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Amateur Community and "Citizen Science"

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Abstract. Citizen Science is the act of collecting or analyzing data by enlisting the help of volunteers who may have no specific scientific training. The workshop discussed how "Citizen Science" fits into time-domain astronomy, what the roles of such volunteers might be, and how amateur astronomers can help in the new era of surveys.

Keywords. surveys, techniques: photometric, stars: variables: other

1. Introduction

Amateur astronomers have been involved in every aspect of astronomy for centuries; in fact, the concept of a professional astronomer is only about a century old. Most early researchers had other careers (for example, Johannes Kepler was a mathematics teacher at a seminary; Isaac Newton was Lucasian Professor of Mathematics at Cambridge, UK) and only made astronomical observations as a hobby.

The concept of using a team of amateur astronomers as volunteers to help professional astronomers in their research is relatively recent. Harvard College, for example, enlisted the aid of amateurs to monitor the variable stars that they were discovering as part of the photographic all-sky survey which was being conducted at the turn of the last century. That group of volunteers formed the core of the American Association of Variable Star Observers (AAVSO), founded in 1911.

Other professions, such as ornithology, have also used amateur researchers for decades. Cornell is currently conducting a programme called "eBird", launched in 2002, where amateur bird-watchers document and enter on-line the date, time and location of their sightings of various bird species. The information is then used to gain a better understanding of patterns of bird occurrence and the environmental and human factors that influence them. The Christmas Bird Count, run in the USA by the Audubon Society (http://birds.audubon.org/christmas-bird-count#), has been in progress since 1900, pre-dating even the AAVSO. The advent of consumer electronic devices such as "smart phones" has greatly enhanced the ability of volunteers to provide useful scientific data, e.g., accurate time and location of bird identifications, and the possibility of taking pictures or recording song.

The Citizen Science workshop concentrated on the following questions:

- What is the difference between crowd-sourcing and true citizen science, and their roles in TDA?
- How should amateur contributions be properly acknowledged?
- How can we put professionals in touch with amateur(s) appropriate for their needs?
- How can we use the diverse professional skills (such as database expertise or website design) of the amateurs within scientific projects?
- What is the role of amateurs in the new age of surveys?

This report summarises the lively discussion which ensued as the group of ∼30 workshop participants tackled those questions in turn.

2. Crowd-Sourcing or Citizen Science?

The largest crowd-sourcing experiment currently in process (Raddick, et al. 2010) is Zooniverse (`http://www.zooniverse.org`). The first "zoo" was *Galaxy Zoo*, which displayed SDSS galaxies to users and asked them basic questions about shape and structure. This task required no knowledge of what a galaxy was; it just used humans to do the image classification. It was launched in 2007 and, when completed, had 10 million galaxies classified by 30 individual researchers each, with a total of about 83,000 participants. The Zooniverse itself reports about 500K volunteers divided among the dozen or so active projects.

Crowd-sourcing can also be applied profitably to time-domain astronomy. An example is the *Planet Hunters Zoo*, an experiment to find extra-solar planets by their transit signatures in the light curves generated through KEPLER public release datasets. The analyst is required to look at graphs (harder and less interesting!), pick out rare dips in brightness, and then see if there is a periodicity to multiple dips. The voluteers have discovered about 30 candidates that have been missed by the KEPLER team itself. The training and background is far more extensive than for *Galaxy Zoo*, and falls more into the amateur data-mining category.

One could imagine a similar team of amateur researchers looking at the time-domain transients found by LSST, or helping train the neural network for PTF that discriminates against image artifacts.

Results from *Citizen Sky* (`http://www.citizensky.org`) also sparked discussion. *Citizen Sky* was a true Citizen Science project in which amateurs and interested general public were trained in how to make brightness estimates of the $3^{\rm rd}$-magnitude star ϵ Aurigae, an eclipsing binary with a 27-year period and which happened to start its 2-year-long eclipse during IYA 2009. The volunteers were encouraged to learn about variable stars, create teams to work on research topics, and learn how to write up their results in papers for submission to a scientific journal.

Variable star astronomy is an obvious topic for citizen science, as amateurs can make brightness estimates with very crude equipment such as binoculars and the human eye, or with sophisticated robotic telescopes and CCD cameras. All such observations have their value. For example, participants noted the advantage of large numbers of observers dispersed in longitude when determining when an outbursting object starts to increase in brightness, alerting professionals quickly for detailed monitoring. Very little equipment is needed for such discovery, yet the amateur then has at least a small chance of becoming very famous. Several researchers using satellites may get alerted by amateurs when an object goes into outburst, so that they can schedule Target of Opportunity programs. Sometimes it is the opposite: objects that might go into outburst need to be monitored just prior to a satellite observation in order to know certain parameters when the object is in quiescence; this was the case for the recent V455 And observations for HST.

Where amateurs really become indispensable is when time-series observations must be made. Certainly cataclysmic variables are obvious candidates, since in outburst one may detect modulations from the accretion disk (such as super-humps), or can detect eclipses more readily than when the system is in quiescence. Time-series observations are also important in many related fields, such as the confirmation of exo-planet discoveries. Many variable stars have multiple periods, such as the Blazhko RR Lyr variables, where many nights of time-series data are required in order to understand fully their behavior. This is nearly impossible to do through prevailing policies of Telescope Allocation Committees for most major professional telescopes. For bright objects, even DSLR cameras can be used for high-precision results, one good example being the light curve of U Sco derived by Loughney (2010) and shown in Fig. 1.

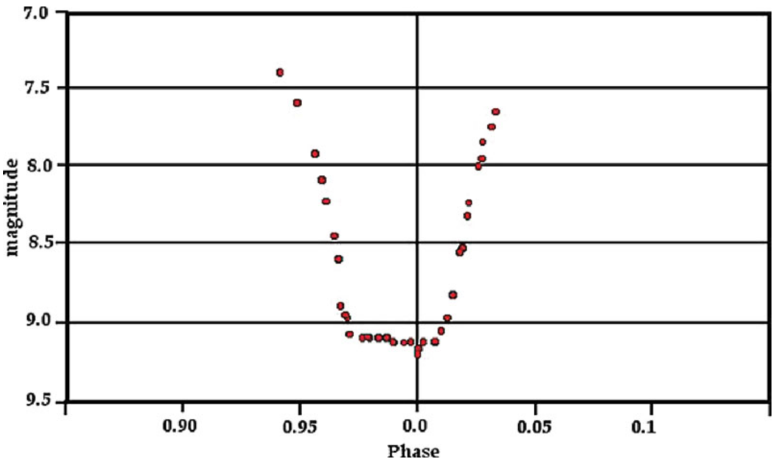

Figure 1. U Sco eclipse light curve, obtained with a digital SLR camera

Amateur participation can also be important when geographical location is an essential ingredient to success, as is the case (for example) for asteroid occultations. During such events a narrow shadow track, with width roughly equivalent to the asteroid diameter, crosses land masses, and in order to get sufficient chords of the event to model the asteroid shape, the event needs to be observed by many stations. Amateurs have even created portable systems (Degenhardt 2006) to monitor events of that kind, setting them up perpendicular to the predicted path so as to obtain as many chords as possible. That kind of activity is impossible with fixed-location professional observatories, neither is the volunteer effort required to set up such portable stations usually possible for professional researchers.

One concern raised by participants was the potential loss of data. Since contributions from amateurs are becoming more valuable, the observations need to be archived carefully. The AAVSO does a good job of archiving individual photometric measures of variable stars (the database contains more than 21 million variable-star observations, mostly by amateurs), but CCD images are not archived by the AAVSO and must be done individually by the amateurs. There are potentially important observations on many of those those images but they are effectively lost unless either the images or at least the photometry of all stars on them are stored in a publicly accessible manner. An example of the need for that kind of access is the recent supernova in M101, where valuable precursor photometry could in principle be obtainable if data archives were set up by the large number of amateurs who record deep-sky images of such objects on a routine basis.

3. Acknowledging Amateurs

Suppose you have worked with a team of amateur astronomers, some of whom have contributed data for your project, and others have done a literature search or have mined existing data catalogues for useful pertinent information. What criteria are you going to use for deciding which participants get recognition as co-authors, which will get an acknowledgement in the body of the paper, and which will be ignored?

The usual model for inclusion is the one established by the Center for Backyard Astrophysics (Patterson 2001), which generally requires that an observer must contribute one percent of the total data used for a paper in order to be considered for co-authorship. Most of the workshop participants felt that amateurs should be acknowledged in a fashion similar to that for professional co-authors, or might merit even stronger acknowledgement since they are contributing their volunteer time and effort.

Amateurs can also be included in the "broader impact" section of a grant proposal, thereby bolstering the proposal and also providing a mechanism to obtain funding, especially for new instrumentation. Amateurs participate beause of they enjoy the process, so the more encouragement that they can be given, the more likely that they will continue to contribute.

4. Facilitation

The American Astronomical Society (AAS) had a "Pro-Am" (Professional–Amateur) working group for a number of years, but disbanded it a couple of years ago on the grounds that most professionals know about amateur capability and individually find a method of locating and working with amateurs with appropriate equipment and skills to be useful for a given project. Since there are European Websites which have databases to link people who wish to share rides to various destinations, could the same basic structure be used to list the capabilities of amateurs so that professionals could make contact more easily with ones that meshed well with their projects? In fact, the AAS Pro-Am working group tried that at one stage but found that the Web design needed a dedicated volunteer, while a long-term coordinator was essential in order to keep entries up to date. With the right volunteers, however, such a facilitation Web-site might yet be workable.

Facilitation works well when it comes to reaching the general public. IYA 2009 demonstrated the (outstanding!) ability of the amateur community to band together and create outreach activities, far more extensively and successfully than those created by the professional community. IYA 2009 is a great example of a successful outreach programme. Amateurs are better connected with the public, so if they can be a part of a research project then they can bring that project to the public, whether through a talk at a local astronomy club or participation at a star party.

5. Use of Talents

Except for crowd-sourcing, the range of amateur expertise is extremely wide. For high-precision, high-accuracy photometry, for example, only the top amateurs can come close to the professional requirements of transforming their data, using proper error analyses, understanding their equipment, and so on. Bad habits are easy to acquire and hard to eliminate. Would it help to create a standardized system, whether of equipment, software or observational techniques, so that more amateurs could provide truly high-quality data?

One concern is the lack of quality software and textbooks for spectroscopy. Very few amateurs are currently spectroscopists, and since there is a lack of adequate training, even they may not be providing spectra of the professional quality of which their equipment could be capable. This is truly a growth area for amateur astronomers, so the professional community needs to devote time and effort into fostering it. However, some amateurs are indeed providing quality spectra, examples being the high-precision radial-velocity work on Polaris by a German amateur (Bücke 2006), the supernova spectroscopy from the French amateurs led by Christian Buil (Desnoux & Buil 2005), and the high-precision

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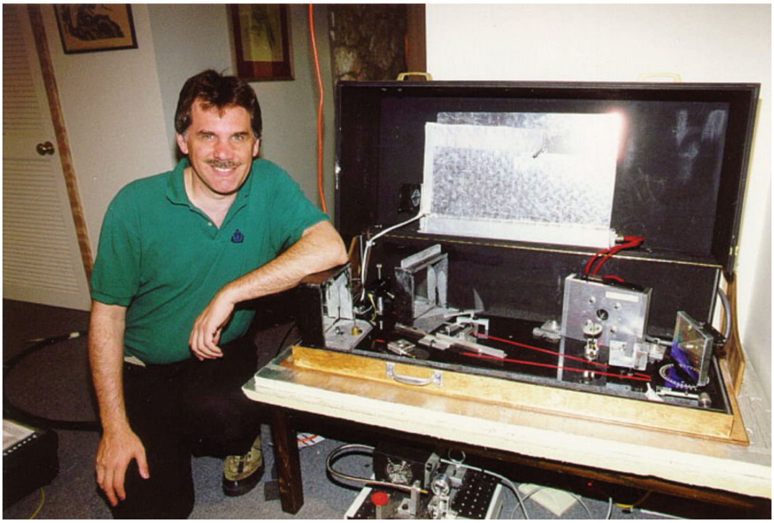

Figure 2. Bench-mounted radial velocity spectrograph

exoplanet radial velocities from the Arizona Spectroshift project (Kaye, *et al.* 2005). An example of a bench-mounted spectrograph for precision radial velocities designed by Kaye is shown in Fig. 2.

It is universally agreed that amateurs have the right attitudes for observing, and that they offer an obvious advantage in nearly limitless telescope time. Their instruments often have a bigger field of view than professional telescopes do. Many have dogged determination, and will follow objects such as WZ Sge systems that might go into outburst once every few decades, or look for eclipses in long-period binary stars where only one eclipse has been seen to date and may nor recur until next century. They also hugely enjoy their contacts with the professional community. Their main limitation is a financial one, since amateurs are self-funded.

It is unfortunate that the word "amateur" does not gain much respect in today's world, even though its basic meaning is simply someone who loves what he or she is doing. Should amateur astronomers be re-branded as "semi-pros"? (that is, professional in quality but not having the status of a professional). "Citizen Scientist" might also be a suitable term, though is somewhat more formal.

It is important to reflect that most amateurs are professionals in other fields, and can bring that expertise to their scientific work, whether as database designers, colour-imaging experts, physicists, statisticians, or the like. Chemists often understand laboratory spectroscopy far better than the average professional astronomer does. Where possible, all that expertise should be tapped and applied to support a research project.

The amateur community has also helped professional astronomy in another way, by generating the incentive for vendors to create high-quality, low-cost equipment and software. Many of the vendors of astronomical telescopes and instrumentation are in fact themselves amateur astronomers. Professional astronomers no longer have to design and build their own equipment, even for some cutting-edge research projects, if the equivalent can be supplied commercially. For example, the MEarth project (Charbonneau *et al.* 2008) to search for transiting exoplanets around M-dwarf stars, uses commercially available RCOS telescopes, Software Bisque mounts, and Apogee cameras.

6. Surveys

There are many surveys underway like the All-Sky Automated Survey, the Palomar Transient Factory, the Catalina Real-Time Survey, SuperWASP, etc., and several—such as the Large Synoptic Survey Telescope (LSST)—in stages of advanced planning. Each covers a large area of the sky, and discovering many new transient objects on a nightly basis. Their archived images offer excellent opportunities to monitor for known variable stars, and have been mined by a number of researchers for new variables or exotic objects. In fact, most of the currently-known variable stars have come from the ASAS, OGLE, MACHO, Kepler and similar surveys, and the LSST team has forecast that it will detect 100K or more transient objects every night.

While on the surface such surveys might appear to be the death knell for amateur astronomy, in reality the case is exactly the opposite. Surveys produce data on large numbers of interesting objects, far too numerous to be followed by existing professional observatories. The amateur community can be relied upon to help in those cases, much as they were in the early 1900s during the last great era of surveys (the photographic plate sky patrols).

Citizen Scientists will also be needed in many of the software tasks relating to surveys and the generation of transient lists. They can examine the transients that are automatically detected by the pipeline software, and classify them. Such classification can then be used for training the software to do a better job on future transients that are detected. The software will also identify a large set of objects for which no classification can be found; those are actually the ones with the greatest potential of being interesting, but require much manual inspection to eliminate any garbage.

7. Summary

Time-domain astronomy is an ideal arena in which Citizen Scientists can participate. Many follow-up requirements dictate the use of multiple telescopes worldwide, and the amateur community is ready for just such involvement. More training is essential, however, both to increase the number of observers who can provide quality data and to improve the quality of those data.

The workshop was unanimous in its support of the work of amateur astronomers.

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