AstroTalk: Behind the news headlines of March 2017

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'Citizen science' on the rise

Thanks to the Internet, amateur volunteers known as 'citizen scientists' can readily donate their time and effort to science—in fields ranging from medicine to zoology to astrophysics. The astrophysics project 'Space Warps' offers a compelling example of why citizen science has become such a popular tool and how valuable it can be.

In late 2015, in a pair of research papers, Space Warps announced the discovery of 29 new gravitational lenses. These arced or blobby features, seen in images of deep space, are actually distant galaxies whose light has been bent by the mass of foreground galaxies. Scientists prize these rare, cosmic phenomena because they offer tantalizing glimpses of objects too distant and dim to be otherwise seen.

This haul of lenses was obtained over an 8 month period by about 37,000 Space Warps volunteers, who reviewed 430,000 digital images in a massive, online photo library. Automated computer programs have identified most of the approximately 500 gravitational lenses discovered to date. However, computers failed to flag the 29 lenses the Space Warps volunteers spotted.

> "*Human beings are very good at pattern recognition. The dynamic range that our eyes and our brains offer is much greater than a computer algorithm*," said Anupreeta More, a project researcher at the Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU) at the University of Tokyo and a co-principal investigator for Space Warps.

More and her colleagues designed Space Warps to take advantage of these human abilities. So far, besides the 29 new gravitational lens candidates, Space Warpers have also turned up a never-before-seen lensing scenario that looks like a red ring in the project's image archive. Researchers are still working out the source of this red ring, which they suspect is the warped features of a background galaxy containing a supermassive black hole as well as regions of new star formation.

Discovering such strange, new phenomena is a hallmark of citizen science. Among the most famous examples is Hanny's Voorwerp, a galaxy-size gas cloud discovered in 2007 in a project called 'Galaxy Zoo,' one of the earliest astronomy projects.

> "*Citizen scientists... have really enabled us to produce important findings. They've inspired us with their dedication and productivity*," said Aprajita Verma, a senior researcher in the department of physics at the University of Oxford (UK) and also a co-principal investigator for Space Warps.

> "*We've learned from our analysis that basically anyone who joins Space Warps has an impact on the results*."

As astronomical data sets continue to increase in size, there will be no shortage of opportunities for eager citizen scientists. For instance, the Large Synoptic Survey Telescope, expected to start operations in 2022, will collect 30 terabytes of data per night as it observes the whole sky every few days from the southern hemisphere. Computerized object-recognition programs will certainly play an important role in analysing these data, but human volunteers are likely to remain integral.

> "*I think there will be citizen involvement for a long while and it will become more interesting as we use machines to do more of the routine work and filter the data*," said Chris Lintott, a professor of astrophysics and the citizen science lead at the University of Oxford. "*The tasks for citizen scientists will involve more varied things—more of the unusual, Hanny's Voorwerp-type of discoveries*."

Lintott, who is also a co-founder of Galaxy Zoo and the principal investigator for the Zooniverse citizen science web portal, added,

> "*Plus, a lot of unusual discoveries will need to be followed up, and I'd like to see citizen scientists get further into the process of analysis. Without them, I think we're going to end up with a pile of interesting objects which professional scientists just don't have time to deal with*."

A new citizen-science project launched this past month, on 22 March 2017. Its aim is to rescue tens of thousands of potentially valuable cosmic images that are mostly dead to science and bring them fully back to life. Called 'Astronomy Rewind,' the effort will take photographs, radio maps, and other telescopic images that have been scanned from the pages of dusty old journals and place them in context in digital sky atlases and catalogues. Anyone will then be able to find them online and compare them with modern electronic data from ground- and space-based telescopes, making possible new studies of short- and long-term changes in the heavens.

> "*There's no telling what discoveries await*," says Alyssa Goodman from the Harvard–Smithsonian Center for Astrophysics (CfA), one of the project's founders. "*Turning historical scientific literature into searchable, retrievable data is like turning the key to a treasure chest*."

Astronomy Rewind is the latest citizen-science programme on the Zooniverse platform, which debuted at Oxford University a decade ago with Galaxy Zoo and now hosts more than 50 active 'people-powered' projects across a variety of scientific disciplines.

After going through a short exercise to learn what they're looking for, users will view scanned pages from the journals of the American Astronomical Society (AAS) dating from the 19th Century to the mid-1990s, when the Society began

publishing electronically. Volunteers' first task will be to determine what types of images the pages contain: Photos of celestial objects with (or without) sky coordinates? Maps of planetary surfaces with (or without) grids of latitude and longitude? Graphs or other types of diagrams?

The images of most interest are ones whose scale, orientation, and sky position can be nailed down by some combination of labels on or around the images plus details provided in the text or captions. Pictures that lack such information but clearly show recognizable stars, galaxies, or other celestial objects will be sent to Astrometry.net, an automated online service that compares astrophotos to star catalogues to determine what areas of sky they show.

Modern electronic astronomical images often include information about where they fit on the sky, along with which telescope and camera were used and many other details. But such 'metadata' are useful to researchers only if the original image files are published along with the journal articles in which they're analysed and interpreted. This isn't always the case—although it's becoming more common—so some electronic journal pages will eventually be run through Astronomy Rewind and Astrometry.net too.

Thanks to these human-assisted and automated efforts, many thousands of 'new old' images will ultimately end up in NASA's and others' data repositories alongside pictures from the *Hubble Space Telescope*. They will also be incorporated into the Astronomy Image Explorer, a service of the AAS and its journal-publishing partner, the UK Institute of Physics (IOP) Publishing, and viewable in WorldWide Telescope, a powerful data-visualization tool and digital sky atlas originally developed by Microsoft Research and now managed by the AAS.

The scans of pages from the AAS journals—*The Astronomical Journal* (*AJ*), *The Astrophysical Journal* (*ApJ*), *ApJ Letters*, and the *ApJ Supplement Series*—are provided by the Astrophysics Data System (ADS), a NASA-funded bibliographic service and archive at the Smithsonian Astrophysical Observatory (SAO), part of the CfA.

Astronomy Rewind is built on a foundation laid by the ADS All-Sky Survey, an earlier effort to extract scientifically valuable images from old astronomy papers using computers.

> "*It turns out that machines aren't very good at recognizing celestial images on digitized pages that contain a mixture of text and graphics*," says Alberto Accomazzi (SAO/ADS). "*And they really get confused with multiple images of the sky on the same page. Humans do much better*."

Accomazzi's CfA colleague Goodman, who runs a collaboration called 'Seamless Astronomy' to develop, refine, and share tools that accelerate the pace of astronomical research, helped bring ADS and Zooniverse together. According to Zooniverse co-investigator Laura Trouille (Adler Planetarium, USA), 1.6 million

volunteers have made about 4 billion image classifications or other contributions using the platform over the last 10 years.

> "*This isn't just busywork*," says Trouille. "*Zooniverse projects have led to many surprising discoveries and to more than 100 peer-reviewed scientific publications*."

If Astronomy Rewind attracts volunteers in numbers comparable to other astronomy projects on Zooniverse, Trouille estimates that at least 1,000 journal pages will be processed daily. Each page will be examined by five different citizen scientists; the more of them agree on what a given page shows, the higher the confidence that they're right. It shouldn't take more than a few months to get through the initial batch of pages from the AAS journals and move most of them on to the next stage, where the celestial scenes they contain will be annotated with essential information, extracted into digital images, mapped onto the sky, and made available to anyone who wants access to them.

> "*Astronomy Rewind will breathe new life into old journal articles and put long-lost images of the night sky back into circulation, and that's exciting. But what's more exciting is what happens when a volunteer on Zooniverse looks at one of our journal pages and goes, 'Hmm, that's odd!' That'll be the first step toward learning something new about the Universe*."

But astronomy is not the only discipline that has benefited tremendously from the involvement of citizen scientists. A wildlife agency studying the Steller sea lion decline in Alaska's Aleutian Islands has also been looking for help from citizen scientists. Volunteers don't need raincoats or rubber boots to pitch in, just eyeballs and a computer screen.

Fisheries researchers at the U.S. National Oceanic and Atmospheric Administration (NOAA) want them to sort through 500,000 images captured by 20 cameras at six remote sites. The job is simple: Flag photos that show sea lions. NOAA Fisheries biologist Katie Sweeney is specifically looking for 256 Steller sea lions captured starting in 2011 that were permanently marked by branding, allowing them to track movement patterns. The image sorting tells researchers which photos are most important to review.

> "*If we see these animals over time, we can estimate their survival*," Sweeney said from her office at the Alaska Fisheries Science Center in Seattle (USA).

Steller sea lions are the largest members of the eared seal family. Adult males in the Aleutians can grow to 2,400 pounds and females to 800 pounds, Sweeney said. They are found in the North Pacific from Japan and Russia to Alaska and as far south as the Channel Islands off the coast of Southern California.

The western population, from Prince William Sound to the Aleutians, was listed as endangered in 1997. They fell to their lowest numbers in 2003 and the population since then has increased just 2.7% annually. Sea lions in the far

western Aleutians were especially hard hit, declining by 94% over the last 30 years.

No one knows why. Tracking marked sea lions has indicated they are not simply moving east to other parts of Alaska or west to Russia. Contaminants and poor nutrition are among the possibilities, but answers don't come easy because of the expense and time needed to reach the remote locations where they live.

NOAA in 2012 turned to remote cameras to gather more information. The 20 cameras work year-round, snapping a digital photograph every 10 to 30 minutes during daylight.

> "*We get on a research vessel and we are out 1,200 miles in the Aleutian Islands*," Sweeney said. "*We go to each site and have to pull out the SD cards and download them*."

A handful of people who volunteered to check the images could not keep up with the volume. Computer analysis was not an option because creating an automated process would have been expensive and time consuming, Sweeney said. Researchers turned to crowdsourcing. They're working with the Zooniverse platform.

One volunteer was Charlene Andersson, a teacher at Meadows Elementary School in Valencia, California (USA), who saw the project as an opportunity to engage her students in curriculum on animals and their habitats. That led to questions on endangered species and causes for sea lion decline.

> "*They're so excited about contributing to the project*," Andersson said. "*They're coming in and saying, 'Can we go on the site right now?'*"

Sweeney had hoped that volunteers would finish that first batch in about three months, when she was due to leave for the Aleutians to count sea lions and brand more of them. Instead, the citizen scientists surprised her and zipped through the first batch in a day and a half.

Researchers have since launched a second phase of the project: Asking volunteers to look at photos with sea lions to see if any animals are carrying the permanent marks that reveal where the sea lions were born, their age and their gender. The sorting will help researchers focus on the most important images.

Citizen science has been around for more than a decade, and it has matured to become a useful input to the work of professional scientists. There are numerous projects one can contribute to, so if you want to 'get your hands dirty' and contribute to science, you are strongly encouraged to get involved!

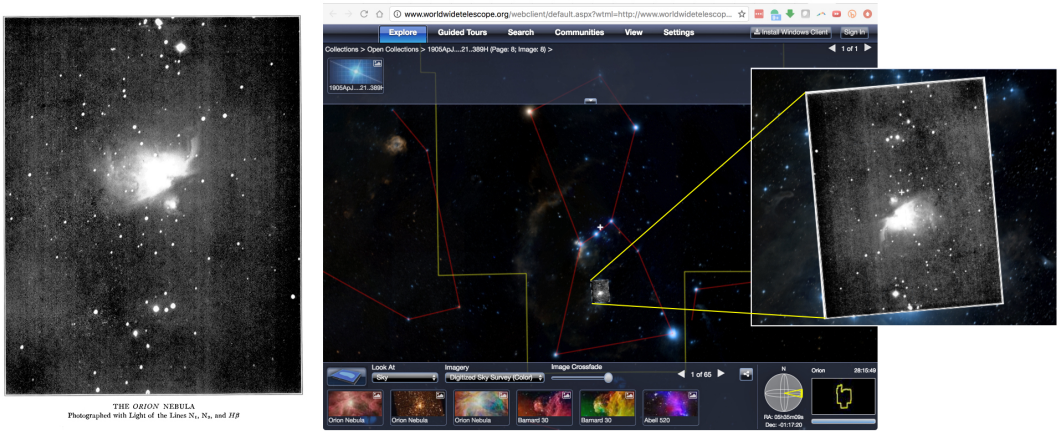

Figure 1: At left is a photograph of the Orion Nebula from page 396 of the June 1905 *Astrophysical Journal*—without coordinate labels to fix its celestial position and orientation. Astrometry.net was able to recognize the star pattern, after which the image was rotated more than 180° to put north up, and placed in context on the sky in WorldWide Telescope. (*Credit: American Astronomical Society, NASA/SAO Astrophysics Data System & WorldWide Telescope.*)

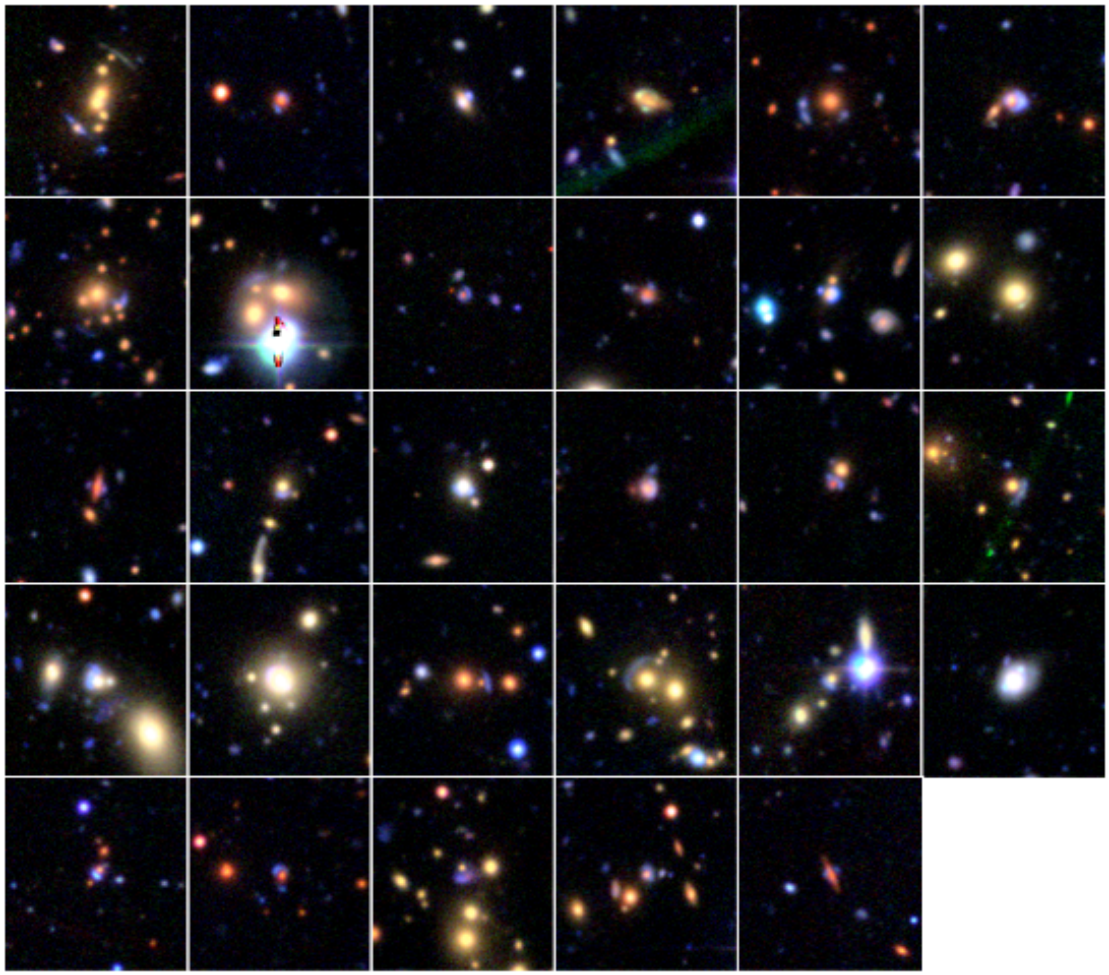

Figure 2: 29 gravitational lens candidates found through Space Warps. (*Credit: Space Warps, Canada-France-Hawaii Telescope Legacy Survey*)

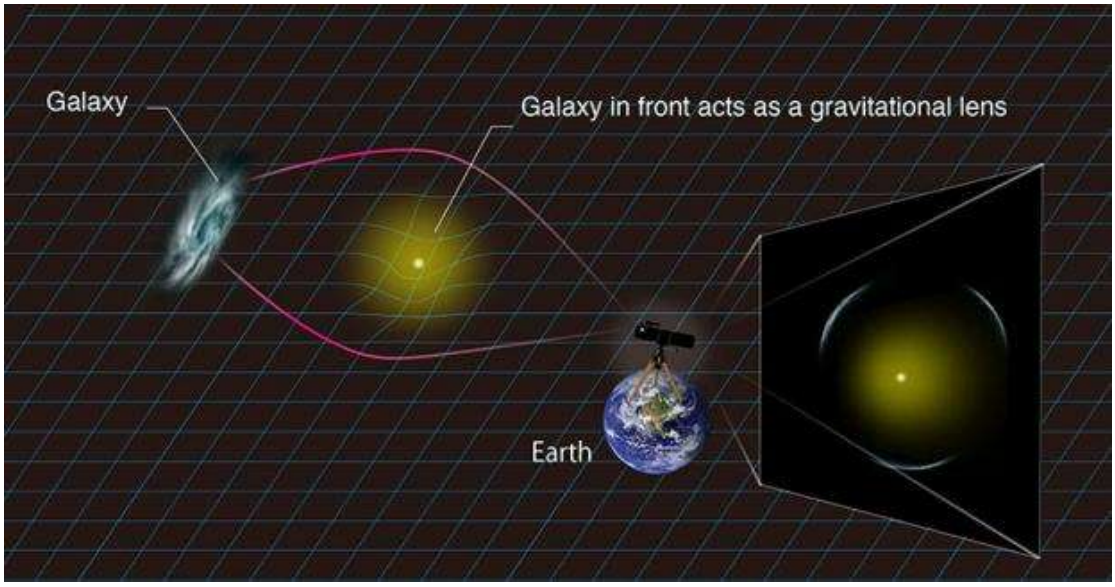

Figure 3: How one galaxy's image appears distorted due to another galaxy. (*Credit: Kavli IPMU*)

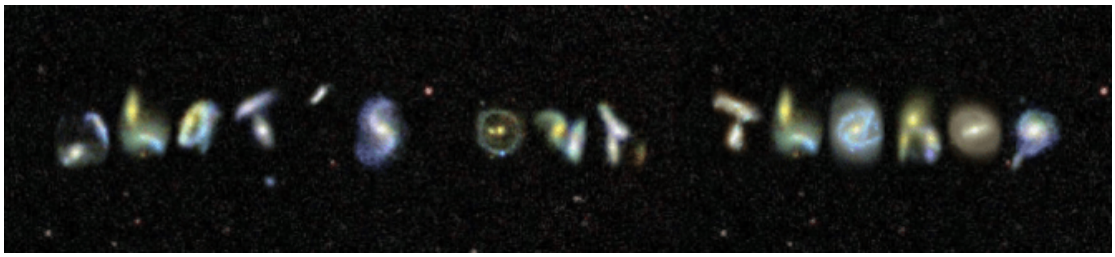

Figure 4: There are so many galaxies, you can write with them! (*Credit: galaxyzoo.org, CC BY-SA*)

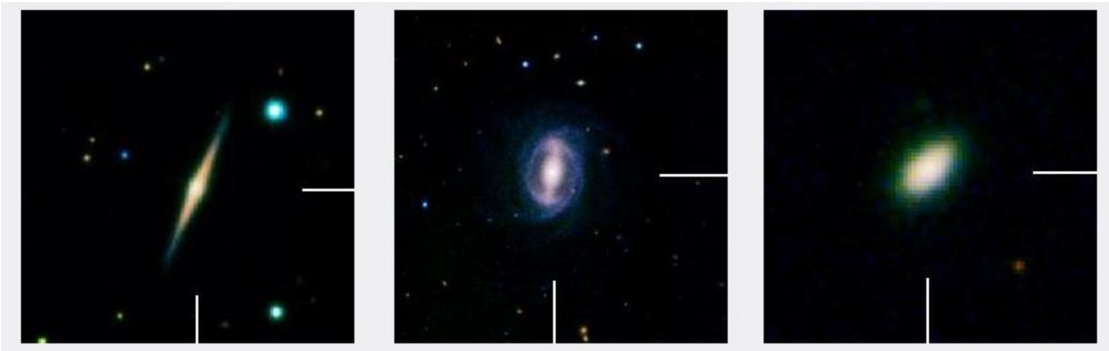

Figure 5: Classify these galaxies from 'Galaxy Explorer:' a galaxy with a bright bulge, a barred spiral, and a featureless galaxy. (*Credit: ABC Science*)

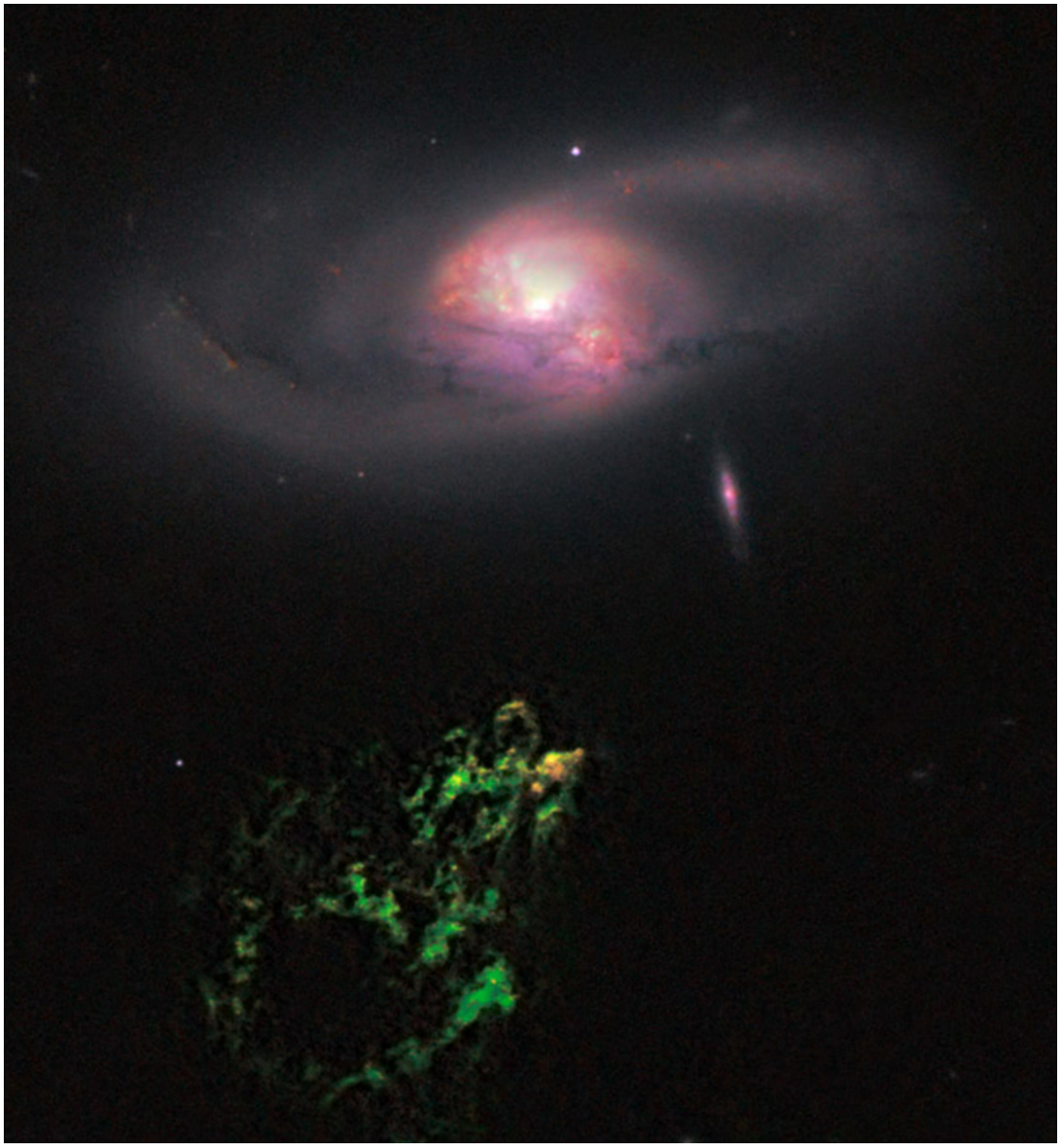

Figure 6: Hanny's Voorwerp is the green blob below the galaxy. It's a stream of gas that's making stars. (*Credit: NASA, ESA, W. Keel/University of Alabama, and the Galaxy Zoo Team*)

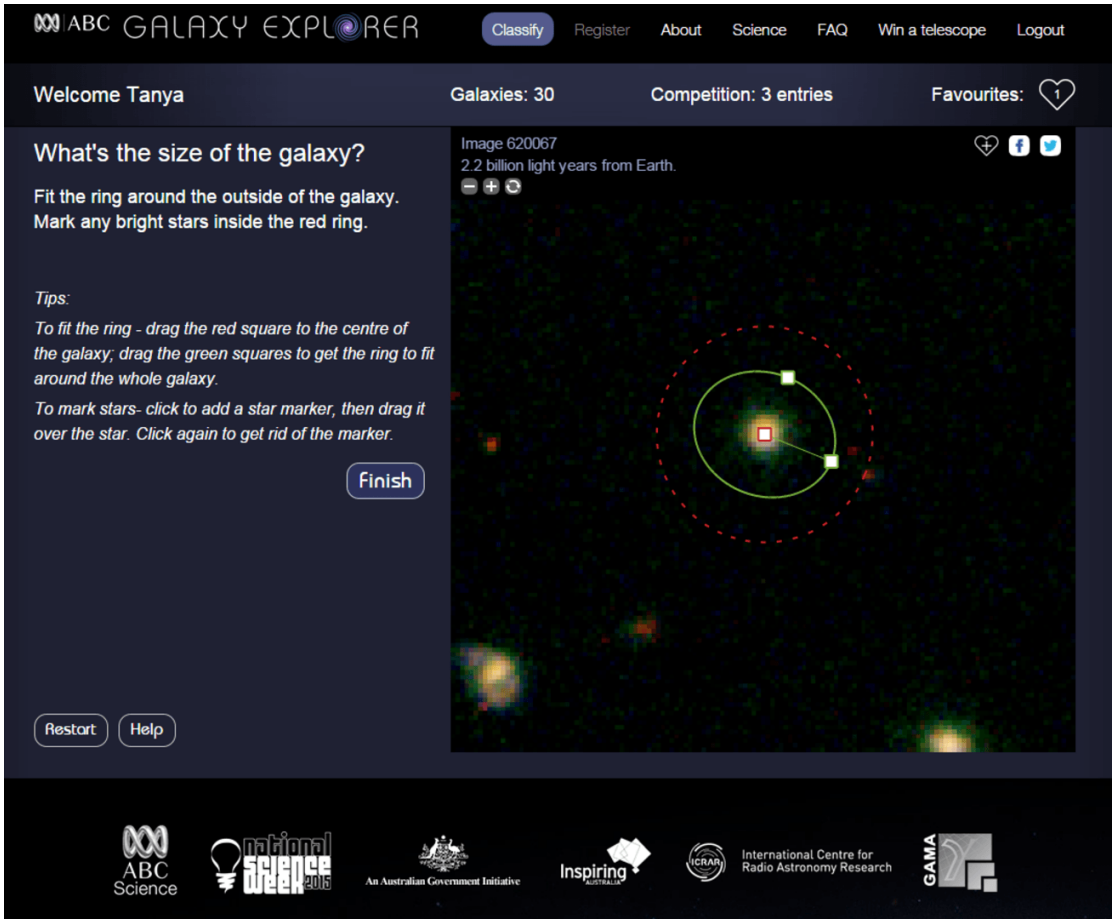

Figure 7: It's easy to measure the size of the galaxy—move the green squares until the ring is snug around the galaxy.

Figure 8: Researchers observing Steller sea lions. (*Credit: Russ Andrews, Alaska SeaLife Center and UAF*)

Figure 9: Sea lion preys on salmon at Bonneville Dam on the Columbia River (USA). (*Credit: US Army Corps of Engineers*)