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Outreach and Education at the ICRC: Summary of the Rapporteur Talk

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Outreach and Education was included within the programme of the 37^{th} International Cosmic Ray Conference in 2021, the first time it has been in the 74 year history of this conference series. 40 abstracts were submitted for the topic, and presentations were delivered in two sessions under the themes of "Outreach Online" and "Schools and Tools". This paper summarises the contents of the rapporteur talk that was given in a plenary session to accompany these contributions. It does not try to précis all the individual contributions, instead it identifies common themes, ideas and issues when delivering science outreach. Outreach often involves education, but not always.

Five themes were identified: Facilities, Funding Agencies, Experiments, Communication and Inspiration. The last of these – Inspiration – does not necessarily directly involve the science, whereas the others do. Outreach is now an integral part of the scientific endeavour, and in the fields of the ICRC has been delivered to audiences ranging from scientists within the presenter's field to the public at large (whatever that actually is). The paper also includes some reflections on matters that should be considered before embarking on outreach, such as being clear about the audience you are trying to reach, as well as on the challenges of evaluating the effectiveness of outreach programmes.

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1. Introduction

The 37^{th} International Cosmic Ray Conference (ICRC), run from Berlin in 2021, was certainly a meeting quite unlike any of the previous 36 meetings, being held virtually as a result of the ongoing COVID–19 pandemic. It was also the first to have a section devoted to outreach and education, 74 years on from the first ICRC in 1947. As such, it marked a recognition that the communication of the science outside and beyond the discipline-specific audience of a front line scientific meeting is an important and integral part of its dissemination process, one that has to start with the scientists engaged in the field.

When Outreach was first proposed for this ICRC meeting it was, of course, not clear what the response would be. However, it was strong, 40 abstracts were submitted under the theme of Outreach & Education (O&E), a sufficiently large number that it was also judged by the meeting organisers that the topic merited a rapporteur talk as well as those for the scientific sessions. Hence this paper too, to summarise its contents.

Speakers submitted videos describing their contributions, to be viewed by attendees beforehand, as well as written proceedings for this Volume. The session was divided into two sub-themes, "Outreach Online" and "Schools and Tools", though there was often no clear category distinction for papers as they sometimes involved all these concepts. Two papers were included for plenary presentations, one in each session, on "Impact and Evaluation in Science Communication" by Ricarda Ziegler [8], and on "Cosmic rays and the structure of the universe studied in the Cosmic Ray Extremely Distributed Observatory (CREDO) with citizen science" by Robert Kaminski [4]. The former was an invited talk by the organisers, the latter selected from all the contributions submitted. There was also a related highlight talk given by Erika Labbé [6] on 'The advantages of making science accessible'.

This summary paper will not attempt to summarise the specific topics covered in all the O&E presentations, rather it attempts to bring together themes and ask general questions about the purpose and intent of education and outreach. It also considers the challenges of evaluating the effectiveness of outreach programmes.

2. What is Outreach?

We will begin by asking what is Outreach in regard to promoting and communicating science? Probably most of us would instinctively reply that it is connected with explaining science to the public, but there is no simple answer to this question. I therefore decided to examine this question by looking at the broad themes provided in the papers presented in the O&E category at ICRC. I could discern five themes in the submissions:

- Science Facilites
- Science Funding Agencies
- Science Experiments
- Science Communication

- Inspiration

Facilities covers telescopes and observatories informing of their existence and purpose. Funding agencies, generally national bodies, wanting people to know of the good work they do in facilitating the science. Experiments relate to a specific project getting a message out. Communication refers to telling stories of science, but not necessarily on a specific theme. Inspiration takes in wonder about nature and the cosmos, but it need not have any underlying message about the science (though often does).

Given this broad range of topics, and an equally a broad range of intended recipients, extending from scientists within one's field to those whose primary interests may lie in the arts and humanities, for the purpose of this paper I am defining Outreach as *communicating a message beyond one's peer group*. This often involves education, but it need not do. Outreach is conducted when there is a need to communicate some type of message beyond one's immediate collaborators.

2.1 Should you do Outreach?

So, should you be doing outreach?! A rhetorical question, of course we all need to be doing outreach, it's a question of what and how. Certainly outreach is much more than giving a public talk about one's own research. While indeed there is a time and a place for doing so, it can be easy to confine one's outreach activity to doing just this and believe it is sufficient. It is not, we all need to do more.

There is a duty on all scientists to communicate, we are nearly all funded, in some way, by public money and therefore need to be accountable to the public for how we have been supported. Outreach can be fun, it can be inspirational, it can even lead to new ideas by being forced to think about how to communicate a message. For it is also essential to consider carefully how to present that message, it needs to be delivered at the right level of language for the intended audience. This can be very challenging, for all fields have developed their own jargon which is essentially a shorthand for expressing concepts that don't need to be repeated to one's peers, but which can be completely foreign even for those in a related field.

For example, think about all the prior preconceptions we have when using the term "massive star" relating to whether the star is massive enough to end up as a supernova and the associated endpoints of stellar evolution. To the public, however, all stars are massive, even those only just on the edge of being able to undergo nuclear fusion, i.e. the low mass stars to the astronomers. Yet I haven't really found a good way to convey this concept succinctly to a public audience, I still end up saying "massive" when the terminology doesn't really convey true meaning to the audience.

Your ability to do outreach, however, will depend on the resources available to you and/or your organisation. Even with all the enthusiasm in the world, communicating needs to be tempered by what is practical, what is achievable given your position, circumstances and the available resources. Sometimes you will want to tell the story of a new discovery and your part in it, after all you have mostly likely been inspired by what you have found and want to tell others about it. However, often it is the case that this discovery is abstract, is very hard to convey outside one's peer group. It may be better being part of a broader collective, communicating general messages of science, but not those of one's specific research endeavour?

2.2 Why are you doing Outreach?

It is therefore worth asking yourself the question of why are you doing outreach? Presumably it is because you want to communicate a message beyond your peer group, i.e., related to the definition I have given above for outreach. However, who is "you"? While it may actually be you, yourself, more normally it will be because of your role in a wider collective. That collective may be the research team you are a member of, or perhaps a research group in your institution. It may be the institution or the facility you are part of, or even the funding agency that has supported you. It may also be a public or government body that you are distantly associated with.

In other words, the reason you are doing outreach can and will vary as to where you fit within this spectrum at any moment of time. All are valuable and valid reasons, all are necessary, and over a career you are likely find yourself reaching out to audiences while representing many of these distinct groups. Outreach is an essential part of doing science today, but takes many forms.

3. Education and Outreach at the ICRC

I will now look more closely at the range of O&E contributions at the ICRC. Table 1 expands on the five outreach themes listed earlier, breaking these down further into the different audience groups they were targeted towards.

Table 1: Outreach Themes at the ICRC in 2021

Theme	**Audience**
Science Facilities	Users
('Telescopes')	Scientists
	Visitors (inc. virtual)
	Education: School visits
	Publicity
(Science) Funding Agencies	Justifying Investment
	Education: High School + Teachers
	Experiments: Students (esp. virtual!)
	E&O Workshops
	Tools
Science Experiments	Citizen Science [data collection]
	Zooniverse [data interpretation]
Science Communication	Scientists ↔ Public
Inspiration	Society
	Tourism
	Sustainable Development

Under Science Facilities, this ranged from scientists (including users of the facility) accessing publicly available data, to visitors to the facility (in particular, virtual tours, as has become necessary under the COVID-lockdown), to providing publicity about the facility itself. For some facilities school visits are of special importance, and can involve providing suitable educational material related to the curriculum that teachers need for teaching classes.

Science Funding Agencies increasingly need to justify, and be seen to justify, their investments in the facilities they support, fund and facilitate. This ranges from ensuring the facilities are known about outside their user community and what they do, to providing a range of educational opportunities arising from them. This latter aspect usually focuses on high school science students (and their teachers) and providing support for the curriculum arising from studying the facility and/or the type of science it conducts. It also includes undertaking experiments that are connected with the science of the facility. For cosmic rays, since these can readily be measured in a classroom setting, there were several presentations describing how these were set-up and conducted. It may also be necessary to provide the relevant experimental apparatus to the teacher to use ("tools"), this was discussed in related presentations. While not directly Outreach, these activities are closely connected as they make some forms of outreach possible. Finally, in this category I include funding workshops by the agencies which bring students (and, again, their teachers) together to learn about an area. Of course, given COVID, these workshops needed to be virtual over the past year. While this meant, of course, that the invaluable in-person element was lost, it has also given many more students the opportunity to participate in these endeavours.

Presentations on the theme of Science Experiments covered both citizen science in undertaking data collection (with some overlap to the experiments aimed at high school students, above), and the data interpretation involved in the people-powered research platform Zooniverse[1] where (generally) the participants are transcribing or interpreting a piece of evidence.

Science Communication encompasses the more traditional ways of outreach, where scientists are directly describing or discussing science in some form of public forum, often also interacting with the audience. While this might be via a talk, the presentations at ICRC in this area looked at more sophisticated and inclusive forms of communication, often involving groups of scientists coming together to communicate ideas or concepts in bite-sized chunks, including interacting with the public to determine what it is they would like to know more about.

In the final category of Inspiration I have included presentations where science provides the inspiration, but the science itself is not the focus. It is wonder about the cosmos or some natural phenomena, the quest for knowledge, rather than the new knowledge itself, that is the primary motivation. This can also include the tourist potential of bringing people to places where they experience that wonder, often to isolated and remote locations where telescopes and observatories might be because of their science requirements. These may also be in non–OECD counties, wherein there are the possibilities of supporting sustainable development through the income brought in via tourism, as well as in the ways the facilities go about their operations (e.g. through the provision of renewable energy to power them).

Table 2 summarises some of the activities for one representative presentation under each of these themes, as an illustration of the types of presentations delivered at ICRC. However these are but a snapshot, I encourage the reader to look at the programme to see what else was presented.

4. Know your intended Audience

There is no one form of outreach suitable for all to whom you want to deliver a message. Outreach needs to be tailored to the particular audience you are trying to reach. It is therefore

[1] https://www.zooniverse.org

Table 2: Illustrative Outreach Presentations at the ICRC

Theme	Title and Lead Author	Comment
Science Facilities	'Outreach, Education and Communication Initiatives of the CTA Observatory', Alba Fernández-Barral [2].	Describes an extensive range of outreach activities being undertaken by a new observatory, the CTA, as part of its development. Audience ranges from communicating with the scientists in the consortium to the public at large via presentations. Activities include education and the provision of a variety of multi-media resources.
Science Funding Agencies	'Discovering cosmic rays with OCRA: outreach activities for students and teachers', Sabine Hemmer [3].	OCRA – Outreach Cosmic Ray Activities, a programme aimed at high school students in Italy, where the students participate in experiments to measure the cosmic ray flux. One of several presentations from Italy around this theme, facilitated by the structure of the school physics syllabus in Italy that motivates teachers to seek out such activities for their classes.
Science Experiments	'Cosmic rays and the structure of the universe studied in Cosmic Ray Extremely Distributed Observatory (CREDO) with citizen science', Robert Kaminski [4].	Describes an innovative science experiment which requires science popularisation in order to collect its data. Uses citizen science to study cosmic ray air showers globally through an extended detector network around the world – mobile phones with a specialist App installed. Seeking to discover the phenomena of super showers.
Science Communication	'2 minute science: A Science Communication Project for Astrophysics', Dimitrios Kantzas [5].	A programme bringing together ECR researchers in Greece to give science talks and write science articles, aimed at public audiences. Both the talks and the reading time for the articles must be no more than 2 minutes! Seeking to stimulate interaction between the public and the scientists when choosing the topics, while also catering for short attention spans.
Inspiration	'Astro-photography as an effective tool for Outreach and Education: IACT in exposition', Simone Lovenitti [7].	An astrophotography exhibition for communicating to the public. Aimed at inspiring through beautiful and awe-inspiring photographs of the sky, some also including telescopes and instrumentation, and in particular Cherenkov telescopes. While the images can be viewed simply for their beauty, each also had an accompanying description written by a scientist explaining what was shown.

important to consider right at the start who or what is the intended audience? This will depend on what your goals and intentions are. While not necessarily explicitly mentioned during the presentations at ICRC, I outline below some of the intended audiences I discerned from these talks. They can require quite different approaches, for while the theme of a presentation may be the same for several different audience groups it still needs to be delivered with a different emphasis and content for each of them. These include:

- Other physicists and/or astronomers. Often we find ourselves preparing for this audience even when they are not the intended recipients of the message, for it is the audience we know best and perhaps tacitly seek approval from, even when the presentation is billed as a public talk. However, there are also times when the message does need to be given to this audience, they are not your immediate peers, but you want them to be aware of some facet or opportunity or

development in your field.

- Other scientists, outside of your discipline, yet still knowledgable about its broad subject area.
- Other academics, in particular within a university environment where you may need to enthuse those in other Faculties to gain support for a programme.
- Education – when your message is primarily being delivered as a form of education, but quite how depends on who is receiving it, for instance:
  - Prospective post-graduate or under-graduate students, i.e. potential researchers of the future you are seeking to attract.
  - High schools, in particular towards their science students. Generally this will be curriculum driven, teachers are very focussed on having to get their classes through the syllabus and may be looking for help to do so. But are you talking to general science students, or is it a physics class? Are they the top students of the year (i.e. prospective researchers of the future)? Your presentation would likely be pitched differently for each of these groups. So it is important to be clear which it is when preparing your material and deciding your approach. It is also resource intensive to deliver outreach at school level. There are many schools but only a few people available to deliver. Judicious choices need to be made about where effort should be applied.
  - Primary schools, where the intent is largely to inspire and perhaps a sow a seed for a future scientist. Here the message needs to be general, it is too early in the child's education to be trying to push them into a specific discipline.
  - Teachers. Often neglected, it is easier to speak to the children, but this audience might provide the greatest gains? Teachers can be the most important factor in influencing the next generation. You can only reach a few children personally, and only for a limited time. The teacher will spend many hours with their classes, an inspiring teacher can be the biggest influence on their career choices. It is much easier to reach several teachers rather than many, many students, and then you use the multiplier effect of those teachers to spread your message further. So think carefully about what the teacher needs, they are often looking for resources to help them teach the more prosaic parts of the syllabus. If you can tailor your material to provide what they need you have more chance in influencing the teachers so as to influence the students. Contributing to, or even running, teacher development classes, is one way of reaching this audience.
- The Public. This has to be in the list, we are always trying to reach the Public, though there is actually no such group. At some level you are wanting to deliver a broad message about the excitement of your science, it is the "public" this message is for.
- Funding Bodies. The message is now specific, it is to a grant awarding body, but here I am not referring to grant proposals and the review panels formed to assess them. A message might need to be delivered before the grant writing stage, that a field is exciting, that there are opportunities to explore, that the funder should be interested in supporting it.

- Stakeholders. Here the message is more likely coming from an organisation, but this does not necessarily mean that it has to be corporate, even if stakeholders suggests corporate image. An academic body, whether it be university, research organisation or observatory, will have many other people and bodies that it interacts with, in addition to the students and scientists who use it. They need to know about the good work you do, but they don't need to know all the detail. Think carefully about what is is the stakeholders need to hear and how that message should be delivered.

- Politicians and their minders, at national, regional and/or local level. Beyond the stakeholders there will invariably be the political support that keeps the funding flowing for an academic organisation to continue, and in particular for the science to be supported. The connection may seem distant, few practicing scientists actually get to interact with politicians on more than an occasional basis. Nevertheless, an institution will ultimately require political support for its continued existence. Outreach provides a means of helping secure that support, but the message needs to be carefully tailored to the audience. You are likely to need help in playing your part in delivering it, there are skill sets involved that scientists are unfamiliar with. So, if your institution director asks for your participation in some seemingly obscure event, there may be a long game at play, you are contributing to your organisation's future health (and so to your own prospects), even if it may not be immediately apparent to you quite how. Finally, do not forget the minders, they can be the source of greatest influence on the politicians. Talk to them too if the opportunity then arises.

5. Issues for Consideration

When delivering outreach there are thus many issues to consider regarding how you reach out and communicate with your audience. For outreach and education is also a compromise, you can cover only a fraction of the available material you may have, it needs to be tailored for the intended audience. In this section I would like to raise some matters you should consider when preparing your activity.

Pitch at the right level – be "not wrong". Researchers rarely are born communicators, we invariably feel we need to provide more detail to justify an argument. In a seminar, perhaps yes, but in outreach, almost certainly no! Almost inevitably it will serve to confuse and result in the audience stopping paying attention. A common mistake is to want to bring in the specifics of one's own research, for instance to show a plot or figure which demonstrates the science, the new result that has been painstakingly achieved, believing one can explain the essentials in an understandable way. Almost always, unfortunately, this will result in your losing the audience. It is just about impossible to explain a graph without significant prior knowledge (axes, in particular, will lose nearly all). An outreach presentation is an exercise in simplification, rather than trying to get all the facts precisely right, it is better to be "not wrong" and still keep your audience enthralled.

Share resources in order to communicate. Outreach can be fun, but it can also be exhausting. It can also be a significant drain on time. We need to be wise about how we expend our efforts. Can you collaborate or share resources to conduct your outreach? Perhaps there is a Faculty or Institutional level publicity department in your organisation, can you work with them to deliver

your message? Of course, this will result in compromises, you may now just be a small cog in a big wheel. You may have to fight hard to ensure your message is not too diluted, otherwise, rather than be "not wrong", it might actually become wrong when finally delivered. Maybe a more fruitful course of action will be to team up with people in your field from several other organisations to deliver your message? It might even be possible to find funds to do so if the idea is pitched correctly.

Be aware there are likely to be ulterior motives, but still embrace them! You might only want to deliver a message about the wonderful science you are doing. Your institution might like you to do so too, but in a carefully controlled way. Your motive is the science, theirs might be more pedestrian, to ensure that budgets are not cut. You can help the institution, and importantly the institution is helping you, even if it is not immediately obvious as to how. As scientists we are always part of a wider team, even if we think we do our work alone or in small groups. Be aware of the wider picture, and your role in supporting it.

Social media is now likely to be an integral part of delivering outreach. That does not necessarily mean that you as a scientist should be doing the social media, it takes significant time and effort, it needs to be done carefully, it does not suit everyone. Others may be better at delivering it, but they will need your input to do so. Social media provides new opportunities for delivering messages, but it also presents threats, bad publicity can easily result if a posting is put out too quickly and not thought through. It can happen anyway, even if it is. Social media now plays an important role in accompanying outreach, but it needs to be planned, it needs to be part of a strategy, quite possibly at organisational level. Be aware, too, that there will be organisational needs when doing your social media, it is not just about your science.

6. Evaluation

The O&E session at ICRC featured an invited talk by Ricarda Ziegler on 'Impact and Evaluation in Science Communication', as mentioned earlier. I will end this paper with some thoughts on this topic. We all know evaluation in some form is necessary, after all we do need to know how well we are doing, learn from what we did, and to make changes accordingly and so improve. This applies across life, not just in the delivery of outreach and education. However, the question here is how does one evaluate outreach in a useful and meaningful manner? I don't have definitive answers to this question, I don't think anyone does, but it is a process we need to pay attention too.

On a practical level, evaluation is often a requirement of the funding, you will need to provide a report to your sponsors on a project's completion, so you will need to have a plan at the application stage. Evaluation is also often a recommendation of a review committee. Though sometimes, it has to be said, this can be a stock response of a review, an easy recommendation for a committee to make, but one that is not necessarily so easy to implement. For good evaluation is hard to do.

Trivial evaluation is simple to do, but is unlikely to be useful. For instance, you can pose a series of questions like "did you enjoy the activity", "would you come again". Easy to answer, they generally result in positive responses that can be reported in your final grant report. However, positive responses here don't really tell you anything insightful, they are not particularly useful. Of course, if you do score poorly that does need to be considered, why was that the case and how can you improve?

Deep evaluation is, however, hard, if not impossible to do. The essential problem is how to separate out the contribution of the activity you have delivered to the overall outreach and learning experience? You can't, no single activity has a stand-alone effect, it is a part of a continuum the participants have experienced over their lives, all of which are different for each person. Of course, one might bias the results of a survey by conducting an exercise in a field the participants are not likely to have been exposed to beforehand, then ask questions of it before and afterwards. It would then be unusual if the participants didn't demonstrate some superior knowledge after, but that is very likely to be temporary and not meaningful. You would need to come back after one month, one year, or more, to test again to see if there is a long term beneficial effect.

Interaction between practitioner and participant, both during the activity and afterwards, is the most likely methodology in guiding the practitioner to how well they did. But this is a gut feeling, it is not quantifiable, unfortunately it has no weight when preparing a grant application. Nevertheless, it is invaluable. From these informal and unscripted interactions we can learn much regarding whether we have been successful. Unfortunately, much of this has been lost during COVID, Zoom does not work well for facilitating such interactions, though of course it is better than not having Zoom at all.

I will end by listing some of the issues associated with quantifying and improving science communication in the delivery of outreach. I do not offer answers to them, I present them merely as areas that practitioners in this arena need to be aware of and to consider when they are conducting their work.

- *The balance between quantity and quality.* Delivery to large audiences might tick boxes but can be superficial. But quality generally requires significant resource and effort, it can only be delivered to a few.

- *Professionalism in Science Communication.* The field can provide a career for many, it is not just an add-on to research. We are being judged as we deliver, and need to ensure we apply professional standards as we do so.

- *Seeking hard evidence not interpreting dodgy data!* This is at the core of the challenge of evaluation for Outreach. Have we generated data on the topic that is meaningful to try and interpret? As scientists we should be able to appreciate the nature of the problem, though that does not always mean we are able to solve it. But we should at least try to avoid creating meaningless data when conducting our evaluations.

- *How to determine and measure impact?* Impact is the long term outcome of outreach, positive impact is what we are seeking. But how do we measure this and can we assign any of the gains so determined to the activities we undertook?

To conclude, I will refer to a slide in Ziegler's talk which outlines the variety of evaluation that might be associated with a project. In a successful endeavour consideration needs to be given to these during project design, in its implementation and afterwards. These are (i) the front-end phase, as the project is being designed and proposed, (ii) the formative phase as the project is being delivered, (iii) the summative phase at the end of the project, for instance associated with its final activity(ies), and (iv) the impact – post-project – and the long term outcomes. There are not simple,

straightforward answers here, not all these phases may be applicable for your project. The onus is on you as the practitioner to give thought to this and decide where effort should be applied, based on the resources available and the importance of the outcomes to you.

Acknowledgments

As the rapporteur for the O&E session, I am honoured by the session's organising committee in inviting me to give it. I wish to thank them for their trust. For, while my own career has involved significant contributions to both education and outreach, I am new to the field of high energy and cosmic rays, my own science having focussed on the low energy universe of molecular clouds and star formation.

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