ASTRO BEAT

June 2023

Figure 1: Banners from select projects hosted on the Zooniverse platform (Photo Credit: Becky Rother, former Zooniverse designer).

Citizen Science in the Undergraduate Classroom: A Tale of Two Use Cases

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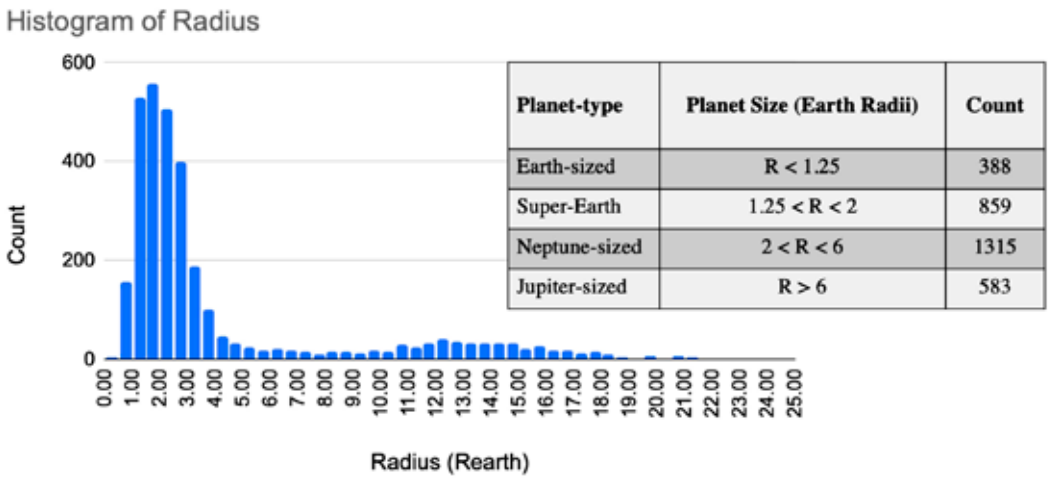
As we've entered the era of big data, research teams from astronomy to zoology are finding themselves inundated with more information than they have time to analyze on their own. Many of these research groups have turned to citizen science, an invaluable practice that allows the research groups to crowdsource components of their data analysis process to the public. Although machine learning continues to gain popularity when it comes to quickly analyzing large datasets, humans have a particular knack for anomaly detection, making the human eye extraordinarily useful when it comes to serendipitous discovery.

From the perspective of a college professor who teaches both introductory and advanced-level astronomy courses, I often think about best practices for bringing citizen science and big data to the undergraduate classroom. My teaching philosophy is centered around the idea that as instructors, we must strike a balance between the coverage and retention of important general concepts, while also empowering students to feel more confident using scientific and quantitative reasoning in their everyday lives. Prior research has indicated that undergraduate students have a difficult time making observations, predictions, and providing explanations when presented with data. Citizen science can be used as a tool to bring large datasets to the undergraduate classroom in a way that is accessible and engaging, but figuring out exactly how to best engage undergraduate students with citizen science is not a one-size-fits-all approach.



Planet-type	Planet Size (Earth Radii)	Count
Earth-sized	R < 1.25	388
Super-Earth	1.25 < R < 2	859
Neptune-sized	2 < R < 6	1315
Jupiter-sized	R > 6	583

Figure 2: Histogram of the radii (R) of exoplanets discovered using the transit method (as of Fall 2020). With the histogram is a table providing the total number of exoplanets for four categories: Earth-sized, Super-Earth, Neptune-sized, and Jupiter-sized.

Zooniverse-Based Activities for Undergraduate Non-Science Majors

Before I held my current position at Arizona State University (ASU), I was the education lead for the Zooniverse[1], the world's largest online platform for citizen science. Since its foundation in 2007, the Zooniverse has hosted over 350 projects and has over 2 million registered users around the world. Zooniverse projects have led to over 200 peer reviewed publications[2], many with citizen scientists as coauthors (Figure 1). What makes Zooniverse so successful is its considerably low barrier to entry. Volunteers can enter their email address and begin contributing to a project almost immediately, directly after viewing a short tutorial that is unique to each individual project. While this model is excellent at garnering widespread participation, Zooniverse typically attracts free-choice learners who already have an intrinsic interest in science and who are eager to participate in authentic research. Undergraduate non-science majors, however, are usually taking a science

course to fulfill their college or university's liberal arts requirement, so when developing a citizen science-based curriculum for those students in particular, additional scaffolding is required.

Between 2020 and 2022, several collaborators and I developed three classroom activities for undergraduates, each highlighting a different citizen science project active on the Zooniverse platform: Planet Hunters[3], Floating Forests[4], and Planet Four[5]. These activities utilize a data-driven approach to teach students about the transit method of exoplanet detection, the impact of climate change on ocean ecosystems, and Martian weather and climate, respectively.

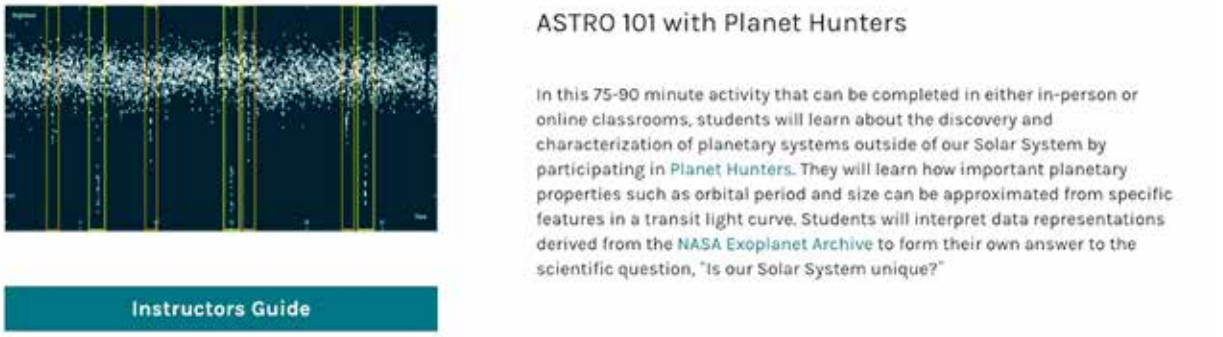


Figure 3: The ASTRO 101 with Planet Hunters brief activity description as provided on the Zooniverse Classrooms webpage. Instructors can access the full activity and a more detailed Instructor Guide by clicking the 'Instructors Guide' button on the website.

Each of the activities were developed using a three-part curricular model discussed in detail in Simon et al.[6] (2022), but what is important to note is that the curricular model (and subsequent activities) were developed with the goal of increasing students' confidence when analyzing data and interpreting a variety of data representations (e.g. plots, charts, and tables), all while improving students' beliefs about engagement in citizen science and science more generally. One such example of an introductory-level data representation from the Planet Hunters activity is shown in Figure 2. In this histogram, students are tasked with making observations about the distribution of planetary radii for exoplanets discovered using the transit method. The question sequence that follows this histogram in the activity ultimately leads students to make comparisons between the properties of the planets in our own Solar System and the thousands of exoplanets we are continuing to discover.

We tested the Planet Hunters, Floating Forests, and Planet Four Activities with over 3,000 undergraduates at 16 colleges and universities across the country between 2020 and 2022. Results from pre-/post-assessments indicated that the implementation of

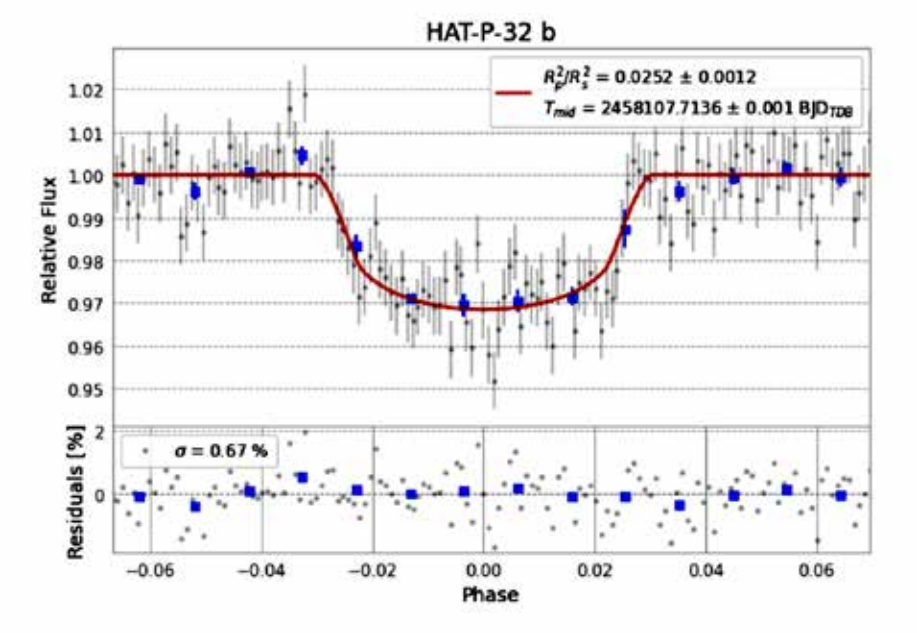


Figure 4: An example light curve generated by EXOTIC for the target HAT-P-32. The dip in brightness corresponds to when the Hot Jupiter HAT-P-32 b passes in front of its host star. The gray points represent each image in the data set. The blue points represent the average of a set of binned data points used to fit the light curve.

these activities in undergraduate science courses for non-majors led to statistically significant increases in students' self-reported data literacy abilities, their beliefs about citizen science, and their interest in continued science engagement. All three activities are available to instructors free of charge on the Zooniverse Classrooms webpage[7] by clicking on the 'Zooniverse-based Activities for Undergraduates' button. The ASTRO 101 with Planet Hunters brief activity description is shown in Figure 3.

A New Online Research Course for Astronomy Majors

The first grant I got funded as a new professor at ASU was to develop and assess one of the world's first fully online research courses for astronomy majors. During the Summer of 2020, ASU rolled out the nation's only fully online Bachelor's degree program in Astronomical and Planetary Sciences (the APS degree). With over 300 students enrolled to date, the APS degree has grown to be the largest major in our department, and it predominantly serves a more diverse population of learners than our in-person degrees (e.g. students with full-time jobs, families, or military status). Quickly after the degree's inception, I learned that these students were eager to participate in authentic research, and being a citizen science enthusiast, I searched for a project fit for more advanced undergraduates.

The citizen science project that serves as the backbone for my online research course is called Exoplanet Watch.[8] Exoplanet Watch is an initiative that uses ground-based telescopes to update the orbital parameters of transiting exoplanets for eventual follow-up observations by space-based telescopes like JWST.[9] Through a collaboration with Exoplanet Watch and the MicroObservatory[10] Robotic Telescope Network, students in my class work collaboratively to update the orbital parameters of a single, Hot-Jupiter target observed over more than 40 nights with MicroObservatory. Students use a publicly available Python program called EXOTIC[11] generated by the Exoplanet Watch team to reduce photometric (light) data and to generate new transit light curves. These

light curves are plots of a star's brightness over time, where periodic dips in brightness can be attributed to a planet passing in front of the host star. An example light curve for the HAT-P-32 system is shown in Figure 4.

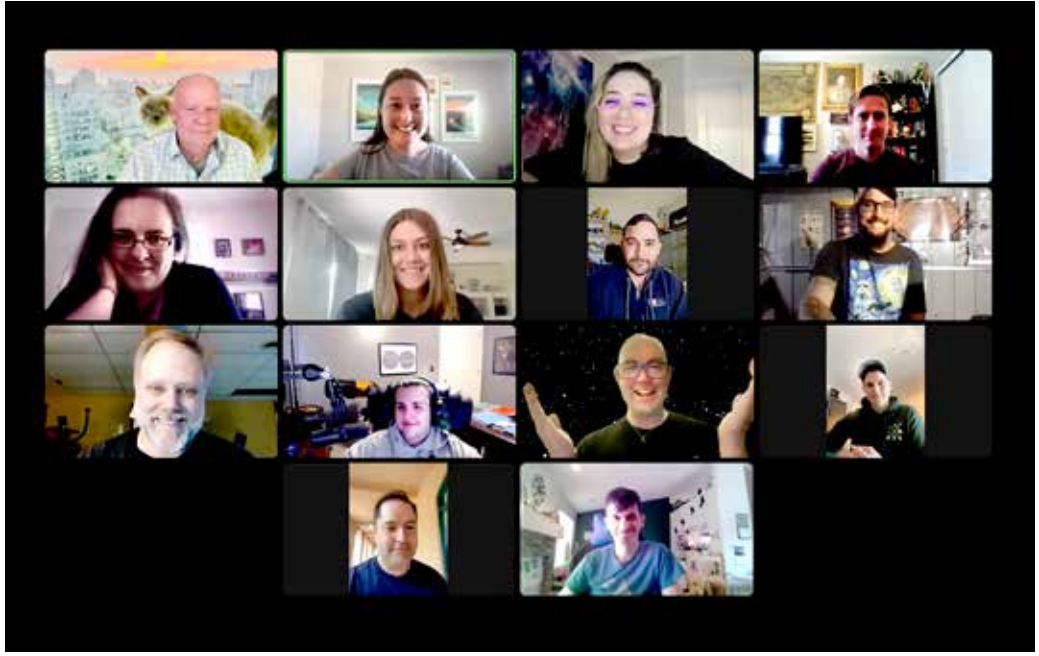


Figure 5: The author (second from left, top row) and students from the online exoplanet research class meeting synchronously through Zoom.

While the majority of the class is conducted fully asynchronously, there is a weekly required Zoom meeting where the students, teaching assistant, and I work through research-related blunders in real time (Figure 5). The latter half of the course involves students working in small groups to write up their findings in the format of a manuscript for publication in a peer-reviewed, observing journal (e.g. Journal for the American Association of Variable Star Observers, JAAVSO). The manuscript from the Fall 2022 course is published in JAAVSO, and all 15 students from the Fall cohort are now published authors![12]

Getting Involved

Both Zooniverse and Exoplanet Watch are excellent citizen science platforms for enthusiasts or educators who want to bring big data into their classrooms. At the start of the COVID pandemic, the Zooniverse team released a blog post[13] with a list of available educational resources for K-12 and college educators. Exoplanet Watch recently debuted their data checkout system, where users can request their own night of MicroObservatory data to reduce with EXOTIC. Wherever your curiosity leads you, there's undoubtedly an opportunity for you (and your students) to make meaningful contributions to active research.

Footnotes

1. https://www.zooniverse.org/
2. https://www.zooniverse.org/about/publications
3. https://www.planethunters.org
4. https://www.floatingforests.org
5. https://www.planetfour.org
6. https://astroedjournal.org/index.php/ijae/article/view/43
7. https://classroom.zooniverse.org/#/
8. https://exoplanets.nasa.gov/exoplanet-watch/about-exoplanet-watch/overview/
9. https://webb.nasa.gov/content/about/faqs/facts.html
10. https://mo-www.cfa.harvard.edu/MicroObservatory/

11. https://github.com/rzellem/EXOTIC
12. https://app.aavso.org/jaavso/article/3876/
13. https://blog.zooniverse.org/2020/03/18/zooniverse-remote-online-learning-resources/

About the Author:

Molly Simon is an Assistant Professor in the School of Earth and Space Exploration at Arizona State University. She received her Ph.D. in Planetary Sciences from the University of Arizona in 2019. During her time as a graduate student, she became interested in studying how general education science students approach concepts taught to them in their astronomy courses. This led her on a path toward becoming an astronomy education researcher. After completing her Ph.D., Molly began a position as an Education Postdoctoral Fellow for the Zooniverse at the Adler Planetarium in Chicago. As a Professor at ASU, Molly utilizes citizen science as a tool to bring authentic research experiences to undergraduate students both in-person and online. She also develops and evaluates curricular materials designed to promote data literacy and engage students in critical reasoning. In her free time Molly loves to travel, play pickleball, and spend time with her husband and two rescue dogs.

AstroBeat

Number 189 · June 2023
Publisher: Astronomical Society of the Pacific
Editor: Greg Schultz
Designer: David Barker

The Astronomical Society of the Pacific increases the understanding and appreciation of astronomy by engaging scientists, educators, enthusiasts, and the public to advance science and science literacy.

astrosociety.org

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