CAP journal
Communicating Astronomy with the Public
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The Edge of the Sky
Explaining All-There-Is with only the most common thousand words

When Astronomy Gets Closer to Home
Why space weather outreach matters

Crowdfunding your way to success
Lessons learned from the UNAWE Universe in a Box crowdfunding campaign

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This poster illustration for ESA's *Rosetta* mission shows the deployment of the *Philae* lander to comet 67P/Churyumov–Gerasimenko.
The *Philae* lander successfully landed on the surface of the comet on 12 November 2014.
This image of the comet was taken with the navigation camera on *Rosetta*.
Credit: ESA/Rosetta/NavCam

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Cover: On the cover of this issue is an image taken during the ESO Ultra HD expedition. It depicts several of the Atacama Large Millimeter/submillimeter Array (ALMA) antennas and the central regions of the Milky Way above. Mars is visible in the lower left of the image with Saturn slightly higher in the sky towards the centre. More information on the exhibition can be found in the article on page 33. Credit: ESO/B. Tafreshi (twanight.org)

Editorial

As 2014 draws to a close the 16th issue of the *CAPjournal* finds itself on your shelf — or screen — just in time for some Christmas reading.

This year has been an exciting one for the astronomy community. ESA's *Rosetta* flooded our Twitter feeds and grabbed the attention of the media, as future missions like the James Webb Space Telescope and the European Extremely Large Telescope gathered momentum. Far from succumbing to complacency in the face of such self-selling projects the communicators of astronomy are showing their knack for innovation, as exemplified by ESA's film *Ambition*.

Whilst editing this issue of the journal I had the pleasure of being a guest at the Space Telescope Science Institute in Baltimore, USA and the fortune to work shoulder to shoulder with their outreach team.

They are one of the many teams striving for ever more creative initiatives to bring astronomy to wider and more diverse audiences. The experience left me buzzing with excitement for what the next few years has in store, and, from a personal perspective given my role as ESA/Hubble press officer, for Hubble's 25th anniversary celebrations next year.

But the community of astronomy communicators goes far beyond those of us in observatory and space agency press offices. The strength of the *CAPjournal* is its role as a common forum for everyone working in the field. From those writing the press releases, to those bringing tools for outreach to underprivileged communities. From the "sit-and-writers", to the "go-and-presenters", and everything in between.

In this issue you will find articles discussing the value of science communication training for scientists, the best practices when looking for crowdfunding, the process of capturing the night sky in Ultra HD and the logic, or lack thereof, behind stripping astronomy engagement of its maths.

I make particular mention of the book *The Edge of the Sky*, the subject of one of this issue's articles. As science communicators we occasionally assume that to find innovation in outreach requires projects above and beyond the page, but here is an example of written communication as innovation in itself. I highly recommend that you read it.

If you have any comments, feedback, or wish to send a submission or proposal of your own for our upcoming issues, do not hesitate to get in touch: editor@capjournal.org.

Many thanks once again for your interest in the *CAPjournal*, and happy reading,

Georgia Bladon
Editor-in-Chief of CAPjournal

Submit articles for one of the following journal sections:

- **News**
- **Explained in 60 Seconds**
- **Announcement**
- **Best Practices**
- **Research & Applications**
- **Column**
- **Review**

Explained in 60 Seconds: The event horizon and the fate of fish

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Keywords
Event horizon, black holes, analogy, spacetime

Every time a physicist says the words “event horizon” a fish dies. It’s not nice and it’s not fair, but there we are.

We should perhaps expect a certain masochism in the type of person who chooses to dedicate their life to studying something so impenetrable as black holes and the fact is that no physicist has ever explained why a black hole is black without using the same fish-killing analogy. An analogy that I will, with wild abandon and an almost sadistic lack of concern for fish-kind, share with you now.

If spacetime is like a river, spacetime at a black hole is like that river flowing over a waterfall. Everything moves through spacetime, wriggling through the spatial elements and following traditionally straight paths through time. That includes light, our precious bringer of information about the Universe. Like a fish swimming down a river, light travels in a straight line through spacetime, oblivious to the larger pattern that guides its journey.

As the river speeds towards the sheer cliff face perhaps the fish realises that it’s meant to be at dinner upstream. If it’s above the crest of the waterfall and in good enough kip to swim faster than the speed of flow, it will swim merrily away. However, once the water flows over that crest and plummets down towards the base of the falls, our little fishy is beyond redemption. It will never be able to swim fast enough through the flow to get back up.

That’s the event horizon. Outside, light can escape the black hole’s pull — flying faster than spacetime flows into the hole. But inside, spacetime “falls” faster than light travels. Escape is denied — and the result? An area in space we can’t see, and several very, very, dead fish.

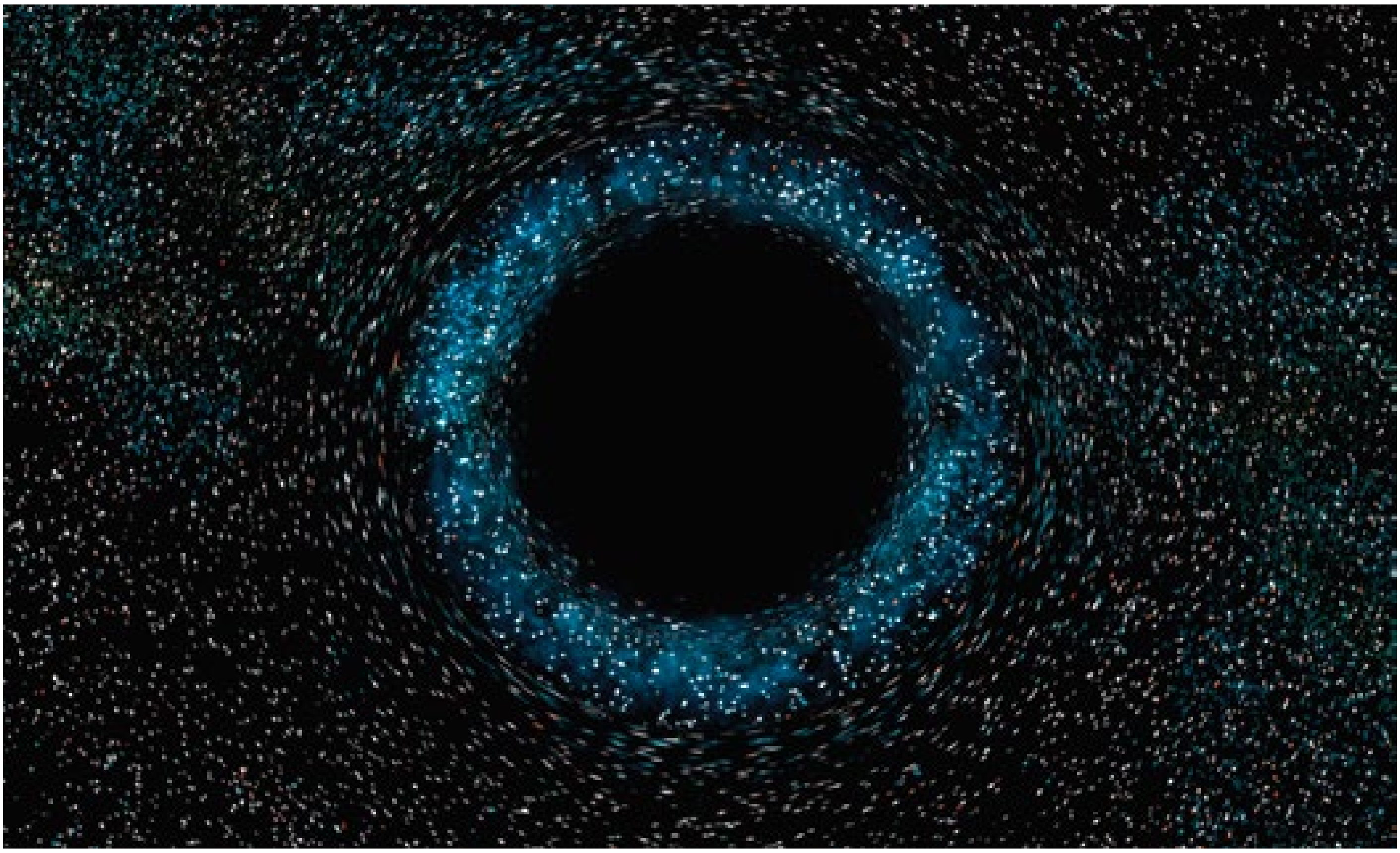

Figure 1. *Artist’s impression of a black hole. Credit: ESA, NASA and F. Mirabel (the French Atomic Energy Commission & the Institute for Astronomy and Space Physics/Conicet of Argentina)*

The Power of Simplicity: Explaining All-There-Is with the most common thousand words

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Keywords
Storytelling, flash-fiction, common language, astrophysics, cosmology

Summary

The book *Edge of the Sky*[1] recounts the story of the Universe — All-There-Is — and its outstanding mysteries by following a female scientist — Student-Woman — as she spends one night observing distant galaxies — Star-Crowds — with the help of a giant telescope — Big-Seer. The story is written using only the most common 1000 words in the English language. In this article author and astrophysicist, Roberto Trotta, reflects on how he came to write the book, why he chose this format and what he has learnt along the way.

A momentous discovery... or is it?

In 1965 Arno Penzias and Robert Wilson published a short article in the *Astrophysical Journal*, barely over a page long. The article was entitled "A Measurement of Excess Antenna Temperature at 4080 Mc/s" and behind its cryptic title lurked one of the greatest discoveries of all time. They had found the cold light left over from the Big Bang, evidence that the Universe had a beginning in time — not something easily gleaned from the title.

Fast-forward to 4 July 2012 when Joe Incandela, the spokesperson for the Compact Muon Solenoid (CMS) experiment at the European Organization for Nuclear Research (CERN), announced to a packed auditorium:

If we combine the ZZ and gamma-gamma, in the region of 125 GeV they give a combined significance of 5 standard deviations!

As everybody cheered — and Peter Higgs shed a few tears — it was not immediately obvious to anybody but the particle physicists in the room what the significance of this was. What Incandela had just revealed was that they had discovered the Higgs boson, the "God particle" that gives mass to all other particles. But, for the public at large to partake in these momentous discoveries, nothing short of a translation would do.

Public communication enemy number one

The obvious enemy to a clear communication with the public is jargon. As scientists, we are guilty of slipping back into it all too often, sometimes involuntarily. The above two examples were cases of scientists writing for or talking to their colleagues, and so in fairness they might not be expected to use language that a non-specialist would understand.

But as fundamental science is funded with taxpayers' money, I believe it is the professional scientist's duty to engage the public in a two-way discussion about their work, its objectives and the very reason for its existence.

The first obstacle to this aim is jargon.

As an astrophysicist with a passion for communicating with the public, I have been looking for novel ways of engaging new audiences with my science. For over a decade I have given public lectures to a wide variety of audiences; worked with film-makers, artists, designers and architects to create videos, artwork and installations inspired by cosmological ideas; and, most recently, as part of my Science and Technology Facilities Council (STFC) Public Engagement Fellowship, using cookery and food to approach astrophysics and cosmology with young audiences in a hands-on way[2].

Figure 1. *The Student-Woman and Big-Seer, under a sky full of stars. Credit: Antoine Déprez*

Figure 2. *The Star-Crowds are running away from each other, as the space between them gets bigger and bigger. The All-There-Is is growing with time. Credit: ESA/Hubble and NASA*

I now realise that for all this time I had been searching for a language to translate the often complex and abstruse cosmological concepts involved in my research — dark matter, dark energy, the Big Bang and the fundamental nature of the Universe — into something more pictorial. A language that would speak not only to people's minds, but most importantly to their emotions. My hope was to bridge the technical knowledge gap that is so often a barrier to genuine two-way dialogue between science professionals and the public.

Learning that less is more

There is an apocryphal story about Ernest Hemingway that has been a source of fascination for me for a long time. It is recounted that one night, around a dinner table, his friends challenged him to write a novel with only six words. After a moment of reflection, the great novelist grabbed a napkin and on it he wrote:

For sale: baby shoes, never worn.

His friends readily conceded the bet.

I loved the immediacy of what would later be called flash-fiction. Its economy of words leaves space for the readers' imaginations to fill the gaps — indeed it demands it. Somehow, this seems to promote a stronger, more active engagement on the part of the reader.

So I asked myself, was it possible to achieve something similar with science?

Then, in January 2013, I stumbled across the Ten-Hundred Words of Science challenge[3] — a website collecting descriptions of peoples' jobs written using only the most-used 1000 words in the English language.

The format had come from a cartoon by Randall Munroe, the creator of the xkcd website[4]. This is a humorous site with original, geeky stick-like cartoons, often revolving around physics, maths, computer science and other technical subjects. Randall had drawn a picture of the Saturn V moon rocket — or Up-Goer Five — and labelled its parts using only the 1000 word list. With this sparse vocabulary the escape pod, for example, became:

Thing to help people escape really fast if there is a problem and everything is on fire so they decide not to go to space.

I could see that this could be fun.

I spent a frustrating hour writing up my job with the 1000-word lexicon, and I found it harder than I had imagined. I posted a copy on my website, then forgot about it. The next month I gave a public talk at the White Building — an art venue in East London. The person who introduced me mentioned that he had found this unusual description on my website, and a member of the audience brought this up at the end — what was this business with the 1000 words about, exactly?

I read out the couple of paragraphs I had written:

I study tiny bits of matter that are all around us but that we cannot see, which we call dark matter. We know dark matter is out there because it changes the way other big faraway things move, such as stars, and star crowds. We want to understand what dark matter is made of because it could tell us about where everything around us came from and what will happen next.

To study dark matter, people like me use big things that have taken lots of money, thought and people to build. Some of those things fly way above us. Some are deep inside the ground. Some are large rings that make tiny pieces of normal matter kiss each other as they fly around very, very fast — almost as fast as light. We hope that we can hear the whisper of dark matter if we listen very carefully. We take all the whispers from all the listening things and we put them together in our computers. We use big computers to do this, as there are lots and lots of tiny whispers we need to look at.

I go to places all over the world to talk to other people like me, as together we can think better and work faster. Together, perhaps we can even find new, better ways to listen to dark matter. Most of them are good people, and after we have talked we go out and have a drink and talk some more.

I was surprised by the unexpectedly strong, positive reaction of the audience to these few paragraphs and it got me thinking that perhaps this was the new language that I had been looking for! Perhaps it could even be used to talk about everything in the Universe, not just my job.

The Edge of the Sky is the result of that small Eureka moment.

A new language

Over the next three months I dutifully sat down at my desk at the University of California Santa Barbara — where I was free of teaching duties during a research stay — and spent some time every day wrangling with the difficulty of talking about the Universe using only the most common 1000 words.

The first hurdle was to find a new word for Universe, which was not in the list. So it became the All-There-Is. A planet became a Crazy Star; a telescope, a Big-Seer; scientists were Student-People; our galaxy the White Road; the Big Bang the Big Flash — after my editor vetoed my earlier choice, the Hot Flash! — and other galaxies became Star Crowds.

As this new language started to emerge, little by little a new voice took over. It was a voice that I hadn't anticipated, and that was created by the poetic straitjacket imposed on me by my chosen format.

Not only did I find that limiting my lexicon to the most-used 1000 words swept the table clean of jargon, as I was sure it would, it also forced me to think afresh about seemingly familiar concepts. I was pushed to describe them in a more pictorial, metaphorical way and this gave me a fresh, childlike perspective on the Universe.

This is particularly important when talking about concepts that might be familiar to us — the professional practitioners of our discipline — but that are very far-removed from the everyday experience of the general public. We tend to get lulled into a false sense of comfort, by using terms that we mistakenly believe non-scientists understand the same way we do, like galaxy, electron, or black hole. So why not get rid of all those words and instead use simple language that everybody can understand?

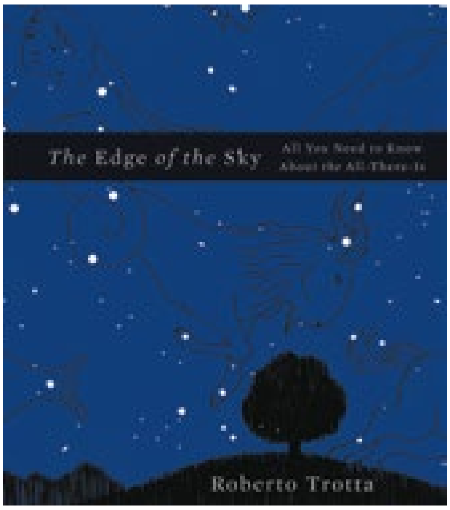

Figure 3. *Cover of* The Edge of the Sky. *(Basic Books)*

The All-There-Is in 707 different words

In *The Edge of the Sky*, I've tried to follow Einstein's advice, who reportedly once said:

You do not really understand something unless you can explain it to your grandmother.

And, a mere 707 words from the 1000 words list is all that I ended up using to do that.

The book tells the story of a Student-Woman who spends a night observing faraway Star Crowds with the help of Big-Seer, looking for dark matter.

She steps outside into the cold night, holding her cup of hot coffee with both hands.

The White Road is beautiful in the dark, clear sky, and, once again, she cannot help but be amazed by it all.

It does not matter how many times she has seen this before, or how much she knows about what is out there. The sight of the stars is enough to make her gasp.

"It all seems so still and yet it's changing all the time," she whispers to no one.

It is hard to believe that everything out there past the White Road and its stars is running away from us.

Yet, like Mr Hubble found long ago, the Star-Crowds are running away from each other, as the space between them gets bigger and bigger. The All-There-Is is growing with time.

From sunset to sunrise, we follow her as she reflects on our Home-World and the other Crazy Stars around the Sun, and the many more that go around faraway stars; the way the All-There-Is grows, and how it began in a Big Flash; and all the questions we still have on it, like dark matter, the Dark Push and the existence of other kinds of All-There-Is.

Whether or not *The Edge of the Sky* succeeded in its goal is a question that only my readers can answer. If it will help them connect with some of the complex ideas of modern cosmology and generate curiosity and enthusiasm for fundamental science, my aim will be achieved.

Notes

1 *The Edge of the Sky* is available from publisher Basic Books, ISBN 978-0-465-04471-9

2 www.hands-on-universe.org

3 Ten-Hundred Words of Science challenge Website: http://tenhundredwordsofscience.tumblr.com/

4 xkcd website: http://www.xkcd.com/

Biography

Roberto Trotta is a theoretical cosmologist at Imperial College London, where he studies dark matter, dark energy and the Big Bang.

A winner of the I'm a Scientist-Get Me Out of Here! Astronomy Zone in June 2014, Roberto is a passionate science communicator and the recipient of numerous awards for his research and outreach. These include the Lord Kelvin Award of the British Association for the Advancement of Science, the Michelson Prize of Case Western Reserve University and the awarding of a Science and Technology Facilities Council (STFC) Public Engagement Fellowship.

His first book for the public, *The Edge of the Sky* endeavours to explain the Universe using only the most common 1000 words in the English language.

The Space Public Outreach Team (SPOT): Adapting a successful outreach programme to a new region

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Science communication, STEM, ambassadors, physics, astronomy, outreach, undergraduate students, professional development

Summary

The Space Public Outreach Team (SPOT) recruits and trains undergraduate ambassadors from all disciplines to deliver astronomy and space-science-themed interactive presentations. They deliver these presentations to primary and secondary schools and organisations across the state of Montana, USA. SPOT was started in 1996 by physics graduate students at Montana State University, USA, and it has grown to reach an average of 10 000 students per year for a low institutional cost of less than five dollars (four euros) per student. In the last year, the Montana SPOT model has been adopted in the state of West Virginia. The West Virginia SPOT programme also shows great potential, with eleven ambassadors trained to give two new feature presentations, reaching over 2600 students. In this paper, we describe how the Montana SPOT model works in practice and discuss how this model was adapted with new resources, and for a new audience, such that others may also adapt the programme to inspire space science interest for their own particular setting. We invite these groups to plug into the SPOT brand to broaden the impact of astronomy and space programmes and applications in their own region.

Introduction

There is a widely accepted international need for more support and participation in science, technology, engineering, and mathematics (STEM) enterprises (White House, 2012). One way that this need is addressed is by recruiting and training ambassadors — STEM role models who travel out into their communities and share STEM content through presentations, activities, and research projects. This helps to forge strong partnerships among students, teachers, researchers, and institutions while increasing STEM awareness, interest, and participation.

Two examples of this type of initiative include:

1. The United States Graduate STEM Fellows in K–12 Education programme. This programme paired graduate student researchers with primary and secondary school classrooms for repeated visits over

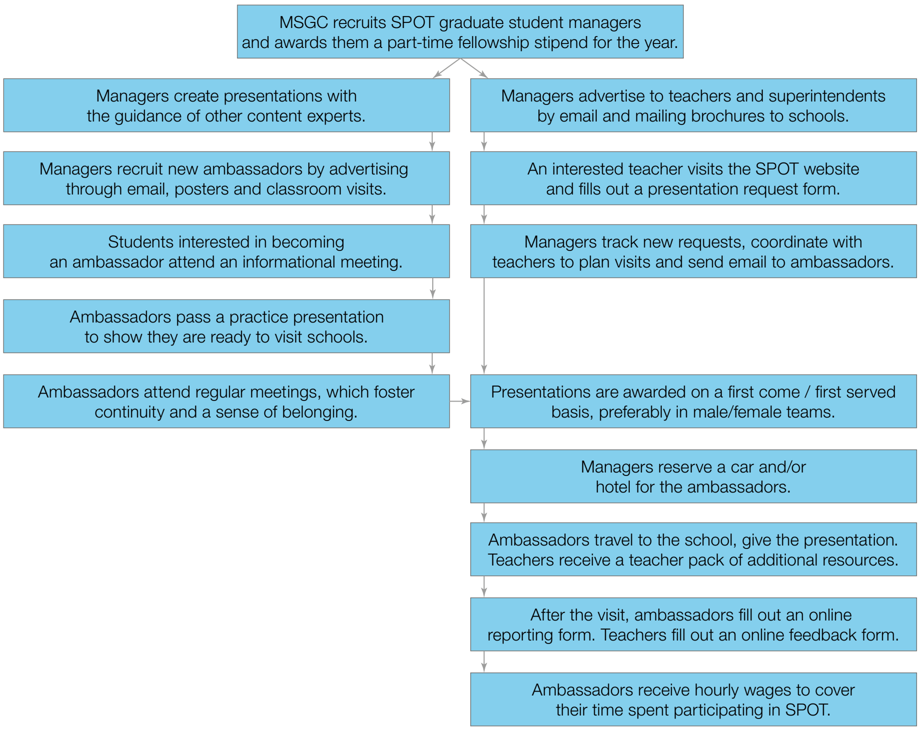

Figure 1. *Schematic of the Montana SPOT model*

the course of a year. Programme evaluation showed that the young students were inspired by the graduate student role models, the graduate students learned how to better communicate their science, and the teachers learned more about the content. Furthermore, the graduate student ambassadors reported extremely positive feelings towards the project, a sense of reward, and an increased interest and ability in science (American Association for the Advancement of Science, 2013).

2. The United Kingdom's national educational charity STEMNET offers a STEM Ambassadors programme through which any STEM worker can volunteer to work with schools to deliver the STEM curriculum and raise STEM awareness. Their network has over 27 000 volunteers, and external evaluation shows that students are 90% more likely to be interested in continuing to study STEM subjects after engaging with STEM Ambassadors. These programmes, however, require ambassadors to take a relatively large proactive role in the development of their presentations and the planning of their visits. This can present many challenges to students and scientists, who often lack significant public outreach experience, resources and time.

The Space Public Outreach Team (SPOT) programme offers a seamless integration of presentation content development, professional development of ambassadors, and logistical planning and coordination of visits. It is a simple, low-cost, and sustainable astronomy education and public outreach (EPO) programme that recruits college students to be space ambassadors and trains them to deliver pre-made interactive slide-show presentations.

The Montana SPOT model

The SPOT concept was originally developed over eighteen years ago by two physics graduate students at Montana State University (MSU) — both of whom are authors on this paper — as a way to celebrate the Mars missions with students. Since then, the programme has been supported by the Montana Space Grant Consortium (MSGC), centralised at MSU, and has grown to include a wide variety of space science and engineering topics. SPOT presentations feature local space science research, institutions, and programmes, with the primary goal being to increase awareness and interest, sending the strong message that you don't have to go far from home to be part of science.

Over time, programme changes were made to reflect changing management, resources, and needs, but the overall model has remained the same. In general, Montana SPOT (MT SPOT) is managed by MSU graduate students who design the feature presentations, recruit college student ambassadors to learn these presentations, and coordinate ambassadors' visits with schools and organisations.

A schematic representation of the MT SPOT model is shown in Figure 1, and details of funding, management, presentation content, ambassador training, programme evaluation, and impact are discussed in the subsections below.

Figure 2. *Montana SPOT programme with visitors at Yellowstone National Park. Credit: Montana Space Grant Consortium*

Figure 3. *Montana SPOT visit to school students. Credit: Montana Space Grant Consortium*

Process

Schools or organisations request a visit from an ambassador via an online form, and with a few phone calls or emails, the SPOT managers coordinate the logistics of the ambassadors' visits. This removes the pressure for the ambassador to design and organise an event from scratch, a task which can be quite daunting and time-consuming. With this simple model, SPOT can be implemented on a variety of scales and can reach thousands of students every year for under five dollars (four euros) per student.

Funding

MT SPOT has been funded primarily by a combination of MSGC Fellowships and the EPO portions of MSU Physics department faculty research grants (Drobnes, 2012), meaning that all presentations are free to schools. The Fellowships pay for graduate student manager stipends, which comprise the main programme cost, and the research grants pay for car rentals and fuel, hotels if necessary, miscellaneous supplies and ambassadors' hourly wages — including driving time and office work.

The specific research group supporting SPOT helps to determine the topics that are featured in the presentations. For example, when the solar physics research group supplied grant money, the featured presentation was the Sun–Earth Connection, and when the gravitational astronomy group supplied grant money, a presentation called *Listening to the Universe* was developed. Since Montana is such a large state, the cost per trip can vary widely depending on how far ambassadors need to travel, but the average cost per trip is approximately 190 dollars. With an annual budget of 30 000 to 80 000 dollars, MT SPOT reaches between 5000 and 15 000 students.

Management

Programme operations typically require two half-time graduate student managers per year. Managers' duties include: advertising to schools and organisations across the state, recruiting and training college ambassadors to learn the presentations, communicating and coordinating with teachers and ambassadors, securing and organising programme supplies and logistics, and designing a new space science presentation for the following year.

Managers generally stay on for two years, ideally with a period of training overlap when a new manager starts. Since these managerial positions are funded as MSGC Graduate Fellowships, SPOT management is folded into the normal day-to-day duties of a graduate student, meaning that a graduate student can have a much lighter teaching-assistantship load. This non-traditional graduate assistantship offers valuable experience in management, mentorship and science communication.

Presentation content

Presentations are interactive PowerPoint slide shows designed to engage audiences of almost any size — ranging from a one-room school house to a large auditorium — and pique interest in a selected space science topic for 30–50 minutes.

The slides include notes that provide a storyline as well as extra information for ambassadors learning the show to study and practice. Content is optimised for student audiences aged 10–14 and made to complement the science education curriculum. The notes include additional information for interactions with older audiences, some of which can be glossed over for younger audiences. For very young audiences, an abridged version of each presentation is also created.

Presentations usually start with general space science and engineering concepts, then delve into more region-specific topics. For example, the presentation *Mission to Mars* talks about what it takes to design, test, and build an interplanetary mission, getting students to help brainstorm the sorts of things that must be taken into consideration.

Fun quizzes, such as "How long does it take to get to Mars?" or "How high could you jump in Mars' reduced gravity?" and videos, such as NASA's *Seven Minutes of Terror* video of the *Curiosity* landing, keep students entertained and invested in understanding. Furthermore, featuring Montana-specific people and programmes, such as a female engineer from MSU who went on to design the *Curiosity* rover's wheels, and the Lunabotics programme in Montana in which students can become involved in designing a moon rover, help to make the content relatable, with the explicit message that you don't need to go far from home to be part of science and space exploration. Figures 2 and 3 show some of the presentations taking place.

Ambassador training

SPOT managers recruit undergraduate ambassadors from all disciplines and give a short invitation to attend an information meeting with food and drink provided. Physics, engineering and education students are especially encouraged to join to ensure that ambassadors will have a range of content and education skills that they can share with one another. During the information meetings, potential ambassadors are introduced to the logistics of SPOT and watch a SPOT presentation given by a current ambassador.

After the meeting the new ambassadors download the presentation with notes and are asked to practice a small portion to be given at the next meeting. This offers a low-stakes environment where ambassadors get immediate feedback on their strengths and weaknesses, as well as a chance to get clarification on content. Ambassadors must pass a practice presentation in which they give the entire presentation without notes to get cleared on content knowledge and communication standards before visiting schools.

Once ambassadors experience the enthusiasm of a captive audience during their first or second classroom visit they are typically hooked, although there are some barriers to participation that must be addressed.

Namely, the initial time investment of learning the presentations and practicing communication skills is often the most difficult part of becoming a SPOT ambassador. Therefore, building incentives for ambassadors to persist with the programme from the start is critical. One way this is accomplished is by withholding payment until ambassadors have actually visited a school.

Secondly, team-building opportunities, such as through an optional one-credit seminar that meets once per week, or student-led movie nights and camping trips, aid in persistence.

Finally, it is important to work with ambassadors' schedules, as college class meeting times often conflict with typical times for school visits. The highest rate of school visits occurs during ambassadors' holidays when term has ended for universities, but not for schools.

These best practices for professional development ensure quality, and help ambassadors to develop translatable skills that will give them a tremendous advantage and flexibility as they go forward with their careers. Furthermore, ambassadors get to know each other and they develop a sense of purpose and autonomy. This kind of involvement and sense of belonging is one of the key factors in university retention efforts (Lotkowski, 2004).

Evaluation

Assessment of the impact of SPOT on the students who receive the presentations is mostly based on teacher feedback via an online evaluation form, providing a suitable indication of the level of student engagement.

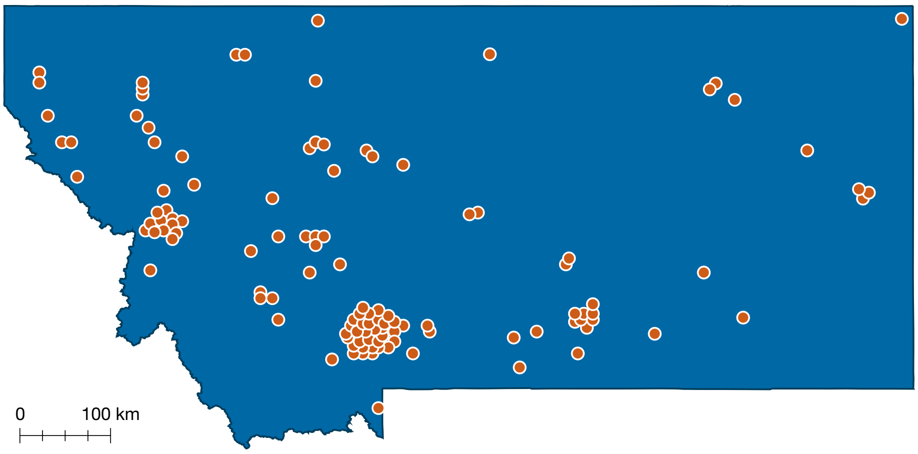

Figure 4. *The 2011–2012 MT SPOT reach. Credit: The Montana Space Grant Consortium*

While teachers of children aged eight and younger have a less uniform perspective of their students' engagement, almost one quarter of teachers of those aged nine and older report on their students' interest in the presentation by commenting that some students might still be talking about what they learned days after the presentation. They also comment on their students' focus and the high quality of questions posed during the presentation. Selected quotes from teachers include:

We were all excited to know about the eclipse that was going to be appearing in the sky the next morning. A lot of kids got up to view it, not many would have even known.

I had two students get interested in the Borealis [high altitude ballooning] project… I have already contacted the Borealis project director so two of our upperclassmen can find out more about the project, and hopefully design an experiment.

Just like any small school, our resources are limited and these presentations are so important for our students to get another resource to add to their science background.

In addition to the online evaluation forms filled out by teachers, reporting forms filled out by ambassadors are also used. These track the ambassadors' impressions of their preparation and comfort level when answering questions, the organisation and relevance of the presentations, as well as recommendations for improvements.

In particular, evaluation data shows overall positive reviews of the SPOT model, with the most frequent suggestions for improvement including a more prominent hands-on component and a way to tie the SPOT visit more easily to the curriculum. Managers monitor these suggestions and strive to continually adapt and improve the presentations and programme logistics to suit these new and changing needs.

The SPOT programme has been touted several times at national and international conferences as a successful EPO model for others to emulate (Larson, 1998; Littenberg, 2007; Williamson, 2011; Williamson, 2014)

Programme impact

External evaluation during the 2011–12 financial year (Grimberg, 2012) indicated that SPOT had a broad reach — 9.7% of all Montana school pupils received a SPOT presentation, with 52% of visits being in rural or under-represented areas; students were engaged with the presentations and learned of new opportunities because of the visits; and college ambassadors gained knowledge of the content and a greater sense of independence and confidence in their science communication and problem-solving capabilities.

For this evaluation report, MT SPOT ambassadors visited a total of 119 schools and organisations across Montana (Figure 4). During these visits, ambassadors gave 208 presentations, reaching 13 642 students and 676 teachers. Of these students, 1822 were from under-represented groups and over half of all institutions reached were located in rural, isolated areas.

On-site observations of a range of schools — small, large, rural and urban — confirm SPOT's positive impacts on students' and teachers' excitement and interest in science, with the additional indication that SPOT ambassadors inspired young students to enrol in higher education, learn about college life, and learn about career pathways in STEM.

The evaluation report also highlighted how valuable the SPOT experience is for the college ambassadors. From a focus group of seven SPOT ambassadors, some of the skills gained and lessons learned that emerged included:

- higher-level communication skills;
- a sense of independence by being exposed to non-mainstream educational settings;
- new insights into science education, how students learn, and ways to engage students;
- a deeper understanding of the subject matter being presented;
- a sense of reward and enjoyment when students asked questions that opened conversations to relevant topics;
- greater comfort in problem-solving real-life situations on the spot;
- an appreciation of the lack of science exposure in small, isolated, rural schools, along with a sense of truly contributing to students' STEM education.

Figure 5. *Ambassadors practicing a hands-on activity during the WV SPOT training weekend at the National Radio Astronomy Observatory (NRAO) in West Virginia, USA. Credit: NRAO*

One MT SPOT ambassador commented:

SPOT was the defining thing in my college career. I came here as a freshman in my physics career. I will always look back at my college years and look at these presentations as the highlight. They represent me so much. College is SPOT.

Not only does SPOT provide professional development for the ambassadors, it also gives them a sense of purpose and belonging in the STEM community.

Finally, perhaps the most important products of SPOT are the partnerships among higher education, research institutions, and schools, in addition to the network of ambassadors for astronomy and space science that it creates.

Ambassadors are available as volunteers for other outreach events, but more broadly, many ambassadors get their friends involved and talk about SPOT on social media, developing a strong commitment to STEM education. Having such a network of connected students working for a cause is the new medium for change in our global economy (Sandu, 2014), making SPOT an important vehicle for enhancing STEM awareness and interest. With modest resources, this network is an almost self-perpetuating way of increasing awareness of STEM concepts and opportunities.

Adapting the SPOT model to a new region: The West Virginia model

During the summer of 2013, the idea of adapting SPOT to a new region was discussed by stakeholders in West Virginia, including the National Radio Astronomy Observatory (NRAO), the WV Space Grant Consortium (WVSGC), and the NASA Independent Verification and Validation Center (IV&V). The SPOT model was recognised as a way to enhance the existing educational efforts of these organisations and to strengthen partnerships with schools, colleges, and universities across the state. The West Virginia Space Public Outreach Team (WV SPOT) was created, with the intention of running a pilot scheme during the 2013–2014 academic year.

To leverage the unique resources of West Virginia stakeholders, and to celebrate the diverse space science being done in West

Figure 6. *Ambassadors next to the Green Bank Telescope during the WV SPOT training weekend at NRAO in West Virginia, USA. Credit: National Radio Astronomy Observatory*

Virginia, the WV SPOT model is slightly different from the Montana model.

First, WV SPOT management is implemented by education and outreach staff at NRAO and IV&V as part of their regular job duties. Second, WV SPOT ambassadors are recruited from existing astronomy and space science engineering clubs at several colleges and universities around the state.

Because ambassadors are geographically distributed, investment is made to bring ambassadors together for one or two immersive training weekends (Figure 5), covering travel and room and board costs — rather than regular short meetings throughout the semester as in MT SPOT. Finally, WV SPOT ambassadors are paid a flat fifty dollar honorarium per school visit, with schools paying an additional fifty dollar travel fee — whereas MT SPOT pays ambassadors hourly and offers presentations free to the school. It is interesting to note that this fee for schools has not seemed to be a deterrent.

During the 2013–2014 pilot year, WV SPOT showed great potential. Two West Virginia specific presentations were created that, as with MT SPOT, highlight other programmes around the state in which students can become involved. For example, the *Invisible Universe* presentation features the Pulsar Search Collaboratory, in which students learn to search for pulsars using NRAO data, sometimes making new discoveries (Rosen, 2010; Rosen, 2013).

In addition, one of the ambassador training weekends was held at the NRAO, West Virginia. This retreat-like setting is particularly immersive because it is located in the National Radio Quiet Zone where cell phones have no signal. Ambassadors collected their very own radio data and visited the famous Robert C. Byrd Green Bank Telescope (GBT), featured in the SPOT presentations (Figure 6).

In total, eleven ambassadors from four different universities completed their SPOT training and visited 26 schools and organisations around the state (Figure 7).

Forty-six presentations were given to 2660 students and 127 teachers for a total programme cost of less than 9000 dollars. Ambassadors' and teachers' responses in reporting and evaluation forms show overall positive reviews, with outcomes and suggestions mirroring those in Montana. After such a successful first year, WV SPOT stakeholders are even more invested in helping the programme flourish, and the impact of WV SPOT is expected to be even greater for the 2014–2015 year and beyond.

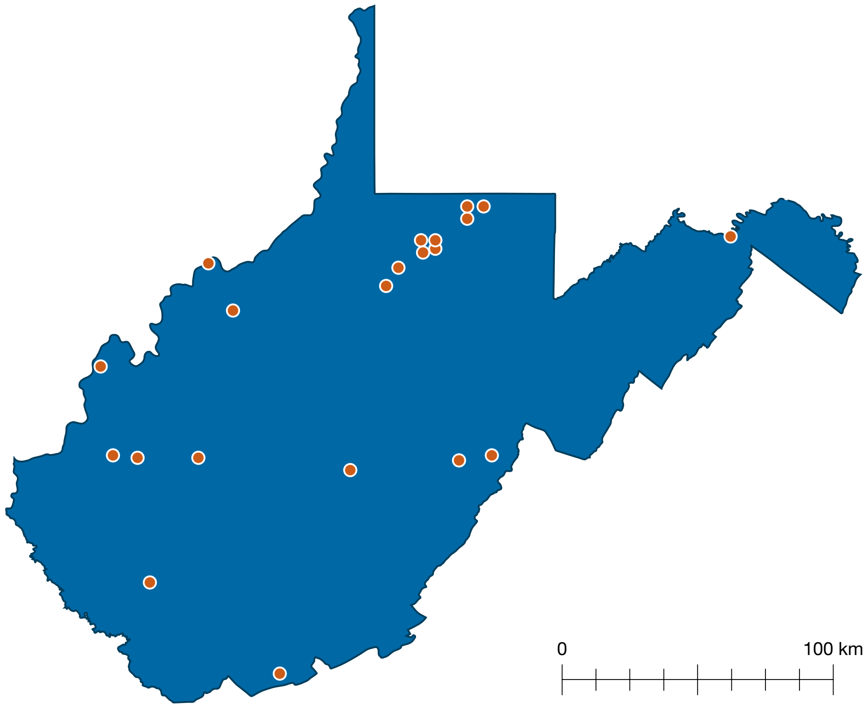

Figure 7. *The 2013–2014 WV SPOT reach*

Conclusion

With over eighteen years of success in bringing astronomy and space science to students and teachers, the Space Public Outreach Team (SPOT) is a simple, sustainable, low-cost outreach model that others can adapt to increase people's interest in and appreciation for science. We invite those looking to leverage the SPOT model to browse our websites and plug into the SPOT brand. We can be contacted to share our pre-made slide shows as a starting point for building content that highlights astronomy and space science research in new areas and with new populations, and we are available for consultation or to answer questions as needed.

Acknowledgements

The SPOT model began under the name of the Mars Pathfinder Outreach Program (MPOP) in Montana in 1996. More people than we can name have been involved in making SPOT a success. Additionally, without the year-by-year commitment to SPOT by MSGC, NRAO and WVSGC, along with significant support from the Solar Dynamics Observatory, dozens of managers and over one hundred ambassadors, SPOT would not be possible.

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Links

STEMNET http://www.stemnet.org.uk/new-report-proves-the-impact-of-stemnets-programmes/

Montana SPOT: http://solar.physics.montana.edu/spot/

West Virginia SPOT: https://sites.google.com/site/wvaspot/

GK-12: http://www.gk12.org/

Biographies

Kathryn Williamson, Joey Key, Angela Des Jardins, Shane L. Larson, Tyson B. Littenberg and Michelle B. Larson were all managers of SPOT during their time as physics graduate students at Montana State University and have dedicated much of their careers to advancing STEM education and research.

Irene Grimberg researches science learning and teaching with a focus on rural and American Indian populations, and served as the external evaluator for SPOT during the 2011–2012 year.

Sue Ann Heatherly has advanced education and public outreach at NRAO through countless high-impact programmes such as the Pulsar Search Collaboratory.

David McKenzie is a solar physicist at Montana State University and provided a critical link with Solar Dynamics Observatory collaborators to increase SPOT's impact.

When Astronomy Gets Closer to Home: Why space weather outreach is important and how to give it impact

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Keywords
Space sciences, space weather, outreach, education, communication, public engagement

Summary

When the public think about natural hazards, space weather is not the first thing to come to mind. Yet, though uncommon, extreme space weather events can have an economic impact similar to that of large floods or earthquakes. Although there have been efforts across various sectors of society to communicate this topic, many people are still quite confused about it, having only a limited understanding of the relevance of space weather in their daily lives. As such, it is crucial to properly communicate this topic to a variety of audiences. This article explores why we should communicate space weather research, how it can be framed for different audiences and how researchers, science communicators, policy makers and the public can raise awareness of the topic.

Introduction

As you sit reading this article, the Sun is brimming with activity. The yellow disc in the sky may appear unimpressive but when looking in the extreme ultraviolet region of the spectrum, the Sun's hot active regions glow bright (Figure 1). These are areas with an especially strong magnetic field — manifested in the form of dark patches or sunspots on the solar surface — that can be the source of explosive bursts of energy and solar material. Even though the Sun is some 150 million kilometres away, these solar storms can alter the near-Earth space environment, changing our space weather.

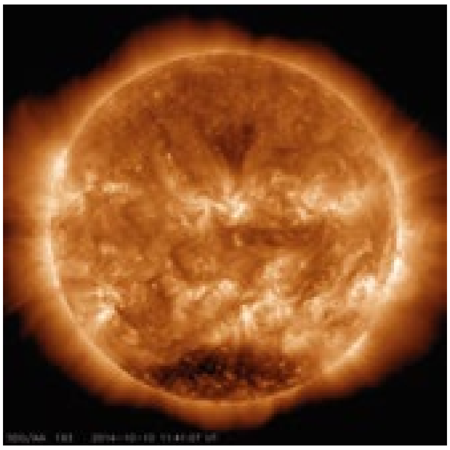

Figure 1. *The Sun in the extreme ultraviolet, imaged by NASA's Solar Dynamics Observatory on 10 October 2014. This wavelength highlights the outer atmosphere of the Sun (corona) and active solar regions, which appear bright in the image. Solar flares and coronal mass ejections would also be highlighted in this channel. Credit: Image courtesy of NASA/SDO and the AIA, EVE, and HMI science teams*

Of the solar storms that can hit the Earth, the most damaging are coronal mass ejections. These high-speed bursts of solar material — if powerful enough and directed towards our planet with the proper orientation of their magnetic field — can disturb the Earth's magnetic field, creating a geomagnetic storm. This can impact power grids and pipelines, and affect communications and transportation systems. Coronal mass ejections and other solar storms such as solar flares — outbursts of radiation and high-energy particles — can also affect spacecraft and satellites and even be a radiation hazard for astronauts and air crews flying at high latitudes and altitudes.

The importance of communicating space weather research

Space weather may be a concept unfamiliar to many, but, as with any natural hazard, it is important that the public know about it and understand the potential dangers. At its most extreme space weather can cause large-scale power blackouts and, thus, affect global supply chains including food and water supplies, damaging livelihoods and the economy in the process. Severe space weather occurs about once a century on average (Riley, 2012), but milder events can disrupt human activity once or twice per decade (POST Note, 2010). At a time when we are over-reliant on technology and our power grids are more connected than ever, meaning they are more vulnerable to space weather, telling people about this natural hazard becomes all the more crucial.

Space weather is an area of astronomy much closer to home than most, which can in itself act as a hook for audiences, whether children or policy makers. After all, most people have either seen or heard about the most visible and stunning space weather-related phenomenon, the aurora, which forms when particles from the Sun energise the atoms in the Earth's atmosphere making it glow (Figures 2 and 3). Communicating space weather is an opportunity to get others interested in space and science, and to inspire younger people to pursue a career in these areas.

In more general terms researchers of space weather, as is the case with many areas of astronomy, have much to gain from communicating their research. Communicating space weather as a researcher can help to improve a CV, hone presentation and writing skills and bring a new perspective to research. Expanding the audience for this research beyond the astronomy community can further lead to interdisciplinary collaborations and an increase in citations for relevant research papers.

In addition, communicating space weather research with the public is a way of justifying the taxpayers' money that funds most solar–terrestrial research. Engaging the public with this often-forgotten subject area could increase public support for it and inform policy, ensuring that legislation relating to space weather is based on sound science.

Defining your audience

As with more general astronomy or science outreach, before communicating space weather it is important to define an audience. Will this be a talk at a school or an article for a popular astronomy magazine? Is the aim to brief engineers who work on infrastructure protection or to give evidence to a parliamentary committee? The message needs to be targeted to the public that the communicator is reaching out to.

Communicating with young people or a general audience

When communicating with school children, focussing on the Sun and the fascinating aspects of solar–terrestrial science is a way to get the audience excited rather than scared about space weather. For both younger crowds and the wider public, the use of images, videos, animations and other visuals helps to captivate the audience's attention and can go a long way towards explaining tricky topics.

A further aid to make the public relate better to space weather is to show them what the Sun looks like at that moment and what the current space weather conditions are. For this NASA and ESA's Solar & Heliospheric Observatory (SOHO) page[1] and the US Space Weather Prediction Centre website[2] are great resources.

To help familiarise the audience with complex concepts, it is often useful to use everyday analogies and examples — like using a peppercorn and a football to give an idea of the relative sizes of the Earth and Sun. In addition, as with other topics, it is important for the communicator to speak or write clearly and avoid technical terms when reaching out to a general audience.

Communicating with technical audiences and policy makers

The language can be more technical when communicating with engineers or policy makers, but should still be free of discipline-specific jargon. Engineers are likely interested in finding out about the properties of solar storms and how spacecraft can be made more resilient, or how the effects of geomagnetic storms could be mitigated to avoid excessive damage to technological infrastructure.

Policy makers want the facts given in a balanced, clear and objective way, and are interested in space weather aspects with policy relevance, such as monitoring, resilience and funding.

Real-world examples and avoiding scaremongering

A crucial aspect is to strike a balance between informing about the dangers of space weather and avoiding scaremongering. The communicator should give concrete examples about past events that have affected human activity. Typical examples include the famous 1859 Carrington event, which affected telegraph systems and caused aurorae as far south as Cuba (Bell, 2008); the Quebec 1989 geomagnetic storm that caused a power blackout affecting several million people and temporarily paralysed the Montreal metro and international airport (POST Note, 2010); or the Halloween storms of 2003 over northern Europe that damaged satellites, caused a blackout in Sweden, and forced air companies to reroute trans-polar flights (POST Note, 2010).

These events illustrate that space weather is something that the public and policy makers need to be aware of because it can affect their daily lives. But it's also important to explain that geomagnetic storms, particularly severe ones that could cause trillions of euros in damage, are not very common (Workshop report, 2008). It is important to raise awareness of space weather and educate the public on the best ways to prepare for and mitigate space weather without getting people needlessly worried about its impact. Always finish on a positive note when doing space weather outreach.

Getting involved as a science communicator, scientist or member of the public

For those convinced about the importance of engaging the public with space weather, and confident about delivering a targeted and informative message, there are many opportunities to get involved in space weather outreach.

If you are an astronomy communicator, and thus likely to already be writing popular sci-

Figure 2. *Green aurora over Abisko in Sweden. Credit: Carme Bosch, distributed via imaggeo.egu.eu*

Figure 3. *Bright aurora over Alaska. Credit: Taro Nakai, distributed via imaggeo.egu.eu*

ence articles or giving presentations about various aspects of astronomy, why not choose space weather as your next topic?

As a researcher, there are science cafes available to bring space weather to the public, you could blog about your work, give talks at local schools, or — if you are preparing a new and exciting paper on the topic — you can reach out to journalists through the press office at your institution.

Experienced scientists have an additional responsibility to communicate with policy makers. They can reach this audience by providing input to a policy briefing, such as those written by the Parliamentary Office of Science and Technology (POST) in the UK, or by contributing to a governmental report through their research council. Scientists can also apply to serve as science advisers to their local politician or to a governmental body, or join science policy groups in their country to raise the importance of space weather in the political agenda.

Finally, if you are a member of the public who knows little about space weather, but is interested in finding out more, you can help researchers and communicators in this area by taking part in public consultations, such as the Space Weather Public Dialogue[3] underway (at the time of writing) in the UK, which is open to people from all countries. The aim of this project is to help UK research councils and entities find out more about how to best communicate space weather and its impacts and to evaluate the public's level of preparedness.

If you want to communicate space weather, or help others do it more effectively, there are plenty of opportunities out there to get involved. Be enthusiastic and pro-active, and encourage others to raise public awareness about what happens on the Sun and in our local space environment.

Acknowledgements

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Links

1 NASA and ESA's Solar & Heliospheric Observatory (SOHO) page: http://soho.esac.esa.int

2 US Space Weather Prediction Center website: http://www.swpc.noaa.gov/index.html

3 Space Weather public dialogue: http://talkspaceweather.com/the-project/

Biography

Bárbara Ferreira communicates Earth, planetary and space sciences to a variety of audiences on a daily basis as the European Geosciences Union's Media and Communications Manager. She has a PhD in astrophysics from the University of Cambridge in the UK, and wrote a short policy briefing about space weather during a secondment at the Parliamentary Office of Science and Technology in London.

The Planeterrella: A planetary auroral simulator

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Keywords
Aurorae, experiment, outreach

Summary

This article presents a plasma physics experiment which makes it possible to produce polar lights. The experiment, named Planeterrella, involves shooting electrons onto a magnetised sphere placed in a vacuum chamber. Inspired by Kristian Birkeland's Terrella, but with several different configurations and technical improvements, the experiment allows the user to simulate and visualise simple geophysical and astrophysical situations. Several Planeterrellas are now used across Europe and the USA. The design of the original experiment and the expertise of its first authors are shared freely with any public institute and are outlined in this article.

Polar lights: A magnificent natural spectacle

Aurorae have always excited people's imaginations and have given rise to many legends and beliefs. These beautiful coloured lights, caused by the interplay between solar activity and the Earth's magnetic field, blaze across the night sky in regions near the magnetic poles.

For the lights to occur, enough electrons and protons must reach us from the Sun either via the solar wind, or due to a solar eruption that has thrown out a cloud of these particles, which have intercepted the Earth as they cross its orbit.

When these conditions are fulfilled a diffuse aurora, starting 100–150 kilometres above the observer, and falling towards the ground, turns the sky green. Sometimes this green veil dances like a curtain at an open window, forming the well-named auroral curtain (Figure 1). Above this curtain the sky can glow cardinal red at about 200 kilometres altitude. If a solar flare has

Figure 1. *An auroral curtain. The intensity is so low that the background stars can be seen throughout. The small spot in the very middle of the picture is not a star, but a comet. Credit: G. Gronoff*

Figure 2. *Planeterrella III. Credit: J. Lilensten*

occurred, new colours can appear down to about 80 kilometres and the aurora patterns can shift on timescales of minutes.

Few people have the chance to admire aurorae. To have such an opportunity, one must travel to high magnetic latitudes, with cloudless conditions and no urban lights or moonlight to swamp out the aurora. Even in the best conditions one can spend hours in the snow, head to the sky, and wait in temperatures that can dip below –30°C with no guarantee of a light show. It was for this reason that the Planeterrella[1] was created — to bring aurorae to the public.

Kristian Birkeland's Terrella

During the 19th century, geographers established that aurorae occur preferentially around the magnetic poles, forming what we now call auroral ovals. In the same century work in electromagnetism led to theories about charged particles such as electrons.

At the end of the 19th century, the Norwegian physicist Kristian Birkeland, an experimental genius, had the idea to shoot a beam of electrons — known as a cathode ray — onto a magnetised sphere suspended in a vacuum chamber. To his mind, the cathode was the Sun and the rays represented the expanding solar atmosphere — later dubbed the solar wind (Parker, 1958) — and the magnetised sphere was the Earth.

In the course of his life, Birkeland built up to 14 variations of his experiment, which he called the Terrella. With it, he succeeded in producing the first laboratory demonstration of the mechanism of aurorae, by obtaining coloured emissions organised along auroral ovals.

The Planeterrella: An improvement on the Terrella

After we had built several Terrellas, we conceived — with the help of many colleagues — a new experiment allowing many more configurations than the original Terrella. For example, rather than suspending the sphere from a fixed rod, making it very difficult to change its design and settings, the sphere is placed on a rod that can move and be adjusted in height (Lilensten et al., 2009).

In addition, the magnet in the Planeterrella can also be set in any desired direction. A simple metal tube acts as an electrical duct and is attached to a wheel inserted into a slot in a curved bracket, so that it can be moved and positioned as required.

In the original Terrella configuration, it was not possible to have two spheres as they were hung on wires, and so would attract or repel each other due to their magnetic fields. With the Planeterrella, the rods are rigid, allowing configurations with more than one sphere.

This flexibility allows the user to study various different star–planet configurations. Usually, there are two moving spheres and one electric duct in the Planeterrella. The duct can be used to replicate the work of Kristian Birkeland.

The Planeterrella set-up

The Planeterrella developed by this team uses a vacuum chamber with a capacity of 50 litres and a diameter of 50 centimetres. The first generation of the Planeterrella, made in 2007, used cylindrical vacuum chambers made of Plexiglas, but newer models use better designed glass chambers, which are visually more dramatic (Figure 2).

The inner spheres have diameters of 10 centimetres and 5 centimetres. While Birkeland used copper, the Planeterrella spheres are manufactured from a non-magnetic metal — aluminium, which is a good electrical conductor.

The vacuum should be of the order of 1–10 Pascal, and can therefore be obtained with a primary pump.

The voltage should be greater than 500 volts for a current of the order of a tenth of a milliamp. At the moment, the Planeterrella uses permanent rare earth magnets, 0.5 centimetres long. The magnetic field strength is approximately 0.5 tesla at the surface of the magnets — roughly three orders of magnitude larger than that of Earth's surface magnetic field.

Demonstrable phenomena

The Planeterrella can be configured in several ways to allow numerous space phenomena to be seen. If one sphere is connected to the anode — the positive electrical pole of the power supply — and the electric duct to the cathode — the negative pole — then the Planeterrella represents a planet receiving a flux of electrons.

With a low-intensity dipolar magnetic field, the audience sees auroral ovals (Figure 3). With a stronger field, one can visualise the generation of Van Allen belts and polar cusps.

A sphere connected to the cathode becomes a star shooting out a stellar

Figure 3. *Auroral ovals. Credit: D. Bernard*

wind made of electrons. This allows the audience to see a shock zone between this star and the second sphere, which is connected to the anode. This configuration mimics a bow shock (Figure 4). A bow shock is a region where two streams of gas collide, usually between a magnetosphere — the region of space near an astronomical object in which charged particles are controlled by that object's magnetic field — and an ambient medium; so for planets with a magnetic field the bow shock is located at the boundary where the stellar wind meets the planet's magnetosphere[2]. In this region the speed of a stellar wind abruptly drops and the solar wind is sculpted into characteristic formations reminiscent of the crest of a wave made by a ship moving through water, showing how the bow shock gained its name.

Figure 4. *Bow shock around the very young star, LL Ori. Credit: NASA/ESA and The Hubble Heritage Team STScI/AURA*

Other phenomena demonstrated by the Planeterrella are further from astrophysical reality and closer to analogies, like the formation of the solar corona and coronal holes (Figure 5) on the anode-connected sphere.

The Planeterrella can also help to visualise night-side aurorae on Uranus and Neptune, which cannot be observed directly. The magnetic axes of these planets are strongly tilted relative to the privileged direction of the arrival of electrons. This is relatively easy to mimic with the Planeterrella, by positioning the electric duct connected to the cathode above the magnetic pole of a sphere connected to the anode.

The economic model and collaboration

The cost of a complete Planeterrella is 8000 to 10 000 euros. However, this cost can easily be reduced in practice, as components such as vacuum pumps, generators or cables are often available on loan from host universities.

In agreement with the French national organisation for scientific research (CNRS), the Planeterrella has not been patented. Instead, we have produced a gentleman's agreement, under which we are committed to providing plans and assistance with the construction, provided that the applicant is affiliated to a public institute. In return, the applicant agrees not to disclose this process and must share progress and plans for the Planeterrella, and credit our institute on the demo table.

We have found that, because scientists are used to sharing research, directors may sign the agreement even if the funding is not acquired, which is reassuring. Planeterrellas are always built in a spirit of collaboration.

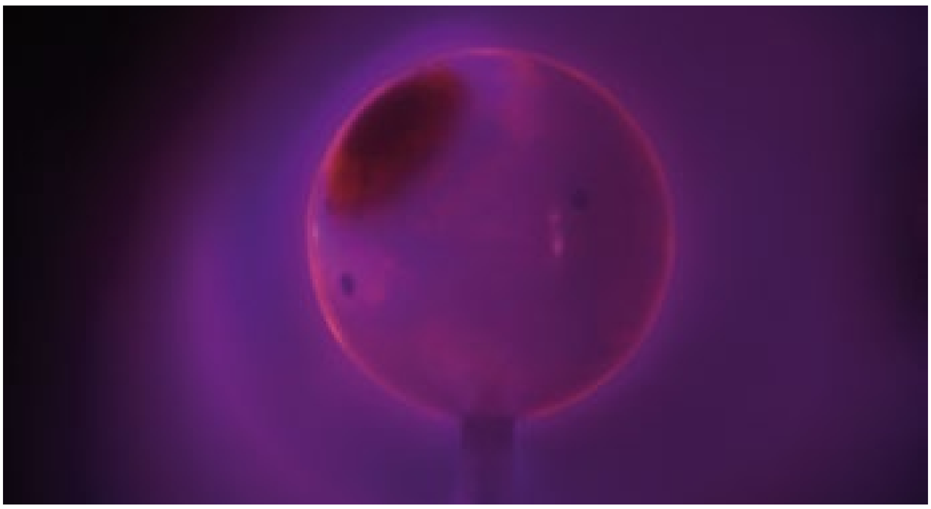

Figure 5. *The solar corona and a coronal hole. Credit: C. Simon*

Current and future projects

Seventeen Planeterrellas now exist in France — including at the Observatoire de Paris, Université Pierre et Marie Curie, Université de Toulouse and the Institut universitaire de technologie (IUT) de Bourges — as well as in Belgium, Switzerland, England, Scotland, Ireland, Spain, at CERN in Geneva, and in the USA — including NASA Langley, University of California, Los Angeles (UCLA) and Princeton. Agreements have been signed with Italy, Norway and Hong Kong. A Planeterrella for the science museum Palais de la Découverte in Paris was commissioned in June 2014 and a recent project aims to build Planeterrellas in Algeria and Tunisia.

The Planeterrella received Europlanet's first international award for public activities in 2010 and the French national prize, Le goût des sciences (Taste for Science), in 2012.

***Figure 6**. A classroom demonstration of the Planeterrella. Credit: C. Simon*

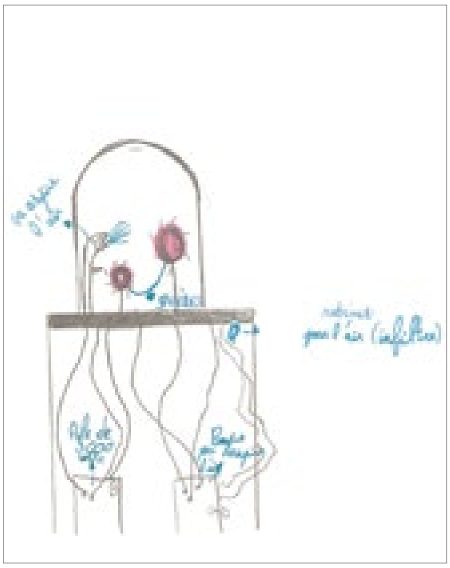

***Figure 7.** This drawing was made by Arnaud, a 10-year-old student from Vienne, France, after his visit to the Planeterella with his class.*

Outcomes: The anticipated and the unexpected

The Planeterrella was designed to be shown in classes or at public exhibitions (Figure 6), but has enjoyed increasing success, and been used for unexpected purposes (Lilensten et al., 2013).

Students have used the Planeterrella for their class projects, artists have found inspiration from it and, in 2013, a professional company created the first artist's show around the Planeterrella. This new artistic dimension multiplies and diversifies the public audience and brings another form of mediation to the dissemination of knowledge in astronomy.

It also serves as an educational tool and has been used at different universities for spectral analysis, by engineering students who perform technical studies to improve it and as a test for Masters' projects in numerical modelling.

Perhaps the most touching outcome is that many school children send drawings of the Planeterrella, which are posted on the Planeterrella website after the demonstrations (Figure 7).

Conclusion

We recently estimated that about 65 000 people of all ages across Europe and the USA have seen aurorae thanks to this experiment. The Planeterrella to be built at the Palais de la Découverte will drastically multiply these audience numbers and once the ongoing projects are finalised, there will also be Planeterrellas in North Africa and Asia. As a result, the number of people who will discover auroral phenomena and have a chance to explore the environment of space will continue to grow. It's very easy to obtain a copy of the plans to build your own Planeterrella: just contact the first author of this article!

Acknowledgements

Colleagues and former graduate students who have helped are now too numerous to be thanked by name, but we especially want to mention Cyril Simon, Guillaume Gronoff, David Bernard and Olivier Brissaud.

Links

[1] Project website: http://planeterrella.osug.fr/?lang=en/

[2] http://en.wikipedia.org/wiki/Bow_shock

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Biographies

Jean Lilensten in an astronomer specialising in the impact of solar activity on the upper atmospheres of the planets. Jean is deeply involved in outreach activities, and, as well as developing the Planeterrella, has published 11 books for various audiences, from children to researchers.

Carine Briand is an astronomer at the Paris Observatory. She studies plasma instabilities, and in particular those related to the strong radio emissions produced during periods of solar activity. Apart from her scientific activity, she teaches at the Pierre et Marie Curie University (Paris) and is involved in numerous public outreach and education projects.

Laurent Lamy is a radio astronomer at LESIA, Observatoire de Paris. He studies the planetary magnetospheres of the Solar System and their auroral processes with a multi-instrumental approach. He managed the building of the Planeterrella at the Observatoire de Paris.

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Increasing Mathematics Engagement in an Astronomy Outreach Context

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Keywords
FRAS, Outreach, Mathematics, Engagement

Summary

The ability to better understand the Universe is very enticing, but for many of us mathematics can be a steadfast barrier to getting there. This article explores the role of mathematics in astronomy outreach and shares my experience of using mathematics to engage an audience, rather than shying away from it.

Introduction

I am currently in my third year of study for an astrophysics degree, but it was not long ago that I too felt that maths was going to stop me fulfilling my ambition of becoming a physicist. Until I had an epiphany. I realised that mathematics is not just vital to a career in physics but is in fact wonderfully interesting in its own right. The more complex maths becomes, the more interesting it is, and the easier it becomes to understand. The key is to transition from *having* to know maths to *wanting* to know maths. Then the rest more or less falls into place. It is for this reason that engaging the public with the maths of astronomy, which is more often than not completely left out of outreach, can be very important.

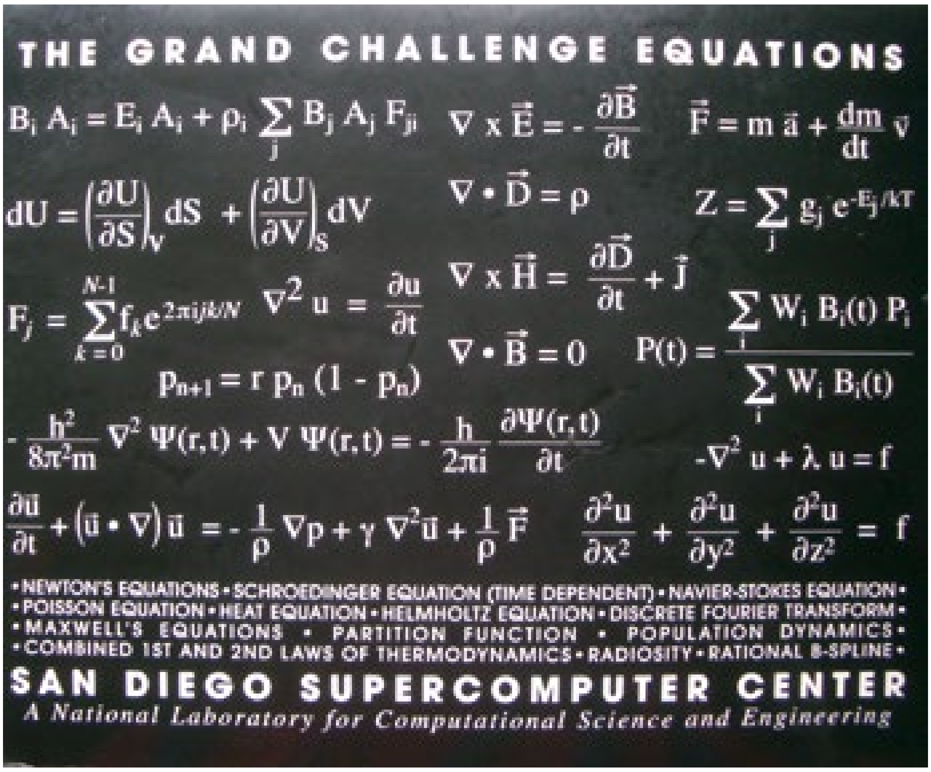

Figure 1. *The Grand Challenge Equations. Credit: Duncan Hull https://www.flickr.com/photos/dullhunk/*

Mathematics in engagement

I recently gave a talk as part of National Astronomy Week on stellar remnants, with particular attention given to black holes. In an astrophysics context this is a very mathematical subject yet in the vast majority of talks on the subject the maths is either extremely sparse, or nonexistent. This is a great shame. So, I went out with the intention of presenting the subject a little differently. To quote Feynman:

"…All kinds of interesting questions which the science knowledge only adds to the excitement, the mystery, and the awe of a flower. It only adds, I don't understand how it subtracts."

This quote can be just as true of maths. If it is communicated in the right way maths does not subtract from the wonder of physics, it only makes it more interesting. Communicating maths in an engaging way is a challenge, due in no small part to the common and instant "I don't understand it" public reaction, but never the less it is something that more science communicators should strive to achieve. It adds, for want of a better word, another dimension to our understanding of the Universe and to the astonishment of learning about it.

In my presentation on stellar remnants, I showed Einstein's equations for general relativity, with an explanation of what was represented in these single lines of letters and numbers. The key here is to plant the seed of curiosity. A full explanation would have lost the majority of the audience, but giving them just enough to get their minds latched onto what was being conveyed was sufficient. Being able to represent gravity in a one-line equation is a beautiful thing, and there is a wonder in it that many in the audience would not have been exposed to before that evening.

I had forewarned my audience that there would be some mathematical content to the talk. This was met with a laugh of trepidation. However by the end of the talk, the audience was transfixated, and I was bombarded with interesting questions about black holes, wormholes and the fate of matter that falls into black holes. Even from the youngest member of the audience, who I believe to have been about six years old.

After the talk, I was approached by a gentleman who shared my opinion on mathematics in outreach:

"It is so refreshing to see maths in an astronomy talk. I wholeheartedly agree with you, it is important to include equations. Even if not explained in full, you can at least talk about what the maths can show you. It is the worst feeling, attending a talk on astronomy, and there is no maths. You know they're dumbing it down!"

My efforts to engage the audience with mathematics had clearly hit home with a number of people and there was a feeling of shared belief in the room that maths does not detract from the subject material.

There will be certain circumstances where heavily mathematical content might not be appropriate, and we have a long way to go before a general audience will see an equation and not shy away from it. However, we should be doing all we can to inspire the next generation of scientists to go out and explore the world for themselves, and to do this they need to both know and want to know about maths. We need to show them that maths isn't just for answering questions for exams. Mathematics is the language of physics; it is something to be embraced, not feared.

Biography

Mark Woodland has been a student in astronomy/astrophysics for nearly ten years. Mark is a fellow of the Royal Astronomical Society, Student member of the Institute of Physics, British Interplanetary Society, UKSEDS, and sits on the committee of the Wells & Mendip Astronomers group. Mark's main interests are black holes and high energy astrophysics.

Crowdfunding Astronomy Outreach Projects: Lessons learned from the UNAWE crowdfunding campaign

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Keywords
Crowdfunding, astronomy outreach, education kits, fundraising

Summary

In recent years, crowdfunding has become a popular method of funding new technology or entertainment products, or artistic projects. The idea is that people or projects ask for many small donations from individuals who support the proposed work, rather than a large amount from a single source. Crowdfunding is usually done via an online portal or platform which handles the financial transactions involved. The Universe Awareness (UNAWE) programme decided to undertake a Kickstarter[1] crowdfunding campaign centring on the resource Universe in a Box[2]. In this article we present the lessons learned and best practices from that campaign.

Why crowdfunding?

For those who have not been involved in a crowd-funded project, it can look like an easy way to raise money. An idea is presented on a platform, where many other ideas are presented, and in an ideal world lots of people put money into it and the project becomes a success. This is not quite how it works.

The idea that it is easy is perhaps the result of the simple nature of the language and the videos used on these sites. Grant proposals are filled with highly technical language, whereas a crowdfunding page has to appeal to, and be understood by, a wider audience.

Crowdfunding is a lot of work. By its nature it requires the mobility and participation of a large group of stakeholders. Many people have to be persuaded that the idea is a good one, not just one large potential investor. On the plus side the effort that goes into selling an idea for crowdfunding brings with it excellent publicity and awareness in addition to a source of revenue.

Name	Focus	Link	Funding model
Kickstarter	Creative projects	www.kickstarter.com	AoN
Indiegogo	Allows a broad range of projects	www.indiegogo.com	KiA
Rockethub	Broad range of projects	www.rockethub.com	KiA
1%Club	Development projects	www.onepercentclub.com/en/	KiA
Global Giving	Donation/ charity	www.globalgiving.com	KiA
Crowdcube	Start-ups	www.crowdcube.com	AoN

Table 1. *Overview of the most popular crowdfunding platforms.*

Crowdfunding platforms

Crowdfunding platforms create the necessary organisational systems and conditions for crowdfunding projects to take place. By replacing traditional intermediaries between supply and demand — such as traditional record companies and venture capitalists — platforms such as Kickstarter link new artists, designers and project initiators with supporters who believe in the project enough to invest financial support.

With so many platforms to choose from it is important to research thoroughly before choosing one. Table 1 is only a selection of those available. This article mainly looks at reward- and donation-based platforms as these are considered the most interesting for astronomy outreach projects, but other platforms can also be equity or credit-based.

Figure 1. *Universe in a Box kits packed and ready for shipping around the world. Credit: C. Leung (UNAWE)*

Of particular note when choosing a platform is the funding model used, which will be either All or Nothing (AoN) or Keep it All (KiA). Under the AoN system, money is only collected from contributors if a pre-determined target has been pledged. If the goal is not met, no money is collected. KiA means that all of the funds pledged (minus fees) are handed over to the project regardless of whether there are sufficient funds to meet objectives.

The UNAWE campaign

The UNAWE programme took the decision to undertake a Kickstarter crowdfunding campaign centring on the resource, Universe in a Box. Universe in a Box is a physical science education kit to assist teachers and educators in bringing astronomy and space science to four-to ten-year-old children around the world.

Goal

The goal of the project was to raise 15 000 euros to cover the cost of distributing 160 Universe in a Box kits around the world to underprivileged communities and producing online training videos (Figure 1). Calculated within this was the amount it would cost to ship campaign rewards and the fees which Kickstarter takes from the total.

Budget

The budget for our campaign was 800 euros to produce a campaign video[3] (Figure 2) in addition to three months full-time-equivalent personnel for before, during and after the campaign.

Campaign overview

UNAWE has an extensive international network which gives a strong foundation from which to launch a crowdfunding campaign, but thorough preparation is also important for success. Before the launch date the equivalent of almost one month of full-time work was spent preparing text and visual content for the Kickstarter page and coming up with a plan of action for during the campaign itself. The Kickstarter campaign page[4] (Figure 3) was talked about and shared before launch to enable a hype to build.

The campaign was promoted using email and social media, as well as through contacts with several journalists and conversations with personal friends and other contacts. The team contributed to several blogs about the campaign and other people also blogged about the project.

Updates from UNAWE were posted on Twitter and Facebook accounts at least twice daily, trying to use images once a day and attempting to make sure that the content was diverse. For example, on one day a particular reward would be promoted, and on the next the number of pledgers would be highlighted. The UNAWE Facebook page is liked by 2343 people and the Twitter page is followed by 4627 people at the time of writing.

The website Peerreach[5] was used to identify high-impact Twitter users, particularly within the relevant fields of science and education. These people were then sent personalised messages with a link to the campaign. We aimed to send 20 of these every weekday to different people.

Emails were sent out to various groups of potentially interested people throughout the campaign and to the UNAWE mailing lists at the beginning, middle and end of the campaign.

The UNAWE international mailing list has 1771 subscribers and the UNAWE Dutch mailing list has 844 subscribers. Press releases were prepared and there was media coverage through a variety of outlets.

Results

At the end of the 31-day campaign 17 037 euros had been pledged, bringing the project above the 15 000-euro goal (Figure 4). After fees had been deducted

Figure 2. *Screenshot from the presentation film for the campaign with the astronomer Monica Turner. Credit: van Schadewijk. R/UNAWE*

and a couple of pledges dropped, and a sum of 15 463.56 euros was received from Kickstarter.

The campaign had 235 backers with an average backing of 72.50 euros, was shared 1395 times on Facebook, and the video was viewed 2664 times with 45.14% of plays completed.

Table 2 is a direct product from the Kickstarter page and shows where pledgers arrived at the Kickstarter page from. Most were direct traffic, but a significant proportion of pledgers arrived at the site from the Twitter and Facebook links.

Blog articles and a widget embedded on the UNAWE website also contributed a reasonable amount to the campaign.

Follow-up

Once the campaign was complete, there were three main obligations: shipping the rewards to project backers, fulfilling the targets set out by the campaign, and continuing to build and strengthen the community.

Lessons learned and recommendations

Much was learnt from this foray into the world of crowdfunding and here we will look at some of these lessons, and then summarise recommendations for any other astronomy outreach projects looking to raise funds this way.

Figure 3. *Kickstarter Universe in a Box campaign page.*

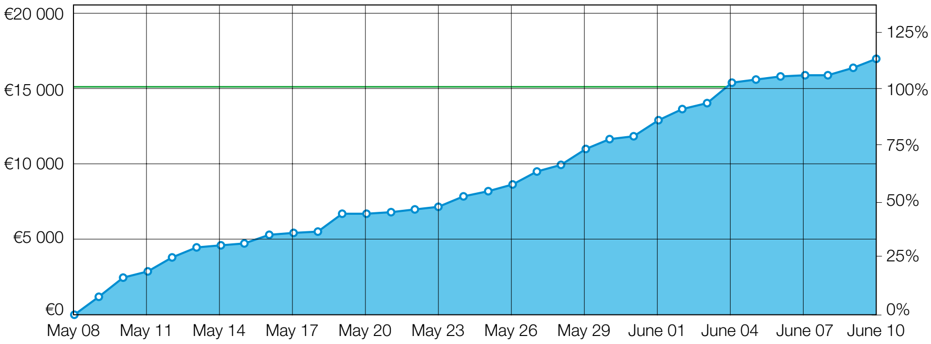

Figure 4. *Evolution of the donations during the campaign period*

1. Don't do it only for the funds

A crowdfunding campaign should also aim to build awareness and a community, as well as raise funds. Community and awareness-building should be as much a part of your goal when running a crowdfunding project as the financial reward.

2. Be prepared

Work on a promotion campaign beforehand and try to have some confirmed pledges beforehand — some say 50%, we had around 25%. Invest in a good video, which should be professional, but not overdone — our video had 2495 views. You should also have a clear plan of how to carry out your campaign if it is successful.

3. Have a clear budget

You need a clear budget for the project, not just a rough estimate. Backers want to know what you will do with their money and you should be prepared to answer any questions they have, like what percentage of funds will be spent on travel or distribution. Don't forget to include any fees for the platform you are using and the cost of reward fulfilment for your backers — how much will it cost to actually send those rewards around the world?

4. Be very active on social media

Twitter: Several updates each day
Tweet celebrities and influential people in the field with personalised messages, do not just copy and paste the URL. Try to vary the updates that you post, sometimes Tweet about a percentage of funds raised and at other times promote specific reward tiers or say what will happen with the funds raised.

Facebook: Around one update a day
You can use Facebook milestones occasionally to really catch followers' attention, but try not to overdo this facility and use it only for big milestones like the half-way mark. Images are good to post with the link, but make sure these are the right size. We used neither Facebook ads nor promotion of posts, but would be interested to hear if anyone has had success with these.

LinkedIn: Two to three updates during the whole campaign.

Kickstarter updates: Five spaced throughout the project
Kickstarter project updates reach people who have already pledged funds to your campaign and people who have chosen to follow your project. They are already interested or motivated by your campaign so these updates should be interesting, friendly and include some sort of call to action, like asking them to share the campaign throughout their own social networks.

5. Tell everyone!

Use all of your networks, including the less obvious ones. If you have an interesting, well-designed project, people will want to hear about it, but whatever you do, don't use spam!

Get featured on the blogs and media of your field and work with your institutional press contacts and trusted media. Keep pushing through all of these channels.

6. Be flexible

If you have a few hundred backers you have to be able to adapt to their needs. So, if most of your backers are in America and Australia, then your social media should be active at times to likely to reach these people, not only at mid-morning Central European Time.

7. The science outreach community won't be your backers' base

Mark Rosin, Guerilla Science, gave us the following advice, and we fully agree:

Getting other people in the PCST (science outreach) community to try and spread the word is not particularly effective. I'm not sure why, exactly, but my best guess is that everyone is competing for bandwidth (and money), so there's only a limited amount of support one can reasonably expect.

So, get your message out beyond your network; it is hard but it is necessary.

Crowdfund your projects, and if you want to...

...develop a product that you can distribute, **use Kickstarter**
...raise money for a specific activity or event, **use Indiegogo or Globalgiving**
...raise money for a project with scientific interest, **consider RocketHub**
...get some time from an expert, **use 1%Club**

Acknowledgement

Universe in a Box development was supported by the European Union. We would like to thank Jaya Ramchandani, Erik Arends and Remco van Schadewijk for their contribution to the crowdfunding campaign and comments to this article.

Source	Number of backers	% Pledged	Amount pledged (euros)
Direct traffic (no referrer information)	97	42.46	7234
Facebook	26	8.74	1545
Twitter	24	9.07	1490
universetoday.com	14	5.52	941
Other sources	14	15	345
Embedded Kickstart widget on www.unawe.org	9	5.05	860
Advanced Discovery on Kickstarter	8	3.09	526
Google searches	7	14	695
unawe.org	5	3.44	586
phys.org	4	1.12	190
scienceblogs.de	4	0.82	140
astronomie.nl	3	1.76	300
Leiden University	3	0.56	95
allesoversterrenkunde.nl	2	1.17	200

Table 2. *Overview of the sources for pledges.*

Further Reading

Kaplan, K. 2013, Nature, 497, 7447

Wheat, R. E. et al. 2013, Trends in Ecology & Evolution, 28, 2

Marlett, D. 2014, *Crowdfunding Art, Science and Technology: A Quick Survey of the Burgeoning New Landscape*. Available at: http://www.academia.edu/6831809/Crowdfunding_Art_Science_and_Technology_A_Quick_Survey_of_the_Burgeoning_New_Landscape

Links

1 Kickstarter: https://www.kickstarter.com/

2 Additional information about Universe in a Box: http://www.unawe.org/resources/universebox/

3 Campaign video: https://www.youtube.com/watch?v=SVwrYbTiuzg

4 Campaign Page: https://www.kickstarter.com/projects/unawe/universe-in-a-box

5 Peerreach, a website used to identify high-impact Twitter users:

Science: http://peerreach.com/lists/science/;

Science UK: http://peerreach.com/lists/science/uk;

Education: http://peerreach.com/lists/education/

Biographies

Abi J. Ashton is a science communicator with a particular specialisation in delivering hands on science workshops to kids around the world. Since discovering the Universe Awareness educational programme almost a year ago and getting involved, she has worked on developing Universe in a Box and would like to see it used in even more schools around the world.

Pedro Russo is the international project manager for the educational programme Universe Awareness. For more information, visit: http://www.unawe.org/russo/

Thilina Heenatigala is an astronomy communicator with an emphasis on education. He is affiliated with the Galileo Teacher Training Program as the communication manager and Universe Awareness as the assistant editor of the IAU astroEDU project. You can follow Thilina on www.twitter.com/ThilinaH.

Masterclasses in Science Communication: An international training programme for scientists and other professionals

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Keywords
Science communication, master classes, training

Summary

This paper seeks to highlight a significant shortcoming in the training of scientists and researchers. A survey of the experiences and needs of a sample of the scientific community has revealed a high level of interest in engaging with science communication projects, but there is a distinct lack of available training in why such projects are needed, and how to carry them out. Based on these findings, SISSA Medialab has developed a set of science communication Masterclasses for scientists, science communicators and other professionals. The content of these Masterclasses is outlined here, and the first stages of their evaluation are described. The courses are relevant across all scientific disciplines including astronomy.

Introduction

In the last few decades, efforts to build a fruitful and long-lasting relationship between the scientific community, their audience and their stakeholders have intensified.

Public conferences, educational workshops, science exhibitions, science cafés, open days, teacher training courses, citizen science projects and public consultations on controversial issues are just a few examples of the diverse activities that research institutions, in collaboration with other organisations and stakeholders, are becoming involved with. A variety of these activities are being developed and experimented with in order to attract the attention of different audiences and to engage them in a deep, open and culturally enriching dialogue.

Figure 1. *Time for peer-to-peer learning was reserved in all courses. Credit: SISSA Medialab.*

Despite the growing importance attributed to the direct participation of scientists in science communication projects, many researchers are still not involved. There are many reasons for this, but lack of time and lack of institutional support are among the most frequently mentioned in national and international surveys. An additional problem that is often reported by scientists is the lack of specific training. Training to communicate science in an effective way is often completely absent in academic curricula, and only sporadically offered in specific programmes or courses.

Moreover, the variety and complexity of these activities necessarily require the participation of various people, with specific professional knowledge and expertise. The contact between these different professional communities, including the scientific community, is all too often non-existent.

This gap in training for the scientific community led the main institutions of the Trieste science system — the informal network of research institutes working in the Trieste region of Italy — to collaborate in a training programme aiming at empowering scientists and other professionals to develop cutting-edge science communication projects.

The project also gives individuals the opportunity to meet people from different countries and with different expertise, competences and experiences. In most cases science communication projects require the collaboration of multi-disciplinary teams, so learning to work in a varied team is a fundamental competence to be acquired.

The training scheme has been promoted by the International School of Advanced Studies (SISSA); the International Centre for Theoretical Physics (ICTP); the International Centre for Genetic Engineering and Biotechnology (ICGEB); and Elettra Sincrotrone Trieste, with the collaboration of the Architects' Association of the Friuli Venezia-Giulia region.

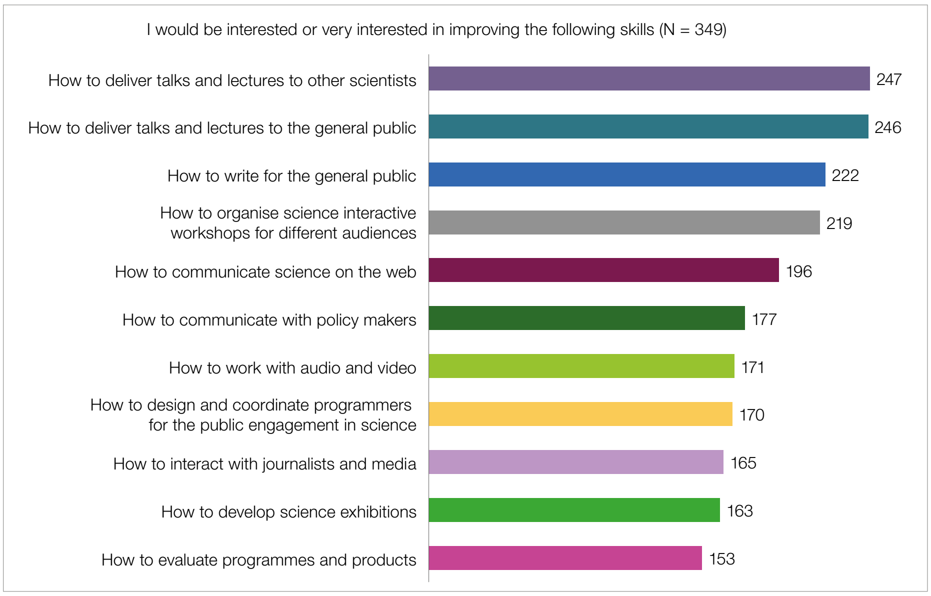

Figure 2. *Personal skills that respondents would like to improve. Respondents were asked to assign a score from 1 (lowest) to 5 (highest) to their interest in the improving certain personal skills. This figure shows the results for the scores 4 or 5.*

Attitudes of scientists towards science communication

In order to develop a programme of courses for the main target group — the scientific community — SISSA Medialab carried out research to investigate whether, and to what extent, scientists were involved in science communication activities, what their interests in it were, and what they considered their training needs to be.

The online questionnaire, carried out in 2013, was sent to more than 1500 scientists, who had come from all over the world to attended conferences or seminars at the ICTP. A total of 420 answers were collected, mainly from physicists.

In general, scientists expressed a strong interest in participating in science outreach activities. Of those surveyed, 65% declared themselves to be personally involved in communication activities and only 5% reported that they are not and will not in future be involved in such activities. The remaining 30% considered that being involved in outreach programmes was a possibility.

Despite the interest in, and personal experience of outreach programmes, most — 68% — of the respondents declared that they had never attended a training course or seminar on science communication, supporting the claim that training in this area is not common practice.

Most of the scientists who participated in the survey declared that they would be interested in attending a course devoted to science communication, with a particular interest from researchers working in Africa, Asia and Central–South America — with a percentage ranging from an average 65% to the maximum of 89% for African scientists.

The strong interest expressed by scientists from developing and recently developed countries towards science communication activities and courses is consistent with informal results from observations and evaluations of SISSA Medialab's many previous international courses. Over the past seven years approximately 3000 scientists, science journalists, museum staff and other professionals have participated in short international courses. Whilst developing these courses it has been found that researchers value science communication and science education programmes as a way of supporting the cultural, technological and economic development of their society.

The communication of science as a powerful tool to empower children and adults, especially from socially challenging backgrounds, also emerged in a qualitative evaluation performed by SISSA Medialab. In June 2014, PhD students and researchers involved in outreach activities in SISSA took part in focus groups to discuss their attitudes and needs after a year of training and experience in communicating their research. A major point that emerged from the discussions was a feeling that communicating science can be a means of giving hope and opening up possibilities to people who do not have positive expectations for their future. Scientists coming from developing countries, or from areas that experience serious criminal and social problems, expressed strong feelings of responsibility towards the younger generation, often viewing engagement with the public as a moral duty and an empowering tool for the scientist.

The importance of a specific training in science communication emerged unanimously from the focus groups.

Scientists' perceived training needs

Figure 2 ranks the survey respondents' interests in different skills. The interest in learning specific skills such as science writing or oral presentation is understandably higher in areas in which the scientific community is already more active.

Figure 4 shows the topics that survey respondents were interested in, and is harder to analyse.

"Women in science" scored the highest for "very interested" (31.8%), while in second place participants declared themselves to be "very interested" in "Science museums and science centres" (31.6%). However looking at the skills survey, the skill "to develop science exhibitions" did not score particularly highly. This expressed interest might indicate that respondents perceive science centres and museums as a fundamental actor in promoting, designing and delivering science dissemination activities, and therefore would like to know more about how they are established and operate, but are not as keen to learn to develop the exhibitions themselves.

JCOM Masterclasses in Science Communication: Planning and delivery

The results of the online survey, the data from the evaluation surveys of previous courses and the qualitative research carried out on SISSA PhD students who are involved in outreach activities has been used by SISSA Medialab to develop a series of four international courses, to cover different areas of the communication of science[1].

The courses are organised within the activities of the Journal of Science Communication (JCOM), an open access, peer-reviewed journal dedicated to science communication[2]. They are intensive one-week-long training courses held in Trieste, Italy, and aimed at scientists, managers of cultural institutions, public information officers, non-governmental organisations and company employees, and other professionals interested in science communication.

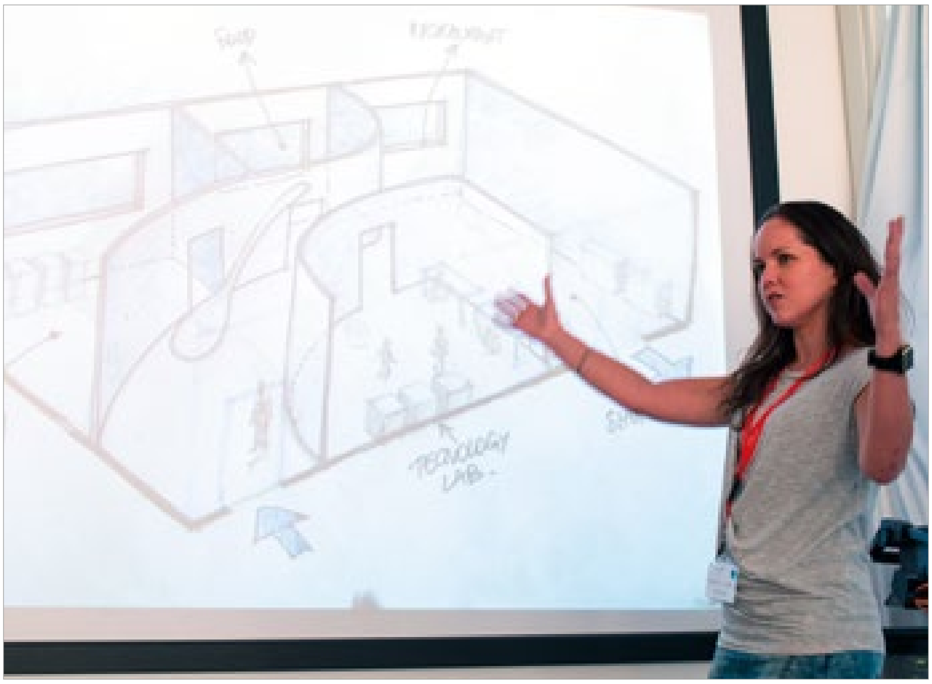

Figure 3. *With the support of the speakers, participants can go through several steps of the exhibition planning, from the general idea to the design. Credit: Lisa Zillio (SISSA Medialab).*

The main objectives of the Masterclasses are to disseminate best practice in public engagement; to facilitate contacts between experts at an international level and participants; and to promote peer-to-peer learning among attendees.

Grants to support participation in the course have been offered, thanks to SISSA, ICGEB and ICTP. In particular, the ICTP offered twenty grants to candidates working in developing countries, thus enabling the Masterclasses to respond to the strong interest expressed by scientists and professionals living in those countries.

The JCOM Masterclasses were advertised in the first six months of 2014 and received an enthusiastic response from the target audience. Two hundred and seventy six applications were received from 54 different countries for a maximum of 100 places.

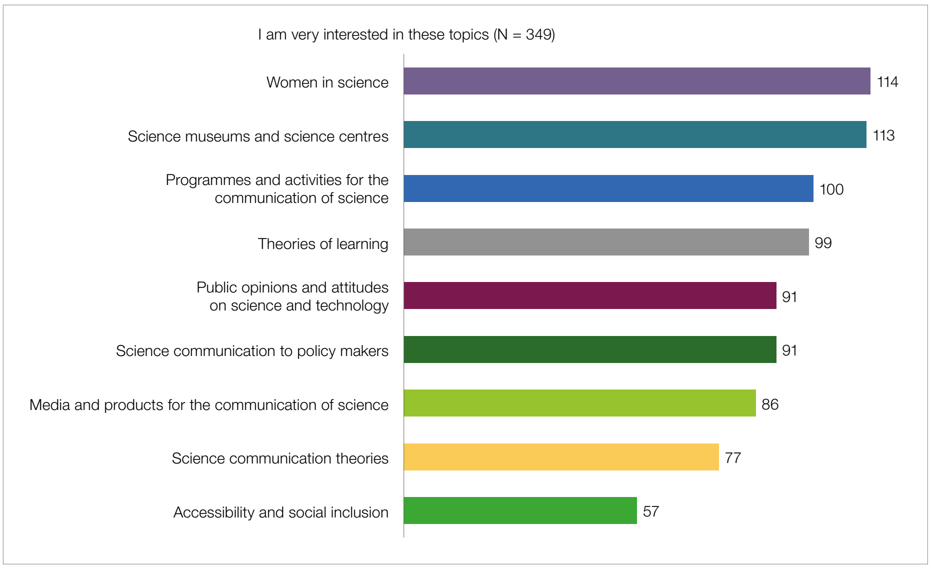

Figure 4. *Topics that respondents were most interested in. Respondents were asked to assign a score on a scale from 1 (lowest) to 5 (highest) to their interest in the different topics. This figure shows the results for the score 5.*

JCOM Masterclasses in Science Communication: Content

The courses were developed to encourage peer-to-peer learning and the exchange of points of view between different communities. Scientists, science communicators, museum staff, architects, designers and project managers brought together different skills, problems and experiences providing a crucial opportunity for shared learning.

In 2014 there were four courses for the JCOM Masterclasses:

- Facilitating the debate on the scientific and technological progress;
- Developing successful exhibitions;
- Developing successful museums and science centres;
- Communicating current research to different audiences.

All the courses present cutting-edge theories and methodologies, and offer innovative training in science communication. Speakers were chosen from among the most experienced professionals working at the highest international level. The diversity of topics has promoted the participation of people coming from different backgrounds and with different training needs.

The first course aimed to empower scientists, educators and museum staff to use new, participatory methodologies to involve the public in discussions about scientific and technological development, the impact on society, and any potentially controversial aspects of these developments.

Figure 5. *A group discussion among participants of the Masterclass. Credit: Lisa Zillio (SISSA Medialab).*

The second and the third courses aimed to empower content developers, architects, designers and managers of exhibitions and museum-like institutions. In the same way that scientists lack formal training in science communication, other professionals — such as architects and interior designers — are very often not equipped during their academic studies to develop narrative, interactive exhibitions. The course addressed training needs that are not covered in universities and briefed participants on how to:

- define the mission and objectives;
- identify potential audiences and the importance of involving stake-holders;
- identify and plan appropriate spaces and facilities to meet the needs of the organisation and the visitors;
- plan and integrate programmes and associated facilities into the development;
- plan the work and organise teams using a project execution plan;
- develop the scientific content of an exhibition;
- incorporate visitors' needs into the design;
- develop a narrative through exhibits and objects;
- choose media and technologies;
- develop a content and design brief for architects and designers;
- plan the work and organise the team;
- and the significance of the brand in the proposed development, communication and marketing strategies.

The objective of the fourth course is to introduce basic science communication skills to scientists. These include oral presentation, science blogging and communication with policy makers, etc. It also includes cutting-edge aspects of contemporary science communication, such as science governance and risk communication.

A crucial aspect of the Masterclasses is the high level of interactivity. Participants are invited to share their experiences and the problems they face with their own pro-

Figure 6. *Gender equality in high education and research was one of the issues discussed during the courses. Credit: SISSA Medialab.*

Figure 7. *All participants worked together to plan a very special exhibition about spoons. Credit: Lisa Zillio (SISSA Medialab).*

jects, so that the speakers and organisers can give suggestions and guidance. A large part of the course is dedicated to projects that participants can develop under the guidance of the professionals.

Evaluation and conclusion

Summative evaluations performed at the end of the first two courses — which are the only ones to have been delivered at the time of writing this paper — revealed a very high appreciation of the experience. Participants reported that they had gained theoretical knowledge, and acquired practical guidelines, new ideas and inspiration.

Participants were asked to rate the different sessions according to their interest in the topic; the relevance to their own work; the applicability of the content; and the quality of materials. On average, the course received a very high score — 3.6 and 3.7 out of 4 for the first and second course, respectively — and participants expressed their appreciation with personal comments.

The diversity of the audience was sometimes demanding and time-consuming during the group work, but all participants appreciated the opportunity to discover the different approaches of people from different backgrounds, experiences and nationalities.

The evaluation will be added to once the courses are complete and will be taken into account during the development of a second series of training courses for 2015.

Links

1 The JCOM Masterclasses website: http://jcom.sissa.it/masterclasses/

2 Journal of Science Communication website: http://jcom.sissa.it/about-jcom/

Biographies

Valentina Daelli is a science writer and science communicator. She has collaborated with SISSA Medialab on different projects, including research about the needs and experiences in science communication training for scientists and researchers. She obtained a PhD in cognitive neuroscience and a Masters in science communication at the International School of Advanced Studies, in Trieste, Italy.

Paola Rodari works for SISSA Medialab as a project manager for several national and international projects aimed at communicating science to different audiences. She has been the project leader for the development of Italian science centres, is on the steering committee of the Ecsite thematic group — THE group — dedicated to professional development for explainers, and teaches museum studies in the SISSA Masters in Science Communication. She is also the project manager of the JCOM Masterclasses international training courses.

ESO Ultra HD Expedition: New clarity for astronomy outreach

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ultraHD, 4K, ESO, #ESOultraHD

Summary

In the spring of 2014 a team of ESO Photo Ambassadors embarked on a pioneering expedition to the European Southern Observatory's observing sites in Chile. Their mission was to capture time-lapses, stills, videos and panoramas in crisp Ultra High Definition from some of the darkest night skies on Earth.

Introduction

Ultra High Definition (Ultra HD), also known as 4K, has been hailed as the next revolution[1] for television after High Definition (HD) TV. With four times as many pixels as HD this crisp and clear format has recently risen to prominence and become the norm for many top-range TV displays.

Although the technology has flourished there is currently very little free, high-quality, Ultra HD content available.

The European Southern Observatory (ESO) set out to change this by delivering free Ultra HD for use by anyone from public consumer to broadcaster. ESO is perhaps the first scientific organisation to produce 4K content for free on a regular basis.

Figure 1. *The ESO Ultra HD Logo. Credit: ESO.*

Why Ultra HD?

Astronomy is a very visual science and, with four times the resolution of HD, Ultra HD offers new clarity to our stunning footage of the cosmos.

The vision of the ESO Ultra HD Expedition[2, 3] was to deliver breathtaking Ultra HD footage that transcended astronomical, geographic and scientific frontiers and brought the Universe closer than ever before.

The expedition was originally conceived as one of the regular visits to the ESO sites where photos and video are taken to document changes and work at the sites. However, this time it was decided that the visit would go further and upgrade to the most current technologies in time-lapse imaging and high-resolution filming.

Embarking on an adventure

In late March 2014, after six months of planning, the team of four world-renowned astro-photographers including ESO's videographer Herbert Zodet, and the three ESO Photo Ambassadors Yuri Beletsky, Christoph Malin and Babak Tafreshi departed. They left equipped with the most powerful photographic and video-graphy tools from the world's top technology names[4].

The logistical challenges of transport to Chile combined with the barren environment in the Atacama Desert put high demands on the equipment cases. Protective cases, called Peli Cases, were offered to the team by Peli and filled to the brim at ESO's headquarters in Garching, Germany. The hardback cases carried technology ranging from a Vixen Polarie Star Tracker — which allows photographers to capture the night sky whilst aligned to the planet's poles — to Angelbird's SSD2go PRO solid-state disks that store the Ultra HD content the team produced with the Canon cameras.

The team first flew from Europe to Chile's capital city, Santiago, home to the ESO Guesthouse. Getting through customs in Santiago with all the high-tech equipment was an interesting experience for the team, but fortunately the official letters and paperwork did the job.

The Guesthouse is a fabulous place to either recover from jetlag or from weeks of consecutive observing at the observatories, and a good stop before heading on to the next stage of the team's adventure — to capture the night sky in high resolution.

Paranal — Jewel on the Mountaintop

The ESO Ultra HD Expedition team first travelled to Paranal Observatory[5], home to the Very Large Telescope (VLT) — ESO's flagship facility for European ground-based astronomy.

Following a short flight from Santiago to Antofagasta, the team picked up their two

Figure 2. *A look back to the team's time at Paranal. Credit: ESO/B. Tafreshi*

four-wheel drives and began the journey to Paranal. The drive through the dusty mining capital Antofagasta presents a great contrast to the hustle and bustle of the modern Chilean capital, as does the drive through the arid desert beyond the city limits. The need for the four-wheel drives became quickly apparent.

The first signs of approaching Paranal are the four Unit Telescopes of the VLT. The telescopes, named Antu, Kueyen, Melipal and Yepun, guided the team to their first destination — a technological oasis 2635 metres above sea level. The views from the mountain peak are breathtaking and the team took advantage of them, taking some sunset shots at this beautiful location.

Figure 3. *This Ultra HD photograph shows almost the full VLT platform with the red shades of airglow visible overhead. Credit: ESO/Y. Beletsky (LCO*

Atacama Large Millimeter/ submillimeter Array

Having spent some time at Paranal the team set off to their next location, the Atacama Large Millimeter/submillimeter Array (ALMA)[6].

ALMA is a large interferometer composed of 66 high-precision antennas. Located on the Chajnantor Plateau, 5000 metres above sea level in northern Chile, the individual antennas can be combined and act together as a giant single telescope.

Having arrived at the basecamp of the ALMA Observatory the team went through

Figure 4. *Night view of one of the ALMA transporters, Otto, at the ALMA high site on the Chajnantor Plateau. Credit: ESO/Y. Beletsky (LCO)*

Figure 5. *UHD image taken with a long exposure to show the movement of the ALMA antennas. Credit: ESO/Y. Beletsky (LCO)*

the mandatory medical exam to check that their bodies could cope with the high altitude conditions and fortunately all of them passed the test. However, human operations at the Array Operations Site (AOS), 5000 metres above sea level, are limited to an absolute minimum due to the extremely high altitude, so they could not linger too long. But they worked hard to deliver as many stunning shots as they could in the limited time available.

Figure 6. *A curtain of stars surrounds the 3.58-metre New Technology Telescope in this Ultra High Definition photograph from the ESO Ultra HD Expedition. Credit: ESO/B. Tafreshi*

Yuri caught a rare night view of one of the ALMA antenna transporters, Otto, at the high site.

Otto is one of the two transporters that are used to reposition the antennas. The twin vehicles are 20 metres long, 10 metres wide and 6 metres high, and each has 28 tyres. The ability to relocate the antennas and change focus is an integral part of what makes ALMA such a powerful telescope.

La Silla — ESO's first observatory

To end the trip the ESO Ultra HD Expedition headed to where it all began — La Silla, ESO's first observatory[7]. Located on the edge of the Atacama Desert, La Silla is 600 kilometres north of Santiago, and 2400 metres above sea level. It is home to the ESO 3.6-metre telescope and the 3.58-metre New Technology Telescope (NTT). Many of the ESO Member States use the site for targeted national projects such as the Swiss 1.2-metre Leonhard Euler Telescope.

Inaugurated in 1969, the facilities at La Silla led Europe to the frontline of astronomical research and, with more than 300 clear nights per year, it provides the perfect backdrop for the 4K shots.

Herbert was able to obtain some Ultra HD footage of the ESO 3.6-metre telescope and the NTT during the opening of their respective enclosures at sunset. The rest of the team took a range of further time-lapse shots at sunset, during the night and at sunrise — both indoors and outdoors.

In particular, the team were keen to take some more transition shots like the fish-eye view, in stunning Ultra HD, 4K format. It is here at La Silla that the team took their last shots of the Ultra HD Universe, at least for now.

Follow-up

Following the expedition, there was a lot for the team to do in terms of processing, colour-correcting and combining all the many SSD disks full of material taken at each of the ESO sites.

The graphics team at ESO Headquarters scrutinised every detail of the IMAX-size

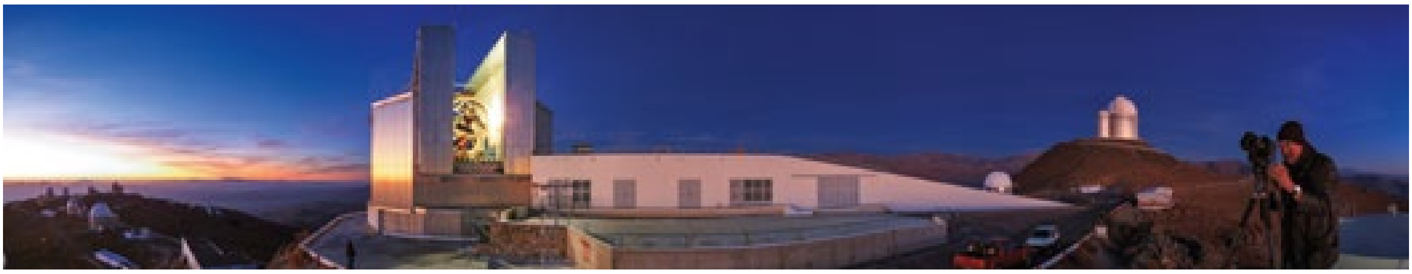

Figure 7. *The sun sets at La Silla Observatory in this stunning Ultra HD panorama. In the centre, the ESO 3.58-metre New Technology Telescope and to the right, the ESO 3.6-metre telescope with ESO's videographer Herbert Zodet at work. Credit: ESO/B. Tafreshi*

4K images and videos using a professional Sharp Ultra HD display which offers extraordinarily high resolution. In order to work seamlessly on the large 4K video files two special Magic Multimedia PC workstations were built and optimised for multi-layer 4K video editing, each with 48 cores and 128 GB of RAM.

The results are now available for free under Creative Commons with more than 200 spectacular photos from the expedition having been published[8]. Several are still in the pipeline as ESO Pictures of the Week and will be released over the coming months. Almost 100 Ultra HD videos are also available, with a few more still being polished, which will then become available over the next months[9].

A behind-the-scenes view of the expedition was released as an ESOcast[10]. It follows the story of the team's journey across the arid Atacama Desert, and includes some of the many wonderful time-lapses, stills and panoramas. As part of the campaign, the team also shared their thoughts on the ESO Ultra HD blog[11], explaining some of the background of the work. A variety of other outputs from ESO also track the exhibition[12].

Spurred by the success of the expedition ESO has continued to produce 4K videos about other topics, and there are now more than 200 free Ultra HD clips published in ESO's video archive[13].

But there's more! ESO's education and Public Outreach Department has now eyed an even larger prey: 4K planetarium shows with frames that are almost twice as big as Ultra HD. With the upcoming ESO Supernova Planetarium and Visitor Centre[14] in mind high-quality material — ultra high-resolution stills and 4K fulldome frames for use in planetarium shows — are now pouring online[15].

Acknowledgements

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Madsen, C. 2012, *Jewel on the Mountaintop — The European Southern Observatory through Fifty Years* (Wiley), Hardcover (free E-book available at http://www.eso.org/public/products/books/book_0050/)

Figure 8. *This Ultra HD photograph taken during the ESO Ultra HD Expedition captures ESO's Paranal Observatory in a 360-degree fish-eye view that can be used for fulldome projection in planetariums. The swirling Milky Way can be seen at its centre. Credit: ESO/Y.Beletsky*

Notes

1. The 4K Ultra HD Revolution http://www.youtube.com/watch?v=miKmxszDg6Q
2. ESO Ultra HD website http://www.eso.org/public/outreach/ultra-high-definition/
3. ESO Ultra HD Expedition brochure http://www.eso.org/public/archives/epublications/pdf/epub_0001.pdf
4. The expedition's equipment included: Vixen Optics Polarie Star Tracker, Canon® EOS-1D C camera, Stage One Dolly and eMotimo TB3 3-axis motion control camera robot, Angelbird SSD2go, LRTimelapse software. Peli™ Cases, 4K PC workstations from Magic Multimedia, Novoflex QuadroPod system, Intecro batteries and Granite Bay Software.
5. More information on Paranal Observatory: http://en.wikipedia.org/wiki/Paranal_Observatory
6. More information on ALMA: http://www.eso.org/sci/facilities/alma.html
7. More information on La Silla: http://en.wikipedia.org/wiki/La_Silla_Observatory
8. Images from the exhibition: http://www.eso.org/public/images/?search=%2B%22uhd%22
9. Videos from the exhibition: http://www.eso.org/public/videos/?search=%2B+%22uhd%22
10. ESOcast 65: The Chilean Sky in Ultra High Definition http://www.eso.org/public/videos/esocast65a/
11. ESO Ultra HD Blog http://www.eso.org/public/outreach/ultra-high-definition/blog/
12. Announcements about the exhibition: The results from the exhibition: http://www.eso.org/public/announcements/ann14035/ ESO Ultra HD Expedition Begins, http://www.eso.org/public/announcements/ann14023/
13. All 4K material available on the ESO website can be found here: http://goo.gl/5J84Rm
14. Find out more about the Supernova Planetarium and Visitor Centre Donated to ESO: http://www.eso.org/public/news/eso1349/
15. Free Fulldome Material for Planetariums is available here: http://www.eso.org/public/announcements/ann14051/

Biographies

Ryan Laird is a science communicator from the UK with a great passion for astronomy and all things space. He obtained a degree in Physics with Astrophysics MPhys (Hons) from the University of Leicester and is an alumnus of the International Space University (ISU) Space Studies Program (SSP). He worked as an intern at Universe Awareness (UNAWE; Space Scoop) and at the European Southern Observatory (ESO) in the education and Public Outreach Department (ePOD). In 2009, he was also the UK Student Representative for the Opening Ceremony of the International Year of Astronomy 2009 (IYA2009).

Lars Lindberg Christensen is a science communication specialist, who is Head of the ESO education and Public Outreach Department (ePOD) in Munich, Germany. He leads public outreach and education for the La Silla-Paranal Observatory, for ESO's part of ALMA and APEX, for the European Extremely Large Telescope, for ESA's part of the Hubble Space Telescope and for the IAU Press Office.

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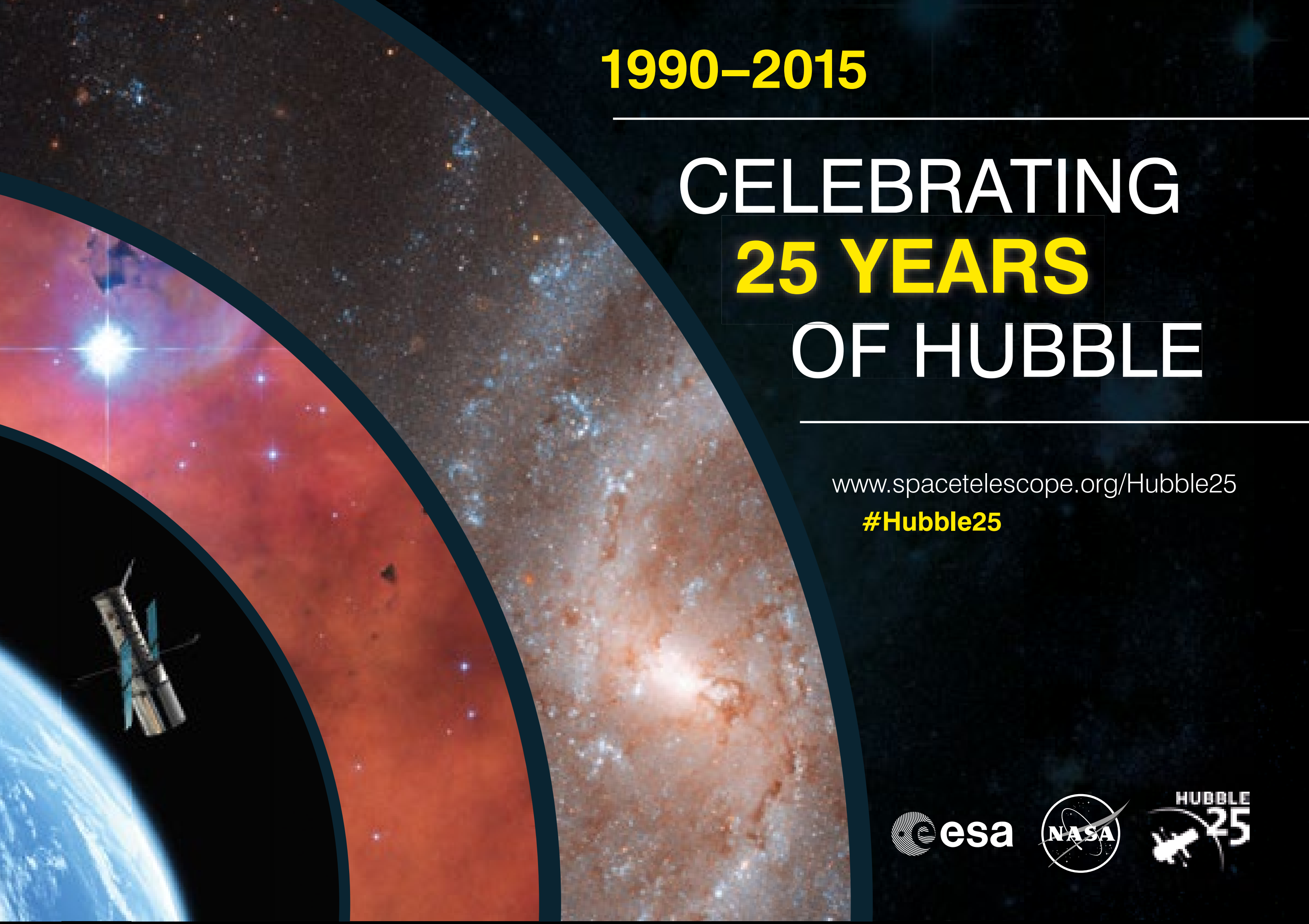

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