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Stellar Variability: from Citizen Science to Citizen Astronomy

Workshop 2

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Abstract. The contribution of citizens to research is irrefutable. Especially this century with the outburst of all-sky surveys, professional astronomers use citizen-science projects to engage the public in analysing and sorting large quantities of data, often leading to noteworthy discoveries. From crowdsourcing to acquiring data, citizens are leaving a significant mark in the science landscape, assisting professional astronomers with their work. In turn, citizen science is a means of increasing science literacy and public understanding of science. At the same time, the time domain enables a more active engagement of backyard observers in research. Citizen astronomers not only take data, but also reduce and analyse them, and participate in preparing scientific manuscripts.

Keywords. Science: education, science: public outreach, astronomy: amateurs

1. Prelude

The contributions of citizens to the astronomy research landscape nowadays are essential. Thanks to citizens, and because of them, we have a good understanding of galaxy morphological schemes (e.g. GalaxyZoo and Zooniverse), we have confirmed variability classification and discovered dozens of new exoplanets (Planet Hunters), and we have an unprecedented collection of long-term variable star light-curves that reveal new phenomena in the interior of stars (AAVSO). We encourage the public continuously to be involved in science projects, declaring – boldly and truthfully – that we are in need of more 'hands on deck' when it comes to citizen participation. Every large-scale project with significant data acquisition has a 'citizen science' component to it, inviting the public to contribute expertise and person-hours mining data. Now, more than ever, astronomy is a science for the wider community, where contributions by non-professional astronomers are routinely joining efforts of professional astronomers, all working in a collaborative manner in order to understand various phenomena in the universe.

No international meeting on time-domain astronomy could be complete without a discussion of the role of citizens in the international landscape of variable-star research. This Workshop was therefore arranged to discuss citizens' contributions to science and the challenges that professional astronomers face while designing appropriate projects for public participation. This Report summarises some very lively discussions. Although no specific action items were defined, the unanimous sentiment from the participants was a wish to improve communication with citizen astronomers, a hope to engage more citizens in scientific research, and suggestions for using astronomy as an attractive tool for comprehending the significance of data in determining solutions.

2. Basic Premises

Each one of us is an expert in what we do, even if in only a small part of it. Whether that expertise was achieved through high-level (possibly expensive) education, or was acquired through other training or apprenticeship, or by 'learning on the job', there is also room for those who engage in some activity for pleasure, rather than as a profession or an occupation. The growing cooperation between professional and amateur astronomers which this Century is now witnessing is no different, but there are some important organizational factors to describe first.

Almost inevitably, many of those factors depend in some way on money, and money creates or signals *status*. An *amateur* pursues an activity for pleasure, is likely to be very highly motivated, and may be well qualified even though there is no gainful employment. A *volunteer* is one who pursues an activity without getting paid to do it – and may do so for pleasure, to answer a call of duty, for work experience, and not infrequently because it is more satisfying than the paid or salaried occupation. A professional, on the other hand, has normally undergone significant and focussed training, has qualifications to match, and is appointed to a paid position which may include responsibilities such as teaching or administration as well as the latitude to pursue research at a fitting (i.e., expected) level.

2.1. *Definitions*

It is very unfortunate that the application of the word *amateur* has deviated so far from its true (original) meaning and has come to represent 'novice' or 'not qualified'. The pioneering scientific researchers were amateurs; they worked alone, frequently in their own laboratories or workshops, with no formal institution for support or assistance, and the quality of their output was often ground-breaking. In modern terminology, they ranked as *citizen scientists*.

In astronomy we can distinguish between two levels of non-professional but potential contributors to our science: citizen scientists and citizen astronomers. Citizen scientists are generally those who assist with analysing data, while citizen astronomers are more deeply engaged in the science itself, including (but not limited to) acquiring appropriate data, analysing them and writing relevant manuscripts. The contributions of either can be acknowledged by including their names as authors of relevant publications (or including them in the acknowledgement section), though that may depend on the nature of the project.

2.2. *Projects suitable for citizen-scientist participation*

The ideal citizen-science project will offer a wide range of opportunities for non-professional input, from data acquisition to scientific interpretation and computing tasks, though obviously not all projects offer that range of openings naturally. Suitable projects therefore need to be advertised well in order to attract an ample team of assistants. The good citizen-science project must also be well nurtured along its course, in order to ensure that the interest of the citizen scientists continues to be fired, and that the necessary level and quality of their efforts are maintained. Commitment is a key ingredient; it can be expected from the salaried staff as a matter of course, but it needs to rely on sustaining that passionate interest which amateurs frequently exhibit.

2.3. *Designing encouragement and reward*

Despite the strong arguments – all based on real-life experiences and undeniable scientific value – for a reorientation of astronomy research towards a more liberal view of the

roles that people of different status can certainly play in the pursuit of new knowledge, many places of work are still less than fully eager for input from volunteers and to make appropriate recognition of the inclusions. Many academic institutions *and funding bodies* have been hidebound for too long, and in the same way that physical structures favour a strong focus on only one field of science (e.g., libraries of books, subscriptions to journals, the teaching of specialist courses, etc.), traditional opinions tend to favour a narrow range of qualified researchers. Especially when it comes to acquiring federal government funding, not everybody is considered eligible to apply for such funds, especially without the appropriate credentials (or affiliation with an academic institution).

Breaking down those systems will be challenging, expensive, and may not always prove beneficial, leaving the decision-making administrators in a catch-22 situation: willing to take the plunge only when the true benefits have been demonstrated unequivocally. But that is no argument as to why astronomy should *not* lead the way (or be added to other citizen-science projects such as *eBird, Old Weather, GBIF (Biodiversity)*, and others.

Although the role of citizen scientists in certain types of research is irrefutable, many professional astronomers are not comfortable with involving citizens in their work. A big factor at play is the current university evaluation system, which does not always appreciate, encourage or reward collaborations between professional and citizen scientists. An important consideration, therefore, is how to bring the importance of contributions by citizen scientist to the notice of Administrators (particularly of universities) who might provide support, in cash or in kind (such as granting access to computing facilities or equipment, or reimbursing certain unavoidable costs incurred during the project) to professional astronomers who wish to work closely with the public. Including acknowledgement somewhere in each publication to the contribution(s) made by the non-professionals then becomes an important way to showcase their impact on the science.

3. Guiding Requisites

3.1. *Flexibility of approach*

Not all science projects are suitable for shared participation by those who are untrained in the specifics of the equipment and its management, or of the different approaches which are wanted or are being planned. Flexibility on both sides is therefore an asset.

3.2. *Fostering interest and commitment*

An ideal professional–amateur collaboration will manifest a strong interdependence of the partners upon the contributions of each team-member, and will enable one to see plainly how the different facets combine so that the scientific output is greater than could have been achieved as a set of disconnected efforts.

For example, many observers follow stellar systems that are known to undergo eclipses, and are well trained in the mechanics of taking subsidiary data to correct for the effects of air-mass variations and transparency on their raw photometry. Such measurements can be used to great advantage in enabling a physical parameter such as a stellar radius to be determined precisely. The same data can also be of value to a multitude of projects; for example, even though a particular investigation may be concerned with stellar abundances and other properties rather than the particularities of the eclipse, the determination of the stellar radius as defined through eclipses is critical, and needs to be seen to be acknowledged as such.

Providing perspective and focus on the research that can be conducted through data acquisition is often a key motivator. Citizen astronomers with data acquisition and analysis abilities are more likely to be engaged in a project once they know what value their

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data bring to it. Amateur observers often set up their own networks, and in the case of (say) an eclipse that lasts too long to be observed thoroughly at a single site, team-work among the amateurs becomes vital. However, this is work that only a dedicated group of observers and observatories can conduct successfully, making the contributions of the amateur networks both unique and very valuable.

3.3. *Engagement*

The overarching aim, clearly, is to engage all parties whatever their level or type of contribution, and to retain their interest. Enthusiasm is fuelled by interest, and a desire to do well at whatever contribution (within the limitations of one's equipment) is an essential ingredient to ensure a quality that is both sustainable and is sustained. A criticism that can often be levelled at many professionals is that insufficient time is invested in capturing and kindling the basic interest of citizen scientists that will not only build a strong team but also hold it together for long enough. Many observers have their own favourite types of object and kinds of observing, so to a considerable extent they must be allowed to select which citizen science programme to join. Appropriate advertising by the professionals will help to recruit the most appropriate citizen-science helpers; continuous dialogue helps retain them.

In terms of engaging amateurs as co-researchers in major new surveys, the big challenge is to work out how to match the potential of the data to the interests of the communities. The surveys will publish alerts, in a multitude of ways, means and devices depending on the nature and expectations of each survey. Should at least some of those alerts be made instantly available to both professional and citizen astronomers so that the right targets are brought to the attention of the right people? An important precedent in this regard in astronomy was of course Galaxy Zoo, which proved so popular that it blossomed into Zooniverse, which caters for major projects in many other sciences too. Matters such as proprietary data, the creation of archives, teamwork and the publication of associated results need to be thought through and planned carefully, especially in the era of large surveys, which are expected to yield an unprecedented data influx that is in need of careful exploration by the community.

4. Scientific Methodology

People who are trained, and very thoroughly practised, in dealing with raw data develop an ethos for scientific integrity: that an observation should be sufficiently well calibrated and reduced and that its acquirer can stand by it, *even if it does not agree with previous observations or with ones that other people have obtained*. There is nothing meritorious in deriving data that fit those of other people; what *is* meritorious is deriving data whose reductions can be repeated and found to be consistent with themselves. The critical stage in such data reductions is a careful awareness of errors – not only their magnitude but also their kind, whether random or systematic. If an observer's assessment of errors indicates that the corresponding data are likely to show random errors (i.e., *precision*) up to (say) 10%, then it could be suspicious if the data provided all agree to within 1%. At the same time, however, an observer's set of data can be affected by a systematic error (i.e., *accuracy*) while having small random errors, and that is where intercomparison of measurements made by different people is valuable in revealing those systematics, whatever their causes: hardware (equipment), software (assumptions in reduction routines) or observing habits (personal equation). It is then fully legitimate to perform *zero corrections* that can bring one precise set of data better in line with another from a different source.

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5. Machine Learning

The many new surveys, recently on-line or not yet launched, are threatening astronomy with a data revolution, not only in the way that reductions are managed but also in the range and types of tools that will need to be used. 'Big data' does not just need more hands on deck – though that could be one solution in some cases. As has been amply described, discussed and shown at this conference, the new era of data gathered from surveys is calling for a new set of technologies to handle data and their reduction efficiently and comprehensively. The challenge, then, is not just how much faster than humans can machines work *and retain the same level of quality of output*, but to recognise, design and implement tools that will amplify the returns from the investment of the observations. There is significant scope for non-professionals to become engaged in machine-designed data reductions, especially at the R&D stage. One consideration to bear in mind is that the human eye is more sensitive to recognising patterns and outliers than is any known algorithm. Therefore, in addition to providing specialised skills, citizens can be part of a team which is endeavouring to improve mechanical classification schemes and associated algorithms. The overall outcome will then help with the automation of astronomy's so-called 'big data deluge' resulting from all-sky surveys.

6. Evaluations and Assessments

At some point, possibly before the formal end of a citizen-science project, and particularly if the project in question is a small element of a much larger (and probably multi-national) project, the supporting bodies will need to be shown how the inclusion of what is still largely regarded as unconventional contributions is working out. What benchmarks might be appropriate? What yardsticks can be employed? Are there precedents?

The unanimous message from the Workshop was clear: How could – and should – the professional community make better use of the thirst exhibited by so many citizens for learning and scientific contributions? In particular, how can we all build stronger teams of individuals whose collaborative efforts will enhance the way astronomers make progress towards understanding astronomical phenomena?

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