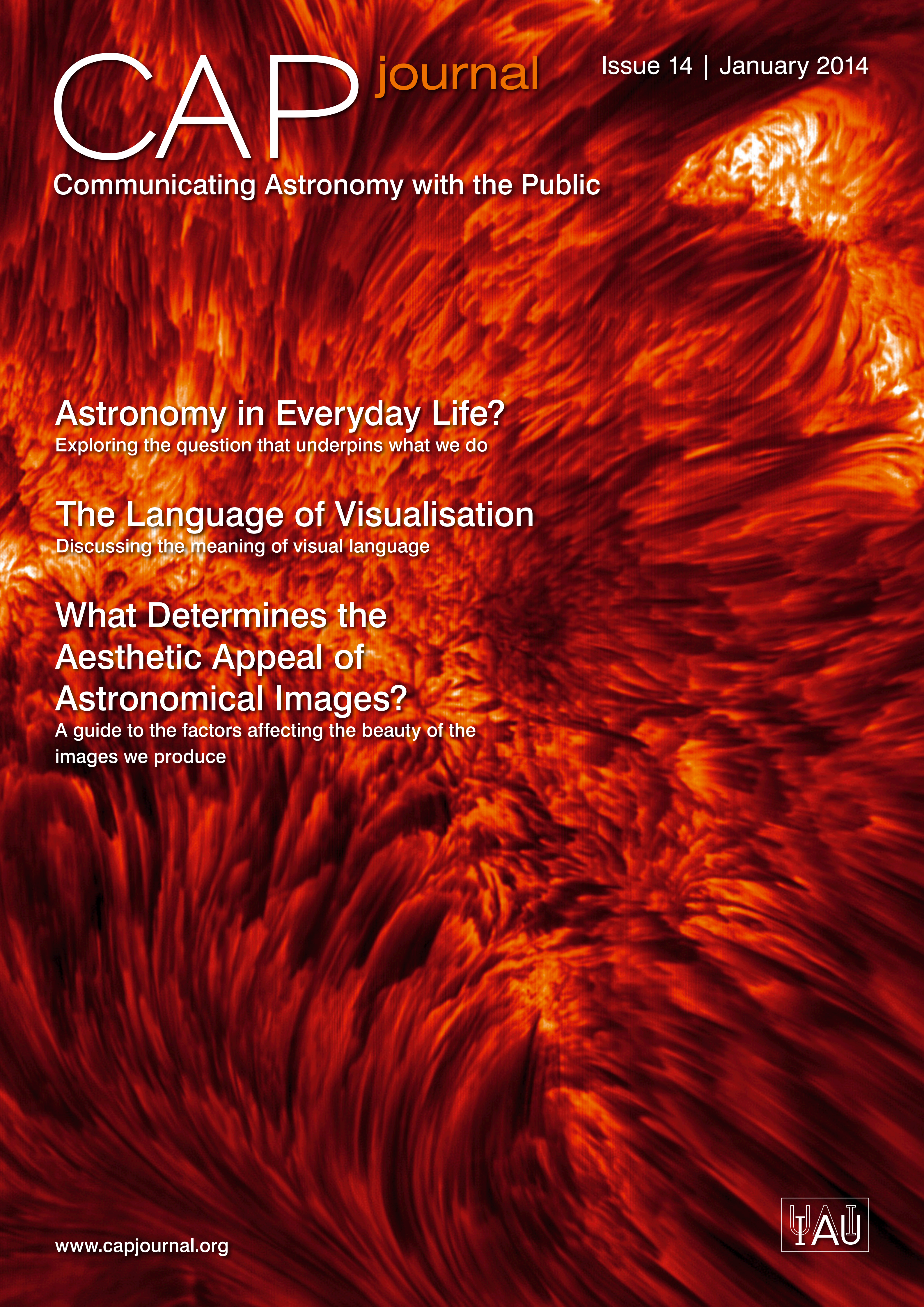


CAP journal

Issue 14 | January 2014

Communicating Astronomy with the Public

Astronomy in Everyday Life?

Exploring the question that underpins what we do

The Language of Visualisation

Discussing the meaning of visual language

What Determines the Aesthetic Appeal of Astronomical Images?

A guide to the factors affecting the beauty of the images we produce

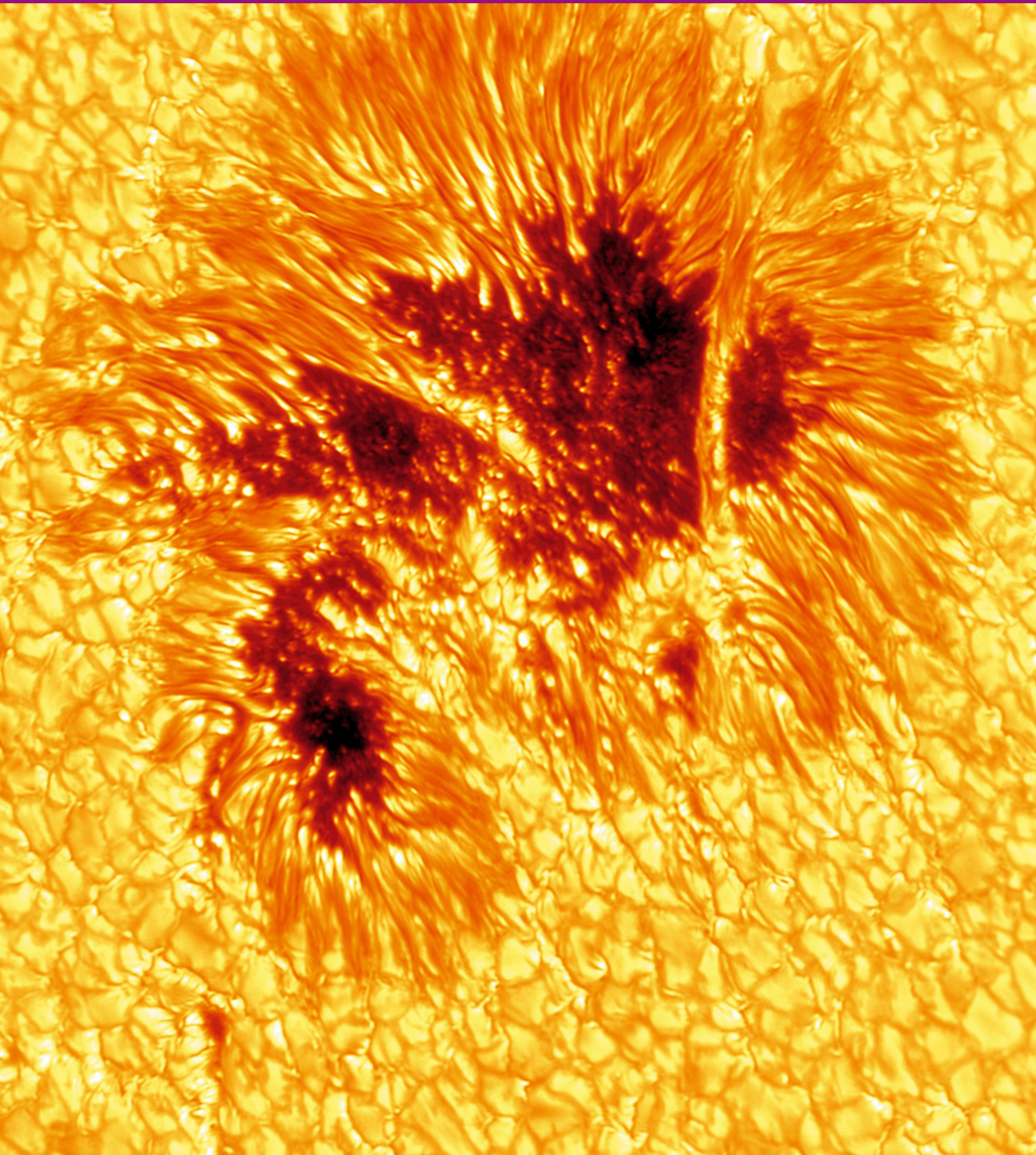
www.capjournal.org

IAU

This is the most precise sunspot image ever taken. It was accomplished using the unprecedented resolution of the New Solar Telescope (NST) and reveals many previously unknown small-scale features. These include the twisting flows along the penumbra's less dark filaments, the complicated dynamical motion in the light bridge that vertically spans the darkest part of the umbra, and the dark cores of the small bright points (umbra dots) apparent in the umbra.

The NST is currently being upgraded to include the only solar multi-conjugate adaptive optics system to fully correct atmospheric distortion over a wide field of view, as well as the only fully cryogenic solar spectrograph for probing the Sun in the near-infrared. Other instruments have been brought online since 2009, to enable the NST to probe the Sun with its full scientific capability for measuring magnetic fields and dynamic events using visible and infrared light.

Image Credit: BBSO/NJIT



Contents

As the new Editor-in-Chief of CAPjournal I would like to first express my apologies for the long wait for this issue. Sarah Reed, my predecessor, decided to step down for private reasons in 2013, and it has taken us time to refuel the journal with the energy it needs to become a reality.

Sarah commissioned and edited a number of the articles in this issue before leaving. I would like to thank Sarah for her dedication to this publication and take this opportunity to wish her the very best in her future endeavours.

Following its period of hibernation I hope not only to continue with the high quality of articles that we have come to expect from CAPjournal, but also bring to it a new life. Having attended the CAP2013 conference in Poland, a review of which you can find in this issue, I have had the opportunity to engage with individuals and groups communicating astronomy to the public across the globe. Hearing about the innovative activities taking place has inspired in me a great sense of pride in this field and it is this that I hope you — our readers, contributors and peers — will share when reading CAPjournal. By pulling together the papers and articles of science communicators and astronomers at the top of their fields we can establish through this journal the best practices in communicating astronomy and provide the tools for others — professional and amateur — to host successful engagement activities that draw on the experience of their peers and predecessors.

In this issue you will find best practice articles on using Google+, engaging the public through social media and involving celebrities in outreach through Twitter. Amongst the research articles are a history of the Hertzsprung–Russell diagram and what we can learn from it about the use of flow diagrams, and a detailed guide to the factors that determine the aesthetic appeal of astronomical images; a must-read for astrophotographers and image processors. In addition, column articles address the use of visual language and how to avoid confusing an audience with it, and take a detailed look at how astronomy affects us all in everyday life.

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

Many thanks for your interest in CAPjournal and happy reading,

Georgia Bladon
Editor-in-Chief of CAPjournal

Cover: On the cover of this issue of CAPjournal is an H-alpha image taken with a visible imaging spectrometer on 22 May 2013 by the New Solar Telescope (NST) at Big Bear Solar Observatory (BBSO), CA, USA. The pattern of the filaments shows ultrafine magnetic loops rising out of the photosphere. Image Credit: BBSO/NJIT

IAU Commission 55: Communicating Astronomy with the Public

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Summary

The International Astronomical Union (IAU) has vested considerable responsibility for its public outreach efforts in Commission 55 (C55), Communicating Astronomy with the Public. This article briefly recounts the origin and history of C55 over the past decade, describing how C55 fits into the IAU's recently revised organisational structure and newly implemented Strategic Plan. It also lists C55's current officers, Organising Committee members, Working Groups, and Working Group chairs and explains how IAU members can join C55, inviting other professionals engaged in astronomy-related public outreach to become associates of C55.

Introduction

Do you know what the acronym C55 stands for? If you're thinking of Caldwell 55, otherwise known as the Saturn Nebula, number 55 on the list of deep-sky delights popularised by the late Patrick Caldwell-Moore, that's pretty good — you're thinking astronomically. However, it's even better if C55 makes you think of the International Astronomical Union (IAU) Commission 55, Communicating Astronomy with the Public. After all, you're reading the CAP Journal, published under C55's auspices.

Remember the International Year of Astronomy 2009[1]? The IAU relied heavily on C55 to coordinate IYA2009's Cornerstone projects and many other initiatives. Perhaps you attended the CAP 2013 conference[2] in Warsaw, Poland, this past October, or you attended one of the previous CAP conferences in the US, Germany, Greece or China. By now you've guessed correctly that these meetings, too, were organised by C55 members.

Counting from its earliest incarnation, C55 celebrates its 10th anniversary in 2013. This is a critical year for the IAU, which is implementing a major reorganisation that was motivated, in part, by the recognition that there is a lot more to the profession of astronomy than just research — including, among other things, communicating research to the public. Accordingly, this seems like a good time to take stock of where C55 came from, where it is now, and where it will go in its second decade.

Ancient history

C55 has its origins in a conference titled Communicating Astronomy to the Public, held in Washington, DC in the US, in October 2003. This "CAP" meeting was a successor to a more general one, Communicating Astronomy, held in Tenerife, Spain, in February 2002. Both meetings brought together an international group of producers of astronomical information (research scientists), public information officers (communications coordinators and/or spokespersons affiliated with, for example, research institutions, funding agencies and space missions), and mediators (science journalists and popular writers; staffers from museums, planetariums, and national parks; operators of commercial websites focused on astronomy; and science educators).

Following the 2003 conference in Washington, DC, an IAU Working Group was set up to coordinate further work on three outcomes from the meeting: the Washington Charter for Communicating Astronomy with the Public (note the intentional change of preposition, from "to" to "with"), an online repository of astronomy communication resources (now the Virtual Astronomy Multimedia Project, or VAMP[3]), and a series of biennial CAP conferences.

At the 26th IAU General Assembly in Prague, Czech Republic, in August 2006, the Working Group became Commission 55, Communicating Astronomy with the Public, under Division XII, Union-Wide Activities. Members of C55 and attendees at CAP 2005 and CAP 2007 conferences (in Garching, Germany, and Athens, Greece, respectively) took many leadership roles in planning, coordinating, and executing IYA2009.

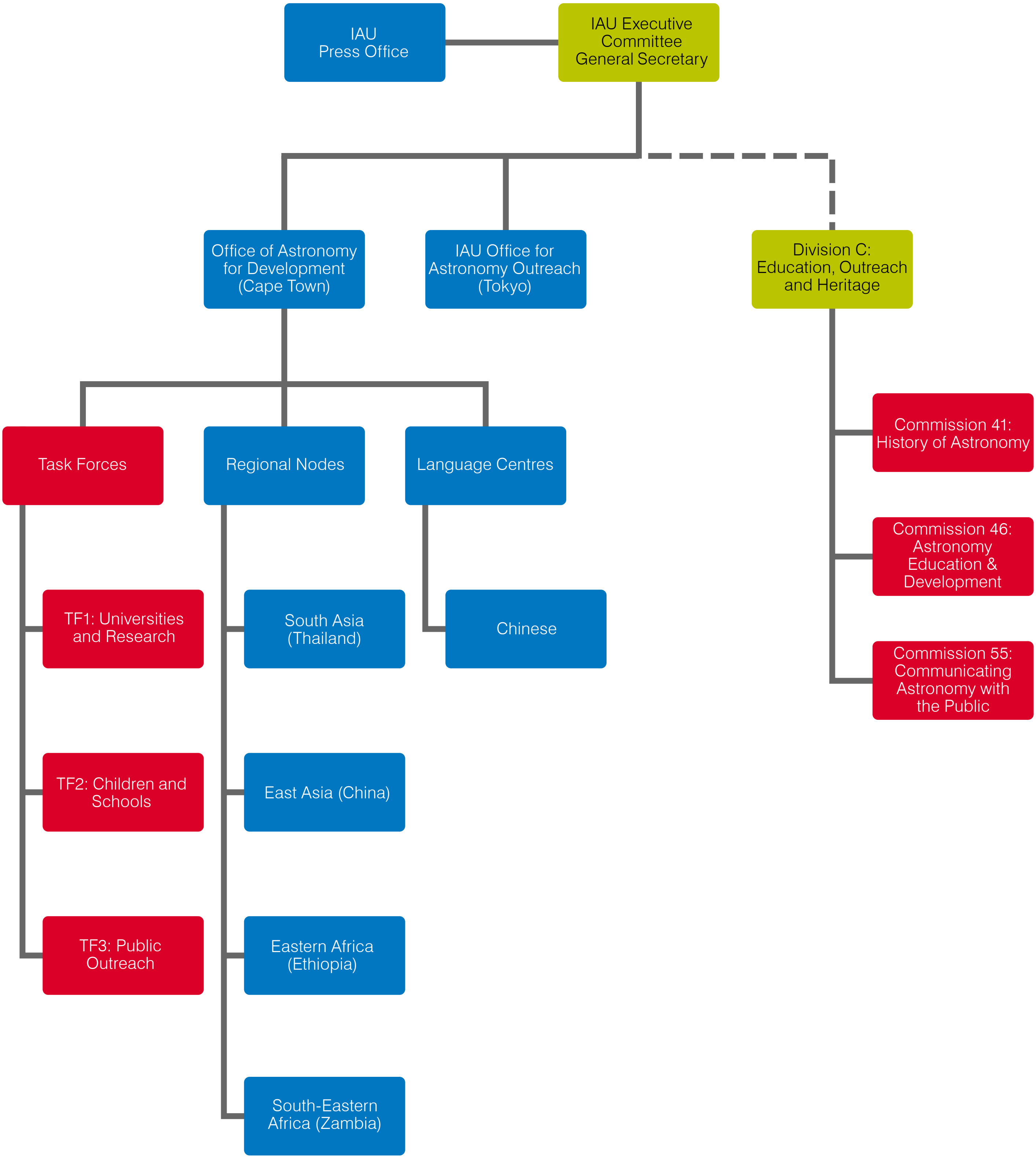

Figure 1. This organisational diagram shows how C55 fits within the IAU's new education and public outreach landscape. It is a simplified overview, which does not show the oversight committees for the OAD and OAO. The entities are connected here by dashed lines to indicate that they have some overlap in personnel and are working together to maximise their effectiveness both individually and collectively. The red colour indicate advisory/think-tank bodies, the blue operational bodies and the green governing bodies. Credit: IAU

Recent history

The enormous impact of IYA2009[4] led the IAU to recognise the importance of not only scientific research but also science outreach, to the health of the profession. To build on the success of IYA2009, the IAU in 2010 adopted a strategic plan that resulted in the establishment of two new institutions: the Office of Astronomy for Development[5] (OAD), based at the South African Astronomical Observatory in Cape Town and led by Kevin Govender, and the Office for Astronomy Outreach (OAO), established at the National Astronomical Observatory of Japan (NAOJ) in Tokyo in 2012 and led by Sarah Reed until the end of May 2013; a replacement has not yet been appointed. The OAD has initiated three task forces to "drive global activities using astronomy as a tool to stimulate development." Task Force 3, Astronomy for the Public, will "drive activities related to communicating astronomy with the public" and is led by chair Ian Robson (United Kingdom) and vice-chair Carolina Ödman-Govender (South Africa/European Union). All are active in C55 (Ian Robson was president 2006–2009).

In August 2012, to further align the structure of the IAU with its Strategic Plan and to better match the organisation of the Union with the activities of its national and individual members, attendees at the 28th IAU General Assembly in Beijing, China, approved a sweeping reorganisation that replaced the earlier twelve divisions with nine new ones. C55 now exists within a new division focused on the external relations of the IAU: Division C, Education, Outreach, and Heritage. The president of Division C is Mary Kay Hemenway (US), and the vice-president is Hakim Malasan (Indonesia).

A significant fraction of the C55 Organising Committee met in Beijing, where C55 organised Special Session 14 (SpS14[6]) titled Communicating Astronomy with the Public for Scientists. During the C55 business meeting, and again during an impromptu gathering a few days later, the members discussed changes in the IAU's organisational and programmatic structure and how these changes might affect C55. Here, we summarise key points and offer ideas about what we are calling "C55 v2.0". For background information and references, see the C55 website at http://www.communicatingastronomy.org.

IAU Commission 55 v2.0

C55 was originally organised with this rationale: "It is the responsibility of every practicing astronomer to play some role in explaining the interest and value of science to our real employers, the taxpayers of the world."

The following mission statement describes the role we envisioned for C55 in the IAU:

Figure 2. In light of recent changes within the IAU, the future of C55 was a hot topic of discussion during the business meeting at the IAU General Assembly in Beijing, China, in August 2012. Credit: IAU

Figure 3. The official group photograph from the Communicating Astronomy with the Public conference 2013 conference, which was held in Warsaw, Poland. Many members of C55 regularly attend this biennial conference. Credit: IAU

- To encourage and enable a much larger fraction of the astronomical community to take an active role in explaining what we do (and why) to our fellow citizens.
- To act as an international, impartial coordinating entity that furthers the recognition of outreach and public communication, at all levels, in astronomy.
- To encourage international collaboration on outreach and public communication.
- To endorse standards, best practices, and requirements for public communication.

The outcome of our discussions in Beijing is that we feel that C55 still has an important role to play in the IAU. Our rationale and mission remain unchanged, but in light of the new division structure and the establishment of the OAD (especially Task Force 3) and the OAO, we will need to revise our approach to conducting activities in support of that mission.

For example, the original incarnation of C55 focused on developing and implementing specific projects, especially in connection with IYA2009. C55 v2.0 could instead serve as a "think tank" that unites the global astronomy communication community and seeds initiatives to explore new ways to communicate astronomy with the public more effectively. C55 could also further the development and improvement of astronomy communication, at all levels throughout the world, through stimulating, gathering, and exchanging ideas and practices.

The IAU website lists more than 230 members of C55, but at the time of writing this article, only a dozen or so have offered their thoughts as to what C55 should strive to accomplish before the next General Assembly and by what means they should do so. Part of the reason for publishing this article is to solicit additional input. After all, C55 should pursue activities favoured by its members and, practically speaking, cannot do otherwise, as we depend heavily on our members' efforts.

C55 Officers, Organising Committee and Working Groups

In Beijing, the attending members of C55 elected the following officers:

- President: Lars Lindberg Christensen (EU, European Southern Observatory)
- Vice-President: Pedro Russo (NL/EU, Leiden University)
- Secretary: Richard Tresch Fienberg (USA, American Astronomical Society)

In addition to the officers, the following persons were elected to serve on the C55 Organising Committee:

- Kimberly Kowal Arcand (USA, Chandra X-ray Center)
- Carolina Ödman-Govender (South Africa, Vice-chair of OAD Task Force 3) *ex officio*
- Sarah Reed *ex officio*
- Ian Robson (UK, Chair of OAD Task Force 3) *ex officio*
- Kazuhiro Sekiguchi (Japan, NAOJ)
- Pete Wheeler (Australia, International Centre for Radio Astronomy Research)
- Jin Zhu (China, Beijing Planetarium)

Much of the activity of the IAU Commissions is carried out through (and by) working groups. Here is a list of current C55 Working Groups, including their chairs and missions. You can find additional information about each of these Working Groups on the C55 website at http://www.communicatingastronomy.org/workinggroups/index.html

- WG Communicating Astronomy with the Public journal (CAPj)
  Chair: Georgia Bladon (Editor-in-Chief, CAPj)
  Mission: To publish a peer-reviewed journal for astronomy communicators.
- WG Communicating Astronomy with the Public conferences
  Chair: Ian Robson
  Mission: To regularly convene producers of astronomical information, public information officers, and mediators worldwide for the interchange of ideas and practices.
- WG Washington Charter for Communicating Astronomy with the Public
  Chair: Dennis Crabtree
  Mission: To promote the importance of astronomy outreach and communication by disseminating information about the Washington Charter and to seek endorsements from funding agencies, observatory directors, department

heads and deans, and other employers of astronomers.

- WG Outreach Professionalization & Accreditation
  Chair: Rick Fienberg
  Mission: To bring a sense of professionalism and professional respect to the field of astronomy communication, to advocate for our needs as professional communicators, and to serve as a means for information sharing and networking.
- WG Public Outreach Information Management
  Chair: Pedro Russo
  Mission: To act as a facilitator for gathering the outreach information management community around a common technical framework, to optimise synergy in the community.
- WG New Media
  Chair: Pamela Gay
  Mission: To nurture a professional astronomy culture that utilises social media to disseminate science effectively.
- WG New Ways of Communicating Astronomy with the Public
  Chair: Michael West
  Mission: To facilitate the sharing of diverse and effective new ways to communicate astronomy with the public, with a focus on creative alternatives to press releases, public lectures, print and broadcast media, and other traditional methods of bringing astronomy to a wide audience. The WG will serve as a clearinghouse and network for the worldwide community of astronomy communicators in order to engage the public by thinking outside the box.

The following Working Group used to be part of Division II, Sun & Heliosphere, but was transferred to Division C and Commission 55 under the IAU's reorganisation:

- WG Communicating Heliophysics
  Chair: Carine Briand
  Mission: Promote the outreach activities of the heliophysics community and encourage increased participation in the activities of C55.

How to join C55

Toward the end of 2012, with the IAU's reorganisation in place, all current IAU members were asked to choose with which Divisions and Commissions they would like to be affiliated. At the time of writing, 237 expressed their desires to be part of C55. If, as we maintain "it is the responsibility of every practicing astronomer to play some role in explaining the interest and value of science to our real employers, the taxpayers of the world", then we have the potential to have all 10 800 IAU members join C55.

Any additional IAU members interested in joining C55 should contact the Commission's secretary by email at rick.fienberg@aas.org, indicating which C55 WG(s) you'd like to serve on. Upon approval by the relevant WG chair(s), Rick will pass your information along to the IAU Secretariat in Paris."

Here is something that may surprise and perhaps even delight you: new members of C55 do not have to be full IAU members. That is to say, they do not have to be PhD astronomers who apply to their national committee for nomination and get elected at the next triennial General Assembly. If someone has a burning interest in serving on a WG they can instead become Associate Members of the IAU via C55, or, more accurately, associates of IAU C55. This is the status of 1.11.13 but the Associate procedures are being reviewed and may be revised.

Some associates will be astronomers who, for whatever reason, have simply neglected to become IAU members; the rest will be people working in related fields and will be primarily associated with outreach and educational activities — this likely describes many readers of the *CAPjournal*.

Note that Associate Members do not have the right to vote at IAU General Assemblies, whereas full members do. Furthermore, associate status is not honorary — associates of C55 are expected to be active, for example, by volunteering to serve on one or more Working Groups.

Conclusion

We are interested in any comments, questions, suggestions, or constructive criticisms of anything in this article. Are you interested in volunteering to serve on any of our Working Groups, or do you have any recommendations for additional Working Groups? Please address your replies to the authors via email. C55 is your organisation — we cannot succeed without you!

Links

1. http://www.astronomy2009.org
2. http://www.communicatingastronomy.org/cap2013/index.html
3. http://www.virtualastronomy.org/
4. http://www.astronomy2009.org/resources/brochures/detail/iya2009_summary/
5. http://www.astro4dev.org
6. http://www.communicatingastronomy.org/meetings/iauga2012-sps14/

Biographies

Richard Tresch Fienberg, PhD, Secretary of C55, is the American Astronomical Society's Press Officer and Director of Communications. From 1986 to 2008, he served in a variety of editorial and management positions at *Sky & Telescope* magazine, including eight years as Editor-in-Chief. He is a co-creator of the Galileoscope educational telescope kit, a Cornerstone project of the International Year of Astronomy 2009. Rick is an elected Fellow of the American Association for the Advancement of Science (AAAS), and the International Astronomical Union (IAU) has named asteroid 9983 Rickfienberg in his honour.

Lars Lindberg Christensen, President of C55, is a science communication specialist, who is Head of the ESO education and Public Outreach Department (ePOD) in Munich, Germany. He is responsible for public outreach and education for the La Silla-Paranal Observatory, for ESO's part of ALMA and APEX, for the European Extremely Large Telescope, for ESA's part of the Hubble Space Telescope and for the IAU Press Office. Lars has more than 100 publications to his credit, most of them in popular science communication and its theory.

Pedro Russo, Vice-President of C55, is the international project manager for the educational programme EU Universe Awareness. He is also Co-Chair of the IAU Office of Astronomy for Development's Task Force 2, Schools and Children. Until 2012, Pedro was Editor-in-Chief of *CAPjournal*, a publication he founded. He was also formerly the global coordinator for the largest celebration of science, the International Year of Astronomy 2009. As a planetary scientist, he worked with the scientific team for the Venus Monitoring Camera on ESA's Venus Express. For more information, please visit http://home.strw.leidenuniv.nl/~russo/cv.html


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V3
a RSA Cosmos Software
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Taking Science On-air with Google+

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Keywords
Dissemination, Social Media, Public Communication, Google+

Summary

Cost has long been a deterrent when trying to stream live events to large audiences. While streaming providers like UStream have free options, they include advertising and typically limit broadcasts to those originating from a single location. In the autumn of 2011, Google premiered a new, free, video streaming tool — Hangouts on Air — as part of their Google+ social network. This platform allows up to ten different computers to stream live content to an unlimited audience, and automatically archives that content to YouTube. In this article we discuss best practices for using this technology to stream events over the internet.

Background

Google Hangouts-on-Air (HoA) went into beta-testing in the autumn of 2011. Almost immediately, teams within the astronomy community received early access to this new way of streaming video, and began to find ways to use Google HoA to communicate science to the public innovatively. The Astronomy Cast podcast, the Planetary Society, the SETI Institute, and Universe Today were among early adopters, who together defined best practices in streaming academic seminars, hosting online star parties and using hangouts to conduct interviews. They were even used to provide special coverage of live events such as the landing of *Curiosity* and the transit of Venus in 2012. Their early efforts garnered audiences often numbering in the thousands, and caught the attention of Google executives, who highlighted the virtual star parties created by Fraser Cain and Pamela Gay during the 2012 Google I/O event. These efforts and Google's support helped to facilitate the rapid growth of a vibrant astronomy community on Google+.

HoA was released for general use as part of Google+ on 7 May 2012. With this expansion of the software, it became possible for anyone (and everyone) to stream content live. This article seeks to disseminate the lessons learned by these early adopters. As with all pieces written about software undergoing active development, the reader is to be cautioned that specifics about the HoA software are liable to change without warning, causing various aspects of this article to become deprecated. In order to stay up to date, please refer to documents linked to http://cosmoquest.org/Hangouts/. Documents on that site include complete how-to guides, and guides to selecting the best equipment and software for streaming content.

Creative applications

In its simplest form, Google HoA technology can be used to stream one person, or even ten people, talking directly via a web camera to an unlimited audience. While this can be effective for some topics, this technology can be stretched to encompass much more creative uses. Video-capture software like CamTwist and ManyCam allows sections of a screen to be captured and streamed into a HoA, while audio-capture software like Soundflower allows audio to be streamed into the hangout. Using these kinds of tools, creative HoA producers can capture and share the output of cameras and other forms of sensors. For instance, it is possible to share the output of CCD cameras, and thus share live observing sessions.

Past hangouts for special events have included film screenings with accompanying panel discussions during Global Astronomy Month; providing live commentary to launches and landings that brought together individuals from multiple sites in combination with a stream from NASA TV; and even watching the transit of Venus from multiple locations with noticeably different viewing angles.

This kind of technology has the potential to enable science to be conducted in front of a live audience. With multi-site capabilities, it may be possible to measure asteroids in real time through carefully planned occultation observations. For educational purposes, it is possible to use this technology to study equinox shadows from different locations and watch eclipses pass across the planet. It is a technology that can break new ground in astronomy outreach and break down geographical restrictions. The only limitations on what you can do are those of imagination.

Conclusion

The Google+ astronomy community is hungry for content, and most community members are eager to share the content of others and to support one another's efforts. When you are ready to dive in and start using Google+, don't be afraid to reach out to existing community members and ask for an introduction or some help. A variety of existing shows, such as CosmoQuest's Learning Space and The Cosmic Ray Show, invite guests to discuss their programmes. Joining an existing show may be a great way to dip your foot in the HoA waters.

You are invited to become part of this growing online community. From discussing astrophotography to discussing open science and even the issues within professional astronomy, Google+ has an audience for your astronomy programme, no matter what it may be.

Biography

Pamela L. Gay is an astronomer, writer, and podcaster focused on using new media to engage people in science and technology. Through CosmoQuest.org, she works to engage people in both learning and doing science. Join her and CosmoQuest to map the Solar System in unprecedented detail through citizen science projects, and learn astronomy through media productions like AstronomyCast.org. Through this weekly podcast, she and co-host Fraser Cain take you on a facts-based journey through the cosmos, exploring not only what we know, but how we know it.

Figure 1. In Learning Space *Episode 22, the Mad Art Lab team discussed communicating astronomy through various artistic means and where they find inspiration. (http://youtu.be/xL5pJRQA39w)*

Google+ terminology at a glance

Circles: Organising people into lists is *passé*. With Google+, people and products are placed in circles. When you share content, you can share it to: individuals, specific circles, all circles, or publicly.
Communities: Groups of people can gather around ideas and form either open (anyone can join) or invitation-only discussions. Content posted to communities can only be seen by community members.
Hangouts: People can chat via text or video using hangouts. Text discussions can include large circles, but video chats are limited to ten people. These discussions are private, and the chat histories are stored and are searchable from gmail.
Events: Similar to Facebook events, Google+ events allow you to invite people (individuals, circles, or the public) to real world or online events. Attendees can use the event page to share photos, videos and comments.

Choosing a New Medium

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Keywords
Millennials, communication channels, marketing 3.0, outreach campaigns

Summary

The Universe fascinates us all, and yet science communicators have a difficult time bringing astronomy into the spotlight. In a society dominated by commercial brands, gadgets, entertainment and social media, we must take a different perspective on what makes a communication channel and how it can be used to foster science appreciation and engagement.

Introduction

In communicating science with the public, we strive to find the best channels through which to communicate. Throughout history, people have adopted and adapted the best means that society and technology can offer to communicate their messages. Recently, we have opened accounts on Facebook, Twitter, YouTube and other online platforms, striving to keep pace. While these tools are valuable, communicators still face the difficult problem of making science stand out: while a YouTube clip of a music video can receive more than 150 million views, a podcast episode about the discovery of 50 new worlds orbiting nearby stars may only get 30 000 views.

A new type of communication channel has the potential to greatly increase the popularity of science, if approached wisely. This new medium is called “the millennials”.

Meet the millennials

Millennials are defined as a demographic group consisting of individuals born between 1981 and 1993. To understand them better, you are encouraged to watch a ten-minute video called *All work and all play*[1], created by the Brazilian research company Box1824. The video explains the work patterns of millennials, revealing many of their characteristics, and makes a crucial contribution to the rationale of this article.

Since the millennials form a demographic group, they would conventionally be considered a target group, rather than a channel. However, there are several features that these people have that give them the potential to become a communication channel. On the one hand, they can become engaged volunteers because they love collaborative work and they are passionate about what they do. On the other hand, they can be powerful endorsers, because they are connected online and very committed to what they believe in.

Engaged volunteers who can act as endorsers have everything that is needed to become powerful brand ambassadors. As a result, such a target group has the potential to become a channel of communication on their own, as multipliers and influencers. From science communicators, information can reach millennials, and from them millions of other people. But how can we activate these brand ambassadors?

How to trigger action

The key to how to trigger millennials is found in *Marketing 3.0*: *From products to consumers to the human spirit* (Kotler et al, 2010), by Kotler, Kartajaya and Setiawan. In the book, Kotler *et al*. introduce the concept of Marketing 3.0, which brings consumer values to the core of every business. In this new model, companies strive to offer products or services that satisfy the higher needs of creativity, participation, community and culture.

The authors identify three essential strategies in moving towards Marketing 3.0: evolve from *delivering* products to *co-creating*; abandon market segmentation and focus on creating communities instead; and move from building a brand to building a character. With this in mind, and taking into account the profile of millennials, the strategy of Kotler *et al.* in transforming millennials into a communication channel can be summarised as “the three Cs”:

1. **Co-creation**
   In the process of co-creation, the communicator invites his/her audience to no longer be just a consumer of information, but to contribute to its creation. This method will appeal to millennials, as they love a work in progress, to collaborate and to contribute to the world. Kotler considers that co-creation can be achieved by opening a platform, by allowing the audience to customise it and by inviting constant feedback. It is worth noting that Facebook is already using this model.

2. **Community**
   Kotler *et al.* argue for building a community around the platforms used to communicate. In *Getting Brand Communities Right* (Fournier and Lee, 2009), Susan Fournier and Lara Lee talk about several ways in which a community can be formed: around shared values, based on interactions, or by gravitating towards a central figure. Out of these options, building communities based on many-to-many interactions is the strongest, as

is shown by the steady rise of social networks.

3. **Character**
By character, Kotler *et al.* describe a brand that manages to create consistency between its identity, image and integrity. In other words, a brand has to be authentic in everything that it does and communicates. For the astronomy "brand", we are lucky to already have high values, such as innovation and accuracy, embedded into the core of our "business".

Figure 1. *Advertisement for the Hidden Treasures competition. Credit: ESO/A. Roquette*

Rules of etiquette

In addition to taking these three steps to reach out to millennials, there are several "rules of etiquette" that have been extracted by looking at the lifestyle of millennials, as researched by Box1824 and the Pew Research Center (2010). These ten recommendations are meant to increase the chances of science communicators winning the support of millennials:

1. Give them a higher purpose because they have high aspirations.
2. Make interactions fun because they want to enjoy the ride.
3. Let them be creative because they live in a creative economy.
4. Engage them in works in progress because they live in a "beta world".
5. Let them collaborate because they believe in collective power.
6. Challenge them to learn new things because they love to discover.
7. Treat them on equal terms because they appreciate knowledge exchange.
8. Do not keep them waiting because they live by fast connections.
9. Follow up because they like to receive constant feedback.
10. Give them a truly engaging experience because this makes them committed.

Putting such actions into practice is not an easy task, especially in the field of science communication, where we are not trained to have a very pragmatic and commercial take on science. Bringing millennials on board means relinquishing total control. It requires us to be more flexible and sometimes willing to make mistakes. Investing in engaging millennials is an effort that does not bring immediate results most of the time, making it important to always see the end destination and appreciate long-term results.

Seeing the results

What follows are three examples of successful science communication initiatives that involved millennials.

Example one: Discover ESO's Hidden Treasures
ESO's Hidden Treasures competition in 2011 was an open invitation to the general public to dig into the data archives of the European Southern Observatory (ESO). The challenge was to find datasets that had not previously been released and to process them using the same techniques as the professionals. The prize was very attractive: an all-expenses-paid trip to ESO's Very Large Telescope in Chile.

The assignment was so complex that ESO thought it would only receive a handful of entries, but the results took everyone by surprise: an impressive 94 entries. The standard of many of the entries was very high, with ESO co-releasing them as (so far) ten Photo Releases and 13 Pictures of the Week (with many more waiting).

What did this competition have that it attracted so many unexpected participants to such a daunting task? It challenged people to learn new things and engaged them in a work in progress. It allowed people to be creative and it treated them on equal terms, giving them the same task as would be handed to professionals in the field. The competition invited people to co-create and it allowed them to share their work on a platform where they could form a community (Flickr).

Later, the same format was applied to the image archive for NASA/ESA Hubble Space Telescope, but this time with two competitions: one for beginners and one for more advanced participants. Hubble's Hidden Treasures had a staggering 1618 entries for beginners and 1208 entries for advanced works.

Example two: I'm a friend of Hubble
This example illustrates the millennials' openness to be part of a common project, to co-create and share what they believe in. The ESA Hubble Facebook page[2] had reached 100 000 friends, which provided an excellent opportunity to tell our friends that every time

they share a news item or photo that they are Hubble ambassadors, playing a role in the bigger picture.

To illustrate the idea, we invited people to tag themselves in a photo with the message "I'm a friend of Hubble" if they wanted to be part of a surprise mosaic picture. As a Facebook photo allows only a maximum of 50 tags, eight identical photos were added to allow more people to join the project. One hour after kick-off, the incredible demand meant that more photos had to be uploaded. By the end of the project, 1153 participants had tagged 29 pictures, expressing their interest in being part of what we create at ESA/Hubble. The 1153 profile pictures were then used to create a giant mosaic image of the Hubble Space Telescope.

Example three: The Next ESO Picture of the Week Could Be Yours
To gather different perspectives on ESO, people were invited to submit their own photos of its observatories and staff to a dedicated Flickr group[3] as candidates for a future Picture of the Week post on the ESO website. To date, the group has more than 800 photos shared and more are added every week. Dozens of Pictures of the Week have resulted, with many more in the pipeline. Through this campaign, ESO engaged in a co-creation process where images of its sites would no longer come just from our professional photographers, but from anyone visiting us.

Links

1. *All work and all play*, Box1824, 2012: http://vimeo.com/44124657
2. ESA Hubble Facebook Page: https://www.facebook.com/hubbleESA?fref=ts
3. The Next ESO Picture of the Week Could be Yours, Flickr: http://www.flickr.com/groups/youresopictures/

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Acknowledgements

The work outlined here would not have been the same without the inspiration of my talented colleagues in ESO's outreach ePOD team, especially Lars Lindberg Christensen and Mathieu Isidro.

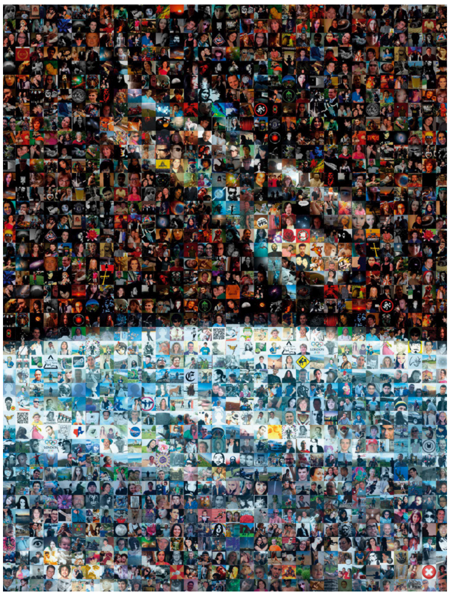

Figure 2. The mosaic picture of all the participants in "I'm a friend of Hubble". Credit: ESO

Figure 3. This image taken by John Colosimo of the Paranal Residencia in Chile is one of those selected from the Flickr Group to be featured on ESO's website as Picture of the Week. Credit: John Colosimo (colosimophotography.com)/ESO

Biography

Oana Sandu works as community coordinator for ESO's education and Public Outreach Department (ePOD). She is responsible for the promotion of outreach products or events and the social media presence of both ESO and ESA/Hubble. With a degree in Communication and Public Relations and a Master's Degree in Marketing, she worked for two years in a leading PR agency from Eastern Europe. As a volunteer, she was involved in projects such as Global Astronomy Month, the Space Generation Congress and World Space Week. She keeps a blog on astronomy communication at www.astronomycommunication.com. To get in touch with Oana you can connect on Twitter (twitter.com/oanasandu) or Facebook (facebook.com/oana.sandu).

Show Me Stars: Engaging Celebrities in Astronomy Outreach with their Twitter Followers

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Keywords
Robotic Telescopes, Social Media, Twitter, Celebrities

Summary

The Las Cumbres Observatory Global Telescope Network (LCOGT[1]) has telescopes in locations around the globe that are used daily by scientists and by the general public.

In a new LCOGT outreach initiative called *Show Me Stars*, celebrities were chosen as guest hosts for a series of Twitter-based observing events using a 2-metre robotic telescope. The celebrities made tweets throughout their one-hour online observing sessions using the hashtag "#ShowMeStars", with the aim of engaging large pools of Twitter followers in astronomy.

Introduction

Communicating science to the public is best achieved by creating a dialogue to pique interest. As a simple broadcast medium, Twitter can be very effective in helping to achieve this. Many professional scientists tweet short snippets about scientific concepts, research or even intriguing aspects of research life. Twitter allows the public to directly interact with these scientists without personal details being revealed. These interactions happen mostly in the open, allowing anyone to eavesdrop and benefit from the exchanges.

Twitter can be thought of as a lightweight, dynamic and personal system of syndicating information. The strength of Twitter is its simplicity; you have only 140 characters per tweet to share your information. This rule applies to everyone, regardless of the information shared.

Twitter broadcasts information instantly and is ideally suited for live news. It has fundamentally changed our way of viewing astronomy. Many people now hear about the latest papers, science communication happening all over the globe, new astronomy software packages and the current state of astronomy research funding via people they follow on Twitter.

Rise of the machines

It has been suggested that using Twitter as an outreach tool would be an interesting path for LCOGT (@lcogt) to explore. LCOGT has previously experimented with automated tweeting of observations as well as tweeting astrophotography images from its network as "editors' picks".

The most successful machines that tweet are the ones with their own personalities. For example, *Mars Curiosity rover* (Twitter username: @MarsCuriosity) always tweets in the first person and frequently uses colloquialisms to make its work more easily digestible (Vertesi, 2010). There are many other examples of this type of science communication using Twitter, including famous observatories such as the Herschel Space Observatory (@ESAHerschel) and the Lovell Telescope (@LovellTelescope) at Jodrell Bank (Lowe, 2008). Both of LCOGT's 2-metre flagship telescopes also tweet observations, images and news in the first person (@FaulkesNorth, @FaulkesSouth).

An alternative way of using Twitter to engage with the public is to use it to start a conversation. In a series of events called Show Me Stars, this is what LCOGT decided to do: invite the public to talk directly with the organisation's astronomers and guests. All that was needed was a high-profile event to attract the public's attention.

Guest host

An astronomy comment from the famous Irish comedian Dara Ó Briain (@daraobriain) brought LCOGT team members into a conversation with him on Twitter about robotic telescopes. Dara was interested in LCOGT, and we recognised the potential to reach his 600 000 followers on Twitter. (Dara has nearly 1.6 million followers.)

A couple of weeks later, Dara took part in a one-hour observing session using the 2-metre Las Cumbres Observatory telescope on the mountain Haleakalā, Hawaii (also called Faulkes Telescope North, @FaulkesNorth) for the first Show Me Stars event. (The observations were made robotically, with Dara at home controlling the telescope from the UK through the LCOGT web interface.) The idea was simple: to ask Dara to post tweets throughout this session to his many followers using the hashtag #ShowMeStars. And, once the observations had been completed, to post links to the astronomical images.

Twitter's hashtag feature allows anybody (whether they have a Twitter account or not) to view a conversation between users. Each tweet that includes "#ShowMeStars" can be viewed in chronological sequence, by anyone[2].

Prior to the session, Dara and LCOGT publicised the event on Twitter (again using the hashtag #ShowMeStars) to build interest, but we relied almost entirely on the serendipitous nature of Twitter for people to find out about the event while it was happening. Twitter tends to be used in a way similar to the way people listen to the radio whilst travelling, as little snatches of entertainment and news, looking at what is current and not scrolling back far into the past.

The hashtag allowed members of the public (or "Twittersphere" as it is often called) to ask questions and engage in discussions with Dara, the LCOGT team, and each other. We also created a website[3] where each image was uploaded automatically, as well as featuring all of the tweets made using the hashtag feature. It allowed us to provide extra information about what was going on at the observatory site, like an all-sky camera image and planetarium view of the sky above the telescope.

Show Me Stars has run twice since this initial event in August 2011, featuring Mark Thompson (amateur astronomer appearing on UK television, @peoplesastro) in March 2012 and Jon Culshaw (UK comedian specialising in impressions and BBC Sky at Night co-presenter, @jonculshaw) in December 2012.

Evaluation

The celebrities who have participated were already "science aware", but they were not professional scientists. Their Twitter followers have selected them because they are entertainers, not because they are known for tweeting about science (with Mark Thompson being the notable exception, although he also regularly appears on light entertainment TV programmes). This allows Show Me Stars to reach a section of the public who may not have actively sought out a science event.

For several reasons it is hard to measure the impact that an event of this kind has had on the public. For example, it is difficult to obtain responses to questionnaires unless there is personal contact with the audience, particularly on Twitter where audience attention spans are very short. The web statistics, however, provide some monitoring data. During the first event, the LCOGT web server logged over 15 000 views — the majority of which were of the tweeted images taken during the observing sessions. The web server failed 15 minutes after the start, due to the high demand, so content was moved onto the cloud, using Amazon Web Services hosting and the image sharing site TwitPic, which registered a further 35 000 hits over the course of the hour.

Over the three Show Me Stars events, the total web traffic logged on http://lcogt.net exceeded 73 000 unique visits. In all three cases, the hour immediately following each event (and sometimes considerably longer) was spent answering the public's questions about astronomy, which were submitted on Twitter. This was an important aspect of the outreach event, and we endeavoured to answer every question (Sandu, 2011).

Tips

- Be accommodating to the host. They are your ambassador and are giving their time for free.
- Find hosts who have a wide reach. Not only should they have a large number of followers, but they should not be best known for science work.
- Make sure your infrastructure is stable. A project of this nature can easily fail if the technology collapses (Lintott, 2008).
- Manage expectations. This may be a member of the public's first encounter with astronomy, and they need to be aware that we have to cope with the weather, for example.
- Try to give people some way to retain enthusiasm. Create a website where you can provide background information and useful links, and create an image archive.

Show Me More Stars?

LCOGT plans to continue Show Me Stars with new guest hosts, and some previous hosts who enjoyed the events have requested to be involved in the future. Jon Culshaw said after his session: *"Show Me Stars demonstrates the brilliant simplicity of astronomy in an online space where people don't feel intimidated or alienated. Welcome to the Universe! You'll never leave."*

Acknowledgments

Thanks to Patrick Conway, LCOGT telescope operations manager, for making sure there were no disasters during every telescope session, and to Stuart Lowe and Haley Gomez for helping to answer the deluge of questions on #ShowMeStars. Most of all, our thanks go to celebrity hosts Dara Ó Briain, Jon Culshaw and Mark Thompson, who allowed astronomy to reach a large and diverse audience.

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[1] http://lcogt.net

[2] WikiHow article on using hashtags on Twitter: www.wikihow.com/Use-Hashtags-With-Twitter

[3] http://lcogt.net/showmestars

Biography

Edward Gomez (@zemogle) is Education Director of LCOGT, based at Cardiff University, UK. His work involves creating web-based projects to enable the public to use the organisation's global telescope network. He has a PhD in stellar wind modelling, but his current research interests encompass exoplanets and Solar System object monitoring. Edward is also Co-Chair of Task Force 2 Children and Schools at the IAU's Office of Astronomy for Development.

Hertzsprung and Russell: The Minards of Astronomy

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Keywords
Infographics, Science Visualisation, Visual Communication, History of Astronomy

Abstract

This article will explore the history of flow maps, the extent of their use and how astronomy has benefited from this illustrative way of communicating ideas. Flow maps are multidimensional infographics that tell a long story in one single image. In 1812 the French civil engineer Charles Joseph Minard created a flow map that is still dubbed "the mother of all flow maps", summarising Napoleon's Russian campaign (Figure 1). Almost 100 years later, in 1910, Ejnar Hertzsprung and Henry Norris Russell created a multidimensional flow map that arguably surpasses Minard's map in ingenuity — the Hertzprung–Russell diagram. The Hertzprung–Russell diagram represents a major step towards an understanding of stellar evolution, or "the lives of stars", and is still used in astronomy today.

Introduction

Charles Joseph Minard's map of Napoleon's disastrous Russian campaign of 1812 (Figure 1) is one of the best known infographics in history. Minard was a pioneer of the use of graphics in engineering and statistics. His *Carte figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812–1813* was published in 1869 and according to infographic guru Edward Tufte it "*may well be the best statistical graphic ever drawn*" (Tufte, 1983). The graph — in fact a flow map — displays several variables in a single two-dimensional image:

1. The size of the army.
2. The geographical coordinates (latitude and longitude) of the army's route.
3. The direction in which the army was travelling, both as it advanced and retreated, showing where units split from and then later re-joined the main army.
4. The location of the army on certain dates.
5. The temperature along the path of the retreat.

According to Harris (1999), flow maps "*can be used to show movement of almost anything, including tangible things such as people, products, natural resources, weather, etc, as well as intangible things such as know-how, talent, credit of goodwill*"; that is, flow maps be used to indicate:

- What is flowing, moving or migrating etc.;
- The direction of flow and/or its source and destination;
- How much is flowing, being transferred, transported, etc;
- General information about what is flowing and how it is flowing.

A good flow map tells a long and complicated story in one single image. In this way it gives a perspective similar that of a journalist and must therefore answer the same questions as the journalist: Who? What? Where? Why? How? (Van den Broek *et al.*, 2012).

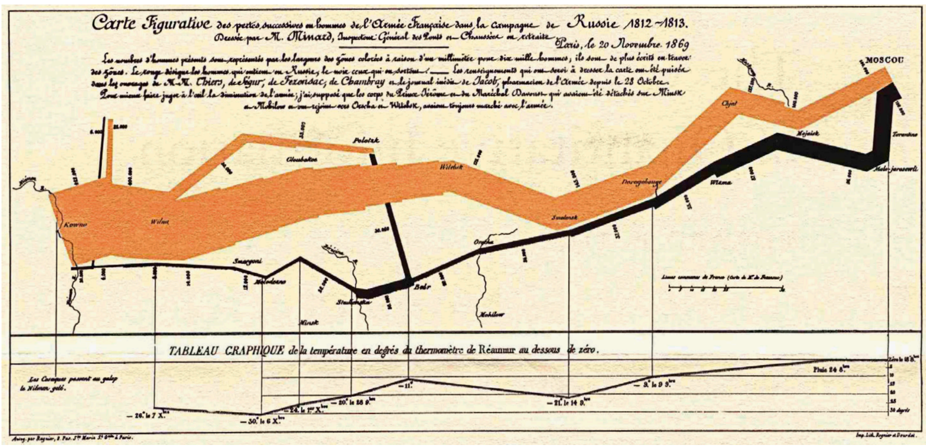

Figure 1. The hellish march of Napoleon's troops in the winter of 1812–1813, as illustrated by Minard. The weather is shown for the period of their retreat. Only a handful of the French troops made it home. Source: Wikimedia Commons.

The stellar Minard map

Astronomers have their own Minard map: the Hertzsprung–Russell diagram (HR diagram; Figure 2). This diagram was independently developed in the period 1911–1913 by the Danish astronomer Ejnar Hertzsprung and his American colleague Henry Norris Russell. Rather than a conventional map showing the locations of the stars it shows the relationship between the stars' absolute magnitudes or luminosities — on the vertical axis — versus their spectral types (or classifications) and effective temperatures — on the horizontal axis, with temperature increasing from right to left.

There are several forms of the HR diagram, but all share the same general layout: stars of greater luminosity lie toward the top of the diagram, and stars with higher surface temperature are toward the left side of the diagram. What makes the Hertzsprung–Russell diagram so brilliant is that it led astronomers to speculate that it might be used to demonstrate stellar evolution. You can see this demonstrated by the white evolutionary track of the Sun in Figure 3.

Figure 3 shows the strength of HR diagrams in illustrating stellar evolution, in this case that of the Sun. Stars can be big or small, hot or cool, young or old, low or high mass:

- On the vertical axis: on a logarithmic scale the brightness of a star (luminosity) with the current luminosity of the Sun standardised as 1.
- On the horizontal axis: from right to left on a logarithmic scale the temperature of a star.
- The temperature as a measure of the star's colour (red is "cold", blue is "hot").
- The size of a circle indicates the size of a star (from dwarfs to supergiants). The size can also be indicated by the lines in which the radius is compared with the current Solar radius.
- By adding evolutionary tracks the diagram can be used to illustrate stellar evolution. In Figure 3 the Sun's evolutionary track is indicated by the white trail.

The interactive website, Star in a Box, beautifully illustrates the evolution of stars with masses higher than, similar to, or lower than that of the Sun. Even the mass decrease during the life of a star can be followed. In Figure 4 the death of a star is mapped in detail. The image shows the evolution of Supernova 1987A, from 11 million BCE (when ape men emerged, lower left) until the outburst of the supernova in 1987. As a size comparison, the orbits of Earth as well as the planet Jupiter are indicated.

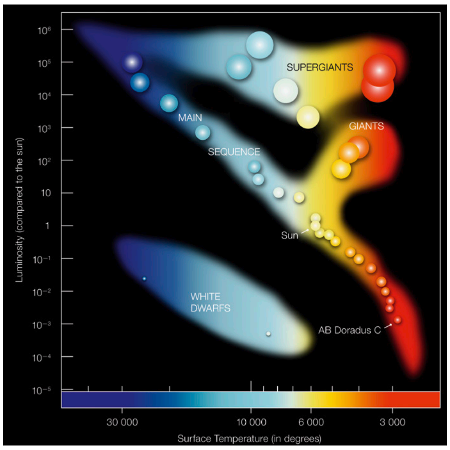

Figure 2. Hertzsprung–Russell diagram with a number of well-known stars including the Sun. Credit: ESO

Multidimensional infographics

The information contained in a chart is generally presented in two dimensions, indicated on the horizontal and the vertical axes. What makes an infographic more than a chart is the possibility of visualising information with more variables. A weather chart, for example, can be a multidimensional or multivariate infographic.

In *The Visual Display of Quantitative Information,* Edward Tufte is an advocate of multidimensional infographics (Tufte, 1983). At times he labours the point, but he is right: by making the best possible use of the different variables, we have the ability to achieve an enormous wealth of visual possibilities that viewers are likely to find pleasing, both visually and cerebrally. He calls this "visual abundance" as the antithesis to the "chart junk" that he deprecates.

Tufte regards as "chart junk" all the visual elements in maps and charts that are not necessary to understand the information being presented, or that distract the viewer from the information. There are many examples of redundant elements: heavy or black gridlines, glaring backgrounds, unhelpful text, strange fonts, images or icons in charts, shadows and unnecessary 3D simulations in line and bar charts. In fact, you could refer to anything that does not meet the criteria for why we make charts as chart junk: we make these charts to communicate numbers or events in such a way that we can compare the numbers or can follow the events by eye.

In Minard's flow map (Figure 1) time, temperature, place, direction, the number of troops, and the division of the troops are combined to form a fine and informative synthesis. Even without a caption, it is possible to read the story from the chart. You can almost feel the cold that the poorly clad soldiers endured — even the tin buttons of their uniform disintegrated as a result of the freezing temperatures.

A remarkable scatterplot

It is quite surprising that Edward Tufte never mentions Hertzsprung and Russell in one of his four highly acclaimed books on visual communication. Rudolf Kippenhahn calls their diagram without exaggeration, "*The astrophysicist's most important diagram*" (Kippenhahn, 1980). In their paper, *A Remarkable Scatterplot*, Ian Spence and Robert F. Garrison call the Hertzsprung–Russell diagram a shining example of the power of visual display (Spence & Garrison, 1993). Although the graph seems simple, it is far from trivial, and astronomers have exploited and extended this remarkable scatterplot in countless ways. The diagram has been described as "*one of the greatest*

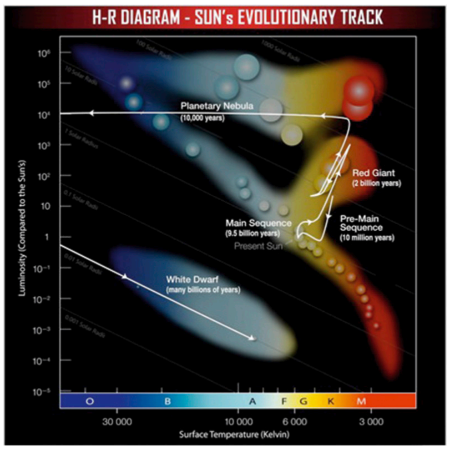

Figure 3. Hertzsprung–Russell diagram showing the evolutionary track of the Sun. Source: chandra.harvard.edu

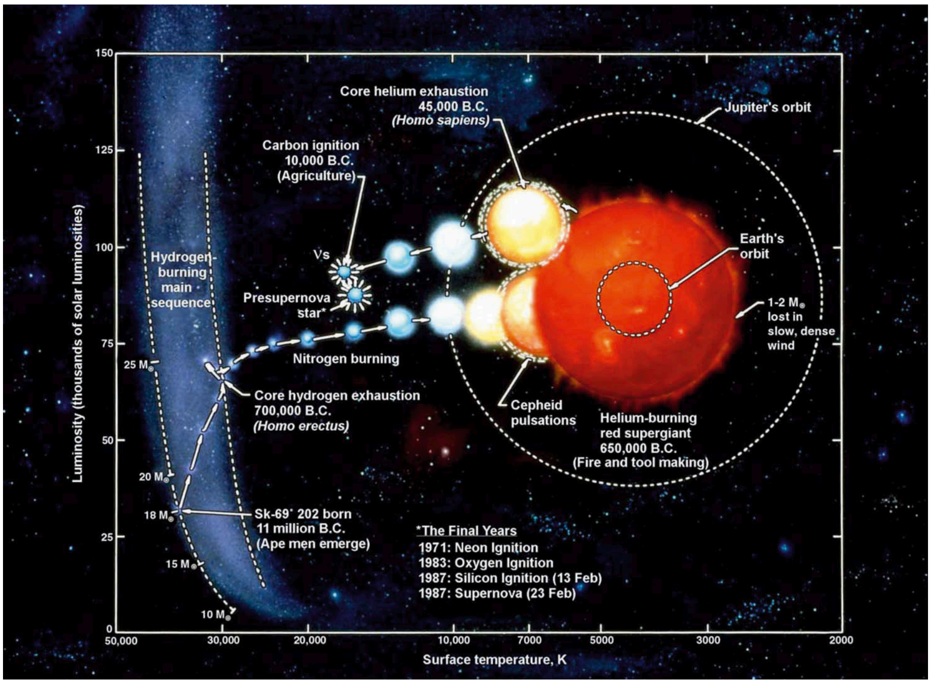

Figure 4. The Herzsprung–Russell diagram for the dying star that led to the famous Supernova 1987A explosion. Source: cococubed.asu.edu

Do's and don'ts for flow maps

Do:	Don't:
Integrate texts and images.	Create texts and images that are not integrated, leading to an insoluble jigsaw puzzle.
Let aesthetics serve content.	Let aesthetics overwhelm content.
Tell a story that can easily be followed.	Have no beginning and no end.
Be multidimensional.	Be "flat".
Answer questions like: who, what, where, in which direction, when, how, how much, how many, and why.	Leave the reader with unanswered questions.
Follow the *gestalt* laws, like the law of good continuation, the law of similarity and the law of proximity (Wikipedia, 2013).	Let it look like a Christmas tree.
Make it appropriate for the audience (contents and semiotics can be easily understood).	Make it unsuited to the audience (too simple, too complicated or with unclear semiotics).

observational syntheses in astronomy and astrophysics" (Smith & Jacobs,1973).

We even dare to go a step further in saying that the Hertzsprung–Russell diagram is a multidimensional flow map that almost surpasses Minard's multidimensional map in its ingenuity. It is a shining example of tinkering with dimensions in order to tell the most important story ever written: that of the evolution of the Sun and its fellow stars. We name Hertzsprung and Russell from now on "the Minards of astronomy".

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Biographies

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Research & Applications

What Determines the Aesthetic Appeal of Astronomical Images?

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Keywords
Astronomical Images, Astrophotography, Photography, Image Processing

Summary

In the context of images used for education and outreach purposes, this paper describes a set of parameters that are key in determining the aesthetic appeal, or beauty, of an astronomical image.

Rationale

The importance of images in the public communication of astronomy can hardly be overstated. Images are not just a means of visual communication. They can inspire awe, wonder and enthusiasm, and portray the Universe as a fascinating place worthy of exploration. Producing engaging astronomical images with aesthetic appeal or beauty is, thus, an important objective for astronomical communicators. If we can determine the parameters that influence how well an image is received by the viewer, it becomes easier (and potentially faster) to produce higher quality images and it becomes possible for a wider range of people and observatories to produce them.

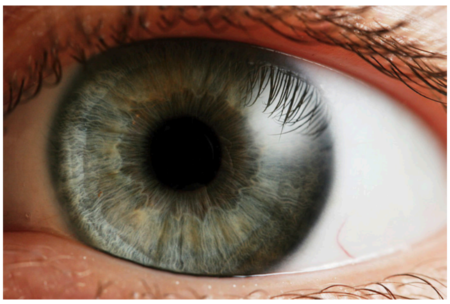

Figure 1. The human eye — one of the most complex creations of nature. Credit: Petr Novák (under Creative Commons via Wikipedia).

Introduction

The human eye (Figure 1) is one of the most complex creations of nature. With its intricate system of sensory cells — light-sensitive rods and colour-sensitive cones — we experience the world around us visually. But what determines whether we enjoy looking at an image or not? Specifically what determines whether we enjoy looking at astronomical images like the ones shown in Figure 2?

The problem of trying to describe beautiful images in a logical manner is not isolated to astronomy. One of the holy grails of computer graphics science is the algorithmic description of beauty in self-similar life forms, for example, as pioneered by Prusinkiewicz & Lindenmayer in their book *The Algorithmic Beauty of Plants* (1990). The aim here is to define the algorithmic beauty of a plant by reducing it to a series of interacting components (see Figure 3).

Based on the experience of composing almost 1000 outreach images from raw data from ESO's telescopes and the NASA/ESA Hubble Space Telescope, in this paper, we propose that six parameters, described in the sections below, are key in determining the aesthetic appeal of an astronomical colour image. These are photogenic resolution, definition (or structure or contrast), colour, composition, signal-to-noise ratio, and how well instrumental artefacts have been removed.

In this paper, we do not discuss the details of producing the final colour outreach images from multiple datasets. In essence, this involves astronomical processing on high dynamic range[1] FITS files, dynamic range compression of the processed files, and final composition and graphical processing to reach the end result of a low dynamic range, publication-ready colour image. An example of a tool for the most sensitive parts of this process is the ESA/ESO/NASA FITS Liberator software. The documentation on this program's website[2] includes a short introduction to astronomical image processing[3] and a step-by-step guide to making images[4]. Other texts on the production of astronomical colour images are Rector *et al.* (2007), Christensen (2007), and sources referenced therein.

Figure 2. *Collage of beautiful astronomical images from small and large telescopes on the ground and in space — such as the Gemini Observatory, ESO's Very Large Telescope, Chandra X-Ray Observatory, ALMA, the NASA/ESA Hubble Space Telescope, NASA's Spitzer Space Telescope, ESO's Visible and Infrared Survey Telescope for Astronomy (VISTA) and ESO's VLT Survey Telescope (VST). These images serve as inspiration for many and are a stark reminder that our existence here on Earth is just a small cross-section of the many different environments that exist in the Universe.*

1. Photogenic resolution

Early marketing for consumer digital cameras often concentrated on the total number of pixels in the detector, and hence in the resultant photographs. A larger number of "megapixels" is often considered to be an indicator of a better camera. However, in real life there are other limiting technical factors such as the quality of the camera's optics. This is also true in the case of astronomical observations: a key factor is the angular resolution of the observation, which, for a diffraction-limited single-aperture telescope, is improved by increasing the diameter of the telescope's primary mirror, but not by increasing the number of pixels in the detector. And since astronomers use big "zoom lenses", another limiting factor for astronomical images at visible wavelengths is the atmospheric blurring of images. A phenomenon that manifests itself in the twinkling of stars at night due to atmospheric scattering or the flickering of distant objects in the daytime due to heat haze.

Figure 3. *Artificial trees generated by biological modelling and visualisation algorithms embedded in the TreeSketch iPad software. Credit: Steven Longay*

So, a large number of pixels alone is not a guarantee of sharpness — the photo may simply be oversampled, i.e., have much more finely spaced pixels than are needed to display the smallest features that are actually resolved. A many-megapixel image of a blurred object is still blurred. Furthermore, an image with excellent sharpness may not be visually appealing if a narrow field of view means that there are not many features in the picture. Therefore, to be more precise, the real factor that limits the aesthetics of an image is the photogenic resolution, r_{photo} — the number of effective resolution elements (the size of the finest feature that can be resolved) across the field of view (FOV):

$$r_{\text{photo}} = \text{FOV}/\theta_{\text{effective}},$$

where $\theta_{effective}$ is the effective angular resolution. For an astronomical image, one can view this in simple terms as the greatest number of stars (considered to be point sources) that can fit side by side across the field of view. In the ideal case, where the optics are perfect and there is no atmospheric distortion, the diffraction-limited angular resolution $\theta_{diffraction}$ for a single-aperture telescope is approximated by:

$$\theta_{diffraction} = \lambda/D,$$

where D is the diameter of the primary mirror or lens and λ is the wavelength observed. As mentioned, however, the real resolution — at visible wavelengths at least — is most often limited by the atmospheric quality, or seeing. In reality, this usually limits the effective resolution of any telescope to that achieved by a 30-centimetre telescope, such as those used by advanced amateur astronomers.

In our experience, for an image to look impressive, the photogenic resolution should be greater than of order 1000. For instance, the MPG/ESO 2.2-metre telescope's Wide Field Imager (2.2-metre/WFI) can produce individual images with $r_{photo} > 2000$, as can the Wide Field Channel of Hubble's Advanced Camera for Surveys (HST/ACS-WFC). Images with rphoto << 1000 will inevitably look blurred. If an individual observation has a low photogenic resolution (due to low

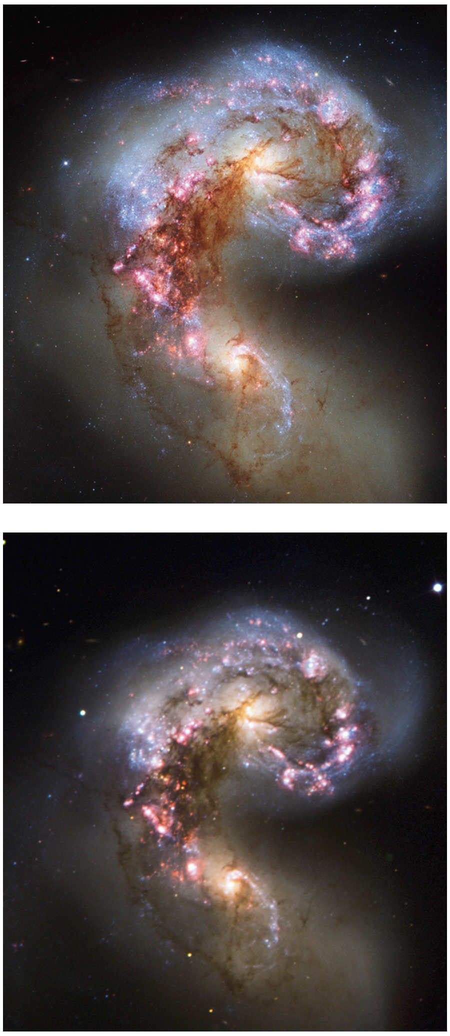

Figure 4. Comparing the effective angular resolution of Hubble (top) with that of the VLT's ground-based 8-metre telescope (bottom). As Hubble's optics are very good, and there is no atmosphere disturbing the resolution of the image, their picture is limited only by the wave nature of light itself and the diameter of the primary mirror. The VLT image suffers from atmospheric distortion and is oversampled (has fewer effective resolution elements). Credit: NASA & ESA/Hubble, European Southern Observatory

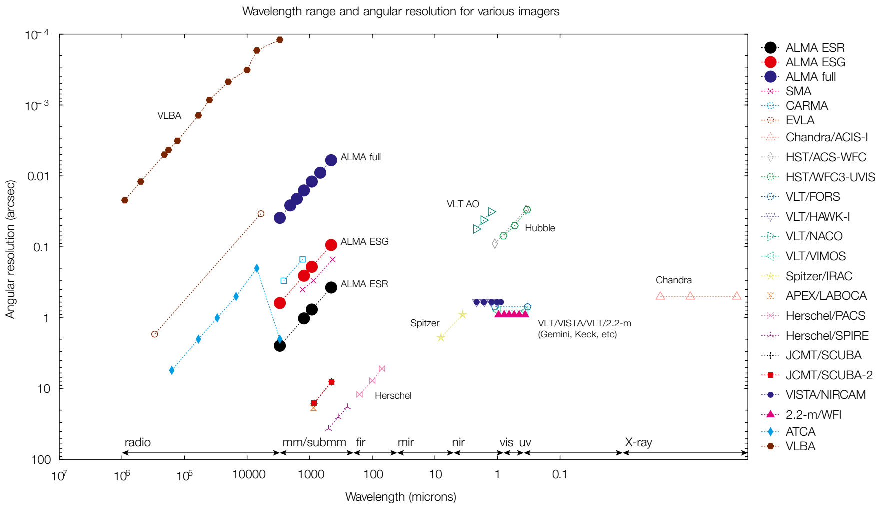

Figure 5. Wavelength range and effective angular resolution for a small selection of different astronomical telescopes and imagers.

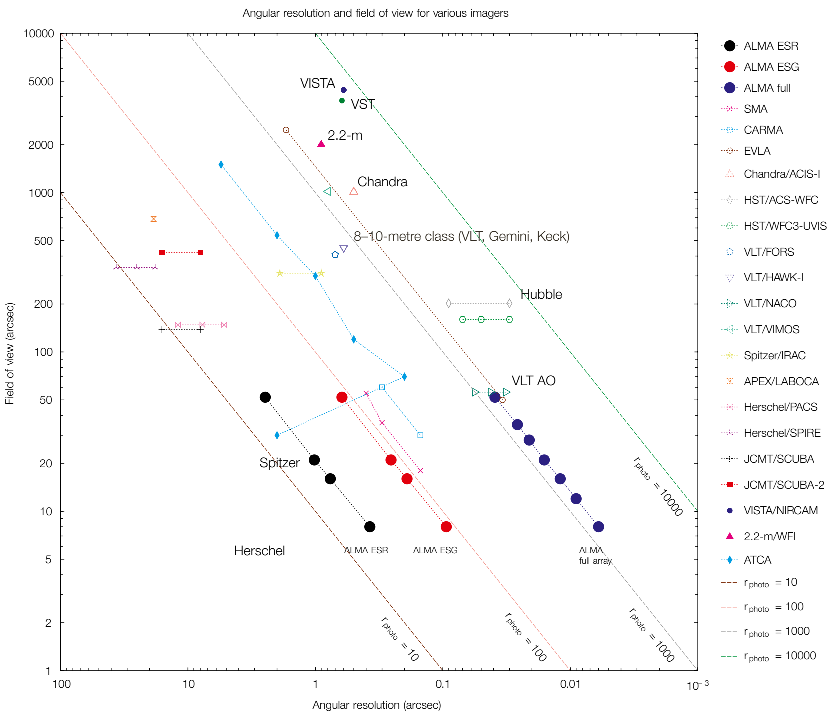

Figure 6. Effective angular resolution plotted against the field of view for a selection of different imagers.

angular resolution, narrow field of view, or both), a mosaic of multiple observations can improve the resulting photogenic resolution. Advanced hobby astronomers often do this and achieve very impressive images — sometimes even outperforming images from professional telescopes.

If we plot the effective angular resolution, $\theta_{effective}$, for different astronomical telescopes and imagers against the wavelength region they work in, we get Figure 5 (Pierce-Price *et al.*, 2011). The optical telescopes all cluster in the same region because the atmospheric seeing — without the use of adaptive optics — restricts their effective angular resolution to around 0.5 arcseconds. To the left of the visible wavelength area is the longer-wavelength radio regime. In particular, the submillimetre part of the spectrum is of great interest at present, as the Atacama Large Millimeter/submillimeter Array (ALMA) has recently begun operating and is revolutionising observations in this wavelength range[6]. ALMA's initial specifications for first observations with a partial array are plotted (ALMA ES, for Early Science) in addition to the resolution achievable with the full array (ALMA full). An interesting comparison is also apparent between Hubble and ground-based 8-metre-class telescopes without adaptive optics (AO). Also plotted is the performance of 8-metre-class telescopes applying AO, such as the VLT, Gemini or Keck: they are very similar to Hubble in terms of resolution, but work in slightly different wavelength regimes (as AO works in the near-infrared).

Although the figure is interesting in its own right, it is more insightful for our purposes to examine the photogenic resolution by plotting the field of view against the effective angular resolution (Figure 6; Pierce-Price *et al.,* 2011). In this plot, lines of constant photogenic resolution form diagonal lines, and examples are shown from r_{photo} = 10 (lower left) to 10 000 (upper right).

Few, or possibly none, of the current imagers deliver a native photogenic resolution of more than 10 000, but this resolution is likely to be achieved with new giga-imagers such as the Pan-STARRS camera (5 gigapixels). It is also interesting that the domain of photogenic resolution between 1000 and 10 000, which, for many years, has been dominated by Hubble, now has several players, such as Chandra, the MPG/ESO 2.2-metre telescope, the Canada France Hawaii Telescope (CFHT), ESO's VISTA and VST telescopes and soon, to some degree, ALMA in its full configuration.

2. Definition

Even if an image has a very high photogenic resolution, its content is still the most important factor. The frame of the image needs to be filled with an object of interesting structure, such as a galaxy or a nebula. And definition or contrast in the interesting parts of that object is our second key parameter in the aesthetic appeal of an astronomical image.

The definition is fixed in the representation of the dynamic range, defined as the ratio between the maximum and minimum values of a physical measurement[7]. The definition is adjusted during image processing, where the original high dynamic range FITS data[8] are mapped to the (often more limited) range of pixel values that can be shown in the outreach image. This is done with the help of a stretch function. The choice of stretch function to reach a good contrast depends greatly on the difference in brightness between the different interesting parts of the images. Typically, a galaxy will need a highly non-linear stretch to reach a good contrast, because of the high dynamic range between the bright centre and the fainter outer areas. However, a nebula will need less stretch (or even a linear stretch) because of the lower dynamic range between the nebulous components and the other interesting parts of the image. Without adjusting the dynamic range, most astronomical images would just show some saturated highlights in a very dark image (see Figure 8), similar to taking a portrait against a background sunset.

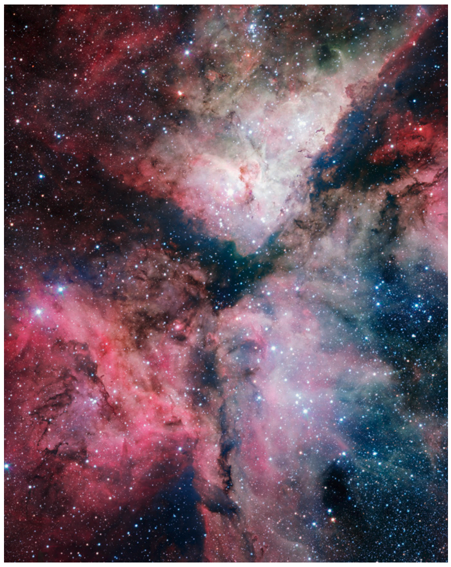

Figure 7. *Carina Nebula taken with the VST, which delivers a Hubble-level photogenic resolution of 5500. Like those from Hubble, the VST image appears sharp and rich in information, with a high aesthetic appeal. Credit: ESO*

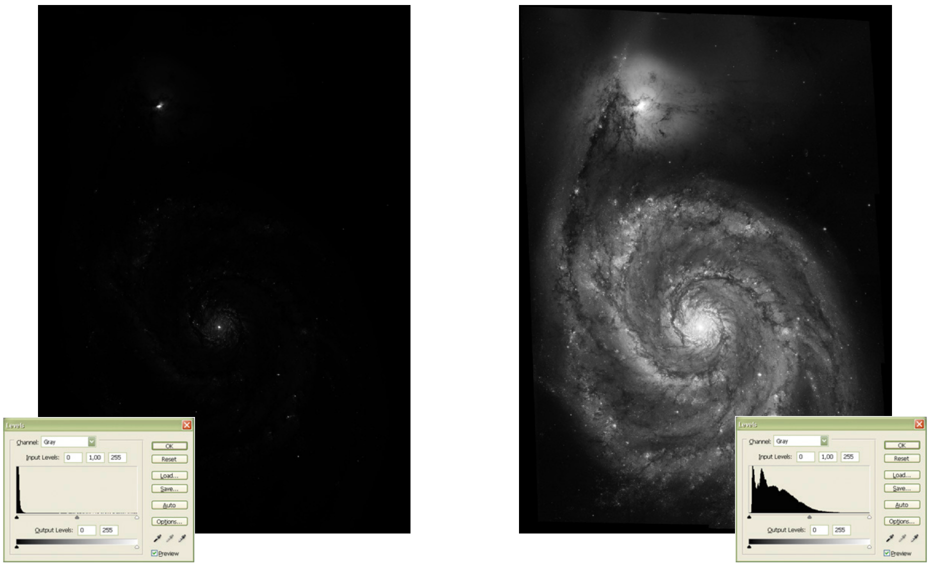

Figure 8. *Difference between a linear and a stretched representation of a high dynamic range astronomical observation of Messier 51. Credit: ESO/ESA/NASA Photoshop FITS Liberator/Davide De Martin*

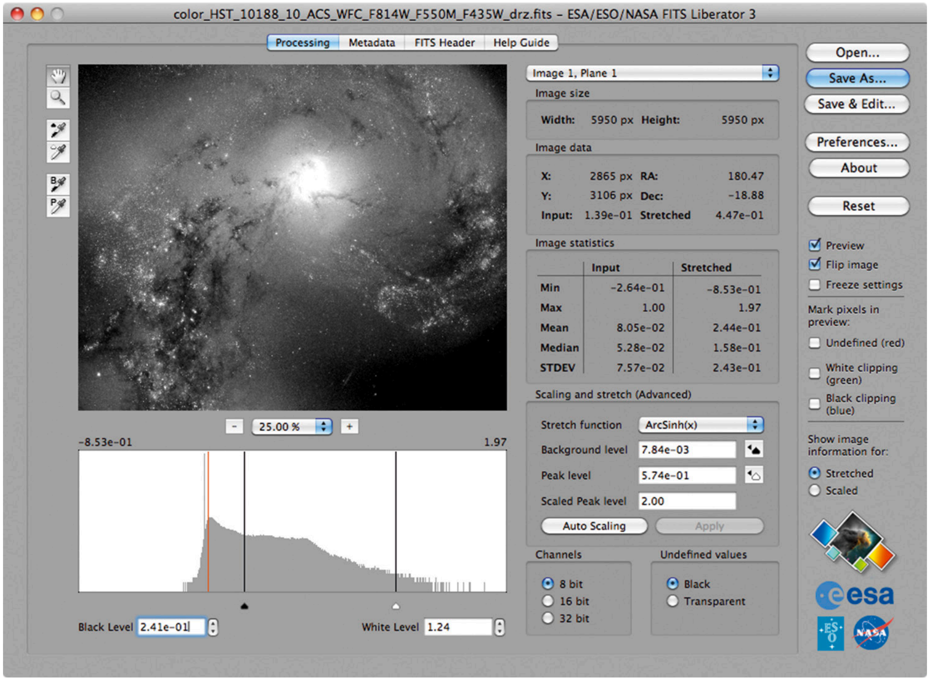

Figure 9. *Adjusting a stretch function. Here, an ArcSinH function is chosen as this often fits well with galaxies with large differences in brightness between the centre and outer parts. Credit: ESO/ESA/NASA Photoshop FITS Liberator*

Furthermore, the choice of filter — narrowband *vs.* broadband — can influence the definition. Observations using narrowband filters are designed to show individual astrophysical processes and most often produce a well-defined and dramatic image.

When adjusting the stretch function (see Figure 9), the aim is to achieve a good balance of midtones: to get a nice contrast without excessively saturating the highlights (the white point) or truncating the darkest parts of the image (Figure 10).

The resulting definition from choosing different stretch functions can be very different, as illustrated in Figure 11.

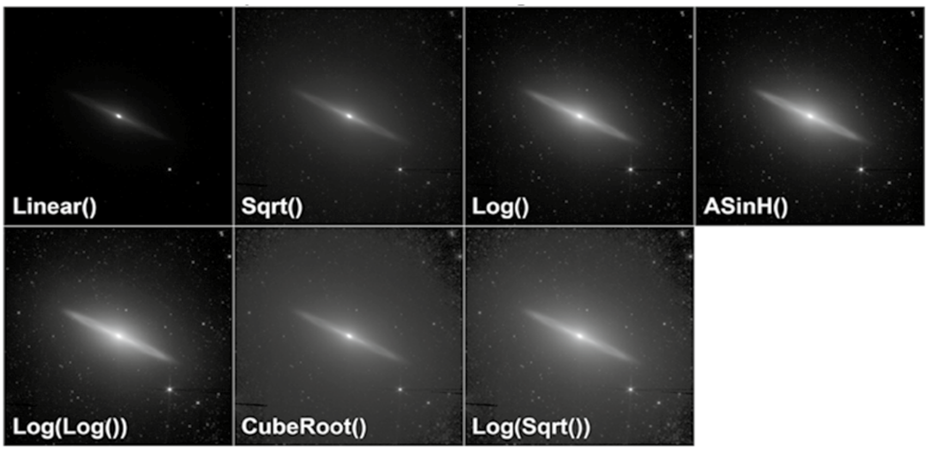

Figure 11. *Different stretch functions give a very different impression of the Sombrero Galaxy as observed with the Spitzer Space Telescope. Credit: Robert Hurt (Spitzer Science Center)*

Figure 10. *Striking the contrast balance. Choosing the right stretch function for a good contrast balance is one of the toughest decisions when processing images. The aim is to achieve a good balance of mid-tones, and nice white and black points. The right choice here would probably be in the middle, between low contrast (left) and high contrast (right; in the analogue photographic world, contrast is chosen by picking paper of different "hardness"). Credit: Robert Hurt (Spitzer Science Center)*

3. Colour

Images of astronomical objects are usually taken with electronic detectors such as charge-coupled devices (CCDs) or infrared arrays. Similar detectors are found in digital cameras. Telescope images are nearly always greyscale, but are, nevertheless, encoded with colour information that comes either from taking each exposure through a particular filter or from using different detectors, each having different wavelength (colour) sensitivity. Colour outreach images are composited by taking the individual greyscale filter exposures, colourising them and "stacking" them together (see, for example, Figure 12). In principle, three 16-bit greyscale images can create a colour image with 281 474 976 710 656 colours (65 565^3).

In general, the more separated the wavelengths of the chosen filters are, the more colourful and appealing the resulting composite will be. Also, the better the filter set is at sampling the observed wavelength range, the more colourful the result will be. In the visible range, for example, the use of BVR filters ensures a good coverage of the visible spectrum (blue to red), samples a typical (e.g., G dwarf) stellar blackbody well (on both sides of the peak), and produces an image with a wide separation of colours (also known as colour gamut).

The chosen wavelength range will have a characteristic temperature, corresponding to the blackbody peaking in that range. In the visible, this is a few thousand Kelvin; in the thermal infrared, hundreds to tens of Kelvin; and a few to a few tens of Kelvin in the submillimetre. For thermal emission processes, picking a set of filters which cover the peak of the blackbody spectrum, and bracket it, often leads to the best result.

Very interesting optical images result from the combination of at least three continuum bands (e.g., BVR to sample the stellar blackbody and reproduce stars with a good white balance) and at least one additional narrowband image (to sample emission from individual atomic transitions).

Although it is, in principle, possible to assign any colour to any exposure, in our images we rarely deviate from assigning colours in the chromatic order that they have been observed in. In simple terms, for an infrared image, the "reddest" exposure should be red, and the "bluest" blue. In the case of narrowband observations, so-called "enhanced colour images" are seen on rare occasions when the narrowband image stacked on a broadband image is assigned an arbitrary colour.

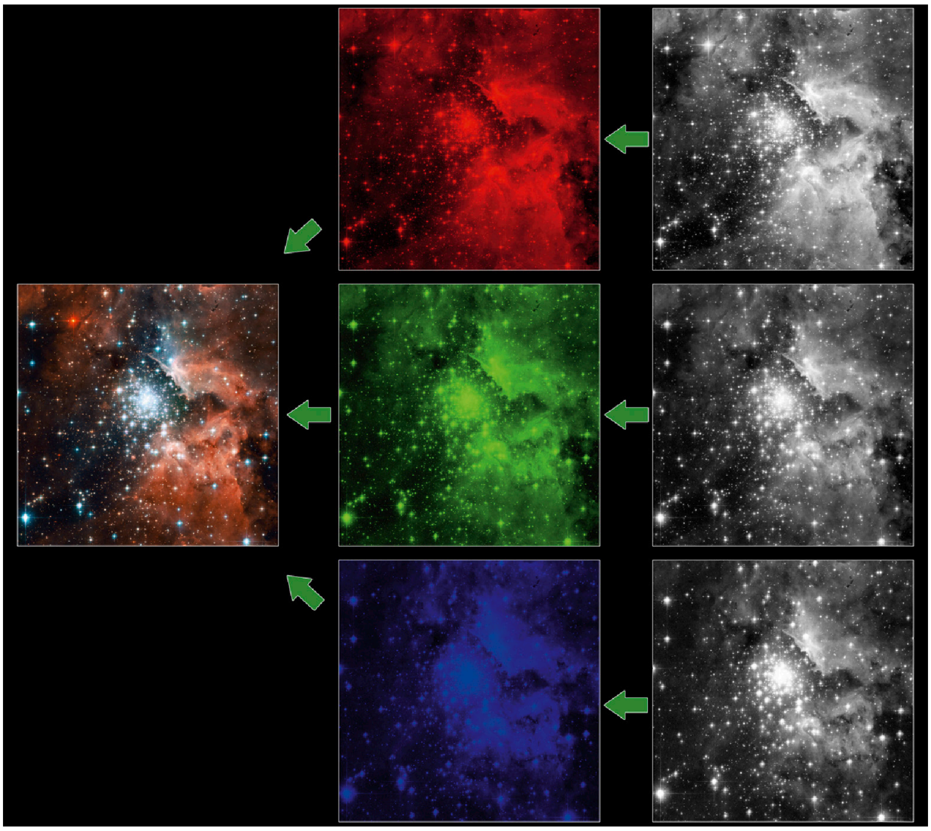

Figure 12. *Colour images are composited by taking individual greyscale filter exposures, colourising them and "stacking" them together as if "sandwiching" film slides together. Credit: The NASA/ESA Hubble Space Telescope/Davide De Martin*

4. Composition

To obtain a pleasing composition and not waste photogenic resolution, the object should in general fill as much of the field of view as possible. The outreach image composition is most often decided in the very last phase when the colour composite is done, just before the image is ready for publication. Since most producers of astronomical images at observatories produce the "raw material" for others to use — journalists, text book writers and movie directors — one can argue that the images should be cropped wider rather than tighter, leaving the final composition to the user's preference. Speaking against this, however, many of these recipients do not have the means to process or even crop large astronomical images efficiently. Moreover, the resolution of images published today needs to be compatible with both large and very small devices. This suggests a need to deliver a final "perfect composition".

On the other hand, the proliferation of very large images today also gives graphic designers the opportunity to be creative, and crop very limited portions of an image for certain applications (Figure 13).

Figure 13. *Creative crop (right) of a large image (left). Both crops are aesthetically pleasing and show widely different content, owing to the large photogenic resolution in the image and the resulting richness of detail. Credit: ESO*

5. Signal-to-noise ratio

To get a good signal-to-noise ratio or "depth" of an image, the exposure time must be sufficient to secure a fairly noise-free representation even in the fainter regions of the object. This usually implies fairly long exposure times, which can be difficult to achieve with large telescopes (see, for example, Figure 14). Sophisticated noise reduction algorithms such as those found in software packages like Photoshop, or in plug-ins like Topaz DeNoise, Noise Ninja or Neat Image, can be applied to mitigate the noise during the last stages of graphical processing.

Figure 14. Short-exposure image with the Very Large Telescope showing a limited signal-to-noise ratio and noise that can distract from the aesthetic viewing pleasure. Credit: ESO

6. Removal of artefacts

Experience shows that one of the things that disturbs the viewing pleasure for members of the public is residual artefacts from the sensor or the telescope. The rule of thumb is simple: while scientists may be able to concentrate only on the parts of the data that are relevant to them, ignoring artefacts, members of the public will focus on anything of non-cosmic. All artefacts must be removed in order to not distract the eye, disturb the aesthetic appeal, or to waste the audience's finite attention span on aspects of the image that are not part of the scientific outreach message. This is something that ESO and ESA/Hubble expend significant manpower on, often to the order of one or two hundred hours of manual cleaning work for a large image. The number of frames must be sufficient to filter cosmic rays and detector blemishes, and to cover inter-chip gaps during astronomical processing.

Conclusion

Turning raw data into aesthetic pictures takes real effort: planning, astronomical

Figure 15. Example of an uncleaned image early in the production (left) and the final clean image (right). Credit: ESO

insight, technical insight, graphical insight and dedication. It is proposed here that at least six main parameters contribute to an astronomical picture's aesthetic appeal: high photogenic resolution, good definition, appealing colour, interesting composition, high signal-to-noise ratio and good removal of artefacts.

In the ideal case, we have a great image when all six parameters are fulfilled — a "Hubble-class image". It is, however, still possible to produce great images with less, but it gets more difficult and compromises have to be made. Some examples of such compromises are:

1. **Photogenic resolution:** If the necessary photogenic resolution is not available (due to atmospheric or weather limitations, a small CCD chip, or use of a small telescope), we can mosaic different exposures together[9]. In some cases, for bright objects, we can also apply so-called lucky imaging, and select just those short exposures where the atmosphere was most stable, and then combine, or stack, the images into an image with super-seeing. Low resolution datasets can also in some cases be combined with higher resolution datasets in different wavebands for a perceived higher resolution.
2. **Definition:** Good definition can be achieved by spending more time tuning the dynamic range compression.
3. **Colour:** If three different exposures through well-separated colour filters are not available, we can create a pseudo-green image by averaging the red and blue exposures, or decide to accept an image that has a smaller range of colours (gamut).
4. **Composition:** Good composition usually comes at the compromise of cropping away parts of a perfectly good image, but it is usually worth it if the aim is to optimise the viewing pleasure of the "innocent" eye that does not know that more data were available.
5. **Signal-to-noise ratio:** For professional telescopes, it is often necessary to use data that comes from rather shallow exposures as the observing time is always in high demand. The compromise can be to accept a noisier image, and then apply advanced noise reduction algorithms. For amateur telescopes, the option is often to spend nights of observing time until the optimal signal-to-noise ratio has been achieved. Impressively deep images can be achieved in this way.
6. **Removal of artefacts:** If a dataset is significantly "dirty", even after the appropriate astronomical processing, it is mostly a simple matter of spending the necessary hours of work on cleaning the image manually. There seems to be no silver bullet, other than endurance.

If you know how to control these six parameters well, know your telescope and data, and are prepared to spend the necessary time on finding your image's niche within this six-parameter space and on finding workarounds and compromises for datasets that are not optimal, we claim that any telescope/imager can deliver aesthetically pleasing astronomical images.

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Notes

1 High Dynamic Range (HDR), see for instance Wikipedia: http://en.wikipedia.org/wiki/High_dynamic_range_imaging

2 http://www.spacetelescope.org/projects/fits_liberator/

3 http://www.spacetelescope.org/projects/fits_liberator/improc/

4 http://www.spacetelescope.org/projects/fits_liberator/stepbystep/

5 The attentive reader will correctly note that Hubble's main mirror is, strictly speaking, not perfect because of its incorrect polishing, but a correction to near-perfectness is achieved by its instruments.

6 See for example ALMA results at: http://www.eso.org/public/news/archive/search/?adv=&facility=36

7 For comparison, the dynamic range of the human eye without any pupillary adjustment is 1000–10 000. In deep astronomical images the dynamic ranges can reach 10 000. Typical computer screens or printers can only show a dynamic range of 700–1000.

8 See http://en.wikipedia.org/wiki/High_dynamic_range_imaging

9 In a quite extreme case, the VISTA telescope in 2012 delivered a mosaic image of 108 200 × 81 500 pixels with a photogenic resolution of ~ 40 000

10 A 120-hour image of Centaurus A can be seen here: http://goo.gl/WOfyz

Biographies

Lars Lindberg Christensen, President of C55, is a science communication specialist, who is Head of the ESO education and Public Outreach Department (ePOD) in Munich, Germany. He is responsible for public outreach and education for the La Silla-Paranal Observatory, for ESO's part of ALMA and APEX, for the European Extremely Large Telescope, for ESA's part of the Hubble Space Telescope and for the IAU Press Office. Lars has more than 100 publications to his credit, most of them in popular science communication and its theory.

Olivier Hainaut is an astronomer specialising in the study of icy minor bodies in the Solar System, such as comets and trans-neptunian objects. While tracking the faintest and most distant ones, he developed techniques that push the largest telescopes to their limits. For the last few years, Olivier has coordinated ESO's ePOD efforts to produce outreach images using ESO's telescopes.

Douglas Pierce-Price began his career as an astronomer, studying the Galactic Centre, before developing an interest in science communication and outreach. After working as Science Outreach Specialist at the Joint Astronomy Centre in Hawaii he joined ESO in Munich, Germany as Education Officer, before becoming ESO's Public Information Officer for the submillimetre-wavelength telescopes ALMA and APEX, and Deputy Head of the education and Public Outreach Department (ePOD). In 2013, he moved from ePOD to lead the newly created Internal Communication Office at ESO.

The Language of Visualisation

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Keywords:
Visualisation; Visual Language

Summary

There is a visual language present in all images and this article explores the meaning of these languages, their importance, and what it means for the visualisation of science. Do we, as science communicators, confuse and confound our audiences by assuming the visual vernacular of the scientist or isolate our scientific audience by ignoring it?

The visual vernacular

In my previous gig at the American Museum of Natural History in New York City, I had the enviable title of Science Visualiser. When I first learned this, well into the application process, I imagined that my job involving sitting in an office lined with tapestries, incense burning, staring off into space… And visualising science.

A Google image search in support of that joke turned up something akin to Figure 1 (reproduced here from scratch to avoid copyright infringement). But as I reflected on the image of Ganesha floating in front of the Pleiades, I realised that it conveys a deeper message. There's a visual vocabulary at work, injecting the image with meaning for those familiar with Hindu culture, but escaping those who don't have a grounding in that iconography. I happen to know just enough to recognise that the position of the god's hands and trunk, the shrew at his feet and the cobra around his middle all have meanings, resonances, and metaphorical implications. But that understanding only scratches the surface, and the average Western viewer (myself included) basically just sees "new-age Hindu something or other".

Figure 1. The god Ganesha floats in front of a celestial backdrop. Ganesha image courtesy of Michael Van Vleet, Pleiades image courtesy NASA, ESA, and AURA/Caltech.

Taken together, these elements constitute a visual language that conveys meaning. Those elements may call on religious or cultural iconography, but fundamentally, they rely on learned structures. For example, comics (a subset of the broader category of "sequential art") require the viewer to understand how images are arranged, in sequence, to convey a sense of time and narrative structure, and a host of other visual elements — word balloons, motion lines — spell out additional details (Eisner, 1990; McCloud, 1993). Most of our audiences will find the core elements of a comic's visual language quite familiar.

The visual language in science

In maths and science we have a well-developed visual language that can cause confusion for many people.

For example, the Cartesian plane has become second nature to most scientists and science communicators. We find the abscissa and ordinate so familiar that we forget how easily they can confound the uninitiated. Even if one explicitly defines the meaning of the two axes, the message might remain unclear: interpreting values in the *xy*-plane doesn't come naturally to everybody.

Scientists also have an unfortunate fondness for the rainbow colour map. Unfortunate because the rainbow palette assumes an ordering of colour that makes scientific sense, following the spectrum from red to violet, but not perceptual sense: humans don't innately perceive colour as ordered. But adding insult to injury, the luminance of the rainbow palette shifts from dark (blue) to bright (yellow) to dark (red), so using the rainbow scheme fights against an innate perception of brightness.

Having expressed my misgivings, I'll note that Figure 2 shows Cartesian mapping and a rainbow colour map used to relatively good effect. Accompanying a Hubble press release from 1997, an image of the galaxy M84 appears next to a visualisation of the STIS spectrum of its interior — a region barely discernable, outlined in the interior of M84 (Hubblesite, 1997). The spectrum uses redundant representation for spectral shift — both colour and position along the horizontal — and the original image caption explains it in detail. Here, the rainbow has a specific, colour-related meaning — the red- or blueshift of the light from the galaxy — so the visual language supports the science content. And even the rainbow's luminance works in this image's favour, since the darker blues and reds express deviation from the bright greens and yellows.

Contrast this relatively clear use of rainbow colour with its completely counterintuitive use in Figure 3, showing a subset of the Planck cosmic microwave background (CMB) data release from this spring. (Admittedly, Planck simply modified the colour scheme of its predecessor the Wilkinson Microwave Anisotropy Probe

[WMAP], but didn't address its core problems). Incredibly, the image caption and press release[1] don't even describe the chosen colour representation, so readers aren't informed that the blue regions correspond to cooler (denser) parts of the CMB, while red maps to warmer (less dense) regions. This visual assumes too much: it assumes that we can "read" the rainbow representation, and it even assumes we know what the colours represent! Furthermore, the luminance issue makes the middling values of the CMB temperature the most visually striking portion of the image.

When we rely incautiously on such mystifying visual language, we risk misleading our audiences — or simply encouraging them to tune out. In the same way that I look at Ganesha and see a nonspecific reference to Hinduism, many people will look at something like the Planck image and see "science something or other".

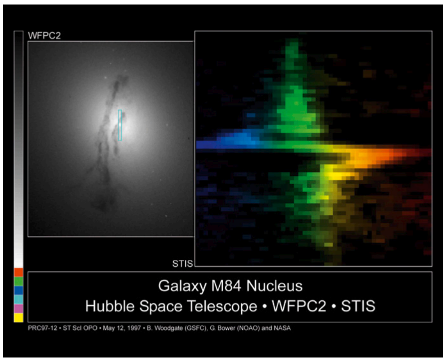

Figure 2. *A reasonable application of the rainbow palette to illustrate gas motions in M84. Courtesy Gary Bower, Richard Green (NOAO), the STIS Instrument Definition Team, and NASA.*

Using visualisation effectively

Fundamentally, visualisations use data to communicate. You may be communicating to yourself — basically, data analysis — or to a peer group or general audience. The differences lie in the visual language you choose to employ: you employ visual elements that your audience will find accessible. With an expert audience, you can make use of shorthand, but for novices, you need to tread more cautiously.

As with all means of communication, all visuals incorporate an element of subjectivity; there is no objective image. Even the most objective graph you can imagine requires making specific choices — the choice of axes, range of data, linear versus logarithmic scale — that reflect human intention.

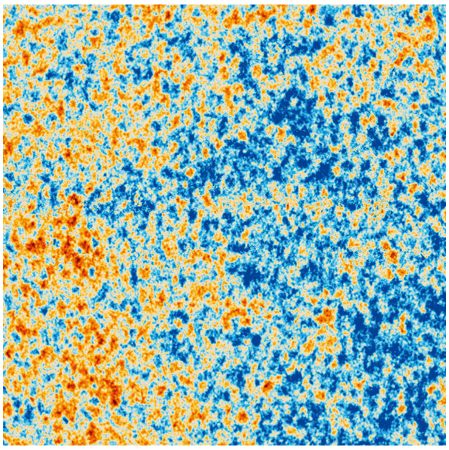

Figure 3. *The Planck cosmic microwave background image makes use of a deceptive and counterproductive rainbow colour scheme. Courtesy ESA and the Planck Collaboration.*

In his "Designing Data Visualizations" workshop at the American Astronomical Society meeting this past January, Noah Iliinsky articulated a similar perspective. He describes two types of visualisation process: "for exploration, when you don't (yet) have a story to tell" versus "for explanation, when you *do* have a story to tell". As an example of the former, Iliinsky offered up the *New York Times* "Jobless Rate for People Like You" (New York Times, 2009) and recommended the interactive software Tableau[2], and within the astronomical community, this category relates most directly to data analysis. But of course those of us involved in public outreach tend to have stories to tell, and we need to tell them consciously and carefully, choosing our visual language with thoughtfulness and respect. We need to consider the needs of those for whom the visualisation is intended and make good decisions in support of our messages. Iliinsky's slim volume, *Data Visualization*, (2010) delves into the process of creating visualisations, and one of his diagrams (Iliinsky, 2012) does a smashing job of encapsulating the constituent components of a visual language.

Perhaps my chance selection of Hindu iconography has a fortuitous metaphorical implication. Many people worship Ganesha as the remover of obstacles, and as such, he can serve as a reminder to remove the barriers of visual representation that can separate our audience from a clearer understanding of our message. Whether or not we need Ganesha's assistance to accomplish this task, we should take it seriously.

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2. http://www.tableausoftware.com/products/public

Biography

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Astronomy in Everyday Life

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Justification, Technology Transfer, Astronomy and Society, Astronomy and World View

Summary

For a long time astronomers and other scientists believed that the importance of their work was evident to society. But in these difficult days of financial austerity, even the most obvious benefits of science have to undergo careful scrutiny. So, now more than ever is the time to highlight the importance of astronomy as a field in terms of its contributions to our technology, our mind sets and our lives.

Here we will outline both the tangible and intangible reasons why astronomy is an important part of society. Whilst considerable attention will be given to technology and knowledge transfer from astronomy, perhaps the most important contribution outlined is the awareness that astronomy gives us of the vastness of the Universe and our place within it.

Introduction

Throughout history people have looked to the sky to navigate the vast oceans, to decide when to plant their crops and to answer the questions of where we came from and how we got here. It is a discipline that opens our eyes, gives context to our place in the Universe and can reshape how we see the world. When Copernicus claimed that Earth was not the centre of the Universe, it triggered a revolution. A revolution during which religion, science and society had to adapt to this new worldview.

Astronomy has always had a significant impact on our worldview. Early cultures identified celestial objects with the gods and took their movements across the sky as prophecies of what was to come. We would now call this astrology, far removed from the hard facts and expensive instruments of today's astronomy, but there are still hints of this history in modern astronomy. Take, for example, the names of the constellations: Andromeda, the chained maiden of Greek mythology, or Perseus, the demi-god who saved her.

Now, as our understanding of the world progresses, we find ourselves and our view of the world even more entwined with the stars. The discovery that the basic elements that we find in stars, and the gas and dust around them, are the same elements that make up our bodies has further deepened the connection between us and the cosmos. This connection touches our lives, and the awe it inspires is perhaps the reason that the beautiful images astronomy provides us with are so popular in today's culture.

Current research in astronomy confronts a host of unanswered questions: "How old are we?", "What is the fate of the Universe?", "How unique is the Universe?" and "Could a slightly different Universe ever have supported life?" Pursuing these questions is a fundamental part of being human, yet in today's world it has become increasingly important to be able to justify the pursuit of the answers. The difficulties in describing the importance of astronomy, and fundamental research in general, are well summarised by Nobel Prize winner Ahmed Zewali:

"Preserving knowledge is easy. Transferring knowledge is also easy. But making new knowledge is neither easy nor profitable in the short term. Fundamental research proves profitable in the long run, and, as importantly, it is a force that enriches the culture of any society with reason and basic truth."
— Ahmed Zewali, winner of the Nobel Prize in Chemistry (1999).

There are other works that have contributed to answering the question "Why is astronomy important?" Dr Robert Aitken, director of Lick Observatory, shows us that even in 1933 there was a need to justify our science, in his paper entitled "The Use of Astronomy" (Aitken, 1933). His last sentence summarises his sentiment:

"To give man ever more knowledge of the Universe and to help him 'to learn humility and to know exaltation', that is the mission of astronomy."

More recently, C. Renée James wrote an article outlining the recent technological advances that we can thank astronomy for, such as Global Positioning Systems (GPS), medical imaging, and wireless internet (Renée James, 2012). In defence of radio astronomy, Dave Finley (2013) states:

"In sum, astronomy has been a cornerstone of technological progress throughout history, has much to contribute in the future, and offers all humans a fundamental sense of our place in an unimaginably vast and exciting Universe."

So although blue-skies research like astronomy rarely contributes directly to tangible outcomes on a short timescale, many are keen to outline its merit. A wealth of examples — many of which are outlined below — show how the study of astronomy contributes to technology, economy and society by constantly pushing for instruments, processes and software that are beyond our current capabilities. The pursuit of this research requires cutting-edge technology and methods that can, on a longer timescale, through their broader application, make a difference. The fruits of scientific and technological development in astronomy have become essential to our day-to-day life, with applications such as personal computers, communication satellites, mobile phones, GPS, solar panels and Magnetic Resonance Imaging (MRI) scanners.

Astronomy is one of the few scientific fields that interacts directly with society. Not only transcending borders, but actively promoting collaborations around the world. In the following paper, we outline the tangible and intangible contributions of astronomy to various fields.

Astronomy, people and history

Although we live in a world faced with the many immediate problems of hunger, poverty, energy and global warming, we argue that astronomy has long-term benefits that are equally important to a civilised society. Several studies have told us that investing in science education, research and technology provides a great return — not only economically, but culturally and indirectly for the population in general — and has helped countries to face and overcome crises. In fact, the scientific and technological development of a country or region has been shown to be closely linked to its human development index — a statistic that is a measure of life expectancy, education and income (Truman, 1949).

Figure 1. A piercingly bright curtain of stars is the backdrop for this beautiful image taken by astronomer Håkon Dahle. The silhouetted figure in the foreground is Håkon, surrounded by just a couple of the great dark domes that litter the mountain at ESO's La Silla Observatory. Credit: ESO/H. Dahle

Although the study of astronomy has provided a wealth of tangible, monetary and technological gains, perhaps the most important aspect of astronomy is not an economic measure. Astronomy has, and continues to, revolutionise our thinking on a worldwide scale. In the past, astronomy has been used to measure time, mark the seasons, and navigate the oceans. As one of the oldest sciences astronomy is part of every culture's history and roots. It inspires us with beautiful images and promises answers to the big questions. It acts as a window into the immense size and complexity of space, putting Earth into perspective and promoting global citizenship and pride in our home planet.

Several reports in the US (National Research Council, 2010) and Europe (Bode *et al.*, 2008) indicate that one of the biggest contributions of astronomy is its provision of a unique perspective that extends our horizons and helps us discover the grandeur of the Universe and our place within it. The awe-inspiring nature of astronomy makes it a perfect vehicle for introducing children to science. It has been found that teaching astronomy to our youth is of great value and that pupils who engage in astronomy-related educational activities at a primary or secondary school are more likely to pursue careers in science and technology, and to keep up to date with scientific discoveries (National Research Council, 1991). This does not just benefit the field of astronomy, but reaches out across all scientific disciplines.

As well as influencing our history and enhancing our present, astronomy also helps us study how to prolong the survival of our species into the future. For example, it is critical to study the Sun's influence on the Earth's climate and how it will affect weather and water levels. Only the study of the Sun and other stars can help us to understand these processes in their entirety, in the same way that mapping the movement of all the objects in the Solar System, is the only way to predict potential threats to our planet from space. Events that could cause major changes to our world, as was clearly demonstrated by the meteorite impact in Chelyabinsk, Russia in 2013.

Technology transfer

From astronomy to industry

Some of the most useful examples of technology transfer between astronomy and industry include advances in imaging and communications. For example, a film called Kodak Technical Pan is used extensively by medical and industrial spectroscopists, industrial photographers, and artists, and was originally created so that solar astronomers could record the changes in the surface structure of the Sun. In addition, the development of Technical Pan — again driven by the requirements of astronomers — was used was used for several decades (until it was discontinued) to detect diseased crops and forests, in dentistry and medical diagnosis, and for probing layers of paintings to reveal forgeries (National Research Council, 1991).

In 2009 Willard S. Boyle and George E. Smith were awarded the Nobel Prize in Physics for the development of another device that would be widely used in industry. The sensors for image capture developed for astronomical images, known as charge-coupled devices (CCDs), were first used in astronomy in 1976. Within a very few years they had replaced film not only on telescopes, but also in many people's personal cameras, webcams and mobile phones. The improvement and popularity of CCDs is attributed to NASA's decision to use super-sensitive CCD technology on the Hubble Space Telescope (Kiger & English, 2011).

In the realm of communication, radio astronomy has provided a wealth of useful tools, devices, and data-processing methods. Many successful communications companies were originally founded by radio astronomers. The computer language FORTH was originally created to be used by the Kitt Peak 36-foot telescope and went on to provide the basis for a highly profitable company (Forth Inc.). It is now being used by FedEx worldwide for its tracking services. Some other examples of technology transfer between astronomy and industry are listed below (National Research Council, 2010):

- The company General Motors uses the astronomy programming language Interactive Data Language (IDL) to analyse data from car crashes.
- The first patents for techniques to detect gravitational radiation — produced when massive bodies accelerate — have been acquired by a company to help them determine the gravitational stability of underground oil reservoirs.
- The telecommunications company AT&T uses Image Reduction and Analysis Facility (IRAF) — a collection of software written at the National Optical Astronomy Observatory — to analyse computer systems and solid-state physics graphics.

From astronomy to the aerospace sector

The aerospace sector shares most of its technology with astronomy — specifically in telescope and instrument hardware, imaging, and image-processing techniques.

Since the development of space-based telescopes, information acquisition for defence has shifted from using ground-based to aerial and space-based techniques. Defence satellites are essentially telescopes pointed towards Earth and require identical technology and hardware to those used in their astronomical counterparts. In addition, processing satellite images uses the same software and processes as astronomical images. Some specific examples of astronomical developments used in defence are given below (National Research Council, 2010):

- Observations of stars and models of stellar atmospheres are used to differentiate between rocket plumes and cosmic objects. The same method is now being studied for use in early warning systems.
- Observations of stellar distributions on the sky — which are used to point and calibrate telescopes — are also used in aerospace engineering.
- Astronomers developed a solar-blind photon counter — a device which can measure the particles of light from a source, during the day, without being overwhelmed by the particles coming from the Sun. This is now used to detect ultraviolet (UV) photons coming from the exhaust of a missile, allowing for a virtually false-alarm-free UV missile warning system. The same technology can also be used to detect toxic gases.
- GPS satellites rely on astronomical objects, such as quasars and distant galaxies, to determine accurate positions.

From astronomy to the energy sector

Astronomical methods can be used to find new fossil fuels as well as to evaluate the possibility of new renewable energy sources (National Research Council, 2010):

- Two oil companies, Texaco and BP, use IDL to analyse core samples around oil fields as well as for general petroleum research.
- An Australian company, called Ingenero, has created solar radiation collectors to harness the power of the Sun for energy on Earth. They have created collectors up to 16 metres in diameter, which is only possible with the use of a graphite composite material developed for an orbiting telescope array.
- Technology designed to image X-rays in X-ray telescopes — which have to be designed differently from visible-light telescopes — is now used to monitor plasma fusion. If fusion — where two light atomic nuclei fuse to form a heavier nucleus — became possible to control, it could be the answer to safe, clean energy.

Astronomy and medicine

Astronomers struggle constantly to see objects that are ever dimmer and further away. Medicine struggles with similar issues: to see things that are obscured within the human body. Both disciplines require high-resolution, accurate and detailed images. Perhaps the most notable example of knowledge transfer between these two studies is the technique of aperture synthesis, developed by the radio astronomer and Nobel Laureate, Martin Ryle (Royal Swedish Academy of Sciences, 1974). This technology is used in computerised tomography (also known as CT or CAT scanners), magnetic resonance imaging, positron emission tomography (PET) and many other medical imaging tools.

Along with these imaging techniques, astronomy has developed many programming languages that make image processing much easier, specifically IDL and IRAF. These languages are widely used for medical applications (Shasharina, 2005).

Another important example of how astronomical research has contributed to the

Figure 2. The debris objects shown in the images are an artist's impression based on actual density data. However, the debris objects are shown at an exaggerated size to make them visible at the scale shown Credit: European Space Agency

medical world is in the development of clean working areas. The manufacture

of space-based telescopes requires an extremely clean environment to prevent dust or particles that might obscure or obstruct the mirrors or instruments on the telescopes (such as in NASA's STEREO mission; Gruman, 2011). The cleanroom protocols, air filters, and bunny suits that were developed to achieve this are now also used in hospitals and pharmaceutical labs (Clark, 2012).

Some more direct applications of astronomical tools in medicine are listed below:

- A collaboration between a drug company and the Cambridge Automatic Plate Measuring Facility allows blood samples from leukaemia patients to be analysed faster and thus ensures more accurate changes in medication (National Research Council, 1991).
- Radio astronomers developed a method that is now used as a non-invasive way to detect tumours. By combining this with other traditional methods, there is a now an exceedingly high true-positive detection rate in breast cancer patients.
- Small thermal sensors initially developed to control telescope instrument temperatures are now used to control heating in neonatology units — units for the care of newborn babies (National Research Council, 1991).
- A low-energy X-ray scanner developed by NASA is currently used for outpatient surgery, sports injuries, and in third-world clinics. It has also been used by the US Food and Drugs Administration (FDA) to study whether certain pills were contaminated (National Research Council, 1991).
- Software for processing satellite pictures taken from space is now helping medical researchers to establish a simple method to implement wide-scale screening for Alzheimer's disease (ESA, 2013).
- Looking through the fluid-filled, constantly moving eye of a living person is not that different from trying to observe astronomical objects through the turbulent atmosphere, and the same fundamental approach seems to work for both. Adaptive optics used in astronomy can be used for retinal imaging in living patients to study diseases such as macular degeneration and retinitis pigmentosa in their early stages. (Boston Micromachines Corporation, 2010)

Astronomy in everyday life

There are many things that people encounter on an everyday basis that were derived from astronomical technologies. Perhaps the most commonly used astronomy-derived invention is the wireless local area network (WLAN). In 1977 John O'Sullivan developed a method to sharpen images from a radio telescope. This same method was applied to radio signals in general, specifically to those dedicated to strengthening computer networks, which is now an integral part of all WLAN implementations (Hamaker *et al.*, 1977).

Other technologies important to everyday life that were originally developed for astronomy are listed below (National Research Council, 2010):

- X-ray observatory technology is also used in current X-ray luggage belts in airports.
- In airports, a gas chromatograph — for separating and analysing compounds — and originally designed for a Mars mission is used to survey baggage for drugs and explosives.
- The police use hand-held Chemical Oxygen Demand (COD) photometers — instruments developed by astronomers for measuring light intensity — to check that car windows are transparent, as determined by the law.
- A gamma-ray spectrometer originally used to analyse lunar soil is now used as a non-invasive way to probe structural weakening of historical buildings or to look behind fragile mosaics, such as in St. Mark's Basilica in Venice.

More subtle than these contributions to technology is the contribution that astronomy has made to our view of time. The first calendars were based on the movement of the Moon and even the way that we define a second is due to astronomy. The atomic clock, developed in 1955, was calibrated using astronomical Ephemeris Time — a former standard astronomical timescale adopted by the International Astronomical Union (IAU) in 1952. This led to the internationally agreed-upon re-definition of the second (Markowitz *et al.*, 1958).

These are all very tangible examples of the effect astronomy has had on our everyday lives, but astronomy also plays an important role in our culture. There are many books and magazines about astronomy for non-astronomers. *A Brief History of Time* by Stephen Hawking is a bestseller and has sold over ten million copies and Carl Sagan's television series, *Cosmos: A Personal Voyage*, has been watched in over 60 countries by more than 500 million people (NASA, 2009).

Many non-astronomers also engaged with astronomy during the International Year of Astronomy 2009 (IYA2009), the largest education and public outreach event in science. The IYA2009 reached upwards of eight hundred million people, through thousands of activities, in more than 148 countries (IAU, 2010).

Astronomy and international collaboration

Scientific and technological achievements give a large competitive edge to any nation. Nations pride themselves on having the most efficient new technologies and race to achieve new scientific discoveries. But perhaps more important is the way that science can bring nations together, encouraging collaboration and creating a constant flow and exchange of knowledge as researchers travel around the globe to work in international facilities.

Astronomy is particularly well suited to international collaboration due to the need to have telescopes in different places around the world, in order to see the whole sky. At least as far back as 1887 — when astronomers from around the world pooled their telescope images and made the first map of the whole sky — there have been international collaborations in astronomy and in 1920, the IAU became the first international scientific union.

In addition to the need to see the sky from different vantage points on Earth, building astronomical observatories on the ground and in space is extremely expensive. Therefore, most of the current and planned observatories are owned by several nations. All of these collaborations have thus far been peaceful and successful. Some of the most notable being:

- The Atacama Large Millimeter/submillimeter Array (ALMA) project is a global collaboration between Europe, USA, Canada, Japan, Taiwan, in partnership with Chile.
- The European Southern Observatory (ESO) which includes 14 European countries and Brazil, and is located in Chile.
- The launch of a US spectrometer by a Japanese rocket.
- Collaborations on major observatories such as the NASA/ESA Hubble Space Telescope.

Conclusion

It is clear that astronomy and its related fields are at the forefront of science and technology; answering fundamental questions and driving innovation. The importance of this contribution to science and to society has been highlighted here and the sheer breadth of what astronomy has to offer will ensure that it continues to be of great importance to the scientific community. It is this breadth of important contributions that explains why the International Astronomical Union's strategic plan for 2010–2020 has three main areas of focus: technology and skills; science and research; and culture and society.

There are still many unanswered questions in astronomy and it is breaking new records every day in the quest to answer them, establishing the furthest distances, most massive objects, highest temperatures and most violent explosions. But the American astronomer Carl Sagan showed us astronomy's simplest and most inspirational contribution to society in his book, *The Pale Blue Dot*:

"It has been said that astronomy is a humbling and character-building experience. There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world. To me, it underscores our responsibility to deal more kindly with one another, and to preserve and cherish the pale blue dot, the only home we've ever known."

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Biographies

Marissa J. F. Rosenberg is completing the final year of her PhD at Leiden Observatory in the Netherlands. Marissa participates in EU Universe Awareness and writes a monthly astronomy article in the children's magazine *Anorak* along with science experiments for elementary school children. Her PhD research specialises in studying excited gas in nearby galaxies and the mechanisms that excite the gas. For more information, please visit www.strw.leidenuniv.nl/~rosenberg/.

Pedro Russo, Vice-President of IAU Commission 55, is the international project manager for the educational programme EU Universe Awareness. He is also Co-Chair of the IAU Office of Astronomy for Development's Task Force 2, Schools and Children. Until 2012, Pedro was Editor-in-Chief of *CAPjournal*, a publication he founded. He was also formerly the global coordinator for the largest celebration of science, the International Year of Astronomy 2009. As a planetary scientist, he worked with the scientific team for the Venus Monitoring Camera on ESA's Venus Express. For more information, please visit http://home.strw.leideuniv.nl/~russo/cv.html

Georgia Bladon is a professional science communicator with an academic background in Physics with Philosophy (BSc) and Science Communication (MSc). She has previously worked in the communication teams of ESO and the Wellcome Trust and currently works as Editor-in-Chief of *CAPjournal* and project manager at Invisible Dust, working on large public engagement projects around the topics of Earth Observation, Space Science and Environment.

Lars Lindberg Christensen, President of IAU Commission 55, is a science communication specialist, who is Head of the ESO education and Public Outreach Department (ePOD) in Munich, Germany. He is responsible for public outreach and education for the La Silla-Paranal Observatory, for ESO's part of ALMA and APEX, for the European Extremely Large Telescope, for ESA's part of the Hubble Space Telescope and for the IAU Press Office. Lars has more than 100 publications to his credit, most of them in popular science communication and its theory.

CAP2013 – Communicating Astronomy with the Public 2013

Ian Robson
Chair of the Scientific Organising Committee and Chairman of the CAP Conference Organising Committee of C55

Keywords
CAP2013; Warsaw, Poland; Copernicus Science Centre; Conferences; Warsaw University of Technology

Summary

The highly successful and very popular Communicating Astronomy with the Public conference series held its fifth event (CAP2013) at the Copernicus Science Centre and the Warsaw University of Technology in Poland, from 13 to 17 October. This review gives a summary of the event proceedings.

Introduction

The CAP conferences are held under the auspices of the International Astronomical Union (IAU) Commission 55 — Communicating Astronomy with the Public and, following the International Year of Astronomy 2009, the conferences are clearly becoming even more popular. CAP2013 was the best attended so far with around 200 participants, including a large number attending for the first time and there were participants from over 40 countries. CAP intends to bring together the sources of information — primarily astronomers, the mediators — public information specialists, press officers, outreach managers, planetarium producers, and the distributors — astronomers, enthusiasts, science journalists, web-activists and teachers, who contribute to the communication of astronomy with the public.

The IAU provided €10 000 of support for registration/travel/subsistence for participants, half of which was designated to support those attending from the UNAWE international workshop in Heidelberg, held the week before. This initiative is partly responsible for the significant presence of participants from outside Europe.

The conference programme was packed with a range of talks, discussion sessions, a fulldome interactive planetarium session, posters, a tour of the Science Centre, a Copernicus planetarium show, an evening IMAX cinema preview showing, and last, but by no means least, what turned out to be a very popular "unconference" session.

Conference welcome

The conference began with welcome drinks and nibbles at the Warsaw University of Technology on the Sunday evening and was officially opened on the Monday morning in the grand hall of the institute's main building. The delegates were welcomed by local dignitaries and the session was hosted by Lars Lindberg Christensen, President of the IAU Commission 55. Welcoming words were given by: Professor Rajmund Bacewicz, Pro-rector of the Warsaw University of Technology; Robert Firmhofer, Director of the Copernicus Science Centre; Professor Lech Mankiewicz, Chairman of the Advisory Board of the New Space Foundation and Claus Madsen, Senior Advisor for International Relations for the European Southern Observatory.

Figure 1. Delegates during the post conference tour to Torun, the city where Copernicus was born and the home of the ASTROBASE project.

A presentation of the naming of asteroid (315166) Pawelmaksym was made to the widow of the Polish astronomer, Pawel Maksym, who was a member of the local organising committee and who sadly died early in 2013 at the age of only 29.

Inaugural lecture

The inaugural lecture was presented by Professor Mark McCaughrean, Head of the Research & Scientific Support Department for the European Space Agency in the Directorate of Science and Robotic Exploration. This was a real *tour de force* and set a very high standard for the rest of the meeting. Mark discussed how we have evolved and how we interact with the Universe and our fellow humans. It was a thought-provoking lecture, especially with respect to communication, with comments cautioning about over-spin in written communication and the use of Photoshop in the truly spectacular images we are all now used to seeing. Hopefully this talk can be videoed for web use at some point in the future — it definitely deserves it.

Talks and sessions

Following the inaugural lecture the conference moved to the Copernicus Science Centre, a new building, completed in 2010, on the banks of the Vistula river (http://www.kopernik.org.pl/en/).

The call for proposals for talks, which were at the core of the event programming, resulted in the programme being very heavily oversubscribed. Many potential talks were instead presented as posters and, as an experiment, some talks were given a 7-minute slot compared with the normal 15-minute length. This appeared to work well and was a salutary lesson in how to capture the key essence of a talk and present it in a very compressed timeframe. I'm sure this experiment will be repeated as it gives the opportunity for more people to present their work to the full audience.

The sessions were split into the following categories: citizen science and crowdsourcing; outreach and organisations; the night sky; non-traditional audiences and methods; fulldome presentations; facilities and projects; country specific activities

Figure 2. Delegates discuss during one of the unconference sessions.

and education and children. It is always invidious to pick out individual talks, but there was a huge spectrum of activities and presentation styles. In keeping with the theme of new media, Pamela Gay broadcast the proceedings to the rest of the Universe on Google Hangouts on Air.

One of the highlights of the meeting was a new experiment for CAP, an entire session devoted to planetarium topics, held in the fulldome in the Copernicus Centre. This really brought together the producers of great outreach with the outreach exponents themselves and demonstrated the huge leap in performance (and excitement) that can now be obtained by fulldomes.

Two evening discussion sessions focused on "New Opportunities for the CAP Community Including Involvement in the International Year of Light 2015" and "Science Communication as a Creative Industry". The former resulted in extensive discussions from the floor about the lack of knowledge from the astronomy community in the Year of Light and the conclusion that perhaps the organisation was somewhat behind the curve for such a global event with potential for such wide interest.

One of the evening events was the special showing of the new IMAX film *Hidden Universe* at the IMAX theatre on the outskirts of Warsaw. This Australian-produced film highlighted the European Southern Observatory's facilities in northern Chile and was very impressive, despite the fact we were only shown the 2D version. There is no doubt that the 3D version should be really spectacular.

The unconference session turned out to be extremely popular with themes selected solely by the conference participants. Kevin Govender, the Director of the IAU Office of Astronomy for Development, organised the session which was broken up into six parallel groups. The topics chosen were:

- What is the future of planetariums?
- How to deal with astrology?
- Astronomy beyond science — astronomy and art;
- How to communicate astronomy to policy makers; The Higgs boson and how to work together (with particle physicists);
- Progress on new ways of communicating astronomy with the public;
- Fast and effective evaluation of projects;
- A South American regional node;
- Google+ is for everyone;
- Backup plans for comet ISON activities;
- Creating a site for testimonials about how people's experiences with astronomy led to science, technology, engineering and mathematics (STEM) careers.

Each group fed back to the whole conference with two-minute presentations

Figure 3. The venue for the talks and sessions as delegates prepare for the start of CAP2013.

and questions from the floor. This was extremely well done and provoked a very enthusiastic response from the audience. We could easily have used more time for this.

Organisation and thanks

The initiator of the CAP2013 Polish proposal was Jan Pomierny of the New Space Foundation. Jan was Chair of the local organising committee and a scientific organising committee member. The local organising committee are to be congratulated for putting on a splendid event with a selection of excellent venues and spectacular opening welcomes, discussion sessions and planetarium and science centre tours. Plus, there was an excellently organised conference dinner, two public lectures and a very special tour following the conference to Torun, the city where Copernicus was born and the home of the ASTROBASE project. The meeting venue deserves special mention; it worked really well, not only in the conference room itself, but also with the excellent refreshments being provided in an adjacent space.

Conclusion and the future

Warsaw was a very interesting and welcoming city, with great food and an extensive range of drinks. We were fortunate in that the weather and the autumn colours on the trees were truly fantastic. Overall CAP2013 was a hugely successful event and a call has now gone out to the community for organisations/institutions wishing to express an interest in holding the next CAP meeting. Because of the IAU General Assembly being held in the summer of 2015, it was agreed at a CAP organisers' meeting held during the conference that the next CAP will take place in spring 2016. CAP2016 will build on detailed evaluation of this event so has the potential to be even better! Overall, an excellent week of outreach activity showing the huge degree of enthusiasm that people bring to this widely loved topic.

The programme and all information about CAP2013 can be found at: http://www.communicatingastronomy.org/cap2013/index.html which is also a repository for numerous photographs (some very humorous) and well worth visiting.

Biography

Professor Ian Robson was the inaugural President of Commission 55 and has been the lead organiser of all the CAP conferences. Although retired he continues to give talks on astronomy to the public and societies. Previously he was Director of the UK Astronomy Technology Centre at the Royal Observatory Edinburgh and prior to that he was the Director of the James Clerk Maxwell Telescope and the Joint Astronomy Centre in Hawaii.

EUROPE TO THE STARS

ESO'S FIRST 50 YEARS OF EXPLORING THE SOUTHERN SKY

Short summary
To celebrate its 50th anniversary year, ESO released the documentary *Europe to the Stars — ESO's first 50 years of exploring the southern sky*. The movie captures the story of ESO's epic adventure — a story of cosmic curiosity, courage and perseverance, the story of discovering a Universe of deep mysteries and hidden secrets, of designing, building and operating the most powerful ground-based telescopes on the planet. The eight chapters each focus on an essential aspect of an observatory: from site testing and explaining the best conditions for observing the sky to how telescopes are built and the mysteries of the Universe that astronomers are revealing.

Features
Produced in Full HD (1080p), available as DVD and Blu-ray
Runtime: 63 minutes + bonus material
Narration in English
Subtitles in 20 languages: Česky, Dansk, Deutsch, English, ελληνικά, Español, Français, íslenska, Italiano, Nederlands, Polski, Português, Português (Brasil), Русский, Română, Slovenski, Suomi, Türkçe, Українська, Hindi
Related book: *Europe to the Stars — ESO's first 50 years of exploring the southern sky*, Wiley, 2012
Web page: www.europetothestars.org

Colophon

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