Ten years of .Astronomy: Scientific and cultural impact

Sarah Kendrew[1], Robert J. Simpson[2], Chris J. Lintott[3], Steven M. Crawford[4], Arfon Smith[4], Carolina Ödman-Govender[5], Amanda E. Bauer[6], Rebecca Smethurst[3], and Wilhelmina Nekoto[7]

[1]European Space Agency, Space Telescope Science Institute, Baltimore MD, USA
[2]Google, London, UK
[3]Oxford University, Oxford, UK
[4]Space Telescope Science Institute, Baltimore MD, USA
[5]Inter-University Institute for Data Intensive Astronomy, University of the Western Cape, Bellville, South Africa
[6]Large Synoptic Survey Telescope (LSST/AURA), Tucson AZ, USA
[7]Freelance, Windhoek, Namibia

Abstract

In the last decades, the growth of the internet and the accessibility of powerful computing systems has driven dramatic change in how we perform scientific research, and how we communicate about science with collaborators, students, and the public. Since 2008, the .Astronomy (pronounced "dot-astronomy") conference has sought to create a community of professionals working in astronomy-related fields who are keen to exploit the enormous potential of computing and the web in all its facets: for research, public engagement, scientific communication and publishing. From the outset the conference has used a unique programme structure, and hosted the first astronomy-themed hack events. In 2017, following the 9th edition of .Astronomy, we set out to gather feedback from our past participants on their experience of attending the conference: have we succeeded in building a community; has the conference influenced our participants' career or study choices, or impacted their research in a meaningful way; is the conference contributing positively to the overall advancement of the field? The survey shows that a high fraction of participants report that their participation in .Astronomy has resulted in new ideas and inspiration (90%), and has impacted their day-to-day work (67%). We provide concrete examples of outcomes from the conference, and discuss the role of conferences like .Astronomy in advancing the field.

1 Introduction

The first .Astronomy conference (pronounced "dot-astronomy") was organised in 2008 by Robert Simpson, then a PhD student at the University of Cardiff. 2008 was a critical year for social media, bringing major growth for Twitter [1], Facebook, and a number of popular blogging platforms. The availability of these tools and their global reach placed science communication to a large audience in the hands of individual scientists, freely and easily. Junior scientists were particularly successful at leveraging the web for creating innovative tech-driven science and engagement initiatives, such as:

- "Tweeting telescopes" [20]
- Astronomy podcasts [25]
- Building apps and tools based on public online services [27, 9]
- Amateur-professional collaborations [18, 15]

and many more. These new initiatives complemented established astronomy projects, such as the Virtual Observatory [16] for seamless data sharing and exploration, and networks of robotic

telescopes [17]. The mix of participants from leaders in the field, junior scientists and science communicators, keen to exploit the new possibilities offered by the web for science, and enthusiastic about communicating their work to a broad audience, brought a push to repeat the conference.

A confluence of factors during the early years of .Astronomy contributed to its initial success. The International Year of Astronomy in 2009 [26] mobilised a large number of researchers into public outreach activities. The increasing adoption and standardisation of certain web technologies and libraries such as HTML5 and JavaScript turned the web into a viable platform for scientific collaboration through new tools for visualization and collaboration. They also eased the development of new web-based tools. Astronomy was entering an age of heightened awareness of the scale of data that the field did and would generate in the future. Initiatives like Galaxy Zoo [29, 19] and its successors demonstrated the true research potential of citizen science.

From the 2009 conference onwards, we adopted novel approaches to conference organisation from events in the tech industry such as Foo Camp[1], which used a more collaborative, open style than traditional conferences. The main schedule is usually 3 days long, of which the middle day is a "hack day": a day where participants are encouraged to work together in small groups on "hacks", or small self-contained projects demonstrating a new technique, concept, or algorithm. Days 1 and 3 contain a small number of invited and contributed talks, with afternoons reserved for small-group "unconference" sessions: the topics for these sessions are proposed and selected by the participants themselves, and they proceed as moderated discussions rather than formal presentations. .Astronomy was the first conference in astronomy to adopt this type of schedule. From year to year some variations occurred in the schedule, depending on the local venue (e.g. .Astronomy 2 at the Lorentz Center in Leiden was 5 days in length). The ratio of first-time attendees to returning participants is typically maintained at around 2:1 to balance bringing new ideas and experiences to the conferences with the momentum provided by returning participants. In the last decade many features of the conference have been adopted by larger conferences; indeed as .Astronomy organisers we are frequently invited onto conference committees specifically to facilitate hack days or discussion sessions.

Since 2009, two changes in the organisation and structure of the conference should be highlighted. In the first 5 years of the conference, as the technical skill level of some participants grew rapidly, others reported (via informal feedback) feeling increasingly intimidated, not technically confident, and reluctant to attend due to this impostor syndrome. In 2015, the local organisers for the Sydney event, introduced a "Day Zero" as an (optional) day for tutorials and introductory sessions. This brought a "workforce training" component to the conference. Second, in 2017 the local organisers for the Cape Town conference employed for the first time an algorithmic selection process using the Entrofy code [10]. Entrofy makes a randomised selection amongst qualified participants (which outnumber the available spaces), with the organiser specifying the desired weighting of the participant pool along different axes, e.g. gender, level of career seniority, first-time or returning participants, ethnicity, etc. This protects against bias in the selection process.

One aim of .Astronomy is to lower the barrier between research and public engagement, and the conference programme contains a mix of topics in this regard. In addition, discussions have gravitated towards cultural issues in the astronomy community that have arisen due to the changing paradigm of research: changes in required skillsets for young scientists, credit for the software development that is increasingly valuable for research, balancing research with public engagement work, and more recently issues with diversity and inclusion in the astronomy community.

As 2018 marks the 10th anniversary of the first .Astronomy conference, we felt it timely to look back at past events and assess the impact within the community. A participant survey was created during the Hack Day of .Astronomy 9 in Cape Town, South Africa. In this paper we present the results of this survey, discuss the scientific and cultural impact of .Astronomy. For background, a list of .Astronomy conferences and their venues is shown in Table 1.

[1] https://en.wikipedia.org/wiki/Foo_Camp

Year	Edition	Venue & Location
2008	1	University of Cardiff (UK)
2009	2	Lorentz Center, Leiden (Netherlands)
2011	3	New College, Oxford (UK)
2012	4	Haus der Astronomie/Internationales Wissenschaftsforum Heidelberg (Germany)
2013	5	Microsoft Research, Cambridge MA (USA)
2014	6	Adler Planetarium, Chicago IL (USA)
2015	7	University of Sydney/Police and Justice Museum, Sydney (Australia)
2016	8	Pembroke College, Oxford (UK)
2017	9	South African Astronomical Observatory, Cape Town (South Africa)
2018**	10	Space Telescope Science Institute, Baltimore MD (USA)

Table 1: Overview of the 10 .Astronomy conferences hosted so far. **The 10th edition was not included in the survey.

2 The .Astronomy Decadal Survey

The survey was created using Google forms, with questions in the following categories:

- Participant demographic information: gender, age, ethnicity, career or study status, geographic background, and which conference(s) they attended.
- Career trajectory since first .Astronomy participation, and whether participation impacted their choices.
- Experience at the conference: what did they gain, learn; positive and negative aspects of the conference; and how their participation impacted their work in astronomy.
- Feedback on the culture at .Astronomy: how did they perceive diversity at the conference; did they feel welcome and heard; did they suffer harassment.
- Overall feedback and suggestions for improvement

Responses were by default anonymous, though the option was given to provide a name. It requested specific consent to be quoted verbatim, either named or anonymously. The format of the questions was a mix of rating on a scale of 1 to 5, selecting from a list of responses, or free-form text responses.

The question format was a mix of multiple-choice, Likert-type scale, and open-ended questions. The open-ended questions were generally optional and therefore not answered by the same number of respondents. The multiple-choice and Likert-type scale questions were non-optional, so these all have the same number of registered responses.

2.1 Dissemination

Using the organisers' lists of participants for all 9 conferences, an invitation to complete the survey was sent to a master list of all past participants, where up to date email addresses could be found. The survey was sent to approximately 370 participants; based on past reported gender information, approximately 30% of these were of a minority gender in astronomy. The invitation was further sent to around 15 participants via social media channels (facebook, twitter), where email addresses could not be found.

The survey was kept open for a period of approximately 6 weeks.

2.2 Response statistics

In the 6-week survey period, we received 122 responses, or a response rate of around 30%, which we consider satisfactory as a representative sample. Importantly, the gender and ethnicity statistics of responses are consistent with the demographics of the survey group, indicating the responses have appropriate representation across the board.

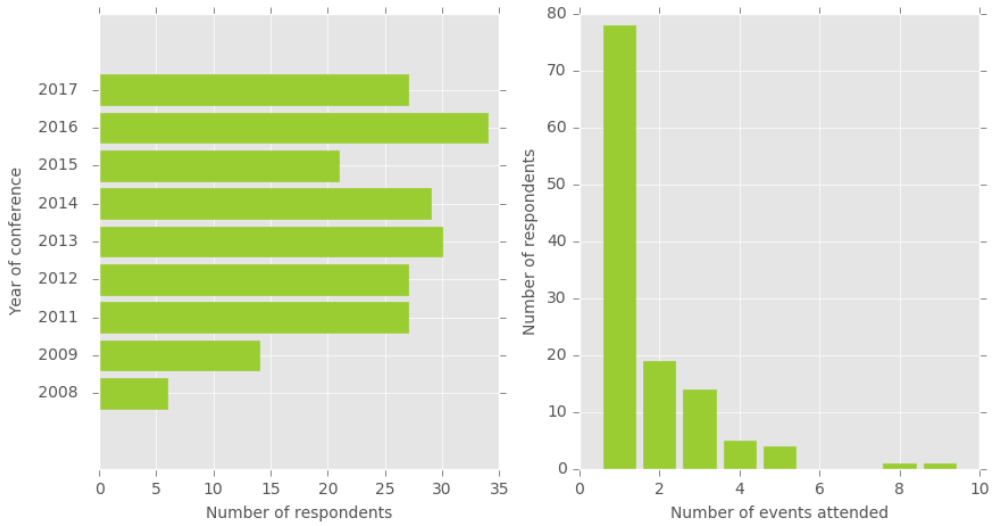

Figure 1: (L) Number of survey respondents per conference. (R) distribution of the number of conference attended amongst respondents.

As every .Astronomy conference is very different, we gathered information on which conference(s) the respondents attended. Using this information we can check for any biases in the responses towards any particular event. This data showed that we have at least 20 responses for each conference from 2011 to 2017. The number of respondents range from 21 to 34 per conference. For 2008 and 2009 the numbers are 6 and 14, respectively; the lower numbers are likely due to our contact information for these participants being out of date, and participants being less likely to complete a survey for an event that took place almost a decade ago. The distribution of respondents per conference is shown in Fig. 1. These numbers indicate that none of the conferences are significantly over-represented amongst our responses.

Over half of respondents (64%) attended just one event, 34% attended 2-5 events. The survey responses therefore contain a mix of one-time and returning participants.

3 Survey results

In this section we present the survey results in the categories listed above.

3.1 Demographics

The demographics questions focused on age, gender and ethnicity, as well as their geographical location at the time of their first attendance, and at time of taking the survey. For gender, we offered a number of options:

- Female
- Male
- Non-binary
- Other
- Would rather not say

Starting from the premise that the astronomy community is majority white and male, we designate all responses other than "Male" and "Would rather not say" as "gender minority". For ethnicity, we asked respondents to self-identify as an ethnic minority *in the astronomy community* (rather than in their country of residence). In the results and analysis presented here, respondents

who identified as part of an ethnic minority group in astronomy are referred to as “non-white” or “people of color” (PoC). The survey included a question about region of primary citizenship; we decided not to present data on this to better protect our respondents’ anonymity. Demographic information on our respondents is shown in Fig. 2.

Approximately 30% of respondents identify as female, which is consistent with our past records of conference participants. 2.5% identify as non-binary, other, or did not want to declare their gender identification. 14% of respondents identify as ethnic minorities in astronomy, with 2% not willing to share this information. In age, over 90% of respondents are between 25 and 54 years old; over 40% of the total are 25-34 years old. This suggests that a majority of survey responses are from early-career researchers.

In the UK, the Royal Astronomical Society (RAS) find women make up 25.5% of all astronomy researchers [22] (results for 2016). The American Astronomical Society (AAS) find a similar number (26%) for women amongst its membership base, as well as 0.2% who identify as transgender [24]. The International Astronomical Union’s most recent numbers show 18% female representation amongst its worldwide membership[2]. In terms of gender we conclude that women are somewhat over-represented in our group of respondents.

In terms of ethnicity, approximately 12% of the surveyed AAS membership reports an ethnicity other than "White"; the RAS reports numbers from 19% non-white amongst UK postgraduate students to 10% non-white amongst permanent research staff. Our fraction of non-white respondents is in line with these figures.

We also gathered information on the region in which the respondents are currently living, these data are also shown in Fig. 2. We note that “Europe” includes the United Kingdom and Republic of Ireland. Three-quarters of respondents reside in Europe and North America, the regions in which all but 2 events have taken place.

The chart in Fig. 3 shows that 28% of respondents had received partial or full funding from .Astronomy to attend. Under “partial funding” we count waived registration fee or small travel bursaries. Financial support is typically provided to invited speakers and to early career participants based on need. The figure also shows the breakdown along gender and ethnicity lines amongst those who received funding, showing 23% of funding recipients identify as an ethnic minority in astronomy (vs. 14% of all respondents) and 40% identify as women (vs. 31% of all respondents).

3.2 Study or career trajectory

A number of survey questions were related to participants’ course of study or career. We were interested in discovering whether conference participants felt their participation in .Astronomy had impacted their career or education trajectory. In Fig. 4 we show the distribution of answers to 4 questions:

- What is/was your career position now/when you first attended?
- Is your work or study related to astronomy (when you first attended and now)?
- Has your education or employment changed since you first attended .Astronomy?
- Did your participation in .Astronomy influence your career or education trajectory?

The responses to these questions show that many of our participants are in junior career stages when they first participated[3]. The "then/now" comparison indicates that some remain in the field, while others transition out to other careers, as is known across the subject. Roughly half of respondents have moved positions since they first attended (52%). If we exclude the most recent 2 events (2016, 2017), given that many fixed-term appointments are 2-3 years in duration, the number of respondents who have moved rises to 63%. Similarly if we exclude those with permanent research appointments, we find 67% of respondents have moved since they first participated in

[2] https://www.iau.org/administration/membership/individual/distribution/
[3] responses include those from people who attended multiple times or just once

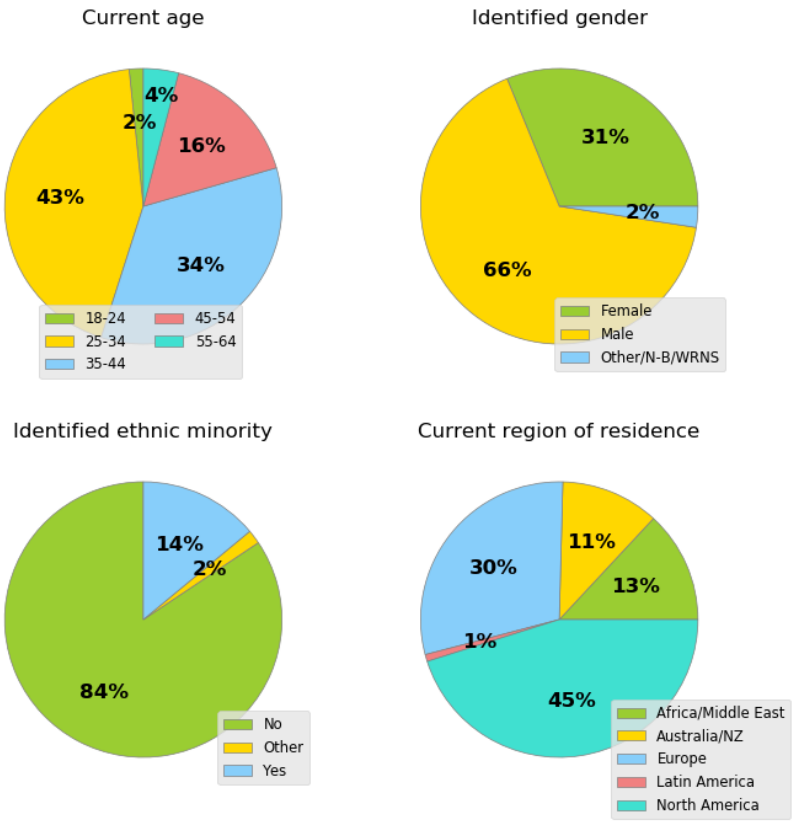

Figure 2: Basic demographic information on the survey respondents: age distribution, identified gender and ethnic minority status, and current region of residence.

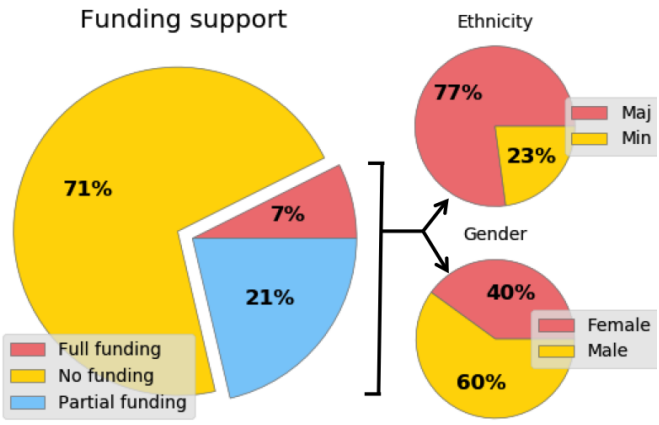

Figure 3: Chart showing the fraction of survey respondents who received full or partial funding to attend .Astronomy from the organisers (main plot); as well as broken down by gender and ethnic minority status.

.Astronomy. These numbers reflect a high level of mobility amongst early career researchers in astronomy.

We regularly invite non-astronomers to the conference to provide a broader perspective, which is reflected in the small fraction of respondents whose careers are not related to the subject. In 2014, the conference organisers were awarded a grant by the Sloan Foundation[4] to invite participation from academics outside astronomy, to advertise the conference and its format to other fields.

Interestingly, almost 70% of survey respondents feel that their participation in .Astronomy may have impacted their career or study trajectory. In Box 1 we provide some quotes from participants illustrating this impact.

Box 1: Impact of participation in .Astronomy on respondents' careers: example quotes

"[.Astronomy] has been central to my career trajectory, influencing who my letter writers are, enhancing my scientific and technical contact network, and fundamentally altering the way I work and who I work with."

"I think [.Astronomy] has boosted the profile and self-confidence of the software-interested community as a whole, and has both reflected and contributed to the rise of this sector of the field. My job now is both built on my previous work in this area and targeted at doing more of it; previously this kind of work would really not have been respected or even professionally recognized."

"I was somewhat under the erroneous impression that being in education/outreach wrote me off from practicing science/technology, but I came back to it and work full time in tech now. How wrong I was and how glad I am to be a living example that such boundaries are in fact porous. [.Astronomy]'s equal respect for science, technology, education and outreach is a great mindset that we may want to promote more strongly."

"It made me focus much more on software development and data analysis and to learn more about how these relate to astronomy. I've pursued job opportunities based on these interests and experience."

"I learnt a lot about how ideas are turned into reality by harnessing support across related discipline areas and globally. I was very impressed with the participatory format and I have used this unconference style since. At the time there was very little citizen science - citizen participation has blossomed since and this Has influenced my way of thinking about museums and community participation. "

"Opened my eyes to the types of tech/freelance careers that other astronomers have pursued, and how we could bring elements of tech/software development into the community improve astronomy research. I currently advise [*national astronomy funding agency (redacted)*] on matters related to things discussed/hacked at .Astronomy"

3.3 Experience at the conference

A number of questions were aimed at participants' experience at .Astronomy: what did they gain and learn? We proposed 6 different categories, and asked respondents to rate these on scales of 1 (not at all) to 5 (very much). The results of these are shown in Fig. 5. As we are particularly interested in the experiences of under-represented minorities at the conference, we show responses from people of colour ("PoC") alongside those from the full group. The PoC group contains ∼40% women of colour. As people of colour are more likely to encounter unwelcome environments in academia and at academic conferences [7, 6], we consider their reported experience an important benchmark for .Astronomy.

The responses to these questions suggest networking at the conference provides the strongest positive experience, and almost 90% came away with new ideas and inspiration for their work.

[4] https://sloan.org/

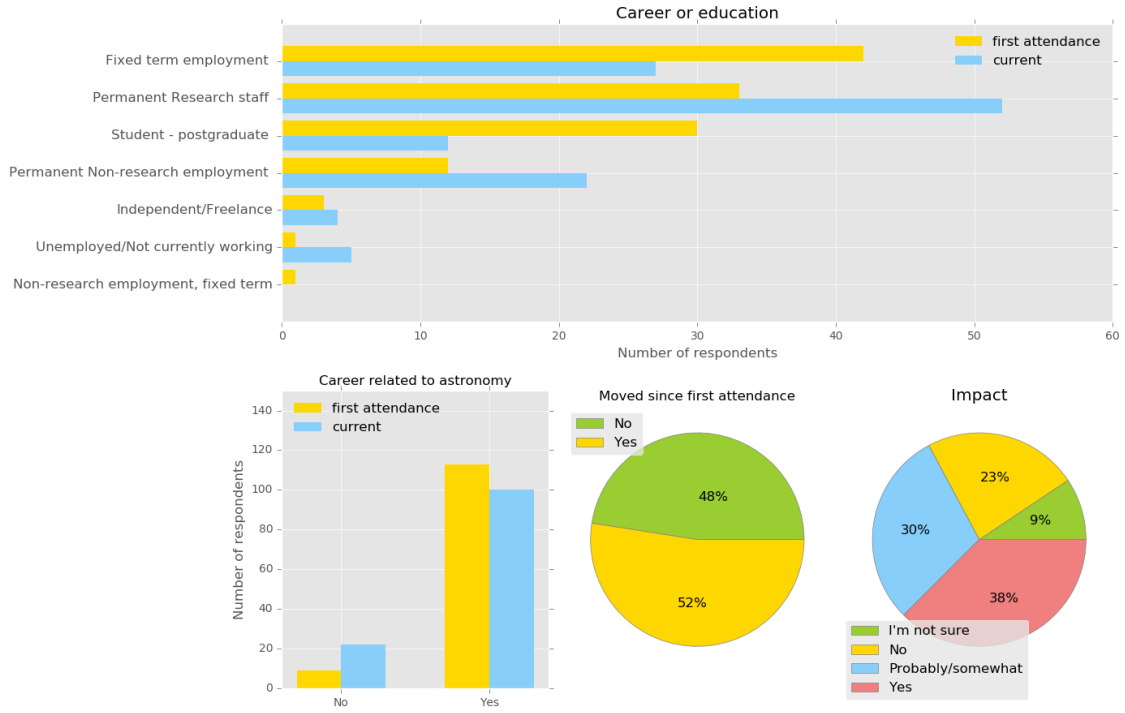

Figure 4: Data on the courses of study and careers of the survey respondents. The top plot shows data on the respondents' career stages, when they first participated in the conference vs. now. The bottom plot show, from left to right: whether careers or education are related to astronomy (when they first attended vs now); the fraction of respondents who have moved positions since first participating; and whether they felt their participation in .Astronomy had impacted their career or study trajectory.

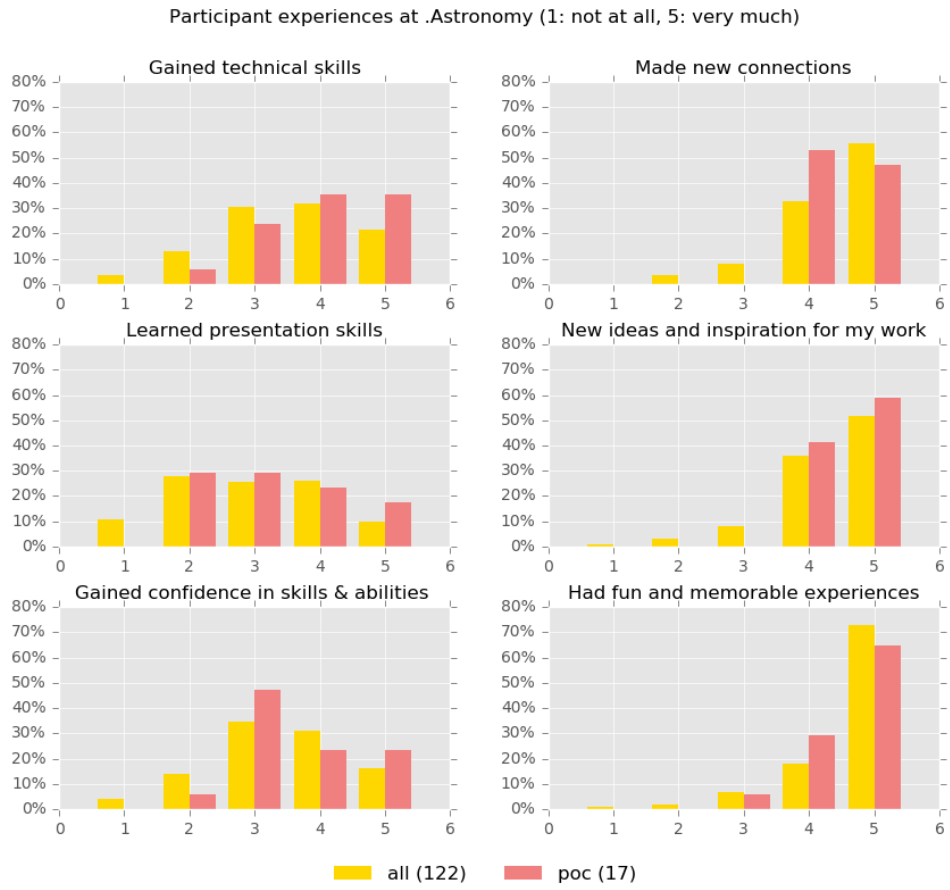

Figure 5: Ratings of participants' experiences at .Astronomy

Many participants also report gaining new technical skills (55% positive score), and around 45% gained confidence in their own skills and abilities. A relatively low fraction of respondents felt the conference had taught them presentation skills. As .Astronomy has relatively few "formal" talks sessions, instead promoting a more interactive conference format, this is not surprising.

The answers from the PoC group largely followed those of the full group, but a larger fraction reported gaining new technical skills at .Astronomy and new ideas for their work. We note the much smaller group of respondents in the PoC group, so we caution that these responses are subject to small number statistics.

3.4 Concrete outcomes

To measure the concrete impact of the conference on our participants' work, we asked participants the following three questions, and show the breakdown of responses in Fig 6:

- Did you transfer any aspect of your experience at .Astronomy to your local institute or workplace? If not, why not? (panel "Transfer to workplace" in Fig. 6)
- Did your participation in .Astronomy lead to any changes in your day to day work or study? If not, why not? (panel "Day to day changes" in Fig. 6)
- Did your participation in .Astronomy directly lead to any new projects, collaborations or publications? (panel "New projects" in in Fig. 6)

We provided additional space for respondents to elaborate on their answers regarding new projects or collaborations. In the survey the first 2 questions were listed with free text response fields rather than multiple choice. To produce the schematic overview we simplified responses into categories, where "yes" was only assigned when the response explicitly included "yes" or concrete

examples were provided. Answers such as “not yet”, “I would like to”, or “definitely in the future” were assigned to the “No” category. A small number of respondents provided no answer to the questions, these are labelled “NA” in the charts.

The charts show that 73% felt they had transferred some of their experiences to their workplace, and around two-thirds (67%) felt the conference had impacted their day-to-day work. In Box 2 we provide some example quotes from the responses to these questions.

Box 2: Example quotes from responses to questions on concrete outcomes

Did you transfer any aspect of your experience at .Astronomy to your local institute or workplace?

"I gave a talk about the experience and shared some of my own insights/impressions/useful tools."

"Much of what we hacked on is extremely relevant to my work and is being used."

"I sketched out the foundation for a series of graduate student tutorials based on .Astronomy sessions"

"I’ve organised hack days at my home institution(s) as I move around."

"I led a series of discussions on emergent technology, demoed several hacks, made a successful push for my department to transition from IDL to Python (at a time when that mattered) and led Python bootcamps."

"I have since not been afraid to just build small hack ideas of my own. It doesn’t have to be perfect or run on highly-optimised code or even work, but trying out ideas, failing and (once so often succeeding) is important."

Did your participation in .Astronomy lead to any changes in your day to day work or study?

"[I am] more confident in the importance of good software- it’s not just a waste of research time, it *is* research time."

"I made the transition to open authorship and dynamic, data-driven plotting. I started a vigorous outreach program at my institution."

"I became much more comfortable using git, GitHub, APIs, twitter. I followed the conference with workshops and reading books on web applications."

"Using version control for collaboration but also stepping back and letting younger people take more active roles in projects."

"I gained several new techniques which helped make my day to day work more efficient."

Some noted outcomes of the conference that were specifically highlighted by respondents:

- .Astronomy led to “Hack Together Days” organised regularly at the annual meetings of the American Astronomical Society (AAS)
- At least 2 web-based citizen science projects were created by .Astronomy participants. The Milky Way Project citizen science project[5] has led to several refereed publications [28, 12, 13, 4, 14]
- Publication of a data visualization book using skills learned at .Astronomy [21]
- Several respondents reported publications based on ideas or skills gained at the conference, co-authored with fellow participants, e.g. [2, 3, 23]

[5] http://www.milkywayproject.org

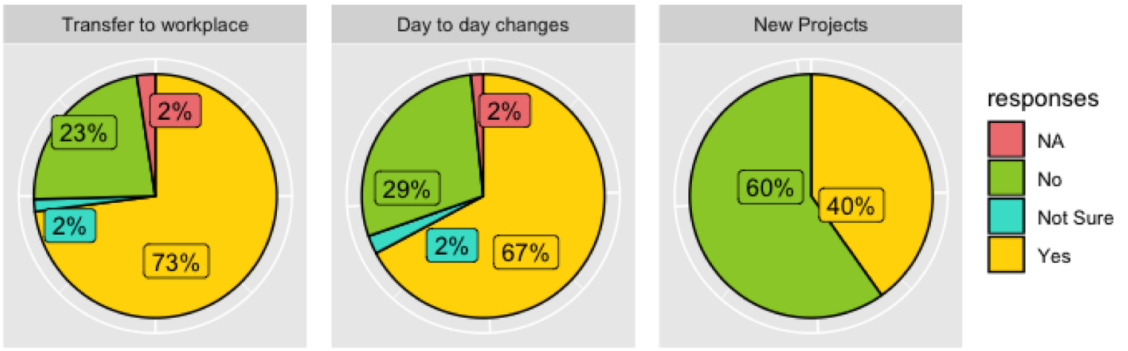

Figure 6: Concrete outcomes from participating in .Astronomy, as reported by the survey respondents. "NA" stands for "no answer".

- Improved social media strategies and new connections between astronomers and public engagement professionals
- Web projects, such as "What's up?"[6].

There is very little quantitative data on the outcomes of scientific conferences to put these findings into context: are these numbers typical of conferences, or does .Astronomy have a larger impact for its participants? The literature that is available typically focuses on publication metrics such as citation counts [5, 8], rather than the broader goal of community building, professional development and career progression. Huppenkothen et al [11] included questions probing these aspects into their survey of participants in AstroHackweek; 65%-70% of their respondents "agree" or "strongly agree" that their participation resulted in improvements in their day-to-day research, a very similar number to the equivalent question in our survey. This is an event with similar goals to .Astronomy.

3.5 Conference culture

Several questions addressed the culture at the conference, asking respondents to rate their experience at .Astronomy on a scale of 1 to 5 on the following points:

- the diversity of speakers and participants compared to other conferences (panel "Diversity of speakers" in Fig. 7);
- openness to conflicting viewpoints (panel "Openness to viewpoints" in Fig. 7);
- promoting change in the culture of academia (panel "Culture change in academia" in Fig. 7);
- giving space to under-represented voices in astronomy (panel "Underrepresentation voices" in Fig. 7);
- promoting good scientific practices (panel "Good scientific practices" in Fig. 7);
- supporting the advancement of astronomy (panel "Advancement of astronomy" in Fig. 7).

The results for this question are shown in Fig. 7, again broken down for the full cohort of respondents and for the PoC group. Particularly positive were responses regarding the conference promoting change in the culture of academia, and supporting the overall advancement of the field; both questions gathering ∼80% positive responses from the full cohort, and 100% and ∼80% positive from the PoC group.

[6] http://www.whatsup.icrar.org

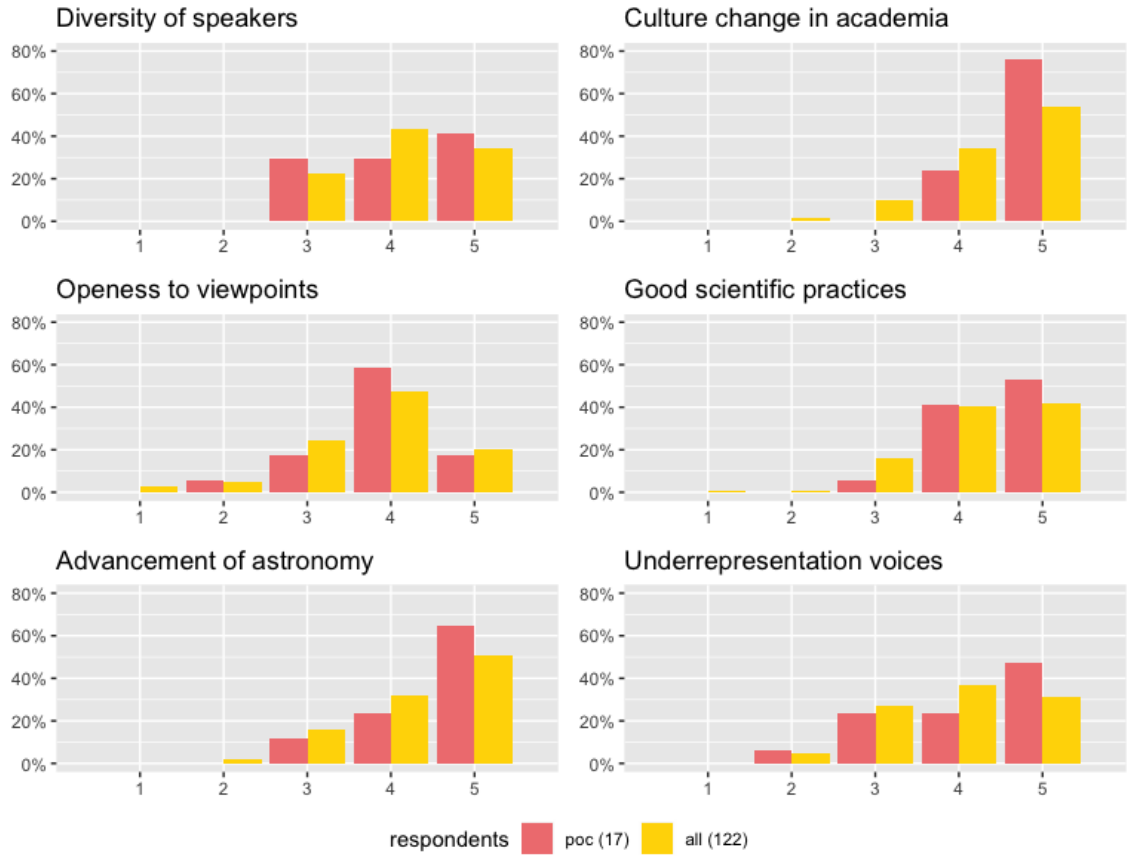

Figure 7: Ratings of participants' experience of the culture at .Astronomy

4 Negative feedback

The survey invited critical or negative feedback in a number of areas. Respondents were asked "What aspects of .Astronomy most put you off?", and provided with a list of options, as well as the possibility of entering new items. While 63 respondents (52%) selected the option "Nothing, loved it all", a significant number of respondents selected one or more other options. The most common choices were "Cost" (chosen by 13% of respondents), and "Hack Day" (11%). Many of these comments were related to "impostor syndrome"-type feelings during the hack day: feeling awkward, inadequate, not skilled enough to contribute. This reinforces the importance of keeping the conference accessible to participants with different skill levels; and providing a fun, stimulating and enriching experience for all.

Two further questions invited specific feedback on negative experiences:

- Did you ever feel unwelcome or unheard at .Astronomy?
- Did you ever experience or witness bullying or harassment at .Astronomy?

A minority of respondents answered positively to either of these questions - 19% and 2% answered "Yes" or "Would rather not say" to these questions respectively. With regards to feeling unwelcome or unheard, some of these responses referred to suffering from impostor syndrome or feeling unsure as to how they could contribute to the conference. Nonetheless, there were a small number of more serious reports of unwelcome behaviour (we will not share the details to protect reporters' anonymity), which reinforces the importance of having a strong code of conduct and procedures in place to deal with such issues effectively when they occur.

The reports of negative experiences in the survey are considered to be a lower limit on the actual occurrences, given the difficulties in reporting such behaviour, even in an anonymous setting such as this survey. We posit in addition that those with negative experience are less likely to have responded to the survey at all.

5 Discussion

5.1 The scientific and cultural impact of .Astronomy

The .Astronomy conference was initially organised to explore new opportunities in research and public engagement afforded by the web and the growth of social media. Over the past decade, it has gathered attention, and is consistently oversubscribed by a factor of 2 or more. Based on the results of our survey, we can break down the impact of the conference into the following categories:

1. Scientific impact
    - Education
    - Career development and networking
    - Community building
    - New research projects and publications
2. Cultural impact
    - Giving space to underrepresented voices
    - Promoting good scientific practice
    - Advancing more equitable scientific practices

We have fostered an open and inclusive culture at the conference, and place a high value on diversity in many forms: we have welcomed participation from amateur astronomers, educators, science communicators, researchers from other fields, as well as professional astronomers; we limit the number of returning participants to ensure each conference brings fresh ideas and experiences; we ensure gender and ethnic diversity by actively reaching out and encouraging people to apply, and since 2017 use an algorithmic selection process to protect against unconscious bias.

The open format of the conference, where many sessions are chosen and led by participants themselves, allows participants to centre the conference themes around their own experiences. These unconference sessions cover a very broad range of topics, from career advice to technical demonstration or tutorial sessions to discussions around academic culture. The continued success of the conference and the positive feedback received in the survey suggests scientists value such diverse conversations, and this need is not addressed by more "traditional" science conferences.

5.2 Diversity and Inclusion at scientific conferences: Lessons learnt

The diversity of participants, speakers and topics at .Astronomy, and the space provided to underrepresented voices in the field is consistently highlighted in the survey responses as a positive aspect of the conference. Having diverse voices and ideas was identified very early on by the organisers as highly important for the innovative and forward-looking nature of the conference. The diversity at .Astronomy is *by design*; and by prioritising diversity we have gathered some important knowledge on this topic. As many scientific conference organisers struggle with this issue, we summarise here some lessons learnt from 10 years of .Astronomy conferences.

- **Actively seek out participants from gender and ethnic minorities.** People from underrepresented minority groups may suffer more from impostor syndrome, or be less connected to the networks around "traditional" research universities. Attracting these talented researchers requires active engagement, issuing personal invitations, and diligently following up email enquiries.
- **Foster interdisciplinary connections.** Some of the most inspirational talks and sessions at .Astronomy have come from speakers outside of the astronomy research community. The conference has hosted participants from science education, science museums, ecology, library studies, computer science, the tech industry, social science, theoretical physics, mathematics, and more. Finding these participants requires engagement with other disciplines, attending interdisciplinary events, and issuing personal invitations to speak at the conference.

- **Keep the conference affordable and provide financial support.** An important aspect of this “active engagement" is prioritising the affordability of the conference, and providing financial support for those participants least likely to have access to resources to attend the conference. One aspect of the cost is the choice of venue: .Astronomy has frequently benefited from venues offered at zero or reduced cost, which hugely reduces the overall budget required. In addition, we have received financial support from numerous funding agencies, non-profit organisations and professional societies. This has allowed us to provide some measure of support to a significant fraction of our participants (28% of survey respondents). In 2018 we earmarked for the first time a portion of our raised funds specifically for child- or dependent care grants to support participants with additional costs due to caring responsibilities. Fundraising for such travel or dependent care support is a significant additional organisational effort; however it is the best way to ensure the most junior scientists and those from underrepresented minority groups can attend.
- **Move the conference around.** Astronomy as a research field is heavily dominated by the North American and European communities. A high fraction of all conferences are held in these regions, despite other regions having active and often growing research communities. By hosting the conference in different regions - Sydney in 2015, Cape Town in 2017 - we were able to increase the numbers of participants from non-dominant parts of the world. We note that scientists from Asia, Africa or Latin America can have significant difficulties obtaining visas for conferences in North America or some European countries, making these events challenging to attend even with funds available.
- **Attempt to remove bias from the selection process.** The participant group for .Astronomy is selected from the group of applicants; this selection over a "first-come first-served" approach is deliberate, to ensure the right mix of participants. There is, however, an inevitable bias when the organising committee hand-selects participants. Even when using an algorithmic selection method, e.g. with the Entrofy algorithm [10], biases remain.

5.3 Towards the Future

We are keen to build on the successes of the conference in the future, and take the feedback from past participants into consideration to keep improving the conferences.

One important aspect of the conference is *community building*. Survey respondents reported making important new connections at .Astronomy, and learning about "what an astronomy career can look like". A significant number report concrete outcomes in research or public engagement. In the future, we aim to explore new ways to improve the community aspect of .Astronomy, beyond the annual conferences. A number of options are under consideration, including a regular newsletter, a Slack team, or more frequent events.

Second, the survey was the first formal effort at gathering participant feedback from .Astronomy. The results have shown us that this is an extremely valuable thing to do, particularly given the more unusual conference format, aspects of which have since been adopted at other events (e.g. Astro Hack Week[7], Detecting the Unexpected: Discovery in the Era of Astronomically Big Data (STScI, 2017), Python in Astronomy[8]). Many participants came away with new technical skills and new connections; a majority of respondents transferred this new knowledge back to their workplace. We note that Huppenkothen et al [11] performed a similar survey for the Astro Hackweek event with comparable findings. However there is little information available in the literature on the impact of conferences and workshops as a whole. Systematically assessing participants' experiences at scientific conferences, and the impact on their careers, could be a valuable step to building an evidence base around scientific conferences. This could provide conference organisers with a basis for how to format an event for maximum impact. Given the cost, travel and time burden of conference organisation and participation, this seems like a worthwhile goal.

Such a formalised assessment of the impact of scientific conferences on the state of the profession and its community should ideally be performed in collaboration with social scientists, who have

[7] https://github.com/AstroHackWeek
[8] http://openastronomy.org/pyastro/

expertise in survey design (including anonymisation) and results analysis. Our experience with the survey presented here, while useful, did not benefit from such a collaboration, and we are aware of this limitation in the interpretation of the results. We are very grateful to the feedback the past participants of .Astronomy have provided us, and we intend to build on our initial study to a more rigorous assessment of our community impact in the future.

6 Summary

We presented in this paper the results of a participant feedback survey for the nine .Astronomy conferences held between 2008 and 2017. The results demonstrate that .Astronomy has made a significant impact on the astronomy community: providing a stimulating, inspirational and challenging experience to the participants, many of whom are early career scientists. A high fraction of respondents report that the conference has impacted their career or study choices, or produced concrete outcomes in research or public engagement. A majority of respondents transferred aspects of what they learnt back to their workplace through talks or locally organised hack days, and 40% reported that new projects or publications resulted from their participation in .Astronomy. The conference was found to promote good scientific practices, cultural change in academia, and overall advancement of the field. Based on the experience of organising .Astronomy and the feedback we have received via the survey, we have presented some lessons learnt about organising a diverse and inclusive conference, for the benefit of other organising committees in our community. In addition, we are considering how to build further on the successes in community building with .Astronomy to support our participants best in their careers. Finally, we highlight the importance of studying the impact of scientific conferences, and the different session types they include, on the lives and careers of their participants; and for this effort to be carried out in collaboration with experts from relevant fields.

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