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Communicating Astronomy with the Public

SPECIAL EDITION
ASTRONOMY COMMUNICATION IN A TIME OF CONFINEMENT

Fundraising
Getting started in fundraising for astronomy outreach

What to do in extreme times?
An analysis of the astronomy communication actions in Brazil during the COVID-19 pandemic

Astronomers for Planet Earth
Embracing virtual communication induced by the COVID-19 pandemic to help tackle the climate crisis

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The featured image is an artist's impression of a galactic wind "blown" by a supermassive black hole located in the center of a galaxy and originally appeared in a Press Release from ALMA, NAOJ. That press release was featured in the article "An ancient, stormy black hole" by Space Scoop. Space Scoop brings the latest astronomy news from across the Universe each week. Space Scoop articles cover the most exciting cosmic events in a language that is easy to understand for younger audiences. With news and pictures coming from some of the best space agencies in the world. Image credit: ALMA (ESO/NAOJ/NRAO)

Editorial

Welcome to the 30th edition of the CAPjournal, this time with a special issue dedicated to astronomy outreach and communication in a time of confinement. While the world still struggles to contain the spread of COVID-19, we've witnessed numerous creative and inspiring science engagement initiatives worldwide.

People from all backgrounds and levels of experience in public communication have risen to the challenge and organised astronomy events to stay connected with their communities. Individuals have streamed their night sky through a telescope at their window; astronomers have held virtual meetups; educators have shared fun DIY activities for parents and children at home; planetariums have broadcast live remote shows, and astronomy challenges have been set up online. The CAP journal team encouraged our community to share their stories behind the outreach initiatives that engaged the public meaningfully with science and astronomy during the pandemic. Outreach professionals, educators, amateur and professional astronomers, and astronomy enthusiasts worldwide have answered the call, and we received nearly 60 submissions from around the world.

In this special CAPjournal issue, we describe the mobilisation of astronomy communicators in Brazil, one of the countries most affected by the pandemic and where the amount and diversity of online activities increased considerably. We address the difficulty of visiting observatories located in remote areas, with the global pandemic making visits even harder and the role of virtual tours to continue engaging with the public. Astronomers for Planet Earth (A4E) and the impact of a global shift to online communication due to Covid-19, and how they utilised digital tools to engage their audience and continue to tackle and communicate help tackle the climate crisis. Discover the Universe team shares how they supported young families to adjust to the challenges faced with school closures by providing daily astronomy content. All of this and more in this special edition.

We want to thank our Guest Editors for their support in identifying and selecting from a vast and eclectic number of contributions the articles that compose this edition. We also want to extend our thanks to the whole CAPjournal team that, twice a year, helps bring you the CAP Journal editions: our thanks to the Editorial Board, peer reviewers and contributing authors for their efforts in bringing you another edition of CAPjournal.

CAPjournal will return in the Spring of 2022 with a regular edition thanks to the continued contributions from our community of science communicators, informal educators and outreach practitioners. If you are interested in sharing your work in a future issue of the CAPjournal, we continually accept abstracts and encourage you to submit them for consideration in issue #32 to be published towards Autumn of 2022.

Wishing you clear skies and good health,

Lina Canas
Editor-in-Chief

Cover: A mosaic composite with the IAU National Outreach Coordinators (NOCs) during one of the NOCs bimonthly online meetings and a detail of a broader image of the Carina Nebula (by ESO/T. Preibisch). The IAU National Outreach Coordinators (NOCs) are national-level representatives for the IAU Office for Astronomy Outreach (OAO). Members of the network act as a point-of-contact for astronomy outreach for a country or territory. NOCs support the implementation of IAU OAO projects on a national level, share astronomy news and events within their country, and bridge the IAU with local communities. Image Credit: IAU Office for Astronomy Outreach

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Column

Explained in 60 Seconds: Getting Started in Fundraising for Astronomy Outreach

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COVID-19 has seen significant shifts in the funding landscape, with resources diverted towards fighting the global pandemic. While this can be challenging, it also presents an opportunity for new initiatives and existing organisations to reassess their goals and priorities, seek new partners and build towards sustainability. We explore some top tips on how to maximise your chances of success.[1]

Vision and Mission

Take time to review your vision, mission and goals. What is your purpose? What is your organisation here to achieve? Who are the key stakeholders you need to involve in this? Who are the partners you can collaborate with? Look at long-term objectives over a series of five to ten years and move away from short term objectives. Be mission driven and not donor driven.

Organisation Message

Once you've identified where you want to go, develop your strategy and write your Theory of Change and Case for Support. Identify the problem, the solution and where your organisation fits into delivering that solution.

- Develop appropriate communication channels such as social media or videos; get creative
- Be sure you're ready to persuade people in a couple of minutes or even less!

Telescope vs Impact

In fundraising, we have what we call the minibus analogy: 'why will no-one fund my minibus?'; let's replace that with a telescope. Think about the impact that telescope creates. What does it do? Why is it necessary? It could boost science education for children, encourage girls into STEM, help combat science denial or improve education outcomes, leading to higher levels of employability.

Impact needs to be front and centre of your message. A set of numbers on how many people you've reached, or events held, isn't what donors are looking for. Have these actions led to behaviour change? Use a framework to help you identify and measure your impact. The UN's Sustainable Development Goals (SDGs)[2] are the best known and most recognised by funders, and you can use the SDG indicators to help you understand how you can contribute not just to global efforts, but at a national and regional level as well.

Be Strategic, Not Transactional

Fundraising in itself is a transaction, a mechanism. Raising money is not the purpose of your organisation. Fundraising is one means among many to help you achieve your vision and should align with your goals. There are some common traps, such as assuming companies are generous donors. They aren't. Move away from short-term funding cycles by looking at the range of financing options which work to strengthen your vision. Consider whether you can earn your own income and look at social enterprise models. Build relationships with other nonprofit organisations. Look to the people you already have. Major donor fundraising is possible and powerful, but will take time. Crowdfunding and movement building are excellent ways to engage your community. For larger trusts and foundations, identify ways they can invest in your organisation so you can then build your sustainability in the longer-term.

Takeaways

- Can you earn your own income? Diversify income across a range of sources
- Look to your existing networks and donors first for support. They are far more likely to give to you. 'Cold' recruitment of donors is much more difficult
- Always assume people don't know what you're talking about! Be sure to explain the 'why' of what you're doing and the change that will effect
- People give to people! Through influencing, the money will come

Notes

[1] To learn more, view the IAU-OAD fundraising webinar (https://www.youtube.com/watch?v=nA12KsdsXhU) and the CAP Conference 2021's oral presentation on fundraising (https://www.youtube.com/watch?v=Y-rYgR6ZZ6i4).

[2] UN's Sustainable Development Goals (SDGs): https://sdgs.un.org/goals

IAU Statement on Climate Change

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The International Astronomical Union (IAU) calls on our community to develop and implement specific actions to help achieve the aims of the 2016 Paris Agreement on climate change. The study of astronomy provides all citizens a unique perspective and view of the Universe that highlights the fragility of life on planet Earth. The first Kavli–IAU interdisciplinary symposium will be dedicated to climate change on planets in late 2022 or early 2023.

The International Astronomical Union (IAU) joins other astronomy institutions and scientific organisations in stressing the importance and urgency of environmental sustainability for the future of our planet. As concluded by the International Panel on Climate Change (IPCC)[1] and highlighted in many scientific reports, increases in anthropogenic carbon dioxide and other greenhouse gases have exacerbated climate change since the industrial revolution, and without mediation, we risk extreme and irreversible damage to life on our planet. The IAU calls on our community to develop, promote and implement specific actions to help achieve the aims of the 2016 Paris Agreement.

The study of astronomy provides all citizens a unique perspective and view of the Universe that highlights the fragility of Earth's biosphere. Additionally, through comparative studies of planetary atmospheres, astronomers can model and measure the impact of greenhouse gases and their consequences for climate and climate change on planets.

The IAU applauds and acknowledges the steps its members are already taking to help protect our climate — from individual organizations that publish their own carbon budgets, to organisations like Astronomers for Planet Earth. The IAU, through its four Offices (OAD, OAO, OYA, OAE), strongly encourages and supports teaching and communicating about the Earth's climate and the consequences of human activity, and we urge our national and individual members to address climate change in connection with their scientific, educational, outreach, and other societal activities.

As one step towards addressing this global problem, the IAU will issue a special call for the first Kavli–IAU interdisciplinary symposium, dedicated to Climate and Climate Change on Planets, to take place in late 2022 or early 2023. The symposium will draw from members of the IAU as well as other relevant unions (such as GeoUnions). One goal of the symposium will be to produce an IAU Springboard for Climate Action, directed to the astronomy community, that will recommend mitigating actions that can be undertaken at the individual, institutional, and IAU level.

(This article was first published as an IAU Press Release on 24 June 2021)

Figure 1. *The IAU calls on our community to develop, promote and implement specific actions to help achieve the aims of the 2016 Paris Agreement on climate change. Credit: Aneta Margraf-Druc/IAU*

Notes

[1] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. Note that the Sixth Assessment Report will be released in 2022.

What to do in Extreme Times? An Analysis of the Astronomy Communication Actions in Brazil During the COVID-19 Pandemic

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astronomy communication, pandemic, virtual activities

In early 2020, the world was taken aback with the spread of the Covid-19 disease by an unknown coronavirus. Months later, the *World Health Organization* characterised this outbreak as a pandemic, urging decision makers to take actions to slow down the infection rate. Science communicators had to adapt their activities in support of recommendations for social distancing. In this article, we describe the mobilisation of astronomy communicators in Brazil, one of the most affected countries, as a consequence of social inequality, cuts in science funding and science denialism by the government. Practitioners filled out a survey, and the results showed that the amount and diversity of online activities increased considerably. Initiatives such as virtual exhibitions, transmission of sky observations and collective planetary sessions engaged thousands of people. Discussions about the pandemic and how science works were also present in several activities. The pandemic forced the community of astronomy communicators in Brazil to adapt to the situation, and motivated many of them to offer online activities. The diversity of those who communicate astronomy is extensive and appears to be increasing.

Introduction

Brazil is one of the most populated countries in the world, with an estimated population of over 213 millions inhabitants according to the Brazilian Institute of Geography and Statistics[1] and also one of the most affected countries by the Covid-19 outbreak in the world. By September 2021, when these lines were being written, over 590,000 Brazilians had lost their lives, and more than 21.3 million cases have been officially reported since the beginning of the pandemic[2]. The number of daily deaths and contamination keep increasing, although at a slower rate since the mass vaccination started. Nevertheless, caution is still a necessity, as the process of vaccination evolves slowly and Delta variant is spreading quickly over the country. Financial assistance for the population is still important, but has been far from what is actually needed since the beginning of the pandemic, and there are signs that human rights have been violated in Brazil during the pandemic *(Conectas Direitos Humanos, 2020)*.

This situation is worsened by a strong anti-science feeling among some groups of the society *(Teixeira & Santos, 2020)* and even stimulated by the Federal Government, which persistently spreads fake news, ignores the seriousness of the situation, and forces legally the use of unproven medical treatments against Covid-19, that may also be dangerous to the health of those who receive such treatments *(Taylor, 2021)*. Moreover, the Federal Government has undertaken substantial cuts in science and education, making the development of these essential areas for the crisis unfeasible in the present and future. Furthermore, the world has bewilderedly watched the fast dismantling of environmental policies during the pandemic followed by intense destruction of the national natural environments, especially in the Amazon and Pantanal ecosystems, which might trigger future pandemics *(Vale et al. 2021)*.

In the face of all these difficulties, the scientific community has strengthened efforts to stand up and to bring scientific information to the population. Public health communication has received lots of attention for obvious and necessary reasons, but communicators from other science fields, such as astronomy, have also mobilised and offered a variety of activities to the public during this period.

For instance, the Brazilian Association of Planetaria organised a collaborative virtual session in which professionals from various centres took part. It was broadcasted live on Youtube in September 2020, and as of September 19th, the video had 259,939 views[3]. Another example was the conjunction of Saturn and Juptier in December 2020, which was also broadcasted live by the National Observatory. The initiative was promoted with the help of amateur astronomers across the country and was followed by nearly 260,000 people[4]. Such examples show an unprecedented public attendance, and high interest for ephemeris.

Another moving activity was a virtual exhibition promoted by the Museum of Astronomy and Related Sciences, which received 142 drawings of children who expressed their feelings about a "pandemic sky". A similar project led by the same institution was dedicated only to indigenous children[5].

Considering the potential that lies within virtual activities, and the current health, socioeconomic and political crises in Brazil that are worsened by the pandemic, we ask ourselves: has the astronomy community been involved and/or motivated with/by this context? How have astronomy communicators reacted to the new way of promoting activities due to social distancing? How have the activities been promoted? Which topics have they addressed? Has the audience of the activities increased?

With that in mind, we designed a study to try to answer these questions, through the perceptions of the astronomy communication community. In this paper, we present a picture of astronomy communication in the country and how the communicators mobilised to offer activities during this pandemic period within the national context raised above.

Figure 1. *"Dissemination and popularization activities for astronomy in times of pandemic" Art advertising the questionnaire on social media, indicating the period the questionnaire was receiving answers and its link. Credit: Freepik, edited by Felipe Carrelli*

Querying the Astronomy Communication Community

For the research presented in this paper, the authors prepared and publicly released a questionnaire to be filled in by any individual who might have performed some teaching or communication activity related to astronomy during the first year of the pandemic.

In order to reach as many people as possible, it was publicised on different channels, such as the official communication bulletin of the Brazilian Astronomical Society; mailing lists for planetaria, science centres and museums; and direct email to astronomy amateur clubs and teachers responsible for the Brazilian Olympiad of Astronomy and Astronautics in their schools. The questionnaire was also posted on the IAU National Outreach Coordinator Brazil[6] social media accounts, such as Facebook[7] and Instagram[8], as well as on several Facebook and WhatsApp groups related to astronomy, always accompanied by a dedicated art for further dissemination (Figure 1).

The questionnaire was presented only in Portuguese, and consisted of 22 closed and open-ended questions and had three main sections. The first two aimed to characterise the demographic profile of the respondents and the activities they performed from March 2020 to April 2021. The third and last section aimed to comprehend the motivations of the communicators and their perceptions about these activities. To that end, we decided to measure the dimensions of "adaptation to social distancing", "engagement" and "motivation" by measuring the participants' level of agreement with sets of three or four statements with Likert-type scale questions. The questionnaire can be found in its entirety in the IAU National Outreach Coordinator Brazil website[9] , both in its Portuguese and English versions, and the data can be obtained on request.

We accepted replies for two weeks in April 2021. Only answers from respondents who confirmed that they had promoted astronomy-related activities during the period of the pandemic were considered valid. Some other answers were also discarded from the final sample either because they were incomplete or because they presented some contradictions in the questionnaire. We received 204 valid responses out of a total of 247.

Who Is Communicating Astronomy During the Pandemic?

When asked how the communicators identified themselves when promoting

Category	Frequency
STEM undergraduates/graduates	72
Amateur astronomers	72
Science communicator in social media	65
School teacher	61
Professional scientists and/or university professors	41
Informal educators, explainers, facilitators of museums, science centres, planetaria or observatories	28
Undergraduate or graduate students of areas other than STEM	18
Project coordinator in scientific association	15
Project coordinator in non-governmental organizations	11
Postdoc	7
Journalist	4
Other	8

Table 1. *How communicators identify themselves when promoting activities for the public, and the frequency each category was chosen.*

astronomy activities for the wider public, respondents were allowed to select multiple options. Table 1 shows the frequency each option was chosen.

47% of respondents chose only one option, while 28% chose two options, 13% chose three options, 7% chose four options, and less than 1% chose five or more options. Among the 72 people who chose the category of STEM undergraduates or graduates, 27 also chose science communicator in social media. However, the number of amateur astronomers who also chose the category of communicator in social media was 38, the highest level of overlap in this category. By communicators in social media, we refer to those who post or replicate posts related to astronomy in their personal social media, which is different from online courses and talks, for instance, or online planetarium sessions. Live talks and podcasts are also considered different from communication on social media as these activities requires a higher level of compromise and time spent in the preparation of the activity, while posts on social media not necessarily.

We also asked for affiliations of the respondents, again allowing them to choose multiple options. "Higher education level institutes" was the most frequently chosen (78 times), followed by "schools" (67) and then by "amateur clubs"(43). Informal education institutions such as "science museums, planetaria and public observatories" were selected 50 times (combined results). Finally, 87.3% of our respondents are frequent communicators, meaning that they were performing astronomy activities before the pandemic.

The results indicate a strong and vigorous community of astronomy practitioners in Brazil, consisting of students, amateurs, professionals, science communicators, and informal educators. Most of the professionals and students are affiliated with universities and science research centres, mainly in the public sector.

As a matter of comparison, the Brazilian Astronomical Society is the body that congregates the professional community, by September 2021 counting roughly 580 active affiliations[10]. The community of amateurs is also quite extensive. According to a census from 2018[11], there were about 780 active astronomical institutions in Brazil at that time, many of them amateur clubs and public and private observatories, but also universities, planetaria, museums, and school groups.

Demographic Profile of the Astronomy Communicators

The demographic profile of the respondents was assessed through several questions that mapped the gender, age, ethnicity, geographic region of acting and educational level.

When asked about their gender, 53.4% of the respondents declared themselves as male and 45.1% as female. People who identified as non-binary and those who preferred not to identify their gender accounted for less than 1.5%.

With respect to ethnicity, as categorised by the Brazilian Institute of Geography and Statistics (IBGE-EDUCA) (2019), 62.7% of the respondents declared themselves as white (here translated from brancos), 30.9% declared themselves as brown or black (here translated from pardos or pretos), 2% as yellow (here translated from amarelos) and 4.4% preferred not to state their ethnical origins. There was also an option in our questionnaire for those who self-identified as indigenous (here translated from indígenas). The results reveal a strong discrepancy with the national census by IBGE-EDUCA, in which people of colour identifying as brown (referring to someone who is of mix of black or indigenous origin with any other colour or race) or black represent more than 56% of Brazilians.

Regarding age, there was a prevalence of respondents who were middle-aged or younger: those within the 35-49 years-old range represented 35.3% of the valid sample; those 25-34 represented 25% and those up to 24 years old corresponded to 19.6%. Those 50-64 also accounted for 19.6% and senior respondents, aged 65 or older, represented less than one percent. As a matter of context, the life expectancy in Brazil was 76.6 years in 2019[12], 73.1 year for men, and 80.1 years for women, while the median age is 33.2 years in total[13]. Due to the severe effects of the pandemic in Brazil, however, life expectancy at birth is estimated to have a reduction of 1.3 years in 2020, and 1.8 years in the first months of 2021 *(Castro, 2021)*.

Figure 2. *Geopolitical division of Brazil in macro-regions. Credit: Felipe Carrelli.*

Activities were concentrated in the South-eastern region of Brazil, which is as expected since the majority of astronomers and astronomy-related institutions are concentrated here. Respondents from this region accounted for 53.4% of the sample. Respondents from the North-east accounted for 20.1% and from the South for 16.2%. Respondents from the Central-west part of Brazil were 5.9% and from the North 4.4%. The shift from southern Brazil to the North-east comes as a surprise, since the second largest hub of astronomers in Brazil is based in the South.

Regarding the educational level of the participants, the majority (22.1%) of the respondents held a PhD. Other respondents held other kinds of graduate diplomas like a master's degree or a lato-sensu specialisation degree (usually shorter than a master course, aims to offer professional and academic training to those already working in some field of knowledge). Those categories accounted for 19.1% and 17.6% of the respondents, respectively. Undergraduate students and respondents holding a bachelor's degree together accounted for 33.8% of the sample. People with high-school level education accounted for 7.4% of the respondents. Worth noticing are the cases of two respondents who are still enrolled in basic school, one of them being a 9-year-old girl managing her own astronomy amateur club on Instagram.

Characteristics of the Activities

As expected in times of social distancing, most of the respondents, 85.8%, declared to have promoted virtual activities exclusively, while the remaining 14.2% developed both face-to-face and virtual actions. None of the respondents performed only face-to-face activities. With respect to the target audience, 40.1% of astronomy communicators aimed at the public, 34.2% to school students and 16.3% to teachers. Interestingly, 8.3% aimed the activities to astronomy experts which, in principle, are not science communication initiatives, but rather as dissemination to peers. Slightly more than one percent targeted other non-specified audiences.

Regarding the types of activities, participants could mark as many options as they wanted. The different categories were marked 1547 times by participants, being the most frequent the "actions undertaken in social networks", closely followed by "lives/talks". The activities promoted during the pandemic and the corresponding frequency are summarised in Table 2.

Activities	Frequency
Actions taken in social networks	297
Lives/talks	255
Informal chats	181
Creation of content for podcasts or videos	175
Writing to press, blogs or magazines	165
Live sessions of night-sky or Sun observations	125
Video exhibitions	113
Virtual planetarium sessions	72
Virtual exhibitions	64
Distance learning teacher courses	59
Science contests/tournaments	41
Other	94
Total	1641

Table 2. *Activities promoted virtually by astronomy communicators in Brazil from March 2020 to April 2021.*

Topics covered during the activities	Frequency
Classical Astronomy and Astrophysics	181
Astronomy in everyday life	118
Ephemeris	114
Topics on Astronomy communication and education	111
History of Astronomy	109
Astronomy research practised in Brazil	67
Pseudoscience and scientific negationism	62
How scientific method works and how research advances	50
How to become a professional astronomer	49
COVID-19 outbreak	48
Gender and ethnic issues in Astronomy	36
Everyday life of a professional astronomer	34
The participation of Brazil in international astronomical consortia	33
How astronomy is financed	28
Availability of Astronomy university courses in the country	25
Other	14
Total	1079

Table 3. *Topics covered during the activities promoted virtually by astronomy communicators in Brazil from March 2020 to April 2021.*

We also asked about the topics covered during the activities, again allowing respondents to select multiple options. In total, the suggested topics have been selected 1065 times, while "Other" were selected 14 times. Results show that themes related to "classical Astronomy and Astrophysics" such as stars, planets, galaxies, cosmology, were the most addressed by respondents. Other highly addressed topics were "Astronomy in everyday life", "ephemeris", "topics on Astronomy communication and education" and "history of Astronomy". The topics and frequency by which they were chosen is summarised in Table 3.

Although the most frequent topics are those directly related to astronomy, other topics were also addressed, such as "History of Astronomy" and "How scientific method works and how research advances". Interestingly, the topics range even further, such as "Pseudoscience and scientific negationism", ranking closely to "Astronomy research practised in Brazil", and even higher than "How to become a professional astronomer".

Contemporary discussions, such as "Gender and ethnic issues in Astronomy" and practicalities, such as "How astronomy is financed" were also present. Not surprisingly, the "COVID-19 outbreak" was another topic addressed by the participants, which, together with "Pseudoscience and scientific negationism", shows that the public is interested in understanding what is science, how it works, and how it may help to mitigate the effects of the COVID-19 pandemic.

Respondents were also queried about the use of accessibility tools during their activities. Most of the answers (67.6%) said they "haven't used any tool for improving the accessibility of people with disabilities" in their activities. Among those, 26.1% mentioned they "will not make use of any accessibility tools in future due to financial and infrastructure issues" while 22% declared they "will use some tools in future endeavours", and 19.5% said they "had never thought about accessibility issues". This brings us to the 32.3% which "did use some accessibility tool" as follows: 19.5% used "subtitles", 6.6% included "Brazilian Sign Language (Libra) interpreter", and 6.2% made use of "audio description".

Communicators' Responses to the Pandemic

As in many other places of the world, the pandemic in Brazil brought changes, challenges and even suffering. In order to understand how astronomy communicators reacted to the new way of promoting activities due to social distancing, which in the specific case of Brazil was unenforced due to the degradation of science by the government, we built three sets of statements aimed to measure the dimensions of "adaptation", "engagement" and "motivation".

To do so, the items of each set were built according to the Likert psychometric response scale, in which responders could endorse their level of agreement to statements, ranging from "totally disagree", "disagree", "don't know", "agree" and "totally agree". Therefore, each set of items consisted of a complete Likert-type scale, whose sum over the statements indicate the measurement of the dimension as based on the perceptions of the respondents.

The dimension of "adaptation" was scaled using four statements. We asked the respondents "regarding the resources

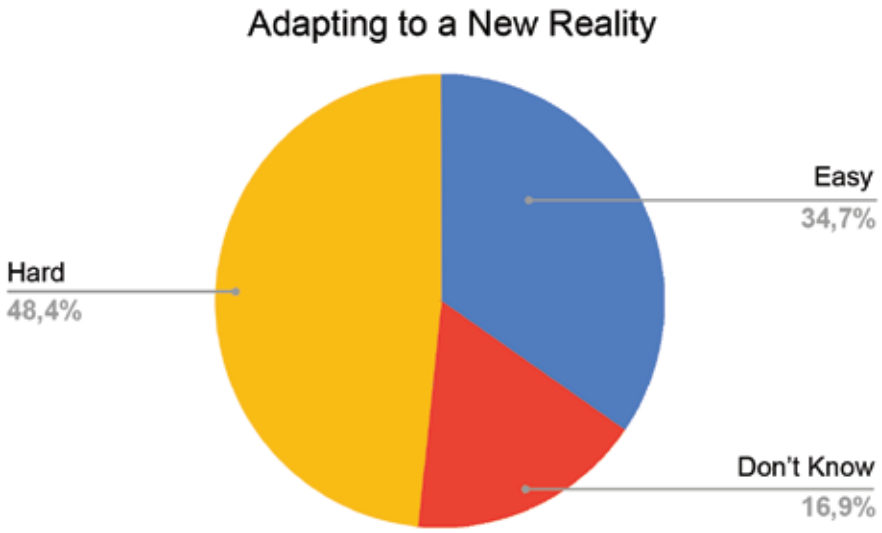

Figure 3. *Level of difficulty to adapt to the new reality created by the pandemic. Credit: authors.*

(financial, technical, human, etc.) necessary to carry out activities during the pandemic period..." and provided the following statements to be endorsed: (1) "my work institution provided me with the support"; (2) "it was necessary to use my own resources", and (3) "I had to adapt abruptly to digital resources" and (4) "The resources available for the activities were adequate for the amount of activities offered so far".

Each respondent was requested to indicate the level of agreement within these four sentences with the following options: totally disagree, disagree, don't know, agree, totally agree. Disagreement with sentences (1) and (4) indicate hardness of adaptation, while agreement indicates easiness. For the sentences (2) and (3) this is the opposite: disagreement indicates easiness, while agreement indicates hardness.

To draw our conclusions, we then decided to join the answers "strongly agree" with "agree" and "strongly disagree" with "disagree". Summing over the selected options of each level of agreement, the cumulative scale indicates easiness-to-hardness in adaptation, yielding in the following frequencies: 276 (easy), 134 (don't know), 385 (hard).

As a result, 48.4% of responses indicated difficulties in the adaptation, whereas those who considered it easier to adapt were 34.7%. Those who didn't know correspond to 16.9% (Figure 3).

For the dimension of "engagement", we opted to split the items into two subcategories: "self-engagement" and "public-engagement". The term "self-engagement", refers to the level of engagement of communicators in offering activities during the pandemic, while "public-engagement" refers to the level of public engagement in the activities as seen by the communicators. Only respondents who were promoting science communication activities before the pandemic were asked to answer this set of questions.

For the first subcategory, by indicating their level of agreement, the respondents were invited to "think if…": (1) "your time devoted to developing the activity increased"; (2) "the number of activities offered during the pandemic increased" and (3) "even after the pandemic is over, you intend to keep offering on-line activities".

Here, disagreement to all three sentences indicates the respondents were less self-engaged with the activities, while agreement indicates they were more self-engaged. Similarly as described above, respondents were asked to indicate whether they strongly disagree, disagree, agree or strongly agree with these sentences, or even if they don't know what to answer. Each respondent indicates their level of agreement with each one of these sentences, and answers are counted. The cumulative scale of answers for each sentence indicates if the respondents were less or more engaged with the promotion of activities during the social distancing period. The sum over the levels of agreement yielded in the following frequencies: 26 (strongly disagree), 76 (disagree), 122 (don't know), 176 (agree), 198 (strongly agree).

Comparing the totality of frequencies of those who think they were more self-engaged than before (374) with the totality of those who think they were less self-engaged (102), it is clear that Astronomy communicators believe they have self-engaged with the activities more during this period. As shown in Figure 4, the sum of frequencies that support this result accounted for almost 63% of all responses, whereas those who considered less engaged were 17%. The remaining 20% did not know.

Similarly, two statements helped us understand the perceptions of the communicators within the subcategory "public-engagement".

By indicating their level of agreement, the respondents were invited to "think if…": (1) "the public taking part in the activities has increased" and (2) "the public diversity has increased (age, gender, geographic location, and others)". The method of analysis is the same as described above: disagreement indicates that the respondents believe their public were less engaged, while agreement reflects the more engagement of the public as seen by the respondents. The cumulative scale indicates whether the respondents think that their public was less or more engaged with the promotion of activities during the first year of the pandemic. The sum of the levels of agreement yielded in the following frequencies: 11 (strongly disagree), 54 (disagree), 104 (don't know), 113 (agree) and 118 (strongly agree).

Comparing the totality of frequencies of those who thought their public was more engaged than before (231) with the totality of those who thought their public was less engaged (65), the results indicate that astronomy communicators believe that the

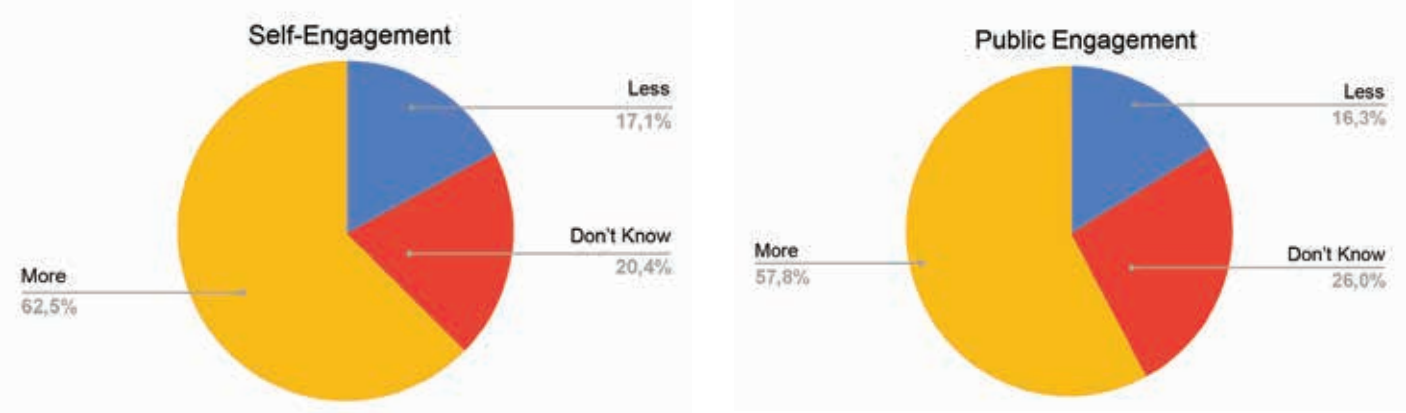

Figure 4. a) b) *Level of self- and public-engagement within the activities according to astronomy communicators. Credit: The authors*

public has engaged more with the activities during the pandemic than they did before, as the number and diversity of the public has increased. As shown in Figure 4, the sum of frequencies that showed agreement with the statements accounted for 58% of all responses, whereas those who considered the public less engaged were 16%. The remaining 26% did not know.

The "motivations" driving the communicators' interest in promoting astronomy-related activities can be of different nature in their origin. In order to explore this dimension, the questions and the cumulative scale indicated if the motivations were of intrinsic and extrinsic nature, i.e. whether the motivation has a stronger personal component, or is due to some external cause.

The respondents were asked "according to your practice as a science communicators in Astronomy" and provided with the following statements to be endorsed: (1) "[you] consider communicating science as a moment of pleasure"; (2) "intend to make profit from the activities in the future" and (3) "[you] intend to obtain professional recognition with the activities".

The statement (1) indicates whether astronomy is a topic of personal interest to the respondent, and not necessarily something related to their professional life or other component. Therefore, when the respondents agree with this sentence, they are indicating that they offer astronomy related activities following a genuine taste for this science, so they have a very personal reason to do so, characterizing intrinsic motivation. On the other hand, when the respondents disagree, they are indicating that the reasons why they are offering activities should be something not related to personal reasons, therefore due to extrinsic reasons. This is indicated by two other statements, which carry a more professional reason behind the intention of the respondents in offering activities.

The levels of agreement indicated a range from extrinsic-to-intrinsic motivation. The cumulative scale yielded the following frequencies: 101 (strongly disagree), 111 (disagree), 97 (don't know), 112 (agree), 181 (strongly agree). When adding the two levels of extrinsic (212) and intrinsic (293) motivations, our results show a slight tendency of communicators being driven by intrinsic purposes.

This result can be seen in Figure 5, which shows that 48.7% of respondents indicated intrinsic reasons driving them to communicate astronomy, while extrinsic reasons correspond to 35.2%. The remaining 16.1% said they don't know the reason.

Finally, we also wanted to know whether the COVID 19 pandemic has played a role in communicators' motivations. This was also possible by asking "according to your practice as a science communicator in Astronomy" and then offering a set of three statements which, again, the respondents could indicate their level of agreement. These items were: (1) "[you] consider important to explain how results in astronomy and science in general are obtained"; (2) "[you] seek to mitigate anti-

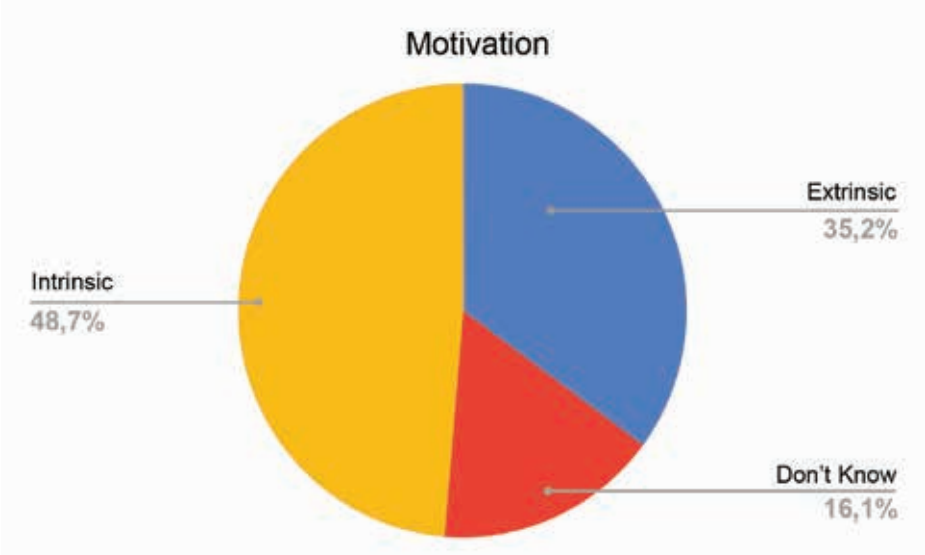

Figure 5. *Nature of motivation driving the communicators' interest in promoting astronomy-related activities. Credit: The authors*

science thoughts and attitudes" and (3) "[you] felt it was necessary to engage with science communication as a result of the ongoing health, political and economic crisis". The cumulative scale yielded in the following frequencies: 29, 46, 56, 198, 280, ranging from less to more motivated by the current context provoked by the pandemic. When adding the levels of more motivated (478) and less (75) motivated, the responses indicate that the pandemic, indeed, played an important role as a motivation for promoting the activities.

This is shown in Figure 6, as 78.5% of respondents are more motivated now than before, 12.3% of respondents are less motivated, and the other 9.2% don't know.

Discussion

Within the present work, we intended to draw a picture of how astronomy-related activities for the wider public are currently being carried out by science communicators in Brazil, one of the countries most affected by the pandemic and one of the worst with regards to mitigation efforts. Even during this period of pandemic, science has been severely attacked even by the President himself, who since the beginning tried to deny the severity of the pandemic, and did not make any effective effort to mitigate it *(Hallal 2021)*.

We were also motivated to understand if the practitioners were motivated by the current context. As such, data were acquired from a questionnaire that was made public to the community of astronomy communicators.

We want to stress that the results presented here cannot be characterised universally. Therefore our conclusions are based solely on the answers received which may not represent the population of astronomy communicators in Brazil, and a direct comparison to the official demographic census is not straightforward.

Astronomy in Brazil, as an academic field, is mostly developed in the South-eastern and Southern regions of the country, where the majority of universities and research centres are concentrated. The two biggest cities in the country, São Paulo and Rio de Janeiro, are located in the South-eatern region, while many other important economic centres are located in the above-mentioned two regions, concentrating most of the cultural and educational institutions in the country.

In the year of 2019, the Southeast region accounted for 30 Physics and Astronomy graduate programs, while 13 and 12 programs were based in the Northeast and South regions, respectively, followed by 3 programs in the Central west region, while the North region accounted with only 1 graduate program in Physics and Astronomy *(Ministério da Educação, 2019)*. Another study of 2015 shows that the distribution of institutions of non-formal education and popularization of astronomy, such as observatories, planetariums, museums, are not well distributed in the national territory, as the regions of Southeast and Southern accounts for slightly over than three institutions per million of inhabitants, while the Northeast and Central-west regions account for a number between one and two, and the Northern region accounts for less than one institution per million of inhabitants *(Marques & de Freitas, 2015)*. This trend doesn't seem to have changed much during the last few years.

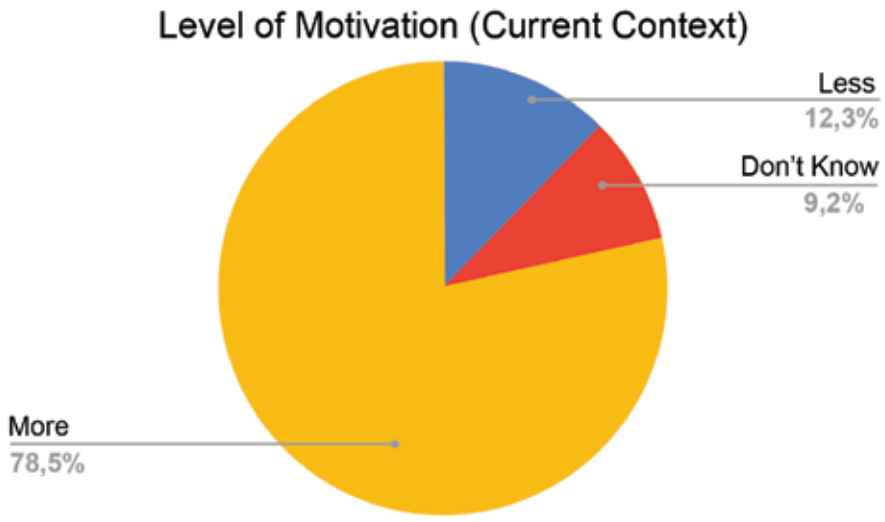

Figure 6. *Level of motivation due to the pandemic. Credit: The authors*

This asymmetric geographic distribution, in a country of continental size, is related not only to the higher population density in those areas, but also the historically higher standards of living. The overall better social-economical indicators in comparison to other parts of Brazil favour the implementation of scientific, educational and cultural resources in those regions.

Our results confirm that the South-east region, which concentrates the most wealth in Brazil, also concentrates the majority of efforts towards astronomy communication. However, this association stops there, as the North-east seems to be the second busiest region regarding astronomy communication, instead of the South, which is the second biggest community of professional astronomers and presents overall better socioeconomic indexes. This could be due to either a higher adherence to the questionnaire or a real higher adherence to the promotion of activities mainly by amateur astronomers, teachers, science communicators in social media and graduate students, as discussed in the section *Demographic Profile of the Astronomy Communicators*.

It is also important to emphasise that Brazilian inequalities in science are not only geographically situated. There is a large underrepresentation of women and minorities in all science and technology careers *(Oliveria et al. 2021)*. As a legacy of its colonial past and the late abolition of the enslaved Africans and their descendants, socio-economic vulnerability in Brazilian society is strongly correlated with ethnic origins and especially with skin colour. Afro-brazilians are therefore the most socially vulnerable group and those

with least educational opportunities and barriers to access cultural activities *(Alves-Brito, 2020)*, having also suffered the most from the impacts of the pandemic *(Polidoro et Al. 2021)*.

The research field in physics, astronomy and all subareas have been predominantly dominated by white, heterosexual and well-off men, that is, white men from privileged social classes *(Alves-Brito, 2020)*. Responding to ethnic-racial, gender issues, and their intersections in astronomy communication shows a democratic commitment to humanity in this century, and is important to include if we seek to improve society.

The participation of women is surprisingly high when compared to the gender statistics in the latest census[10] of Brazilian Astronomical Society, where roughly 30% of active affiliates identified as female.

Respondents to our survey were able to indicate when they identify themselves as indigenous, but unfortunately no respondent selected this option.

Despite all this, our results indicate a non-negligible amount of astronomy communicators from underrepresented groups taking the lead in the promotion of activities. Although white men are the majority, the percentage of women and black people accounted for 45.1% and 30.9% of respondents, respectively. Even if this might be considered as a positive sign, the path towards a fairer society is still long, so that we can overcome the symbolic dimension of male domination *(Bourdieu, 2002)* still strong in Brazil, also in the astronomy communicators community. Results indicate that both female and male communicators felt similar levels of difficulties with adaptation. With reference to the ages of communicators, youngsters up to-24 years old seem to have felt mostly difficulties with adaptation, while all other ages also felt difficulties but at a lower level, although increasing with age.

Further regarding inequalities in science, it is evident that most astronomy communicators do not have proper conditions to offer activities specially created or at least properly adapted to those with an impairment. This is especially worrying if we consider that a significant percentage of those activities have been designed for the academic community. According to a recent census about basic education in Brazil *(Brasil, 2020)*, the percentage of students with disabilities, global developmental disorders, or high achieving enrolled in mainstream non-specialised schools has gradually increased over the years in all teaching levels, reaching 92.8% in 2019. It is therefore time to tackle accessibility in astronomy communication activities in a more effective manner.

Our results also indicate that communication of astronomy during the pandemic in Brazil is mostly being carried out by scientists still in school and by amateur astronomers. However, we have to be careful when extrapolating these results since our study cannot be characterised as universal or comprehensive, as mentioned above. Thus, it is also possible that scientists, university professors, and other high-level professionals have simply not joined our study. In fact, the number of respondents within this group, 41, is considerably lower than the number of effective associates of the Brazilian Astronomical Society, which is nearly 580 professionals. Nevertheless, the responses to our survey indicates that, overall, this category felt difficulties to adapt to the new reality, and most participants declared it was necessary to make use of their own resources to offer activities, although responses also indicate that the institutions where they work made some efforts to offer support. Therefore, even though this category had some support from their institutions, this should be not enough to handle all the demand for online work that has arisen due to the pandemic, probably decreasing the time available for this category to promote extra online activities at the same time the need for using one's own resources increase. On the other hand, *Massarani & Peters (2016)* have found that only 30% of top-career scientists in Brazil who took part in their study had a website with information related to their research and 63% of those in this group had not updated the content in the 12 months that preceded that study. The authors have also found that 80% of the responding scientists mostly used their social network to contact family and friends and learn about the latest political and cultural matters. Of course, since 2016, things might have changed.

In our survey, we found that topics mostly addressed were those related to basic concepts in astronomy and astrophysics, but social aspects of science have also been a matter of discussions. For instance, gender and ethnic issues in astronomy and the financing of science are among those topics. Topics mentioned which might be related to the current context were: pseudoscience and scientific denialism, how scientific method works and how research advances, and the Covid-19 outbreak itself.

Regarding the communicators' response towards the pandemic, we noticed that adaptation has been a hard process for the majority of them, as many had to adapt abruptly to unfamiliar online tools. They tend to agree that it was necessary to make use of their own resources, and the institutions where they work could not afford sufficient support. Therefore, the available resources to promote totally adequate activities were not enough to respond to the amount of offered activities. This might reflect on the fact that just a few activities accounted for accessible tools, which is usually costly to be implemented, except for subtitles.

Among all categories of communicators, only postdoctoral researchers haven't declared much difficulties to adapt to the new reality, they are probably used to employing digital tools to promote virtual meetings, while school teachers were the ones that mostly experienced difficulties, probably following lack customary lack of investments, and increase of demanding work, as classes switch completely to remote mode.

According to the responses we received, the motivation driving the communicators to offer astronomy-related activities is mostly of an intrinsic nature for all categories of communicators, although extrinsic reasons are not negligible. This intrinsic motivation is led by a genuine feeling of pleasure when promoting astronomy-related activities. All ethinic groups declared mostly intrinsic factors that drove their motivation, feeling strong in the groups of yellow, balck and white. Similar results were found when considering gender, as both male and female declared intrinsic reasons behind their motivation to promote activities.

Even though the pandemic has imposed several difficulties in everybody's daily

lives, this is still a reason for the motivation for communicators to offer activities, as declared by the overwhelming majority of respondents. Our study indicates that respondents tend to agree that "it was necessary to engage with science communication as a result of the ongoing crisis", promoting activities that "explains how results in science are obtained" and trying when possible to "mitigate fake news." As paradoxical as it may sound, the discourses of science denialism employed by the government triggered the astronomy communication community to promote virtual activities, who even spoke on subjects like the Covid-19 to engage their audiences.

Brazilian astronomy communicators also felt that they have been more engaged with their activities than before the pandemic, agreeing that they spend more time on outreach now. It is tempting to speculate that there is a connection between other tasks being put on hold during the pandemic and extra time now available for astronomy communication, but the questionnaire was not directed toward this specific subject.They also felt that their audiences are responding more, and becoming more diverse.

Despite all the difficulties, we see that the astronomy communication in Brazil is robust, being carried out by a variety of people across the country, from different segments of the society, ages, gender and ethnicity. There is still a long way to go before these activities can be offered in plenitude, but the efforts carried out until this moment are marvellous, reinforcing the capacity and commitment of astronomy communicators in Brazil, a breath of hope and potential for a country that has so suffered.

Conclusions

We conclude that the astronomy community dedicated to science communication in Brazil has been intensively involved in on-line activities during the COVID 19 pandemic. At this point, the authors wish to stress that the situation in Brazil is deeply aggravated by the local social and political context, as reported in several works *(Barberia & Gómez 2020, Lotta et al. 2020, Polidoro 2021, Hallal 2021)*, even if not specifically tackled in this survey. Yet, this reality can be perceived in some answers to the questionnaire as when 26.1% mentioned they "will not make use of any accessibility tools in future due to financial and infrastructure issues".

Also, the fact that most of the respondents declared intrinsic reasons for offering astronomy-related activities might reflect not only the fact that the respondents have a taste for astronomy, but also because they cannot rely on work opportunities to do so, as there is scarce investment of resources in outreach.

Moreover, from the emergencies initially pointed out in this research, namely, the pandemic context together with the widespread of fake news and anti-science behavior including the Brazilian authorities, it is clear that part of the astronomical community is dedicated to the communication of astronomy as well as of contemporary issues related to it, such as gender and ethinical diversity in science.

Finally, this research showed that the pandemic has been a source of motivation for science outreach practitioners to discuss not only astronomy, but also to address contemporary issues, and to spend longer on the preparation of virtual activities despite all difficulties.

Notes

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[2] Johns Hopkins University and Medicine, Coronavirus Resource Center: https://coronavirus.jhu.edu/map.html (access in September 19th)

[3] Collaborative Planetaria Session from the Brazilian Association of Planetaria: https://www.youtube.com/watch?v=qJA-WKN4Q-w (access in September 19th)

[4] Saturn and Juptier conjunction by the National Observatory: https://www.youtube.com/watch?v=4IrSJH1aDH4 (access in September 19th)

[5] The Sky that Connects Us" (O céu que nos conecta) exhibition: http://mast.br/ceuconecta/ and "The Sky of First Nations" (O céu dos povos originários) exhibition: http://mast.br/ceus-originarios/ (access in September 19th)

[6] National Outreach Coordinators national pages: https://sites.google.com/oao.iau.org/iauoaonews/national-pages (Access in September 2021)

[7] Facebook page of the IAU National Outreach Coordinator Brazil Facebook: https://www.facebook.com/nocbrasil (access in September 2021)

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Under One Sky

Call for Proposals

The IAU Office for Astronomy Outreach invites proposals of projects relating to the United Nations International Day of the World's Indigenous Peoples, which will be celebrated on 9 August 2022.

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Virtual ALMA Tour in VRChat: A Whole New Experience

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Keywords
virtual reality, immersive visualisation, science communication

Many forefront observatories are located in remote areas and are difficult to visit, and the global pandemic made visits even harder. Several virtual tours have been executed on YouTube or Facebook Live, however, it is difficult to feel a sense of immersion and these are far from the actual experience of visiting a site. To solve this problem, we pursued an astronomy outreach event on the virtual reality social platform VRChat. To provide an experience similar to visiting the site, we performed a virtual tour of the ALMA Observatory in VRChat guided by an ALMA staff member. 47 guests participated in the tour. The post-event survey showed that the overall lecture and guided tour were very positively accepted by the participants. Respondents answered that the communication in the VRChat was more intensive than in other online outreach events or on-site public talks. The ratio of respondents who answered that they were able to communicate well with the guide was higher for those who used head mounted displays than for those who participated in other ways. 40 answered that the tour increased their interest in astronomy, and this did not show a clear difference depending on how they participated. In the free descriptions in the responses, there were noticeable mentions of the physical sensations received from the realistic 3D space, which left a positive and strong impression on the participants. The responses show that VRChat has the potential to be a strong tool for astronomy communication in the pandemic and post-pandemic eras.

Introduction

Astronomy observatories in various locations of the world and in orbit are producing a number of amazing pictures of the universe and unravelling a variety of cosmic mysteries. The results are disseminated daily through websites, press releases, and social media. People can access the latest results through these media, however, they face difficulties learning about the research process.

Visiting the observatories and getting explanations from the researchers and engineers actually working there is one important way to understand how astronomy research is carried out. As such, many observatories accept public visits[1]. In Chile, there are numerous large-scale astronomical observatories, and visits to astronomical facilities and other Astro-tourism projects are highlighted by the national government[2]. Other locations such as Hawaii, the Canary Islands, and China are also active in Astro-tourism with astronomical observation facilities at the core.

One drawback of visiting astronomical observatories is that most of the cutting-edge facilities are in remote areas to avoid light pollution and radio interference from cities and to seek a clear atmosphere. This makes facility visits time consuming and sometimes require special safety considerations. An extreme example is the summit facility of the *Atacama Large Millimeter/submillimeter Array (ALMA)*[3], which is located at an altitude of 5000 metres, so visits by the general public are restricted to prevent altitude sickness. These and other hurdles make a visit to observatories a very limited experience and inaccessible to many people.

The global pandemic of Covid-19 has raised these hurdles even higher. The pandemic forced heavy restrictions on both international and domestic travel, and many observatories suspended their public visit programmes as a precaution against infection. This resulted in a significant loss of opportunities for the non-specialist public to come into contact with the places where cutting-edge astronomy research is being carried out.

One way to overcome the geographical difficulty is live webcast from observatories. One pioneering example of the virtual observatory tour is “Around the World in 80 Telescopes” held during the International Year of Astronomy 2009 *(Pierce-Price et al., 2009)*. The webcast connected 80 observatories around the world one after another over a 24-hour period to introduce the facilities and astronomical highlights. It gave the public an unprecedented experience to visit such a large number of observatories and to see life at observatories.

In the pandemic era, several observatories have provided online virtual tours. For example, the E*uropean Southern Observatory (ESO)* organised virtual tours to their Paranal and La Silla Observatories[4]. They use omnidirectional images of the observatories as a staff member explains how the observatories look, how telescopes are operated, and how the observatory staff works. The tour is streamed on their Facebook page and YouTube channel. Questions from viewers are submitted via chat and answered by the guide. This form of virtual tour can provide some sense of realism and two-way communication through questions and answers between the viewers and the guide. However, even using omnidirectional photos, it is difficult to feel immersed in the enormity of actual telescopes in a flat video window.

By wearing a head-mounted display (HMD), immersive virtual reality (VR) allows one to enter a world created by three-dimensional (3D) computer graphics (CG). In this report we use the word "immersive" to refer to the feeling of the experiencers as if they were present in the virtual world. There are several examples using VR for astronomy communication. *Arcand et al. (2018)* describes the visualisation of the supernova remnant Cassiopeia A so that people can virtually walk through the object and understand its structure. *Ferrand and Warren (2018)* describes a VR demo in an open house of a research institute. Visitors wore a headset and viewed volume renderings of actual science data of supernovae and supernova remnants while receiving explanations from a researcher acting as a guide. *Kersting et al. (2021)* reported a VR tour featuring gravitational astronomy at a science festival and discussed the effectiveness of the immersive VR environment for engagement in education and public outreach activities.

Hiramatsu, the lead author of this paper, led the initiative by the ALMA Project of the *National Astronomical Observatory of Japan (NAOJ)* to create an immersive virtual reality tour of the ALMA facilities in 2016. The tour is a 4.5-minute omnidirectional compilation of the photos and fulldome videos of the observatory with the recorded voiceover, and viewers can watch the video with a HMD. NAOJ ALMA Project has used this VR content at the NAOJ Open House and the VR video is now available on YouTube[5]. At the Open House, visitors could watch the video through a GearVR headset or a smartphone in an HMD set-up. After they watched the video, they commented that VR video provided a good sense of immersion and most people indicated that they were very satisfied with the realism of the experience. The comments well described one of the profound affordances of VR, the feeling of presence *(Johnson-Glenberg, 2018)*. However, the viewpoint is limited to a fixed location. It is impossible to walk through the video, and there is no live interaction with the researchers during watching the video.

VR is also being used for outreach in fields other than astronomy. *Tibaldi et al. (2020)* reported a VR program featuring the 3D immersive visualisation of volcanic outcrops, which used both for scientific research and public outreach. *Gochman et al. (2019)* developed a VR tool to simulate the sight of tarsiers. They conducted demos in schools and received very positive feedbacks for better understanding of visual optics and evolution. Having VR contents in public events and schools can create real-time communication, unlike a VR experience with a pre-recorded video described earlier. However, in a pandemic, it is difficult for people to come together and share a single device, so this virtual experience would only be safe in certain circumstances.

In this article, we report a guided tour of the virtual ALMA observatory created through the VR social platform VRChat in response to the Covid-19 pandemic and discuss the possibility of breaking through the difficulties such as:

- in visiting remote observatories,
- in having the feeling of presence with the traditional virtual tours using YouTube or facebook live,
- in organising VR tours in an on-site science event in the pandemic era.

Virtual ALMA Observatory Tour

Virtual ALMA Observatory in VRChat

VRChat[6] is a platform where people use avatars to communicate with other users in 3D CG worlds through voice and gestures. In VRChat, any user can virtually construct various "worlds" and other users can visit them. One can join the VRChat worlds either through an HMD connected with a PC or regular flat display using VRChat's Desktop mode. In the Desktop mode, although the sense of immersion and the freedom of gesture are limited, users can still communicate with their voice and move freely around the world as one would with an HMD. One of the features of VRChat is that participants do not need to gather in one place or share a device, as they can connect via the Internet[7] from home or elsewhere. This feature can be an advantage to organising events under the pandemic. A precedent similar to VRChat is Second Life and *Gauthier (2007)* describes an example of astronomy communication on Second Life.

In May 2019, the number of unique users in VRChat was 430,000[8], and the user base showed a large growth during the pandemic[9]. As of May 2019, 75% of users were under 35 years old and 43% of users were under 25 years old, which means that the user base is heavily skewed towards the younger generation. Although gender distribution is highly biased: 81.5% of the users are male it was not addressed in the context of this work.

Two of the authors of this report are members of the Virtual Space Program (VSP)[10], a group of people who are interested in astronomy and space development and are active mainly in VRChat *(RORERU et al., 2020)*. VSP has produced several virtual worlds in VRChat, such as a planetarium, museum of space probes and space telescopes, and a rocket launch pad, and organises virtual tours regularly. VSP made a presentation introducing their activity at the annual meeting of the Japanese Society for Education and Popularization of Astronomy held in August 2020. After this presentation, the other authors of this report contacted with the VSP members to discuss possible future collaboration. In the discussion the authors came up with an idea to build a virtual ALMA world and organise a virtual tour of the world.

After the initial discussion for the collaboration, S_Asagiri of VSP voluntarily made a virtual world of the ALMA Observatory in VRChat (Figure 1). The world consists of 66 realistic antenna models and terrain. The real-scale antenna models were created based on photos of the actual ALMA antennas and partly based on the blueprint of miniature models

Figure 1. *Virtual ALMA Observatory made in VRChat. Credit: VSP*

of the Japanese ALMA antennas made by NAOJ. Four types of the ALMA antenna models were created using Blender, a free and open-source 3D-CG software toolset. The created models were exported to Unity, which is a cross-platform game engine, via fbx format. Unity is the only toolkit to upload 3D models to VRChat. The colors and textures of the antennas were adjusted on Unity. It took about 10-20 hours to model each type of the ALMA antenna, one hour to create the terrain, and a few hours to place each antenna to the actual configuration. The antenna location is based on the actual ALMA antenna configuration in January 2016[11], which was displayed in real-time on the observatory's website at that time. The antenna array was in its compact configuration[12]. In the compact configuration, the antennas are densely packed together, and it is easy to see the whole group of antennas. Hiramatsu, as the East Asian ALMA Education and Public Outreach Officer at NAOJ, offered advice on how to make the world more real, including the colour of the sky and the ground, the terrain, the shape of the antenna pads, and detailed shape of the antennas. Input from a person with in-depth knowledge of the real telescopes and first-hand experience of the site greatly improved the reality of the virtual world.

The visitors to the virtual ALMA Observatory can move freely around the antennas as if they are on the actual site. One feature unique to VRChat that cannot be realised in the real world is that one moves through the air and observe the antenna array from above. In addition, one can move the virtual antennas synchronously by pressing a button in the VR world. These features help participants better understand how the ALMA antennas work as a single telescope. The VR world also has miniature models of the four types of the ALMA antennas and users can pick up the antenna model and take a closer look. These miniature models are helpful to find out differences in the designs of the antennas developed by Japan, US, and Europe.

Prior to the virtual tour, a preview was held with a limited number of people to improve the ALMA world and to plan the tour. This test was held because some of the organisers of the virtual ALMA tour had never experienced the VRChat. The testers were selected from the TENPLA project *(Takanashi & Hiramatsu 2018)*, a group of astronomers and communicators, including the authors of this report. With this test the organisers were able to familiarize themselves with the world of VRChat and also conceptualize and test the content of the virtual tour. In addition, this test was an opportunity to improve the reproducibility of the virtual ALMA world, such as the colour of the sky and terrain, and the position of the Sun and the mountains. After the virtual tour, this ALMA world opened to the public in VRChat and anyone can access it now. There is a simple virtual explanation panel written in Japanese in the ALMA world and visitors can freely walk around the world. The cumulative number of the visitors to the world is 2025 as of September 5, 2021.

Setting the Tour

The virtual tour of the ALMA Observatory in VRChat was held in the evening (18:00-19:00 local time) of Saturday 17 October 2020, free of charge. We selected this timeslot to maximize the number of participants. This event was advertised with VSP's Twitter and Discord, NAOJ ALMA Project's Twitter, and an article on a news website featuring VR. The upper limit of the participant in a VRChat World is set to 80, however, the maximum number of people who can comfortably experience a VRChat world depends on the amount of data in the world and the avatars used by the participants. To avoid the system overload, we had to limit the number of participants. As a result, the actual number of total participants in the VRChat was 47, and one guide. To further reduce the load on the servers, VSP distributed lightweight avatar data and asked the participants to use the avatar. In addition to the tour in VRChat, the tour was streamed on YouTube[13]. One of the tour organisers from VSP held a virtual camera in the VRChat and its output was broadcast to YouTube. Participants via YouTube watched this streaming video, and therefore they could not change the angle of view of the video by themselves and participate in the conversation taking

Action	HMD	Desktop Mode	YouTube
Walk freely	Yes	Yes	No
Voice communication	Yes	Yes	No
Gesticulate, use gestures	Yes (HMD controller tracks body motion)	Yes (use a keyboard to gesture)	No
Chat via text	No	No	Yes (texts cannot be seen from VRChat)

Table 1. *Summary of what the participants can do through HMD, desktop mode, and YouTube.*

place in the VRChat. Table 1 summarizes what the participants can do through HMD, desktop mode, and YouTube. The highest simultaneous YouTube viewership of the tour was 61 people and a total of 159 people joined the stream by the end of the tour. The entire virtual tour lasted about an hour and ten minutes, after which some participants and the guide stayed behind for additional questions and explanations. Since most of the participants stayed until the end of the event, the organisers consider that one hour was about the right length for the event. If it had been longer, we could have given a more detailed introduction to the technical features and scientific achievements of ALMA, but as a first tour, we thought it was important to give an overview and let the participants enjoy the world by looking around the virtual observatory, rather than deepening the knowledge of ALMA. For participants who want to know more details, it would be better to provide another opportunity.

Table 2 shows the tour programme. The tour started with a 30-minute introductory presentation of ALMA in the middle of the virtual ALMA world (Figure 2). Hiramatsu was the lecturer and guide for the tour. He made a presentation file with Microsoft PowerPoint and sent it to the VSP organiser so that the presentation was shown in the VRChat world. In this presentation, the lecturer explained why astronomers observe radio waves from celestial objects, why multiwavelength astronomy is important, why ALMA was built in the Atacama Desert in Chile, as well as ALMA's representative results on planet formation, distant galaxies, and the discovery of complex organic molecules around young stars.

After the presentation, the lecturer guided the participants to the vicinity of the virtual array to explain the technical details of the antennas, including design ingenuity to achieve sufficient accuracy, differences in the antennas manufactured by Japan, US, and Europe, and how the antenna configuration is changed (Figure 3). During the tour, participants in VRChat were able to look around the antenna from any angle. They also freely express their impressions through voice chat as the lecturer explained.

An interesting point is that they were not merely reacting alone, but listening to the voices of other participants around them and responding to them. Although virtual tours via Facebook or YouTube also allow people to express their impressions via text chat, VRChat allows communication via voice. The participants were able to have two-way communication more easily and naturally in a similar environment to a real tour.

At the end of the tour, we had a question and answer session. The participants surrounded the lecturer and asked questions (Figure. 4). A wide variety of questions were asked, such as the mechanism of how to make a radio image from observational data, the cost to construct ALMA, radio interference, and data calibration after antenna relocation. Questions about the instruments from a technical point of view were raised during the tour and those were apparently evoked from watching the realistic antenna models, but the questions that came up during the Q and A session were more general in nature and not much different from those in typical face-to-face lectures.

Time (JST)	Content
18:00-18:30	Introductory lecture of ALMA, explaining significance of multiwavelength astronomical observations, and introducing ALMA's representative results such as the protoplanetary disk around a young star HL Tau and the most distant detection of oxygen at a galaxy 13.28 billion light years away.
18:30-18:50	Virtual guide in the ALMA world, explaining the basic function of the ALMA antennas, technological differences in the antennas developed by Japan, US, and Europe, and actual operation of the telescope including the reconfigurations of the antennas.
18:50-19:10	Questions and Answers session at the middle of the antenna array.

Table 2. *A timetable of the virtual tour.*

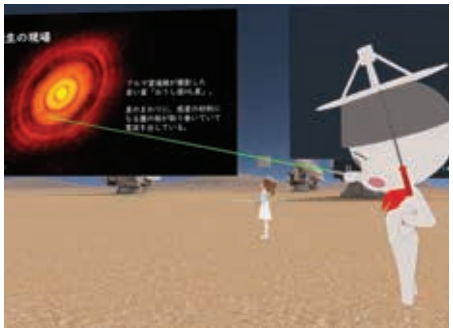

Figure 2. *Overview lecture of ALMA. Powerpoint presentation is embedded in the virtual world. The lecturer wears an avatar of an ALMA antenna. Credit: VSP*

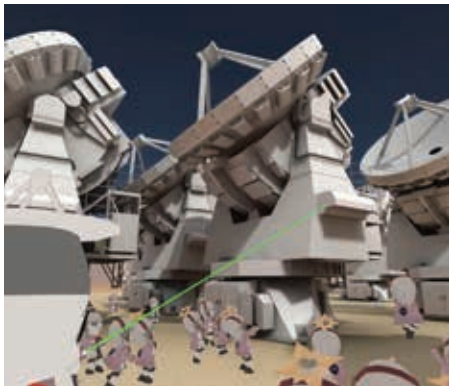

Figure 3. *Masaaki Hiramatsu, the East Asian ALMA Education and Public Outreach Officer explains ALMA's 7-meter antenna array developed by Japan in the VRchat CG world. In order to avoid overloading the server with individual participants using different heavy-weight avatars, all participants use the same avatar. Credit: VSP*

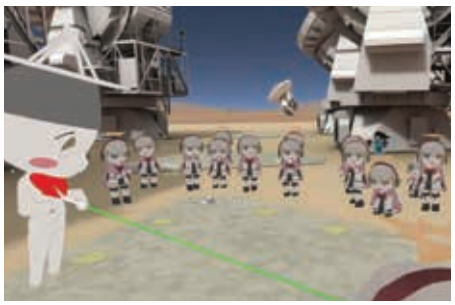

Figure 4. *Questions and Answers session at the end of the tour. This session was held in the middle of the virtual antenna array. Credit: VSP*

Results of Questionnaire to the Participants

At the conclusion of the tour, we asked the participants to answer the questionnaire on

their experiences via Google Forms[14]. We received 44 responses. In this section, we summarise the responses and discuss the advantages of using VRChat in astronomy communication.

User Environments and their Background

Among 44 respondents, 21 were in their 20s or younger, accounting for nearly half of all participants[15]. This agrees with the overall demographics of VRChat but is in contrast to the audience for the NAOJ public lecture featuring ALMA held in a face-to-face format in Tokyo in February 2020, in which only 15% of the participants (35 out of 239) are in their 20s or younger. VRChat is a good way to approach and communicate with the younger generation with a high interest in the cutting-edge technology of VR.

We asked why they participated in the tour by presenting three options (1. Because it is a VSP event, 2. because it is in the virtual ALMA world, and 3. because an expert will give a talk) and they were allowed to select multiple options. Out of 44, 43 selected the option 3. It is still uncommon for a professional astronomer to give a talk on VRChat, and it was the first time for VSP to invite an astronomer to their event. Several participants highly evaluated in the questionnaire responses that the organisers invited an expert to give a talk in the VR world, which shows that there is a high demand for expert's participation. 34 and 27 selected option 1 and 2, respectively. 16 out of 44 did not know about ALMA before the event. Considering that more than 75% of the participants chose the option 1, it can be said that most of the participants are already familiar with VR and are interested in advanced technologies like VR.

We asked about the level of interest in astronomy before the event. Figure 5 shows graphs of the responses from VSP members and others separately. In total, 25 answered that they were "very interested" in astronomy, 16 answered "some level of interest", and 3 had "little interest". The proportion of the responses was almost the same between VSP members and others. Since the event was mainly advertised via VSP's and NAOJ ALMA Project's social media, it is natural that most of the participants are already interested in astronomy. To increase the participation of people who are not interested in astronomy, we can strengthen announcements on web media that cover general VR topics.

We asked if their interest in astronomy had increased after this event.27 said it had, 13 said it had increased somewhat, and 4 said it had remained the same. Of the 41 participants who said they were "very interested" or "somewhat interested" in astronomy before participating, 38 said the interest was "increased" or "somewhat increased" after the tour. Among the three who answered that they had "little interest" in astronomy before the event, two answered that the interest somewhat increased after the event, and one answered that the interest level keeps same. This result indicates that the program had the effect of arousing further interest in astronomy in participants who were already interested, and also had a

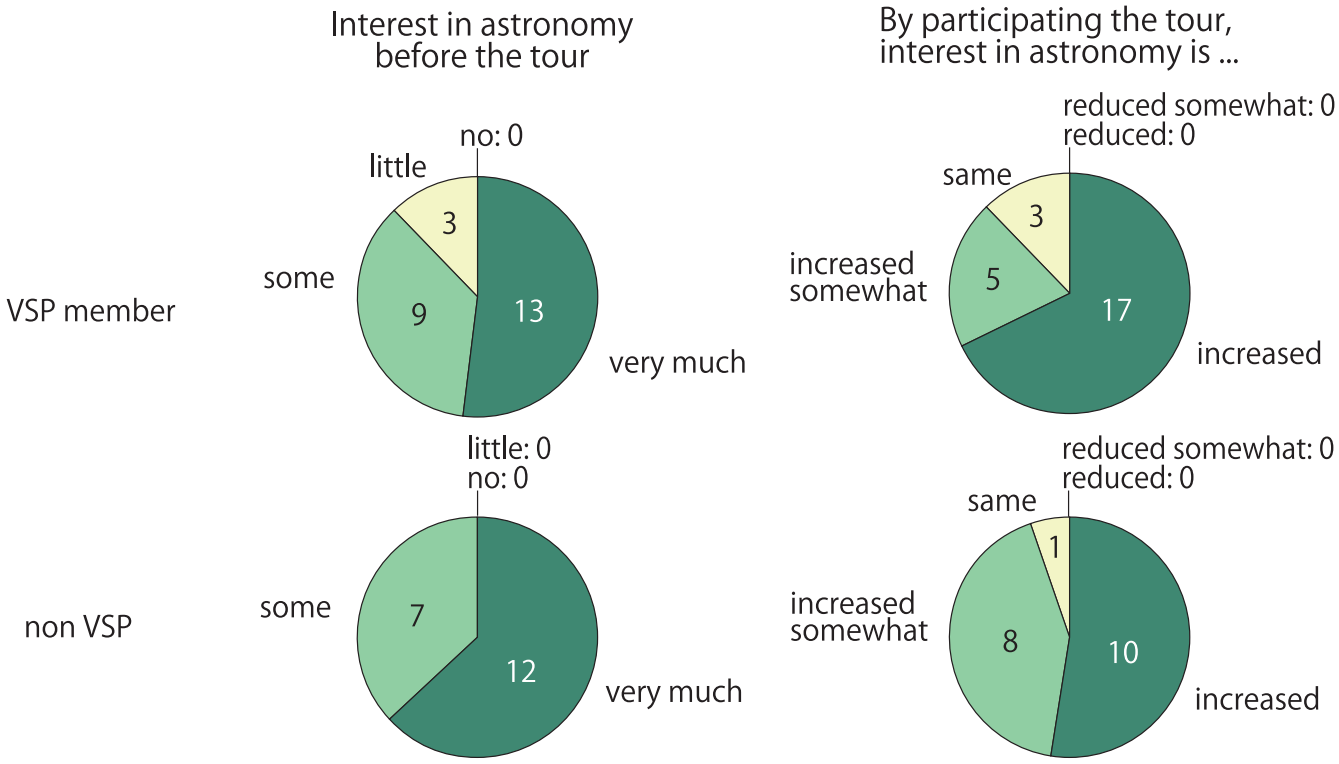

Figure 5. *Summary of survey responses. The diagrams show the difference in responses depending on the environment through which the respondent participated in the lectureby the participating environment. Credit: Masaaki Hiramatsu.*

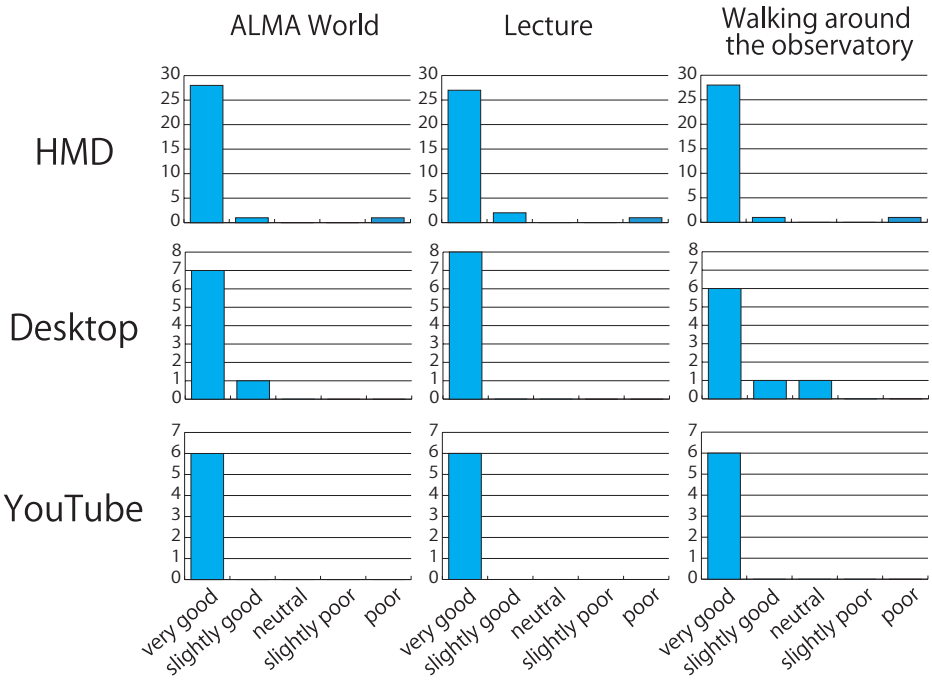

Figure 6. *Survey responses on the satisfactory level for the ALMA world, lecture, and walking around the virtual observatory. Credit: Masaaki Hiramatsu*

positive impact on the participants less interested in astronomy.

We asked the participants if they had attended any in-person or online science public lectures prior to this tour. Out of 44, 27 answered that they had attended in-person science lectures before, and 16 answered that they had attended online lectures. Half of those who have attended an in-person lecture said they have never attended an online lecture. Considering that the demand for expert's talks as described above, this indicates that there is still a great potential for VR lectures, but that the science side has not yet captured it.

User Experience with Different Media

Among 44 respondents, 30 joined the tour with an HMD, 8 joined with the Desktop mode of VRChat, and 6 watched the streaming on YouTube. There was no significant difference in the overall satisfaction level with the tour based on the medium through which they participated (HMD, Desktop mode, or YouTube) as shown in Figure 6. A possible reason for this is that the participants with the Desktop mode and YouTube have less experience of HMDs and do not know how was the experience with HMD. In the free-text feedback from participants who used HMDs, there were many positive comments attributed to the immersive experience of using HMDs, as described in a later section, so it is possible that the experience when using HMDs is more positive than when the same person uses other methods. In order to have a full-scale experience using HMDs, however, users need to prepare their own equipment, but this requires a certain level of cost (more than 2000 US dollars for an HMD and a high-spec PC) and it is not easy to attract a wide range of participants if we organise an event only in VRChat. The fact that this tour received high evaluations regardless of the participants' environment shows that a hybrid event combining the use of HMD and YouTube streaming can also have a high outreach effect. One respondent answered "poor" to all the questions, but wrote comments in the free text section praising the event highly, which might indicate that he/she mistakenly selected the answers.

To see the difference in user experience through different media, we separately summarised the responses in Figure 7. More than 70% of the HMD users answered that they had interacted with the lecturer a lot or to some extent. This shows that the immersive environment possibly makes spontaneous communication easier. The free-write responses described in the following sections and personal feeling by the guide supports this interpretation. Although the numbers of responses for Desktop mode and YouTube were small and it is difficult to be definitive, the fraction of those who had good interaction with the guide was smaller than those with HMD. Users who participated through the Desktop mode could use their voice and gestures with their avatars. Although it was not an immersive environment, the survey responses show that some levels of communication took place even with the Desktop mode (survey responses indicate that this occurred but no further detail on what kind of communication was described). In contrast, we did not have a way to communicate directly with YouTube viewers. The participants through YouTube can use text chat to interact with other YouTube viewers, but there were no channels of communication with other participants and the guide using HMDs and the Desktop mode because they could not see the YouTube chat. The two respondents from YouTube who answered "very much" may highly value one-way communication, rather than two-way communication.

Next, we discuss the communication between the participants. Judging from the survey responses, the participants with HMDs had slightly better communication compared with those with Desktop mode and YouTube, however, not many participants communicate with other participants. This weak communication among participants would be due to the overall structure of the event. A lecture and a guided tour are mainly based on communication between the lecturer/guide and each participant, and communication between participants is outside the main scope of this programme. Within VRChat, it is also possible to organise activities by dividing participants into small groups to interact, since voices are heard louder when they are close together in the virtual space and quieter when they are farther away, just like in a real space. If organisers are able to invite more than two experts, it could organise a virtual observatory tour in smaller groups that would better facilitate communication among participants and between participants and guides.

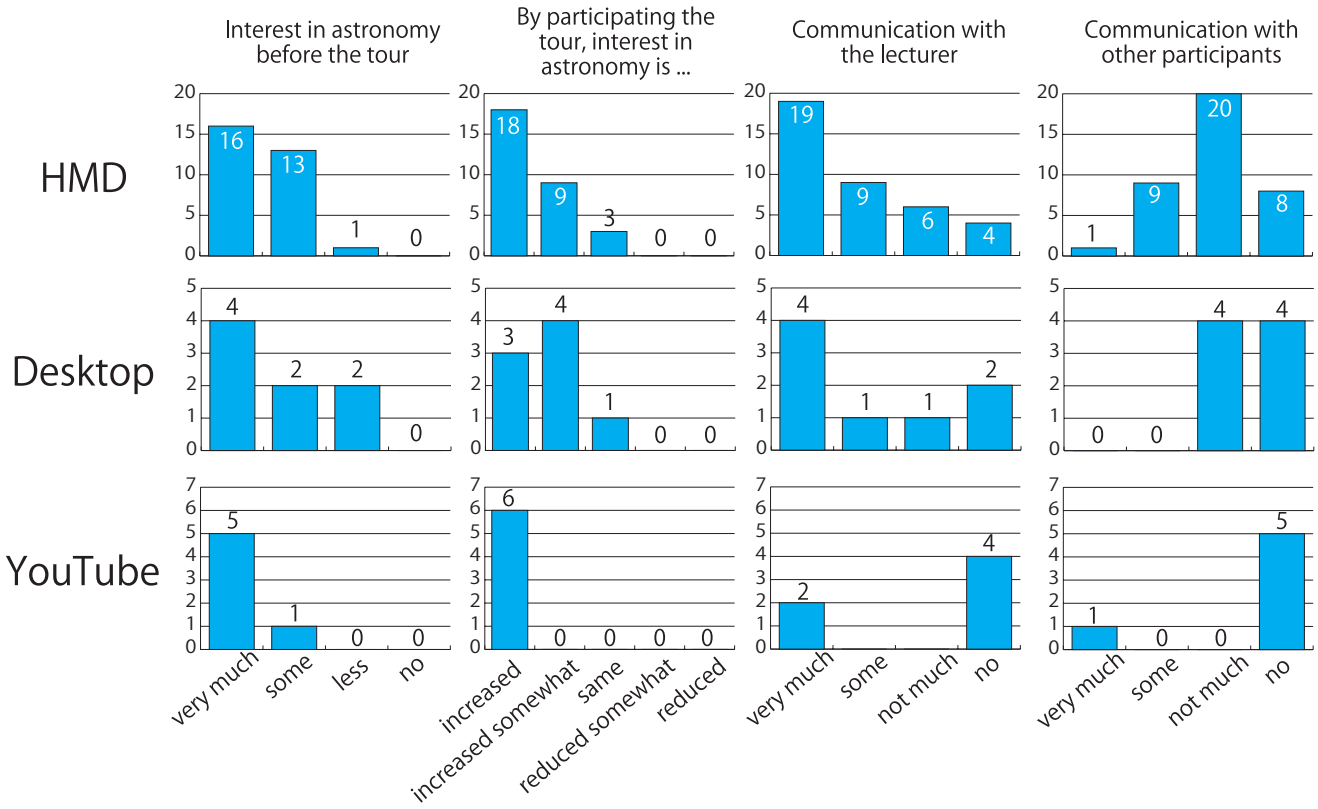

Figure 7. *Summary of survey responses compiled by participating environment. Credit: Masaaki Hiramatsu*

Difference between Face-to-Face Events and VRChat

To find out how participants felt about the event in the VRChat world, we asked those who had attended face-to-face lectures in the past about the biggest difference between the face-to-face event and this virtual tour. 27 out of 44 respondents answered that they have attended in-person lectures, and 24 described the differences. Two characteristics in VR emerged from the responses. One was the realistic experience, and the other was the closeness to the lecturer.

The HMDs provide an immersive experience, allowing one to look around the realistic virtual antenna like they could do if they were actually at the observatory. Selected responses to this question are

- "It was as if I had actually been there in Chile."
- "The explanation with the virtual model in front of me is easier to experience it as something that is happening to me proactively than the video or slides, and it seems to attract more interest."
- "Since the lecture was given in the VR world, which is a reproduction of the observatory site, it left a stronger impression than explanations and questions using only slides."

Phrases like "my own experience," "right in front of me," "right next to the telescope," and "experience as if I was actually there" appeared in the responses as evidences that the participants felt a sense of reality in the CG environment and had positive impressions to understand the world and ALMA itself. Only two people (including the guide) in the tour had actually visited the ALMA Observatory, but both of them felt that the VR experience was very similar to an on-site visit. An interesting point is that the responses from those who watched the streaming on YouTube included words like "realistic sensation", but words based on physical sensations like "in front of me" did not appear. Although the participants via YouTube had a vivid impression through the tour because of the high level of reproduction of the ALMA Observatory in VRChat, the difference in the responses indicates that experience with HMD provides a good sense of immersiveness.

The immersiveness of VR experiences using HMDs is also reported in *Kersting et al. (2021)*. In their VR experience on the subject of gravitational wave astronomy, most of the participants described their immersive engagement as a positive experience.

In addition, the lecturer felt as if he was actually guiding the participants in the real observatory because he could feel the participants' "eyes" on him even though they were in avatars, and he also could hear them voice their own impressions. Overall, for both the guide and the participants, the VRChat tour felt similar to the actual observatory tour. The ALMA Observatory is far away from most of the cities and it is difficult to visit. The pandemic is making it even more difficult, but the VRChat tour is a valuable way to experience the atmosphere in which cutting-edge astronomy is being performed.

As for the second point, six respondents pointed out the closeness to the lecturer. A representative answer was "it was very easy to ask questions because I was physically and psychologically close to the

lecturer." Here we have two non-exclusive possible reasons why the psychological distance between the participant and the guide becomes closer in a guided tour in VR space. One is that the participants and the guide are spatially close to each other. In the tour participants could "stand" next to the lecturer through avatars. This is in contrast to typical face-to-face lectures where there is a distinct difference in locations between the lecturer and the audience. The other is that the use of friendly-looking avatars by both lecturers and participants increased anonymity and reduced the authority of the lecturer, creating an atmosphere where it was easy to talk to the lecturer. One respondent clearly stated that "participating with an avatar is fun and friendly."

It is interesting to consider whether this closeness is characteristic of VR. Even in face-to-face activities, it is possible to minimize the physical distance between the lecturer and the audience by mixing the lecturer into the audience rather than having the lecturer stand behind the podium, and this may also contribute to reducing the psychological distance. In an in-person event, however, it is difficult to reduce the authoritative nature of the appearance of the lecturer, since the appearance of the lecturer cannot be changed. Nevertheless, wearing familiar costumes in the real world could also create a sense of discomfort because it is unnatural that only the lecturer has a different appearance than usual. On the other hand, in the VR space, since everyone participates using avatars, it is possible to reduce authority without creating a sense of discomfort.

Difference between Conventional Virtual Events and VRChat

We also asked the participants about the difference between conventional online talk events and the tour in VRChat. Many participants expressed similar sentiments to those described in "Difference between Face-to-Face Events and VRChat". Notable points are:

1. A higher-quality audio-visual experience,
2. Participants can sense the responses of other participants.

As for the first point, VRChat provides an immersive experience in which one can get a 3D sense of place both visually and aurally. It is as if they were actually there. Some selected responses are as follows.

- "I enjoyed the realistic feeling of being able to see the antennas from a 360-degree direction, which is not possible with photographs."
- "It was easier to see and hear than a lecture through a two-dimensional screen."
- "The image quality of VR tours is much better than normal online lectures. The user experience is much better than Zoom lectures, and there are no distractions, so I was able to concentrate more on the lecture."

The immersive feeling cannot be obtained in normal 2-D virtual events. The participation of many people may overload the system and it is difficult to have hundreds of visitors at once in a VR environment, but the proper handling of the total number of participants and data sizes of the avatars and the world provides a satisfying environment for virtual observatory tours.

Regarding the second point, one participant described that "The audience's reactions were conveyed through their voices and gestures, which increased the sense of presence and live performance, and the lecturer seemed to be comfortable speaking." In virtual events on YouTube, participants can post their impressions in the text chat. However, compared to written communication, voice and gestures can achieve more direct communication, even if the participants are in avatars. Also, a respondent pointed out the possibility that VR would allow participants to talk with each other before and after the tour itself. This again shows the similarity between observatory visits in VR and actual visits.

Other Responses

In the free-write sections of the questionnaire, there were several comments pointing out the compatibility between VR and science communication. Notable responses are:

- *"I was very impressed by seeing the details of ALMA, which we can't actually get close to, with explanations by the lecturer who actually works for it. The lecturer's explanation about the coldness and shortness of breath on site made me experience a more realistic atmosphere of the site, which complemented the VR experience."*
- *"It was an experience that made it stand out from other online talks. Although it will be very difficult to construct worlds and reproduce items one by one, it will be a great pleasure for the learners if cutting-edge researchers (in other research fields) give lectures in the same way, and it would also be very rewarding activity for lecturers."*
- *"I'm really happy to discover for the first time an event like this! It's a really good experience for me, I'm really happy to see some professionals join an event like this!"*

In addition, we asked what the participants discovered during the tour. The purpose of this question was to understand how much the participants understood the guide's lecture and the tour, and what caught their attention. The answers ranged from the differences in the ALMA antennas developed by different countries, the meaning of their differences in shapes, and detailed information about telescope operations. The keywords we found in the responses are "realistic" and "detail". This showed that the various information disclosed by the guide during the tour was very well communicated to the participants, aided by the realism of the reproduced observatory in the VR world.

Conclusions

The virtual ALMA Observatory tour in VRChat was a very effective and fruitful experiment to overcome the difficulties of visiting remote astronomy observatories, especially under the global pandemic. The responses by the participants show the great potential of VR and also provide important insights into how to organise effective virtual tours. Important points we found are as follows.

- The quality of the virtual model of the observatory is essential. Recreating every detail increases the reality felt by the participants and the impression on the participants becomes stronger.
- It is important to cooperate with those who have strong modelling skills and who can explain them properly. In this case, the collaboration between VSP and the NAOJ ALMA staff member

worked very well and was key to the successful organisation of the tour.

- Even in the VR environment, sharing the same space enhances communications between the lecturer and participants, and among participants. The feeling was more similar to a face-to-face tour rather than a conventional virtual talk on YouTube. The lecturer has given many public lectures over YouTube, but he has not been able to go into much depth on topics because he could not see the audience's reactions and measure their level of understanding. On the other hand, with VRChat, even though the participants were in avatars and the guide could not see the faces directly, he saw that the participants were looking around the antennas and heard their murmuring their thoughts and interjections. Sensing these reactions he was able to confirm that the audience kept interest in his talk and provide further explanations at an appropriate level.

- Once the guide is sure that the participants are receptive to technical explanations, the guide can take full advantage of the detailed reproduction of the antennas in front of the participants to explain the technical details, which will be easier to understand than other virtual events and also leave a strong impression.

- The technical difficulties for virtual tours using the VRChat world is the limitation of the number of participants in one event. In fact, there were several people who could not enter the world by the time due to the heavy access a few minutes before the start. One of the workarounds is to extend the waiting time for entering the world.

- Some participants suffered from technical glitches of their VR instruments and had difficulties in entering the world or showing the proper avatars. A few VSP members provided technical support during the tour. The VR environment is currently in the process of spreading, and there is a possibility that some participants may be unfamiliar with its operation and problems. When possible, it would be desirable to have someone who is familiar with the VR environment, like the VSP members this time, as support members.

The findings from our activity align well with those by *Kersting et al. (2021)*. Despite the difference of the VR contents and the format of the experience, the importance of high-quality visualisation, interaction between professionals and participants, and collaboration is common to the two for realizing engaging and effective experience in science outreach.

Even after the pandemic, virtual tours in VR worlds will be very useful for the public to gain a deeper understanding of inaccessible astronomical facilities. On the other hand, it should be noted that the number of people who can use HMDs to participate in immersive VR events is still limited compared to the number of people who can browse YouTube, etc, considering the number of active users in VRChat. VR equipment is rather expensive, but not many people may buy it just for scientific events. For the time being, until VR becomes more widespread, streaming events in the VR space to YouTube is one way to provide tours in VR to a wider audience, even if the sense of immersion is somewhat lost.

VSP has made other telescope models such as the Subaru Telescope and the Thirty Meter Telescope, as well as several scale models of space telescopes and space probes including the Hubble Space Telescope and the Hayabusa2. With the collaboration between astronomers/communicators and someone with sufficient knowledge of Blender and Unity, other telescope models can also be built in the VRChat. A variety of effective virtual tours could be organised; possible programs are to compare different telescope models to understand the characteristics and importance of multi-wavelength astronomy, and to focus on the cutting-edge technologies that drive modern astronomy. It is impossible to actually visit the telescopes in remote sites instantaneously, however, we can do it in the VR world. We are looking forward to seeing many virtual tours providing a fun, vivid experience to visitors.

Notes

[1] Selected examples of the observatory public visits are the Atacama Large Millimeter/submillimeter Array (https://www.almaobservatory.org/en/outreach/alma-observatory-public-visits/), European Southern Observatory's Paranal Observatory (https://www.eso.org/public/about-eso/visitors/paranal/), and W. M. Keck Observatory (https://keckobservatory.org/visit/).

[2] The governmental agency for tourism in Chile highlights Astro-tourism for visitors on its official website, including information about tours of astronomical facilities: https://chile.travel/en/what-to-do/astrotourism

[3] ALMA is a radio astronomy observatory located in the Atacama desert, northern Chile. It consists of 66 parabolic antennas combined to function as one giant telescope.

[4] Announcement about virtual guided tours from the European Southern Observatory: https://www.eso.org/public/announcements/ann20020/

[5] This VR tour video is available on the YouTube ALMA Japan Channel with Japanese narration: https://www.youtube.com/watch?v=e3T_p4MPlWo

[6] VRChat (https://hello.vrchat.com/) is compatible with most of HMDs connected with a PC, but not compatible with stand-alone-type HMDs, PlayStation VR, and VR using smartphone.

[7] As for the internet bandwidth, while 10 Mbps may be enough for conversations and motion tracking on VRChat, loading the world data could be a bottleneck. For example, the size of the ALMA world is 62.24MB, so at 10Mbps, it takes about 50 seconds to load the data. The recommended bandwidth for stress-free participation is 100Mbps.

[8] Wagner James Au, "VRChat Site User Demographics: 430,000 Uniques, Mostly Male And Over 25", New World Notes blog: https://nwn.blogs.com/nwn/2019/05/vrchat-user-numbers-demographics-social-vr.html

[9] Ben Lang, "Social VR App 'VRChat' is Seeing Record Usage Amidst the Pandemic", Road to VR: https://www.roadtovr.com/vrchat-record-users-coronavirus/

[10] The website of Virtual Space Program (VSP) (Japanese): https://virtualspaceprogram.org/

[11] The ALMA antenna configuration is available in this short video: https://www.youtube.com/watch?v=-UcrXSs39U0

[12] The ALMA Cycle 3 Technical Handbook describes the antenna configuration: https://almascience.nao.ac.jp/documents-and-tools/cycle3/alma-technical-handbook

[13] The recording of the virtual ALMA tour on VRChat is available on YouTube: https://www.youtube.com/watch?v=NYCsUA0r_Y0

[14] The survey was done in the Japanese language. Quotations in these sections are literal translations.

[15] Organisers of VR events should be aware that there are restrictions on the use of HMDs for people under certain age (around 12 years old).

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Column

Astronomers for Planet Earth: Embracing Virtual Communication Induced by the COVID-19 Pandemic to Help Tackle the Climate Crisis

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On behalf of Astronomers for Planet Earth Network collaboration

Keywords
Climate, Online, Action, Environment, Astronomy, Sustainability

Astronomers for Planet Earth (A4E) is a global collective, whose main goal is to communicate the fragility of our planet from an astronomical perspective. A4E works hard to equally engage with astronomers and educators worldwide, by encouraging the communities to reduce emissions and providing a space to collaborate and share resources. These actions have led to increased sustainability and the incorporation of climate change lessons and activities into teaching and outreach. With the global shift to online communication due to Covid-19, Astronomers for Planet Earth has utilised digital tools in the form of online conferences and seminars, high-impact journal articles, webinars, social media, and video production to engage its audience and grow a membership of around 1300 astronomers in 70 countries around the world. Our article addresses the importance of communicating the climate crisis from an astronomical perspective and explores the successes and challenges of our group's virtual communication with the astronomy community and the general public thus far.

Introduction

The Covid-19 pandemic has completely reshaped social interactions and communication between colleagues, family members and friends. Like most fields, astronomy has been affected by the pandemic and, like others, was quick to adapt to the sudden changes. With teaching being shifted from classrooms to online platforms and observing being done from remote desktops instead of in-person in remote areas, the oldest science has received a major update. Interfaces such as Skype, Zoom, Microsoft Teams and Gather (or Gather Town) are now used to host a variety of meetings, including workshops, conferences, small collaborative gatherings and even summer schools, allowing astronomers to connect across time zones for events that would otherwise have required them to (often) fly many miles with serious resulting CO2 footprints *(Burtscher, 2020).* Many of these changes were thought to be impossible before the pandemic forced society to restructure its behaviour. People across the globe have risen to the challenge of remote working/learning, balancing this with childcare (which has exacerbated gender inequality within the field *(Inno, 2020)*) and all the other additional commitments intensified and created by the pandemic. Despite what institutions and companies have previously claimed, the virtual model is working successfully for many *(Massey, 2021).* Within astronomy, conferences have seen dramatic increases in attendance

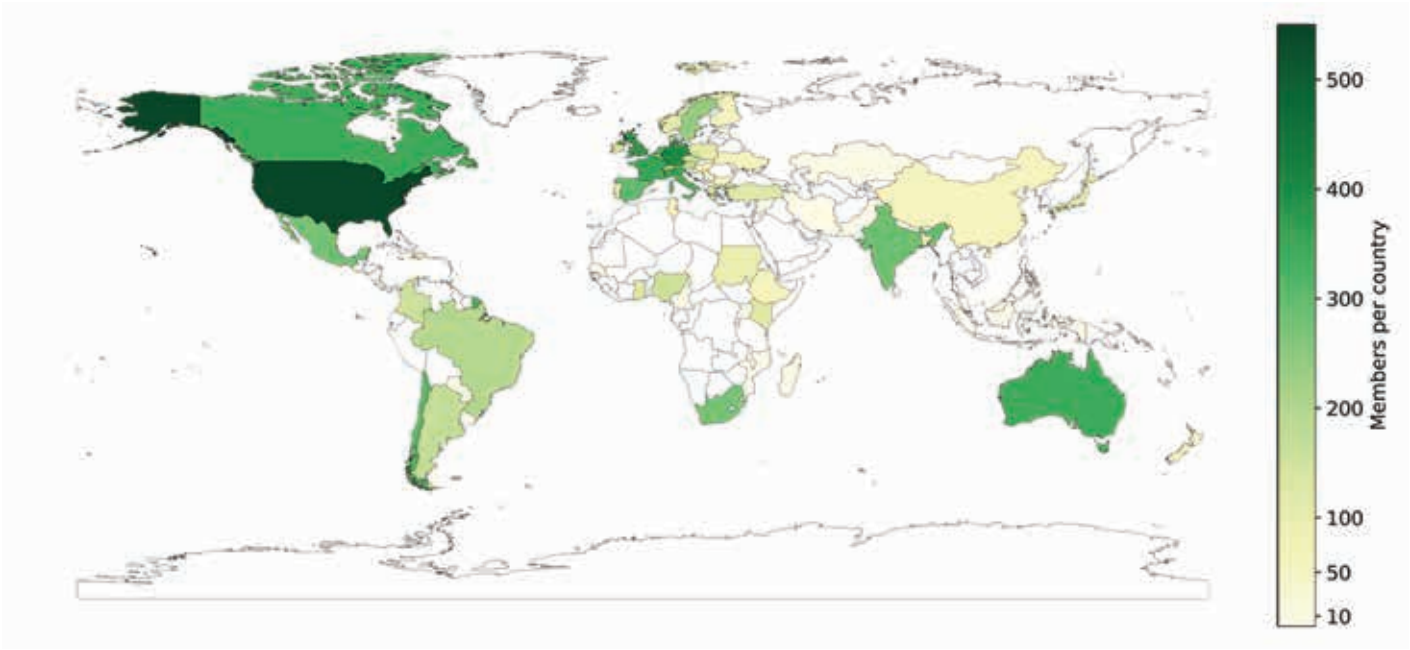

Figure 1. *A colour map displaying the level of Astronomers for Planet Earth membership in mid-2021. Credit: C. Hill*

and the need to provide content online has made it more accessible for everyone, especially those from the Global South. Now that vaccinations are in production and being distributed the question remains - will astronomy continue to reap the benefits of online communication post-pandemic?

The mobilisation of organisations and everyday people in response to the pandemic has shown that, when required, we can band together, adapt to the crisis and carry on. However, this is not the only crisis humanity currently faces and this is not the only time we will need to adapt. The climate emergency is here *(Ripple, 2020)*. Unprecedented global warming is occurring, as tracked within the oceans and the Earth's atmosphere, which in turn is causing extreme weather events such as floods, heatwaves, droughts and hurricanes to become more common. Like the Covid-19 crisis, the influence of humans has been established as the root of the climate emergency we now face. Since the 19th century, the world has warmed by about 1°C and should the warming exceed 1.5°C the planet will be irrevocably altered, with horrific consequences for the planet's ecosystems *(World Meteorological Organization, 2018)*. There still exists a window within which we can prevent exceeding the 1.5°C mark, but this opportunity will disappear in the next few years unless we act swiftly and sufficiently *(United Nations Environment Programme, 2020)*.

Through the regular discovery and examination of the habitability of (exo) planets, astronomers have a unique perspective on the subject of the fate of our Earth. Despite media hype about the future colonisation of other planets in our Solar System such as Mars, the reality is that within the time frame of the climate crisis, the Earth is the only home the vast majority of us will ever have. According to a new index computed by Ipsos Mori *(Ipsos Global Trustworthiness Index 2019, 2019)*, being a scientist is considered one of the most trustworthy professions. Furthermore, astronomers tend to communicate with the public more than other scientists *(Entradas and Bauer, 2018)*. This provides the astronomy community with a unique opportunity to convey the urgency of the climate crisis, while we still have the time to act. Recent research has also shown that astronomy as a field contributes disproportionately to the acceleration of climate change (through observing, supercomputing and travel *(Stevens et al., 2020) (Jahnke et al., 2020)*) which will ultimately make astronomy more difficult *(Cantalloube et al., 2020)*. Therefore the need to mobilise and promote positive change within and beyond our field to tackle the climate emergency is even more evident.

Astronomers for Planet Earth

Astronomers for Planet Earth (A4E) is a global organisation, created to utilise the unique perspective and reach of astronomy to assist in highlighting the need for societal change to help halt climate change *(White et al., 2021)*. Originally formed in December 2019, A4E is a network of volunteers composed of people who have worked in, currently work in or are associated with the field, including students, amateurs, enthusiasts and academic staff. The organisation provides a community for astronomers interested in addressing the climate crisis to share resources and to engage in discussions. A4E also aims to inform the general public about the climate crisis, and to support the climate movement with an astronomical perspective. The community is truly international with around 1100 members[1] across 67 countries, as shown in Figure 1.

As A4E was started in 2019, the Covid-19 pandemic began to cause disruptions on a worldwide scale soon after its formation. Regardless, A4E's activity has always been based online, making it

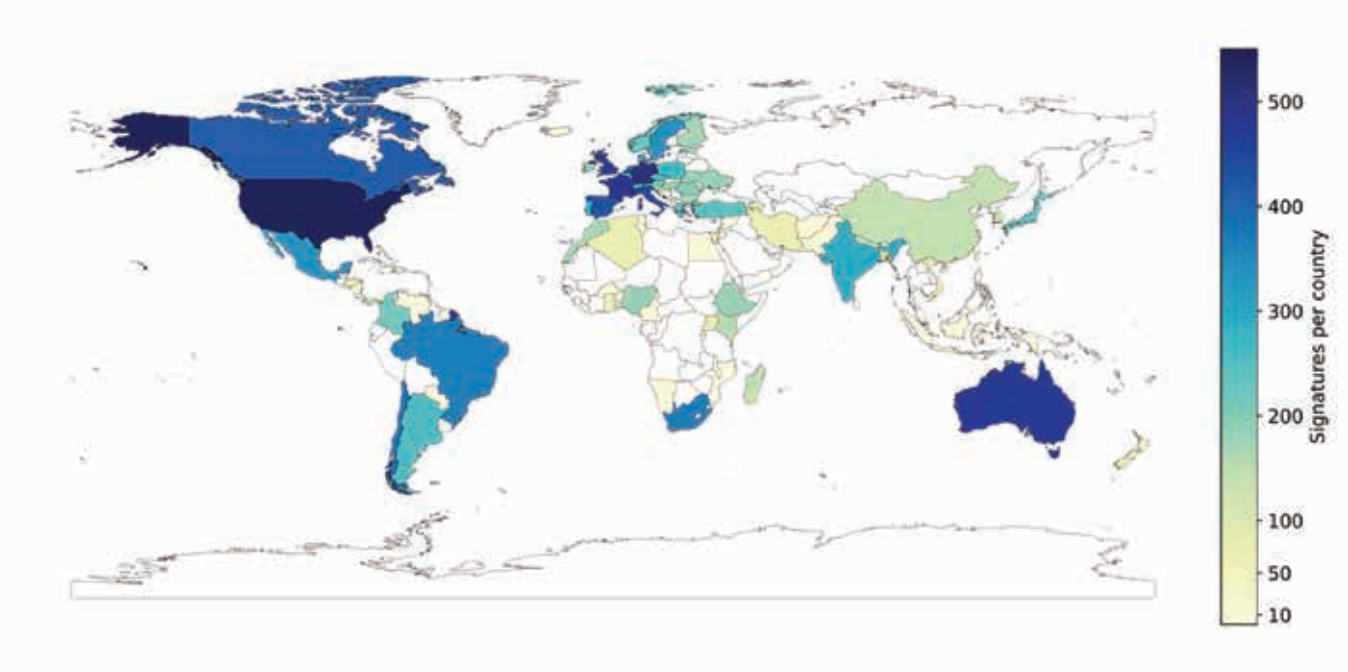

Figure 2. *A colour map displaying the density of signatures to the Astronomers for Planet Earth open letter worldwide. The letter invites educators and researchers who work/have worked in astronomy to call for immediate action from astronomy-related institutes to tackle the climate crisis. Credit: C. Hill*

essentially a virtual community. Building the community when you are limited to online communication requires an outlook with multiple approaches. Social media is a powerful tool when it comes to connecting people around the world, and media posts, in particular, can be used to grab attention and alert people to an organisation. A4E has an active presence on Facebook, Twitter, Instagram, Vimeo and Youtube. Twitter and Facebook have provided the most reach, with tweets and Facebook posts by A4E being seen by 1000s-10,000s of people. A4E gained a lot of exposure with a call for action on the global day of climate action on 25 September 2020. Across all social media platforms, the original post reached about 73,000 people, alerting many to the existence of a group where they could join forces to help prevent the climate crisis. Using social media and online communication, A4E has reached people all over the world, including the Global South, in contrast to astronomical conferences which are predominantly attended by scientists from the Global North (Nshemereirwe, 2018). When communication is done predominantly online, these issues can begin to be alleviated. Although A4E has members from across the globe, fewer members are from the Global South (15% at the time of writing) and this may also be a reflection of the distribution of astronomers worldwide. This bias towards the global north can been seen in data collected by the International Astronomical Union on their own membership, who find that all the countries that have 400+ members are from the global north. While visits to the Astro4Earth site are dominated by people from the U.S. (37% at the time of writing), overall engagement with the main website of A4E is encouragingly global. Continuing to engage our colleagues and spreading the word about the organisation within the Global South is an ongoing goal.

Another aspect faced by most organisations is the need for economic sustainability. In-person conferences require a great deal of financial support, but the online nature of A4E has managed to keep costs down thus far. The organisation hosts regular webinars and discussions with invited experts on climate and astronomy and their intersections on platforms that offer free and low-cost options (e.g. Zoom, Youtube and Vimeo). Resources are shared through Google Drive and Slack, the latter of which is also the hub for the organisation's working groups. Therefore, despite lacking official charity status or even an official bank account, A4E has been able to grow and share its message thanks to its virtual nature. However, it is worth noting that because no money is involved, all of the work done for A4E is voluntary. This presents limitations on the organisation's achievements, as no one has dedicated work hours. Now that the group has grown to about 1100 members, the pool of people available to assist is increasing, but communication becomes challenging. In the free format, interfaces such as Zoom and Slack place a limit on the number of participants and messages that can be stored in a free account, curbing the number of people who can be engaged in any one meeting and compromising the record of previous discussions within the group. To deal with this, A4E archives the Slack messages up to the 10,000 limit, so

Box 1: The Goals of A4E

1. Provide the public with information to fight climate change
2. To provide astronomers with the tools to fight climate change

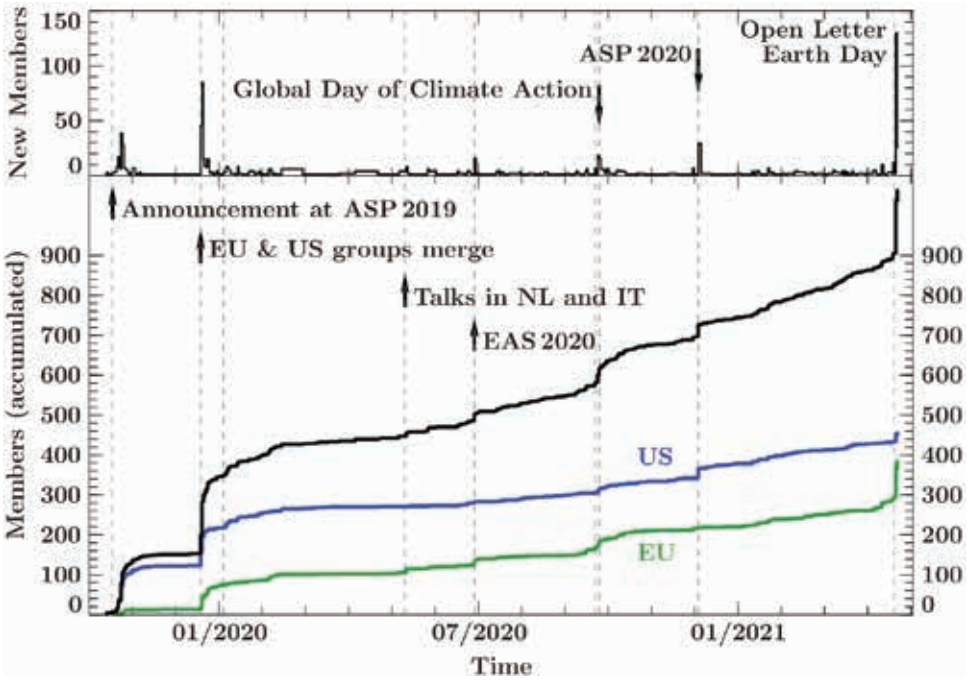

Figure 3. *A graph displaying the variation in Astronomers for Planet Earth membership over time. Despite the challenges posed by the Covid-19 pandemic, membership has continued to increase thanks to Astronomers for Planet Earth's exclusively online format. ASP stands for Astronomical Society of the Pacific. Credit: T. Beuchert*

there is always a record of the groups past activities and discussions.

Despite the challenges faced as a volunteer-only, virtual organisation, A4E has made significant achievements throughout the pandemic. A4E encompasses a large number of working groups. There are dedicated education groups that discuss working points such as how the climate message can be incorporated into (1) outreach talks by members and other astronomers and (2) general astronomy classes and astronomy-related teaching resources. Other working groups focus on driving change within the field. For example, recent efforts have resulted in an open letter[2] addressed to major astronomical institutions, asking them to commit to naming sustainability as a primary goal. At the time of writing, this letter has now been signed by over 2800 people associated with astronomy, from academics to amateurs, technicians and students from 83 different countries (illustrated in Figure 2) showing that many outside of the organisation also support the need to address the climate crisis. This effort has truly utilised the pool of expertise within the A4E community as, since the letter has been released, action is now being taken to lobby astronomical institutions to improve their sustainability practices and a press release is now in preparation, without the support of an institution such as a university. Those skilled with social media management also continue to make sure A4E has a prominent voice, through website development and content creation. The A4E Youtube channel[3] has thousands of views, with regular webinars and Q and A sessions with experts on astronomy, sustainability and environmental science.

At the academic level, the group has made several contributions to journals and at conferences. At the 2020 European Astronomical Society Annual Meeting, A4E organised a session dedicated to astronomy and the climate crisis. They are also organising a full-day special session in 2021, where talks and presentations will be given from prominent climate researchers and communicators as well as astronomers[4]. Additionally, a lunch session at the conference aims to reach the wider astronomical community with a number of high-profile talks. In the summer of 2021, A4E is organising a one-day meeting at the Astronomical Society of the Pacific[5]. As a result of A4E, individual members have come together to host sustainability sessions at other astronomy meetings for the first time (e.g. the Royal Astronomical Society's National Astronomy Meeting 2021). An article specifically about A4E has been published in the Bulletins of the AAS journal *(White et al., 2021)*. Furthermore, in 2020 the journal Nature Astronomy published a dedicated Climate issue *(Nature Astronomy, 2020)*, with many of the articles authored and co-authored by A4E members. Thanks to these continued efforts of the A4E community, membership continued to increase throughout the pandemic (Figure 3), with significant increases in membership following our large online communication campaigns, such as the global climate strike and the launch of the open letter.

Conclusions

The example of Astronomers for Planet Earth has shown that, despite the additional complexities induced by Covid-19, action groups can not only grow but thrive by utilising various communication mediums. A4E has shown that actions involving thousands of people from across the globe can be taken to communicate the magnitude of the climate emergency and push for necessary steps to tackle the crisis. Through online seminars, conference days and presentations,

articles and meetings, the members of A4E have successfully reached out to the general public, other scientists, and the heads of astronomical institutions. In doing so, they have demonstrated that even in these unpredictable times, online communication can facilitate engagement and expansion, allowing groups like A4E to respond to the threat of the climate crisis and engage in the fight to protect our planet.

Notes

[1] Astronomers for Planet Earth (2021): https://astronomersforplanet.earth/about-us

[2] Astronomers for Planet Earth Open Letter 2021: https://astronomersforplanet.earth/open-letter

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A4E's work, including the production of this article, is only possible due to the immense efforts of its members. We extend our thanks to them all, and to everyone else trying to protect our planet against climate change.

Biographies

Astronomers for Planet Earth is a volunteer network of astronomers, astronomy students, and astronomy educators committed to bringing our voices to the struggle against climate change and for climate justice. The organisation was first formed from two independent groups in Europe and North America, and now has around 1100 members from 67 countries across the globe.

Discover the Universe: Astro at Home Series

Column

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Keywords
Outreach, Livestream, Students, Pandemic, Community, Astronomy

When faced with the news that school closures were taking place across Canada due to the Covid-19 pandemic, the small Discover the Universe team knew they wanted to support young families. Within 48 hours, Discover the Universe started an initiative to help entertain and educate youth through daily astronomy content. After 11 weeks of content, more than 50 twice-daily episodes in English and French were presented by science communicators, astronomers, physicists and an astronaut! In the first week, we saw 6,000+ live viewers. Each day, hundreds of families joined us on YouTube where all episodes are still available. The Astro at Home series is now a legacy astronomy educational resource designed for a young audience, in both official languages of Canada.

Introduction

At its roots, Discover the Universe[1] is an astronomy training programme for teachers. We offer workshops, webinars, and educational guides for elementary and secondary teachers and informal educators. For the past ten years, we have been working in support of astronomy for all learners. After a decade of training teachers, we saw the need to shift our focus last spring.

In early March 2020, the national government announced that due to the global Covid-19 pandemic, businesses would close and schools would not reopen following the March break. As an education-based organisation, we immediately understood the effect this would have on the school year, parents, and teachers. While we all were reeling at the impact of the pan-Canadian shutdowns, we felt compelled to be of service.

At the time, we believed the lockdown would last three or four weeks and we wanted to bridge this gap in learning. We decided we would create content directly geared to students. We also wanted to provide some relief to teachers and parents by delivering fun and engaging content that would keep students' attention. So, over the course of a weekend, Discover the Universe reimagined its approach to disseminating astronomy education. Our small team meant we were able to mobilise quickly, and six days following the initial lockdowns, we launched Astro at Home.

Over the eleven weeks, we surprised even ourselves with the reach and impact our programming would have; not just in terms of educating youth, but in bringing the Canadian astronomy outreach community closer together, propelling us into new forays previously unimagined.

Regularly Scheduled Programming

Astro at Home was designed for students aged 8-12 years. We knew that parents of children in this age range would also benefit from our programming by diverting their now at-home children with educational content. Being familiar with the national curricular content, we knew this age-range would be well served by what we could offer; most astronomy-related curriculum across Canada happens in Grade 6 (ages 10-12) when students learn about our Solar System. We planned two

Figure 1. *Screen capture of one French-language Astro At Home presentation on YouTube. Credit: Discover the Universe*

half-hour livestreaming sessions twice a day. The morning session would be in French and the afternoon would be in English, continuing our mission to provide training in Canada's two official languages. We hosted our sessions on Zoom and broadcast to the Discover the Universe YouTube page[2] for maximum engagement.

The day before launch, we emailed our network of educators announcing Astro at Home, hoping they would get the message to their students. We really were not sure how successful it would be given the short notice. Some of our colleagues and peers also shared the news with their network, gaining the interest of parents in their circles. Eventually, news outlets also promoted our programming. We also applied to be listed on provincial and national educational programming lists for at-home learning.

Despite only having one day to spread the news of our new initiative, Julie Bolduc-Duval and Lindsay Mann hosted an unbelievable number of people for our first lesson. We saw nearly 6,000 audience members populate the YouTube stream for the French morning session. This was way more than we could have ever anticipated, and it speaks to the power of our network. Later, when we hosted our second stream in English, just over 3,000 people attended. Our numbers did dwindle over time when some schools reopened and virtual learning started in earnest, but these inaugural videos alone have now been seen more than 20,000 times (live views and replays). Interestingly, we consistently had about three-times the participants in French than we did in English. We believe this is due to a lack of educational materials offered in French online.

Participants came back every day to take in the lesson and engage with their peers. And, while we geared content to students aged 8-12, we saw some precocious 6-year-olds really connecting with the lessons. We also had teens and adult amateur astronomers joining us regularly. At the conclusion of the series, we heard a story of one child and their grandparents watching the programme together but apart, who would later chat on the phone to share what they had learned.

Challenges

Pivoting our delivery after more than 10 years of presenting only to teachers was an adjustment. We found that being relaxed, open and honest went a long way to engender a sense of intellectual safety so the kids were comfortable asking any question. We also encouraged them to interact by using emojis or sharing anecdotes in the YouTube chat. We found that some of the students were understanding faster than others, and they would help explain concepts to each other. They were so supportive and patient with one another.

Interestingly, we had no issues with bullying. We witnessed the opposite: a bonded community of young astronomy enthusiasts developed over the course of the programme. The only issue we had was with some kids spamming the chat (sending several messages in a row) making it difficult to read everyone's messages and questions. We simply undertook a no-nonsense approach by laying out the rules at the beginning of each presentation and temporarily blocking anyone who broke those rules. This strongly discouraged others from doing the same, and it became a rare event after a short time.

One of our major concerns was the safety of the viewers. We encouraged parents to watch with their children but knew this was not always possible. Some participants were eager to connect with each other outside of Astro at Home and would share private information in the chat. We made a concerted effort to maintain the safety of the children by immediately deleting any messages with personal information, and not saving the chat for replay videos. This worked quite well and kept us in compliance with YouTubes guidelines for young audiences.

Figure 2. *A mosaic of all 36 Astro at Home volunteer presenters. Credit: Discover the Universe*

Our first significant challenge was the workload. At the beginning of Astro at Home, Discover the Universe had a full-time Director (Julie Bolduc-Duval) and a part-time Coordinator (Lindsay P. Mann). Originally, they managed both sessions as a team; Julie would present while Lindsay moderated and fielded questions. But it soon became challenging to keep up with the pace of it all. We had to come up with content, create a presentation, promote the programme, and then actually deliver the two 30-minute sessions each day. It became a full-time endeavour for both. In an effort to reduce pressure, we reached out to our professional astronomy network, inviting guest speakers who would design and create content they were interested in. Julie continued to manage the programme, coordinating the speakers, while Lindsay took over coordinating the English sessions, and Frédérique Baron was hired to coordinate the French sessions. This system worked wonderfully, in large part because our speakers were passionate about astronomy outreach and could be doubtlessly relied upon to create new and engaging content.

We worked with astrophysicists, amateur astronomers, engineers, STEM outreach professionals, teachers, authors, and astronauts. We hosted a total of 36 speakers, many of whom made repeat appearances. We wanted to represent all people and genders, and by the end of Astro at Home we had several female speakers and people of colour present on their expertise. Topics covered include everything from the basics of our Solar System to gravitational waves and dark matter! As a result of having some unilingual speakers, our content in English and French was not the same most days. This wasn't an issue, and in fact encouraged bilingual children to tune in twice a day. We realised that as we continued to see participants come back time and again that they wanted to know more about niche areas of study. Even when some of the material was difficult to fully understand, our students asked poignant questions and seemed to thrive with the challenge. In total, 51 lessons were delivered in each language during the course of Astro at Home. These videos now live as a legacy on YouTube and are a lasting resource for STEM learning.

In retrospect, the challenges we faced were the things that gave us momentum and pushed us out of our comfort zones. Without adjusting our perceived roles, hiring new staff, and inviting guest speakers we would not have run such a successful programme. If we had not reached out for help from our peers; we would not have covered so many topics, or been able to answer as many questions; we would not have been able to really focus on the students at all.

Successes

One amazing outcome is the large attendance for our first day, and while it might have been discouraging to see our numbers decline over the weeks, our audience distilled into a group who were truly engaged and excited about astronomy. After about a month, our number had dropped to approximately 200 viewers per session each day and later dipped a bit further to 100 viewers per session each day. But we had audience members from across North America, and of various ages. We know that those who stuck with us were deeply affected by what they learned. Some even shared how they were often bullied at school because of their interest in science, but that through Astro at Home they had found friends who were just like them. They were being encouraged by their peers to pursue their interest in science for the first time; an undeniable benefit to our programming! In the end, the programme had a tremendous impact on the children.

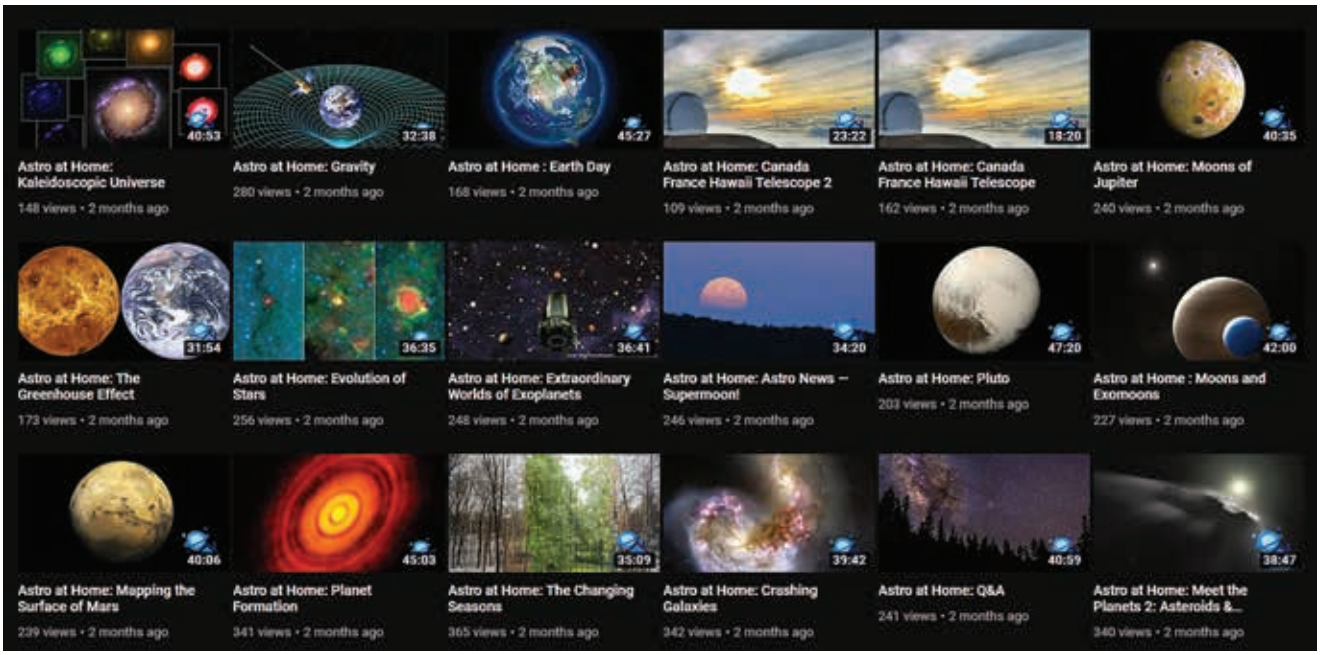

Figure 3. *Screen capture of some of the Astro at Home presentations. All Astro at Home videos are available on YouTube. Credit: Discover the Universe*

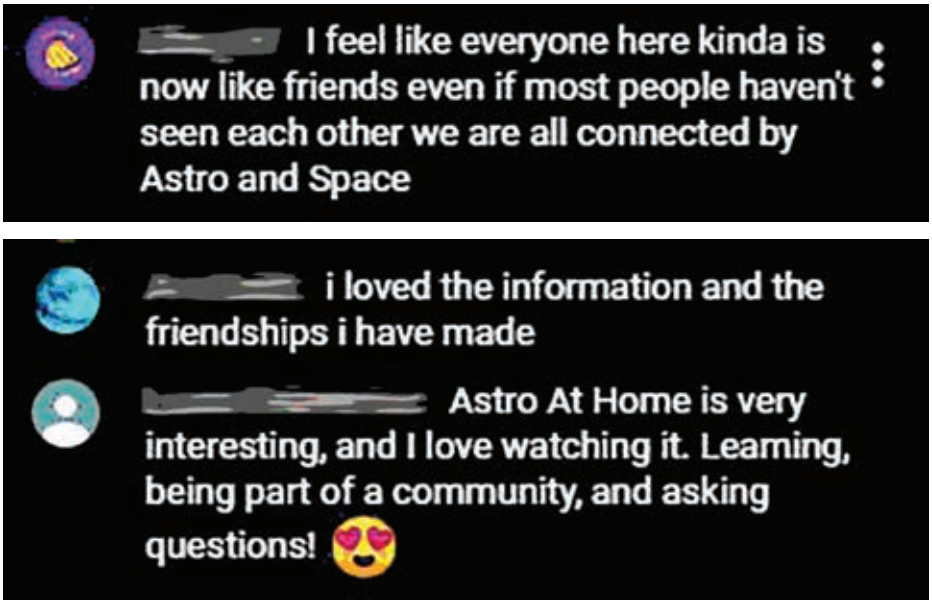

Figure 4. *Quotes from young participants on YouTube, creating a community together. Credit: Discover the Universe*

After the first couple of weeks, Astro at Home had self-propelled momentum. Speakers were much more comfortable and were happy to present at the last minute if changes were needed. The students became more and more familiar with each other and our guests, so the conversation in the chat flowed more freely. The moderators had a little less work as the audience diminished or opted to hide the chat function to focus on learning.

We were able to keep the programme running for a total of eleven weeks even though that seemed impossible in the beginning. Our run time was due in large part to that momentum we built, the amazing pool of volunteer speakers, and the relaxed approach we had taken to managing the series. We believe it was a success because of the passion for astronomy shared among all contributors and participants.

Our greatest success is probably the communities we inadvertently created. The engagement and feedback from our young participants were overwhelming. Many of them said they would pursue careers in astronomy, and thanked us for showing them all the amazing things our universe has to offer and teach us. On the final day, we were all overcome with emotion as these virtual learners said goodbye to us and each other. One viewer even said that she would thank our little programme as the seed that started her career trajectory when she became a famous astrophysicist.

The second community we created was actually with our speakers! For a few weeks, Astro at Home was a central hub for astronomy communicators. We welcomed volunteer speakers from various institutions across Canada: universities, research institutes, science museums,

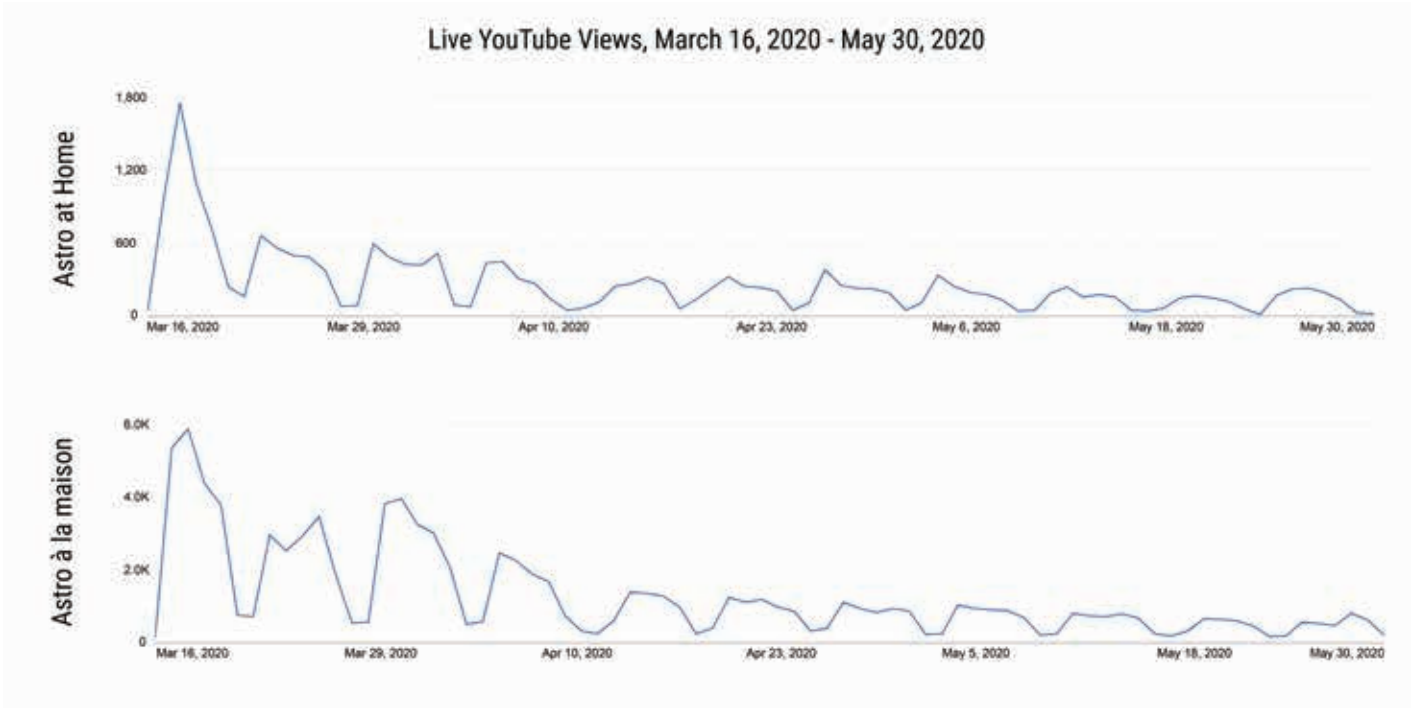

Figure 5. *Graph showing the viewership of Astro at Home over the 11-week run. Starting out strong, our numbers declined over time, but interest and engagement never waned. Credit: Discover the Universe*

planetariums as well as observatories in Canada and abroad (Hawaii and Chile). We had quickly launched a Slack channel where everyone involved in the planning and presenting could connect with each other. This Slack channel still exists and keeps us all connected.

Conclusion

What might have been an impulsive decision transcended all expectations, becoming a deeply meaningful and impactful experience for all involved. Since Astro at Home, we have seen more parents attending our workshops, and we have partnered with astronomy organisations to develop more teacher training and educational content. Discover the Universe has been presented with so many new opportunities for growth that we have now hired three additional staff members.

Astro at Home helped strengthen the Canadian astronomy community by connecting professionals to one another, and sharing the joy of the sky with young people. The programme also drew the attention of other organisations, who approached us to forge new partnerships for creating new educational content.

We have refocused on teacher training, equipped with new insights into engaging young learners. With the pages of questions they asked, we are inspired to create content that we know they will enjoy. In the next year we hope to publish a few more teacher guides, as well as new webinar content, and more.

We are still feeling the positive impact of our Astro at Home initiative a year later. It ended up being a greater outreach tool than we could have imagined and continues to be a catalyst for growing our reach and impact in astronomy education.

Notes

[1] Discovery the Universe website: https://www.discovertheuniverse.ca/

[2] Discover the Universe YouTube page: https://www.YouTube.com/channel/UCdfR3_eoqih4_VyYnxfzQng

Acknowledgements

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Biographies

Julie Bolduc-Duval is the founder and executive director of Discover the Universe. She has been involved in astronomy education and outreach for more than 20 years.

Lindsay Mann is the communications coordinator for Discover the Universe. With a background in the arts, she has been working freelance for science and heritage non-profits for more than 10 years.

Frédérique Baron is an astrophysicist with a PhD from the University of Montreal. She works as a scientific mediator and project manager for the Institute for Research on Exoplanets and the Mont-Mégantic Observatory. She also helps Discover the Universe on various initiatives, including Astro at Home.

Column

‘Planetarium@home’: Digital Astronomy Outreach During the Covid-19 Pandemic

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Keywords
crisis communication, immersive environments, sciencetainment

The Planetarium Bochum is one of Germany´s largest, most frequented, and modern multi-functional planetariums. It is known for programmes ranging from educational astronomy shows for adults and children, music concerts, and numerous live events covering scientific, cultural, and immersive live performances. When the German government decided to implement the first national lockdown in mid-March 2020, the planetarium´s communications team knew they needed to act quickly. They produced a consistent, educational, and entertaining digital offer to fill the gap of not having any visitors for an unknown length of time. Correspondingly, they came up with a range of digital activities under the content bracket, ‘Planetarium@home’, online and on the planetarium´s social platforms of Facebook, Instagram, Twitter, and YouTube. One activity that requires highlighting is the weekly video series ‘Streifzüge durch das Universum’, translated into ‘Expeditions through the Universe’, a highly edutaining science format delving into topics like ‘the possibility of life on other planets’ to last December´s Jupiter-Saturn conjunction.

Introduction

The main goals of the communications strategy of the Planetarium Bochum are to inform the public and advertise the scientific and cultural shows and events on offer, to establish, strengthen, and upkeep the perception of being a compelling site of live cultural events for its science and astronomical educational content. When the German government implemented the first national lockdown in mid-March 2020, the planetarium´s communications team acted quickly by producing a consistent, educational, and entertaining digital offer to fill the (visibility) gap of not having any visitors for an unknown length of time.

Planetarium@home

The Planetarium Bochum is one of Germany´s largest, most frequented, and modern multi-functional planetariums. It is known for programmes ranging from educational astronomy shows for adults and children, music shows, and numerous live events covering scientific, cultural, and other immersive performances. When the worldwide Covid-19 pandemic hit, the German government implemented the first lockdown, including the closure of cultural institutions such as theatres, cinemas, and museums. The planetarium´s communications team was as unprepared as others, but responded to this challenge by implementing proactive communicational strategies under extensive supervision. The first phase of communication includes the closure of the venue and sorting the basics, such as events and tickets cancellation, and informing about office opening hours (Figure 1) for refunds. The adapted strategic focus then shifted towards the question, how to remain visible and transport high-quality and valuable content while closed for visitors for an unpredictable period.

Figure 1. *Artwork for initial lockdown communication. Credit: Planetarium Bochum*

This challenge was met with a key visual element, namely, an addition to the logo (Figure 2) with ‘Planetarium@home’. This addition was simple and served two communication purposes:

1. To emotionally convey a continued presence while everyone was asked to ‘stay at home’ and shelter-in-place, and
2. A pointer to an expansion of the planetarium´s digital offers with the ‘@’.

`Planetarium@home´ became the brand to communicate all (educational) public

Planetarium
@home

Figure 2. *Planetarium@home logo. Credit: Planetarium Bochum*

Figure 3. *Artwork for the educational video series 'Streifzüge durch das Universum'. Credit: Planetarium Bochum*

Figure 4. *Artwork for 'Astro-Feeling für Zuhause'. Credit: Planetarium Bochum*

engagement and visibility activities while the planetarium remained closed. The Planetarium Bochum first had to close on 13 March 2020, after which it went to limited/regulated operations from 6 June to 26 July. From 27 July to 15 December, the dome auditorium and its technology were renovated and updated thoroughly - a well-planned measure before any notion of the woldwide coronavirus pandemic. The planetarium´s regulated re-opening happend over six months afterwards, in 17 June 2021 and is still ongoing according to German regulations concerning cultural institutes. Up until then, all expectations and visibility actions were met by the Planetarium@home actvities, thereby creating quality content with value for star-lovers and space-gazers who during that time could not visit the real-life dome. All activities listed here are specific to the communicational challenge posed by the pandemic, as communication and marketing measures did not instantly serve the purpose of informing and raising interest for the shows and events on offer. The focus shifted in keeping the planetarium visible and engaged, thereby strengthening its image and people´s relation to the place and its topics, and promoting free, entertaining, and informative astronomy content with pandemic-specific uplifting and solidary content and messages.

The activities planned and implemented ranged from YouTube formats to Instagram video series, online concerts, DJ-gig-premieres, and astronomy live streams. In the following list, we name and highlight a few of these activities:

- *'Streifzüge durch das Universum'* ('Expeditions through the Universe') is a weekly video series (Figure 3) posted on both YouTube and Facebook channels. 'Streifzüge durch das Universum' is a highly edutaining science format delving into topics, ranging from 'the possibility of life on other planets' to current events, such as last December´s Jupiter-Saturn conjunction. Typically, the 'mini-talks' are approximately 15 minutes long and come with various images. We switch between astronomical observation hints for the naked eye and binocular observations, recent research highlights, and occasional excursion into astrophysical basics such as stellar evolution or Black Hole physics.

- *'I Need Space: Unser Sonnensystem'* ('Our Solar System') is a six-part educational and entertaining lecture format with astrophysicist and science slammer Michael Büker, who used gimmicks such as avocado halves, muffins, and confetti to explain astronomical phenomena, catering to a younger audience. The videos were filmed in front of a green screen; the background was edited in post-production and visually expanded by freely available astronomy images from the NASA and ESO image libraries.

- *'Astro-Feeling für Zuhause'* (At-home Astro feels'. For special occasions, such as the Easter holidays 2020, when people had to shelter-in-place but assumingly had a longing to be entertained and educated, we decided to adopt two of our popular dome shows in a 360 degrees video format sold-out at regular ticket pricing and posted them online for free (Figure 4).

- *'Insta Space Facts'* is a weekly playful Instagram story format that gives a snippet of the 'Streifzüge durch das Universum' content combined with flashy bullet-point explanations, engaging GIFs, and precise info while linking to the longer and more educational original YouTube format.

- *'Sterne über dem Ruhrgebiet'* ('The Stars over Germany´s Ruhr District') is a monthly series in the online version

Figure 5. *Artwork for 'Astro Live Streams'. Credit: Planetarium Bochum*

Figure 6. *Artwork for the Instagram format 'Behind the Scenes: Show Productions'. Credit: Planetarium Bochum*

of the largest regional newspaper 'WAZ', explaining constellations and current astronomical phenomena with a short video, an explanatory text, and highlighting an object of the month.

- *'Astro Live Streams'*: With the updated technological possibilities after the planetarium´s renovation (see part 2), we offered different educational astronomy live streams from the dome, integrating live visual rides through the universe using the 'Uniview' software for the astronomical visualisations and the OBS suite software for live editing the stream in three different perspectives, while streaming via our YouTube channel (Figure 5).

- *'Behind the Scenes Show Productions'* and *'Behind the Scenes Planetarium Technology Tour'* were two Instagram story formats that invited the channel followers to virtually step inside and have an exclusive glance behind hidden doors and processes. It involves the actual production process of a new full-dome show (Figure 6) and a tour of the planetarium, including what it does and what it takes to make full-dome shows come alive on the screen with an on-site seated audience.

- Service topics: *'App and Telescope Check'* During the weeks before Christmas, we decided to introduce two service topics for potential amateur astronomers with testing astronomy and stargazing smartphone apps and various types and price ranges of hobby (and advanced hobby) telescopes (Figure 7). It, thereby, delivered added value for those Planetarium@home-users who not only wanted to receive information but were interested in exploring with the help of our professional guidance.

- Podcast *'Gemeinsam durch die Galaxis'* ('Crossing the Galaxy Together'). The podcast (Figure 8) is the newest

Figure 7. *Artwork 'Telescope Check'. Credit: Planetarium Bochum*

Figure 8. *Artwork for podcast 'Gemeinsam durch die Galaxis'. Credit: Planetarium Bochum*

Figure 9. *Artwork for music compilation series 'Apollo Mixe'. Credit: Planetarium Bochum*

communications venture that has long been pre-planned and emerged at the perfect time in mid-April 2021 when cultural institutes remained closed. In the general atmosphere of unrest and impatience (along with a third pandemic wave and ongoing vaccinations), the podcast contributed to an educational and highly entertaining audio format simultaneously that delves deeply into various astronomical topics in a chatty tone. The half-hour format is hosted by Prof. Dr. Susanne Hüttemeister, the Head of the institute, alongside Jochen Malmsheimer, a professional planetarium show speaker, regional satirical review star, and astronomy expert. They bring together an intriguing mix of topics and conversational approaches to complex scientific matters while catering to a general audience.

- *'Kulturkuppel'* ('Culture Dome'). A modern planetarium is more than a place of scientific education and entertainment. The range of live concerts, DJ gigs, digital art events, etc, has become increasingly important over the years. To honour this ever-growing programmatic side, we integrated concerts, DJ gigs, and astronomy-related music compilations (the 'Apollo mix' series, which can be downloaded from Mixcloud for free). (Figure 9) Whenever possible, we integrated 'pay-what-you-want' requests to support the local artists and thereby demonstrated solidarity.

Closed but Open to the Public Eye: Renovations During a Pandemic

The communications challenge met by the 'Planetarium@home' activities described above was heightened by the planetarium entering a remodelling and technology update in late July of 2020, which had been pre-planned for years. The venue remained closed, even beyond what the legislation demanded of the lockdown of cultural event sites. During the construction period, the @home-measures were flanked by exclusive 'sneak peeks behind the scenes'. It was achieved by working together with two micro-influencers ('Schichtmeister' and 'Ruhrpoet'), who focused on regional (cultural) topics and photography with two very distinct and complementary visual styles. (Figure 10 a), b), c)) For every construction milestone (be it the delivery of the new Zeiss Velvet beamers or a Christo-like wrap-up of the star projector in the dome´s centre), the two Instagram photographers developed unique posts

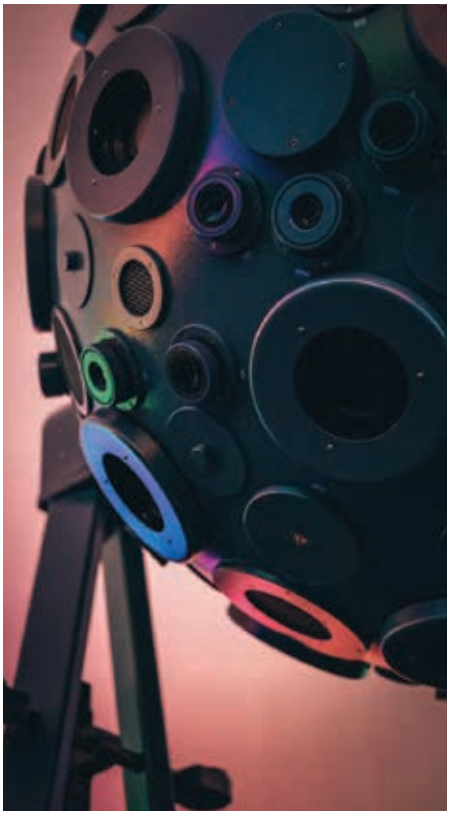


Figure 10. a) b) *and* ***c)*** *Behind the scenes construction photography for Instagram. Credit: Planetarium Bochum*

Figure 11. *Artwork for the 'Es ist nur eine Phase' campaign. Credit: Planetarium Bochum*

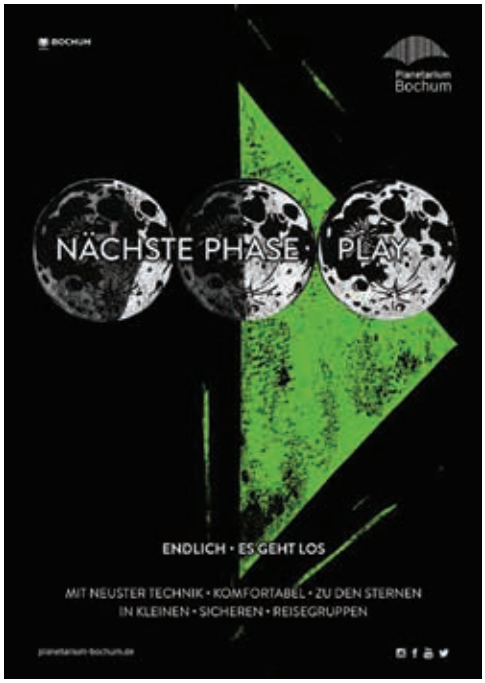


Figure 12. *Artwork for the 'Nächste Phase: Play' campaign. Credit: Planetarium Bochum*

and (video) stories that were shared on the planetarium´s channel, thereby inviting digital followers to a transparent, vibrant, exciting, and exclusive glance behind closed doors. The 'behind the scenes' appeal was also highlighted in two YouTube films featuring major advancements in the overall construction process and a time-lapse movie documenting the entire 5-month process in only 2.5 minutes.

It´s Just a Phase: Emotionalizing a Delayed Re-opening

By late December, it became clear that there was no possibility of planning, celebrating, and communicating a re-opening post-construction, but a whole new world (nay, universe!) of technological possibilities waiting to be used and shown to visitors. The communications team thereby developed a visual campaign (Figure 11) that works on several levels. 'Es ist nur eine Phase' ('It´s just a phase') is a lithographic design of the moon´s phases in black and white with a prominent red stop sign on it and a slogan suggesting, 'We are ready whenever we get a go'. The visual was hung across and in neighbouring towns, covering bus stations, prominent framed poster spots, and 'city lights', which are premium out-of-home advertisements and awareness spots. Therefore, while the planetarium had to remain closed to visitors, a reliable stream of astronomical and cultural output with the planetarium@home activities continued. The 'It´s just a phase' campaign managed to foster emotional connections and brand loyalty, and its supportive message, connected and drew old and potential future customers to the planetarium. The campaign succeeded in triggering interest, established an emotional connection, signalled solidarity in hard times, and guaranteed visibility. The second campaign wave exclaimed ´Nächste Phase Play´ (Next Phase: Play) for the re-opening in mind-June 2021, as the next step to connect to the first campaign motif (Figure 12), in this process underlining both the transitory nature of both astronomical phenomena and the global pandemic and the connected next step.

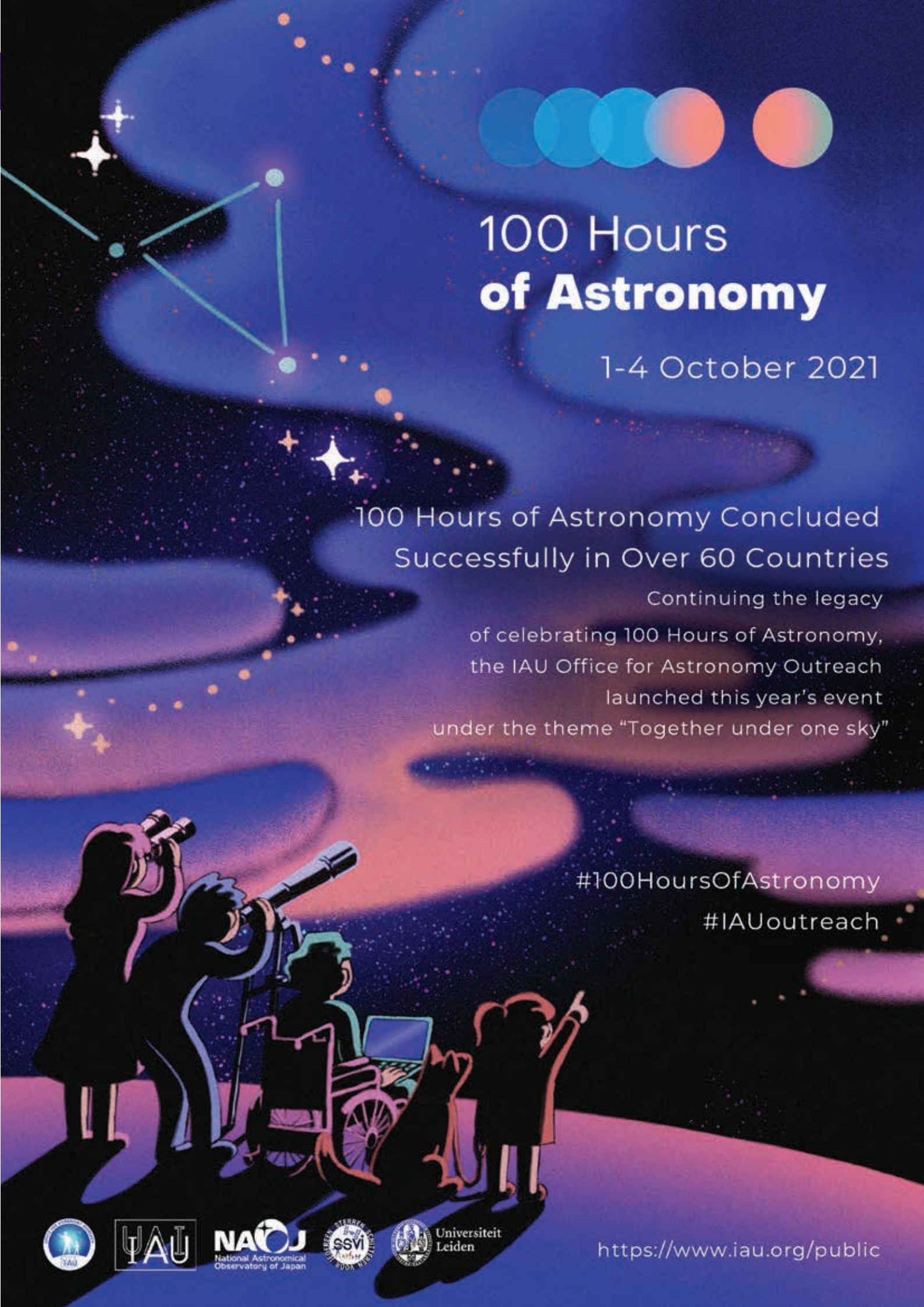
Final Considerations

2020 and 2021 prove to be the worst business years for a long time. However, during the continuous closure of the highly successful event venue, it is satisfactory that no time is lost sharing astronomical, educational, and cultural content to real-life visitors. With Planetarium@home, those who otherwise attend these shows in our dome auditorium, experiencing unique visual and sound travels to space establish brand trust, loyalty, and connection. We have managed to raise awareness and digital reach on all channels and create an active, responsive, emotionally and factually involved, interactive community in the process.

Biographies

Jennifer Christoph has a Master's degree in American literature and is responsible for the planetarium´s communications and marketing. Her communication career has focused on topics of science, technology, education, and culture. The planetarium encompassing all these aspects makes a perfect place to work for this communications all-rounder.

Susanne Hüttemeister studied physics and astronomy in Bonn and spent several years as a postdoc in the US and Sweden. She holds an adjunct professorship in Astronomy at Ruhr-University Bochum has been director of the Planetarium Bochum for more than a decade. She also coordinates a citywide network of STEM-related activities and organisations and is Vice President of the Association of German Language Planetariums.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