Ideas for Citizen Science in Astronomy

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Abstract

We review the relatively new, internet-enabled, and rapidly evolving field of citizen science, focusing on ideas from which astronomy either has benefited, or could benefit in the future. We consider contributions to science in the form of observations, instrumentation, data processing, data modeling and the design of new scientific inquiries. Engaging a large and diverse community of both professionals and citizens, we digest and present their suggestions for ideas for citizen astronomy in the future. The limits to this approach to scientific investigation are not yet known, but we make some rough estimates for astronomy in particular.

CONTENTS

1 Introduction (2 pages)

The term "Citizen Science" refers to the activities of people who are not paid to carry out scientific research, but nevertheless make intellectual contributions to scientific research in their spare time. These contributions are diverse, both in type and research area. The people who make those contributions can, and do, come from all walks of life. This review is about the science projects they have participated in to date, the tasks they have performed, and how astronomy has benefited – and could benefit further – from their efforts.

Citizen involvement in science pre-dates the profession itself, and there is a long and honourable tradition of amateur observers making important discoveries and significant sustained contributions. However, the advent of the world wide web has changed the face of professional and amateur collaboration, providing new opportunities and accelerating the sharing of information. People are now connected to each other in a way that has never happened before. Professional scientists can interact with citizens via a range of web-based media, including purpose-built citizen science websites which increase the potential for shared data analysis and exploration as well as data collection. Meanwhile, communities of citizens have sprung into existence as like-minded people have been able to find and talk to each other in a way that is almost independent of their geographical location. The result has been an exponential increase in citizen involvement in science. The field is evolving very quickly, with more and more professional scientists becoming aware of the possibilities offered by collaborating with, for example, specialists operating outside the usual parameters of professional astronomical observation, or tens of thousands of people eager to perform analysis in their lunch hours via microtasking. Our aim in this review is to review the scientific literature as it stands for ideas implemented in citizen science projects, primarily in astronomy but also in other fields, and then produce a summary of successful project characteristics for future research groups to learn from.

As our title states, this is a review of ideas for astronomy. We will look forward as well as back, and try to answer the questions: How can the full potential of citizen science be realised in astronomy? What are the particular niches that citizen science can fill, in our field? How might it contribute to the solutions of the Big Data problem in astronomy?

This review is organised as follows. We survey the contributions to science that citizens have made to date, organized according to the stage of the scientific enquiry that those contributions fell into. Astronomy research typically starts with observations: so do we, in Section 2. We then proceed through a discussion of citizen instrumentation, data processing, data modeling and finally citizen-led enquiry in Sections 3–6. With this overview in place, we review in Section 7 the literature on, and the collected experience of, the population of citizens who have taken part, or are currently taking part, in scientific research, before summarizing progress in citizen science to date in Section 8. In the second part of this review, we turn to the future. We first report a variety of suggestions for how citizens might contribute to astronomy there in Section 9. Then, in Section 10 we consider possible limits to citizen science, including challenges associated with data rates and volumes, data complexity, the difficulties of large-scale collaboration, and finally the barriers to accessibility. Finally, we give some concluding remarks in Section 11.

2 Data Acquisition: Citizen Observing (5 pages)

Typically, data in astronomy is aquired with some sort of telescope. In the 21st century there certainly is an active community of well-equipped amateur observers making observations of great utility. There are also many other citizens observing the night sky with less sophisticated equipement, and/or less enthusiasm – and as we shall see, there are plenty of citizens making astronomical observations almost inadvertently. What astronomical data are the citizenry taking, and what is it being used for?

2.1 Active Observing (Leigh, Chris, 3 pages)

Short case studies:

- Impacts on planets, the Moon.
- International Meteoroid Association, world coverage.
- Planetary observations: JUPOS observers, nightly monitoring. Martian meteorology?
- Cometary monitoring.
- Asteroid and TNO searching.
- Variable nebulae.
- Supernova detection.

2.2 Passive Observing (Phil, Chris, 1 page)

While amateur astronomers have aquired a great deal of very useful data, the general population is better equipped than ever to image the sky and make that data available for scientific analysis. This has been demonstrated by two recent professionally-led studies, that made use of a largely passive observing community connected via online social networks not usually associated with astronomy.

- *The Orbit of Comet Holmes from the Photographs Uploaded to Flickr.* **?**) used N images scraped from the photo sharing website Flickr as inputs to a reconstruction of the orbit of Comet Holmes. This comet was bright enough to be visible with the naked eye in XX, 20XX, and a large number of photographs were taken of it, and uploaded to the Flickr site. **?** were able to astrometrically calibrate the images that contained enough detectable stars in the background using their automatic image registration software, `astrometry.net`. This had been enabled as a Flickr "bot," crawling over all images submitted to the `astrometry.net` group and sending the photos' owners messages showing them where on the sky their images were taken. The calibrated images trace out the trajectory of the comet over N nights, allowing a refinement of the comet's orbit of ... As the authors point out ... While in this case the photographers did not realize they were participating in a scientific study, the potential of combining powerful calibration software with large amounts of citizen-supplied imaging data is made clear.

- *Detecting Meteor Showers with Twitter.* By saving a nightly (?) log of all tweets submitted to the web service Twitter, **?**) were able to detect several new meteor showers simply by searching for the text string "meteor." Unwitting naked-eye observers had spotted shooting stars and tweeted about them, giving rise to a detectable signal in the steam of tweets that night. The detected sample is incomplete/unlocalised/ etc... However, this work illustrates the potential both of Twitter as a communication system for connecting large numbers of observers with a science team, and of networks of unequipped observers for doing very bright object transient astronomy.

TODO: Phil: Comment on passive vs organised observers. Ethics? Gains?

2.3 Data Aquisition in Other Fields (Chris, Phil, 1 page)

Case studies:

- Ecology?
- Social science?
- Others?

3 Data Acquisition: Citizen Instrumentation (2 pages)

The observations described in the previous section were typically made with the citizens' own equipment; in many cases, just as with professional astronomers, the science contributed to is driven by the available technology. This citizen instrumentation has in some case become quite advanced, as a result of the citizens own customisation work. What have the citizens been building?

History: Grote Reber. Recent examples. Rosing at LCOGT. Spectroscopy.

Better monitoring of impacts.

Studying planetary weather.

4 Data Processing (6 pages)

Building, instrumenting and maintaining a telescope, and then observing the night sky with it, are perhaps the most familiar activities to amateur astronomers. Professional astronomers spend far longer working with the data they have taken after their observing run, reducing and exploring images and spectra, and detecting and characterising objects and features. This data processing phase is an essential part of the scientific process; it results in a set of summary statistics or descriptors of the data, that can be more conveniently propagated through to the interpretation phase. That is, data processing involves distillation of data into knowledge – but stops short of the generation of understanding. What sorts of data processing have citizens been actively engaged in? We include the word "actively" here, to differentiate between the data processing that astronomers carry out, and computing jobs that can be farmed out to grids of computers owned by citizens.

4.1 Visual Classification in Astronomy (Chris, Phil, 3 pages)

Visual classification holds something of a central position in astronomy: there is a strong historical tradition of astronomers asking, "What's that?" in response to a new observation, and the first answer is usually (and most usefully) descriptive, rather than explanatory. In the internet age, classification of features in images, spectra and time series can be carried out at enormous scale by crowds of citizens with web browsers. Such web interfaces have come to be known as "zoos," after the first project to engage crowds in this way, Galaxy Zoo. Just as in a zoological park, the visitors are shown various example specimens, and invited to consider what those specimens might be. At the Galaxy Zoo, the visitors are asked to go one step further, and are presented with a questionnaire about each specimen they see.

Case studies:

- Galaxy morphology with Galaxy Zoo
- Surfaces of solar system bodies: Moon Zoo, Moonwatch. Saturn storms. JUPOS measurers.
- Time domain astronomy: Supernova Zoo, PlanetHunters
- Rapid-reaction events (jovian/lunar impacts, storm/plume eruptions)
- Data mining for asteroids and TNOs.

4.2 Visual Classification in Other Fields (Chris, Phil, 1 page)

There is now a diverse range of zoo-like citizen science portals online, covering social as well as natural sciences. What can we learn from visual classification projects outside astronomy?

- Annotation in Ancient Lives
- etc.

4.3 Image Processing (Leigh, Phil, 1 page)

Visual classification is by no means the only activity in which citizens have been participating. What else have people been up to, turning raw data in to knowledge?

Case studies:

- Jupiter: lucky imaging
- Mars rover images.

4.4 Software development by citizens (Phil, Chris, 1 page)

Phil: I think citizen software belongs here...

JUPOS measurers: wind measurement. Impact detection.

PlanetHunters, Galaxy Zoo analysis.

Stumm at astrometry.net.

Collaborative development projects with citizens.

5 Data Modeling: Citizen Analysts (4 pages)

New understanding of the world comes from the interpretation of data, in the context of a model. The modeling activity itself often has technical difficulties that computers may find hard to overcome, associated with complex and/or computationally expensive, likelihood functions. Humans, by applying their developed intuition, can often contribute a great deal to the exploration of a model's parameter space by closing in quickly on the model configurations that are fit the data well. This process can be particularly satisfying, rather like solving a puzzle. How have citizen scientists been involved in model making and fitting?

5.1 Data Modeling in Astronomy (Phil, Chris, 2 pages)

Case studies:

- Neptune encounter
- Image modeling: Milky Way Project
- Lightcurve analysis: PlanetHunters' offline analysis
- Galaxy Zoo mergers

5.2 Data Modeling in Other Fields (Phil, Chris, 2 pages)

Case studies:

- Protein folding with Fold.it. Gamification as a technique.
- Other examples?

6 Data Exploration: Citizen Enquiry (3 pages)

The previous sections have focused on specific, and isolated, activities in which citizens have participated. In most cases, the community's involvement has been a *contribution* to a scientific investigation, while not being involved in the design of the investigation. The most important part of any scientific investigation is the question at the heart of it: what is it we are trying to find out about the world? In this section we look at some cases where the process of enquiry, the science, has been instigated or led by citizens. In principle, this is an area of great potential. Professional scientists can find it very difficult to step back from the technical details of their work, and see the bigger picture; in contrast, outsiders only see the big picture, and so we might expect them to ask some unusual, surprising and searching questions.

6.1 Individuals in action (Leigh, Phil, 1 page)

Case studies:

- Teacher-led science: Blackawton Bees.
- Families as research groups: Monster eyes.

6.2 Facilitated research groups (Chris, Phil, 2 pages)

Case studies:

- Galaxy Zoo forum. Voorwerp, Green Peas. Lens thread: search and model.
- Planet Hunters' investigations
- Quench.
- Deep sky obs (variable nebulae etc). Amateur asteroid observations and follow-up.

7 Understanding the Citizens (2 pages)

Having surveyed some of the activities involving citizen scientists, we can now consider some questions about this community itself. Who participates in citizen science, and what motivates them?

7.1 Demographics (Leigh, Chris, Phil, 1/2 page)

Who is participating in citizen science? Who could be, but is not? Breakdown by activity, if possible.

Relationship between citizen science and schools, colleges. Education programmes associated with citizen science.

7.2 Motivation (Chris, Phil, Leigh, 1 page)

What motivates citizen scientists?

Raddick et al paper for online classification: contributing to science as number one motivation. Secondary motives: discovery/legacy.

Benefits to citizens. Hobby becomes a useful tool. Satisfaction comes from working towards improving our understanding of the Universe.

Similarities with professionals.

7.3 Ethics (Phil, Leigh, Chris, 1/2 page)

Relationships between citizens and professionals. Mostly one-way? Examples of two-way interactions: zoo forum. Solar system monitoring, spacecraft support.

Breaking down of boundaries. Professionals are citizens when outside their own field. Citizens turning professional.

People as ends in themselves. The need to understand black box systems – especially if the box is full of people.

8 Summary: Characteristics of Successful Citizen Science (1 page)

To emerge.

9 Ideas for the future (possibly absorbed into sections above?) (4 pages)

Preamble.

Phil: Should these parts be folded into the sections above? This might make for an easier to read article.

9.1 Observations and Instrumentation in the future

Robotic or automated telescopes to feed data to amateur processors/users for immediate analysis. Long term baselines with the same instrument/calibration.

Global telescope networks for continuous monitoring. Distributed stations and networks for stellar occultations by TNOs and KBOs. Mobile observing stations and international coordination?

Video monitoring for meteors from multiple interlinked stations for 3D trajectory reconstruction.

Amateur observing follows professional:

- Deeper field for amateur observations of Uranus and Neptune, particularly near-IR.
- Visible-light and near-IR spectroscopy; long-term datasets, serious photometry. Calibration, calibration, calibration...
- Advanced technologies such as AO for image stabilisation?

Adoption of uniform standards for amateur imaging to be provided to online databases (already underway with PVOL).

9.2 Classification in the future

Live data: task assignment.

Human-computer partnerships. Replacing citizens, see SN Zoo.

9.3 Data modelling in the future

Easily installed apps or browser-based tools enable outsourcing of data modelling. Operation of code, development of code. Crowd-sourcing of current detailed analyses.

9.4 Scientific enquiry in the future

Huge public databases from wide field surveys: LSST, Euclid, SKA. User interfaces designed for anyone, with social networking enabled.

Provide publishing support, see Letters.

10 The Limits of Citizen Science (3 pages)

We have argued that a critical part of 'citizen science' lies in the ability of the amateur to make an authentic contribution to science. Earlier in this part of the review, we looked forward to a richer future for such interaction, but in this section we consider the potential limits and checks on citizen science.

10.1 Data limits data rates: some worked examples

Problems presented by data volume, and data rates. Case studies: Large samples of lenses? Transients with SKA?

10.2 Limits from complexity

Difficult analyses. Microtasking only suitable for certain parts of the process?

10.3 Limits to collaboration

Collaboration between professional and citizen astronomers. Does it scale? Communication issues: forum, letters. Contrast supervisor to student, with scientist to crowd. Prospects for large collaborations? Collaborations between citizens, eventually linked to professionals?

10.4 Limits to access

Connections between citizen science and open data, and open publishing. Citizens reading papers: accessibility, potential barriers.

International CS. Language barriers, cultural issues.

11 Concluding Remarks (1 page)

Does astronomy have any sort of special place in citizen science?

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12 Literature Cited