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VOLUNTEERING FOR SCIENCE
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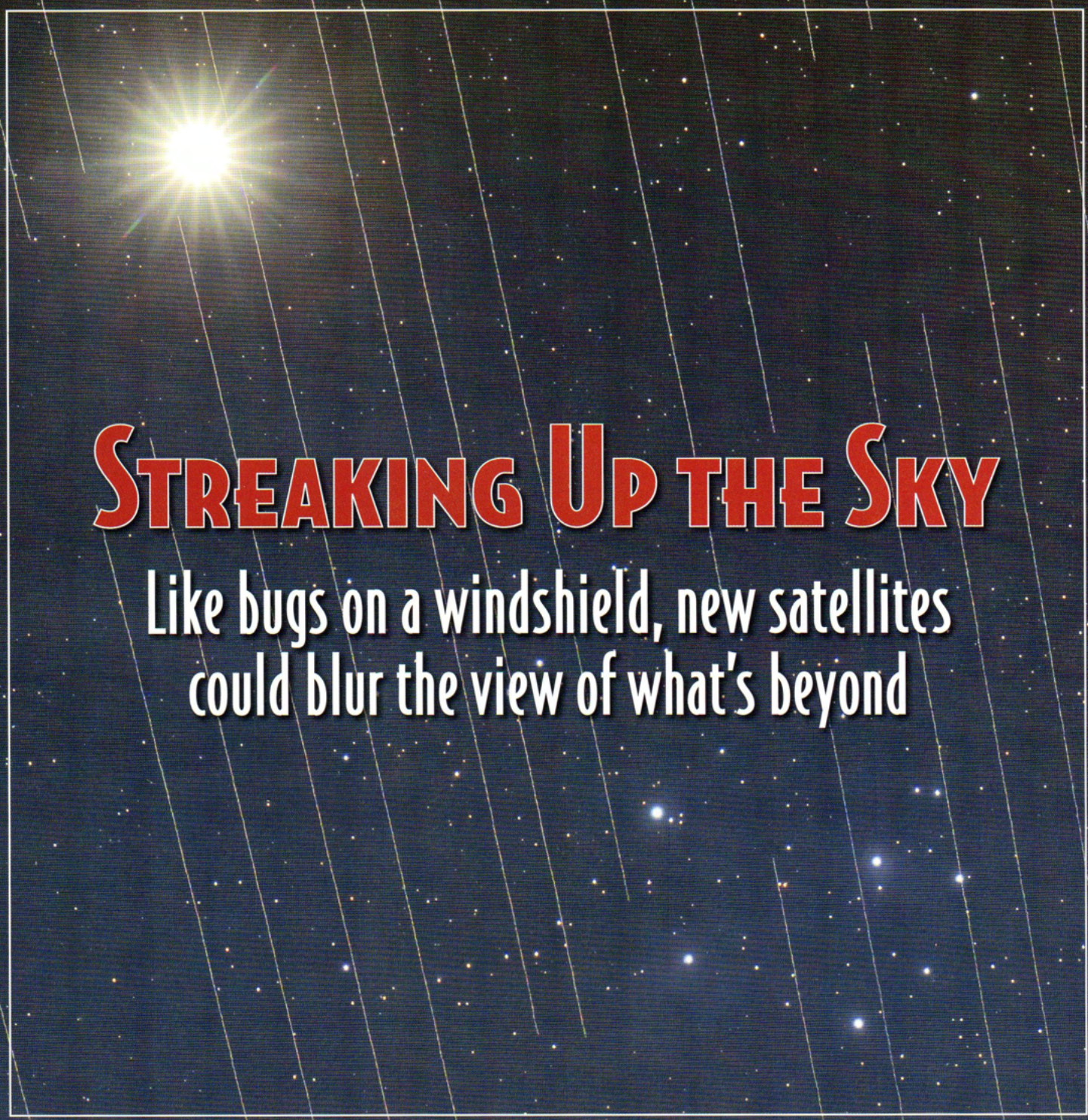

STREAKING UP THE SKY

Like bugs on a windshield, new satellites could blur the view of what's beyond

THE UNIVERSITY OF TEXAS AT AUSTIN McDONALD OBSERVATORY

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TORSTEN HANSEN/MAU OAE

On The Cover

A newly launched group of Starlink satellites leaves trails across Venus and the Pleiades star cluster (lower right). Astronomers are concerned that an explosion of new satellites could ruin some of their observations. *See page 4.*

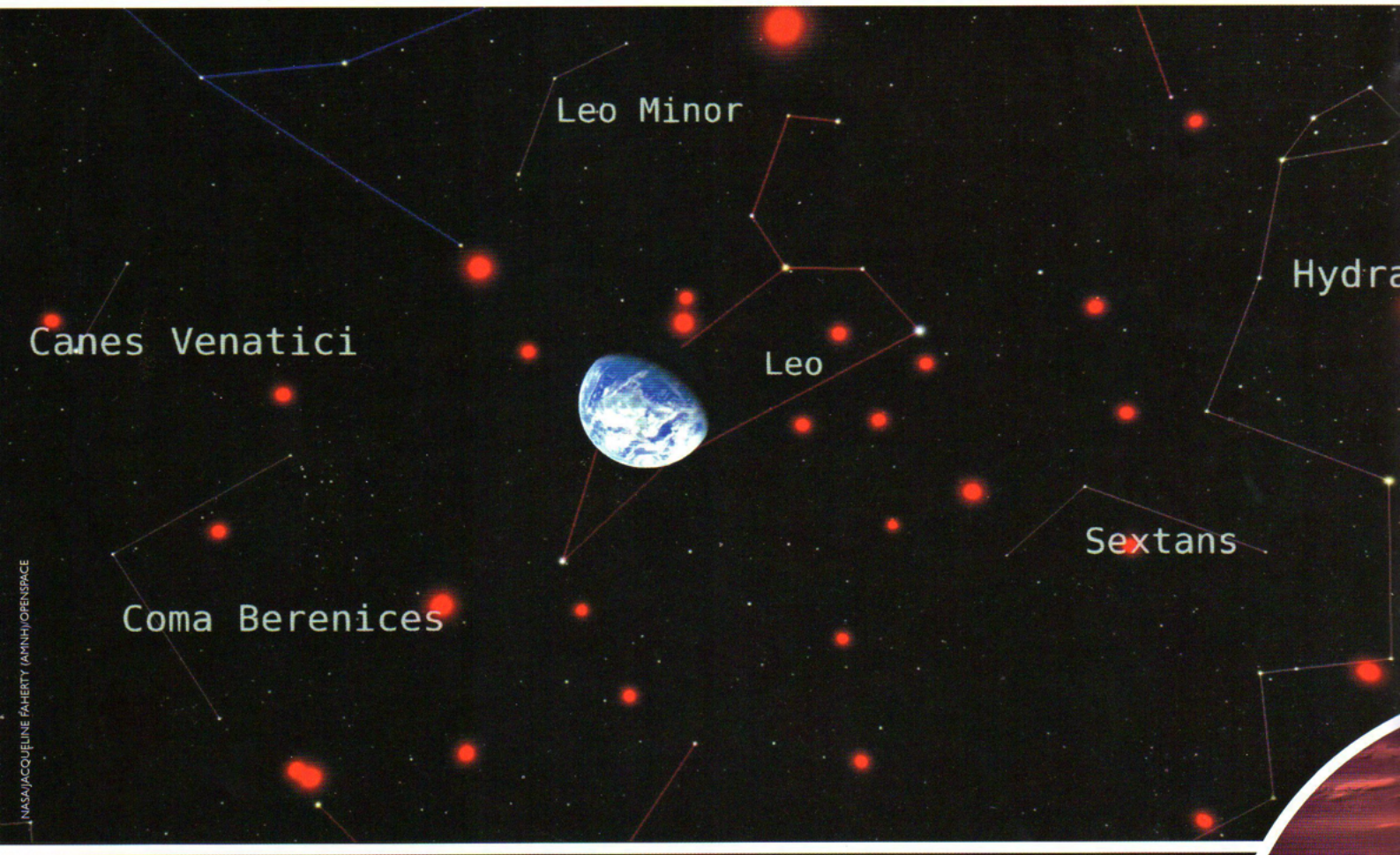
This Page

Arp 107 consists of a pair of galaxies 465 million light-years from Earth. The galaxies are sideswiping each other, pulling out huge streamers of stars and triggering the birth of many more stars.

Coming in January

Get ready to plan your 2024 nights under the stars with our Sky Calendar issue. We'll have all the details on April's solar eclipse, plus meteor showers, the planets, and profiles of a dozen prominent stars.

Signing Up for Science



NASA/JACQUELINE FAHERTY (AMNH)/OPENSPACE

Volunteers help astronomers probe everything from comets to exoplanets to dark energy.

BY STEVEN MURRAY

New comets. New planets. New types of stars. Discoveries by non-scientist volunteers are accelerating the pace of discovery, and opportunities to break new scientific ground have never been greater. "It's open to everybody, and there's a project to fit everyone," says Marc Kuchner, an astrophysicist with NASA's Goddard Space Flight Center in Maryland and citizen science officer for the agency's Science Mission Directorate.

Volunteers have contributed to dozens of projects covering almost every field of astronomy and planetary science, and opportunities may balloon in the coming years as giant new projects, which will generate terabytes of data every few days, overload professional scientists with more data than they can handle.

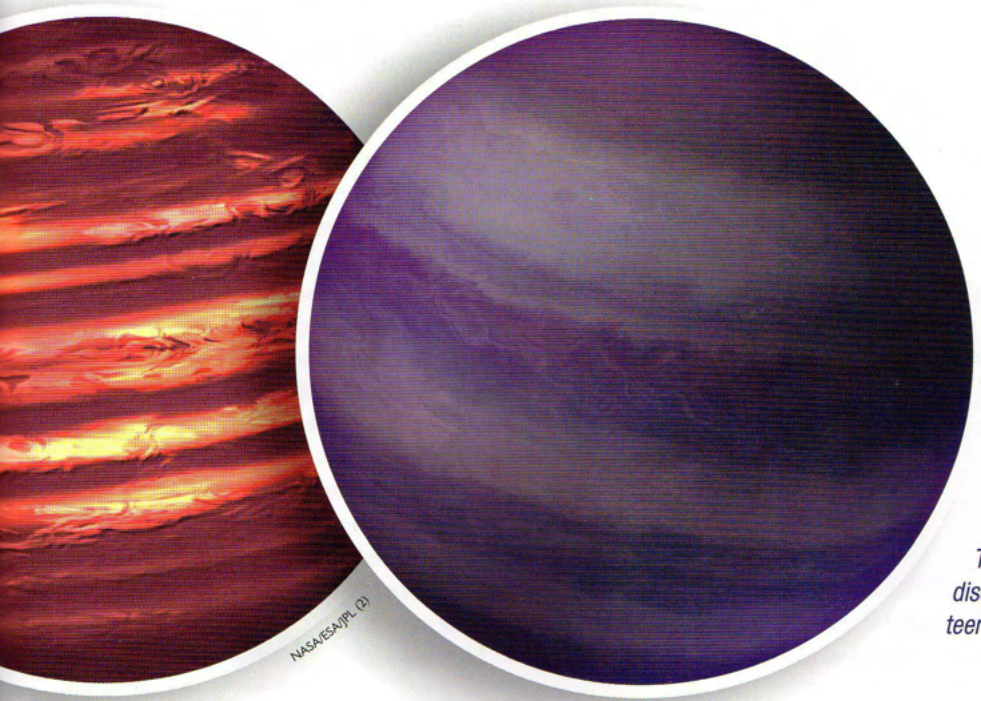
The American Association of Variable Star Observers (AAVSO), which began in 1911, likely represents one of the first organized efforts to allow amateurs to contribute to professional astronomy. There were (and still are) simply too many variable stars—which change brightness, for a variety of reasons—for astronomers to study on their own, so early volunteers did it for them. "We'd send star charts and instructions out to people, and we'd record what they sent back on paper and hand-drawn graphs," says Brian Kloppenborg, AAVSO executive director. Today, "researchers can access our databases or ask our volunteers to collect current data about specific targets."

Home computers and the Internet drove the expansion of what's known today as "citizen science" into the 21st century. Stardust@Home, for example, launched in 2006, with volunteers evaluating images of bits of comet dust returned to Earth by the Stardust mission. Galaxy Zoo started in 2007, with a similar approach to evaluating images of galaxies from the Sloan Digital Sky Survey (SDSS). Galaxy Zoo revealed the potential of science crowdsourcing when investigators, hoping to sign up perhaps 30,000 volunteers, instead garnered more than 100,000 eager helpers. These projects are still active today, and have been joined by dozens of others.

While many astrophysics teams design and manage their own volunteer activities, two big resources for helping both scientists and volunteers get started are Zooniverse and NASA.

Lucy Fortson is Professor of Physics and Astronomy at the University of Minnesota and one of the co-founders of Zooniverse, a largely grant-funded, non-profit clearinghouse for volunteer science efforts. "My work in citizen science started around 2005," she says. "I was leading a grant to get high school students working ... with Sloan Digital Sky Survey data." While attending a meeting of the American Astronomical Society, in 2008, Fortson met with some astronomers who were starting Galaxy Zoo, and "it took about 20 minutes to see that we needed to collaborate." Their mutual goal was to speed up analysis of the enormous volumes of data coming in from ever-more-powerful telescopes. The question was, could they generalize their designs to other astronomy endeavors beyond SDSS images.

The answer came quickly. Today, the Zooniverse web platform offers easy access to resources for both scientists in search of help and volunteers in search of opportunities. "We had all of our goals laid out as early as 2009," she notes, "and that vision is still inspiring



Top left: A map shows the locations of brown dwarfs discovered by WISE, with the help of its team of volunteers. Left: Artist's concepts depict ultra-cool (right) and warmer brown dwarfs discovered by the satellite.

us today." Zooniverse currently hosts dozens of projects across a spectrum of science domains.

NASA also has been engaging help from volunteers for a long time. "Citizen science here has exploded in the last 15 or 20 years," says Kuchner. He says that most of the known comets, all of the known samples of interstellar material, most of the ultracool brown dwarfs (objects that are heavier than planets but not massive enough to shine as stars), and a planet in a quadruple star system have all been discovered or studied by NASA volunteers. Kuchner's office provides seed money and "best practices" guidance to help researchers get their studies going with crowdsourced support. Beyond that, however, the agency encourages its investigators to leverage existing platforms like Zooniverse.

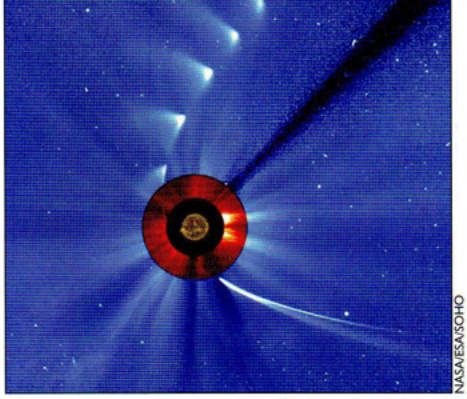
If volunteer response to the early Galaxy Zoo call was strong, it shouldn't have been surprising. An even earlier project, Solar and Heliospheric Observatory (SOHO), which studies the Sun, received help that its research team hadn't even been looking for.

"SOHO launched over 25 years ago," says Karl Battams, an astrophysicist and computational scientist at the Naval Research Laboratory who has headed the Sungrazer Comets citizen science project since 2003. "The Internet was still developing, so we'd get these nice images from space and then just put them online." Amateur astronomers soon found the photographs, noticed that comets were showing up in them, and reported their discoveries to the SOHO project team. "They did their own measurements and saw really small comets that we hadn't noticed," Battams says. By 2001, there was so much information coming in from the public that the team had to create a special website and project structure to manage it all.

"I'm astounded on a daily basis that this spacecraft, which was designed just to look at the Sun, has discovered over 4,600 comets, with more to come," says Battams. "And the science we've gleaned about the dynamics and chemistry of comets as they get near the Sun all comes from volunteers who spend huge amounts of their time looking for these things."

These early efforts showed that large numbers of people are ready and eager to engage in scientific work, and that thousands of human eyes can advance a project faced with overwhelming volumes of data. But while many investigators include crowdsourcing in their research efforts from the beginning, others realize the benefits only after their work is under way.

In 2018, for example, astronomers with Transiting Exoplanet Survey Satellite (TESS) had the same problem as the one faced by SDSS investigators years earlier. TESS, notes Kuchner, "discovered more transiting planets than researchers could possibly follow up on themselves." (A transit occurs when a planet passes directly in front of its star, causing the star's brightness to fade slightly.) Furthermore, TESS scientists realized that still more planets were likely hiding in their data. Investigators therefore developed two Zooniverse projects—Planet Hunters TESS and Planet Patrol TESS—to search TESS data, which helped to make new discoveries and led to published papers.


NASA/ESA/SOHO

Volunteers were among the first to catalog comets flying near the Sun in SOHO images. This is a composite showing a bright comet as it loops close to the Sun, which is blocked out to allow scientists to study the region near the Sun.

Results like these are capturing the attention of even more astronomers.

"My realization about citizen science happened later than it should have," says Aaron Meisner, an astronomer with the National Science Foundation's NOIRLab who specializes in large survey datasets, which contain information on thousands or millions of astronomical objects.

Meisner works with a Kuchner project, Backyard Worlds: Planet 9, which examines data from Wide-field Infrared Survey Explorer, a NASA mission that launched in 2009 to study the universe at infrared wavelengths, which are invisible to the human eye. "I was kind of skeptical when Marc first contacted me about it," Meisner says. "I thought I could just write code to do it all, and was pleasantly surprised about how wrong I was." Project volunteers helped filter out image artifacts, which improved the team's automated scanning algorithms.

Along the way, they also made their own original discoveries. "Our citizen scientists have found things like white dwarfs and cool brown dwarfs—intermediate between stars and planets," says Meisner. "That's amazing. The real benefit is that they're not just like machines doing rote tasks. They contribute their own creativity and original thinking, which helps us discover more than what we thought we could."

Even as awareness spreads among experienced professionals about the value added by volunteers, young astronomers are starting their careers already geared in to the approach.

Lindsay House, for example, is a doc-

RESOURCES

INTERNET

Most of the astronomy projects here need only a computer, tablet, or phone. Others work best with binoculars or a telescope.

American Association of Variable Star Observers (AAVSO)
www.aavso.org/databases#research

An AAVSO-NASA search for exoplanets
www.aavso.org/exoplanet-section

NASA
science.nasa.gov/citizenscience
A variety of astronomy, physics, and Earth science opportunities

Sungrazer Comets
sungrazer.nrl.navy.mil

Zooniverse
www.zooniverse.org/projects
Projects are searchable by interest area (more fun) or by typing in a project title.

The Zooniverse projects discussed in this story include:

Backyard Worlds: Planet Nine
www.zooniverse.org/projects/marckuchner/backyard-worlds-planet-9

Dark Energy Explorers
www.zooniverse.org/projects/erinmc/dark-energy-explorers

Galaxy Zoo
www.zooniverse.org/projects/zookeeper/galaxy-zoo

Planet Hunters: TESS
www.zooniverse.org/projects/nora-dot-eisner/planet-hunters-tess

Planet Patrol
www.zooniverse.org/projects/marckuchner/planet-patrol

toral student at the University of Texas at Austin who is working with the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX). HETDEX scientists initially used machine learning algorithms to scan observations of galaxies, but the results weren't what they needed. Reviewing the data by hand worked better but was too time consuming. "The team had heard about citizen science, but they didn't really know how useful it could be," says House. "I came on as a grad student to create a volunteer program and to train the public to classify these objects." In 2021, she launched Dark Energy Explorers on Zooniverse. It provided ready access to a database of volunteers and helped get her recruiting message out to teachers, science museums, and planetariums.

But science is only as good as the quality of its data, and while participants are motivated and conscientious, most have little training or experience. Therefore, like most citizen-science efforts, House and her team vet results of Dark Energy Explorers. "At least 10 people look at every source, and then we average them," she says. The challenge is to make the process easy for everyone. "We want to encourage participants to interact with us and with each other, so they can post images on discussion boards and ask questions, or ask for a second opinion."

Dark Energy Explorers also reflects many other projects by using volunteer results to generate datasets of "right" and "wrong" exemplars that can improve machine learning performance. "We've been really surprised at how accurate our volunteers have been," says House. "They're great at pattern recognition and picking out signal from noise. That's giving us much cleaner samples."

As researchers grow more experienced with these efforts, they also learn the best ways to achieve success. Zooniverse organizers recognized early on that researchers would need help to get started and, in 2015, created a web-based tool that allows scientists to design and manage new studies around volunteer support. "With a few button clicks, an investigator can populate their project, include the questions they want answered, and launch it to the public," says Forston.

But the rewards of volunteer projects are accompanied by a special responsibility for investigators—one that isn't part of more conventional research activities: the need to keep volunteers engaged and to make them feel like the valued resources they are. Zooniverse studies have shown that project productivity scales with the amount of time investigators spend interacting with volunteers. "Knowing how to work with citizen scientists is now an essential job skill for our research teams," says Fortson. "On the flip side, it can also humanize scientists, which is a good thing."

There are rewards to people who volunteer their time and energy to science projects. For most, the primary return is the chance to participate in professional-grade science and the personal excitement of "first access" to raw data. Theirs are the first eyes to see new signals from space, even before project investigators.

For some, that experience will lead down a deeper path. "A portion of our volunteers are 'super users,'" says Meisner. "They're highly engaged and we interact with them just like other professional colleagues. Many have been co-authors on peer-reviewed publications with us, some as first author, and some have even been co-investigators on successful Hubble and James Webb Space Telescope proposals."

And for still others, the path can carry them in new life directions. "We're starting to see a crop of students that have had their career choice impacted by Zooniverse," says Fortson. "Applicants say that they got their start in astronomy through a Zooniverse project their teacher wanted them to do. How cool is that?"

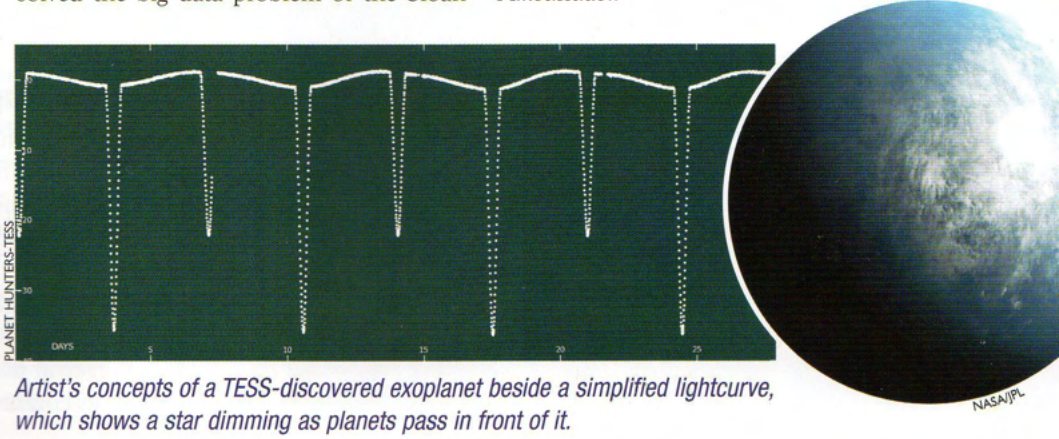
As bigger waves of information grow into tsunamis, volunteers likely will become even more essential. "We say that Zooniverse originally solved the big data problem of the Sloan era with 'little b and little d' projects," says Fortson. But upcoming facilities, such as the Vera Rubin Telescope in Chile, which will observe the entire sky every 2.7 nights, will gather as much data per night as the Sloan survey collected in years. "All of the eyeballs on Earth couldn't look through those data, so we've got to start structuring the 'big B and big D' projects now," Forston says.

But what about artificial intelligence and machine learning? Humans were essential to data analysis in the early 2000s because these systems weren't capable of handling things on their own. Anyone who reads the news, however, knows just how fast those capabilities are improving. Can volunteer humans be replaced by technology? It's not likely, because every pair of human eyes has an insightful, curious mind behind it. "People can pivot," says Kuchner. "They'll look at a dataset and discover something that you didn't even know you were looking for."

"It's the citizen scientists that will make sure that we don't miss anything," says Meisner. "We'll find out more about what we know, plus all kinds of weird things that we might not imagine."

As opportunities expand for public engagement, the future of scientific inquiry could, itself, look very different. "What I find most important about citizen science," says Fortson, "is that it's more of a level playing field now, with people sharing different strengths. Citizen science enables people to reclaim agency in the science enterprise, opening it up for everyone. Professional astronomer and citizen scientist—it's a great team, right? Think how much can get accomplished when you have that."

Steven Murray, a former research engineer, is a freelance science writer and NASA Solar System Ambassador.



Artist's concepts of a TESS-discovered exoplanet beside a simplified lightcurve, which shows a star dimming as planets pass in front of it.