Bustling public communication by astronomers around the world driven by personal and contextual factors

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Astronomers have a long tradition of outreach to satisfy public enthusiasm about stars and the universe. Anecdotal evidence shows that astronomers love to popularize[1], and their efforts reach millions around the world[2,3]. Yet, no systematic comparisons may be performed without evidence. The general literature on scientists' outreach focuses on barriers and finds lack of fun, time, skills or recognition, or seeing it outside of the professional role[4] and a threat to reputation - the 'Carl Sagan effect', to discourage outreach; an activity generally more frequent among the most senior and academically productive male scientists [5,6,7]. This is the first systematic study of astronomers' outreach activities beyond local case studies[8,9,10] which shows how these barriers compare within this community and in different research systems and environments (IAU; n=2,587, 30% response rate). We show regional variation of outreach activity, higher activity among astronomers in South America and Africa, and find that personal factors are important yet contextual factors matter too. Among astronomers, gender, rewards and fear of peer criticism do not matter. Future research should focus on explanatory factors inherent to the ecology of scientific work to better understand what drives scientists within their specific cultural and research environments.

In 2016, we asked the members of the International Astronomical Union (IAU), to respond to questions which address two issues: firstly, what, how much and with whom are professional astronomers engaging? And secondly, what factor combination best explains high participation of astronomers in communication with the public, and how does it compare across world regions? We expected differences in performance of astronomers across regions with higher activity in Europe and North America, due to higher performance of the scientific system[11] with wealthier countries having larger communities and more scientifically productive astronomers than poorer economies[12,13], greater public access and interest in science[11], and older traditions of public engagement[14]. Our findings challenge our expectations.

Among all respondents (n=2,587, response rate of 30%), the large majority of IAU astronomers reported engaging with the public (87%, n=2,226), and also doing it frequently and regularly both through public events and the media. Astronomers reported a total of 40,826 activities, which amounts to an average of 18 activities per 'communicative' astronomer (87% of all), with half engaging in at least 9 activities per year (median is 5 participations in public events and 4 in news channels) (SI, Table 2 and Table 3). These numbers are strikingly high when compared with other studies that show fewer activities per scientist. For example, 30% of biomedical scientists had 5 contacts or more with the media in three years[15]. This high intensity might reflect astronomers' long history of outreach.

The general public is the main audience addressed by astronomers (35% addressing it frequently), followed by schools (23%), mass media and journalists (26%). Public lectures are the most frequent events, followed by talks in schools and open days[i]. As for media channels in use, most popular are interviews with newspapers, radio interviews, and articles in magazines (Figure 1). Only a minority reported using social media regularly (less than 20%); 80% never used twitter nor blogs, and 60% never used Facebook (Figure 2). This is an interesting finding if we consider the full spectrum of activities which a scientist engages in. Traditional means are most used by astronomers, and social media channels rank lower when compared to them. It remains a question as to whether this is a characteristic of this community; and are social media being adopted slowly or has it stabilised as practice for a few – these are questions that deserve further investigation. The dominance of one-way communication found amongst astronomers is not different from other natural sciences. High intensity suggests, however, that astronomy may be top the performer among the natural sciences[16].

Figure 1. Average participation in public events and media channels by astronomers. The bars show the means and whiskers show the standard error (SE).

Figure 2. Frequency of participation in social media channels (per year).

Comparing the intensity of activity across regions for events and media channels reveals interesting patterns[ii] (Figure 3). In absolute terms, communication is concentrated in North America and Europe (more than 70%) with the remaining 30% distributed across Asia, South America, Australia, and Africa. This is not surprising given the population of astronomers and research development in more astronomically developed regions[12,13]. The relative level of activity, however, is higher in South America and Africa for events, and in South America, Australia and Africa for news channels (higher median and means; see SI, Tables 2 and 3). This may be explained by the presence of many high performers in South America and Africa, with more astronomers doing more activities (larger SE). For example, 50% of the astronomers perform 6 or more public events in Europe, the number rises to 10 in Africa. On the contrary, in Europe and North America, the distribution of activity is concentrated around the mean suggesting a similar level of activity amongst astronomers in these regions (smaller SE). The same is observed in media relations. The use of social media, though limited, follows the same pattern as events across regions: more intense use in Australia, South America and Africa ($p<0.05$).

This is an intriguing finding for regions of the world with less astronomy infrastructure and lower numbers of astronomers such as Africa or South America[12]. This might be in part explained by the fact that many of the world's top astronomical research facilities are built in less developed regions; see, for example, the European Southern Observatory in Chile, or the world's largest radio telescope, the Square Kilometre Array (SKA) in South Africa promote education and outreach programmes with local communities[17], mobilizing astronomers in these regions. It may be that these international installations and the local research context that derives from them, have a catalysing effect on the outreach activity of the local astronomical communities. This observation might deserve further attention. The representativeness of our sample indicates that these patterns may reflect the contexts of astronomers' communication across these regions (see SI, Table 1b).

Figure 3. Intensity of participation in events and channels across regions. The bars show the means and whiskers show the standard error (SE). In parenthesis, we report k as the number of activities reported for each region (k), and n as the number of respondents (n) per region.

For such a 'communicative' community, our second goal was to investigate the factor combinations that drive high participation, i.e. the likelihood of an astronomer engaging in public events and media channels (2 dependent variables) at a level above the median, and thus being called a high performer. Factors are seniority, gender, research productivity, intrinsic motivation, extrinsic motivation 'role' and extrinsic motivation 'rewards', and indicators of institutional support including training, funding, and collaboration with communications staff (see Methods). Binary logistic regression models specify the contribution of each set of factors and overall. Model 1 includes motivations, seniority and research productivity; Model 2 adds gender and regions; and Model 3 adds institutional support. All models explain variance in astronomers' outreach and we document the increase in the explained variance from Model 1 to Model 3 (SI, table 6 and table 7).

Intrinsic motivation and seniority are important factors for high performance in events and media channels (SI, Models 1); and remain significant as we add other factors (Models 2 and 3). As in other scientific communities[7], also among astronomers the more motivated and more senior are likely to engage more in outreach. Yet, intrinsic motivation is more important for face-to-face events, while seniority is a more important factor in media channels; for media contacts, research productivity is also important. This is not totally surprising: while a public lecture or a skies observation' event can be performed at any career stage, depending mainly on intrinsic motives, it is the most senior and academically productive who engage in the publicity of news, a relationship that is both normative and empirically documented in other scientists' media studies[18,19]. This trend could however be threatened as the use of social media increases among a cohort of younger, less senior researchers.

'Role' is also significant. Public outreach seems to be normatively accepted among this community. Only 20% view outreach 'as a hobby rather than a duty', and 96% disagreed that outreach 'will negatively affect [their] reputation'. This suggests that fears of peer criticism regarding public visibility and being seen as a bad scientist – the so called 'Sagan Effect'[20] - as found among physicists[4] for example, do not seem a significant concern to this community. Yet, it indicates that outreach is a core component of the professional role of the astronomer. 'Rewards' are not important. Only 27 % say they would participate more if there were awards and prizes and 43% if it would help them to progress in their careers. However, junior scientists seem to value them more than their senior peers do, perhaps a result of pressure for career progress (not statistically significant).

Adding gender and regions to the regression models (Models 2), we find only minor differences across regions. Contrary to other communities[4,21], gender does not matter; nevertheless it is important to note that the overall number of women is very small in this community. Compared to Europeans, astronomers in Africa are more likely to be high performers in events, and astronomers in North America are overall less likely to be so, perhaps an effect of the lower number of (available) astronomers in the US compared to Europe. The relatively likelihood of an astronomer in Africa being a high performer may be explained by the recent developments in astronomy infrastructure in the region[22,23], in particular in South Africa where we also found most activity within the African region; among others, the large ongoing developments in astronomy (e.g. SKA as mentioned and the MeerKAT telescopes), and the Office for Astronomy Development (OAD) drive[iii] that create many opportunities for astronomers to engage with the public[17]. In Asia, astronomers were less likely to be higher performers in media channels, perhaps a result of the challenges faced by science journalists in Asia who struggle with access to scientists who have restricted freedom of speech to share their research[24].

Model 3, our best explanatory model, provides evidence of the importance of the organisational context in outreach (Figure 4). Intrinsic motivation and seniority explain most variance, though role, research productivity, global region, and institutional support play a significant role too. Those who reported training, funding, and support from communications staff were more likely to be high performers. Staff only makes a difference for news media relations, suggesting that astronomers may look for these professionals to get media visibility[18]. Still the large majority reported having no training (68%), no funds (71%), and only 43% worked with staff despite 86% reporting their institutions having them. Astronomers said they 'did not need their help', 'preferred to organise their own activities', and 'communications staff is too busy with other tasks'. Yet, 30% agreed that they lacked institutional support. These findings suggest a certain gap or psychological distance between astronomers and communications' professionals, which could be an indigenous tradition of outreach among astronomers 'we know what we are doing'; it is certainly an indicator of the individual practice of the community.

Figure 4. Forest plot showing binary logistic regressions for communication activities. Models include 'communicators' only. Data correspond to the odds % ratio at 95% confidence intervals (CIs). The chart on the left presents the likelihood of being a high performer in events and the one on the right presents the likelihood of being a high performer in news channels. Diamonds represent the odds and the whiskers the CIs. Significant associations are shown when CIs do not overlap with the 0=line; diamonds on the 0=line are the reference categories. Africa is not represented in the charts given the small n which affects the CIs.

Our findings have important implications for the communication of astronomy with the public. Highly communicative members of this community are more intrinsically motivated, more senior and prominent, and receive more institutional support. Institutions wanting to increase scientists' communication with the public might do so by strengthening resources and cultivating intrinsic motivation, which may require fostering a climate of doing outreach for a higher purpose and community building; while bearing in mind that external rewards can be counterproductive[25]. In regions with less astronomical development, a step forward direction could be expanding international collaborations, and scientists' skills training. Future research needs to study additional explanatory variables inherent to the culture and ecology of scientific work to better understand what mobilizes scientists within their particular research systems and environments.

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Authors' contributions

M.E. and M.B. designed the instrument measurement. M.E. collected the data, performed the analysis, and wrote the manuscript and SI. MB contributed to analyzing and interpreting the results.

Methods

Data collection. We carried an online survey between November 2015 and January 2016 with the members of the International Astronomical Union (IAU). Each participant received a generalised link. Three reminders were sent, and one-week extension was provided. We analysed n=2,587 responses from astronomers working in six main global regions: Europe, North America, South America (including Mexico), Asia, Australia, and Africa. The sample is representative of the IAU membership for gender, age, and global regions (see SI, Table 1a and 1b).

Sampling procedure. The IAU membership of Individual Members, is the largest body of professional astronomers in the world. The IAU is composed by National Members (n=79 countries that adhere to IAU) and Individual Members (individuals usually from national member countries, but there are a few astronomers registered in the IAU databases from nonmember countries; 22 astronomers according to the IAU website[iv]). The IAU Individual Members - structured into Divisions, Commissions, and Working Groups – are professional astronomers from all over the world with a PhD, who are active in research in astronomy. The IAU Directory has currently more than 10,000 researchers with a valid-public email on the IAU website and affiliated to at least one Division, covering most countries where professional astronomers operate. Statistics on the number of astronomers per country show that, the non- IAU member countries have small populations and most have no astronomers. In 2008, only 14% of the world's population lived in a country with no professional astronomical community; and 99% of astronomers of IAU individual members live in countries that adhere to IAU[12]. These numbers show that the IAU membership reaches the majority of the countries where professional astronomers work, making it ideal to investigate our research questions.

We considered only astronomers active in astronomy research. 'Non-active' researchers were excluded including those who identified themselves as retired, no longer active in astronomy research, communications personnel at planetariums/ museums/research institutions, and deceased[v]. IAU 'non-active' members are removed from membership lists only after being inactive for more than 10 years, so memberships are not fully updated. Taking this into account, we excluded non-actives as follows: firstly, through a filter question at the beginning of the survey that asked respondents to identify themselves as *active* or *non-active* astronomers. We asked 'This survey is directed at active astronomers, i.e. currently involved in research', giving them the options: 'I am an active astronomer' and 'I am not an active astronomer (e.g. communication and education professional, PR officer, retired, left astronomy); non-actives were directed to the end of the survey. This was mentioned in the emails to encourage those in such situations to let us know. It is possible that our response rate is then higher as we believe that not all 'non-active' astronomers informed us. Secondly, we excluded those who though had identified themselves as ‘active’, identified ‘outreach and education’ as main professional activity.

We also encouraged ‘non-communicators’ to participate by making clear in the emails that the study was aimed at both communicators and non-communicators. Participants were also informed that the study was conducted under the auspicious of Commission 2 (C2), Communication of astronomy with the Public, Working Group Science Communication Research for Astronomy, for which the corresponding author is Chair, and supported by the European Southern Observatory (ESO) and Leiden University. ESO contributed with a prize (astronomy posters and books) as an incentive to participation.

We contacted all IAU members with a valid email at the time of the survey (n=9,162, (this number excludes bounced emails). We received 3,440 responses. After excluding for ‘non-actives’ n=395 and incomplete questionnaires (n=458), we analyzed n=2,587 completed questionnaires for a response rate of 30%. Our sample is representative of the IAU membership for gender, age, and geographic region ($p>0.05$). To the best of our knowledge, this is the first and most comprehensive study on scientists’ engagement of an entire scientific community with a global reach, and first of the international astronomical community.

Measures

We examine *high participation* of astronomers in *events* and *news channels* (two dependent variables). We asked scientists ‘Roughly, how many times in the past 12 months have you engaged in the following activities either as organiser or contributor?’ From a list of eleven types of events, public lectures comprised 36% of the total of all events astronomers participated, followed by talks at schools (18%), open days (8%), public exhibitions (7%), workshops with local organizations (6%), science festivals or fairs (5%), citizen science projects (5%), science cafes or debates (5%), participatory events in policy-making (3%), National Science Week (2%). As for *news channels:* 21% of the total participation reported were interviews for newspapers, interviews for the radio (17%), articles in magazines or newspapers (12%), interviews for the TV (8.2%), newsletters (7%), brochures or non-academic publications (5%), materials for schools (5%), multimedia/videos (5%), other TV (shows or programmes) (3%), press conferences (2%), press releases (2%), policy papers (1%) and popular books (1%).

Intensity indices were constructed from counts across several activities and dichotomised on a median split in low (0) and high (1), defining high and low participation.

Independent variables included motivations, socio-demographic factors including gender, age and seniority; academic productivity; country of work. Gender was coded (0) for male and (1) for female; age was ordinally coded (1) for <=43, (2) for 44-52, (3) for 53-62, and (4) for >=63; Seniority was coded (1) for Head/Director, (2) Professor, (3) Associate Professor, (4) Assistant Professor, (5) Postdoctoral Fellow, and (6) Research Fellow; Research productivity, respondents were asked to estimate how many peer-reviewed publications they have produced over the past 5 years. This variable was ordinarily coded (1) for <=16 and (2) for >16 publications corresponding to a median split; Country, we asked scientists for their country of work (see Table 1b). We recoded country into geographic regions (1) for Europe, (2) for North America, (3) for Asia, (4) for South America, (5) for Australia, and (6) for Africa. This categorization reflects the distribution of astronomers in the IAU, and the differential R&D expenditure in astronomy[12]. Overall, the global astronomy performance and expenditure remains highly concentrated in Europe and North America, when compared with other regions. Hearnshaw (2006) in an analysis of the IAU members shows that the number of astronomers and academic production in astronomy is lower in developing nations with Africa being the least scientifically productive.

To measure motivations, we asked scientists to agree or disagree on a 5-point scale, with 12 claims on intrinsic and extrinsic motivations[25] (see SI, table 4). We used motives identified in previous studies[26, 27] and Self-Determination Theory (SDT)[28] as framework. The SDT distinguishes between types of motivation based on the rationales for performing a task/action. Intrinsic motivation refers to doing something because it is inherently enjoyable or interesting, and extrinsic motivation refers to doing something for an instrumental reason such as external pressures, instrumental value or utility (e.g. prizes, money, responsibility).

Index for motivations. We first conducted Exploratory Factorial Analysis (EFA), resulting in three factors (Cronbach's α =.73) (KMO=0.80, Chi square= 7911.5, df= 91, sig=0.000). The 3Dimension structure was then tested with Confirmatory Factorial Analysis (CFA). The model fit indices showed a strong internal consistency and reliable indicators for the construct 'motive' (cfi=0.96, rmsea=0.05, tli= 0.94, bic= 88785.20), which was preferred over EFA factors. We named the three factors: intrinsic motivation, referring to a personal drive towards and enjoyment of public communication; extrinsic motivations referring to incentives such as 'rewards' to be gained (prizes, awards or recognition) or given by the 'role', i.e. acknowledging public communication as part of informal or formal job descriptions of astronomers. All three factors were recoded into binaries using a medium split for low (=0) and high (=1). Table 3 shows factor loadings for motivations[vi].

Organisational context as measured by indicators of institutional support that a scientist receives. Institutional resources and PR offices are playing an increasing role in leading scientists into communication activities[29,18], yet, the interactions between them and how their support impacts on scientists' outreach practices are still poorly understood. Institutional support indicators included 'funding', i.e. amount of scientists' research grants allocated to communications, levels of 'staffing', i.e. scientists' collaboration with professional communications staff, and ‘training’, i.e. astronomers receiving training in science communication. 43% reported using no funding for outreach, 40% spend less than 5%, and 17% more than 5%. 32% have had training, 48% had not, and a further 20% would be willing to. When asked ‘how often have you worked with the communications staff at your research institute in the past year?’ 57% reported ‘never’, 19% worked 1-2 times, 24% more than 3 times. All three variables were coded no (0) and yes (1).

Analyses. We modelled the factors using binary logistic regression. This was appropriate given the distribution of our data not being normal, the existence of few cases in certain regions, and skewedness of the data. Three sets of variables were entered in separate blocks, to investigate the individual contribution of each set and overall. We report B (95% CI=B (Lower – Upper), Nagelkerke’s R2, the p value of significance and the predictive accuracy of the models. Variance Inflation Factor (VIF) was used to test for multicollinearity among factors. Age showed a strong correlation with seniority and was excluded from the models. Reference categories are: for gender is ‘male’; for seniority is ‘Head/Director’; for geographic region is ‘Europe’; for motivations, reference categories are low for intrinsic motivation and extrinsic motivation ‘role’, and high for extrinsic motivation ‘reward’; for publications, the reference category is low (<=16 publications in the last 5 years). Training, funding and collaboration with the communications staff, reference category is ‘no’. Extreme outlier cases (beyond 3SD) were excluded from all analyses reported here.

Limitations. Although the survey is the largest into astronomers' outreach practices till date, there is a need for further investigation, especially in those regions where there were a limited number of responses such as Africa, South America and Asia, to better understand the variance of activity found amongst these regions. For example, China, Japan and Chile all having high levels of astronomical production, have been analyzed with other countries as part of the same region making it difficult to conclude at the country level. Also, the fact that the IAU membership accepts only members at the level of PhD may have excluded some younger researchers and PhD students. However, there is no reason to believe that the relationships analyzed here would vary, as our sample contained younger researchers.

Data Availability Statement

The data that support the plots within this paper and other findings of this study are available from the corresponding author upon reasonable request.

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[i] This might include visits to the institutional astronomy facilities such as telescopes and observations.

[ii] We exclude social media from our pattern analysis of events and channels given its limited use.

[iii] In 2010, the IAU Office of Astronomy for Development (OAD) was set up as a joint partnership by the IAU and South African National Research Foundation (NRF) to implement the IAU decadal Strategic Plan, Astronomy for Development (2010 – 2020) with offices at the South African Astronomical Observatory (SAAO) -- the national centre for optical and infrared astronomy in South Africa. South Africa also counts with a strong government support for research in astronomy

[iv] WWW.iau.org last accessed on 02 September 2018.

[v] We received a few responses from institutions reporting deceases.

[vi] Attitudinal items in factor 1 and factor 3 were all negatively-keyed i.e. phrased so that an agreement with the item represents a relatively low level of the attribute being measured. For example, an agreement with the item 'I do not enjoy it', rated on a 5-point scale (1 = Strongly Disagree, 5 = Strongly Agree) indicates a relatively low level of intrinsic motivation.