IAU

OAE Mini-Review

Citizen Science

IAU OFFICE OF ASTRONOMY FOR EDUCATION

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The following is a collection of summaries originally published in the proceedings of the 3rd Shaw-IAU workshop on Astronomy for Education held 12 – 15 October, 2021 as a virtual event. The workshop was organised by the IAU Office of Astronomy for Education. More details can be found on: https://astro4edu.org/shaw-iau/3rd-shaw-iau-workshop/.

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The IAU Office of Astronomy for Education (OAE) is hosted at Haus der Astronomie (HdA), managed by the Max Planck Institute for Astronomy. The OAE's mission is to support and coordinate astronomy education by astronomy researchers and educators, aimed at primary or secondary schools worldwide. HdA's hosting the OAE was made possible through the support of the German foundations Klaus Tschira Stiftung and Carl-Zeiss-Stiftung. The Shaw-IAU Workshops on Astronomy for Education are funded by the Shaw Prize Foundation.

The OAE is supported by a growing network of OAE Centers and OAE Nodes, collaborating to lead global projects developed within the network. The OAE Centers and Nodes are: the OAE Center China–Nanjing, hosted by the Beijing Planetarium (BJP); the OAE Center Cyprus, hosted by Cyprus Space Exploration Organization (CSEO); the OAE Center Egypt, hosted by the National Research Institute of Astronomy and Geophysics (NRIAG); the OAE Center India, hosted by the Inter-University Centre for Astronomy and Astrophysics (IUCAA); the OAE Center Italy, hosted by the National Institute for Astrophysics (INAF); the OAE Node Republic of Korea, hosted by the Korean Astronomical Society (KAS); OAE Node France at CY Cergy Paris University hosted by CY Cergy Paris University; and the OAE Node Nepal, hosted by the Nepal Astronomical Society (NASO).

Citizen Science

Session organiser: Asmita Bhandare, Office of Astronomy for Education, Germany and CRAL/ENS Lyon, France

Session overview

In the last few years, several citizen science projects have been very successful in introducing and engaging the public in authentic research. Citizen scientists continue to be a valuable asset in helping scientists tackle large data sets and extract useful information to solve some exciting mysteries of the universe.

This session included contributions from several ongoing citizen science initiatives across the globe, with an aim to encourage participation in various projects and even motivate anyone who wants to set up their own citizen science projects.

The keynote speaker, Molly Simon introduced the concept of citizen science and highlighted the past, present and future projects on Zooniverse, which is the largest online platform for citizen science. Ananda Hota shared his experience on establishing the first ever Indian citizen science project - RAD@Home, involving several research institutes and successfully engaging the public in various research projects. Masayuki Tanaka introduced Galaxy Cruise, a citizen science project run in Japan, which is an exciting opportunity for the public to use imaging data taken with the Subaru Telescope to help identify interacting galaxies. Marc Kuchner gave an overview of NASA's growing citizen science program and discussed the lessons learned from various projects. Pamela Gay emphasized on providing a supportive, diverse and inclusive community for anyone who wants to be a citizen scientist and shared insights on ways of adapting this in citizen science initiatives.

Lastly, four additional citizen science projects were highlighted as poster contributions about monitoring meteor shower activities using machine learning (by Siddha Ganju), using citizen science as a tool for science popularization (by Felipe Sérvulo Maciel Costa), tracking effects of the solar eclipse on GPS signals (by Carla Hernández), and a project involving the science of gravitational wave detectors (by Francesco Di Renzo).

Why Citizen Science: Unlocking the Potential of People-Powered Research

Speaker: Molly Simon, Arizona State University, USA

Collaborators: Laura Trouille (Adler Planetarium, Northwestern University), Chris Lintott (University of Oxford), Edward Prather (University of Arizona), Isaac Rosenthal (UMass - Boston)

The vast wealth of astronomical datasets produced by modern surveys - and our shared access to the sky - make astronomy a natural home for citizen science projects which provide participants with authentic experiences of scientific practice. In this talk, I will draw on examples both historical and contemporary from the Zooniverse, to ask what makes an effective citizen science project and how such projects can be incorporated in broader engagement programs. I will conclude by highlighting the new classroom.zooniverse effort to bring data-rich, citizen science-based, classroom experiences to introductory undergraduates across a wide array of disciplines.

Talk link: https://youtu.be/A4Tn2w3V_0c

With the expansion of big data, many research teams across a variety of disciplines are left with more data than they have time to analyze independently. Citizen science (commonly referred to as people-powered research), is an invaluable method that involves crowdsourcing aspects of the data analysis process, enabling research teams to solve problems involving large quantities of data more efficiently while simultaneously taking advantage of the inherently human talent for pattern recognition and anomaly detection (see e.g. Trouille et al. 2019 and the references therein). Zooniverse (https://www.zooniverse.org/) is leading the way in providing a robust platform for online citizen science. Since its inception in 2007, the Zooniverse has hosted over 350 projects with over 2 million registered volunteers making over one million classifications across the platform weekly. These projects have led to more than 200 peer reviewed publications to date (https://www.zooniverse.org/about/publications).

At a time when citizen science is gaining in prominence across the world, the Zooniverse has become a core part of the research infrastructure landscape. The Zooniverse encourages participation in active research by supporting the general public to contribute to the cleaning, annotating, and processing of scientific data. Zooniverse projects also facilitate direct interaction between citizens and scientists. Raddick et al. (2013) found that the most important motivator for Zooniverse volunteers is the desire to contribute to ongoing scientific research. Through the Zooniverse discussion forums, volunteers discuss objects of interest, generating hypotheses and examining them in the light of new evidence, alongside members of the research team. In addition, each Zooniverse project has a blog and other social media outlets through which research team members share results of the data analysis, publications, and more.

Considering that classifying on Zooniverse projects has a considerably low barrier to entry (volunteers simply need an email address), the Zooniverse team has invested considerable thought and effort to ensure data quality and reliability. Lack of specialist knowledge or misclassification can lead to errors within data produced by citizen scientists (Freitag et al. 2016). Zooniverse's approach to citizen science directly addresses these concerns and has led to an established track record of producing quality data for use by the wider scientific community. By creating consensus results based on numerous classifications, researchers working with Zooniverse have been able engage a disparate crowd of volunteers to produce reliable results (e.g., Lintott et al. 2008, Schwamb et al. 2012, Johnson et al. 2015), leading to discoveries both intentional and serendipitous. Within the field of astronomy in particular, citizen scientists have contributed to the discovery of new exoplanet candidates (Zink et al., 2019, Eisner et al. 2020), identified previously undiscovered protoplanetary disks (Kuchner et al. 2016), and revolutionized astronomers' understanding of galaxy morphologies (Masters et al. 2019). This list is by no means exhaustive, and accounts for just a tiny fraction of the discoveries Zooniverse volunteers take part in on a regular basis.

The Zooniverse is an excellent resource when integrating an authentic research component into college-level general education science courses. By providing these students with insight into what actual scientists do, and how modern data analysis works, citizen science can be used as a tool to contribute to a more scientifically and data literate population of learners. To this end, we have developed four lab-type activities aimed to improve college students' data literacy while emphasizing that citizen scientists make valuable contributions to a variety of scientific disciplines.

Two of these activities based around the topics of extrasolar planets and climate change, incorporated data from the Zooniverse projects Planet Hunters (`www.planethunters.org`) and Floating Forests (`www.floatingforests.org`), respectively. These two activities have been pilot tested with over 3,000 college students enrolled in introductory astronomy and earth science courses. Preliminary results indicated that after completion of these activities, students' confidence with respect to utilizing data-representations (e.g. graphs, charts, and tables) to make evidence-based conclusions increased significantly. Similar results were found for students' beliefs that citizen science is a valuable tool when making scientific contributions, and that they (as non-science majors) can contribute in a meaningful way to real research (Simon et al. 2021 in prep, Rosenthal et al. 2021 in prep). These two activities will be available for public use on the Zooniverse classrooms webpage (`https://classroom.zooniverse.org/#/`) by the Fall of 2021, while we expect the two additional activities developed around the projects Planet Four (`www.planetfour.org`) and Gravity Spy (`www.gravityspy.org`) to be available by the Summer and Fall of 2022, respectively.

For a more extensive list of Zooniverse educational resources, particularly for online classrooms, refer to: `https://blog.zooniverse.org/2020/03/18/zooniverse-remote-online-learning-resources/`

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#RADatHomeIndia a Collaboratory Model of Citizen Science Research

(Big-data is a big-resource for development if citizen science follows a Collaboratory approach)

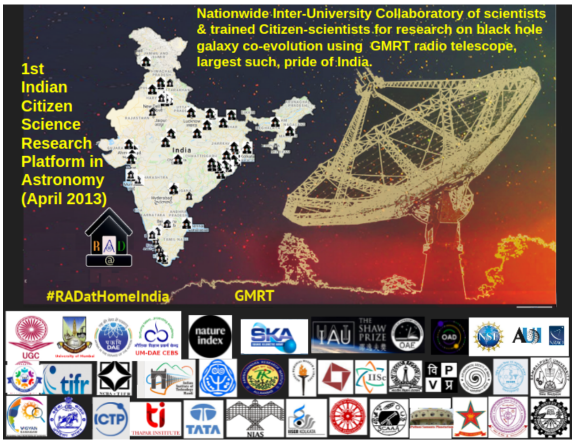
Speaker: Ananda Hota, UGC-faculty, UM-DAE Centre for Excellence in Basic Sciences, RAD@home Astronomy Collaboratory, India

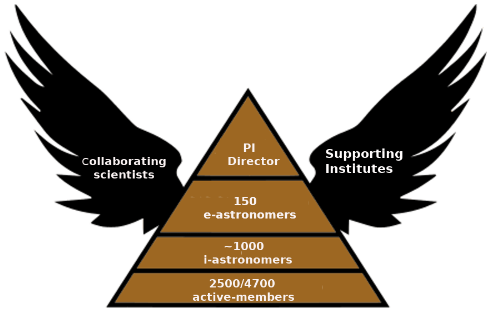
RAD@home (#RADatHomeIndia) is a nationwide, Inter-University Collaboratory of professional astronomers, trained citizen scientists and technical/administrative facilitators. It is the only Indian citizen science research platform in astronomy. Nearly 30 institutes and similar number of professionals have contributed to its growth since 2013. In a "flying pyramid" model, scientists and facilitators are its wings, and large number trained citizen-scientists (e-/i-astronomers) at multiple levels of expertise make the multi-layer pyramid. It has 150 e-astronomers, 1000 i-astronomers, 2500 active learners, 4700 total members. This way citizens achieve GMRT telescope time, co-authorship in papers on galaxy evolution and MS/PhD selections abroad or all round growth.

Talk link: https://youtu.be/VMZzP4BPCsU

RAD@home Astronomy Collaboratory, India (#RADatHomeIndia, https://radathomeindia.org/) is a nation-wide Inter-University Collaboratory of dozen professional astronomers, 150+ e-astronomers (trained citizen-scientists), 1000 i-astronomers & 2500 active learners in a group of astronomy-interested 4700 Indians. Its motto is any BSc/BE/BTech can do research (#ABCDresearch) using the Giant Metrewave Radio Telescope (GMRT) sitting @home anywhere in India free of cost. Though launched as a zero-funded, zero-infrastructure, human-resource network on Facebook and Google on 15th April 2013, the Collaboratory has achieved significant progress since the last eight years. It has grown to be a self-sustainable network of citizen-scientists trained to discover exotic black hole galaxy systems primarily from the low frequency 150 MHz TGSS DR5/ADR1 data taken with the GMRT, the largest such in the world and pride of India. These citizen-scientists not only come from all parts of India, as shown in the map of India, but also from all walks of life, as long as they have entered University-level science and engineering education.

In last eight years, numerous one week-long Citizen Science Research (CSR) training workshops known as "RAD@home Discovery Camps" and one day RAD@home Astronomy Workshops have been organized with the help of nearly 30 institutions all over India, including UM-DAE CEBS (Mumbai) where the Director & Principal Investigator (PI) of the Collaboratory works as an UGC-faculty (University Grant Commission, Ministry of Education, Govt of India). Over 150 students/citizens have been trained in Camps co-organized by this research startup (under UGC-FRP mission). Those Camp-hosting institutions are International Centre for Theoretical Sciences of the Tata Institute of Fundamental Research (ICTS-TIFR, Bangalore), Institute of Physics (IOP, Bhubaneswar), Harischandra Research Institute (HRI, Allahabad), Nehru Planetarium (Delhi),





Vigyan Prasar (Department of Science and Technology (DST), Govt of India). Following Discovery Camps, the CSR continues from home and is facilitated by online e-class-cum-e-research sessions (launched on 14th June 2015) organized by the PI of the Collaboratory. A Camp can accommodate only 10-20 participants. To train and engage even larger community in CSR, One-Day RAD@home Astronomy Workshops (ODRAW) are also organized (as in ICTS, IOP, NISER, IIT (BHU & Mandi), IISER (Kolkata & Berhampur)) and even mini-ODRAWs (IISc & DAE-DST-NCSM Vigyan Samagam (Mumbai, Bengaluru, Kolkata & Delhi)), which can accommodate 50-100 participants who continue to learn from Camp-trained e-astronomers. Purely online/live Workshops are also organized during Covid-19 pandemic (IAU-OAD sponsored programme at Indian Institute of Technology (IIT, mandi), DST (Govt of Rajasthan), Thapar Institute of Engineering & Technology (Patiala)). In these Camps/Workshops/talks nearly 40 Institutes have supported RAD@home and nearly 30 scientists have contributed to the citizen science research training to the students/citizens.

Exotic black hole galaxy systems discovered this way were proposed to the GMRT for deep observation and advanced analyses. These proposals named GOOD-RAC: GMRT Observation of Objects Discovered by RAD@home Astronomy Collaboratory, have been rewarded over 50 hours of observing time, in four different cycles, in this world-class facility after going through standard international review. Several never-seen-before objects/features detecting old/relic magnetised relativistic plasma, emitting preferentially at low radio frequencies of the GMRT (India) than higher radio frequencies of the Very Large Array (USA) telescope, have been detected. Such synchrotron emitting plasma could be due to past ejection of radio jets, millions of light years long and 10-100 millions of years old, from accretion of matter onto super massive black holes, million to billion times the mass of our Sun, located at the centres of massive galaxies. Alternatively, part of the plasma could also originate in the turbulence and shock waves produced during the collision between two clusters of galaxies containing thousands of galaxies each. These cosmic giant particle accelerators, million light years long, accelerate cosmic rays to relativistic speed by Fermi acceleration process and emit synchrotron radiation to be detected by GMRT. We keep our scientific aims well aligned with that of the national and international mega projects. The research results led by the PI have been press-released internationally by NRAO-NSF, NASA-JPL-CalTech, RAS, CFHT, NAOJ-Subaru, NCRA-TIFR etc. and recently has become a representational icon for one of the seven science goals of the Square Kilometre Array (e.g. SKA-brochure explaining galaxy black hole evolution, and SKA-posters in DAE-DST-NCSM Vigyan Samagam). Along with this scientific goal our aim is also to achieve the social constitutional goals of equity, sustainability and inclusivity through empowering the public through the Internet via people-powered citizen science research (CSR). Potential of such a modified CSR collaboration in converting the Big Data problem in to a Big Prospect for a Big Nation has been outlined in the following two publications titled 1. "New results on the exotic galaxy 'Speca' and discovering many more Specas with RAD@home network" (Ananda Hota et al. 2014) & 2. "Tracking Galaxy Evolution Through Low-Frequency Radio Continuum Observations using SKA and Citizen-Science Research using Multi-Wavelength Data" (Ananda Hota, Chiranjib Konar, C S Stalin, Sravani Vaddi et al. 2016). Several citizen-scientists are co-author in these papers. Camp-trained e-astronomers as well as e-class or RAW-trained i-astronomers become co-authors of such journal papers and international presentations. This has been brought to public notice, in the interest of the public, by a News/Press Release in the India Science Wire by the Vigyan Prasar, Department of Science & Technology, Govt of India. RAD@home citizen science research has been highlighted internationally by Nature-Index in an article titled "How to run a successful citizen science project: Keeping participants involved can go a long way". International Astronomical Union (IAU) and Square Kilometre Array, organizations building largest radio telescope on earth, listed citizen science efforts for public benefit, specially to take advantage of it during the pandemic. We welcome individual astronomers for co-authorship in publishing papers and institutions for hosting CSR training workshops (contact: RADatHomeIndia@gmail.com).

GALAXY CRUISE

Speaker: Masayuki Tanaka, National Astronomical Observatory of Japan, Japan

Collaborators: Michitaro Koike, Sei'ichiro Naito, Junco Shibata, Kumiko Usuda-Sato, Hitoshi Yamaoka (National Astronomical Observatory of Japan)

We present an on-going citizen science project, GALAXY CRUISE. GALAXY CRUISE aims to identify interacting galaxies based on imaging data taken with the Subaru Telescope, and it differs from previous citizen science projects in a few key aspects; unprecedented image quality, efficient tutorial based on public experiments, gamified user interface, and two-way communications. We believe that even elementary school students will find GALAXY CRUISE interesting. More than 1.5 million classifications have been collected in 1.5 years after the launch of the project, and interesting results are being unveiled and are shared with the participants. We also discuss future prospects of GALAXY CRUISE, including machine-learning.

Talk link: https://youtu.be/J-Ru1r7a_eY

GALAXY CRUISE is a cruise ship sailing across the cosmic ocean. The cruise ship offers an unprecedented view of the Universe with great details of galaxies that have never seen before.

You, as a cruise member, classify galaxies into various categories, which will help professional astronomers to address interesting scientific questions about how galaxies evolve. Unlike previous citizen science projects, GALAXY CRUISE is very interactive and has a lot of gamification aspects; passport stamps, souvenirs, classification ranking, etc. There are also monthly news articles, seasonal promotions, twitter, etc, to keep the cruise members motivated. Over 1.7 million classifications have been made so far and secrets of galaxies are being uncovered.

The Subaru Telescope and Hyper Suprime-Cam

The Subaru 8.2m telescope is located at the summit of Maunakea, Hawaii. It is among the biggest telescopes in the world and has addressed many unresolved issues in astronomy. Hyper Suprime-Cam (HSC) is one of the main instruments at the telescope and a big observing program is being conducted with this instrument. GALAXY CRUISE is based on data from this observing program. Details of the instrument and program can be found at `https://hsc.mtk.nao.ac.jp/ssp/`.

GALAXY CRUISE

We have launched a citizen science project, GALAXY CRUISE, in February 2020 (Japanese site was launched a few months earlier). It is a cosmic cruise ship sailing across the universe and it provides an unprecedented view of galaxies in the today's Universe.

Scientific motivation: GALAXY CRUISE focuses on morphology of nearby galaxies with an emphasis on interacting galaxies; astronomers know that galaxy-galaxy interactions and mergers are a key phenomenon to drive the galaxy evolution, but its details are not understood very well. The unprecedented images from Subaru make it possible to address this long-standing question.

How to participate: It is easy! Launch your web browser and go to the Galaxy Cruise website (`https://galaxycruise.mtk.nao.ac.jp/en/`). You can then go over the online tutorial to learn about galaxy shapes. There are three lessons, but they are not very difficult (except maybe for the last one). After the training, you will get a boarding pass to GALAXY CRUISE. Welcome aboard!

Sail around the universe: GALAXY CRUISE has a lot of gamification factors. It takes you to a galaxy and you classify it in an interactive fashion. You can zoom in/out and pan as you like. The universe is split into multiple continents and you will get a stamp on your passport when you leave a continent. You can also collect souvenirs as you go along. We also encourage you to freely explore the universe, discover interesting galaxies and take photos. It is simply fun to sail across the universe!

We will keep you motivated: We issue monthly news articles about various topics about galaxies and citizen science. We also often send messages on twitter. Seasonal promotions are a very popular event and many passengers participate to complete a mission. We also answer any questions you might have during the course of the cruise.

Join GALAXY CRUISE today! We are looking forward to welcoming you on board!

Citizen Science at NASA: Overview and Best Practices

Speaker: Marc J. Kuchner, Citizen Science Officer, Science Mission Directorate, USA

What would you do with help from 10,000 volunteers? Would you scour a complex data set, quickly explore many out-of-the-way places, or simply harness the creativity of that many unique human minds? That is what citizen science is all about: imagining new possibilities, solving hard problems, and at the same time, sharing your love of science far and wide. I will give an overview of NASA's citizen science program, tell the stories of remarkable citizen scientists and citizen science projects, and share best practices gleaned from the NASA community. For more information, take a look at science.nasa.gov/citizenscience.

Talk link: https://youtu.be/xn8BGXQiPGM

Volunteers from around the world drive NASA's citizen science program, collaborating with scientists on real cutting-edge research. NASA's citizen science projects have come to **dominate** their scientific fields. They have discovered **most** of the known comets, **all** of the known samples of interstellar material, **half** of the ultracool brown dwarfs and **most** of the long period (>2 yr) extrasolar planets from Kepler.

Beyond NASA, the term "citizen science" is applied to a wide range of activities and projects. But at NASA, our policy says: "All NASA citizen science projects shall be designed and implemented to meet the **same rigorous standards as any NASA science** program". As a result of this insistence on rigor, nearly 200 NASA citizen scientists have become named co-authors on scientific papers.

Many of the biggest citizen science discoveries from NASA citizen science have been surprises, recognized by citizen scientists, but unanticipated by the science teams involved: Tabby's star and the "Dipper" star phenomenon (Planet Hunters), the Meyer group comets (Sungrazer Project), the oldest white dwarf with a disk (Backyard Worlds: Planet 9), the Peter Pan disks (Disk Detective), and STEVE, a new kind of auroral phenomenon (Aurorasaurus).

At science.nasa.gov/citizenscience, you will find 25 active NASA citizen science projects online, 13 of which are astronomy projects.

NASA Citizen Science as a Tool for Science Education: We are just starting to study this application of citizen science (and note that NASA's educational efforts are now quite limited). But anecdotal evidence is accumulating that we are changing people's hearts and minds and teaching them about science – e.g., students who have changed majors and started science degree programs as a result of their involvement in NASA cit sci. Personal stories of NASA citizen scientists are online at **science.nasa.gov/citizenscience** under People.

NASA citizen science shares the **process of science** with >1.5 million volunteers, including these Shaw University students, who are working on the Floating Forests project.

Several NASA Citizen Science Projects now have classroom materials – see the NASA Citizen Science Resources for Educators document via https://www.dropbox.com/s/b1tuk90vrqsfnxj/NASA_Citizen_Science_Resources_for_Educators.pdf?dl=0.

Here are three best practices collected from our community of NASA citizen science practitioners.

1. **Use citizen science to teach students that in science, everyone's work is checked and double checked.** Scientific work must be reproducible, scientific research must pass peer review, and many citizen science projects have multiple layers of vetting and redundancies in them to ensure data quality. Understanding this aspect of science is a key component of science literacy, and these are special lessons that citizen science experiences can deliver in a uniquely powerful way. Learning these concept helps build trust in science (Weisberg et al. 2021). Help students see the many checks and double checks built into the citizen science projects they use!

2. **Help your students get involved in videocons with scientists!** E.g. Stardust@Home has videocons on the 3rd Thursday of each month. Radio Jove has regular phone calls with volunteers. Planet Patrol and Disk Detective have videocons once per week. Backyard Worlds: Planet 9 has three videocons per week. Participants in these videocons, meet actual scientists, work on advanced projects and observe how scientists work both in teams and in competition. Meeting an actual scientist, even on a videocon, goes a long way toward helping students establish their scientific identities. Ways to get involved are generally described on each project's website—though you may need to read the whole website to find them.

3. **Encourage students to try NASA citizen science on the road to doing a science internship.** When you apply for an internship, working on a NASA citizen science project looks great on your resume because it demonstrates a deep interest in NASA science. For more career and educational opportunities with NASA, see science.nasa.gov/learners/learner-opportunities

Boosting Online Community to Drive Engagement

Speaker: Pamela L. Gay, Planetary Science Institute, USA

Humans are social creatures, and while we all vary in how much we do (and do not!) want to interact, everyone wants a place to belong. With CosmoQuest, we enhance citizen science engagement by making sure those who join know they are welcome and will be supported no matter who they are. This is accomplished by: having a leadership team that is open about their disabilities and differences; using the pronoun "they" until told otherwise; facilitating non-science conversations around topics like LGBTQ+ that impact engagement; providing moderated places where people can hang out; and more. In this workshop, the structure for designing a community will be laid out, and how to emphasize each aspect in your own community will be discussed.

Talk link: `https://youtu.be/BhKXaSukTaw`

One of our most important roles as Citizen Science project leaders is to show day after day that everyday people can learn and do science; making contributions that help advance our understanding of the universe. To be successful in recruiting people to participate in our programs we have to break down the stereotypes of science being done by isolated geniuses. We would not be able to have citizen science projects if we had not sorted how to do that to some degree. The stories we tell inspire people to join our projects. We see in our data the folks who want to contribute, and who will click and observe for years, content to know they are making science possible. We also find there are community leaders, engaging in both science and in facilitating conversations and communications in our forums. With these core groups, we end up with groups that in many ways reflect professional science communities. But can we do better?

Professionally, astronomy is male-dominated, white-dominated, and we need safe places and support groups for members of the LGBTQ community and people of faith. If we do our job right, our communities will not reflect our profession, but be a better version of the diverse society we live in. This is not to say we can be a true reflection of society - my programs are not suitable for the blind, and they require people to have computers, free time, and the ability to learn certain needed tasks. These are limits.

This brings us lesson 1: Decide who you want to be as a community. At CosmoQuest we start by targeting the science adjacent: sci fi lovers and podcast listeners. From there, we say "we will tolerate no hate. This is a place where people are accepted without regard to their color, culture, religion or lack of religion, their education level, their wealth, or their caste. We do not care who you love, but only that you find love in this world. We believe that everyone can do great things, and we welcome everyone to be part of us doing great things." When we started our program, we drew in our audience from the Astronomy Cast podcast audience, and we started out primarily male, white, educated, and affluent. This was not our goal, so we have worked to change as we grow. This required us to both listen on platforms like Twitter when people talk about why they do not feel welcome in the sciences, and learn. It also requires us to ask the people we do have who are not the generic affluent white male science lover why they have joined us, and why they stay. This is an iterative process; people and society are constantly evolving, and it is a process we can never call good enough.

When you decide who you want to be, you should strive to reflect that from top to bottom. This meant asking, 1) what is necessary to create a work environment that is welcoming and supportive of a diverse staff, 2) are we communicating in ways that are as inclusive as possible, and 3) does our community provide support to people such that we are providing a place that provides equity rather than just equality.

To facilitate a diverse staff, we looked to Bryan Gaensler's efforts at the University of Sydney and at Dunlap Institute. All paid positions have allowed part-time and flexible hours. We make it clear that we will schedule meetings around family obligations, and make it a goal that everyone is cross-trained so folks can take time off without work piling up behind them. We also approach our volunteers from a position of trust; assuming people who want to help might make mistakes but can be trusted just as much as our staff, and may have more experience or expertise than we could afford to hire on academic budgets. Today, our core team is made of majority women, and quite by accident, we have landed in a place where we are all some combination of disabled, queer, and/or people of faith; we are the people who are not majority in science, and we are the leaders of a community who seeks to reflect society instead of science. No group starts as actually diverse. It is a process. Lesson 2: Find the kinds of people you want to see in your community who are not already there, listen to them and learn what they want, need, and dislike. Then change what you need to change.

Creating a place of diversity has required the entire team struggling together to find ways to present ourselves that leave spaces for everyone to feel included in our messaging. This takes many forms. For instance: we default to the pronouns they/them until we are told to use something else. We work to provide transcripts of all of our recordings, and to make content available in ways that can be accessed with screen readers and on multiple devices. We also make efforts to admit our own differences, struggles, and failings so people see role models, and if not role models, at least space for their differences to exist alongside our differences. This care is carried all the way through to how we word surveys. When we ask, "What is your gender?" it is not multi-choice. After talking through how people want these questions to appear, we now give people a blank space to answer. This makes data analysis harder, but leaves space for humans to be true to themselves.

In a recent marketing survey, we found that the majority of the community is still male, at about the 70% level, and uncomfortably white. That said, more people identified as having a disability than is typical of the US population, LGBTQ roughly tracks with the population, and our community includes many self-identifying conservative religious folks who co-exist in a community with no clear majority between atheists, agnostics, and people of faith. This was a non-scientific study used to understand how to improve programs. We are seeking funding for more in-depth research. Of particular interest, we want to explore how the digital divide affects engagement by minorities, and how the demands of household and children - the so-called second-shift - impact the ability of women to participate in citizen science and other volunteer activities.

Lesson 3: You need to set down community guidelines that are enforced with room for forgiveness and honest mistakes. Part of creating rules is asking "What is required to make the people we want to welcome feel comfortable? We have forbidden references to weapons or violence, even Marvin the Martian. Sometimes this takes forms I never quite imagined. Recognizing that people are more than the science they do, our discussion server has channels to share photos of nature and animals, and all spiders and snakes are hidden behind Spoiler Tags. It is a small thing, but it matters. We do what we can to create a community focused on helping and contributing. This includes people live streaming their citizen science efforts and sharing their pain and triumph, and it has matured in these Covid times into people supporting each other in voice chats, and when folks need a break, we even created a place to play games, tell stories, and just be humans.

We have adopted a spirit of aggressive acceptance and compassion and are becoming who we want to be. I hope our lessons will help you build the long-lasting, healthy and growing community that you want to see.

How Citizen Scientists are Monitoring Global Meteor Shower Activity with Machine Learning Open Source Research

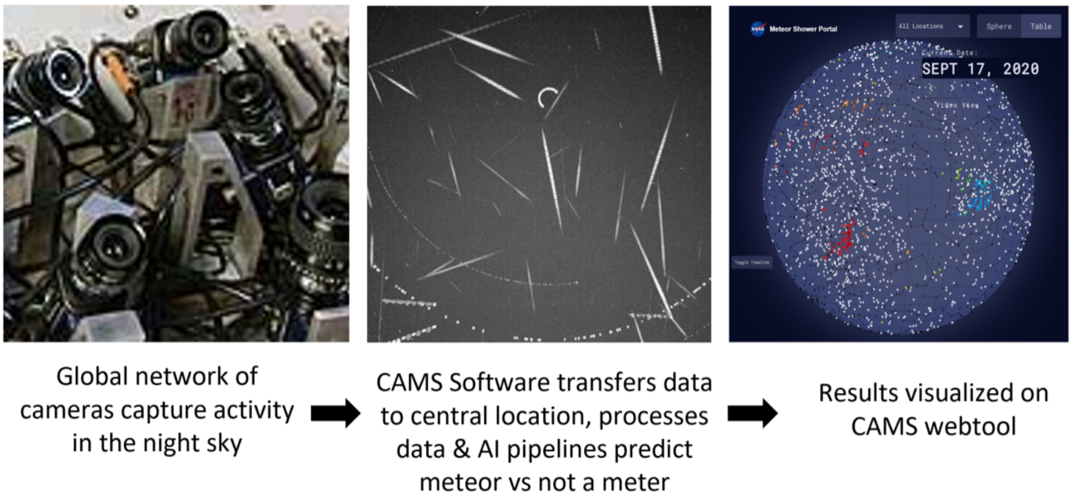
Presenter: Siddha Ganju, Frontier Development Lab, SpaceML, Nvidia Corporation, USA

Citizen scientists have automated the Cameras for Allsky Meteor Surveillance (CAMS) data network, so data is automatically downloaded from the cameras, prepped for triangulation, and analyzed. Additionally, an ML algorithm replicates the scientists thought process to sift through the video captured each night to identify meteor showers with results published on the NASA CAMS Meteor Shower Portal. The open source portal not only aids in effective communication of ideas and results to a diverse audience but is a useful interactive educational tool used to explore meteor shower activity from the previous night globally and encourages citizen scientists to develop an interest in space science. Learn how to reuse the open source code for your datasets and explore meteor showers!

Poster link: https://youtu.be/qbppMOc4dHs

While many of us in astronomy are domain experts, we could utilize the talent and skills of people outside the domain, and that is where citizen science can help. With proper engagement and mentorship, citizen scientists (ranging from high school to university students, all the way to tech industry veterans) can be guided to start contributing innovations to astronomy, spearheading research into new uncharted domains, ultimately publishing research in journals and top conferences.

CAMS or Camera for All-Sky Meteor Surveillance project (https://www.seti.org/cams), which started with just a single camera trying to map the night skies above California, has now grown to 600+ cameras today, spanning citizen scientist-run observatories all over the globe such that we have eyes on the skies worldwide 24x7. Peter Jenniskens (https://www.seti.org/our-scientists/peter-jenniskens) who founded CAMS would travel daily to the Lick Observatory, take the hard drive, drive back to the SETI Institute and replay the captured data, sitting in long moments of uneventful darkness waiting for that momentary streak of light to verify if it was a meteor or not a meteor. Teams of citizen scientists have built the (1) CAMS software that transfers data saving valuable time but also an incredible amount of carbon emissions, (2) trained an AI model to replicate the scientists thought process to distinguish between meteors and other objects in the night sky, and (3) build a user-centered visualization portal that displays night activity from all over the world within your browser.



The figure shows the CAMS pipeline build by a team of citizen scientists.

As of 2021, CAMS is a mature TRL-9 deployed machine learning project for planetary defense and has been one of the first machine learning-enabled NASA-funded projects that includes pro bono contributions from citizen scientists. CAMS has run multiple Facebook, YouTube Live events with 10k+ views. Recently, a team of student citizen scientists were also able to organize a fundraiser, raising 30,000 USD to establish camera stations in India, closing the blind gap which existed over the North-Eastern Hemisphere.

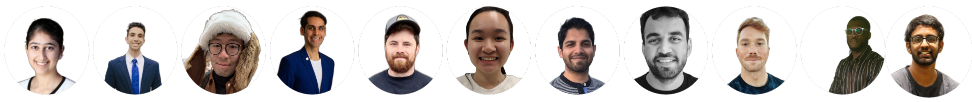
SpaceML: How to run a citizen science team/Learnings from running the Citizen Science team: There are few organizations in the world like NASA, where the opportunity to work can have a huge positive impact on the planet. However, opportunities are very selective, often available to researchers with advanced educational backgrounds, with the most common starting positions being Postdoctoral positions. And while the funnel of students in advanced STEM fields is already low, it is even lower for women and people of color.

SpaceML helps connect aspiring change-makers with the opportunity to make an outsized impact. It does that by inspiring them through talks, training them, opening opportunities to conduct research in a state of the art field, guiding them through generating publications and releasing free open-sourcing tools, and then giving them the stage to showcase their work in front of NASA Scientists, significantly accelerate the speed of usable research for NASA and its adoption by scientists. And it does it in an inclusive manner, irrespective of academic background. With 50+ contributors now, starting from summer 2020, the majority of the students have a high school / undergraduate background. With the students scoring an open offer for future internships. And even two English teachers who were motivated by climate change, who went through a career transition into data science, with one having landed in a full-time technical role. And more importantly, with stories of relatable young changemakers, more people will follow onto using their talents for social good.

The north star for the program is not research but readily usable, deployed research, a short-coming in the common academic research process. Most free tools released in this program do not require the user to know computer programming or pre-requisite knowledge of artificial intelligence, all it requires is one line to get them running. This further reduces barriers to entry and enables researchers across all disciplines to benefit from the project.

The program facilitator provides customized learning resources to each candidate to upskill them in a fast yet approachable manner. Few weeks in, they are paired with their primary mentor who will closely guide them through the rest of the program. Mentors meet with their mentees every week to discuss progress on their project, next steps and longer term goals. As the project reaches a certain level of maturity the candidates present their work to a panel of NASA scientists and stakeholders. This step serves as a useful checkpoint to ensure that the project is going in the right direction and that it is readily deployable for real-world scenarios. Contributors are held accountable through a set of key objective metrics. Through this process of delivering short yet impactful demos, the candidates learn valuable skills in public speaking and presentations. The candidates are also provided guidance on scientific communication for research publications at prestigious conferences.

SpaceML is unique because there exists no other distributed open-source program that upskills contributors from a variety of backgrounds (technical and non-technical), ultimately helping them deploy code for high public value areas like planetary defense, climate change in a short span of time.



Zooniverse and IASC: Citizen Science at the Service of the Popularization of Astronomy

Presenter: Felipe Sérvulo Maciel Costa, ECIT Melquíades Vilar, Brazil

In times of remote education, astronomy education has also had to adapt. Today, there are citizen science projects that provide tools and resources to support astronomy education remotely, such as the Supernova Hunters and Planet Hunter Tess projects on the Zooniverse platform, as well as the International Astronomy Search Collaboration, an asteroid hunting project. In addition to contributing to astronomy education, such projects also allow citizen scientists and amateur astronomers to contribute to new discoveries of planets, supernovae, stars, and asteroids not yet discovered by the algorithms that scour the cosmos through large telescopes. Such initiatives also have the potential to contribute to the popularization of the field of astronomy and general interest in STEM.

Poster link: https://youtu.be/i6WhN-fYSEc

Started in the mid-1900s and popularized in the last 20 years, citizen science is the kind of science that involves the participation of volunteers who actively contribute in various areas of research. In the field of astronomy, in addition to seeking a greater participation of amateur astronomers and astronomy enthusiasts in scientific research, there is a parallel objective of providing greater dissemination and increased general interest in the areas of STEM (Science, Technology, Engineering and Mathematics), more specifically, in the field of astronomy (which can be called citizen astronomy).

Currently, there are initiatives such as Zooniverse (www.zooniverse.org), a virtual platform that hosts the largest citizen science projects on the internet and is headquartered at Oxford University and at the Adler Planetarium. Zooniverse's projects span several areas of knowledge, including astronomy, ecology, cell biology, humanities and climate science. Some examples, in the field of astronomy, stand out the Planet Hunter Tess (project that identifies exoplanets through starlight curves recorded by the TESS telescope), the Supernova Hunters (project that searches for supernovas through images from the PanStarrs Telescope), Cosmological Jellyfish (initiative that searches for exotic galaxies), and the recent Active Asteroides project, which searches for asteroids with characteristics of a comet. Another important citizen astronomy project is the International Astronomical Search Collaboration (IASC - http://iasc.cosmosearch.org/), one of NASA's citizen science projects that provides high-quality astronomical data to citizen scientists around the world through search campaigns by major belt asteroids (MBAs).

In recent years, there has been a considerable increase in the number of people joining citizen science initiatives aimed at astronomy (citizen astronomy) around the world. Participation includes astronomy clubs, schools, science dissemination projects, universities or even amateur astronomers or astronomy enthusiasts. The present work evidenced the participation and discoveries of the Mysteries of the Universe Project, from Taperoá, Paraíba, Brazil, and the Melquíades Vilar School, in the projects of citizen science of asteroid search (IASC/NASA/MTCI) as well as in the search for supernovae (Supernova Hunters/Zooniverse) between July and September 2021. Citizen astronomy is a two-way street: more people contributing to citizen science projects helps to improve and refine astronomy research, improve the algorithms. and produce more data, at the same time, these people learn. Without leaving home, with the help of the internet, teachers, students, astronomy enthusiasts and astronomy club members have the opportunity to contribute to cutting-edge professional science in astronomy and participate in important discoveries. In addition, citizen science projects aimed at astronomy promote the growing participation of people in science, multiplying the number of enthusiasts (including children), and fostering interest in astronomy.

Solar Eclipse 2019: Citizen Science Initiative to Investigate GPS Signals in Chile

Presenter: Carla Hernández, Center for Interdisciplinary Research in Astrophysics and Space Exploration (CIRAS) Physics Department, Universidad de Santiago de Chile, Chile

Collaborators: Sebastián Pérez, Roberto Bernal, Marina Stepanova, Cristóbal Espinoza and Miguel Pino, CIRAS, Physics Department, Universidad de Santiago de Chile

The solar eclipse in Chile 2019, was a perfect opportunity to invite the public to join a scientific investigation through a citizen science initiative. The aim was to gather data that would help us understand how changes in the illumination pattern affect our planet's ionosphere. Shadowing by the Moon is expected to produce deviations in the Global Positioning System (GPS) accuracy. Our initiative, named "Hago Ciencia", invited people to collect GPS data with their smartphones before, during, and after the eclipse. Participated approximately 5,000 people, providing more than 280,000 geolocation. We found evidence that the positioning accuracy worsened by several decades of meters during the passage of the Moon's shadow when compared to before and after the time of totality.

Poster link: https://youtu.be/pTe5cNVXJGM

The solar eclipse that happened on July 2, 2019 was visible throughout continental and insular Chile, with magnitude 1.0459; Range -0.6466; and a maximum duration of 273 seconds (4 min. 33 sec.).

On this occasion, we developed a citizen science initiative called "Hago Ciencia" (translated as "I do science") in order to encourage the participation of people throughout the country. The initiative was aimed at studying how the main ionosphere is affected by reduced sunlight for a short time interval, by detecting changes in artificial geolocation systems. Studies in previous eclipses of the Sun have reported weakening of the ionosphere and effects on the transmission of radio waves (Cervera and T. J. Harris, 2014).

During a solar eclipse, when the Moon blocks the solar radiation completely over some area of the ionosphere, we expect changes in the density of free electrons in that gas column. A 60% decrease of the electron density in the F1 region was observed during the maximum of a total solar eclipse (Ding et al., 2010; Coster, A. et al., 2017).

Citizens had to enter the designated website through their mobile phone, and accept access to geolocation data. In the instructions, users were suggested to connect several days before, at approximately the same time of the eclipse (16:30 CLT) from the same place of registration. The

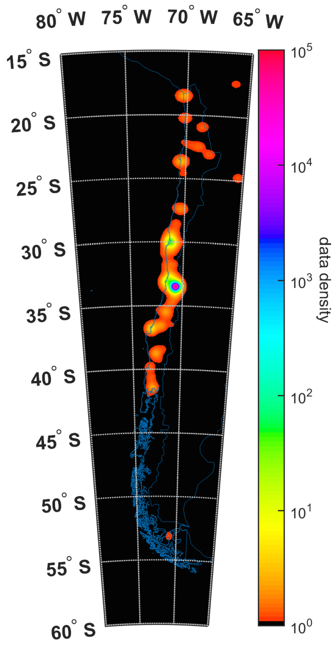


Figure 1: Density data distribution/latitude.

initiative involved 4,809 people who contributed to the registry of 284,610 geolocation data (Figure 1). Registration was carried out from different parts of the country, both in continental and insular territory.

We found evidence that the positioning accuracy worsened by several decades of meters during the passage of the Moon's shadow (Figure 2). The results obtained suggest that the GPS embedded into the cell-phones are able to detect the changes of TEC. This finding was possible thanks to the active participation of citizens in the data collection process. High citizen participation during the eclipse and the large amount of data collected in this initiative confirms the community's interest in scientific research.

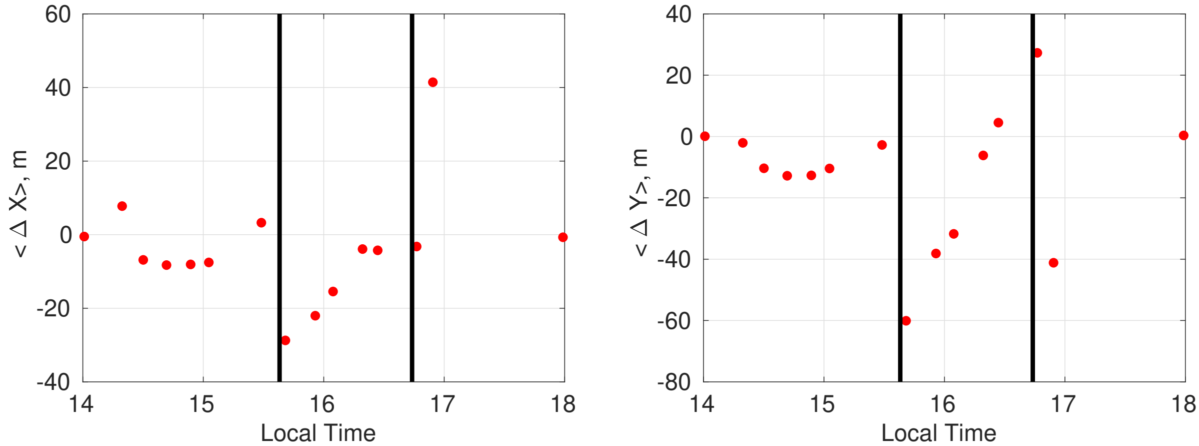


Figure 2: Averaged differences in meters between the apparent and real locations of cell-phones in latitude (Y) and longitude (X).

GWitchHunters - The Citizens for the Improvement of Gravitational Wave Detectors

Presenter: Francesco Di Renzo, on behalf of REINFORCE-WP3, University of Pisa and INFN section of Pisa, Italy

Gravitational wave detectors are very sophisticated instruments devoted to the formidable task of measuring space-time deformations as small as a thousandth the size of the atomic nucleus, such as those produced by astrophysical phenomena like coalescence of compact stars or the Big Bang itself. This citizen science project aims at demystifying the detectors functioning and the work of the scientists to improve them. We present their data in the form of images and sounds, and we ask the citizens to identify relations between them or peculiar patterns in images and sounds. All of this is presented with the interface of the Zooniverse platform as a game for the citizens, which, playing with simple tasks, can give a significant contribution to better understand the detectors and improve them.

Poster link: https://youtu.be/KmJgBJKQuzg

GWitchHunters, from the blending of the Gravitational Wave acronym (GW) and glitch hunters, is a citizen science demonstrator developed within the REINFORCE (Research Infrastructures FOR citizens in Europe) Research & Innovation Project, with the support of European Union's Horizon 2020 SWAFS "Science with and for Society" work program. Its objective is to engage and support citizens to cooperate with scientists 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 first step in the development of the project has been to present the data recorded by GW detectors in a format that enhanced the physical properties of interest and that these were easily recognizable by the general public, without any specific expertise in signal processing. Our focus has been in particular on transient signals, such as those expected from the coalescence of compact binary stars, like the celebrated first detection event GW150914[1], or other short excesses of energy of environmental or instrumental origin, colloquially referred to as *glitches*. To represent them we make use of specific transformations that normalize the data with respect to the energy of its stationary and Gaussian part (*whitening transform*), and we visualize them by means of *spectrograms*, heat maps that show the evolution of their energy with time and frequency.

In order to make concepts like energy and frequency more friendly to unexpert participants,

[1]Abbott, B.P. et al., "Observation of Gravitational Waves from a Binary Black Hole Merger," Phys. Rev. Lett., vol. 116, no. 6, p. 061102, 2016.

like young kids, and provide a multisensorial view of this data, useful for people with vision impairment, we have developed a new *sonorization* strategy to convert the spectrogram images into sounds. We have done that associating to every frequency interval of these images the corresponding note of the C-major scale of Occidental music, that is, 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 signals examples at outreach events or in schools, making use of common musical instruments.

From these images and sounds, we can recognize the peculiar shapes and tones associated with the coalescence of compact binary stars and those from signals of terrestrial origin, which we would like to get rid of in the search for astrophysical signals. Most importantly, we are then able to distinguish them, and 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*, our detectors constantly monitor the status of their instruments and environment with dedicated data acquisition channels. If we observe the coincident presence of an excess of energy in the main channel and in one of the latter, with a similar image shape or sound, then this provides evidence for a terrestrial (i.e. instrumental or environmental) origin for that, and also gives researchers information on where in the detector this noise has spawned from. This is very important for the identification of the various noise sources and, getting rid of them, the improvement of the detector sensitivities. This is also one of the tasks that citizens are asked to complete in the GWitchHunters.

We have delivered this project via the Zooniverse web platform, which includes a nice looking interface for visualizing the data and performing the previous tasks, and also plenty of additional resources and discussion boards about the science of gravitational wave detectors and how to get in touch with researchers in the field.

Discussion summary

The two informative citizen science sessions were followed by very lively discussions. Overall there was a consensus that not only does citizen science prove to be a very useful tool for outreach but it also helps with introducing research activities and methods. It is essential to find the right balance between outreach and authentic research, while designing citizen science projects. To make sure that the project is rigorous and productive scientifically, it is beneficial to include scientists in the team, to define a clearly stated science question that is accessible for everyone and to have the data quantity and quality as needed to answer the question. It is also important to strive towards a more equal, diverse and inclusive community, which takes a lot of work and dedication.

To grow the community further, a few ideas of promoting citizen science projects were discussed. Ananda Hota mentioned the importance of highlighting the outreach aspect of citizen science initiatives, especially in order to acquire government funding and recognition. Masayuki Tanaka and Pamela Gay encouraged using social media to help spread the word, e.g. facebook groups, promotions via National TV stations as done in Japan for GalaxyCruise, and different live streaming platforms like discord, twitch, YouTube live, etc.

There was a discussion about including citizen science projects into the K-12 curriculum. Molly Simon suggested that many of the activities developed for college students can be used in high school classrooms and that the Zooniverse projects on the website are accessible to most ages, starting with middle school (https://blog.zooniverse.org/2020/03/18/zooniverse-remote-online-learning-resources/). Marc Kuchner pointed out that there are some challenges for classroom projects in the USA since the next-generation science standard curriculum does not have a lot of flexibility for adding these kinds of activities. However, several NASA projects have been successfully incorporated for high-school students in India and Brazil. Pamela Gay stressed on the importance of being respectful and giving due credits to all those involved at different levels of the initiative, especially among minority students (see also https://arxiv.org/abs/1907.13061). Pamela Gay mentioned that several different citizen science projects exists, which also work in areas lacking the access to technology, such as observational work that uses unaided eye where the data can be reported through the phone (e.g. monitoring novas for AAVSO, https://scistarter.org/).

Marc Kuchner shared a funding opportunity called the NASA Citizen Science Seed Funding Program (https://nspires.nasaprs.com/external/solicitations/summary!init.do?solId=%7BA08B277F-1BFE-4663-3E6F-C178EBA87C8C%7D&path=open) for educators or researchers who want to propose new projects in Astrophysics, planetary science, biological and physical sciences, and Helio physics. Molly Simon also shared that the publicly available project builder tool (https://www.zooniverse.org/lab) on the Zooniverse platform can be used to build a Zooniverse project and get help from 2 million+ volunteers around the world to classify the data.

Although involving machine learning techniques in citizen science initiatives seems like the way forward, Marc Kuchner emphasized that citizen scientists will always have a feature that machines do not have, and that is curiosity. The more we can inspire people from all kinds of backgrounds, the more science we will do!

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