detectors with **timestamped** data acquisition can turn into **monitoring** instruments for **lahars** and other dangerous mass displacements which can prove **catastrophic** for people and their communities.

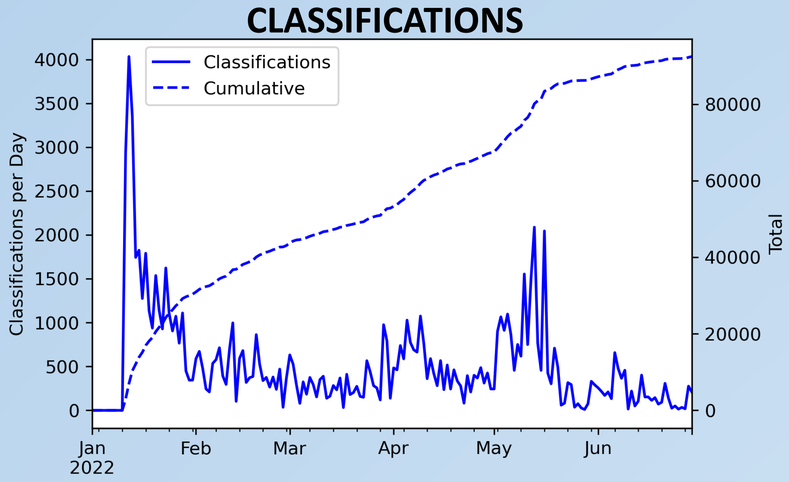


Cosmic Muon Images

is a citizen science project developed within the REINFORCE collaboration that aspires to familiarize people with **muon tomography** and **particle detection** techniques through active participation. Citizen scientists analyze data acquired during the **Arché** mission of 2018 to the archaeological site of **Apollonia** in Khalkidhiki, Greece. These are data that were excluded from the analysis as **background**. Our volunteers use tools provided by the Zooniverse platform to identify patterns within these data. A combination of lines and hits surrounding them is used classify the most prominent features for these events. This work entails that volunteers become familiar with the detection principle and the background types for muon tomography through the materials found on the website. These results will be used to develop background rejection algorithms through **Machine Learning** and will improve our understanding on the background itself.

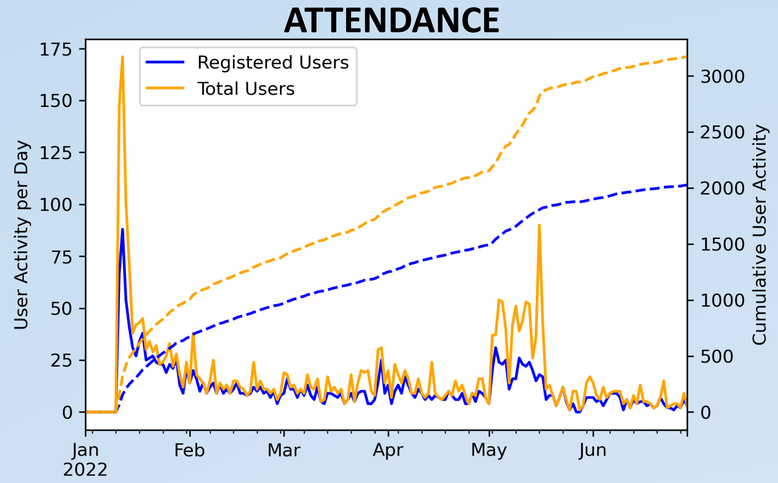
Live Time	Volunteers	Classifications	Subjects	Completed Subjects
169 days	977	92,217	17,628	12,372

CLASSIFICATIONS



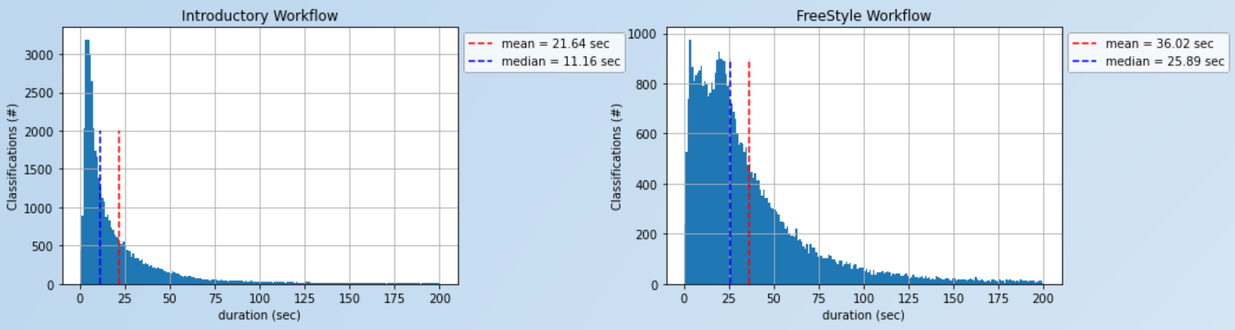
During the six-month duration of the project, we have seen a fair number of daily classifications. So far more than 90.000 classifications have been completed and the number is constantly rising due to the commitment of the most loyal citizen scientists. The spikes in participation during April and May are the result of interesting challenges and informative talks to spice up the interest of our attendees.

ATTENDANCE



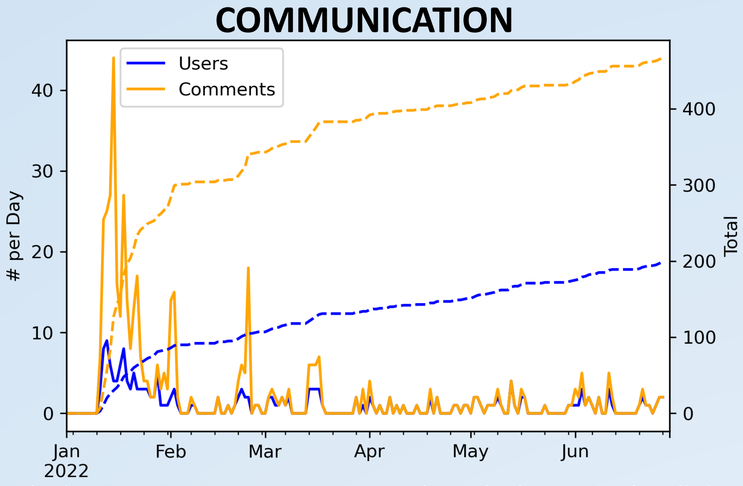
Citizen scientist visit our project's webpage daily and perform classifications. At the start of the project the attendance was at its peak but since then few people return to the project. Nevertheless, these are the most loyal and a recent analysis showed that 10% of the volunteers perform 50% of the total classifications. Since this kind of projects rely on few individuals it is always useful to find ways to reach out to them and ask for their feedback.

CLASSIFICATION TIMESCALES



Our project hosts two workflows, the Introductory that treats simple cases and one with more complicated topologies named Freestyle. The average time per classification for both workflows would be 28 sec but in half cases the classification time will not exceed 19 sec. Since for an expert a classification shouldn't take more than 10 sec, these times show that indeed citizen scientists perform these tasks with care and to the best of their understanding.

COMMUNICATION



Citizen scientists can reach the Cosmic Muon Images team through the project's talk boards. The conversation revolves mostly around pattern identification and event topology. People often ask for guidance and clarifications on topics not covered by the materials of our site. The most active period was the first month of the project when most important issues were addressed, since then most question come from newcomers.

OUTLOOK

Reinforce is coming to its conclusion by the **end of** 2022 but this is not the end of the journey for **Cosmic Muon Images**. We are currently analyzing the data from the two workflows and while the Apollonia datasets are far from being exhausted, we have plans for two more new workflows with data from **Volcanology**. Our detector in Iceland is scanning the interior of **Snæfellsjökull stratovolcano** and its **glacier**, a very important site so much for its **geological** as much for its **ecological** implications, since glacier melting is directly relating to **climate change**. We look forward to this and the discussions it will trigger on **ecology**, volcanology and the comparison with the Apollonia dataset.


Snæfellsjökull, Iceland


Apollonia, Greece

Cosmic Muon Images

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Come and play with our Cosmic Muon Images Zooniverse project at
https://www.zooniverse.org/projects/reinforce/cosmic-muon-images

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