PROCEEDINGS OF SCIENCE

REINFORCE-ing citizen science

Manolis Chaniotakis,[a,*] **Francesco Di Renzo,**[b,c,*] **Christine Kourkoumelis,**[d,*] **Grace Milne**[e] **and Francesca Spagnuolo**[f]

[a] *Ellinogermaniki Agogi,*
GR-15351, Pallini, Greece
[b] *Università di Pisa,*
I-56127 Pisa, Italy
[c] *INFN, Sezione di Pisa,*
I-56127 Pisa, Italy
[d] *National and Kapodistrian University of Athens,*
GR-10679 Athens, Greece
[e] *The Lisbon Council,*
B-1040 Brussels, Belgium
[f] *European Gravitational Observatory (EGO),*
I-56021 Cascina, Pisa, Italy

E-mails: echaniot@ea.gr, francesca.spagnuolo@ego-gw.it

REINFORCE (REsearch INfrastructures FOR Citizens in Europe) is a "Science with and for Society" (SwafS) project, funded by the European Union under the Horizon 2020 research programme. REINFORCE partners have developed four demonstrators, two of which were presented in a hands-on session during the Engaging Citizen Science Conference 2022 in Aarhus, Denmark. In the "Search for new particles at CERN" demonstrator, citizen scientists contribute to the search for undiscovered particles at the ATLAS experiment, while in the "GWitchHunters" demonstrator, they contribute to the improvement of the sensitivity of the current generation of gravitational-wave detectors.

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*Speaker

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1. Introduction to the REINFORCE project

Even though scientific research in frontier physics has provided humankind with breakthrough discoveries, the knowledge and skills needed to understand these discoveries and their impact on society are far beyond the reach of the average citizen. Citizens are mainly exposed to discoveries through outreach activities and press coverage, which, while being effective in temporarily drawing their attention to science, do not provide opportunities for active participation in the pursuit of new scientific knowledge. Going beyond outreach, citizen science has the great potential to bridge the gap between cutting-edge research in physics and society, and the ability to support citizens to become critical consumers of and contributors to scientific knowledge. The REINFORCE project (REsearch INfrastructures FOR Citizens in Europe) [1] is a "Science with and for society" (SwafS) project, funded by the EU-H2020 research programme. The project brings together expertise from world-leading large research infrastructures and research institutions in frontier physics with citizen science, science education, social innovation, policy and economic competitiveness with the goal to design, explore, support, implement and assess the impact of a series of pioneering research infrastructure-powered citizen science initiatives (demonstrators) for the benefit of science and society. As the field of frontier physics is rapidly growing in sophistication, several questions arise over the actual effectiveness of citizen engagement. In particular: Can citizen science help minimise the knowledge gap between large research infrastructures and society and help reinforce the science capital of citizens? Are untrained citizens able to develop new scientific knowledge and contribute to sophisticated scientific fields? Is it possible to balance inclusive citizen engagement with scientific efficiency?

For the purpose of answering these questions, REINFORCE has developed a citizen engagement methodology based on the state-of-the-art literature on citizen science [2], and has produced a dedicated template of a citizen science project. In collaboration with researchers in the fields of Gravitational Wave Astronomy (Virgo detector), High Energy Physics (ATLAS experiment at CERN), Neutrino Physics and Astronomy (KM3NeT experiment) and Cosmic Muon Tomography, four Citizen Science "demonstrators" have been developed utilising the Zooniverse platform [3]. The demonstrators provide citizens with open access to the data from these fields, encourage them to support the optimisation of the associated infrastructures and create an open communication channel with researchers and peers. Finally, a rich inclusion and diversity programme has been included in the project supplemented by a platform for demonstrator data sonification for the benefit of citizens with visual and multimodal impairments. In order to engage citizens from different target groups (such as the general public, students, teachers, senior citizens, and citizens with visual and multimodal impairments) and different countries, a dedicated framework has been developed adapting to the different needs of each target group. The overall recruitment of citizens has been done via the organization of a large dissemination campaign which included webinars, events for the general public (such as art and science events), virtual visits to labs, dissemination within Zooniverse as well as dissemination to the large networks of teachers and students operated by consortium members. More than 100,000 citizens have been informed about the proposed approach through this rich dissemination programme. The engagement of citizens has been achieved and sustained through the organization of dedicated activities, including visionary workshops, online and face to face training workshops, summer and winter schools, online challenges as well as the production of training material and online tutorials embedded within the pages of

the demonstrators [4]. Furthermore, the Zooniverse platform offered the opportunity to manage large communities of citizens and foster interaction with researchers through dedicated forums. More than 10,000 citizens are actively collaborating in REINFORCE thanks to these activities and have contributed more than 650,000 classifications. Finally, citizens have offered their feedback through practice reflection workshops and dedicated surveys, and a mechanism has been created to ensure the empowerment and accreditation of citizens by offering them recognition for their contribution and advanced role in the project activities.

2. The GWitchHunters project for the improvement of gravitational-wave detectors

GWitchHunters [5] is a citizen science demonstrator developed with the objective of involving citizens in the field of gravitational-wave research. In particular, this project aims at delivering a deeper, but easily accessible, knowledge of the physics behind GW detectors and how these can be improved to achieve better sensitivity for the experimental study of the universe. The data recorded by GW detectors is presented in a form readily understandable by people without any specific expertise in physics or signal processing. The demonstrator focuses on transient signals like those expected from the coalescence of compact binary stars, such as the celebrated first detection event GW150914 [6], or other short excesses of energy of environmental or instrumental origin, colloquially referred to as "glitches". To visualise them, GWitchHunters makes use of spectrogram images, which are heat maps showing the evolution of the signal energy with time and frequency.

In order to make concepts like energy and frequency more accessible, REINFORCE has developed new sonorisation strategies to convert spectrograms into sounds. This is achieved by associating every frequency interval of these spectrograms to the corresponding note of the C-major scale of Occidental music, which corresponds to the white keys of a piano keyboard. Then, the energy in each band is associated with the intensity one plays the corresponding note. This strategy encourages practical demonstrations of signal examples at outreach events or in schools, making use of common musical instruments. From these images and sounds, one can recognise the peculiar shapes and tones associated with the coalescence of compact binary stars and those from glitches of terrestrial origin, which scientists seek to remove. This is one of the tasks that the participants in this project are asked to accomplish. Moreover, besides the data channel that records the gravitational-wave strain, GW detectors constantly monitor the status of their instruments and environment with dedicated data acquisition channels. If we observe the simultaneous presence of a glitch in the main channel and in any of the latter, then this provides evidence for a terrestrial (i.e., instrumental or environmental) origin for that, and also provides researchers information on where in the detector this noise has originated from. This is very important for the identification of the various noise sources and, by removing them, the improvement of the detector sensitivities. This is also one of the tasks that citizens are asked to complete in GWitchHunters. This project is available via the Zooniverse web platform and mobile app [3], which include a user-friendly interface for data visualisation and performing the described tasks, as well as discussion boards about the science of gravitational-wave detectors and how to get in touch with researchers. In five months from the launch, dated 16 November 2021, about 4,000 volunteers have contributed to the demonstrator by scoring more than 350,000 glitch classifications.

3. New particle search at CERN

The purpose of the "New Particle Search at CERN" demonstrator uploaded on the Zooniverse platform is to allow citizens to explore the cutting-edge research done at CERN. It is designed for citizens to perform scientific research by using data recorded by the huge general-purpose ATLAS experiment [7] at the Large Hadron Collider (LHC) of CERN. Ten years ago, ATLAS—together with CMS—announced the discovery of the long sought-after Higgs boson. This was a major scientific achievement since it established the validity of the Standard Model (SM): the theory which describes the known elementary particles, how they attain their mass, and how they interact. Nevertheless, the SM does leave some fundamental questions unanswered which are addressed by a number of theories beyond the SM. In particular, theories that predict the existence of yet-undiscovered long-lived particles or decays of the Higgs boson into two photons, one (or both) of which convert into an electron-positron pair, can produce, in the sample of interactions to be examined, a so-called Displaced Vertex (DV). A DV is a point with two or more particle tracks located away from the main vertex, where the LHC proton-proton collisions take place. The task of the citizens consists in identifying these DVs, together with the tracks associated with them, in order to make potential discoveries of such beyond SM particles.

The demonstrator [8] was developed by a team of researchers at the Institute of Accelerating Systems and Applications (IASA) in Athens. By using specialised software developed by the IASA team [9], citizens search for visual evidence of signatures of new particles in the data collected by the ATLAS experiment and/or in the simulated data for their training. The users do not only classify static images, but also interact with the event display, select specific tracks, and calculate various kinematic quantities of interest for their "discoveries".

The demonstrator divides the citizens' path of study into a three-stage process. There is a tutorial for each stage, along with an extensive help session (including a video) provided on the platform. In the first two stages, the citizens are guided in locating DVs and identifying the traces which different particles leave in the detector, using simulated data. Each identification that the citizens perform is an important data point for REINFORCE, that will help in the team's goal of comparing humans and computers more accurately. In the third "discovery" stage, the citizens' results could lead to a discovery, which would be a direct proof of new physics and would highlight a path for future research. Since the launch of the platform in October 2021, there are already more than 165,000 classifications from approximately 2,400 volunteers. Several new particle discovery candidates have been found by the citizens and will lead to further detailed investigation by the IASA team.

4. Conclusions

The workshop concluded with a question and answer session, at which attendees and presenters engaged in critical discussion on how frontier physics citizen science projects can increase citizens' scientific literacy and tackle pseudoscience amongst the general public. By giving citizens the opportunity to participate in frontier physics projects such as gravitational wave noise hunting and searching for new particles, citizens are exposed to and become actively involved in scientific processes. A number of attendees were also curious to hear more about the process of hosting a

project on Zooniverse, as they had their own citizen-science projects that they were eager to bring to a wider audience.

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References

[1] "REINFORCE." www.reinforceeu.eu (2020).

[2] "REINFORCE D2.1 "Citizen Engagement Plan"." www.reinforceeu.eu/sites/default/files/2020-08/REINFORCE_D2.1CitizenEngagementPlan.pdf (2022).

[3] "ZOONIVERSE." www.zooniverse.org (2009).

[4] "REINFORCE Workshops and Training Courses." http://reinforce.ea.gr (2021).

[5] "GWitchHunters." www.zooniverse.org/projects/reinforce/gwitchhunters (2021).

[6] LIGO Scientific, Virgo collaboration, Observation of Gravitational Waves from a Binary Black Hole Merger, *Phys. Rev. Lett.* **116** (2016). 061102 [1602.03837].

[7] ATLAS collaboration, The ATLAS Experiment at the CERN Large Hadron Collider, JINST **3** (2008). S08003.

[8] "New Particle Search at CERN." www.zooniverse.org/projects/reinforce/new-particle-search-at-cern (2021).

[9] C. Kourkoumelis and S. Vourakis, HYPATIA—an online tool for ATLAS event visualization, *Phys. Educ.* **49**, 21 (2014).