CAP journal
Issue 18 | September 2015
Communicating Astronomy with the Public

Cosmic Fiction, Drama and Poetry
Cataloguing Interdisciplinary Approaches to Astronomy

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On 21 August 2015, ESA's billion-star surveyor, *Gaia*, completed its first year of science observations in its main survey mode. One and a half million kilometres from Earth, *Gaia* surveys stars and other astronomical objects as it spins, mapping in arcs across the sky. By repeatedly measuring the positions of the stars with extraordinary accuracy, *Gaia* can measure their distances and their motion through the Milky Way. This image shows the launch of *Gaia* on 19 December 2013 from Europe's spaceport in French Guiana, on the shuttle *Soyuz VS06*.

Credit: ESA/S. Corvaja

Contents

On the cover of this issue is the best image of the dwarf planet Pluto ever made, in a rendering based on data from NASA's *New Horizons* spacecraft.

Several images from the Long Range Reconnaissance Imager (LORRI) on *New Horizons* were combined with colour data from the Ralph instrument to create this enhanced colour global view. The images were taken when the spacecraft was between 450 000 and 80 000 kilometres from Pluto's surface.

Credit: NASA/JHUAPL/SwRI/ESO

Editorial

Welcome to another issue of the *Communicating Astronomy with the Public Journal*.

As many of you may know, our journal forms part of Commission 55 of the International Astronomy Union's (IAU) Division C — known as Communicating Astronomy with the Public. To begin this issue I would like to acknowledge a recent change in this commission. Lars Lindberg Christensen, who has been president of the commission for three years, officially stepped down in August during the IAU General Assembly in Honolulu, Hawaii. Lars has made a significant contribution to the commission, including helping to bring this journal to life. I would like to sincerely thank Lars for his unwavering support of astronomy communication, the commission and the journal.

In addition to celebrating Lars's successes as president we also have reason to celebrate the arrival of our new president, Pedro Russo. Pedro has been vice-president of the commission for three years; he played a leading role in its development and initiated the creation of *CAPjournal* in 2007, before becoming its first editor. Congratulations Pedro, we all very much look forward to working with you in your new role.

Another exciting result from the General Assembly was the announcement that the Office of Astronomy for Development (OAD) will open new coordinating offices in Armenia, Colombia, Jordan, Nigeria and Portugal. One of our leading aims at *CAPjournal* is to represent astronomy communication activities from across the globe and in doing so reflect the IAU's strategic plan — to realise the societal benefits of astronomy. These new offices will support this aim and we hope to hear more from representatives in these areas in upcoming issues of *CAPjournal*.

In this issue of the journal we reflect on some key findings in astronomy communication, including research into astronomers' views on outreach; reflections on the highly successful Galileoscope project and Global Astronomy Month; and insights into new ways to share and improve access to the huge files we, as astronomy communicators, are creating.

We also gain a new perspective in this issue by hearing from those who have participated in our projects. ESO Astronomy Camp students reflect upon what they gained from the camp, whilst a winner of the ESA/Hubble *Ode to Hubble* competition explains how she tied together photography, philosophy and astronomy for the competition, and why.

If you have any comments, feedback, or wish to send a submission or proposal for our upcoming issues, please contact: editor@capjournal.org. Many thanks once again for your interest in *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: Why is Pluto not a Planet?

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Keywords
Dwarf planet, Pluto, planet, Solar System, Eris

On 24 August 2006 an International Astronomical Union (IAU) resolution changed the shape of the Solar System and redefined what it meant to be a planet. As a result, Pluto, the smallest and most recently discovered planet in the Solar System, became a dwarf planet.

In the months that followed, the initial surprise over this decision gave way to acceptance, although many remembered Pluto the planet fondly.

These memories surfaced again just recently, when NASA's New Horizons spacecraft flew by Pluto and captured the distant world with vivid clarity. People around the globe asked anew: Why is Pluto not a planet?

Pluto became the smallest planet, and, for most of its orbit, the furthest out from the Sun, following its discovery in 1930 by Clyde Tombaugh. However, the early 90s saw the discovery of a spate of objects that resided beyond Neptune and Pluto. Their existence cast doubt upon the validity of this initial decision. Pluto's pedigree was called into question once and for all with the discovery of Eris in January 2005. Although slightly smaller than Pluto, Eris was found to be more massive, and questions about what it really means to be a planet again came to the fore.

Pluto was reclassified in Prague at the IAU XXVI General Assembly. A resolution passed on the closing day of the assembly provided a threefold definition of a planet. Pluto met the first two criteria with admirable ease: it is a celestial body that orbits the Sun, it is round, indicating that a state of hydrostatic equilibrium prevails, indicating that inward gravitational forces are balanced by an outward pressure.

The final hurdle, however, proved fatal. To be a planet, the object must have cleared the neighbourhood around its orbit. Pluto is surrounded by shards of rock and ice, and so failed miserably to achieve this; its cluttered surroundings and poor housekeeping were its undoing.

This third criterion is, in effect, a determination of size. Pluto is too small to gravitationally dominate its environment by absorbing and ejecting material in its path. It is for this reason that when we look upon the New Horizon mission's high-definition images of Pluto, we see more that a dwarf planet among many; we see a planet that once was, and an important piece of astronomy's history.

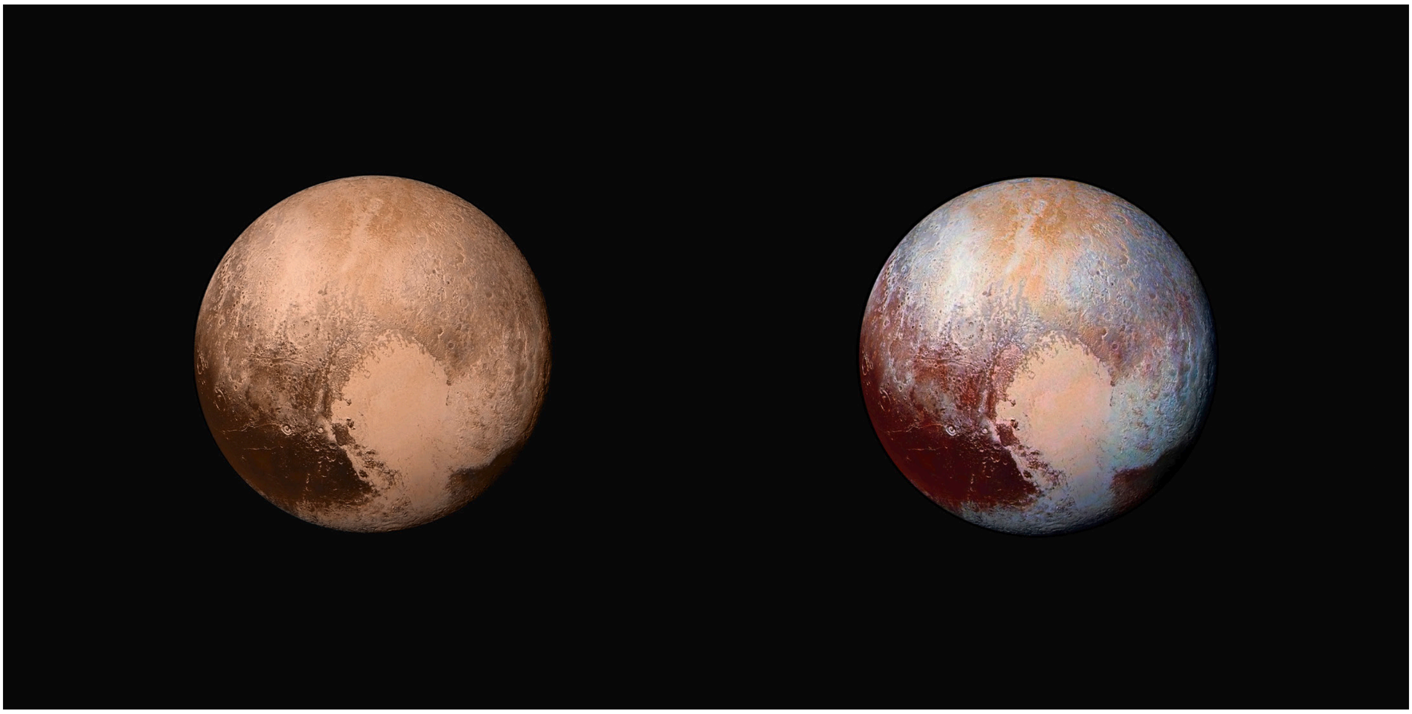

Figure 1. *In both of these views of the dwarf planet Pluto, four images from* New Horizons' *Long Range Reconnaissance Imager (LORRI) were combined with colour data from the Ralph instrument. In the left image this was done to create a sharper view of Pluto and on the right to create an enhanced colour view.*

Catching Cosmic Light with the Galileoscope

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Keywords
Galileoscope, telescope, International Year of Light, International Year of Astronomy, celestial observation, planetary observations, optics

Created for the 2009 International Year of Astronomy, the Galileoscope solved a long-standing problem: the lack of high quality, low cost telescope kits suitable for both optics education and celestial observation. Through an effort managed entirely by the volunteers who have authored this article almost 240 000 Galileoscope kits have now been distributed in 106 countries across the globe, for use in science teaching and public outreach. The Galileoscope outreach programme for the 2015 International Year of Light is now in full swing, giving tens of thousands of students, teachers and parents their first telescopic look at the Moon's craters and Saturn's rings.

Galileoscope and the International Year of Light

The Galileoscope has been named part of the Cosmic Light cornerstone project of the 2015 International Year of Light (IYL); a project coordinated by the International Astronomical Union (IAU)[1,2,3]. Plenty of these IYL-branded kits remain available for direct purchase and for donation through the Telescopes4Teachers programme[4,5].

Since its inception, the Galileoscope project has facilitated gifts to teachers and students who might otherwise not have access to a telescope[6]. During the 2009 International Year of Astronomy (IYA), some 7000 kits were donated and distributed to educators throughout Africa and the Middle East[7]. That same year, Jean and Ric Edelman, the founders of Edelman Financial Services, donated 15 000 Galileoscopes to science teachers in the USA[8].

For the IYL2015, the Edelmans have made another generous contribution to Telescopes4Teachers to support the distribution of 10 000 more Galileoscopes to science educators[9]. Ric Edelman promoted their availability via his biweekly radio programme, *The Truth About Money*, in late May, and all 10 000 kits were claimed within four days by teachers in 48 states of the USA, the District of Columbia, Puerto Rico, and Guam[10].

What the Galileoscope has to offer

In the process of assembling the Galileoscope, students explore fundamental optical concepts such as how lenses form images. Then, with their completed 50-millimetre diameter, 25- to 50-power, achromatic refractor — which attaches to any photo tripod — they can enjoy sharp views of lunar craters and mountains, Jupiter's moons, Saturn's rings, the phases of Venus, and other bright celestial objects.

The kit is augmented with free optics education and observing activities. These well-tested activities can be used by classroom and after-school teachers, as well as informal educators and outreach

Figure 1. *Assembled Galileoscope. Credit: Joson Images/Galileoscope, LLC*

Figure 2. *Galileoscope kit. Credit: Joson Images/Galileoscope, LLC*

specialists, to provide a rigorous approach to teaching science and the scientific method.

The Galileoscope has been featured in professional development workshops for educators worldwide. Among the organisations routinely incorporating the kit into their teacher training are the U.S. National Optical Astronomy Observatory (NOAO), the Astronomical Society of the Pacific (ASP), and the Galileo Teacher Training Program (GTTP). NOAO has established a programme of workshops for educators that can be carried out virtually anywhere — including online — at minimal cost to the host institution[11].

At the IAU General Assembly in Honolulu in August, more than 400 local Hawaiian students visited the exhibit hall to meet scientists and engage in hands-on astronomy activities. As they left, each was given a Galileoscope kit by the event's sponsor, Associated Universities, Inc. As seen in Figure 3, the children were all smiles!

Figure 3. *Children celebrating receipt of Galileoscopes at the IAU General Assembly in Honolulu, Hawaii, in August 2015. Credit: Coty Tatge, University of Wyoming*

Notes

1. More on the Cosmic Light cornerstone project: http://www.light2015.org/Home/CosmicLight.html
2. More on the International Year of Light: http://www.light2015.org/Home.html
3. More on the International Astronomical Union: http://www.iau.org/iyl/
4. IYL-branded kits available for direct purchase: http://galileoscope.org/order-kits/
5. IYL-branded kits available for donation through the Telescopes4Teachers programme: http://galileoscope.org/support-schools/
6. More information on the Galileoscope project: http://galileoscope.org
7. More information on the 2009 International Year of Astronomy: http://astronomy2009.org/
8. More information on Edelman Financial Services: http://www.edelmanfinancial.com/
9. Press release on the Edelmans' 2015 donation: http://galileoscope.org/celestial-wonders-await-thousands-of-schoolchildren/
10. Ric Edelman's biweekly radio programme The Truth About Money: http://www.edelmanfinancial.com/radio
11. Programme of workshops for educators developed by NOAO: http://galileoscope.org/workshops/

Figure 4. *Jean and Ric Edelman, philanthropists and founders of Edelman Financial Services, who donated 15 000 Galileoscopes to science teachers in the USA in 2009 and a further 10 000 in 2015. Credit: Edelman Financial Services*

Biographies

Rick Fienberg is Vice-President and one of the founders of Galileoscope, LLC, which supports and promotes the manufacturing and distribution of Galileoscope kits. Fienberg is also Press Officer and Director of Communications at the American Astronomical Society.

Doug Arion is President and one of the founders of Galileoscope, LLC, which supports and promotes the manufacturing and distribution of Galileoscope kits. Arion is also Professor of Physics and Astronomy and Professor of Entrepreneurship at Carthage College, USA.

Interdisciplinary Approaches to Astronomy: Cosmic Fiction, Drama and Poetry

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Keywords
Interdisciplinary, science fiction, science in cinema, science in literature

I have spent four decades teaching introductory astronomy to university students whose primary subject of study is not astronomy, as well as developing activities to help the public appreciate astronomical ideas and developments. One of the more effective tools that I have found for capturing the interest of non-scientists has been approaching astronomy through its influence on the humanities. In this article I examine some examples of astronomical inspiration in the humanities, looking at plays, poetry and fiction. A second paper, devoted to music inspired by astronomy, will appear in a future issue of the *CAPjournal*.

Introduction

Astronomy has long been an inspiration for creative people in other fields and examples of astronomical influence seem to be everywhere in modern popular culture — from astronomically named chocolate and beer to song lyrics, television programmes, plays, poetry and films.

To show this, one of the best ice-breaker activities for a class or workshop is to divide your audience into small groups and ask them to come up with as many astronomical product names and film and music titles as they can. By the end of this exercise, they will conclude for themselves that astronomical words and ideas are woven throughout modern culture. But I hope to demonstrate through this article that the inspiration of astronomy goes deeper than mere names and titles.

In such a short introduction, there is not enough space for more than a few specific suggestions and they will be restricted to relatively modern ones, leaving the astronomy of Shakespeare, Homer and other classics to more qualified scholars[1]. Resources that can be used to explore the topic in more depth will be signposted throughout. The examples are also restricted to materials in English, for which I apologise and welcome examples from readers of astronomically-themed works in other languages.

Classroom lectures and public astronomy talks can be easily enhanced by drawing from these other fields. It creates a feeling of familiarity amongst students and audiences and makes the sometimes abstract scientific concepts more approachable by highlighting the influence they have had on writers, composers, and other artists they admire.

Plays about astronomers

In the twentieth century Bertolt Brecht wrote a play about the later period of Galileo's life, which he revised twice[2]. At the time, a popular play about the life of an astronomer was unusual, but in recent years we have experienced a small flood of plays and operas about the lives of astronomers — a number of which have been professionally produced and performed.

Lauren Gunderson, a playwright from Atlanta, USA, now living in San Francisco, has written a number of plays about science, some more straightforward than others. Her play *Leap* explores how inspiration came to a young Isaac Newton, while *Background* is about the physicist Ralph Alpher, who helped George Gamow develop some of the theoretical underpinnings of the Big Bang, and his emotional reaction to Penzias and Wilson receiving the Nobel Prize. Both plays are published in her *Deepen the Mystery* (2005).

Gunderson's more recent — and so far unpublished — play, *Silent Sky*, follows the life and work of Henrietta Leavitt, exploring the role of women at the Harvard Observatory, and her struggle with her hearing disability. The play has been performed on both the East and West Coasts of the USA[3].

Other female astronomers have also been portrayed in drama. Irish actress and playwright Siobhan Nicholas has a play about Caroline Herschel, which has seen performances in the UK[4], while New Zealand dramatist Stuart Hoar's play *Bright Star* concerns cosmologist Beatrice Tinsley, her brief life, her work, and her struggles with the barriers against women[5].

A new play by William Kovacsik is currently premiering at the Fiske Planetarium. The play, called *Vera Rubin: Bringing the Dark to Light*, involves two actors who play Rubin and Isaac Newton, and the planetarium itself will play a central role in the

Figure 1. *Photograph of Vera Rubin with Andrew Fraknoi in 1992. Credit: Andrew Fraknoi*

performance with audiovisual materials being projected onto the dome[6].

Many of the plays exploring the lives of astronomers focus on their relationships with one another. *Reading the Mind of God* is a play about Tycho Brahe and Johannes Kepler, by the American playwright Patrick Gabridge, which focuses on their relationship at the end of Brahe's life[7]. Another astronomical rivalry, that between Edmund Halley and John Flamsteed in England, has been explored by British dramatist Kevin Hood in *The Astronomer's Garden* (1991).

More recent plays have used fictional astronomers to highlight characters who are unworldly, or represent a scientific perspective. These include Kenneth Lonergan's *The Starry Messenger*, recently performed on Broadway, which features an astronomy instructor at the old Hayden Planetarium in New York City, USA, on the eve of its being torn down[8]. Jamie Pachino's *Splitting Infinity* explores interactions between a fictional female astrophysicist, her Christian Scientist postdoc, and a rabbi who has known her since childhood. The play received mixed reviews.

The life and work of a somewhat more obscure astronomer, Guillaume Le Gentil, an 18th century observer who was especially unlucky with the locations he chose to measure the transits of Venus, is the inspiration for the play, *Transit of Venus*, by the Canadian playwright Maureen Hunter (2007). The play later became an opera with the same title, with music by Victor Davies.

Astronomy at the opera

Operas about astronomers have also become more common in recent years. Paul Hindemith's 1957 opera, *Harmonie der Welt*, was inspired by some of Kepler's ideas on the similarities between mathematical and musical harmonies, which resonated with the composer's own views on harmony theory. It is a complex opera, which contrasts Kepler's search for laws and harmony in the Universe with the disharmony and chaos of human existence, and especially the times and wars during which Kepler lived[9].

A more modern opera by Philip Glass about Kepler, titled *Kepler*, premiered in

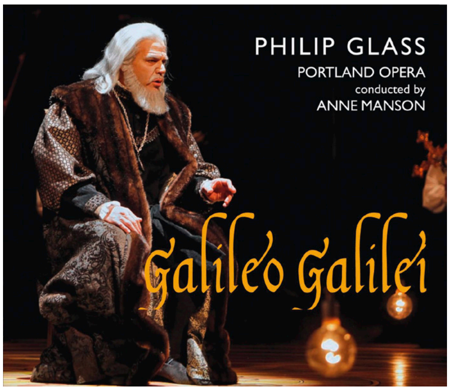

Figure 2. *Cover of the* Galileo Galilei *opera by Philip Glass.*

2009. Glass is one of the most successful of modern classical composers, with music that crosses over to film scores and is enjoyed by many who are not fans of classical music. His *Kepler* is more a meditation on themes and ideas than a complete story with a lot of action. Glass, like Hindemith, points out the contrast between Kepler's challenging, complex life and his dreams of order in the sky. An Austrian production of this opera is available on DVD from Orange Mountain Music. Glass has written a series of operas about noted scientists. The series began with the rather infamous *Einstein on the Beach*, a meditation on Einstein's life and ideas, now available in several recorded versions and first performed in 1976. Next was *Galileo Galilei,* which has recently been issued on CD by Orange Mountain Music label, featuring a performance at the Portland Opera[10].

A few films with astronomers

In cinema, astronomers have been portrayed in a range of roles, from hapless romantic foils to villains or unwitting victims whose discoveries lead to the end of the world. I will leave the older science fiction films to others to catalogue, but can mention a few examples from other film genres.

In *Roxanne*, a modern retelling of *Cyrano de Bergerac*, Daryl Hannah plays an astronomer who comes to a small town to look for a comet. In *Addicted to Love*, Matthew Broderick is an astronomer who follows the woman he is in love with to the city. In both films, astronomy takes a back seat to romantic comedy. Astronomy — and long nights at the telescope — are more central in the 1944 comedy *The Heavenly Body*,

Figure 3. *Film poster for the 1944 comedy* The Heavenly Body.

in which Hedy Lamarr plays the neglected wife of an astronomer who turns to an astrologer for advice. A 2011 Brazilian film, *Corpos Celestes* — rendered in English as *The Sky We Were Born Under* — uses the protagonist's profession as an astronomer not as a catalyst for romance, but to represent life and loneliness.

Two portrayals of astrophysicists in recent cinema take a more straightforward approach. In *Contact* Jody Foster plays a radio astronomer engaged in a Search for Extraterrestrial Intelligence (SETI) project, a character based, in part, on Jill Tarter, at the SETI Institute. The film is based on a best-selling book by Carl Sagan (1985), in which he tried to portray what a SETI success might involve[11]. In *The Theory of Everything*, which won actor Eddie Redmayne an Oscar for his remarkable portrayal of Stephen Hawking, it is the personal challenges of Hawking's illness, rather than his scientific work, that takes the fore.

Science fiction with good astronomy

I recommend science fiction stories which build on good science in all of my classes

Figure 4. *Fred Hoyle cuts a cake showing the Galaxy with a black hole centre at a reception in his honour at the Berkeley astronomy department, USA, in 1970. Credit: Andrew Fraknoi*

and public talks. Over the years, I have put together a website which organises the stories that I have collected by scientific topic[12]. One interesting observation from pulling together this list is that the number of stories written by authors who have advanced degrees in astronomy or physics continues to grow[13].

Perhaps the best-known example from the 1950s and 1960s is the late British cosmologist Fred Hoyle.

It is rumoured that Hoyle wrote science fiction to get into print those of his ideas that the scientific journals were not willing to indulge. For example, his best known novel, *The Black Cloud*, suggested the possibility of organic molecules — and life itself — in interstellar clouds years before such molecules were discovered[14]. His novel, *October the First is Too Late* (1966) may well be the first fictional working out of the implications of the many-worlds interpretation of quantum mechanics. These works present a strong case for the value of fiction as a platform for exploring new scientific concepts.

Nowadays a good number of practicing astronomers and physicists are writing interesting science fiction, among them Alastair Reynolds in England; Gregory Benford from the University of California, USA; Yoji Kondo — pen-name Eric Kotani — and Geoff Landis, who both work at NASA; Mike Brotherton at the University of Wyoming, USA; and Michael Shara at the American Museum of Natural History, among others.

Several other distinguished astronomers have written works of fiction that can be worth searching out for their informed take on the science. These include planetary scientist William Hartmann of the Planetary Science Institute, USA, who wrote *Mars Underground* (1977), describing the search for life on and under the surface of the red planet; nuclear astrophysicist Donald Clayton of Clemson University, USA, whose novel *The Joshua Factory* (1986) tells a tale of neutrinos; and J. Craig Wheeler, the former President of the American Astronomical Society, who explored threat of quantum black holes in *The Krone Experiment* (1986).

Among these authors, Benford has perhaps the highest reputation for writing outstanding fiction. Many of his novels make a point of showing scientists at work in realistic laboratory and academic settings, whilst grappling with fictional scientific problems[15]. Benford's early novel, *Timescape* (1980), features astronomers like Fred Hoyle, Margaret and Geoffrey Burbidge, and Carl Sagan as characters. His novels featuring organic and machine life locked in a life-and-death struggle at the centre of the Galaxy are now classics, and his recent short stories have addressed cosmological and SETI issues from interesting viewpoints anchored in current scientific thinking[16].

Reynolds established his reputation a generation later than Benford, but is winning many awards for his film noir portrayals of our future in space. His novel *Revelation: Space* (2000) is a marvellous place to begin exploring his work and it is worth finding an anthology that features his short story, *Beyond the Aquila Rift* (2005) — rarely has an author succeeded in portraying the truly astronomical distances of the objects we study so movingly[17].

Some of the most engaging science fiction stories are those in which the reader is given a realistic picture of what it might be like to stand on the surfaces of other worlds and experience their alien environments. Biologist Paul McAuley is one master of such stories, for example in his *Quiet War* (2002) series which explores all of the Solar System's planets during a time of war over the genetic modification of organisms. Engineer G. David Nordley has also written some wonderful stories about Solar System exploration, including *Crossing Chao Meng Fu* (1998), set on Mercury, and *Into the Miranda Rift* (1994). For a gripping tale on what it would be like to be stranded on the Moon, I recommend *A Walk in the Sun* (1992) by Geoff Landis. These are just some of the stories that could seize the imagination of a young reader and lead them toward science. You can do your students and audiences a lifelong favour by recommending some of the stories that celebrate our modern understanding of the Universe[18].

Poetry and the Universe

Doing justice to the wealth of astronomical inspiration expressed through poems is not possible in such a short introduction, but there are some key examples of informed astronomical poets whose work can be used to illustrate outreach work.

A number of astronomical poets wrote from an informed perspective. The American poet Robert Frost, for example, was an amateur astronomer. Poet and essayist Diane Ackerman received her Masters and PhD at Cornell University, where she took astronomy classes from Carl Sagan. Her 1976 collection, *The Planets: A Cosmic Pastoral*, shows the influence of her study of astronomy most directly, although you can find other astronomy poems in her collection, *A Jaguar of Sweet Laughter* (1993).

Robinson Jeffers (1887–1962) was a 20th century poet who celebrated nature and the coast of his native California. The poet's brother was the Lick Observatory astronomer Hamilton Jeffers; as a result, the poet Jeffers was well informed about developments in astronomy and included them in his works. One of his most powerful poems, *Margrave* (1932), contrasts the vast impersonality of the expanding Universe with the horror of a child kidnapping and killing here on Earth[19].

Astronomer Rebecca Elson was actively writing poetry alongside technical papers on globular clusters. Some of the poems celebrate astronomy, while others movingly anticipate the inevitable course of her

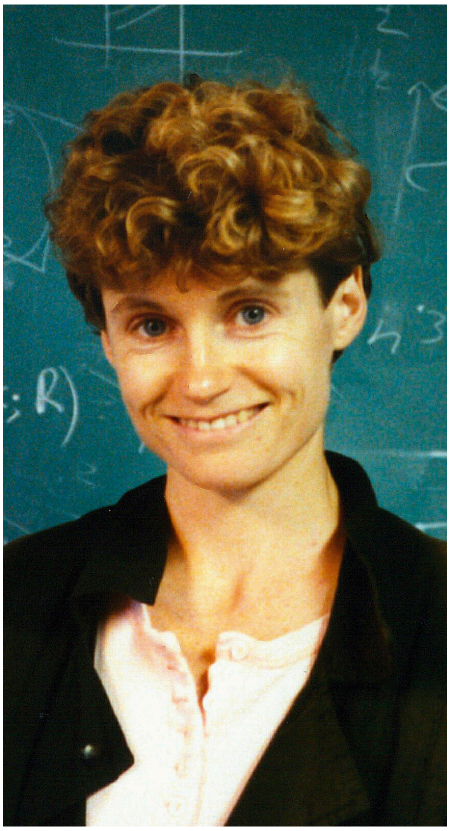

Figure 5. *Astronomer Rebecca Elson. Credit: Wikimedia*

illness — she died of leukaemia at the age of 39. The poems are collected in the posthumous volume, *A Responsibility to Awe* (2001), part of the Oxford Poets series.

I should note that several astronomers share my interest in poetry that is inspired by astronomy, including Canadian-born comet hunter David Levy, who has a degree in English, and the British discoverer of the first pulsars, Jocelyn Bell-Burnell. Both of them have put together anthologies of astronomical poetry, which cover a range of poetic styles, from old-fashioned odes to modern experiments with the power and pattern of language.

Maurice Riordan and Jocelyn Bell-Burnell's collection, *Dark Matter: Poems of Space* (2008), brings older poems together with a number commissioned specifically for the book, while David Levy's *Starry Night: Astronomers and Poets Read the Sky* (2001) interweaves poems with the story of the poets and the history of astronomy.

A number of others have put together anthologies of poems related to science. Although many of these collections are out of print, a little research will unveil a number of useful websites that list and even give the text of astronomical poems[20].

Literature with astronomy: A sampling

There are two authors in the United Kingdom who have been writing biographies of astronomers with a fictional twist, which may attract the general public to some of the interesting history of our field. Astrophysicist and science journalist Stuart Clark, a senior editor for the European Space Agency, has written a trilogy of such novels, which includes *The Sky's Dark Labyrinth* (2011), on Kepler and Galileo; *The Sensorium of God* (2012), on Halley and Newton; and *The Day Without Yesterday* (2013), on Einstein and Lemaitre. Award-winning Irish novelist John Banville wrote *Kepler: A Novel* (1981) and *Dr Copernicus* (1976), which are directly biographical in nature, and *The Newton Letter* (1982), which is more of a meditation on the difficulty of capturing the life of someone as complex as Newton in a narrative.

The novel *Theatre of the Stars* by N. M. Kelby has as its protagonist a female astronomer who has discovered an X-ray binary system that contains a black hole and, at the same time, is trying to unwrap the complex life story of her mother, a physicist and Holocaust survivor. Steve Maran and Alyssa Goodman are among the astronomers that the author thanks in her acknowledgements.

Another novel in which the author thanks astronomers for their contribution — in this case, Canadian astronomers James Hesser and Dennis Crabtree — is *Cold Dark Matter* by Alex Brett (2005). This one is a mystery whose plot centres on astronomical observations of the effects of dark matter on the rotation of the Andromeda Galaxy. Another astronomical mystery is laid out in *Total Eclipse* by Liz Rigbey (1966) which takes place at a Californian mountain-top observatory, with a lot of atmospheric detail; it received mixed reviews for its plot, however.

More recently, Pippa Goldschmidt, who has both a PhD in astronomy and a Masters in creative writing, has published her first novel, *The Falling Sky* (2013). Goldschmidt's intriguing short stories are collected under the title *The Need for Better Regulation of Outer Space* (2015) many of which have scientific themes, and some of which include characters like Albert Einstein and Robert Oppenheimer.

Conclusion

I hope these few examples have provided an indication of the wealth of interaction between astronomy and the humanities that exists for your exploration, or for the exploration of the students or audiences who we, as science communicators, work with. Whether you include them in your PowerPoint slides, or provide a printed resource guide to take home, they should reinforce in the minds of your students or audiences the idea that their appreciation of astronomy is shared by many creative people the world over.

Notes

1. There is a regular series of international conferences entitled *The Inspiration of Astronomical Phenomena*: http://www.insap.org/. Their proceedings, recently published through the Astronomical Society of the Pacific Conference Series, are a treasure trove of more scholarly articles and resources in this field.
2. Bertolt Brecht's play *Galileo* can also be found on film directed by Joseph Losey, and starring Topol as Galileo, available on King Video.
3. A brief, humorous excerpt from *Silent Sky* can be found on YouTube at: https://www.youtube.com/watch?v=KiwG6r-9gcw and Gunderson describes the astronomy and history behind the play in this short video: https://www.youtube.com/watch?v=b7XQG-Mnxikw.
4. Video excerpts of Siobhan Nicholas's play about Caroline Herschel are available at: https://www.youtube.com/watch?v=_nzf-1wZNQhY and a brief review in *New Scientist* can also be found online: https://www.newscientist.com/article/dn23863-new-play-shines-light-across-time-on-women-astronomers/.
5. Stuart Hoar's play *Bright Star* has now been retitled *The Smallest Universe in the World*, and the play's website is at: http://www.brightstar-theplay.com/.

[6] More information about William Kovacsik's play premiering at the Fiske Planetarium: http://betc.org/fiske-planetarium-boulder-ensemble-theatre-company-collaboration.

[7] More information on *Reading the Mind of God* by American playwright Patrick Gabridge: http://www.gabridge.com/full-length-plays/reading-the-mind-of-god/.

[8] The *New York Times* review of *Starry Messenger* can be read at: http://www.nytimes.com/2009/11/24/theater/reviews/24starry.html?_r=0

[9] The first complete recording of Paul Hindemith's play is available from the Wergo label catalogue for: http://www.wergo.de/shop/en_UK/3/show,132906.html.

[10] Some excerpts from *Galileo Galilei* showing key scenes in the opera can be seen on YouTube at: http://www.youtube.com/watch?v=lhL_C3QqaY8.

[11] Jill Tarter discusses the novel, the film and her relationship to them in this brief video: https://www.youtube.com/watch?v=1-akFL-FLgAk.

[12] For the author's topical guide to science fiction with good astronomy see: http://www.astrosociety.org/scifi.

[13] A brief list of science fiction authors with science degrees can be found in Appendix 1 of my article on teaching with science fiction: http://dx.doi.org/10.3847/AER2002009.

[14] Jennifer Ouellette discussed *The Black Cloud* in a 2014 web post at: http://skullsinthestars.com/2014/08/03/fred-hoyles-the-black-cloud/.

[15] For a slightly eccentric introduction to Benford, see: http://www.gregorybenford.com/gregory-benford-intro/.

[16] Some of his stories available on the web include *The Final Now*: http://www.tor.com/stories/2010/03/the-final-now and *SETI for Profit*: http://www.nature.com/nature/journal/v452/n7190/pdf/4521032a.pdf.

[17] To find any published science fiction story by title or author, check the Internet Speculative Fiction Database at: http://www.isfdb.org.

[18] For a list of ten favourite science fiction authors to recommend to students, and what stories of theirs to start with, see my essay at: https://www.researchgate.net/publication/261364023_Ten_Science_Fiction_Writers_for_Scientists_and_Science_Enthusiasts.

[19] The full text of *Margrave* can be found at: http://www.poemhunter.com/best-poems/robinson-jeffers/margrave/.

[20] Among the collections, you might start with: Brown, Kurt, ed. *Verse and Universe: Poems about Science and Mathematics* (1998, Milkweed) and Heath-Stubbs, John & Salman, Phillips, eds. *Poems of Science* (1984, Viking). Good websites to begin with include Mario Tessier's *Nox Oculis* at: http://pages.infinit.net/noxoculi/poetry.html and *Astropoetica* (a journal publishing new astronomy poems, which has ended its run, but has beautiful archives) at: http://www.astropoetica.com/.

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Biography

Andrew Fraknoi is Chair of the Astronomy Department at Foothill College near San Francisco, and was for many years the Executive Director of the Astronomical Society of the Pacific. He co-founded the journal *Astronomy Education Review*, and is the lead author of the *Voyages through the Universe* series of college textbooks. His first science fiction story is being published in a Mars anthology entitled *Building Red* later in 2015.

Launching *Light: Beyond the Bulb* for the United Nations' International Year of Light 2015

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Keywords
Light, astronomy, exhibits, public science

In astronomy, light is the language used to understand the Universe. From radio waves to gamma rays, light in all its forms delivers information that helps astronomers learn about the Universe. When the United Nations declared 2015 to be the International Year of Light and Light-based Technologies (IYL2015), it presented an opportunity to share the role that light plays in astronomy and beyond. The IYL2015 also offered a chance to build on experiences and sustain networks from the International Year of Astronomy in 2009. *Light: Beyond the Bulb* is an IYL2015 project that melds both of these goals. The project takes the form of an exhibit that showcases what light can do, from here on Earth and across the vastness of space, hosted by volunteer networks in public spaces for informal science learning.

Introduction

Whether it comes from a distant galaxy or a neon sign around the corner, light is all around us. We use it to communicate, navigate, learn and explore. But light is far more than just the visible light that we can detect with our eyes. It takes the form of radio waves, infrared, ultraviolet, X-rays and more. Astronomy communicators often find that engagement has to begin with an explanation of the existence and nature of types of light other than those observed with the human eye, a concept that is not common knowledge for most public audiences.

Due in part to the opportunity provided by the International Year of Light and Light-based Technologies (IYL2015)[1] a new exhibit called *Light: Beyond the Bulb (LBTB)* has been developed to help address this knowledge gap and engage non-expert audiences with the capabilities of light. This global initiative was adopted

Figure 1. *A selection of images from the* Light: Beyond the Bulb *project, from a mouse retina, to light pollution, to star formation. Credit:* Light: Beyond the Bulb

by the United Nations and, supported by The United Nations Educational, Scientific and Cultural Organization (UNESCO), the International Astronomical Union, and a host of other scientific societies, organisations, corporations and individuals around the world.

LBTB[2] is a free, open-access international exhibition containing 75 images that were crowd-sourced from photographers, scientists and artists. The exhibits are curated by experts for science content, high-quality printability, aesthetics, and the potential to be relevant and interesting for non-experts.

In collaboration with experts in the field, the project creators developed short, descriptive captions designed to focus on various aspects of light and its properties; from refraction and reflection, to transits and shadows. The scales that the photographs represent vary from cell-sized to Universe-sized and encompass a range of topics from microbiology to astronomy, creating connections with physics, optics, photonics, atmospheric and earth sciences, astrophysics and more.

Building on the 2009 International Year of Astronomy

During the International Year of Astronomy in 2009 (IYA2009), the authors and their colleagues created the *From Earth to the Universe (FETTU)* project[3], which developed an online repository of curated material that allowed large-scale astronomical imagery to be placed in approximately 1000 public spaces around the world (Arcand & Watzke, 2010). This public science model (Arcand & Watzke, 2011) is a useful way to communicate with non-experts in everyday venues such as shopping malls, outdoor parks, hospitals and cafes. These experiences can lead to small learning gains, inspiration and increased interest in science for participants, as well as the creation of networks of science event hosts (Arcand & Watzke, 2013).

Exhibits and materials

There are approximately 200 exhibit locations[4] in progress or being planned for 2015–2016, in over 30 countries, with the majority of locations signing up throughout 2015. Examples of locations include exhibits at the O'Hare Airport in Chicago, USA; Baykal, a village in Dolna Mitropolia, Bulgaria; the Saint Ignatius College Siggiewi Primary School in Siggiewi, Malta; the K11 Art Mall in Shanghai, China; and the Galway Astronomy Festival in Ireland. Figures 2–7 show images from *LBTB* events that have occurred so far and highlight the variety in the events.

In addition, there are another five hundred locations, including schools, science centres, libraries, parks and other informal learning spaces that are hosting small exhibits of *LBTB* posters as provided by the Chandra X-ray Center and the international society for optics and photonic (SPIE) — these posters can be downloaded for free from the *LBTB* website.

Materials developed for the exhibits over the past year include videos, infographics, slide shows, handouts, posters and guideline documentation. Translations of the LBTB texts into languages including Spanish, French, Portuguese, Brazilian Portuguese, Mandarin, Afrikaans and others, are in progress, or have already been completed, by networks of volunteers.

Networks of science hosts were created through previous projects spearheaded by the Chandra X-ray Observatory Center — including *From Earth to the Universe, From Earth to the Solar System*, and *Here, There & Everywhere*[5] — and for this project these were combined with networks from the international society for optics and photonics (SPIE), as well as the International Astronomical Union and others. These networks were used to announce the project, garner programme interest and help promote the events. Tapping into networks of volunteers, has been shown through evaluation of previous projects to be critical to a successful project (Arcand & Watzke, 2013) and was an important

Figure 2. *For the month of April in 2015 a Chandra-funded exhibit of* Light: Beyond the Bulb *was displayed at the main library of the University of Puerto Rico (UPR) and was seen by thousands of people, according to event coordinators. Exhibit tours with hands-on activities on the topics of lensing, shadows, electric discharge, atomic collisions and others were conducted by volunteer physics students. Additional talks, conferences, and other events connected to the exhibit attracted many hundreds of participants. Groups of local school children and their teachers visited from neighbouring towns and university students attended with professors from courses in physics, architecture, art and education.*
Credit: University of Puerto Rico

Figure 3. *In conjunction with the* Light: Beyond the Bulb *exhibit events mentioned in Figure 2, on 17 April 2015 an inclusive event on light was held at the University of Puerto Rico for the visually impaired and blind and their families titled* Estrellas Para Todos*. This activity had 26 participants, including 11 who were blind. Organisers displayed tactile posters on light, plus a tactile Moon, Sun, spiral galaxy and several tactile books including* Touch the Sun *and* Touch the Star*.*
Credit: University of Puerto Rico

Figure 4. *At Duke University in North Carolina, USA, the Fitzpatrick Institute for Photonics Annual Symposium hosted the World Photonics Forum with international speakers as well as an Open House for the greater public. One goal of the event was to help bring together experts and non-experts to discover new ideas about light and light technologies in celebration of IYL2015. Held during the week of 8 March 2015, about 700 people attended, with approximately 500 members representing the public and 200 representing symposium attendees and speakers. Credit: Duke University*

Figure 5. *In February 2015, an amateur astronomy organisation created a special event for the Palora Higher Secondary School in India. The exhibition was conducted alongside an inauguration event for a new telescope. Approximately 2500 attendees participated in the exhibition programme to celebrate the International Year of Light 2015. The head of the physics department, MR Sreekumar of Devagiri College Kozhikode, delivered a lecture on light pollution, one of the key topics of IYL2015, and its effects on nocturnal life.*
Credit: Chindankutty Nambiar, Astronomical Organisation Kerala (AASTROKERALA)

Figure 7. *International Astronomy Day 2015 at the Royal British Columbia Museum (Victoria, BC, Canada) was celebrated on 25 April 2015. Organisers collaborated with the Royal Astronomical Society of Canada (RASC) for a daylong event. The hosts provided* Light: Beyond the Bulb *posters, a monitor displaying images, and a large wall screen displaying more science images. Approximately 750 people attended the event. Credit: Dennis Crabtree*

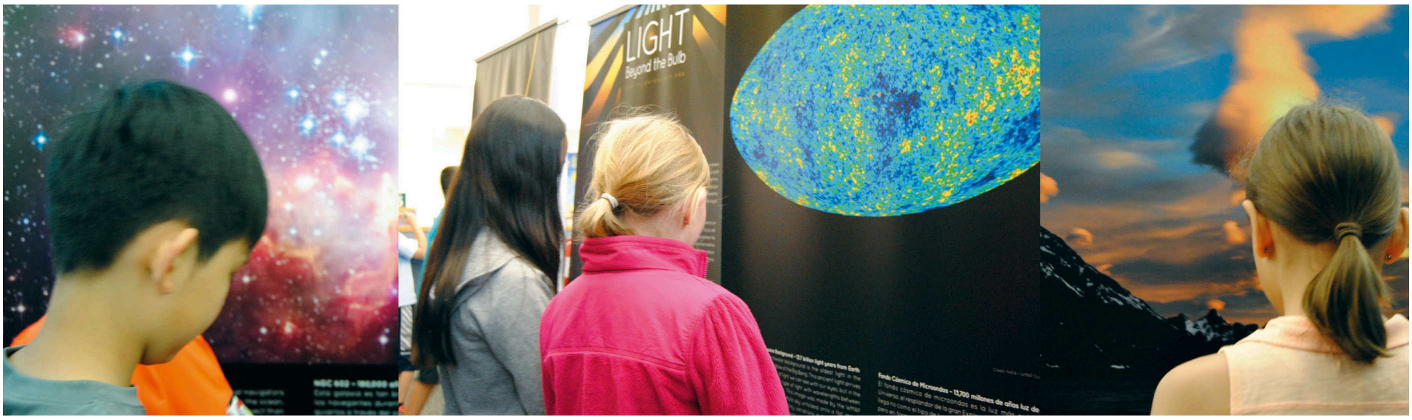

Figure 6. *A traveling* Light: Beyond the Bulb *exhibit visited the Carmel High School (CHS) for the month of May 2015. Local school children toured the exhibit at the CHS Media Center as part of their annual field trip to the school's planetarium. The exhibit tied in with the children's science curriculum, with students also learning about the Hubble Space Telescope, the International Space Station, and other observatories. Credit: CHS*

component when launching a new project in the relatively short time period of one year. There was existing buy-in for such community-based, grassroots projects from a number of hosts as well as proof of concept for new hosts.

Conclusion

Initiatives such as IYL2015 provide those who communicate astronomy with a chance to connect scientific results in astrophysics with those in other fields of academic and industrial research. Placing astronomy in a wider context can provide a thought-provoking experience for both those who create events and ultimately for those who attend them (Arcand & Watzke, 2014).

By bringing together organisations and scientific disciplines that don't regularly work closely together, this project generated new thematic content. For example, the need to connect the concepts of reflection and absorption across the electromagnetic spectrum allowed those working on the project to break down more traditional ways of discussion within their own scientific disciplines. By "stretching" efforts beyond astronomy and into the fields of optics and microscopy, for example, the content creators learned new ways of describing concepts that may benefit astronomy communication efforts in the future.

LBTB has also re-energised existing networks that have been developed over years of astronomy communication, including IYA2009, and has provided the opportunity to reach out to new partners and delve into topics that are often beyond the scope of astronomy outreach. Using light to thread these seemingly disparate scientific topics together has allowed for a more coherent scientific story to be told for the scientific disciplines involved.

Acknowledgements

Together with the international society for optics and photonics (SPIE), the Chandra X-ray Center/Smithsonian Astrophysical Observatory is leading *LBTB* for the International Year of Light 2015 (IYL2015). *LBTB* is also a cornerstone project for the International Astronomical Union. IYL2015 was declared by the United Nations and is supported by UNESCO.

Notes

1. A full version of the IYL2015 Resolution is available in several languages: http://www.light2015.org/Home/About/Resources.html
2. More information on the *Light: Beyond the Bulb* project: http://lightexhibit.org
3. *From Earth to the Universe* project for the International Year of Astronomy in 2009: http://www.fromearthtotheuniverse.org/
4. Full exhibit list: http://lightexhibit.org/iylexhibits.html
5. *From Earth to the Universe:* http://www.fromearthtotheuniverse.org
   From Earth to the Solar System: http://fettss.arc.nasa.gov
   Here, There, & Everywhere: http://hte.si.edu

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Biographies

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How Astronomers View Education and Public Outreach: An Exploratory Study

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Keywords
Attitudes towards outreach, education and public outreach, funding

Over the past few years there have been a number of studies exploring the development of an interest in science and scientists' views on public outreach. Yet, to date, there has been no global study regarding astronomers' views on these matters. Through the completion of our survey of 155 professional astronomers online and in person during the 28th International Astronomical Union General Assembly in 2012, we explore how these individuals developed an interest in astronomy, the part outreach played in this and their views on the time constraints and budget restrictions associated with public outreach activities. We find that astronomers develop an interest in astronomy between the ages of four and six, but that the decision to undertake a career in astronomy often comes during late adolescence. We also discuss the claim that education and public outreach is regarded as an optional task rather than a scientist's duty. Our study reveals that many astronomers are of the opinion that a larger percentage of their research time should be invested in outreach activities, calling for a change in grant policies.

Introduction

In 2004, the European Union issued a major report addressing the need for more scientists and students to be involved in advanced studies of science and technology in order to achieve the desired economic growth (European Commission, 2004). The European Union is not the only body concerned by the decrease in the number of scientists and the associated effect on the economy. In 2005, the National Academies in the United States published a report discussing the condition of science and technology that emphasised the importance of science education to the economy. In 2006, during a speech following the publication of this report, the then President of the United States of America, George W. Bush, brought up the concern that corporations have about the imminent retirement of baby-boomer scientists over the next decade (Bush, 2006). Nowadays, the importance of science education and communication is recognised globally.

One approach to improve science education and communication, as well as developing methods that ignite interest and awareness amongst the public, is to understand scientists' perception of education and public outreach (EPO). In order to implement science education and outreach initiatives it is useful to identify what sparked the initial interest in science in working scientists. Many studies have reported that an interest in science is likely to develop at primary school age, but that the decision to become a scientist often comes towards the end of adolescence (Maltese & Tai, 2010).

Maltese and Tai (2010) investigated the importance of an early interest in science in developing scientists. Their survey received 116 responses from both practicing and retired physicists and chemists, as well as graduate students across the USA. The participants were asked about the moment when they first became interested in science and what initiated this interest. This survey concludes that for the majority (about 65% of the sample), an interest in science developed before or during primary school — up to the age of twelve — which is six times greater than the proportion who claim to have developed an interest for science at college age — between ages 16 and 18.

Additionally, in 2004, the Royal Society in England conducted an online survey with scientists and engineers where participants were asked when they first considered a prospective career in science (Royal Society, 2004). The majority (63%) of the respondents claimed that they had thought about becoming a scientist or an engineer by the age of 14. This is another piece of evidence that shows the importance of initiating an interest in science through education and public outreach at a young age.

A study conducted by Cleaves (2005) in the UK examined the factors that led students to pursue academic studies in science during college. A total of 69 students from six different schools were interviewed four times during a period of two years before entering college. The goal was to follow their thought processes regarding the decisions they took concerning their career choice. Surprisingly, many of the students who chose to continue studies in science, technology, engineering and mathematics (STEM) did not enjoy secondary school science. Their choices were mainly based on the idea of the career they wanted and the flexibility that science studies offer. On the other hand, students who did not plan on pursuing STEM studies also did not find secondary school science interesting, and they had been deterred from further science studies in college by their experience at school.

A study conducted by Lindahl (2007) investigated the factors influencing why students persist in advanced studies of science. This showed that these students claim that an interest in science is one of the most important factors in their decision to pursue a career in science. The survey was conducted with 70 Swedish students between the ages of 12 to 16, and consisted of a combination of interviews and questionnaires. It revealed that these students started considering a potential scientific career as early as the age of 12. Students also reported that the way science is taught in school was usually not representative of the natural world they experience on a daily basis and did not make them more engaged in classrooms. Consequently, their classroom experiences often affected their decisions to continue to study science. This highlights the importance of igniting an interest in science amongst children and younger teenagers both inside and outside of the classroom.

Nowadays, many scientists have a positive attitude towards science communication, EPO (Andrews, 2005; Poliakoff, 2007; Ecklund, 2012). However, there is still room for improvement in the number of scientists taking part in EPO and the amount of effort that they dedicate to these activities. Many studies have tried to investigate the motivating and inhibiting factors influencing scientists when deciding whether to undertake EPO initiatives. Ecklund's studies explored physicists' and biologists' views on science outreach and revealed that for many of the scientists who took part in the research, one of the most common factors acting against more public engagement was the time constraint. Many scientists already invest a lot of time in either research or teaching, leaving very little time for EPO. Other important inhibiting factors are disapproval by mentors and department heads, and the lack of career recognition associated with taking part in EPO activities.

A report published by the Wellcome Trust in 2000 on the role of scientists in society revealed similar results, stating that many scientists (23% of the participants) think that time constraints play a significant role in preventing them from participating in EPO activities. Sixty percent agreed that what was required from them each day left them with very little time for EPO initiatives. Participants also noted that EPO activities are not financially advantageous. Given this general perception of EPO initiatives, it can be rather difficult for scientists to meet the criteria that science communication guidelines suggest for effective outreach projects, and money and time constraints often discourage scientists from taking part in EPO activities.

While there are several studies regarding the development of an interest in science at an early age, its importance in developing scientists (Maltese & Tai, 2010; Cleaves, 2005; Lindahl, 2007; The Royal Society, 2004) and factors motivating or inhibiting EPO initiatives (Poliakoff, 2007; Ecklund, 2012), there is currently no global study addressing the role of an early interest in developing astronomers or their views on EPO. Most studies include data from former, current and future scientists from different fields, but we would like to examine current astronomers' opinions and see if they differ from other fields of science. Moreover, little published research has studied the amount of time, effort and money scientists invest in EPO.

We would like to answer the following questions:

- At what point in their lives did astronomers develop an interest in astronomy?
- Are EPO activities viewed as a hobby rather than a duty?
- How important are EPO activities according to astronomers?
- What do astronomers think of the budget allocated to EPO activities?

These results will then be compared to other studies in the literature and we will see whether astronomers' views differ from those of scientists working in other fields of science. This will also serve to pinpoint when and how an interest in astronomy starts.

Methods

The data collected for this analysis consisted of both quantitative and qualitative answers from a survey[1]. A questionnaire was designed to collect information on the development of astronomers' first interest in astronomy and their views on EPO. The target groups of participants for this study were future, current and retired professional astronomers. The groups therefore comprised, more specifically, astronomy students involved in either undergraduate or graduate studies, PhD candidates, postdoctoral fellows, faculty members and directors.

The International Astronomical Union, the largest association of astronomers across the globe, has 11 319 individual members. In August 2012, more than 3000 astronomers gathered at the 28th General Assembly in Beijing, China, to discuss, share, present and debate the most exciting discoveries about the Universe. Universe Awareness (UNAWE), in partnership with the IAU Office of Astronomy for Development, carried out individual interviews with 61 randomly selected astronomers attending the General Assembly in order to investigate when they first became interested in their field and their views on EPO. In addition, other potential participants were solicited by email through their Canadian Astronomical Society (CASCA) membership. A total of 94 responses were obtained from the online survey between 11 December 2012 and 24 January 2013.

In total, 155 responses were obtained for this study. Although these methods of sampling are, most of the time, the best option when searching for a representative sample, they restrict how far the results can be generalised as the solicited potential candidates were offered the choice of not participating in the survey.

The answers provided through the online survey and collected at the General Assembly of the IAU were combined and then a preliminary descriptive statistical analysis was made of each set of data to gather an overview of the distribution. Further statistical tests were applied to confirm or disprove the correlations between different variables and ascertain meaningful differences between groups of astronomers.

Sample

The sample consists of 155 astronomers from 31 different countries across the globe. This includes 102 males, 51 females and two individuals who did not disclose their gender. The ages of the participants vary from 23 to 72, with 55% in the age range of 25 to 45. The sample contains both students and professional astronomers. The majority of the sample are currently practicing astronomers, including 58 faculty members, 28 postdoctoral fellows and 29 PhD candidates.

Developing an interest in astronomy

The questionnaire revealed that 65% of the respondents had developed an interest in astronomy between the ages of four and twelve years old. Nearly 50% of all the participants first developed an interest between the ages of four and nine years old. These results are in agreement with other studies such as Lindahl (2007), Cleaves (2005), the Royal Society (2004) and Maltese & Tai (2010), which reported that scientists from other fields first established an interest in science during primary school and early adolescence.

As the data for the age at which astronomers were first excited about astronomy is not normally distributed as shown in Figure 1, the Maan–Whitney's U test, a non-parametric test, was used to assess whether there was a gender-related difference in when interest developed[2]. The analysis showed that there is no significant difference in the distribution (p) of the ages when interest in astronomy developed associated with gender ($p > 0.05$). This was expected as it agrees with the Maltese & Tai's (2010) studies on sources of early interest in science.

Whilst an interest in science is shown to occur at an early age, the decision to become a professional astronomer or to pursue studies to become an astronomer happens later. Over half of the participants claimed this decision was taken at the end of secondary school or during undergraduate studies. For many, taking an introductory course in astronomy during their undergraduate studies at university was the decisive factor. In a similar result to Lindahl (2007), this implies that even though the first interest in science often occurs at a fairly young age, if interaction with science during secondary school and the first years of university is not engaging, this can dissuade individuals from choosing a career in science. This implies, as might be expected, that decisions about an eventual career path occur later than childhood or early adolescence.

But what ignited the astronomers' interest in the subject to begin with? Over a quarter of our participants did not have a specific starting point, but those who did pointed to their inspiration from the night sky (42%) or their excitement after reading a popular science book (32%). In addition, looking through a telescope and following the Apollo missions appeared to be of great importance in initiating the first spark of interest in astronomy for many participants, as did being inspired by a family member or teacher. This shows that a first interest in science often happens outside the classroom, which is also in agreement with Lindahl (2007), who reported that participants found science, as taught in class neither particularly engaging nor representative of the natural world as experienced in everyday life. These results highlight the importance of both having EPO activities for children of primary school age outside the classroom and of ensuring that teenagers have an enjoyable experience of science within the classroom.

Views on education and public outreach

Many studies have revealed that most scientists have a positive attitude towards EPO initiatives (Poliakoff, 2007; Andrews, 2005; Ecklund, 2010). Our study showed similar results, as 79% of the respondents think that EPO initiatives are essential, and 19% claim that they are important. Another way of assessing scientists' views on EPO initiatives is to evaluate the amount of time and financial support scientists dedicate to EPO. Participants were

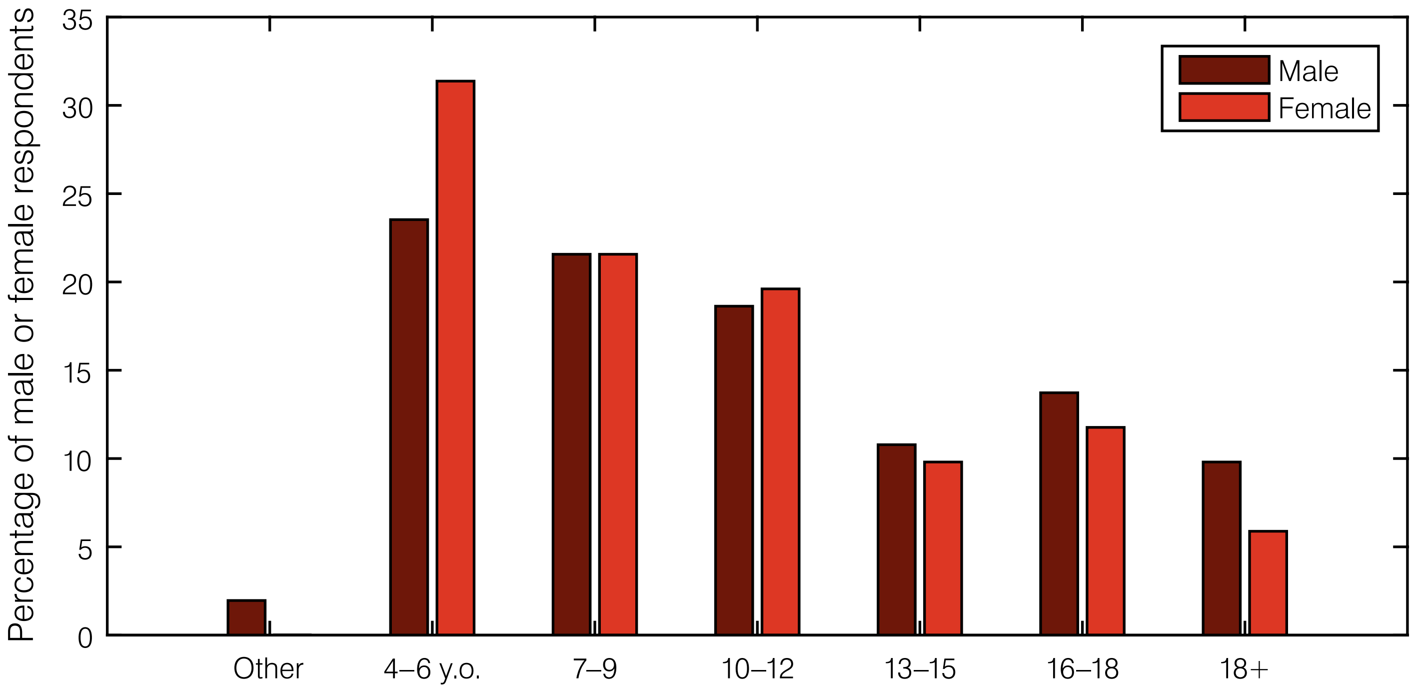

Figure 1. *Reported age at which astronomers first became interested in astronomy.*

given the option not to disclose answers to questions concerning the budget and time spent on outreach initiatives.

As previous studies showed that many scientists viewed EPO as a hobby rather than as part of their duty at work, the participants were asked for the amount of free time and working time spent on EPO activities (Poliakoff, 2007). The analysis of the data revealed no significant difference between the amount of free and working time allocated for EPO activities with a median of zero to two hours spent on EPO per week on average, as shown in Figure 2. After using the Spearman's ρ correlation, it was determined that scientists who claim to spend more time at work on EPO activities weekly also dedicate more time outside work. The analysis showed a moderate correlation between the two variables ($\rho = 0.46$; $p < 0.05$). Interestingly, this does not agree with Poliakoff's study, which reported that scientists considered EPO activities to be a hobby rather than a work duty. This implies that time constraints are not the main factor influencing astronomers when deciding to take part in outreach activities, and that other factors motivate them to invest both time at work and outside work to such projects.

Out of the 155 respondents, a quarter (56 participants) chose to not disclose the percentage of their research grant attributed to EPO. Among those who did answer the question ($N = 116$), 50 astronomers claimed that 0% of their grant money was allocated to EPO and 15 of them use between 0–2% for EPO activities. Hence, most of the respondents reported that less than 2% of their research grant went into EPO initiatives, which is less financial support than is suggested in many science communication guidelines (Brake, 2010; Bowater, 2013). As mentioned before, the 2000 Wellcome Trust report flagged this issue and showed that there was a lack of financial support for EPO.

To explore this shortfall in funds available for EPO, astronomers were asked what percentage of grant money should be invested in EPO. The response rate for this question was 83% (138 out of 155 participants). Interestingly, the results differed significantly from the previous question ($p < 0.05$) as shown in Figure 3. This time, only 13 respondents claimed that 0% of research grants should be invested into EPO activities. On average, astronomers suggested that 5–10% of research grants should be allocated to EPO activities, which is significantly greater than the amount actually used for outreach.

Given this result, a new question arises, do astronomers generally wish to spend more of their research grant on EPO than is currently offered? The Spearman rank correlation test revealed a correlation between respondents' current and suggested budget spent on EPO activities ($\rho = 0.59$; $p < 0.05$). This shows that in general in this survey, the participants suggested a higher portion of their research grant than is currently allocated to outreach initiatives. This implies that astronomers generally think there is a lack of financial support for EPO activities and suggests that policies on the distribution of their research grant should include a higher budget for EPO.

An interesting finding from Poliakoff's studies on factors predicting whether scientists would decide to participate in EPO activities was the indication from past behaviour. The research revealed that a scientist who has been involved in EPO projects in the past is more likely to participate again in the upcoming year. Consequently, taking part in outreach activities in the early stages of a research career increases the chance that a scientist will participate in EPO activities regularly at future career stages. However, Ecklund's studies on views concerning public engagement activities among scientists demonstrate that one of the participants' concerns was the lack of support from mentors for taking part in outreach activities. Deterring early career researchers through lack of support will therefore also affect their decision to take part in outreach projects at later stages in their careers. To address this,

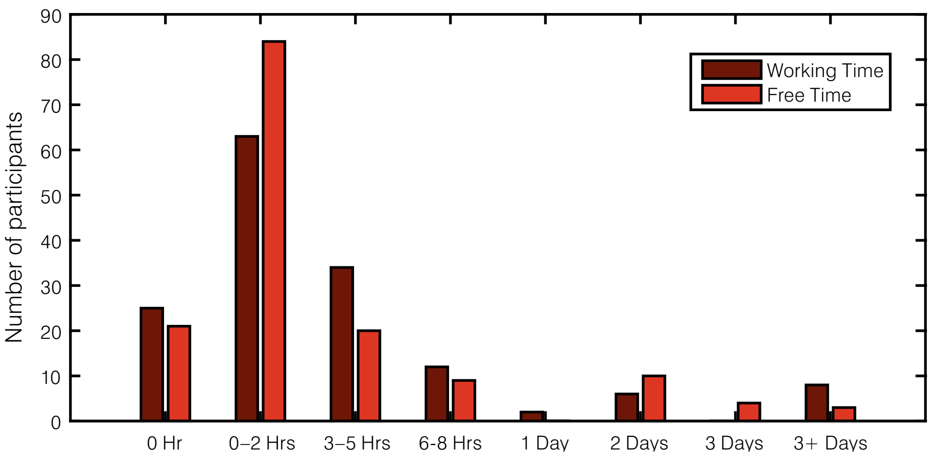

Figure 2. *Distribution of working and free time spent on EPO activities per week on average.*

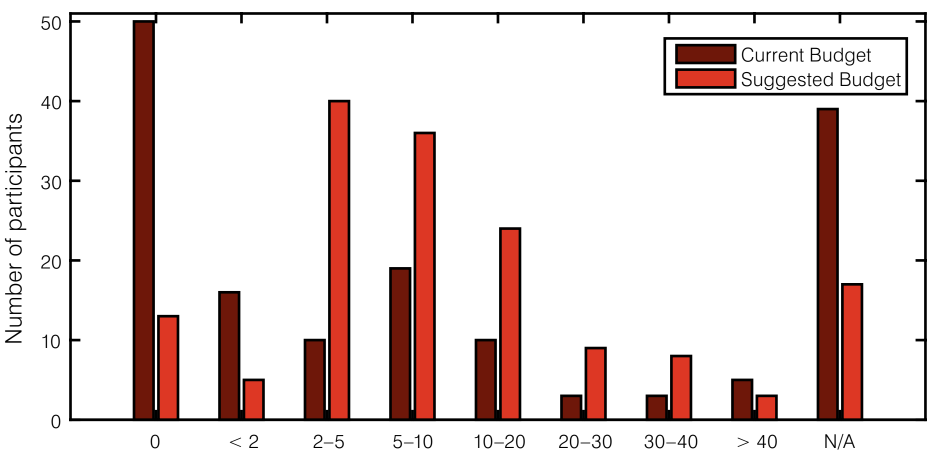

Figure 3. *Distribution of percentage of research grant that astronomers currently invest in EPO compared to the percentage they suggest allocating.*

astronomers were asked whether they recommended or encouraged their students to get involved with EPO projects. For the most part (70% of the participants), the answer was positive, as opposed to 2% who answered negatively. The majority of the 43 participants who did not answer the question were either Masters/PhD students or postdoctoral fellows for whom the question was not applicable. This was unexpected since many scientists claimed a factor inhibiting the participation in EPO initiatives was disapproval by mentors and department heads (Ecklund, 2012). This could mean that encouragement to participate in outreach projects is more present in the community of astronomers than other sciences. However, the way the question was posed was biased towards a positive response. A more accurate way to measure this would have been to give the respondents an ordinal scale rather than only the option to answer either positively or negatively when they were asked whether they encourage their students to participate in EPO initiatives.

Conclusion

Astronomers' interest in astronomy is shaped from a very young age (4 to 6 years old). As expected, despite the gender imbalance in the astronomical field, there is no evidence of a difference between genders in the age at which an interest in astronomy develops. The decision to undertake a career in astronomy only comes later, at the end of adolescence or during early adulthood, which shows the importance of nurturing an interest in astronomy up to this age.

Most astronomers claim to have a positive attitude towards EPO and those in authority encourage their students to participate in outreach. However, other studies have shown that although scientists have a positive view of EPO, some of them do not participate due to disapproval from their mentors and department heads, which is not consistent with our results.

The results show that astronomers allocate less time to EPO on average than the amount recommended by practical guides for science communication. Some science communication books explain this by making the assumption that science communication projects are initiatives that researchers would only undertake if they have extra time beside their other duties in academia. However, this study also disproves the theory that EPO activities are viewed as a hobby rather than a duty, as no significant difference between the time astronomers put into EPO during work time and free time was found. Interestingly, the analysis showed that those who claimed to spend more working time on EPO activities also invested as much of their free time. This implies that there must be some factors other than their views on their responsibility as scientists which motivates working on EPO projects both at work and outside of work.

Another finding from the study is that the percentage of their research grants that astronomers allocate to EPO does not align with the amount that they would suggest is optimal. In general, most of them suggest a higher amount than is currently assigned to EPO activities. This indicates that astronomers would like to invest a larger ratio of their grants towards EPO and therefore, calls for a change in grant policies.

Limitations and future work

The collection of data did not keep track of the number of solicited astronomers who chose not to participate in the survey, so this prevented us from obtaining a response rate to evaluate whether the sample was a good representation of the target group. In addition, online surveys also imply a certain level of self-selection bias; which is a limitation of this study.

Some questions about the value of EPO and the encouragement given to take part of EPO activities were asked in a manner biased towards a positive answer.

The data obtained revealed some interesting insights, but it is not complete. A more detailed study about the views of astronomers would allow us to tackle the motivating and inhibiting factors for public outreach initiatives. It would also give more insight into the changes that need to be made in order to increase the number of astronomers participating in EPO and how these changes can be implemented. The next goal is to explore astronomers' points of view on different aspects of their attitude towards engagement initiatives, their level of confidence in taking part in EPO activities, their perception of the public and their peers and the value of EPO at their institution.

Acknowledgements

We would like to thank Valério A. R. M. Ribeiro, Thilina Heenatigala, Avivah Yamani, Mara van Beusekom, Gimenne Zwamam, Joshua Borrow and Jack Sankey for their support and contributions to this article.

Notes

[1] The source data files used in this paper are available on an open repository: https://github.com/unawe/research/

[2] More information on the Mann–Whitney *U* test: https://en.wikipedia.org/wiki/Mann%E2%80%93Whitney_U_test

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Using Content Distribution Networks for Astronomy Outreach

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Keywords
Content distribution network, data exchange, sharing outreach materials, video streaming speeds

Thousands of people from all over the world search the internet on a daily basis for the newest discoveries in astronomy: be it in the form of press releases, high resolution images, videos or even planetarium fulldome content. The growing amount of data available, combined with the increasing number of media files and users distributed across the globe, leads to a significant decrease in speed for those users located furthest from the server delivering the content. One solution for bringing astronomical content to users faster is to use a content delivery network.

A growing problem

The basic architecture of the internet and its organic pattern of growth result in a number of bottlenecks that impact its overall performance and mean that its end-to-end reliability cannot be guaranteed (Nygren, 2010).

During an exchange of data both the server and the user have to continuously exchange acknowledgements of the data packets being sent. So the distance between the server and the end user can become the overriding bottleneck in download speed — or throughput — and have a large impact on video viewing quality. Therefore, if the server hosting the files is not close to the end user then the streaming of HD videos, or even the download of large files, becomes difficult, or even impossible.

The magnitude of this effect can be seen in Table 1 from Nygren et al. (2010). Their

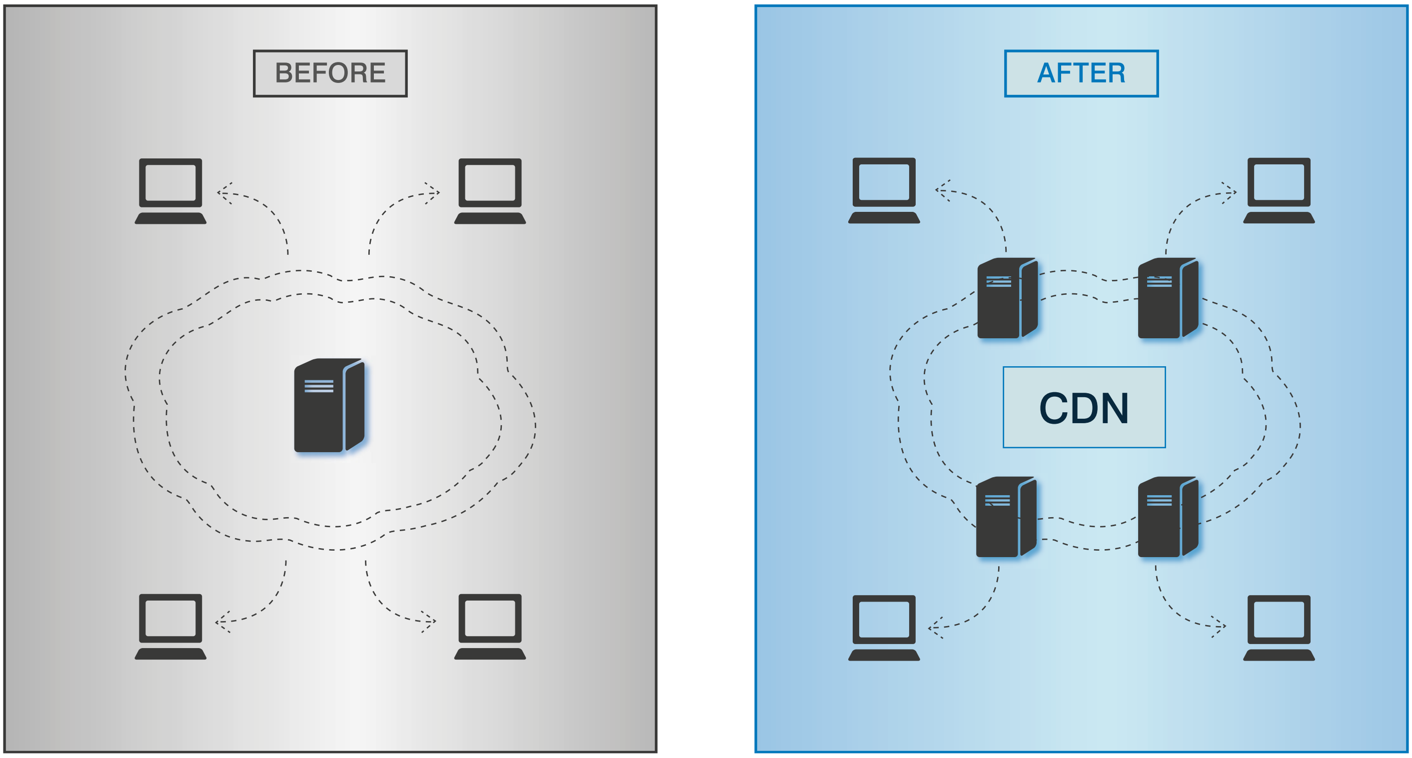

Figure 1. *Comparison between content distribution from a single server (left) versus a content delivery network (right).*

Distance from server to user (km)	Network round-trip time (ms)	Typical packet loss (%)	Typical throughput (Mbit/s)	Typical download time for a 4-gigabyte DVD movie
Local: < 150	1.6	0.6 %	44 (high quality HDTV)	12 minutes
Regional: 800–1500	16	0.7 %	4 (basic HDTV)	2.2 hours
Cross-continent: ~ 5000	48	1.0 %	1 (SDTV)	8.2 hours
Multi-continent: ~ 8000	96	1.4 %	0.4 (poor)	20 hours

Table 1. *Effect of distance on typical throughput and download time for a fast consumer connection. Credit: Nygren et al. (2010).*

measurements show that the network round-trip time, which measures the time required for a data packet to travel from a server to an end-user and back again, can reach up to about 100 milliseconds (ms) for a distant server with more than 1% of all packets lost on the way. The resulting throughput in megabits per second decreases dramatically the further away the server is.

Until February 2015 the European Southern Observatory (ESO), which also hosts the European Space Agency's Hubble webpage spacetelescope.org, only had one server location, at ESO Headquarters in Garching bei München, Germany. All content from this leading ground-based observatory, including almost 15 000 breathtaking high-resolution images and more than 3500 spectacular videos in many formats up to, and including, Ultra High Definition[1], was distributed across the globe from this single location. This posed a problem, as analysis showed that more than 40% of the public traffic to both sites originated from outside Europe. Since the content was available only from the server in Garching, this led to a significant decrease in speed for those users accessing it from outside Europe. This issue is accentuated further in the case of videos that are designed to be viewed on screen in real-time, as high latency and slow transfer speeds result in stuttering video playback.

This issue is not unique to ESO, but is relevant to anyone distributing content via the internet to international users. So far, few scientific organisations have addressed this issue, meaning that significant parts of the content fail to reach audiences on the other side of the globe.

Recently, this problem has been exacerbated as High Definition (HD)[2] and Ultra HD videos have become a much larger part of worldwide internet traffic. Many scientific and astronomical organisations, including ESO, now distribute video podcasts in HD or Ultra HD format. Some of the recent video files available from ESO and ESA/Hubble can easily reach several gigabytes, especially those in formats produced for broadcasters. ESO has also found that a

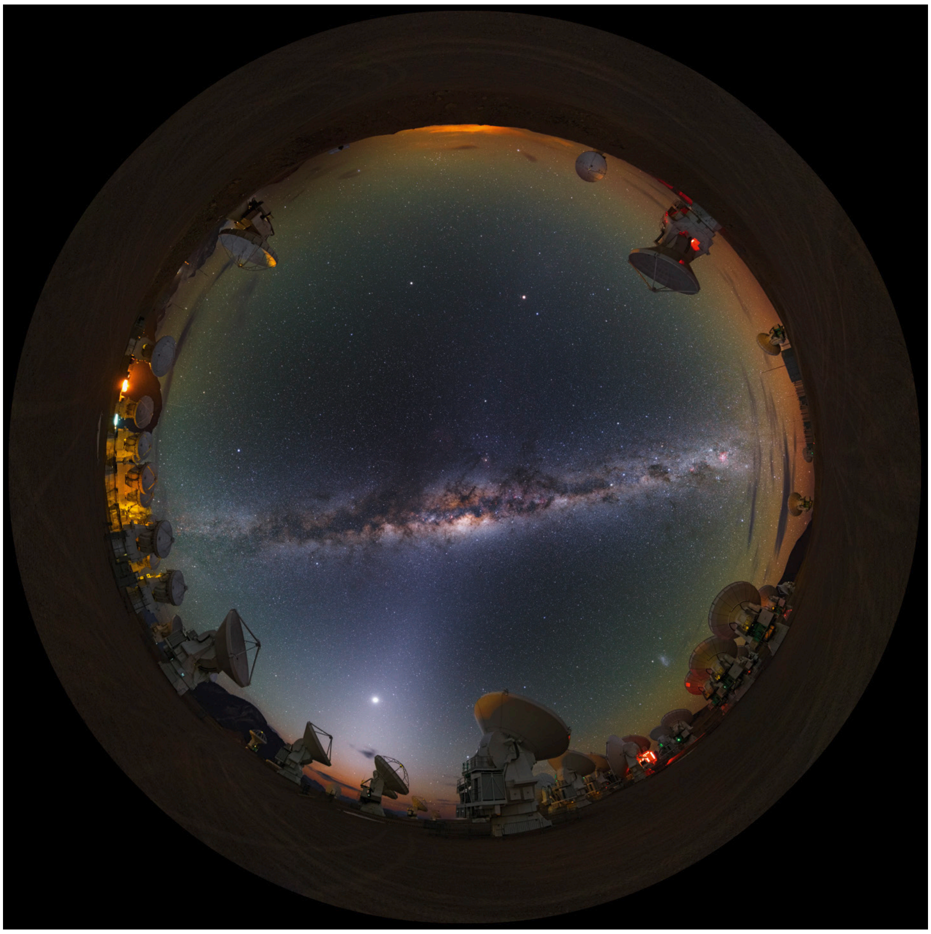

Figure 2. *Fulldome frame for use in a planetarium. Credit: Y. Beletsky (LCO)/ESO*

good fraction of the more technologically avid of our audience want the images and videos in the highest resolution possible. To fulfil this need, we have had to find a way to deliver these products effectively.

The biggest challenge: Distributing planetarium materials online

Another recent trigger that has spurred ESO and ESA/Hubble to look into this problem has been a need to pursue the production and distribution of fulldome planetarium shows for the upcoming ESO Supernova Planetarium & Visitor Centre[3] at ESO's Headquarters in Garching, Germany. The planetarium community is expressing a deep and urgent wish to receive more fulldome productions[4] from scientific organisations, as well as more direct and timely access to visualisations of new discoveries and data. These fulldome movies can reach 400 gigabytes for a full 30-minute show and make the need to solve the above-mentioned geographical problem even more pressing.

To demonstrate the feasibility of distributing files of this gargantuan size online — provided the problem can be solved — Table 2 shows the download times of planetarium clips and shows for different typical internet connections. The throughputs of the connections quoted are ideal ones with little associated latency, packet loss, network outages, and inter-network friction.

Table 2 demonstrates that distributing planetarium material — even full shows — is entirely feasible, although there are several requirements:

- A decent internet connection is needed, similar to a good private 16 Mbit/s internet connection.
- The user needs a bit of patience and a full night or weekend at their disposal.
- The use of a download manager like Free Download Manager[5], or a command line tool like aria2[6] in case there is an internet outage, is required on either side.
- Sufficient free disk space is required at the location where the file is to be saved.
- A nearby server is needed to deliver the material and solve the geographical problem.

None of these expectations are unreasonable for many facilities, although there are naturally local challenges that may make the download times longer.

Content delivery networks

Content delivery networks (CDNs) can solve all of the above-mentioned problems. A company provides a distributed system of servers deployed in multiple data centres worldwide. This network ensures that users access data from a geographically nearby location, which gives a better guarantee of availability and high performance. As part of the service the CDN provider ensures that all content is synchronised and available from all of the servers.

CDNs are not a new concept: they have been around for more than ten years, but they have only recently become an affordable option for outreach and communication departments, such as that of ESO, which delivers around 0.3 petabytes of outreach internet traffic per year. Due to changes in the market and the arrival of new, cheaper and more flexible CDN providers, prices now start in the range of 50–100 euros per terabyte of data transferred, depending on how many data centres are offered, and their locations.

Originally, CDNs improved website performance by caching static site content in order to avoid intervening bottlenecks as much as possible. But the range of applications has now expanded, and CDNs are extremely important for transferring large files, such as high-resolution images and videos, and for live streaming of media. They are also used to serve normal web content — including JavaScript or CSS (Cascading Style Sheets) files and graphics — e-commerce applications and social networks.

CDNs do not only provide better performance and availability of the customer's content, they also offload the traffic served directly from the content provider's servers which can then effectively accommodate large-scale and short-term variations in demand for the content. This reduces the pressure on content providers to accurately predict capacity needs and enables them to gracefully absorb spikes in website demand — sometimes colloquially known as the Slashdot effect. Managing these spikes in demand can lead to a possible cost saving for the content provider, as sites no longer need to support a substantial local server infrastructure as a contingency against large sudden demands, that may sit underutilised except during popular events.

How hard is it to implement a CDN solution?

With limited time and manpower available to make information technology (IT) infrastructure changes in a scientific

File size	Small DSL connection (4 Mbit/s)	Mobile 3G (16 Mbit/s)	Large DSL connection (16 Mbit/s)	Mobile LTE (100 Mbit/s)	Fibre cable connection (100 Mbit/s)	Large institutional cable connection (1 Gbit/s)
Fulldome clip (10 Gigabytes)	5.5 hours	1.4 hours	1.4 hours	800 seconds	800 seconds	80 seconds
Fulldome movie(400 Gigabytes)	9.26 days	2.3 days	2.3 days	8.9 hours	8.9 hours	0.88 hours

Table 2. *Theoretical shortest download times of planetarium materials for different typical internet connections.*

Figure 3. *Location of CDN77 servers worldwide. Credit: CDN77*

	Local		European			Non-European			
	Munich, Germany	Augsburg, Germany	London, UK	Helsinki, Finland	Batalha, Portugal	ESO, Santiago, Chile	New Jersey, USA	Salt Lake City, USA	Cartagena, Colombia
Pre-CDN average through-put (Mbyte/s)	0.02	0.11	0.05	0.05	0.04	11.94	0.04	0.12	0.04
Post-CDN average through-put (Mbyte/s)	0.01	0.10	0.06	0.08	0.08	20.42	0.05	0.61	0.11
Improve-ment	-53%	-7%	39%	47%	73%	71%	30%	428%	188%

Table 3. *Summary of a simple test of download speeds from nine geographical locations before and after ESO's and ESA/Hubble's CDN installation.*

organisation it is important to ask how hard it will be to implement a CDN solution. In our experience it is fairly simple to make the changes needed. To get a simple system running it is only a matter of updating the links to static files on the web pages to point to the CDN system instead of the local server. The CDN system will then automatically fetch the files from the nearest server on demand.

However, especially if dealing with large files, the files should be uploaded to the CDN system in advance and then pre-loaded onto the many servers on the network. This is again simple to implement, but it is important to ensure that a tight workflow is followed when dealing with the data locally. Any files that change on the local master server also need to be re-synchronised with the CDN system to ensure that changes percolate through the network. It is much easier to implement the more advanced features of a CDN system if good data workflows are already in place, and followed.

ESO's partnership with CDN77

Since February 2015 ESO and ESA/Hubble have been using a CDN. As part of a collaboration, the CDN provider CDN77[8] has now placed all of ESO and ESA/Hubble's images and videos on 28 servers worldwide. They are distributed in 23 different countries and cover all continents besides Africa. This gives users — particularly those outside Europe — significantly faster access to content and allows them to play back videos live onscreen and download even the largest videos and images in a reasonable time. This is especially advantageous for web visitors from ESO's 16th Member State Brazil, which is currently undergoing the last stages of ratification and Chile, the location of ESO's telescopes.

As a sanity check on the usefulness of the CDN solution ESO performed a basic and independent test before and after the installation of the CDN network (Table 3). This test confirmed that the throughput of ESO and ESA/Hubble's images and videos outside Europe was improved with an average factor 179% (between 30% and 428%) using a variety of small, medium and large files. This is consistent with the values of up to 130–400% faster downloads quoted by Nygren et al. (2010). The ability to stream live video was also significantly improved as expected, but quantitative data were not measured.

It was not possible to control the local test conditions when collecting the results other than by normalising for the available internet speed at the time of testing[9]. Despite being a fairly crude test there were also indications that, as expected, there was a small drop in throughput within the local radius of the master server, in our case those users within 15 kilometres. This is because the CDN-routed traffic will need to go to the nearest CDN server, which is usually further away than the local server used. In our case the nearest CDN server is in Frankfurt, Germany, which is 300 kilometres as the crow flies. For the rest of the test locations in Europe a small improvement in download speed could be seen.

In conclusion it can be stated that a CDN system provides quicker and more convenient access to content worldwide for users who are far from the location of the master server. This was measured both for downloading files and streaming video, with a measured average improvement outside Europe of 179%, and up to more than 400%, depending on the end-user's location and the proximity of the nearest CDN server.

Acknowledgements

Many thanks to those working with us on this project from CDN77, including Veronica Minovska and Tomáš Sýkora. Thanks also go to our colleagues spread over large parts of the world for helping with the testing: Javier Enciso, Adam Hadhazy, Georgia Bladon, Max Rößner, Bruno Rino, Simo Pirinen, Francisco Rodriguez, Kevin Scott, Michael Naumann, Klaus Herzig and Daniel Schweizer.

Notes

1. Ultra High Definition is 3840 x 2160 pixels per frame.
2. High Definition is 1920 x 1080 pixels per frame.
3. More information on the ESO Supernova Planetarium & Visitor Centre: http://supernova.eso.org/
4. The most common fulldome standard format is 4096 x 4096 pixels per frame.
5. Free Download Manager is available at: http://www.freedownloadmanager.org/download.htm
6. Aria2 is a command line tool that downloads a file from multiple sources/protocols and tries to utilise your maximum download bandwidth to speed up your download. It is available here: http://aria2.sourceforge.net/
7. More information on content delivery networks: http://en.wikipedia.org/wiki/Content_delivery_network
8. More information on CDN77: http://www.cdn77.com/
9. Internet speeds at the time of testing were established using speedtest.net.

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Biographies

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Mathias André obtained an MSc in Computer Science in England and worked for several years as a Unix system administrator and IT Operations Manager before joining the ESO outreach group to tackle new challenges as Web and Advanced Projects Coordinator.

Bariónica: Combining Photography, Philosophy and Astronomy for the ESA/Hubble *Ode to Hubble* Competition

Column

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Keywords
Art, competitions, photography, Hubble Space Telescope, philosophy, baryonic matter, cosmology, education, meaningful learning

In early 2015 the artist behind the photographic collection *Bariónica* entered it in video form into the European Space Agency's (ESA) *Ode to Hubble* competition — a public video competition organised to celebrate the 25th anniversary of the Hubble Space Telescope[1]. The photographic collection aims to show the connection between cosmic matter and the matter which constitutes mankind, using images and ideas from astronomy to symbolise the connection between what we are, and where we came from. On 24 April 2015, Hubble's 25th birthday, *Bariónica* was announced as one of two winning videos of the contest. In this article its creator, Desiré de Palacio, tells us about the fundamental ideas that led her to create her piece, and about the experience of being one of the contest winners.

Science in vogue

The philosophy of science is something that has fascinated me for some years, but my interest in astronomy topics began in the wake of discovering the documentary that I consider to be the flagship of science communication: Carl Sagan's *Cosmos*. Sometime later, with the new version presented by Neil deGrasse Tyson, I once again found myself in awe of both the grandeur of its contents and its capacity to express complex knowledge in such a direct and simple way.

My way of working as a photographer always goes hand in hand with the philosophical ideas that I am investigating at the time. The series *Cosmos* planted a new seed: the idea of creating a photographic composition which blended mankind with astronomy. Shortly afterwards, I discovered the Hubble images and this idea began to germinate

In my academic training I have tried to combine philosophy with knowledge about audiovisual technology. Presenting complex ideas in this way is very effective for reaching a broader public audience. Using audiovisual content as a creative tool for outreach and education is becoming ever more popular, especially in science. Through this means, an open and communicative relationship can be fostered between the public and those behind the science, which can enrich the lives of a great many people.

Figure 1. *Photograph from the* Bariónica *collection and its inspiration; a Hubble Space Telescope image of the planetary nebula NGC 5189. Credit: Desiré de Palacio and NASA, ESA and the Hubble Heritage team (STScI/AURA)*

Documentaries are not the only means through which video popularises science: entertainment plays its part too. In the past few years, the situation comedy, *The Big Bang Theory*, in which the main characters express their passion for science, has become a television phenomenon. If, to all this, we add the use of social media networks for science outreach, we end up with a new horizon for science communication. Something is changing, and is being achieved with the help and input of many people across the globe: science is in vogue.

This new interest in science will no doubt have highly positive consequences, which we will be able to analyse in the coming years. Nevertheless, we cannot lower our guard, as we are just beginning to take this path and still have a lot of work to do.

What do people think about the Universe?

Whilst surfing social networks I came across a video that ended up going viral[2]. This video illustrated a simple idea; that the Solar System is in movement. It showed both the movement of the planets around the Sun and also the movement of the Solar System as a whole with respect to the centre of our galaxy.

What really drew me to look further at the video was my own curiosity. What had made this video go viral? Whilst rummaging through the comments and links, it became clear that it was not because of the quality of the animation, but instead, that the users had been fascinated to discover that the Solar System moved within our galaxy, and in turn our galaxy moves through space.

What does this tell us? We can interpret it in several ways. One inescapable interpretation is the implication that our compulsory education system has shortcomings. This awe of something very simple, and central to our existence, implies that our education system does not cover basic knowledge about the Universe sufficiently well.

Another way of seeing this could be to recognise the need to support the ideas which help pupils to learn about the Universe by connecting them with their own experiences. So here, for example, the public are connected with astronomy by discussing our place within the Universe — in other words, to explore the philosophy behind the science.

The place of philosophy in science and culture

Exploring philosophy as part of science is not only about increasing our level of scientific culture, but also about creating concepts that can be useful to us in our day-to-day lives when trying to understand our own existence. Our culture is based on permanence and not reaching it creates serious internal conflicts, in addition to dissatisfaction with the lack of change in our lives. Integrating ideas such as movement, chance, creation, transformation or change can help to mitigate the fear of the future that appears to be innate in us. What better example to assume change

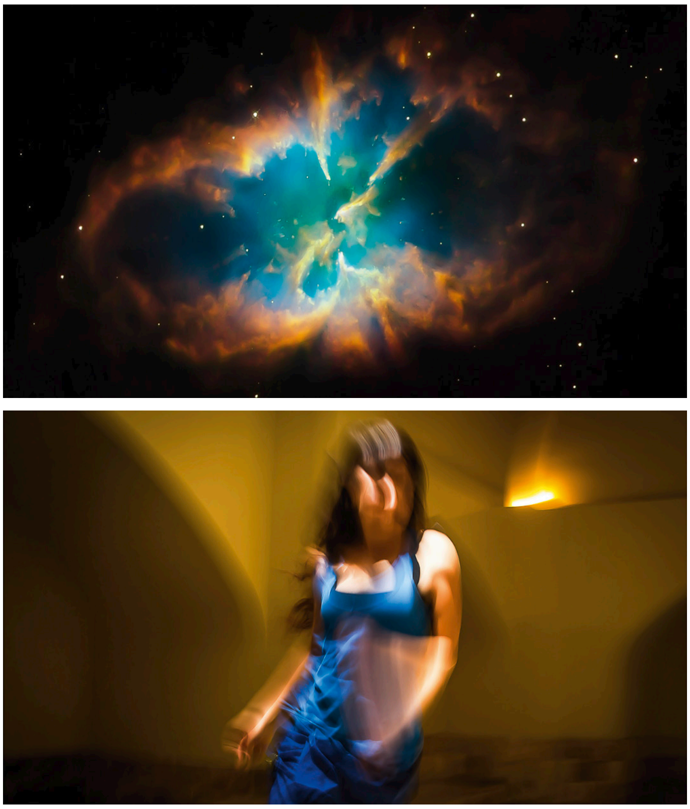

Figure 2. *Photograph from the* Bariónica *collection and its inspiration; a Hubble Space Telescope image of the planetary nebula NGC 2818. Credit: Desiré de Palacio and NASA, ESA and the Hubble Heritage team (STScI/AURA)*

Figure 3. *Photograph from the* Bariónica *collection and its inspiration; a Hubble Space Telescope image of the planetary nebula NGC 2346. Credit: Desiré de Palacio and NASA, ESA and the Hubble Heritage team (STScI/AURA)*

Figure 4. *Photograph from the* Bariónica *collection and its inspiration; a Hubble Space Telescope image of the star cluster Westerlund 2. Credit: Desiré de Palacio and NASA, ESA and the Hubble Heritage team (STScI/AURA), A. Nota (ESA/STScI), and the Westerlund 2 Science Team*

as something necessary in our lives than the data we possess about the creation of the Universe and how the matter within it develops and evolves.

It was my aim to revitalise the fundamental philosophical issues and concepts explored in Pre-Socratic philosophy[3], and update them using modern, scientific explanations. Playing with this idea in my mind I decided to undertake an investigation which is, currently, still in development. It is based on two main questions: What do people think about the Universe? And how can the knowledge of the cosmos affect our perception of life?

The study is focused on Spanish society, with a wide-ranging group taken from the general public, with different profiles based on age and academic training. It is about drawing conclusions both from the general level of knowledge, and also from the repercussions that this has had on people.

Although the study is not yet complete, we can catch a glimpse of some interesting data. A barrier seems to exist when conceiving the Universe as part of the actual history of the human being. There is a kind of intrinsic fear of reflecting on what exists beyond our atmosphere. Leaping into the unknown is always a challenge.

The oldest and strongest emotion of mankind is fear, and the oldest and strongest kind of fear is fear of the unknown.
H. P. Lovecraft

The history of philosophy shows that many existential questions have arisen, and continue to arise, ever since people began to reflect on their wider origins: What is mankind? Why are we what we are? Where do we come from? Whither are we heading? What is our place in the Universe?

Science has gone a long way towards answering some of these questions, but although it plays an important role in helping us to understand ourselves and our history it does not reach everyone. Barriers to this enriching information include the complexity of the ideas, the need for some previous knowledge, or the debates between different theories, which for those who are taught that science is a case of right and wrong, can add even further to the confusion. As human beings, we yearn for answers, and without them we turn to unscientific criteria, or even pseudo-sciences, as a haven. This creates a further reason for engaging everyone with science.

With the photographic series, *Bariónica,* my intention is to use light to pass through the barriers to reaching scientific knowledge and to make this knowledge into something visual with which we can all identify. This would not have been possible without having delved into the discoveries and images from the Hubble Space Telescope.

Figure 5. *Photograph from the* Bariónica *collection and its inspiration; a Hubble Space Telescope image of the Horsehead Nebula. Credit: Desiré de Palacio and NASA, ESA and the Hubble Heritage team (STScI/AURA)*

Hubble's magnetism and the power of scientific diffusion

The images from Hubble were already present in our textbooks and museums before the internet boom, and nowadays, they are everywhere. At the beginning, for those of us not involved, it was unclear whether these images were just drawings or if the stars were actually as they appeared when captured by the images.

When someone observes images from the Hubble Space Telescope, they are not left indifferent. On social networks we can find profiles of many different characters and

Figure 6. *Photograph from the* Bariónica *collection and its inspiration; a Hubble Space Telescope image of the pair of colliding galaxies known as NGC 2207 and IC 2163. Credit: Desiré de Palacio and NASA, ESA and the Hubble Heritage team (STScI/AURA)*

people among the telescope's followers. These images produce an aesthetic experience that rapidly hooks the spectator.

Transcending the visuals, the telescope's magnetic appeal is also due to the enigma that we sense behind each image. There are those who are content with the aesthetic experience, but for those who want to delve deeper into the phenomenon behind the images, the task has become ever easier thanks to the informative work of pages such as the ESA/Hubble website and its partners[4]. For me the reward of delving into these images further was extensive and my decision was made: The photographic essay that would link my current concerns would have Hubble discoveries at its heart.

Bariónica

Art can be conceived as an ability to create significant connections with our thoughts. Achieving a good synthesis, one which possesses strength and concordance with the idea you want to express, is not an easy task. For me it was a huge challenge.

There were two fundamental ideas that I wanted to display to the public in the *Bariónica* collection. The first, was to highlight that mankind is not distinct from other matter that exists throughout the Universe, but is part of something intrinsic. I decided to use the physics concept of baryonic — or physical — matter to create a simple link between the matter shown by Hubble's images and that which constitutes our own bodies. My intention was to integrate the Universe within the history of mankind.

The second idea behind the collection was to express and draw attention to the constant changes that matter experiences.

Photography has its limitations when it comes to expressing points, especially when dealing with movement, and Hubble's own images create a paradox: How can we perceive, for example, the full power of a supernova as a static image?

The weight of constant change, in this case, falls to the background and because of this, assuming the challenge of representing it through photography became interesting. This helped me to determine which photographic technique I was to use for the portrait of the human being, a portrait in motion.

For one half of the collection I used portraits in motion which I had previously created. Limiting myself to finding similarities, I searched through Hubble's pictures for the ones which were most alike. For the second half of the piece I selected a group of images taken by Hubble and had models imitate the shapes of the nebulae to create the analogy.

After a lot of work I started to feel satisfied with the results, so that around the middle of March 2015, I had a collection from which I intended to create an exposition. During the process I could not help but ask myself what the thoughts of the actual Hubble team would be if they ever saw my work. It was only a dream; I never thought that it would actually happen. The stars aligned in my favour though.

Ode to Hubble

During the creation of *Bariónica* I visited Hubble's webpage almost every day, searching for information regarding its images. Shortly after finishing my photographic collection I discovered the contest, *Ode to Hubble*, organised by ESA as part of ESA's and NASA's programme of activities to celebrate 25 years of Hubble. They asked the public to answer, in an artistic manner, the question: How has Hubble inspired you? That was the exact question I had been waiting to be asked: I had my answer!

To take part in the contest I created a video piece featuring and building upon my photography work that explored the questions I had set out to address. Taking part in the contest was a fun experience, and the initiative was a dynamic and active way to involve the public with astronomy. To watch the interpretations that each contestant presented concerning the Universe and Hubble, in addition to the audiovisual manner in which the ideas were developed, fascinated me.

As the contest carried on, being one of the six finalists was already achievement enough, and I was delighted by the thought that the judging panel, composed of members of the Hubble team, would see my video.

I never thought that I would win the contest, and when this happened I felt truly lucky. Thanks to this, the *Bariónica* collection has been revitalised, with many new followers. This has given me the strength to continue joining science and art in my work. Due to this, I will always be grateful for the opportunity that the Hubble Space Telescope and its team have given me.

I have closed a highly positive feedback circle in which science outreach has awoken new concerns in me, allowing me to access areas where my academic training had not previously taken me. With my artistic creation I have tried to contribute by adding my piece to the diffusion of astronomy ideas and I was able to do this to better effect, and reach far more people, through an innovative science outreach initiative.

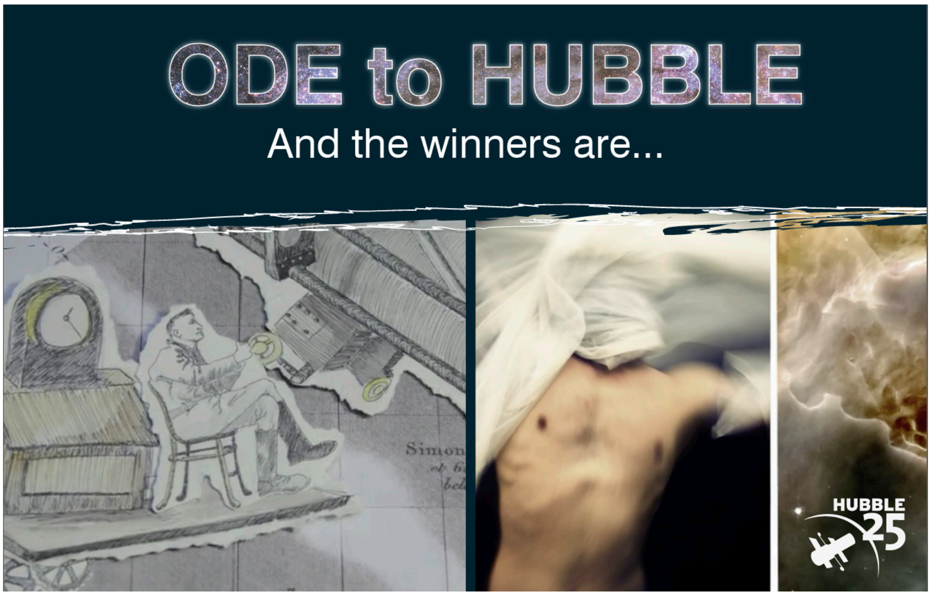

Figure 7. *Promotional banner from the ESA/Hubble* Ode to Hubble *competition. Credit: ESA/Hubble*

Notes

[1] Find out more about the *Ode to Hubble* video competition and watch *Bariónica* and the other shortlisted and winning videos: http://www.spacetelescope.org/projects/Hubble25/odetohubble/

[2] Watch the viral video of the Solar System in motion: https://www.youtube.com/watch?v=mvgaxQGPg7I

[3] More on Pre-Socratic philosophy: https://en.wikipedia.org/wiki/Pre-Socratic_philosophy

[4] There are two websites dedicated to news, information and science from Hubble. One is run by ESA (http://www.spacetelescope.org/) and the other by NASA and the Space Telescope Science Institute (http://hubblesite.org).

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Biography

Desiré de Palacio is a philosopher and photographer interested in science. Through her photography she expresses the ideas investigated in philosophy. One of her aims is to create tools and audiovisual material to reach school students and allow them to more easily understand some complex issues in science and philosophy education.

Participant Perspectives on the ESO Astronomy Camp Programme

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Laura Angelica Irineo Tellez
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Keywords
Education, camp, community, outdoor learning environment, secondary school students

This article describes the experience of attending the European Southern Observatory (ESO) Astronomy Camp from the perspective of its participants — students aged between 16 and 18 years old from around the world. The students shared a week together during the winter of 2014 in the Alpine village of Saint-Barthélemy, Italy. The camp was organised by ESO in collaboration with Sterrenlab and the Astronomical Observatory of the Autonomous Region of the Aosta Valley and offered a rich programme of astronomy and leisure activities. This article focuses on the concept of astronomy camps, and their role as a unique tool to complement formal classroom education, rather than on the astronomy activities and the scientific programme. Thus, it is not an academic review of the implemented methodologies, but rather a reflection on the overall experience. The article was brought together from collaborative accounts by some of the participants who were asked to reflect on the experience. The participants who contributed to this article represent the diversity of the ESO Astronomy Camp's alumni community.

The outdoor learning environment

There are many learning experiences that cannot be achieved through standard school courses. Attending the ESO Astronomy Camp 2014, was for the participants, a unique opportunity that complemented formal teaching. Some of the most stimulating parts of the camp were the opportunity to travel abroad, stay in an unknown environment, and explore and establish new relationships. The camp was located in a remote Italian Alpine village with very little ambient light at night — every astronomer's dream — and a fairly dry climate, which reduces atmospheric turbulence. This environment made both the sessions and free time incredibly enjoyable and productive. Of the 56 young adults who attended the camp all were overwhelmed by the amazing views of the constellations at night — with everyone taking out their cameras to capture the stars.

The camp allowed the students to meet a number of individuals who have dedicated their lives to astronomical achievement and research, and gave them the opportunity to use high technology instruments for learning. In addition, the camp helped with the interpersonal and social skills that are needed to develop a cohesive group, and promoted the teamwork that comes from working with new friends, who were strangers at the beginning of the camp.

Exposure to scientific facilities

In school, students do not get a chance to use research instruments. The ESO Astronomy Camp 2014 provided an opportunity for students to gain real insight into the nature of research and a hands-on experience of how it is carried out. Using telescopes for observations of celestial bodies provided an excellent introduction to astronomical observation.

The programme included the chance to choose a star and record its spectrum, and to capture images of star clusters to measure the distances to them. These observations let the students apply the theoretical explanations learnt in the classroom to data that they have collected themselves.

The instruments were only one part of the research facility; the scientists themselves were a fundamental part of the learning process. The combination of access to facilities and to researchers is something that cannot be experienced in a formal teaching environment, but for the motivated and interested students who have had a chance to participate in this kind of initiative, the experience provided important insights into the world of research. The experience taught the students that they can interact with the scientific world, and be part of it, no matter what career they ultimately choose.

A cup of tea with an astronomer

All the camp participants attended informal talks with the astronomers around dining tables during lunch and at teatime. These talks demystified the scientists and showed that they are real people leading normal lives. The image of an astronomer, who is often seen as someone who may be hard to relate to, who uses many big words while talking, who spends nights watching the sky or staring at a computer monitor, or even as someone who always looks out into infinity, was dispelled. Astronomers are not a sort of alien nor are they special people doing work that no ordinary person can aspire to do, they do not have to live alone, hiding from society and enclosed inside a private world, instead they are quite normal in terms of their lifestyle and work. This shows that becoming an astronomer does not mean changing, but rather cultivating, a passion for learning about the Universe and that it is a job that all the camp attendees could aspire to.

These valuable talks with astronomers were quite different from the kind that a student normally has with teachers at school, where students sit at their desks, listen to the professor and take notes. In this setting, the initial tension caused by the presence of individuals who might be considered impressive and different subsided due to the friendly and intimate environment.

Students learned that the astronomers' strength and love for the Universe were the drivers that allowed them to achieve their goals. For example, several astronomers had made countless changes of place and undertaken various programmes of study to obtain the position they were aiming for, in this case, working and studying in Chile. It was very enriching to understand how it is possible to reconcile a private life with such demanding work and this was an issue that many of the participants considered important. It is difficult to understand how to make compromises or sacrifices regarding personal relationships for a career, even a successful one, and many students do not have the opportunity to see or discuss this so early in life.

Relevance to the school curriculum

Most of the students did not see the astronomy camp as an extracurricular activity, but as a way to master or put into context scientific concepts learned at school, mainly those from physics. The camp workshop on the measurement of distances introduced concepts such as Kepler's laws and logarithms from mathematics that are part of the formal school programme. The younger participants were introduced to these concepts for the first time, while for others it was a review. In both cases, however, the topics were introduced in a clear and concise way and, most importantly, applied through exercises that were worked through alone or in groups — first during lectures, then developed on their own.

Once the students returned to school some of the schools found ways to broaden the experience, giving other students a taste of what was learned. Teachers asked participants to give presentations about the camp to fellow students. This allowed other students to benefit from the experience of a single participant. Some students were financially sponsored by their school, thanks to the support of teachers and headteachers who considered the camp to be an invaluable way for students to see how the concepts they learn at school are applied in a real scientific environment.

A growing community of alumni and researchers

An important aspect of the ESO Astronomy Camp is the opportunity to meet like-minded students from all over the world. Even though all the participants on the 2014 trip had experienced a family or school trip abroad, only an intensive experience like this camp could give them the chance to meet students from other countries and gain an international perspective. From the moment the participants met at the airport, they started to talk, forming bonds based on common interests and attitudes. By the time the group arrived at the hostel, long-lasting friendships had already been established. It is for this reason that the leisure activities are an integral part of the ESO Astronomy Camp programme.

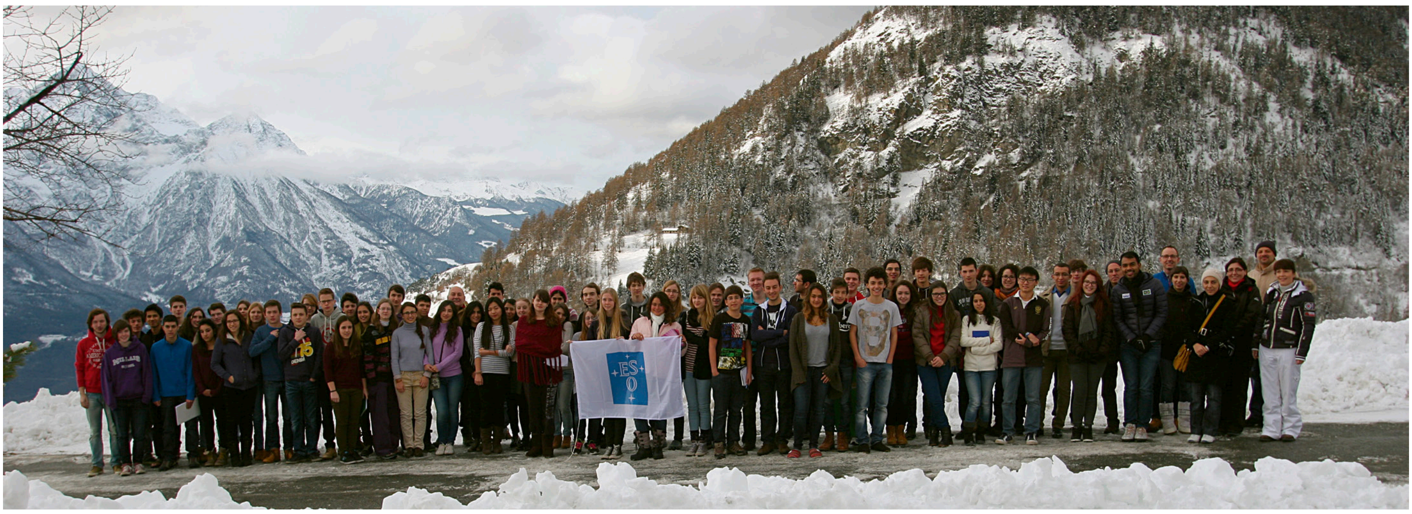

Figure 1. *Group picture from the ESO Astronomy Camp 2014. Credit: P. Calcidese–Fondazione C. Fillietroz, ONLUS/ESO*

The organisers believe the group experience improves self-confidence and reinforces the feeling that the talented students, who sometimes have struggled to find friends with the same interests at home, are actually part of a larger community. The ESO Camp is a closed group on Facebook, and is a hub where students continue to share practical information and interact with participants from previous years, the organisers and astronomers about anything related to science and astronomy. In the future, it is hoped that the group will become an important tool for mentoring and sharing opportunities among all participants, including senior astronomers and ESO staff.

At the end of the camp, after such an intense week together, everyone was quite emotional. At the same time, there was the general feeling that most of the members who are now part of this small but vibrant community would meet again for holidays or for their studies, fostering a true European spirit.

What long-term effects can be expected from attending the camp?

Attending an ESO Astronomy Camp gives the participants a big motivational boost that inspires a continuing interest in astronomical research and observation and influences the choices they make in their lives. All of the participants who came to the 2014 camp, came with a great deal of curiosity and a passion for astronomy — and they left with even more.

Many of the students plan to pursue university studies connected to astronomy after finishing secondary school. The ESO Astronomy Camp deepened their interests in discovering more about the Universe in ways that regular science lessons will never be able to. The camp gave students insights into many fields within astronomy and let them catch a glimpse of what professional research is like. This unique opportunity will surely help those who want to follow a career in professional astronomy, and it will also ensure that those who take different career paths remain passionate hobby astronomers.

Several students asked for a certificate of participation, which they wish to use in a university application, as participation in the camp is proof of their motivation, interest, scientific knowledge, ability to work in a team and English-language proficiency. The camp was also an excellent place for networking with potential future colleagues in research, as well as with current experts in astronomical research from ESO and various other institutions. These connections are extremely helpful in terms of receiving advice and mentoring.

Another major advantage that the camp brought to the students is internationalisation, in both the scientific and non-scientific sense. In today's global village it is essential for future professionals to be aware of and understand other cultures and ways of life. This is especially important for astronomers-to-be, since astronomical research is mostly carried out at venues of international cooperation. For these students, the ESO Astronomy Camp was the first step in this direction.

Figure 2. *Image of observing activity taken by participating student. Credit: Tomasz Świerczewski*

Conclusions

The main aim of the ESO Astronomy Camp is to bring together astronomers and students from different countries to learn, work and discuss in an open and informal way. The organisers believe this approach is a powerful means of letting students make connections between what they learn in school and the world of research; it allows students to increase their science and astronomy literacy and provides a unique opportunity to interact with working professionals at a research centre.

The ESO Astronomy Camp follows the European guidelines for promoting excellent and socially desirable science and technology. Besides being exposed to the academic content, the students had the chance to engage in discussions with astronomers on the role of astronomy in our society. This gave them new perspectives on how they can apply their skills to new domains. The researchers, in turn, interacted with this younger generation, and learned about their needs, issues and expectations.

The ESO Astronomy Camp brought together a mix of motivated and talented people who have a shared vision and interest and who enjoyed spending time together to enhance their learning. Overall, in this Alpine environment, this group of talented like-minded individuals and experienced astronomers provided an opportunity for students to make the most of the out-of-school learning experience.

Biographies

Davide Cenadelli graduated in physics and received a PhD from Milan University. His interests span stellar astrophysics, spectroscopy, and the history and philosophy of science. He is currently part of a research group at the Observatory of the Autonomous Region Aosta Valley involved in the quest for exoplanets around red dwarfs in the galactic neighbourhood.

Cristina Olivotto graduated in physics at the University of Milan and was awarded a PhD in the history of physics. After graduation, she started to work in the field of science communication and education with several national and international organisations. She founded Sterrenlab in 2011.

Global Astronomy Month: Astronomy around the World

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Keywords
Outreach, global programmes, Global Astronomy Month, GAM, Astronomers Without Borders, AWB

For six years Global Astronomy Month has taken place each April, growing into a wide-ranging and diverse array of programmes comprising the world's largest worldwide, annual celebration of astronomy. Innovative programmes developed through partnerships, along with the availability of this novel platform, have allowed an expansion of what the month has to offer. Beginning with familiar observing programmes that engage amateur astronomers, programmes have become increasingly inclusive, extending to non-astronomy fields inspired by space. This article explores the development of Global Astronomy Month, the lessons learnt and how the project has provided a stage for expanding existing programmes and testing new ideas.

Introduction

Global Astronomy Month (GAM) was created as a follow-up to the highly successful 100 Hours of Astronomy (100HA), a Cornerstone project of the International Year of Astronomy 2009 (IYA2009)[1,2,3]. The public observing programmes of 100HA, led by Astronomers Without Borders (AWB) founder Mike Simmons, achieved an unprecedented participation by amateur astronomers and astronomy institutions[4]. AWB sought not only to continue this momentum, but to expand the programmes, making Global Astronomy Month even more diverse and inclusive.

The first programmes organised by Astronomers Without Borders involved observing and public outreach events similar to those in 100HA, such as the Global Star Party and SunDay[5,6]. Public star parties are the most common events that amateur astronomers participate in as a group regardless of location, culture or nationality, and the same objects are observed around the world. Sharing the sky with the public fits perfectly with sharing activities with each other, in tune with AWB's motto, "One People, One Sky".

Sharing is central to both Astronomers Without Borders and Global Astronomy Month. The AWB website, through its sub-site dedicated to GAM each April, provides not only programme information and resources, but tools for sharing events, event reports, and photos[1].

Programme management

There have been six Global Astronomy Months to date, spanning 2010 to 2015, which have provided many lessons in running global programmes and adapting to the changing landscape of astronomy outreach and education. New programmes have been added to the schedule each year as GAM's popularity has increased worldwide.

Programme management and responsibilities fall into three categories:

1. Programmes organised and managed entirely by AWB.
2. Programmes organised jointly by AWB and one or more partner organisations.
3. Programmes organised and managed entirely by partner organisations.

Programmes with shared responsibilities between AWB and a partner organisation may use the resources of either or both, such as networks, websites, social media and management personnel. Often each partner brings resources that the other lacks, allowing more to be done together than either could accomplish alone. For example, partner organisations that want to increase their international visibility often leverage AWB's global reach during Global Astronomy Month and the AWB and Global Astronomy Month brands have benefited from well-known partners such as NASA. No one organisation ever has it all.

Lessons learned

The size and scope of Global Astronomy Month have made it a vehicle for trying new programmes and activities, with varying results. Partner organisations may use Global Astronomy Month not only to expand programmes internationally, but also to increase awareness or scale up existing programmes. Pilot programmes test new ideas and gather data for making adjustments. In addition, reaching out to developing countries allows the transferability of programmes and resources from the higher income nations to be tested.

Unfortunately, there are always more new ideas than can be managed. After GAM 2011, when almost forty programmes were scheduled, the number of programmes was scaled back. Due to the difficulty of managing so many programmes on a limited budget, only the highest-profile programmes receive the attention they deserve in such a crowded schedule. Even if programmes are marketed to appropriate audience niches, the array of programmes presented to website visitors can still be overwhelming. With too large a menu of programmes to choose from, many are missed by those who might have participated.

Community-based observing programmes, such as the continuations of 100HA's Global Star Party and SunDay, are perennial favourites. In these activities astronomy clubs that do outreach all year have a chance to interact with others and be a part of something larger through global programmes. GAM also schedules observing programmes based on current astronomical events such as the conjunctions of major planets or eclipses.

Astronomy across borders of all kinds

Some of the most accessible and popular GAM programmes are the online observing sessions conducted each GAM by Doctor Gianluca Masi of the Virtual Telescope project[7]. Five sessions were successfully held during GAM 2015, with two more cancelled due to poor weather. Two further sessions were added to the schedule when near-Earth asteroids were discovered passing close to Earth during April. In total, 70 000 viewers from 174 countries attended these online sessions, many of whom may not have been able to attend a live session. A chat box is available to the audience during the sessions to allow questions to be posed to Masi, and discussions to be held among the participants.

An example of innovation during GAM was the project, *Stars for All*, which made real-time online observing accessible to the visually impaired alongside sighted people. This project, which we believe to be a first, was run through a collaboration with Astronomers Without Borders, the Virtual Telescope, the Galileo Teacher Training Program, and the Astronomical Observatory at the University of Valencia link. During *Stars for All* images were processed for special devices that create tactile versions. At schools for the visually impaired with these devices the students could experience the wonder of observing with the Virtual Telescope and follow the narration in real time.

Stars for All received a great deal of attention from the media and AWB is now working with partners to develop a year-round programme for the visually impaired using the remote telescope network of Las Cumbres Observatory Global Telescope Network[8].

Figure 1. *Giovanni Renzo performs his original composition against a backdrop of astronomical images and videos during the annual Cosmic Concert broadcast live from Rome, Italy. Credit: Giovanni Renzo*

Combining astronomy with art has become a big segment of the Astronomers Without Borders programme. Special events organised by GAM encourage the crossing of the border between art and science by both artists who do science, and scientists who do art.

Daniela De Paulis, founder of the AWB AstroArts project, sent artworks to the Moon and back during her OPTICKS programme[9]. This was achieved with help from radio amateurs who encoded the images, and transmitted and received the images bounced off the Moon. Several artists contributed to the images, from schoolchildren to professionals. For GAM 2015, two *Apollo* Moon-walkers took part, with a painting by astronaut–artist Alan Bean (*Apollo 12*) making the round trip, and a family photo left on the Moon during Charlie Duke's visit (*Apollo 16*) making the trip from Earth again — and back this time — at the speed of light. Both images were used with permission from the astronauts. Duke even scanned his original photo to provide a higher resolution, and previously unpublished, version for this event.

There is also a Cosmic Concert performed each year by the Italian composer Giovanni Renzo against a backdrop of space images that has a large following.

Contests

Contests are always popular, and the unique global platform that Global Astronomy Month creates has been used to launch two annual contests with broad participation.

The AstroPoetry Contest, based on AWB's popular year-round Astropoetry Blog, is an example of adjusting to the needs of the target audience. Classrooms around the world took part, but the submission dates had to be adjusted to accommodate various school years based on early feedback. New resources also help teachers to structure lessons around writing poems.

The International Earth and Sky Photo Contest, introduced in the inaugural GAM, has become a major event. More than 1000 images were submitted from 54 countries in GAM 2015. Winning images, in categories highlighting the beauty of the night sky and the battle against light pollution, are

Figure 2. *Observing the Sun on SunDay during GAM 2010 in Romania. Credit: Romanian Society for Meteors and Astronomy*

published by National Geographic Online and the BBC, among others. The contest is organised by The World at Night and the U.S. National Optical Astronomical Observatory as part of GAM's slate of dark skies awareness programmes.

New online tools

The growth of social media since 2010 has changed the way that Astronomers Without Borders interacts with the community during Global Astronomy Month. Reports and images are shared on the AWB website but groups increasingly use social media to organise observing events, share photos and stories, and attract new members. The choice of medium depends on the type of content. More complete reports are still posted on the website, but simple photo sharing with brief descriptions is often done on the Global Astronomy Month Facebook page.

While social media limits the amount of information shared, its ease of use has increased sharing and interaction through likes, shares and hashtags like #GAM2015. This sharing has important benefits for community-based programmes. Posts on social media publicise events that the community would not otherwise have been aware of and the event organisers are then urged to register their events and post reports on the GAM website.

While social media is useful for announcements and reminders, more complete information and news is still shared via the website and biweekly GAM newsletter, including the complete programme schedule, detailed programme information, and resources. Events registered on the website appear on the world map of events, which is an important social incentive. Astronomers Without Borders is now using Geographic Information Systems (GIS) software to display results, particularly a new, interactive platform from Esri called Story Maps[10]. Registered events are also eligible for personalised certificates created for download for anyone taking part in the local events. Event registration is allowed even after GAM ends to help fill in the map, and also to stay in contact with organisers and engage them on the website, particularly for event reports. These reports are more in-depth than on social media, are easily accessible and searchable, and serve as a permanent archive of that year's GAM activities. Event reports are regularly featured on the website and in newsletters, another social incentive for posting.

Conclusion

The success of Global Astronomy Month is largely due to it being community-driven. For clubs and organisations around the world that organise events and activities as part of the larger GAM programmes, the added value comes from having an event that is part of something much larger, something they're doing with others around the world. The outreach programmes, with local events organised by astronomy clubs as part of the larger programme, attract, engage, and inspire the public. Browsing images from these events, it is strikingly obvious just how universal the joy of discovery and exploration is, with the same excited look on the faces of all those looking through a telescope for the first time; regardless of the country, culture, or age. GAM inspires people to learn more, try something new, and share their passion with others. Every year we see stories shared via member reports from people who held their first star party, saw something new for the first time, inspired someone or were inspired themselves. GAM is driven by the enthusiastic amateur astronomers who take part and the reason for its global acceptance is its success in sharing the joy and excitement of astronomy with the world.

Notes

1. More about Global Astronomy Month: http://astronomerswithoutborders.org/global-astronomy-month-2015/280-gam2015/global-astronomy-month/2609-global-astronomy-month-2015.html
2. More about 100 Hours of Astronomy: http://www.eso.org/public/events/special-evt/100ha/
3. More about the International Year of Astronomy 2009: http://www.astronomy2009.org/
4. More about Astronomers Without Borders: http://astronomerswithoutborders.org/
5. More about the Global Star Party: http://astronomerswithoutborders.org/gam2015-programs/observing/1558-global-star-party-for-gam-2015.html
6. More about the SunDay project: http://astronomerswithoutborders.org/member-reports/2705-april-12-2015-alp-global-sunday-report.html
7. More about the Virtual Telescope Project: http://www.virtualtelescope.eu/
8. More information on the Stars for All project: http://astronomerswithoutborders.org/gam2014-programs/online/1471-stars-for-all.html
9. More about the AWB AstroArts programme: http://astronomerswithoutborders.org/projects/13-current-projects/1259-astroarts.html
10. More about StoryMaps and how it can be used here: http://storymaps.arcgis.com/en/

Biographies

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ISSNs
1996-5621 (Print)
1996-563X (Web)

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