Citizen science – the new helping hand for scientists

In 19th century North America, Christmas time was closely related to a tradition known as 'side hunts', where men competed with each other to kill as many birds as possible. However, at the end of the century, the foundations of that tradition were shaken by an ornithologist Frank Chapman, who suggested that people count birds, instead of killing them. The project named Christmas Bird Count was initiated in 1900 with 27 volunteers from USA and Canada, who were man enough to believe they can find pleasure in counting birds as much as, or even more than killing them. The 111th Christmas Bird Count that just ended, registered tens of thousands of bird enthusiasts armed with binoculars, bird guides and a strong sense of belonging to a common cause. For twenty days they counted and classified birds throughout North America. What they found will be used by various conservation organizations to help them assess the health of bird populations and shape effective conservation strategies. The Christmas Bird Count is the oldest running citizen science project, but it is surely not the only one. The last two decades have seen citizen science emerging as yet another trend in conducting scientific research with growing and far-reaching impact on scientists, citizens and society as a whole.

What is citizen science and doesn't science belong to scientists to play around with? And aren't citizens the mere recipients of bits and pieces of science disseminated by the scientists as a payback for the citizens' taxpayer money? Well, citizen science is an attempt to convince scientists and citizens that instead of playing tug of war, where scientists are trying to pull off more money for their research, while citizens demand faster and smaller gadgets, better environment with higher energy consumption and a cure for AIDS, both communities should rather play games like bridge as partners. Citizen science is a collective term for projects that engage non-scientists and non-experts in the process of collecting, evaluating and/or computing various scientific data – from counting birds and recording the phenology of plant species to classifying galaxies and finding the optimal 3D folding structure of a protein. On one hand, scientists borrow the computational or intellectual power of citizen volunteers to increase their research productivity. On the other hand, inevitably this process strengthens the interaction between the two communities, introducing to a much larger public not only some of the esoteric scientific wonders, but also the scientific way of looking at them. But when did scientists and citizens start to realize the mutual benefit of citizen science?

Intoxicated by the fast progress in instrumentation, web-, computer- and storage-based technology, in the last 15 years, hungry-for-data scientists quickly started accumulating unimaginable volumes of data. Somewhere in the process of filling the vast data-storage warehouses, a handful of scientists recognized their limited human and computer processing power, and after few quick calculations realized they would need more than a life-long stretch of time to complete their search through the acquired data. In mid-1999, researchers at the Space Sciences Laboratory at UC Berkeley launched the first scientifically driven distributed computing project called SETI@home, which harnessed the CPU power of the public when their computers were idle but still connected to the Internet. SETI@home was set to search for signatures in the Arecibo Radio Telescope data that may bring the coveted evidence for the existence of extraterrestrial life. The unexpectedly high number of volunteers who donated their home-based processing power to SETI@home, led to a modification of the software platform on which it was running to make it flexible for a diverse set of public-resource computing projects. In 2002, David Anderson, a computer engineer at UC Berkeley and his team released the Berkeley Open Infrastructure for Network Computing (BOINC) and currently, there are more than 60 active projects running on the computers of over 2 million volunteers from around the world.

Inspired by the success of SETI@home, Myles Allen at the University of Oxford proposed a distributed computing project that would help refine and improve climate prediction models. At first rejected as being completely unrealistic, the project called climateprediction.net finally took off on 12 September 2003. Just a day after, the total computing capacity of the project exceeded the most powerful supercomputer available at that time – the Earth Simulator. As of now, climateprediction.net is one of the largest climate modelling facilities with ever-expanding popularity in present times, when much of the attention of not only scientists but also national governments and international organizations is focused on understanding and predicting the effects of climate change and global warming.

Astronomy is another area in science that has fallen in need of enormous computational resources in order to continue to unravel the mysteries of the cosmos. Our ability to see tiny objects located further in the space–time of the universe has led to a mind-boggling increase in the volume of accumulated astronomical data. Not surprisingly, astronomers are leaders in the number of distributed computing projects dedicated to helping them process the vast amount of data. The most popular of these projects is Einstein@home, which was launched in February 2005 as part of the contributions to the World Year of Physics 2005. Run jointly by the Max Planck Institute for Gravitational Physics, Germany and University of Wisconsin, Milwaulkee, Einstein@home uses hundreds of thousands of personal computers to sieve through large sets of data from Laser Interferometer Gravitational Wave Observatory (LIGO) in search of gravitational waves and their sources. The second goal of Einstein@home is to detect new and unusual pulsars looking through data from the Arecibo Observatory. And while computers running Eistein@home might still be deaf to the gravitational waves, the project marked its first success in June last year. The computer of a casual family in a small town in Iowa detected a pulsar, emitting radio pulses with a rate higher than most known pulsars. The discovery of the PSR J2007+2722 pulsar was validated by observations with the Green Bank Telescope in West Virginia and published in *Nature* just few months later.

The list of distributed computing projects is growing fast and the scope of problems that are being tacked has long left the well-established fields of astronomy, climate modelling and protein folding. However, recently, their popularity has been shadowed by a new trend known as distributed thinking projects. Such projects embrace a different scientist–citizen interaction scheme, where computers are now mere delivery boys for the intellectual output generated by citizens themselves. This has taken citizen science to a whole new level, where citizens are helping scientific research not when they are sleeping in the night with their computers deliberately left on, but when they are actively engaged in the processing of data themselves, be it trying to find an optimal 3D protein folding, tracking solar storms through space, or classifying galaxies and chasing stardust particles.

Soon after the inception of yet another '@home' project called Rosetta@home, a unique evolution from distributed computing to distributed thinking commenced in the laboratory of David Baker, a biochemist at the University of Washington, Seattle. In October 2005, by which time BOINC projects were well-known phenomena, Baker's team launched Rosetta@home in an attempt to tap into the abundance of idle public computational power. The problem he needed help solving was related to the optimal shape of proteins. To attain that shape proteins fold their chains of amino acids in complicated 3D structures that are rather difficult to predict. Just like many other BOINC projects, participants could watch their PC working for the scientists on their screen-saver at home. But in the case of Rosetta@home, computers soon seemed rather dumb to many enthusiastic volunteers who stared at the screen-saver in their free time. The superior spatial and visual perception skills of humans helped them see quickly and almost intuitively how to arrange bits and pieces of amino acids in the best possible way. So, soon after Rosetta@home became a reality, Baker started receiving responses from people who suggested faster and better ways of creating optimal protein structures. What happened next was the logical step every good manager takes – Baker found a better performer for the job and quickly promoted him. With the help of his computer-savvy colleagues, Baker created an on-line game called Foldit (Figure 1), where participants play around with proteins individually or in teams aiming at collecting as many points as possible and moving up to the next level in the game. Taking advantage of the natural human competitiveness, Baker is now enjoying a crucial output of the game – novel folding strategies developed by Foldit gamers, which he incorporates back into his Rosetta algorithms.

If biology never really managed to find its place in the list of your interests, but the space beyond the earth has always attracted you, you still have plenty of opportunities to play, learn and assist scientists. Another pioneering distributed thinking project called Stardust@home was launched in August 2007 by Andrew Westphal, a physicist at UC Berkeley. After NASA's Stardust mission returned to earth in 2006, Westphal was faced with a daunting task. He was certain that dozens of interstellar dust particles were nested somewhere in a specially designed collecting area that was exposed to outer space during the 7-year long journey. Using image-processing techniques, he managed to divide the area into 1.6 million images that needed to be checked – a task that would take him close to a century. Drawing on the example of the then well-established distributed computing projects, but realizing that humans can easily outperform computers in image recognition tasks, Westphal asked volunteers, rather than their computers to help him search for interstellar dust particles. Finding volunteers and giving them incentives that would increase their productivity was quite straightforward. The problem Westphal faced was how to reliably validate the results of Stardust@home. He and his team developed various techniques, like assigning a skill level to each volunteer and setting a threshold of a minimum matching number of answers before an image is accepted and classified. These and other similar techniques are now regularly used for almost all distributed thinking projects. The efforts eventually paid off, when in March last year Westphal's team published in *Nature* the discovery of two possible interstellar dust particles. They were found in one of the millions of images from Stardust@home by Bruce Hudson, a layman from Midland, Ontario, who spent around 15 h a day on the project after he suffered a stroke that left the right side of his body fully paralysed. According to the project rules, Bruce could give a name to the two particles he discovered, and he did so. Orion and Sirius are currently being analysed by various laboratories around the world and the hope is that they will shine more light on the chemical evolution of stars, planets and galaxies. Meanwhile, Westphal is using the characteristics of Orion and Sirius to teach his volunteers how to improve their efficiency in the search of other elusive dust particles.

Inspired by Stardust@home, a team of researchers at University of Oxford designed another distributed thinking project called Galaxy Zoo, where volunteers were asked to classify millions of galaxies as elliptical or spiral using data from the Sloan Digital Sky Survey. The incentives were thrilling – when launching the project Chris Lintott, one of the founders of Galaxy Zoo stated: 'One advantage is that you get to see parts of space that

Figure 1. The on-line game Foldit allows enthusiasts to solve hard scientific problems while folding proteins. Image Credit: Foldit, University of Washington, USA.

have never been seen before. These images were taken by a robotic telescope and processed automatically, so the odds are that when you log on, that first galaxy you see will be one that no human has seen before'[1]. Sure enough, just a day after coming live, the Galaxy Zoo website was receiving around 70,000 responses/h, and within a year more than 50 million galaxies were classified. The staggering success of Galaxy Zoo, whose volunteers have helped create the largest database of galaxy shapes in the world, led to swift expansion of the original project to include more and diverse tasks using data from other astronomical facilities. What started as Galaxy Zoo is now known as Zooniverse with eight live projects – Galaxy Zoo: Supernovae, Galaxy Zoo: Mergers, Solar Stormwatch, Galaxy Zoo: Hubble, Moon Zoo, The Milky Way Project, Planet Hunters and Old Weather. The latest of these projects, Old Weather, is trying to move away from astronomy, asking volunteers to read and digitize hundreds of log books belonging to numerous British ships that criss crossed the world's oceans in the late 19th and early 20th century. These log books contain valuable information about weather conditions over the oceans like temperature, pressure and wind. Data from the log books can help validate and significantly improve climate prediction models – an idea reflected in the logo of the project, 'Our Weather's Past, the Climate's Future'.

Traditional science is already benefiting from citizen science and projects like Zooniverse. The case which recently brought the attention of many to the newly emerging powerful symbiosis between scientists and citizens was the discovery of the 'Voorwerp' (the Dutch word for 'object'). Hanny Van Arkel, a school teacher from The Netherlands, regularly logged onto Galaxy Zoo during her free time. In 2008, she found a strange green blob in one of the Galaxy Zoo images and asked for help in identifying it through the website forum. No one really knew what the voorwerp was, but it was interesting enough to trigger the curiosity of many researchers who started conducting further observations of the object in the optical, UV and X-ray spectrum. It turned out that the voorwerp was a giant dead quasar in the vicinity of the constellation Leo Minor, which had lightened up the gas around it before dying (Figure 2). Chris Lintott and Kevin Schawinski, founders of Galaxy Zoo, said that the voorwerp represented 'the first direct probe of quasar history on these timescales'[2]. Hanny's discovery can help scientists find out more about the formation, evolution and death of quasars – the most luminous of all objects in the universe.

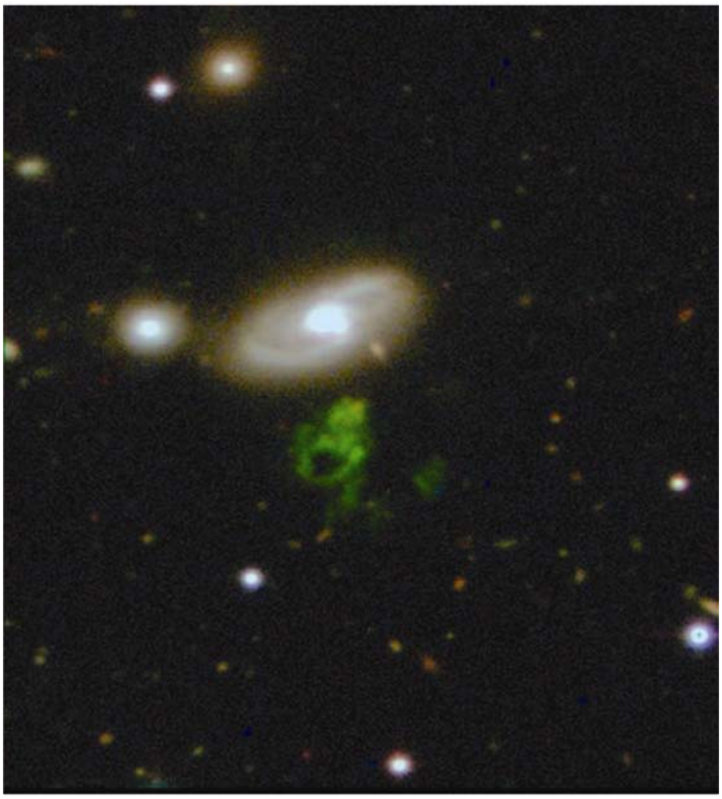

Figure 2. Hanny's voorwerp generated a lot of excitement within the astronomical community, revealing remnants of a dead quasar. Image Credit: Sloan Digital Sky Survey.

The citizen science phenomenon is quickly becoming an important topic in many funding agencies, educational organizations and research institutions in USA and western Europe. These institutions conduct scientific research to: (i) generate a comprehensive definition of citizen science to understand the requirements needed for the successful implementation of such projects; (ii) study the effect of citizen science on both science and society, and (iii) try to predict how citizen science will change research practices and their outcomes. In September 2010, *Nature*, Mendeley, and the British Library organized a two-day conference in London (*Science Online*, London, 2010) focusing on revealing the enormous potential of citizen science to researchers from all over the world and explaining to them the diverse ways in which they can benefit from it. One of the conference organizers, Francois Grey, who is a physicist in CERN, has also established a Citizen Cyberscience Center in Geneva in an attempt to expose developing countries to the idea of citizen science and train scientists from these countries to use citizen science as a tool in their fight against challenging health and educational problems. Sciencefor-citizens.net – a website that connects all science-loving enthusiasts with prospective citizen science projects was launched in August 2010 and has ever since gained spectacular popularity.

While citizen science is gaining strength in the developed world, in India it is still very much in its infancy. Out of the hundreds of research institutions in the country, only one is running citizen science projects. The National Centre for Biological Sciences (NCBS), Bangalore, launched its first such project called MigrantWatch in 2007 (Figure 3). Citizens were asked to monitor and record the arrivals and departures of migrant birds in the vicinity of their home, work place or favourite park. The data, which are also available to the public on the website www.migrantwatch.in are used to study the migration patterns of many bird species and the effect of climate change on these patterns. Currently, there are only 1200 participants in the MigrantWatch programme. The second citizen science initiative by NCBS is called SeasonWatch. The website www.seasonwatch.in/new has been launched recently and the number of participants is growing slowly. So far, the project has been introduced to 7000 schools in Kerala in collaboration with a local initiative called SEED, and will soon be available nationwide. SeasonWatch asks nature lovers to observe the seasonal changes that occur in trees in their backyard, street or neighbourhood. Recording the time of leaf foliage, appearance of flower bud, blossoming, etc. volunteers can provide vital information about the phenology of the observed trees. Such information is crucial to scientists evaluating the impact of local environmental factors and climate change on the ecology and life cycle of various ecosystems. 'Involving citizens in science not only helps answer scientific questions that would otherwise be hard to address, but is important because it engages the larger populations in the process of science, and so de-mystifies this process,' mentioned Uttara Menditatta, the NCBS Citizen Science Program Coordinator. A handful of NGO-initiated projects like The Asian Waterbird Census, Project PteroCount: South Asian Bat Monitoring Programme, Eclipse Watch and the Great Himalayan Bird Count Initiative quickly exhaust the list of citizen science projects in India at the moment.

Figure 3. Asian Paradise Flycatcher is among the many migrant birds that are being monitored by citizen scientists participating in MigrantWatch project to study their migration patterns and design better conservation strategies. Image Credit: MigrantWatch Project, NCBS, Bangalore.

Even the biggest skeptics out there cannot fail to notice and acknowledge the current presence of citizen science, and its potential to add a new aspect to traditional science that can bring closer and empower both citizens and scientists. Citizen science is a powerful form of social learning and a unique opportunity to engage hundreds of thousands of people in the collective efforts to combat climate change, understand life on our planet, find treatment for currently incurable diseases or peek into the very creation of our universe. The exposure of citizens to scientific problems and the generated knowledge and insight they collect during their participation in such projects will quickly trickle down to affect their local communities in a much more effective way, that any institutional outreach programme. By exposing scientific problems to citizens and asking them to participate in the process of solving them, citizen science can change the largely false conception that science can be done only by a chosen few, opening a new pool of young talent and intellectual capital that scientists can draw from. Direct communication with scientists through forums, blogs and Q&A sections of citizen science projects can prove to be extremely beneficial for instilling in the participants scientific values like curiosity about the world, critical evaluation of facts and evidence, and open mind to alternatives. Conversely, scientists can learn to be better communicators and leaders who have to run a project not with two, but 200,000 'graduate students'. Often, the enthusiasm of volunteers in such projects can far outreach that of an average graduate student, invigorating the scientists and sometimes even offering fresh, new perspectives to their research ideas. There are many questions to be answered and many challenges to be faced before citizen science can become 'just another way of doing science'. But one thing is certain, citizen science has firmly came onto the stage and is here to stay.

1. *Nature News Online*, doi:10.1038/news070709-7; http://www.nature.com/news/2007/070709/full/news070709-7.html
2. Lintott, C. and Schawinski, K., *Mon. Not. R. Astron. Soc.*, 2010, **399**(1), 129–140.

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