CAP journal
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Communicating Astronomy with the Public

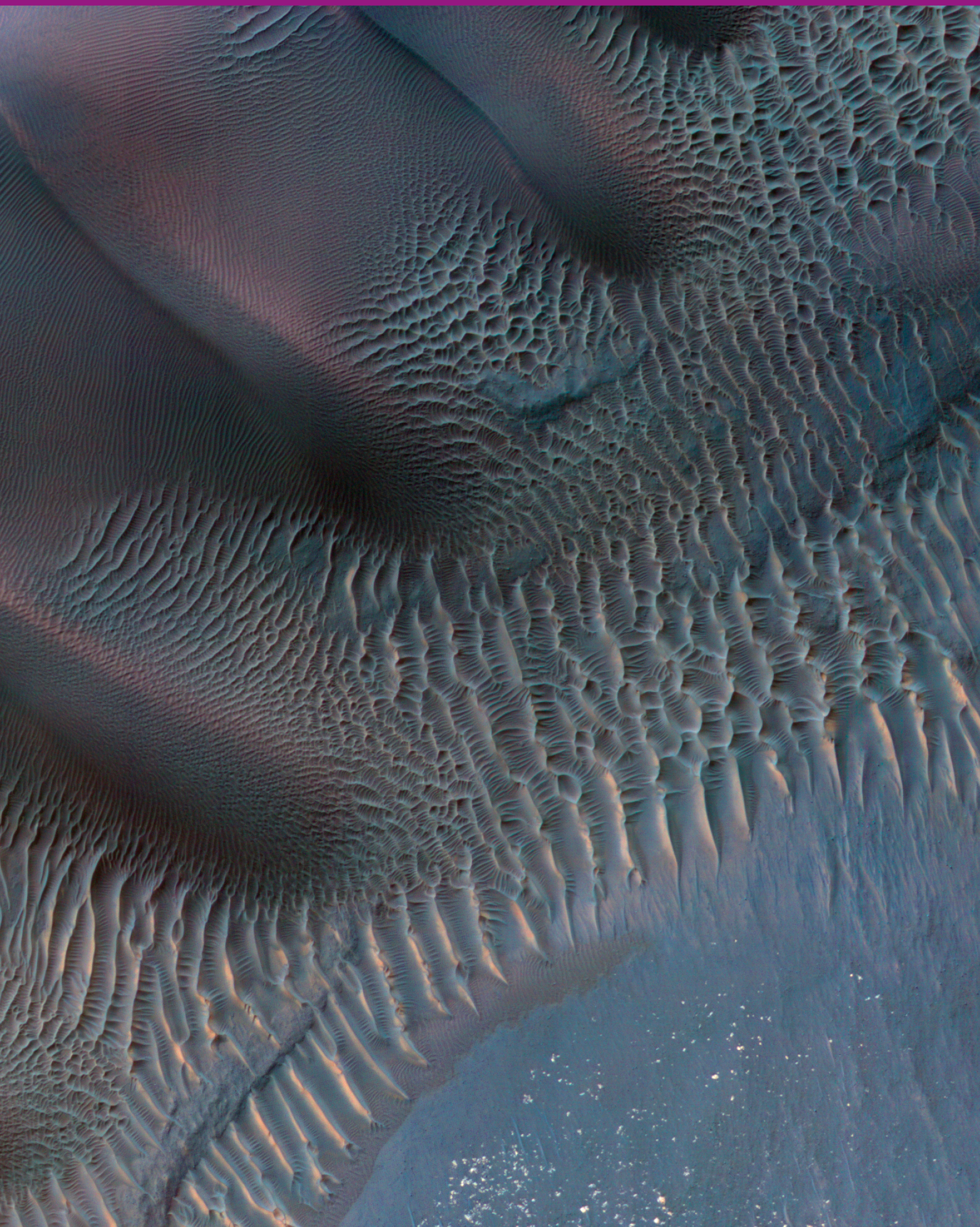
Rock'n'Astronomy
Astronomy meets pop-rock

How Do We Know What Works?
Reaching our Target Audiences

Cerberus
The Mars Crowdsourcing Experiment

www.capjournal.org

This enhanced-colour image shows sand dunes trapped in an impact crater in Noachis Terra, Mars. Dunes and sand ripples of various shapes and sizes display the natural beauty created by physical processes. The area covered in the image is about 1 kilometre across. Credit: NASA/JPL-Caltech/Univ. of Arizona.



They say that all good things take time.... But it has taken almost a year to create this new issue of CAPjournal, and clearly this is too long even for the CAPjournal. The CAPjournal is produced on a voluntary basis, with logistical and editorial support provided by the International Astronomical Union (IAU), the European Southern Observatory and EU Universe Awareness. Everyone involved had expected to have more time available to dedicate to the CAPjournal in the years following the International Year of Astronomy 2009. However, we have found ourselves busier than ever, with many new and exciting projects in astronomy communication and education. Apologies for this.

But things are moving in a positive direction for the CAPjournal. The IAU is currently reorganising its education and public outreach efforts within the framework of the IAU Strategic Plan for the Developing World. On the public outreach front, the National Astronomical Observatory of Japan is just concluding the process of finding an IAU Public Outreach Coordinator (POC), who will coordinate efforts from around the world to promote public awareness, appreciation and education of astronomy and related sciences. As part of this remit, the IAU POC will take over editorship of CAPjournal — if all goes well from as soon as the next issue. With this dedicated effort CAPjournal will return to a publication schedule of three issues per year. Stay tuned for more developments on www.astro4dev.org.

Returning to the current issue, it may have been a long time in the making, but we hope that it was well worth the wait: the authors in this issue share their insights on a wide range of topics, ranging from rock'n'roll to evaluation, from history to citizen science.

Happy reading,

Pedro Russo
Editor-in-Chief

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Cover: This image was taken in 2011 over Jökulsárlón, the largest glacial lake in Iceland. Stephane Vetter combined six exposures to capture not only two green auroral rings, but their reflections off the serene lake. Credit: S. Vetter/TWAN

Explained in 60 Seconds: A collaboration with *Symmetry* Magazine, a Fermilab/SLAC publication

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Keywords
Redshift, Explained in 60 Seconds

Redshift

Redshift is the observed change in the colour of light emitted by a star or other celestial object that is moving away from Earth.

Light, like sound, travels in waves that are stretched or compressed when the source or the observer is in motion. Imagine a passing train blowing its horn: You hear a high-pitched sound as it approaches and a low-pitched sound as it recedes. The approaching sound waves are compressed and the receding sound waves are stretched, causing you to hear different frequencies.

You experience a similar effect with light emitted by a moving object. The wavelength of light appears shorter for an approaching object and longer for a receding one. In the visible spectrum of light, the longest wavelengths are red, so the light from a receding source is said to be "redshifted".

In the 1990s, astronomers measuring the redshifts of distant, bright objects discovered that they are further away than one would have expected from the expansion of the Universe as influenced by gravity alone. Confirmed by more recent observations, the discovery means that the Universe is expanding at an increasing rate. This accelerated expansion is thought to be caused by dark energy, the physical nature of which is one of the most compelling mysteries of modern science.

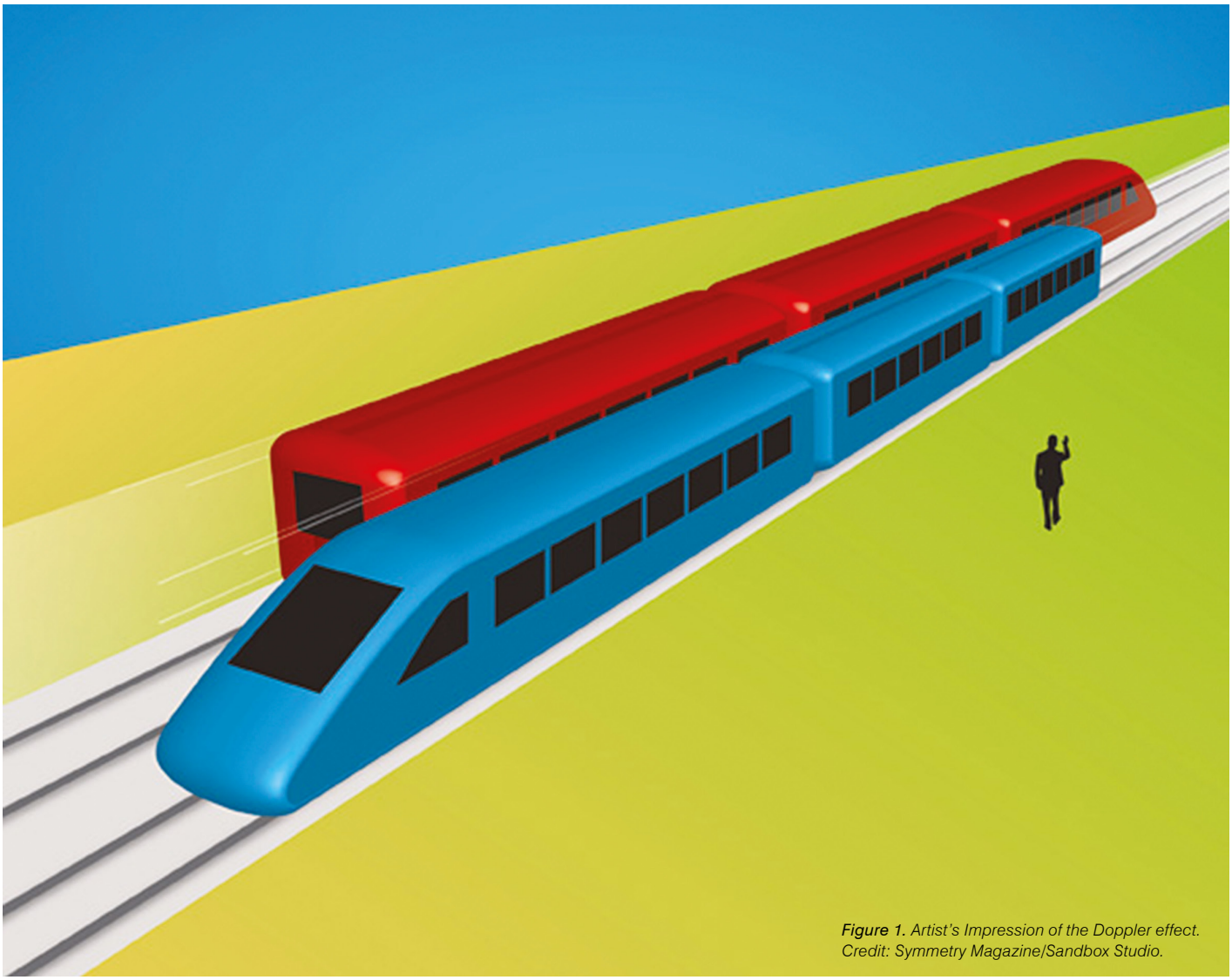

Figure 1. *Artist's Impression of the Doppler effect. Credit: Symmetry Magazine/Sandbox Studio.*

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Multiverso: Rock'n'Astronomy

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Keywords
Astronomy, Arts, Music, Poetry

Summary

In the last few years, there have been several projects involving astronomy and classical music. But have a rock band ever appeared at a science conference or an astronomer at a rock concert? We present a project, *Multiverso*, in which we mix rock and astronomy, together with poetry and video art (Caballero, 2010). The project started in late 2009 and has already reached tens of thousands people in Spain through the release of an album, several concert-talks, television, radio, newspapers and the internet.

[...] que las estrellas deben ocupar su distancia

para que no se extingan cuando abajo las mire.

[...] that the stars must hold their distance

for not being gone out when I see them from below.

Enrique Morente (*Tarantos griegos, Pablo de Málaga*, 2009)

First movement: Allegro con brio

Imagine that you are an astronomer, and use your fingers only to type in target coordinates at the telescope, reduce images and spectra with IRAF, or write papers for scientific publications like *Astronomy & Astrophysics*, and are unable to play an electric guitar. Yet you also love music, work in front of the computer wearing headphones, and dream of playing with your favourite rock band in a tumultuous concert. Imagine then, that after a "cosmic fluke", you share the stage with the band whose tunes you have hummed since you were a teenager.

Imagine being a rock star who played a leading role in the best Spanish album of the 90s (*Omega*, with Enrique Morente), that your songs are routinely played by Radio 3 (a Spanish national radio station similar to BBC Radio 2), but that you are never have been able to detect an exoplanet or a galaxy at a high redshift. Yet you love astronomy, regularly observe Moon craters and the Andromeda Galaxy with your small telescope, and have explained to your daughter why Pluto is no longer a planet. Imagine that you are a musician who, after a "cosmic fluke", gives a talk that follows one from a Nobel Laureate who discovered the cosmic microwave background radiation.

Such "cosmic flukes" sometimes happen. The musician is Antonio Arias, the leader of the rock band Lagartija Nick; I am the astronomer; and the first person to nimbly climb the stage and warmly congratulate us on our astro-rock show was a cordial, venerable Nobel prize winner named Robert W. Wilson.... Yes, *the* Wilson of "Penzias & Wilson"!

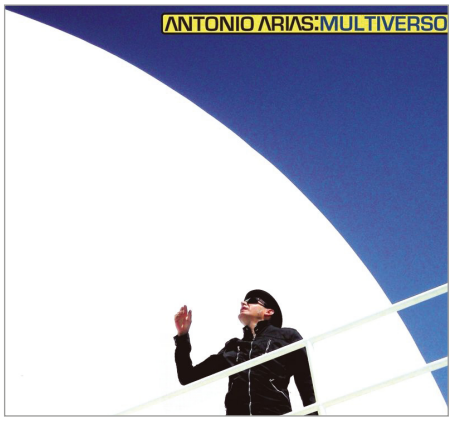

Figure 1. *Cover of the album* Multiverso *by Antonio Arias. The white dome is home to the 2.2-metre telescope at the Calar Alto Observatory in Almería, Spain. Credit: A. Arias.*

Second movement: Andante con moto

This is what happened during the closing ceremony of the International Year of Astronomy 2009, in Granada, Spain[1,2]. There, we mixed space sounds (such as the radar echoes from Titan's surface received by ESA's *Huygens* probe during the last few kilometres of its descent[3,4]), with a historical lecture on the relationship between music and astronomy illustrated with fancy images and videos, followed by a rock concert given by members of the

Figure 2. *Three different moments during the closing ceremony of the International Year of Astronomy 2009 in Granada, Spain: Robert W. Wilson during his talk, "The discovery of cosmic microwave radiation (CMBR)"; the author during the performance of* Génesis*, a musical track based on a David Jous poem on the Big Bang and CMBR; and part of the rock band (Florent, Julián, Antonio and Popi, from left to right) during the performance of* Mar de la Tranquilidad*. Credit: E. Trinchant.*

most famous bands in Granada: Lagartija Nick, Lori Meyers and, of course, Los Planetas[5] (The Planets).

The whole story had started much earlier. The full version, starting at the very beginning, with Thoth, Euterpe, Urania, Pythagoras, Johannes Kepler, William Herschel, Gustav Holst, David Bowie and Brian May as the main characters, has been already told elsewhere. So I will simply go back to early 2006, when I had just finished writing up my PhD thesis on substellar objects. Each thesis chapter was headed with lyrics, extracts and verses of the songs that I had listened to while I was in front of the computer. While Claude Bertout's review on T Tauri stars (Bertout, 1989) started with Leonard Cohen's *Another Night With Telescope*, my chapter headers looked like this:

¡No hay atmósfera ni viento ni lluvia
sobre el Océano de las Tempestades!
¡Agua para el Mar de las Nubes!
¡Agua para el Mar de los Vapores!

There is neither atmosphere nor wind nor rain
on Oceanus Procellarum!
Water for Mare Nubium!
Water for Mare Vaporum!

These selenographic verses form the chorus of *Mar de la Tranquilidad*, a Lagartija Nick song from their 1999 album of the same name. There you can also find *Newton-Espacio 1999*, with statements by the Spanish astronaut Pedro Duque, *Pulsar* or *Azora 67*, the only song that I know about fighting light pollution. After receiving my doctorate, I wrote an outreach article on music and astronomy that became a cover story for *AstronomíA*, the first popular science magazine on astronomy in Spanish (Caballero, 2007). Antonio Arias read the article and liked it. We made contact and I provided him with some astronomical images for the booklet for his next album, *El Shock de Leia* (2007). However, the turning point came when I wrote another outreach article for *AstronomíA* on poetry and astronomy (Caballero, 2009). Most of the selected poems were in Spanish, but there were also a few in English, Catalonian, Latin and even kanji. The following verses were written by Al-Mu'tamid, an Andalusian-Arabian king of Seville in the 11th century:

Luego, cuando la Luna quiso pasearse hacia Oriente,
levantó por encima de sí a Orión como un dosel,
y las estrellas avanzaron a sus lados
como batallones que alzaban a las Pléyades por bandera.

Next, when the Moon wished to wander towards the East,
it lifted Orion above itself like a canopy,
and the stars moved forward at its sides
like battalions that raised the Pleiades as flag.

A couple of weeks after its publication, Antonio Arias phoned me: "Jose, I am preparing three or four songs based on the poems in your article." Having said that Lagartija Nick is my favourite Spanish rock band, I was almost moved to tears when I heard that....

Third movement: Scherzo. Allegro

The three or four songs became a dozen and, after a few months, Antonio Arias had released *Multiverso*[6], his first solo album. It starts with the peculiar noises of the dome and encoders of the 2.2-metre telescope of the Calar Alto[7] observatory, in Almería (Spain), which merge with a pulsar-like sound, a bass guitar, an electric guitar, a drum kit and, finally, Antonio Arias's voice:

L'ordre matemàtic simula el món real,
crea un altre món de càlcul i mental.
En el ordenador renacen las estrellas,
como hace tantos años nacieron.
Somos como creadores....

The mathematical order simulates the real world,
it creates other world of calculus and mind.
In the computer the stars are reborn,
like they were born so many years ago.
We are like creators....

A set of poetry books that David Jou sent us in early 2009 were a gold mine: the lyrics of four songs in *Multiverso* are written by him. One of them is *El ordenador simula el nacimiento de las estrellas (The computer simulates the birth of stars),* part of which is shown above. David Jou is a professor of condensed matter physics at the Universidad Autónoma de Barcelona and also a poet with works translated into English, German, French and Russian. *Multiverso* also includes lyrics by other renowned poets, such as José Emilio Pacheco. By chance, on the day of the album premiere, it was announced that Pacheco had received the Miguel de Cervantes Prize (the Spanish equivalent of the Nobel Prize for Literature).

The last track of the album lasts over seven minutes and has no lyrics. During the preparation of the album, I had told Antonio about Johannes Kepler's *Harmonices Mundi*, the medieval concept of *Musica*

Figure 3. Pictures taken during astro-concerts at the Teatro Isidoro Máiquez, Granada (Juano, Antonio, Julián), Sala el Sol, Madrid (Xarim, Antonio, Popi), and Universidad Complutense de Madrid (Nayra, Antonio), the most recent with an image of particle collisions at the Large Hadron Collider in the background. Credits: M. Calle (www.indy-rock.es) and Ávatar (laletracapital.blogspot.com).

Universalis, the Music of the Spheres, and its 20th century musical readout that is flying beyond the Solar System with the Voyager spacecraft. To satisfy me, Antonio prepared *Harmonia Mundi 2009*, the first music of the spheres to include only eight planets (i.e. without Pluto).

Fourth movement: Allegro

After the release of *Multiverso* and our participation in the closing ceremony of the Spanish IYA2009, I made a short appearance at the beginning of one of Antonio's rock concerts at a club in Madrid: can you imagine the faces of the public when they saw a science freak telling them that MUSE is not only a famous rock band[8], but also the Multi-Unit Spectroscopic Explorer[9] at ESO's Very Large Telescope?

Next, we tried to obtain a grant from the Spanish Ministry of Science to take our astro-rock show on tour through Spain, but did not succeed. However, somebody read our funding proposal and we were invited to perform our show during the meetings of the professional and amateur Spanish Astronomical Societies in Madrid in September 2010, where our honourable curtain-raiser was Carlos S. Frenk, the director of the Institute for Computational Cosmology at the University of Durham.

As I write these lines, Antonio and I are preparing a new astro-rock show to be held at CosmoCaixa[10] Barcelona on Europe's Museum Day. We are preparing newer and better videos, images and songs, including one devoted to CARMENES[11, 12], a German-Spanish high-resolution two-channel spectrograph that will perhaps detect the first habitable exo-Earth. More information on the project can be found at http://exoterrae.eu/usc/ (the outreach project now receives the name "unitedsoundsofcosmos").

Acknowledgements

Of course, the Rock'n'Astronomy project would not have come to pass without the most important person, the music composer, vocalist, guitar and bass player: Antonio Arias. But the two of us want to respectfully remember a very special person and artist who recently left behind millions of flamenco orphans: *maestro* Enrique Morente.

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[5] http://en.wikipedia.org/wiki/Los_Planetas

[6] http://www.myspace.com/antonioariasmultiverso

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Biography

José A. Caballero is a young Spanish astrophysicist whose interest in astronomy began when he first saw Star Wars: A New Hope at the age of only four. Now, he is a Ramón y Cajal fellow at the Centro de Astrobiología, the co-project manager of CARMENES and an expert of the σ Orionis region, close to the Horsehead Nebula.

How Do We Know What Works?[1]

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Keywords
Science Communication, Evaluation

Summary

There are many reasons why communicating science with the public is a good idea. There are also many views on how this is best done. This article will not focus directly on these questions, but rather on: how do we know that we are reaching our target audiences, how do we know whether our output is well received — in short, how do we know what works?

Introduction

This article presents experiences from the press and outreach activities for the European Space Agency's share of the Hubble Space Telescope (ESA/Hubble) — an integrated part of ESO's education and Outreach Department (ESO ePOD), for which the methods described here also apply. While astronomy is in some respects atypical in the broader field of science communication (there is a ready, supportive and enthusiastic public, which is not the case for numerous other sciences), the methods of gathering data and feedback which inform ESA/Hubble's work are broadly applicable.

ESA/Hubble's outreach straddles several different forms of communication — interaction with the media (which inevitably takes a top-down approach), direct communication with the public via information and videos on the web (similarly top-down), and a growing effort to engage with audiences-as-stakeholders via blogs and social media (a bottom-up approach). In this respect, ESA/Hubble bridges the divide between the traditional "public understanding of science" models of science communication and contemporary "public engagement with science" models. As such, its operations could be of broad interest in the science communication community.

The Hubble Space Telescope is a programme of international co-operation between NASA and the European Space Agency (ESA). Since 1999, the well-established and highly successful Office of Public Outreach (OPO) at NASA's Space Telescope Science Institute has been complemented by a European outreach office, ESA/Hubble, based at the European Southern Observatory (ESO) in Germany. While there is extensive cooperation between OPO and ESA/Hubble, they remain quite separate operations.

Outreach for ESA/Hubble takes a number of forms. The primary channels are press releases (both of new science results and of newly processed images), the spacetelescope.org website (which is updated several times a week with pictures, news and videos), video podcasts, and engagement with the community via social networks. Due to the complexity of the information flow in modern day society, the dividing lines between these are of course not always clear-cut — press releases are read by the public on our website; videos from our podcasts are widely used by broadcasters; social media reach opinion leaders and journalists.

Different types of communication have to be assessed in different ways, and it's important to understand that it is not an exact science. The purpose of monitoring output is not to write up the results in a scientific journal, but rather to inform and direct the work of the organisation towards what is most effective. The impact of a web page can easily be measured through visitor numbers, while a video podcast which is shared and re-posted virally is much harder to assess — this is not a weakness, but simply a recognition that we have to do our job with imperfect information at our disposal. Nevertheless, with this broad range of indicative data we can get a good handle on what works and what doesn't.

Effectiveness

Monitoring the effectiveness of the ESA/Hubble website[2] using Google Analytics is arguably the most straightforward element of our evaluation strategy (which is just one part of the larger departmental strategy). This gives a wealth of information, not just about reader numbers for individual pages but also on the paths readers take through the website, geographical location, technical info, and many other metrics. As would be expected, the readership fluctuates considerably depending on how much Hubble appears in the news, but there is a constant baseline thanks to the sizeable archive of news stories, images and videos. Note that the materials on the site are made available for reproduction with very open licensing conditions (Creative Commons 3.0 Attribution), which encourages dissemination of Hubble science and images to a wide audience, but inevitably makes any analysis of how broadly it is used incomplete. In 2010, we ran a competition asking members of the public to identify cases of Hubble imagery in popular culture, which brought many to

Figure 1. The Hubblecast, presented by Dr Joe Liske (aka Dr J) is one of the most popular science vodcasts on iTunes. It is also widely shared on YouTube, where success is harder to quantify. Credit: ESA/Hubble.

our attention, but this was only scratching the surface.

We monitor the impact of press releases both quantitatively and qualitatively. The quantitative approach is essentially bibliometric — the number of times a story's keywords appear in Meltwater, an online news monitoring service (this figure, although admittedly only a small part of the total media coverage, is our proxy for how many times a story has been picked up in the media); combined with page views on our website as measured by Google Analytics (a proxy for public interest); and hits in Eurekalert, a science press release service (a proxy for journalists' interest in a story).

These figures vary considerably between press releases, and the impact is not necessarily immediate or predictable. While interest typically peaks in the few days following a release date, it can sometimes have a second burst of life — we are regularly contacted by people who use images in commercial products, TV programmes, books, etc, years after they are first published. A broad approach combining qualitative and even anecdotal evidence with quantitative data helps see this broader picture.

Press releases vary in their immediate impact too — certain "sexy topics" (exoplanets, black holes, record holders such as most distant galaxies or most massive stars) are naturally more media-friendly than others (such as cosmology). Pictures and illustrations, of course, help a great deal, particularly in the general interest press — we have a small team of graphic designers and image processing experts to provide world-class visuals with our press releases. But regardless of how good a press release is and how well processed the graphics are, some topics will inevitably have a bigger or smaller impact than others simply because of how intrinsically interesting they are. In general our experience shows that the most important and intrinsically interesting stories or images make the press releases with the most impact and penetration.

Qualitative monitoring of press release impacts is by its nature less complete, but it gives a complementary view of press coverage. We use Meltwater's online news and monitoring of magazines and newspapers in print to build up a library of press clippings. This serves as an archive — a form of feedback on the effectiveness of our press releases.

Since 2007, ESA/Hubble has produced the Hubblecast, one of the first HD video podcasts (see Christensen & Hurt, 2008). It has since established itself as one of the most popular sources of audiovisual science

Figure 2. The Hubble website, spacetelescope.org. Google Analytics produces detailed statistics about readership, traffic sources and popularity of content. Credit: ESA/Hubble.

news on the internet. Each issue focuses on a single topic, for example a new discovery, or a presentation of Hubble observations of a particular object, or a certain type of observation. To use some science communication buzzwords, they cover both downstream (scientific results, observations) and upstream (methods, technology, etc) topics.

Hubblecasts are distributed through the iTunes store and on dozens of video sharing websites including YouTube and Vimeo. Rankings from iTunes are easy to get hold of — the software offers a "most popular" selection both for podcast series and for individual podcast episodes in any of the store's subject areas. Hubblecast HD is consistently in the top ten video podcast series in the science and medicine category in the UK, US and Germany, alongside Hidden Universe, the Spitzer Space Telescope's official podcast, PBS Nova and NASAcast. Note that these statistics are for the 720p HD version of the Hubblecast alone — our standard definition and 1080p Full HD videos are listed separately and do not count towards Hubblecast HD's rankings. These also perform well, with the Full HD edition frequently in the top ten too. This means the true position of the Hubblecast (all versions combined) is higher than it appears — it may be the most popular science video podcast in the world — but impossible to measure quantitatively since iTunes provides only relative rankings rather than absolute viewing figures.

Charts of individual episodes are obviously more volatile and we do not keep a regular tab on these — *ad hoc* checks suggest we frequently have episodes in the top ten, but not always. We have elected not to monitor these charts systematically; there are simply too many variables at work. Nonetheless, anecdotal evidence suggests that, if anything, our longer episodes (six to ten minutes) are more popular than the shorter ones (three to five minutes). Dire warnings of the short attention spans of internet users seem not to be justified in this case.

While these iTunes statistics give an idea of how successful our video podcasts are relative to other comparable ones, they don't offer any absolute numbers. While we can, in principle, track subscribers to the podcast (both those who subscribe through iTunes and those who do so directly from spacetelescope.org) via Google Feedburner, it is in fact very hard to gain any meaningful insight from these figures. Our total of around 30 000 subscribers is based on the number of users whose client software checks our feed every day, which is not a particularly useful number. More meaningful, but still problematic, is Feedburner's measurement of "reach" — the number of downloads initiated per day through the feed. This figure of around 2500 per day is more useful, but a small caveat needs to be mentioned: subscribing to a podcast in software like iTunes automatically downloads new episodes regardless of whether they are ever watched.

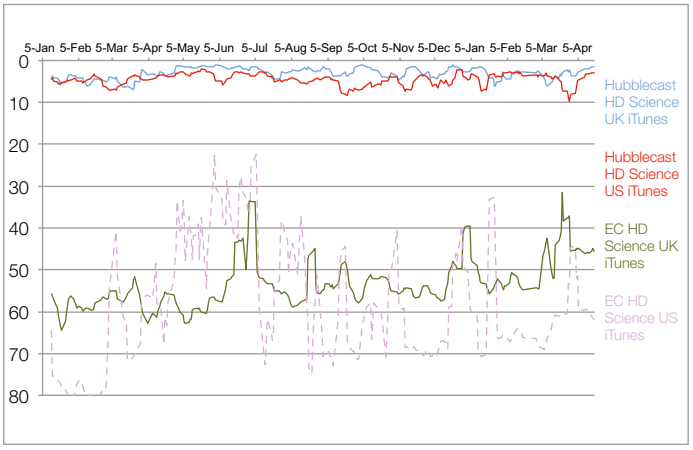

Figure 3. This graph shows the five day rolling average position of the HD edition of the Hubblecast, in the US and UK stores. Equivalent figures for the ESOcast are included for context. Credit: ESA/Hubble.

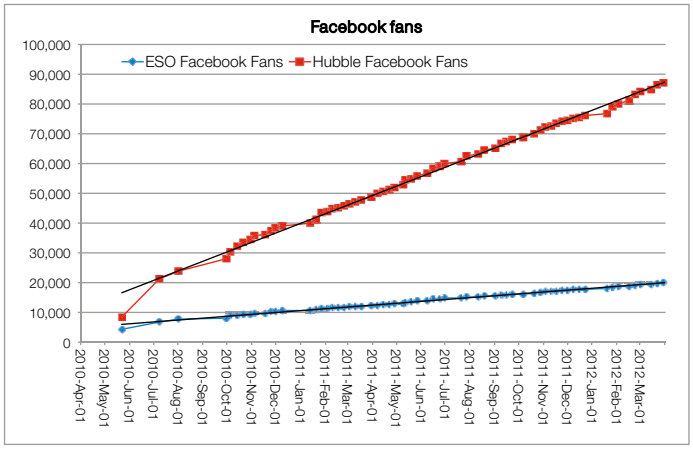

Figure 4. This graph shows the progression in Facebook fans for Hubble since January 2010. Equivalent figures for ESO are included for context. Credit: The authors.

Performance of the Hubblecast on YouTube can give a clearer idea of public reception than subscriber or download statistics — partly through viewing figures, which are publicly available, but also through user comments. Here again, though, our copyright policy, which is such a help at disseminating Hubble science and images, is a hindrance to evaluating precisely the success of our science communication strategies: the vast majority of views of Hubblecasts on YouTube are actually not through the official channel at youtube.com/hubbleesa, but through users who legally upload the video to their own accounts and share the videos themselves.

It is quite common for these re-uploaded videos each to have hundreds of thousands of views and hundreds of user comments. While the quality of user comments on YouTube is far from being legendary, it can at least give some idea of public interest and appreciation.

The complex interaction with users, as well as instant (if ambiguous or throwaway) feedback on YouTube is typical of the fourth major aspect of Hubble outreach (after press work, web content and audiovisual) — community interaction, primarily through social media. This is the primary mechanism for public dialogue in our outreach operations, ensuring that we carry out best practice in science communication.

Engaging with online communities has rapidly grown into one of ESA/Hubble's main outreach methods in recent years: the social media are experiencing an explosion in their journey from new media to mainstream media. Social media have opened a door for science communicators into a fascinating territory — one where "the public" is made up of individuals with personal opinions, ideas and preferences that make them opinion leaders in their own online community. Each individual connects with hundreds of other individuals and creates their own sphere of influence. It is in this complex landscape that information spreads, traveling from one group to another. The power of socially fuelled word of mouth is incredible, but also incredibly hard to monitor.

The main channels ESA/Hubble uses to engage with its online communities are Facebook and Twitter. We also use YouTube and Vimeo for sharing our videos and Flickr for our photos, but most of the interaction between ESA/Hubble and its community happens on the ESA/Hubble Facebook Fan Page and on its Twitter feed.

We use both channels for two main purposes

Firstly, we share all our scientific results and images, drawing more attention to our science and photo releases and we also promote our Pictures of the Week and Hubblecast episodes when they are published. This helps us to communicate our output to the online community and directs them to where they can find further information. Social media messages have to be concise and appealing, so these channels are not suitable for explaining science — they serve instead to stimulate interest, engagement and curiosity. There's only a limited amount of information that can fit into fewer than 140 characters!

Secondly, in addition to disseminating information we also try to encourage people to engage in a dialogue with other Hubble and astronomy fans. This makes people more enthusiastic about our discoveries so that they want to learn more, and also share the information with their friends. Our goal is to transform passive consumers of information into active, engaged ambassadors in their own online communities, helping us take Hubble from one sphere to another in this vast social universe. This enthusiastic and engaged audience can be used to feed back into other areas of our work: for instance, requests and questions from our fans on Facebook and Twitter formed the basis of the 50th episode of the Hubblecast, which took the form of a question and answer session.

The potential of viral information is enormous and hard to keep track of, but not completely obscure. Even if the impact of social media is hard to grasp, there are still a number of indicators that tell us whether our input has brought results and how many resources we should continue to invest in social media.

For our Facebook page we do a quantitative evaluation that focuses on the number of fans we have. This number has been constantly growing — to more than 75 000 at the time of writing (December 2011), which makes ESA/Hubble the most popular Facebook page among astronomical observatories.

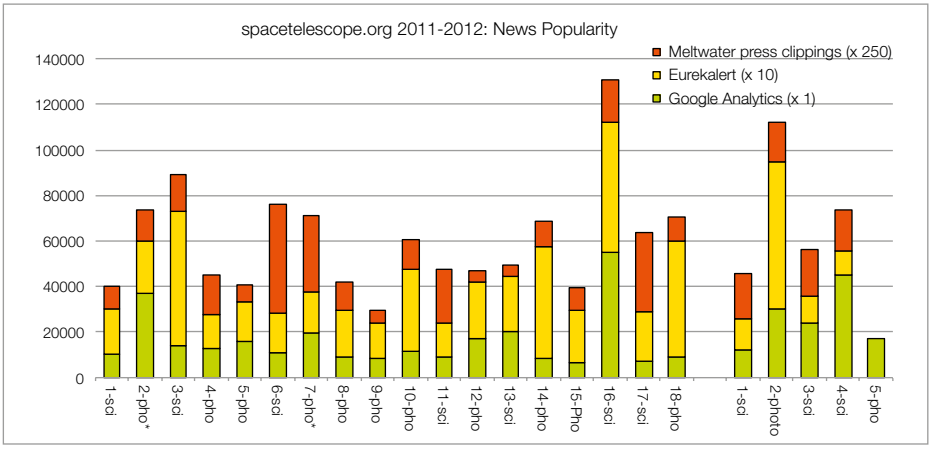

Figure 5. Popularity of the news releases published 2011 and 2012 on spacetelescope.org. The news releases are identified by their release number and type. Credit: The authors.

However, since everything we post on our page is publicly available to everyone, not only to our fans, people do not necessarily have to "Like" our page in order to see the contents. For this reason, there are several more relevant indicators that show some very impressive numbers. Facebook offers page administrators a service called Insights, which provides interesting statistics.

In November 2011 we had 1.25 million post views — the number of times people have viewed a news feed story — which is almost twice the number of website pageviews for that month. A narrower view of user interaction is the number of people who have commented on, liked or shared one of our posts, which gives a more modest figure of around 10 000 per month.

Another interesting factor to take into account is that if we look at Google Analytics we see that among traffic sources, Facebook is number two in most months, right after Google's search engine. This means that we have a large community reading our news on Facebook and many of these people go on to look at our website. This number varies a lot, depending on factors such as the topic of the story, the day or the hour when it was posted. Luckily, it is possible to drill down in these statistics and see which posts have had the most views and thus which topics are of more interest for fans.

Facebook also collects data about the gender and age of Facebook friends, as well as the countries and cities where the accounts are most popular, which can be an important variable if it's necessary to justify a local impact.

In the case of Twitter, evaluation is even harder because the platform does not have a well-established monitoring service. Until recently, all we could do was to keep track of the number of followers (around 6000 as of December 2011) which shows a steady increase over time. We then looked at Google Analytics and saw that Twitter was also bringing more and more people to the website, which was reason enough to believe that we were reaching and engaging with more Twitter users. However, we had no other data and we could not analyse what worked best.

In spring 2011, HootSuite, a software platform used to manage social media accounts launched an evaluation tool that generates reports on individual account activity and its impact. As we gather data from this, we should be able to gain new insights and spot new trends in our social media use.

Conclusions

Analysing the success of outreach efforts is not a simple matter of clean, unambiguous statistics. It relies on educated guesses and common sense too, because we function with an imperfect dataset.

However the purpose of evaluating scientific outreach is not to come up with detailed, accurate statistics which can be published, but rather to assess whether what we do actually works. Effective evaluation holds a paradoxical position, in that it should be both tightly integrated with science communication work, and clearly secondary to it. If there is one thing worse than not measuring output at all, it is to cripple the output (for example by enforcing strict copyright terms) in the name of measuring it properly.

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[2] www.spacetelescope.org

Biographies

Oli Usher studied History and Philosophy of Science at University College London and the University of Cambridge, and has written widely about science, technology and their place in society. At Cambridge, he became interested in science communication when he studied how flawed government decisions about how to communicate scientific information led to public mistrust of medical science. Before coming to ESO, he worked as a journalist, writing science stories for a range of publications in print and online, including *The Guardian* and the London-based political magazine *Tribune*.

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.wordpress.com. To get in touch with Oana you can connect on Twitter (twitter.com/oanasandu) or Facebook (facebook.com/oana.sandu).

Lars Lindberg Christensen is a science communication specialist heading 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 (the largest optical telescope in planning), for ESA's part of the Hubble Space Telescope and for the International Astronomical Union Press Office. Lars has more than 100 publications to his credit, most of them in popular science communication and in its theory.

Santa and the Moon

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Keywords
Books, Moon Phases, Christmas

Summary

This article reflects on the use of illustrations of the Moon in images of Santa Claus, on Christmas gift-wrapping paper and in children's books, in two countries which have been important in shaping the image of Santa Claus and his predecessor *Sinterklaas*: the USA and the Netherlands. The appearance of the Moon in Halloween illustrations is also considered. The lack of either knowledge concerning the physical origin of the Moon's phases, or interest in understanding them, is found to be widespread in the Netherlands, but is also clearly present in the USA, and is quite possibly global. Certainly incomplete, but surely representative, lists that compile occurrences of both scientifically correct and scientifically incorrect gift-wrapping paper and children's books are also presented.

Introduction

Images of the Moon are often used to indicate an evening or night scene, not only as illustrations in books (for adults and children), but also on product packaging, brochures, greetings cards, gift-wrapping paper, in advertising, commercials, as pictograms, etc. A full Moon is often used, partly hidden behind trees or clouds, but a partially lit Moon — half or crescent — also frequently appears. The latter case leaves no doubt as to an image's identification with the Moon; a full Moon could possibly be mistaken for the Sun. There are two ways of depicting a partially lit Moon: around its first and its last quarters. A crescent Moon, on its way towards first quarter is called a waxing Moon, and such a waxing Moon can be observed in the afternoon twilight and in the evening. Its right hand side is illuminated, for observers in the northern hemisphere (left for observers in the south). The first quarter Moon sets at midnight, a waxing Moon even earlier. A waning crescent Moon (from third quarter to new Moon: left hand side illuminated) rises around 3 am, hence can only be observed late at night and in the morning twilight. The full Moon is directly opposite the Sun in the sky, and hence rises at sunset.

Moon illustrations are occasionally incorrect. There are postcards showing artist's impressions of tropical evenings with both the Sun and the full Moon close to each other. Full Moons sometimes rise around midnight in movie scenes. Illustrations which show Moon crescents are also occasionally wrong: third quarter Moons or waning crescents are depicted when the actual scene is in the evening. A 2010 UNICEF Christmas card as well as the opening scene in the 2010 Jacquie Lawson animated Advent e-Calendar — both widely sold items — provided the culmination of several years of frowning (and smiling) about this misconception or ignorance, and triggered the research presented below. The UNICEF card, of British design[1], shows children decorating an outdoor Christmas tree. Judging from the Moon phase, the scene takes place at 4 am or 5 am in the morning, which is not impossible but unlikely. The village scene that opened the 2010 Jacquie Lawson[2] digital Advent Calendar depicts a Christmas carol concert, sung in the village square. Whereas the thin waning Moon indicates an early morning event, the artist undoubtedly wants to show us an early evening scene, judging from the people on the square and the lights in the houses, shops and the church. It is just about possible that both artists intended to create Australian scenes with reversed Moon phases, but the presence of snow in both scenes is strongly suggestive of the northern hemisphere in December.... The same misunderstanding is frequently seen on gift-wrapping paper in the Netherlands, displaying *Sinterklaas*, the predecessor of Santa Claus, distributing presents in the evening with a third quarter or waning Moon in the sky.

To quantify the level of ignorance concerning the phase of the evening Moon related to the *Sinterklaas*, Santa Claus and the Christmas season, a (jolly) research project was conducted, examining illustrations in children's books, on gift-wrapping paper, and on Christmas cards, both in the USA and in the Netherlands. These are the two countries that have shaped the image of Santa Claus and his name-giver *Sinterklaas* (Saint Nicholas, Sint Nicolaas), the benevolent figures who have been of key importance in commercialising the December holiday season. The goal of publishing this research is obviously to focus educators' attention on a great opportunity to explain the (origin of the) Moon's phases, as offered by these happy end-of-year events. The need for such education has been, for instance, well demonstrated by the video *A Private Universe*[3].

Theoretical background

The *Sinterklaas* and Santa Claus stories are well known and date back to the fourth century bishop Nicholas of Myra (now Demre, in southern Turkey). Legends of his generosity and kindness spread over Europe and he became the patron saint of many groups, cities, and even countries. The 5 December, the eve of his death, was commemorated with an annual feast in many European countries. Following the Protestant Reformation in the sixteenth century, some countries merged the

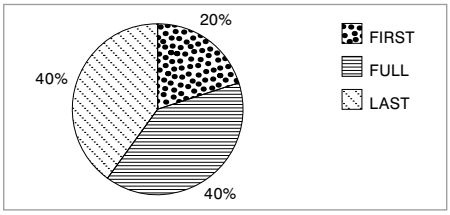

Figure 1. Book statistics from the Netherlands.

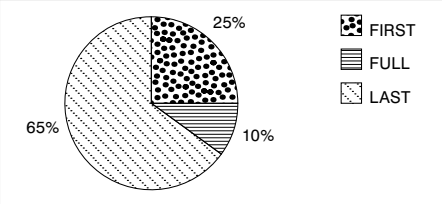

Figure 2. Wrapping paper statistics from the Netherlands.

Figure 3. Scientifically correct Sinterklaas gift-wrapping paper. Credit: Keyzer Co., Wormerveer, The Netherlands: type 090011 (reproduced with permission).

St. Nicholas celebration with Christmas, but others stuck to 5 December. The characteristic features of benevolence and the exchange of gifts obviously hark back to legends around St. Nicholas. Local folklore was added, which resulted in different flavours for the celebrations in various countries. Dutch settlers in the New World celebrated St. Nicholas' Eve in the 17th century, and those celebrations evolved through contacts with immigrants of other nationalities. Concerning the transformation to Santa Claus, the importance of the author Washington Irving in 1809 and of the 1823 poem *A visit from Saint Nicholas*, commonly known as *The night before Christmas*[4], is well documented, as are the drawings of Thomas Nast in the 1860s and the Coca Cola advertisements in the 1930s (e.g., Jones, 1978; Crichton, 1987; and www.stnicholascenter.org).

The Dutch *Sinterklaas* together, with his helpers, is believed to distribute his presents on the evening of 5 December. He may also pay visits during the evenings and nights before 5 December, leaving some candy in shoes set before the fireplace, but the main event is the evening of the 5th. Once delivered, the presents are unwrapped during that same evening. Scenes depicting the 5 December *Sinterklaas* events should depict waxing, first quarter or full Moon (or no Moon) to be scientifically correct.

On Christmas Eve Santa Claus works through the night of 24–25 December to get his job done: the gifts are unwrapped on Christmas morning. If a Moon is shown in a Santa scene that takes place at the beginning of the night, its phase should be waxing, quarter or full, otherwise it can have any phase. The poem, *A visit from Saint Nicholas*, has the father witnessing Santa's arrival before going to bed, and thus in the evening. The Moon "on the breast of the new fallen snow" must have been a waxing, first quarter, or full Moon to be scientifically correct.

In summary, illustrations should preferentially show first quarter or full Moons on *Sinterklaas* or Santa Claus scenes, unless it is clear from the text that Santa's job is nearly done (i.e. he has a nearly empty sleigh...) Any winter evening scene in general, and certainly those having children around, should have a first quarter or full Moon, if the artist wants to show one.

Measurements and results

December events

All data were obtained in the months November 2010–January 2011, and can be found compiled in Tables I through IV, which are available online[5]. In the Netherlands, two dozen book stores and department stores were visited, during November–December 2010. Book illustrations depicting *Sinterklaas* and the Moon were examined, with regard to the Moon phase. Twenty-five images selected from 25 books (Table I) provide the pie chart statistic as shown in Figure 1. It is seen that 40% of the pictures display the last quarter Moon, which is incorrect.

The Netherlands wrapping paper analysis (20 different designs, from various firms, department stores and book stores) indicates an even higher level of misunderstanding. The chart in Figure 2 indicates a 65% occurrence of the incorrect last quarter or waning Moon. There is no reason to believe that this statistic is not representative, because examination of a collector's sample of older *Sinterklaas* gift wrap[6] yields the comparable figure of 67% (six out of nine Moon designs incorrect).

It must be concluded that the Dutch are often wrong, both on wrapping paper and in book illustrations; and more often so in the former case. Figure 3 nevertheless presents an example of nice wrapping paper with a correct waxing evening Moon.

The US research was carried out during November 2010–January 2011, in New England and in Los Angeles: also here roughly two dozen book stores, stationery stores, pharmacies and department stores were visited. In addition, samples of commercially available wrapping paper and Christmas cards were inspected on the internet. Thirty-three Moon scene images selected from 30 different books (Table III) provide the pie chart statistic as shown in Figure 4. It is clear that most of the time (70%) a full Moon is drawn, but it should be noted that 17 of the 30 inspected books were renditions by various illustrators of the poem *A visit from Saint Nicholas*. Inspection of illustrated editions of this poem[7] from the 19th and early 20th century indicates that the full Moon is indeed shown very frequently, throughout the lifetime of this poem. Whereas the text does not explicitly mention the full Moon, that Moon phase may have become implicitly "attached" to its lines over the years: the full Moon moreover provides a nice background for sleigh and reindeer.... Nevertheless, in several American books an incorrect waning or third quarter Moon is seen accompanying stories involving children in evening scenes, or illustrating Santa with a full sleigh, i.e., at the beginning of a night's work. The booklet, *The Night before Christmas in California* (Smith & Egan, 1992) displays two different Moons (full and waning) during one and the same evening....

With only a few exceptions, wrapping paper and Christmas cards sold in the USA (book

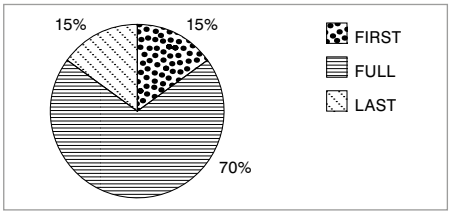

Figure 4. USA book statistics.

stores, general and department stores, stationery stores and pharmacies: single cards and boxed sets) were found to display full Moons, with or without Santa. The UNICEF card referred to in the Introduction represents one of the incorrect cases. Also a 2010 Holiday Delices set (cookies), sold by a famous (Fifth Avenue) department store, was found displaying a last quarter Moon at the beginning of a night of hard work by Santa and his crew. It must be concluded that the Americans are occasionally wrong, but not as frequently as the Dutch.

Other events

Other relevant happy outdoor evening events include Trick-or-treat (Halloween, the eve of Old Hallows) and Sint Maarten (Saint Martin), widely celebrated each year respectively in the USA, the UK, and Canada (31 October) and the Netherlands, Belgium, France, and Germany (11 November). Often carrying lanterns and costumed, children go from home to home, begging for candy or money. Short songs about Sint Maarten are performed, whereas trick-or-treat is obviously accompanied by an innocent threat to the home owner's property. Given that these are early evening activities, then any Moon depicted should be waxing, first quarter, or full. With reference to Table IV, inspection of eleven American trick-or-treat books indicated five cases (45%) of an incorrect last quarter Moon, one first quarter, and five full Moons. Three Dutch books dealing with Sint Maarten all showed the incorrect last quarter Moon. Two of these, however, were translations from German and Swiss editions: it is conceivable that the misunderstanding or lack of knowledge is global.

Finally, the well known classic children's book *Goodnight Moon* (Brown & Hurd, 1947) displays a correct full (evening) Moon, while the various Moon phases are also correctly dealt with in the classic *Moon Man* (Ungerer, 1967). On a last note, however, several titles in the Good Night Our World boardbook series (www.goodnightourworld.com), where children say goodnight to their city or region, display incorrect waning moons.

Discussion

We have established that illustrators and designers draw Moons *ad libitum*, according to their taste, but that these illustrations are often astronomically incorrect. The most common mistake is to show the early morning waning Moon in an evening scene. Our research focussed on *Sinterklaas*, Santa Claus, and Christmas scenes, with a short side trip to Sint Maarten and Halloween. The apparent lack of knowledge concerning the physics of the Moon phases is most likely widespread and not just limited to the countries examined here. Further investigations are however outside the scope of the present research. We note in passing that also the psyche could play a role: people may for instance be more inclined to draw Moon crescents which are open to the right, i.e. northern hemisphere waning Moons.

Naturally, the question arises: so what, who cares? The errors are innocent, somewhat comparable to incorrectly drawn rainbows, with the red colour at the inside of the arc. Now, watching beautiful natural phenomena like rainbows and Moon crescents is one thing, but understanding them makes them a whole lot more interesting. Moreover, understanding leads to knowledge which lasts. A tiny bit of insight, leading to the conclusion that the full Moon, being opposite the Sun, rises when the Sun sets and sets when the Sun rises, so that first quarter Moon, being at ~90 degrees, sets around midnight, and that last quarter Moon, at ~270 degrees, rises around that time, is required to avoid making the reported mistakes. The Halloween, Sint Maarten, *Sinterklaas*, and Santa Claus settings provide wonderful opportunities for Moon phase education[8], through simple naked eye observations. If this paper stimulates that education and leads to improved understanding, we would all be pleased. "You better watch out" is often heard in the December month: it should also be taken literally....

Acknowledgements

The author acknowledges useful comments on the manuscript by Drs Andrew Fraknoi, Bob Sanders, Scott Trager, Piet van der Kruit, Gijs Verdoes Kleijn, and particularly three unknown referees.

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[4] The widely known poem, with credit to Clement Clarke Moore, can be found for instance on http://poets.org/viewmedia.php/prmMID/19286 (retrieved 7 January 2012). The site http://rpo.library.utoronto.ca/poem/1312.html (retrieved 7 January 2012) attributes it to Henry Livingston, Jr., following research published in 2000 by Donald Foster. A critical assessment of the authorship case can be read on http://www.common-place.org/vol-01/no-02/moore/ (retrieved 7 January 2012

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[7] http://www.iment.com/maida/familytree/henry/illos/editions/index.htm

[8] Useful Moon phase education webpages are maintained by NASA and by NOAO: http://www.jpl.nasa.gov/education/index.cfm?page=123(retrieved 7 January 2012) and http://www.noao.edu/education/phases(retrieved 7 January 2012). Excellent moon phase activities can be found on http://www.dennisschatz.org/activities.html

Biography

Peter Barthel is astronomy professor at the Kapteyn Institute, University of Groningen in the Netherlands. In 2008, together with his team, he won the national Dutch science communication contest. Since the International Year of Astronomy 2009 he has been collaborating with the professional pianists Elies van der Heiden and Siebert Nix in the project *Keys to the Stars*, merging astronomy and music.

Astronomy Outreach in the Remote Mid West Region of Western Australia

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Keywords
Radio Astronomy, Square Kilometre Array, Outreach

Summary

The Square Kilometre Array is a global mega-science project to build the world's largest radio telescope. One of two shortlisted locations for the telescope is Western Australia's Mid West region, a geologically stable area with a very low population density making it an ideal location for sensitive radio telescopes. It is vital that the local population, although small, is aware of the project and the impact it will have on the region, so outreach in the local communities is imperative. Over the last few years, many trips have been made to the Mid West with the aim of bringing astronomy to the local population. While outreach in such remote areas brings its own unique challenges, it is every bit as worthwhile as in more traditional locations.

The Square Kilometre Array

A thorough understanding of the physics of the Universe often requires information across much of the electromagnetic spectrum, not just what can be gleaned from visible light with the type of telescopes that the public may be familiar with. Radio astronomy has many important applications and is an essential tool in many diverse fields of astrophysics. At the low energy end of the spectrum, radio waves can penetrate the thick, dusty regions often found in the discs of active galaxies for example, providing vital information on star formation processes and gas dynamics that would be very difficult, if not impossible, to obtain by any other means.

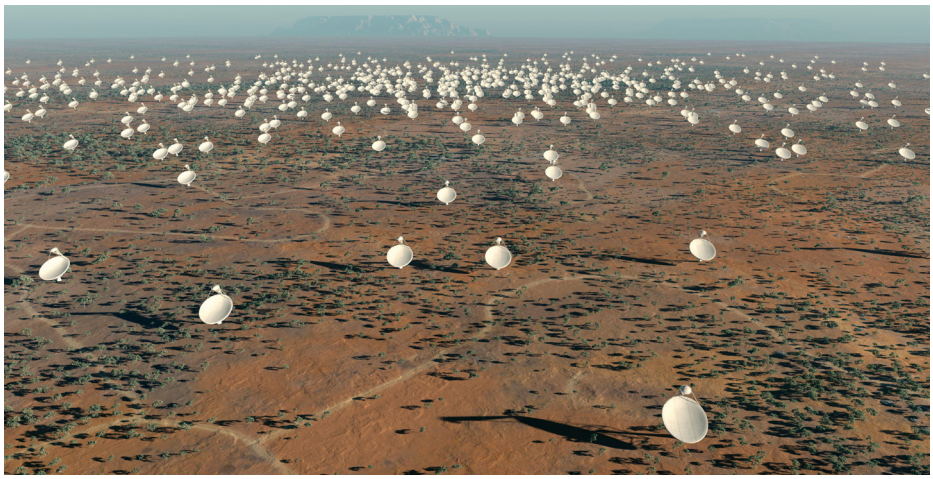

Figure 1. *Artist's impression of what part of the completed SKA might look like. Credit: SPDO/TDP/DRAO/ Swinburne Astronomy Productions.*

While there are numerous radio telescopes scattered around the planet, the Square Kilometre Array (SKA)[1] will be the most ambitious array of telescopes ever constructed. Radio astronomy is primed to help answer some of the big questions in astronomy, and SKA will provide a huge step forward in capabilities. SKA will address five fundamental unanswered questions about our Universe:

- Testing the predictions of general relativity — was Einstein right?
- How were the first black holes and stars formed?
- How do galaxies evolve?
- What generates galactic-scale magnetic fields?
- Are we alone?

Composed of three different types of antennas, the array will operate between 70 MHz and 10 GHz (wavelengths between 4 metres and 3 centimetres) and will have 50 times the sensitivity and 10 000 times the survey speed of any current radio telescope. A large fraction of the antennas will be located in a central core area, but remote stations will also be located across an area the size of a continent. Figure 1 shows an artist's impression of what part of the array might look like when complete.

Any large telescope should be built in the best possible location to maximise the science output. Just as optical telescopes are severely hampered by light pollution, radio telescopes are very sensitive to interference from manmade sources such as radio and television transmissions, mobile phones and pagers, and numerous other modern technologies which generate radio waves as a byproduct of their operation. There are two locations shortlisted to host SKA: southern Africa, and Australia/ New Zealand. Both candidate core sites (Western Australia's Mid West, and the Karoo region of South Africa) have relatively low population densities, and hence low levels of manmade interference, and already host precursor telescopes which are currently under construction. As well as performing exciting new science, these precursors will act as testbed instruments,

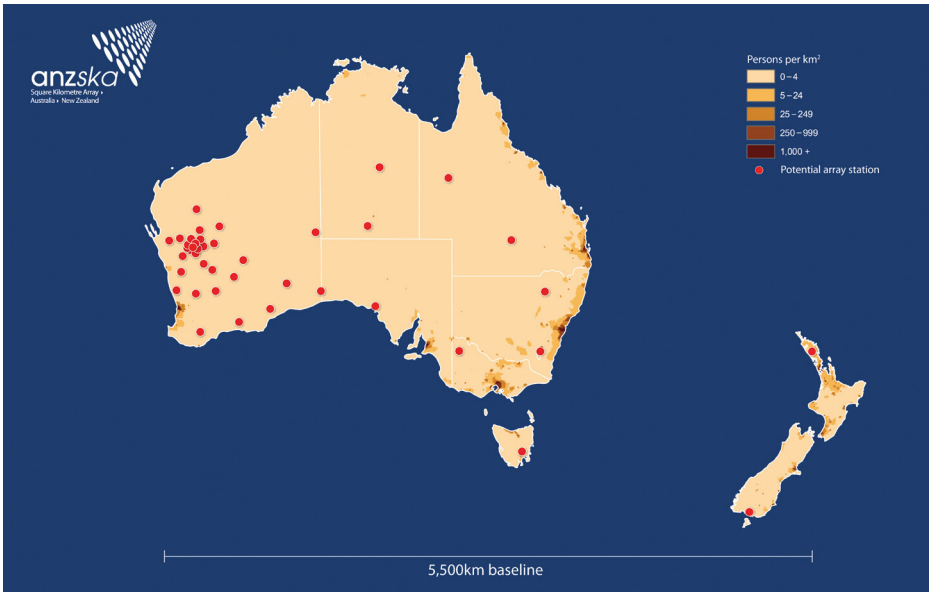

Figure 2. Potential SKA array station placement in Australia and New Zealand overlaid on a population density map. Credit: CSIRO.

proving new technologies for the full SKA. The final site decision will be made in 2012, construction is scheduled to begin in 2016, and the first astronomical observations with SKA should be carried out in 2020.

The Mid West region

The Australian/New Zealand candidate site for the core of SKA is located in the Mid West region of Western Australia (see Figure 2) and is home to the Murchison Radio-astronomy Observatory (MRO) where several telescopes are already under construction, including the Australian SKA Pathfinder (ASKAP) and the Murchison Wide-field Array (MWA). Centred on Boolardy station, a pastoral station 200 kilometres west-south-west of the small town of Meekatharra, the MRO covers a circular area 70 kilometres in diameter.

The Mid West region stretches from the west coast inland to the Gibson Desert. Covering an area of 472 336 square kilometres, the region has a population[2] of 51 748 or 0.1 people/sq km, more than 65% of whom live in the town of Geraldton on the coast. The remainder live in small communities scattered throughout the region, or on homesteads in pastoral areas accessible only by unsealed dirt roads. The shire of Murchison itself, within which the MRO is located, is the only shire in Australia without a gazetted town. The shire is approximately 50 000 square kilometres in size and contains 29 pastoral stations with a total population of approximately 160 people. The main industries in the region are mining, agriculture, fishing and tourism.

There are many communities and more than 30 schools in the Mid West region, six of which are classified as remote by the Australian Department of Education and Training. Often the population is largely Aboriginal, especially in the remote communities where schools must cater for a wide range of ages and abilities in just one or two classrooms. In contrast, many of the primary-age children living on pastoral homesteads would have to travel many hundreds of kilometres to reach their nearest school and so are enrolled in a School of the Air where their lessons are largely delivered to them interactively over the internet. Secondary-age children from pastoral stations normally attend high schools in Perth or in regional towns as boarders.

School and community visits

Over the last few years numerous outreach field trips have been undertaken in the region by staff from both the International Centre for Radio Astronomy Research (ICRAR) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Due to the distances and logistics involved in such excursions, many of them are planned so that several locations can be visited in a single trip. Recent visits have included the communities of Pia Wadjarri, Yalgoo and Yulga Jinna, and the towns of Meekatharra and Cue. Some of these are remote Aboriginal communities, but primary and district high schools in the larger settlements of the Mid West have also been included. Outreach initiatives have also included schools in the larger town of Geraldton, including professional development workshops for local and regional teachers.

Events have also been organised for both Meekatharra and Carnarvon Schools of the Air. Children attending such schools spend most of their time on their home station receiving lessons from teachers via the internet, but regular school camps are held where all the pupils get together in one location for a week or more of activities, and astronomical viewing nights have been held during such camps.

In addition to specific outreach in schools, these visits have engaged the wider community in the region. Public viewing nights are often held following a day of activities within a school, usually on a nearby oval. These are community events with entire families attending and a friendly social atmosphere. Not only is the region an excellent location for radio telescopes due to the low levels of radio interference, the low population density and small number of settlements mean that there is also very little light pollution, making the night sky especially dark.

Projects

In addition to school and community visits, other significant outreach projects have been carried out in the region over the past few years. In 2006–2007 CSIRO's Wildflowers In the Sky involved numerous school visits by professional astronomy educators and astronomers, providing telescopes and training for local teachers. Thanks to this initiative, many of the community schools in the shire of Murchison own simple Dobsonian telescopes. A component of this project involved public viewing nights in each of the towns and communities. Follow-up visits since the project ended have sustained interest and awareness.

One highly successful project was Ilgarijiri, a collaboration between local indige-

nous artists from the Mid West region and astronomers from the ICRAR in Perth, carried out as part of the International Year of Astronomy 2009. Following a tour of the MRO and a cultural exchange around a campfire at Boolardy station, the artists created more than eighty pieces of unique Aboriginal art for an exhibition that toured Australia during 2009. The title of the exhibition, *Ilgarijiri* is a word in the local Wadjarri-Yamatji language meaning "things belonging to the sky".

In 2010 a project was carried out with the Carnarvon School of the Air under the Universe Awareness (UNAWE) banner as part of the International SKA Forum held in the Netherlands. The aim was to link up a primary school in each of the SKA candidate areas with a school in the Netherlands and give the students the chance to talk to each other and learn about other countries and cultures, as well as finding out about the radio telescopes being built in their respective countries. The link took place via the internet in May 2010 and was filmed for a short video which was distributed to participants at the SKA Forum in June. The project also resulted in the distribution of Earth balls and teaching materials to a large number of schools in all three countries.

Challenges

Due to the wide geographical spread of schools and the nature of outback travel, tours in the region require both careful planning and flexibility. Off-road vehicles are required to reach many of the communities, even in good conditions, and a satellite phone is necessary for emergency communication due to lack of mobile coverage (one factor which makes the area such a radio-quiet zone, ideal for placing a sensitive radio telescope!). Supplies of food and water need to be carried in case of emergency; in the event of a breakdown it can be many hours before help arrives. In summer, temperatures routinely reach more than 40 degrees Celsius, and in the wet season the roads can flood, making them impassable and cutting off communities for weeks at a time.

All schools in the region are generally well-resourced and all have internet access via satellite, but there are various issues. Due to the often very remote locations, there is a very high turnover of teachers in many schools and a high proportion of newly qualified teachers, very few of whom have any science specialisation. One result of this is that knowledge can leave the community very quickly, and training in the use of telescopes usually has to be carried out on each visit.

There is a high proportion of indigenous students in the region, and most of the pupils in remote schools are Aboriginal. While many of them have a good level of ability in English, they can have different attitudes and knowledge levels to "city" kids. Especially in the smaller remote communities, activities must often be aimed at a mixed group containing children at several different stages of education.

Visits to the region usually include viewing nights for both schools and the wider community. The best telescopes for trips to the area are Dobsonians due to their simplicity; power cannot always be guaranteed at remote locations and the set-up time before an event is often very short, so simple telescopes are a must.

However, not all visits result in successful night-time viewing events. Sometimes the weather fails to cooperate and in such cases it is often possible to do an informal Ask an Astronomer session instead or (if facilities are available) a demonstration of a planetarium program such as Stellarium, and some additional astronomy in the classroom the following day. Daytime activities include using planetarium software, model Solar Systems, solar viewing, and launching water rockets.

Conclusions

Recent outreach in the Mid West has included successful visits to several remote schools and communities with whom good links have been established. These efforts have resulted in an increased local awareness of SKA, the reasons why the Mid West is an ideal location for radio telescopes, and the local impact these projects will have on the region.

For all the difficulties associated with outreach in remote areas, the extra effort is worth it. The local communities are always interested and usually turn out in large numbers to attend viewing nights, and the kids are always curious and full of questions. School ovals provide great locations for viewing nights (although power is usually not available) and due to the lack of light pollution the skies are stunning.

Due to outreach initiatives such as Wildflowers In the Sky, several of the remote communities now have their own optical telescope, although sometimes operational knowledge is lacking due to the high turnover of staff.

Outreach in Western Australia's Mid West region in particular is important both for creating a general awareness of SKA and developments under way at the MRO, and for getting local children interested and aware of the possibilities and jobs that these developments will bring.

Flexibility is vital when conducting outreach in areas such as this. It is always helpful to have a backup plan, and some extra resources and activities, just in case!

Acknowledgements

The outreach efforts described here would not be possible without the organisational support of both CSIRO and ICRAR, and the time and effort of the numerous staff and students who volunteer their time to participate in field trips.

Notes

[1] www.skatelescope.org

[2] As of 2006; source, Mid West Development Commission statistics

Biographies

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Medieval Stars in Melk Abbey

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Keywords
International Year of Astronomy 2009, Lecture Series, Exhibition, Medieval Astronomy

Summary

Melk Abbey, a marvel of European high baroque architecture, is one of the most frequently visited tourist attractions in Austria, attracting 450 000 visitors each year. The monastery's museum presents selected aspects of Benedictine life in Melk since the monastery's foundation in 1089. After the church, the library is the second-most important room in a Benedictine monastery. Due to the wide scientific interests and contacts of the medieval monks, these libraries also contain manuscripts on mathematics, physics and astronomy. In 2009, the International Year of Astronomy (IYA2009), the annual library exhibition was fully dedicated to astronomical manuscripts and early prints from the past 1000 years. Following earlier research work on astronomical manuscripts in Melk's library, we were invited to organise the exhibition. In addition, we also presented a lecture series and provided more background in an accompanying book. Because of positive feedback from the visitors, the exhibition was extended until March 2011. In the two years of its duration, the exhibition was seen by more than 900 000 visitors. In this article, we describe the background to the scientific project, how the exhibition was organised and lessons learned from this project.

Elements of a unique exhibition project

Historical context of the project

One might think of monastic libraries as book collections that only contain theological paperwork. However, after the Council of Nicaea (325) decided on the criteria for the Easter date, astronomy became an important tool in the Middle Ages for computing Easter Sunday and the corresponding feast days. Therefore, some of the oldest books in monastic book collections contain manuals on the so-called *computus ecclesiasticus* (Figure 1).

Figure 1. The first display of the exhibition contained about 3500 years of accumulated history: The books in the lower row are about 550 years old, while the two large-format books were written in the 11th and early 9th centuries. Except for the book in the centre, all deal with variations of the Computus Ecclesiasticus*, the calculation of the date of Easter Sunday. Credit: G. Zotti.*

In the early 15th century, an inner-monastic reform movement, known as the Melk Reform (Bruck-Niederkorn, 1994), was initiated by the Council of Constance (1414–1418) and spread from this abbey to over 40 Benedictine monasteries throughout central Europe. Besides the restoration of monastic values and the economic system, the education of the monks was also a main concern of the reformers. The reform therefore initiated an extension of the spectrum of scientific interest in education and monastery libraries towards the *artes liberales*. These seven subjects, including astronomy and mathematics, were considered to be the general education of a free man, hence the Latin word *liber* for liberal or free. The general level of education in the convent was improved, and gifted novices were sent to study at the University of Vienna. On the other hand, young *Magistri* who had finished their studies of the liberal arts in Vienna were contracted to Melk to teach at the abbey's school. Consequently, the abbey's school, first mentioned in 1140 (and still in existence today), reached its first academic peak in the 15th century. In the reform's new philosophy, the influence of the academic tradition of Nikolaus Seyringer (~1360–1425), who was the reforming abbot of Melk and the former rector of the University of Vienna, is clearly visible. This epoch overlaps with the early phase of the

University of Vienna (founded in 1365), when astronomers such as Johannes von Gmunden (ca. 1380/84–1442), Georg von Peuerbach (1423–1461) and Johann Müller, better known as Regiomontanus (1436–1476), worked. An intensive academic and scientific collaboration between Vienna University and Melk Abbey was established on multiple levels. As a result of these developments, the monks of Melk Abbey collected, among other things, several hundreds of pages of astronomical manuscripts by copying, exchanging duplicates with other monastic libraries or by purchasing. As we will show later, several rare manuscripts were thus preserved from loss throughout the centuries.

Figure 2. Melk Abbey viewed in the evening sun from a hot-air balloon. Below, the historic city centre of the town of Melk can be seen. Melk is the starting point of the Danube landscape known as the Wachau. Credit: M. Rotheneder OSB.

Modular project concept

From the very beginning of our work in the library of Melk, our main concern was not to stack dates and facts onto each other. We saw the exhibition items as witnesses to an evolution of scientific focus and knowledge, thus using them to illustrate this increase in knowledge. Therefore, we conceived the IYA2009 project as time travel through more than 1000 years of history and developments in astronomy, told by documents and items from the library, including the instrument and mineral collections of the Abbey. We offered several ways of exploring the rich historic documents on astronomy at Melk.

A. Exhibition: Historic Astronomy and Austrian Astronomy in 2009

The exhibition was divided into two sections, which formed a continuous timeline from the earliest astronomical manuscripts, dating from as early as the 9th century, focusing on the work of astronomers at the young University of Vienna and observations obtained in Melk Abbey over the centuries into the age of modern astronomy. The end of the journey showed the contemporary international astronomical research in 2009 in which Austria is involved, such as that carried out at the European Southern Observatory (ESO).

B. Lecture series: Astronomical Colloquium 2009

For advanced visitors, talks on historical and modern astronomy were given. The topics were related to those addressed in the exhibition, but which could not be followed through there to the fullest extent. Before every lecture, we gave a special guided tour through the exhibition. One lecture evening was dedicated to astronomical observations in collaboration with the Lower Austrian Amateur Astronomers, which had to be cancelled due to bad weather. However, it is worth noting that for this evening the complete outdoor illumination of Melk abbey (usually a brightly-lit tourist landmark) was switched off to expose the dark skies over Melk.

Also workshops with students in the high achievers programme were held and will now continue on a yearly basis.

C. Publication of exhibition proceedings

Edited by the librarian, Father Professor Dr Gottfried Glaßner OSB, the first volume of the new publication series *Thesaurus Mellicensis* was dedicated to the scientific results discovered by the members of the project team. The contributions have been reviewed by members of the medieval book commission of the Austrian Academy of Sciences.

Selected highlights of the exhibition

The oldest item of this exhibition was written before the year 825 and contains a copy of *De Temporibus*, the standard book on the calculation of the Easter date by the Venerable Bede (Codex 412)[1]. It is one of the oldest books in an Austrian book collection. (Figure 1, top right).

A central point of the exhibition was based on notes, manuscripts and *incunabula* of the early phase of the University of Vienna, when an intensive collaboration between the two institutions was established (see section 3). As a place of spiritual and political influence, Melk also had contact with the imperial family of the Habsburgs. Two groups of items were displayed, firstly, a pair of globes, one of the Earth and the other celestial, manufactured by Vincenzo Coronelli in the late 17th century, and secondly, meteorites, which were donated by the Habsburg family to the Melk Abbey school.

A showcase was dedicated to pre-telescopic instrument reconstructions and a 19th-century telescope from the monastery's school reminded visitors of the 400th anniversary of Galileo's discoveries.

In the second module of the exhibition, we presented two international research projects that include Austrian participation. Austria's new ESO membership was brought to the attention of visitors by hosting ESO's photo-panel exhibition. Furthermore, Austria's first satellite project, BRITE–Constellation (Weiss, 2008) was represented by a true-scale model.

Concept implementation and lessons learned

Early experiences in the design phase

First discussed in late 2007, the basic concept for this project grew in our minds for about a year and condensed towards a consistent proposal in 2008. For the title of this project we have chosen the German translation of Psalm 192, "The heavens declare the glory of God...", which was quoted in a sophisticated Latin manuscript on the construction and usage of astrolabes (Cod. 511). At the first work meeting with the cultural administration of Melk Abbey in December 2008, we soon learned to understand the basic concept of the abbey's museum: Everything has to fit into the architectural atmosphere of the rooms. This is especially important for projects in the

library, as its main room is itself a significant piece of art, including the uniform leather-bound book covers, which match the wooden baroque bookshelves. The allegorical figures in the area of the architectural painting surrounding the ceiling fresco are dedicated to the research topics covered by the books in the library including astronomy.

To accommodate this we had to revise the arrangements of the external items slightly, but the science was untouched. Once the ESO exhibition was moved to the next event location in Innsbruck, this philosophy even allowed us to place the shiny gold BRITE satellite model in the baroque library's main hall, as it fits with its colour concept perfectly.

Preparing the displays

The museum and the church of Melk Abbey are open for visitors throughout the year. The main season starts traditionally with the Easter week, which was in early April in 2009. Aside from a few details, the showcases and the explanation cards for each item were finished in mid-March so as to be able to present the exhibition at the celebration for the proclamation of the Wachau region and Melk Abbey as the Best Historic Site by the *National Geographic Traveler* magazine.

From our work in the library, we knew of several important books in the collection, which formed a firm basis for the exhibition. Around Christmas 2008, we spent several days in the library halls screening all catalogue entries which could contain astronomical content for interesting items. Our search was based on authors and titles of the books and also on catalogues of incipient words, i.e the first few words of the opening line of a text. Cross-references in the scientific literature were also used. However, we did not restrict ourselves to modern, electronically available catalogues, but we also investigated older compilations of book catalogues, which gave valuable information on the historic book inventory. We will discuss the findings in the next section.

Figure 3. *The exhibition authors Paul Beck and Georg Zotti with the true-scale model of the BRITE satellite in front of Melk Abbey's church. The model "hovered" in Melk above visitors' heads until the end of the exhibition. Credit: G. Zotti.*

During our work, we were supported by the abbey's librarian, Father Glaßner, OSB, and his assistants, Mag. Christine Preiner and Mag. Bernadette Kalteis. Additionally involved in the investigations and publication on specific topics were Mag. Nora Pärr (Univ. Vienna), Dr Vittoria Feola (Univ. London), Giles Davison (London), Karl Heinz Keller (Bavarian State Library) and others. Dr Christine Glaßner from the Commission of Palaeography and Codicology of Medieval Manuscripts of the Austrian Academy of Sciences also contributed her expertise. As each of the team members has a different core competence, many fruitful discussions were held, where scientists from one discipline had to explain their approach using non-expert words. In the preface of the accompanying book, *Thesaurus Mellicensis Vol.1*, Father Gottfried Glaßner addressed this by stating that the key to the success of this project was the willingness of everybody to listen and join in the discussion.

Once the museum was closed to the public in the evening, we tested potential configurations of the presentation by placing the books on top of the showcases and documented the options photographically. We used these sketches at our meetings in Vienna to visualise the current layout and discuss further improvements. Finally, in February, we placed the books in the showcases according to our final concept. Special care had to be taken for conservation reasons. Again, the librarians guided us with their expertise. To protect the displayed pages from ultraviolet light, the glass was covered with an ultraviolet-reflecting foil. Also the windows were permanently covered with curtains to reduce the incoming light, and flash photography of the manuscripts was forbidden.

To be able to show selected pages of the books, we had to prepare the books in a certain way so as to avoid further damage. The pages were fixed with strips of the same foil that was used to cover the glass of the showcases and acid-free paper. Due to the old wooden and leather bindings, the books had to be supported with little wooden book stands. If several, non-adjacent pages contained details that we wanted to show, we included a photographic reproduction on the relevant explanatory card.

Although working with white gloves when handling the pages inside the books, when working on the final placement blackened fingers and hands were unavoidable while carrying books around or aligning them. Being in such an environment, browsing through thousands of pages of ancient knowledge and having the plot of Umberto Eco's (1986) bestselling book, *The Name of the Rose*, in mind, we could not resist referring to certain passages of the story when we saw our black fingers. However, we survived.

Other items were placed between the books. Meteorites from the abbey's mineral collection (founded in 1767) and several historic instruments from the physics department of the abbey's school were displayed between the books. The exhibition also included the excellent pair of Coronelli globes, a celestial and an Earth globe, which form a permanent part of the library exhibition, as well as several details of the fresco, showing astronomical allegories or instruments.

Optimising a scientific exhibition for a high throughput of international tourists

The main goal of this exhibition was then put into an overall context: the evolution of research interests in astronomy. During our work on the showcases, we developed a first impression of how much time an average guided tour takes for the library module. At peak times, the tour guide has about five to ten minutes to explain the rich library and its long history to the group before the next tour approaches the displays. Although in certain cases little radio headsets are handed to the tour participants, which give a bit of extra time because they avoid confusion between different guided groups, we still had to condense the concept of the exhibition to a few basic lines.

Each tour is different and every tour guide has his own style and area of expertise. Therefore, we were requested by Melk Abbey authorities to prepare educational material, which was handed to the guides in advance of a special training session in the library. In this written summary, we drew attention to and gave detailed information on a few selected books, which we thought of as cornerstones of astronomical history (see the next section), and also provided information on each item. Over the two years, the authors also did some "sneak touring" for quality control by listening anonymously to tours passing through the library. A more extensive guided tour was given by the authors on every lecture night.

In the peak season (April to October), tourists are not obliged to follow a guided tour, but can visit the museum independently. So, to convey the essence of this exhibition to international and individual tourists, an exhibition sign welcomed them with the exhibition prologue not only in German, but also in English, French and Italian.

Connections to the First Viennese School of Astronomy and Melk Abbey during the 15th century

As the first peak of astronomical research in Vienna coincided with a phase of strong interest in astronomy in Melk, we found many documents on interactions. A very interesting document for astronomical research is one of the only four existing copies of the Latin *Iudicium super Comete* 1456 (Cod. 1605, fol. 162rv). The early Habsburgs assigned Peuerbach to present an expert view of the great comet of 1456, which is nowadays better known as 1P/Halley. While the original manuscript is lost, this excerpt has survived for more than 550 years in the library of Melk. This shows the importance of monastic libraries for preserving scientific treasures over centuries.

Figure 4. Impression from one of the numerous guided tours through the library exhibition: A tour guide explains the concept of the exhibition to an international group of tourists. Credit: P. Beck.

Although Peuerbach was paid as a court astrologer, he minimised the astrological interpretation of the comet. In fact, this work represents one of the first empirical approaches to the phenomenon of a comet and is structured in a similar way to a modern publication. To give readers the opportunity to discover the text of this important document on their own, the Latin transcript (Ferarri, 1961) and a translation were published in the exhibition book (Beck & Zotti, 2009a). A more extensive, critical discussion on astrology by Georg von Peuerbach was found in a unique manuscript which is described in the same book in more detail by Glaßner & Keller (2009).

As mentioned earlier, we also investigated older book catalogues, which gave valuable information on the historic book inventory. The most impressive direct evidence that the keepers of the library did not simply collect material blindly, but also evaluated its quality was found in the oldest library catalogues written in 1483 (Cod. 874, fol. 50v) and in an edited copy that was written around 1495 (Cod. 1075, fol. 31r). In the register of authors, we found not only the name of the astronomer Johannes de Monte Regio (Regiomontanus), but also a statement underlining the respect that the monks of Melk had for him and his place in his science: "rightfully the king of the Viennese astronomers".

Another interesting note on the interaction between the astronomers of the University of Vienna and Melk Abbey was found in a baroque book of colloquium abstracts. In this publication, Georg Matthias Bose, a mathematician and astronomer at the University of Wittenberg, invited readers to celebrate the 300th anniversary of the observation of the lunar eclipse of September 1457 by Peuerbach and his young student, now known as Regiomontanus (Bose, 1757). From Bose's point of view, this observation marks the restoration of astronomy, as it appears to be the first one after antiquity where European astronomers recorded exact stellar altitude data to derive the local timestamps of the contacts. According to Regiomontanus's journal of observations, which is quoted by Bose, the astronomers observed in Melk. We therefore were initially surprised that there was no note concerning the stay of both astronomers in Melk, although about 25 years later one of them is highly glorified in the library catalogue. However, we found indications that King Ladislaus [Postumus] (1440–1457), whom Peuerbach served as royal astrologer, stayed for some time as a guest in Melk Abbey in September on the way to his planned wedding in Prague, where he instead found an untimely death. Also, the measured timestamps perfectly fit with an observation made in Melk, and the fit is definitely much better than for Vienna as an observation location.

Among many other documents, we also want to highlight Fragment 229, which was also published as the APOD for 17 April 2009 (Beck & Zotti, 2009b). The (assumed) author (cf. Bruckmüller, 1989), Magister Wolfgang de Styria (1402–1491 or 1498), was a student of the liberal arts at the University of Vienna before 1423, at a time when Johannes von Gmunden was dean of this faculty and also gave lectures. After Wolfgang had completed his studies in Vienna, he was contracted to teach at the abbey school. A year after he arrived in Melk, he also joined the monastery. However, the latest research suggests that this fragment was already written in the 14th century[2], which would show another fascinating example of the tradition of astronomical knowledge. This fragment was probably written for teaching basic astronomy in the abbey's school. It explains the Ptolemaic, geocentric system and how in this geometry a lunar and solar eclipse can be explained. Finally, the circular table in the lower right of the page gives an algorithm to calculate the date of the Easter full Moon (cf. Beck & Zotti, 2009a).

Press work and media feedback

In 2009, the project was advertised nation-wide by Melk Abbey and excursion web pages as a special project for the International Year of Astronomy 2009. Klösterreich, an Austrian collaboration of monasteries with a combined marketing concept, proclaimed 2009 as the year of monastic libraries and also advertised this exhibition as one of their highlights.

For the domestic press release, several photos of the displayed items were provided. The picture that was chosen most often by the media is shown in Figure 3. The original intention for this picture was that this façade is generally recognised by Austrians as part of Melk Abbey, and we assumed that Austria's first satellite would catch people's attention. Obviously, we were right. The catchiest headline found with this picture was "Scotty, beam me into Melk Abbey".

To draw international attention, a photograph of Fragment 229 was submitted to APOD and this was published on the opening day of the exhibition. The mainstream coverage of the project concentrated around the opening of the exhibition in spring 2009. More sophisticated reports followed during the year. Also, the project was reviewed in annual reports such as the Austrian commission for UNESCO (2009 Annual report, p. 29):

"Throughout the year, numerous activities took place in all of Austria, which are described in more detail under www.astronomie2009.at. Special highlights were an exhibition 'The heavens declare the glory of God' at Melk Abbey, and 'Travelling to the stars' at Rein Abbey near Graz, both of which centred around historically valuable books from six[3] *centuries of astronomy."*

Conclusions

Having the chance to work on such a large collection of astronomical manuscripts and prints was a very interesting experience. During the last 50 years, several individual manuscripts, such as the *Iudicium*, have been analysed in detail or from the viewpoint of the University of Vienna and its famous astronomers. In the course of this project, however, we have analysed the scientific interest and usage of astronomy in a monastic, medieval environment. In addition to the central role of the *Computus*, we were able to show that the Benedictines did not defend old views, but were interested in ongoing astronomical research and were able to discuss the arguments for all proposed theories.

The project definitely benefited from the fact that we could utilise the complete infrastructure of a location used to working with hundreds of thousands of tourists per year. This was very helpful from an organisational and marketing perspective, as we only had to provide the text for the flyers and a press release, while the layout, production and distribution in the printed and electronic formats were done by the Cultural Office. Also, the press release received a wider response as it was sent out via Melk Abbey's network. Only the explanatory cards in the displays were laid out by us. By following this strategy of work distribution we could optimise the workflow and outcome.

The feedback we received from visitors and audiences following the guided tours and the lecture nights was very positive. In general, people were impressed by the astronomical work contained in monastic libraries. Also, the open way in which we presented the history of astronomy was appreciated.

Acknowledgements

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Notes

[1] Codex numbers refer to the inventory of the library of Melk Abbey.

[2] Priv. Com. Dr. Christine Glaßner, Austrian Academy of Sciences, Commission of Paleography and Codicology of Medieval Manuscripts.

[3] Note that for the exhibition in Melk this number is too small by a factor of two.

Biography

Paul Beck, graduated as a master in astronomy from the University of Vienna, Austria. Now working as a PhD student at the Katholiek Universiteit Leuven, Belgium, on the asteroseismology of red giant stars with photometry from the Kepler satellite, funded through an Advanced Grant from the European Research Council under the European Community's Seventh Framework Programme (FP7/2007–2013)/ERC grant agreement n°227224 (PROSPERITY).

Georg Zotti graduated in computer science from Vienna Technical University, and astronomy undergraduate from the University of Vienna/Austria. Now working as post-doc on the archaeo-astronomy of Neolithic circular ditch systems at the Vienna Institute for Archaeological Science (VIAS), University of Vienna. (Supported by the Austrian Science Fund FWF, project no. P 21208-G19 "ASTROSIM").

Astronomy Week in Madeira, Portugal

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Public Outreach, Informal Education, Exhibitions, Non-traditional Events

Summary

The outreach programme *Semanas da Astronomia* (Astronomy Weeks) is held in late spring or summer on the island of Madeira, Portugal. This programme has been attracting enough interest to be mentioned in the regional press/TV/radio every year and is now, without doubt, the astronomical highlight of the year on Madeira. We believe that this programme is a good case study for showing how to attract the general public to astronomy in a small (population 250 000, area 900 km^2) and fairly isolated place such as Madeira. Our Astronomy Weeks have been different each year and have so far included exhibitions, courses, talks, a forum, documentaries, observing sessions (some with blackouts), music and an astro party. These efforts may contribute towards putting Madeira on the map with respect to observational astronomy, and have also contributed to the planned installation of two observatories in the island.

The relevance of the Astronomy Weeks for Madeira

The *Semanas da Astronomia* began in 2001. The success of the programme has varied over the years. However the Weeks have attracted enough interest to be mentioned in the regional press/TV/radio every year. This could be a crucial element in improving how the public and regional authorities perceive the relevance of astronomy to attract general support for two observatories (optical and radio) that we plan to install on Madeira (e.g., Augusto, 2011).

The Inception

The island of Madeira is famous for its astounding natural beauty, and notably for the World Heritage Laurissilva Forest. More than a million tourists visit each year, to enjoy the spectacular scenery that the island has to offer, and especially that found on the trails known as the Levada Walks, so that tourism is, by far, the main industry on Madeira. As a natural consequence, many (nature) themed *Festas* (festivals) now take place throughout the year. For example, the *Festa da Anona* (Festival of the Cherimoya – a type of pawpaw), *Festa da Vinha e do Vinho* (Wine Festival), *Festa da Castanha* (Chestnut Festival), *Festa da Flor* (Flower Festival), *Festa da Cereja* (Cherry Festival). In most cases the *Festas* last a whole week, albeit with an emphasis on weekends. So, why not a *Festa* of astronomy?

Figure 1. The poster of the XI Encontro Nacional de Astronomia e Astrofísica showing part of the south coast of Madeira.

In 2000 the Astronomy Group of the Universidade da Madeira[1] took formal shape as we were already setting up the first ever national astronomical meeting in Madeira: the XI Portuguese National Meeting of Astronomy and Astrophysics[2] (Figure 1). Since the scientific programme was to last only two days (there are not so many astronomers in Portugal; although the vast majority of them did come to this

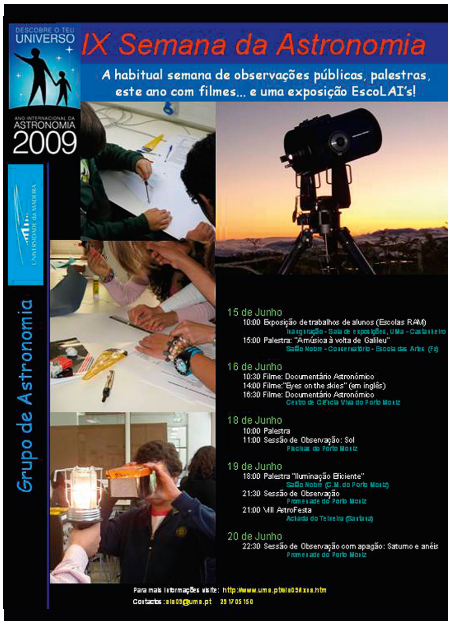

Figure 2. The poster of the IX Semana da Astronomia, held during the IYA2009 as an official event in that programme.

meeting), a Thursday and a Friday, we decided to convert the whole week into a *Festa da Astronomia* (23–27 July 2001[3]) during which time the closed meeting would take place, with most public activities taking place between Monday and Wednesday. We held three observing sessions. One in the day, for sunspots — the Sun was particularly active that year — and two at night, with telescopes and equipment set up on the terrace of the University building, and a wide selection of nine small astronomy courses (each 1.5 hours long), given by five different coordinators, covering all the main basic astronomical topics, and with catchy titles: "The Sun, our star", "The amazing planets", "The fascinating stars", "The Milky Way, our galaxy", "The majestic normal galaxies", "Black holes", "Fantastic active galaxies", "The origin of the Universe", "The big mysteries of astronomy". The open part of the week concluded with a public talk entitled, "Is there alien life?", which proved particularly attractive (an almost full auditorium). Finally, we started a tradition that lasted several years, with the characteristic look of our Astronomy Week posters.

The natural consequence

Having had success with our first attempt at an Astronomy Week, the natural reaction was to try to repeat it in the following year. However, the second attempt in 2002 would be riskier. Not only because a repeat of the initial success couldn't be guaranteed, but also because we would be lacking our greatest attraction: a meeting of national relevance. So we would have to fill up the last two days of the week with events. We had the idea of doing an all-night star party, hoping to make it the climax and finale of the week (as it still is today, taking place on the night of Friday into Saturday). That was our first *AstroFesta* (AstroParty) and this event was also our best chance of keeping the attention of the press for the second year running too[4] — 15–20 July 2002. It worked fine. Since the AstroParty was now the main event, we made sure that the public would not be disappointed: we set it up in the hills at a very dark site at an altitude of 1600 metres, but accessible by road (although a special permit was required from the Regional Forests Department). It was no accident that this was very close to the only site in Madeira with published results on its splendid observational quality (McInnes, 1981). However, that was not enough for us. We also made sure that no moonlight would disturb our observations of deep-sky objects; after all, we were taking our 30-centimetre automatic telescope up on the mountain, as well as a generator! We kept the day-time session to observe sunspots, but the night-time sessions were now replaced by the AstroParty. We reduced the number of astronomy courses offered from nine to five (five speakers, one of whom was new) with a resulting drop in public interest.

Finally, the presence of a visiting astronomer (Ivan Andronov, Odessa National University, Ukraine), on a three-month professorship at Madeira, motivated us to change the initial emphasis of the Week: the opening address was now given by the Rector, followed by a public talk (mid-week) given by our guest (on cataclysmic stars). Our hope was to have a repeat event with an international speaker every year but, unfortunately, this has not been possible.

An established event

Each year we have experimented with new events, to keep the interest of the public (and the press). We tried changing the date to early June, so that schools were still in session (for both students and teachers) since, when lectures finish on Madeira, students and teachers tend to "disappear" for the summer. We have also tried events at different times of day, to attract more working people (out of office hours) and university students: events early in the day were not getting much attention, nor were we successfully attracting the students (and unfortunately, this has only changed for the worse in recent years).

Over the years from 2003 to 2008, the AstroParty continued to be the most popular event. We have summarised the Astronomy Weeks III to VIII in Table 1. We maintained the number of courses offered and had roughly the same number of speakers, but public interest in these events diminished from year to year. We kept, for the first four years, the observation model of the previous years (sunspots + AstroParty). A turning point came in 2006, when hardly anyone attended either the AstroParty or the courses (despite choosing very focused themes like: "News from Saturn (Cassini)" or "The discovery of the first young radio galaxy in a super-galaxy") and so we decided that we should get back to the city (the terrace of the University) to attract the public back again; and cancelled all the courses. In 2007 and 2008 we went back to night-time observations with great success (twice during the Week, in addition to the day-time observation session and the AstroParty). Since then the AstroParty (the landmark of the Astronomy Week) has remained popular. In 2007 and 2008 we offered a single, longer (six-hour) course, for free, on basic astronomy. This course was mainly targeted towards teachers, and was successful in 2007, but less so in 2008. We also radically changed the look of the poster in 2007; and we celebrated the inauguration of the Laboratory for Astronomical Instrumentation (the highlight that year). In 2008 we held an exhibition and officially presented the first confirmed 100+ events for the International Year of Astronomy (IYA2009) on Madeira (in the end we passed the 200-event mark[6]).

In 2005, the International Year of Physics, we devoted a week-long exhibition[7] to Einstein and his many contributions to astrophysics. That was another turning point for our Astronomy Week, and we held exhibitions every year until 2009 (although we hope to resume these in 2011: see more below). The start of the exhibitions

Figure 3. A group of 4–7 year olds waiting for the Sun to come out from behind the clouds, at Porto Moniz, during the IX Semana da Astronomia.

was combined with the official opening of Astronomy Week at the University, with an address by the Rector or another official representative.

The International Year of Astronomy 2009

The year 2009 was the one to make it big. And we tried all we could. We designed a brand new poster (following the general template of all the posters for the initiatives[8] that we conducted for the IYA2009), see Figure 2. The Week took place from 15–20 June.

Since we had plenty of astronomy going on elsewhere for the public and schools on Madeira in 2009, we had to select a special programme for the Astronomy Week. We started by changing the place: eight out of the eleven activities of the Week took place in Porto Moniz, in the northern part of the island. Only the AstroFesta, the exhibition (in their usual places) and the first novelty (a talk/performance on "Music by Galileo" at the music school in Funchal) did not take place in Porto Moniz. The second new event was a series of three astronomical documentaries that were shown with an expert commentary, one in English (for tourists). The third new event was part of the Dark Skies Awareness Cornerstone project of the IYA2009[9] and began with a talk on the subject[10], followed the next day by a night-time observing session with an intentional blackout, to show people how much we lose of the night sky though bad artificial lighting. In addition, we ran the usual day-time and night-time sessions and a talk on astronomy, this time for 4–7 year olds (Figure 3). Finally, our exhibition was also different. Since, by this time, we had had roughly 900 school students who had passed through the Laboratory doing Hands-On Universe experiments, we could not resist showing off their best constructions — the theme for that year's exhibition (Figure 4).

The bad year of 2010

After so many versions of the programme, one year was bound go less well. And that happened in the tenth year, when we were planning a flashback exhibition of the previous nine years of Astronomy Weeks. But the University of Madeira had other plans. In 2010 the Astronomy Group was formally closed (and now still exists only through the work of volunteers like us) and there was a lack of interest from the University of Madeira in keeping up the "traditional" exhibition, and the Astronomy Week. We were forced to postpone the Week from May to November (22–26 November), when we were able to include the closing ceremony of the IYA2009 on Madeira — the highlight).

Even in this difficult year we still managed to include some new features, like a localised blackout around the University (including a section of a nearby major highway!) during a night-time session. The weather did not help either — rain and clouds. The same happened on another day when we conducted a day-time observing session. And, for the first time, we did not even leave Funchal for the AstroFesta, since there was an orange alert of wind and rain for the mountain site. With the Week taking place in Funchal again, we had a talk on black holes, a commented astronomical documentary, and a full National Science Day on the 24th, with the closing Ceremony of the IYA2009, where prizes were given to many collaborators from all parts of Madeiran society after a short summary talk, and a two-hour long forum on "The Universe" (from all perspectives). This forum was a new event and it worked really well, with scientists and laypeople together presenting their views.

Summary: Highlights

As usual when dealing with the press or the public, we must have a strong programme to continue to catch their interest in the Astronomy Week every year. Hence, we have tried, almost every year since the first version of the programme in 2001, to add something to attract attention. We have been fairly successful.

In addition, there are some global statistics on the past ten editions of the Astronomy Week that give a hint of the variety. Excluding exhibitions, documentaries and night-time sessions (not every year) we have had 40 talks by nine different speakers, and the two of us contributed to only about half of these. Ten Sun-observing sessions had 50% success (the weather was poor in the other half) while only two out of nine AstroFestas were cancelled due to bad weather, indicating an excellent choice of site (Achada do Teixeira).

Week	Year	Dates	Moon phase during the AstroParty	Courses	Speakers
III	2003	15–20 July	Last quarter	7	7
IV	2004	19–23 July	Last quarter	3	3
V	2005	04–08 July	New	5	4
VI	2006	05–10 July	Full	5	5
VII	2007	11–15 July	New	0	0
VIII	2008	23–27 June	Waning gibbous	1	1

Table 1. A summary of the Astronomy Weeks from 2003 to 2008 (III to VIII). The dates are shown (all occurred in June or July), as well as the phase of the Moon (relevant for the AstroParty). Also the number of different astronomy courses and speakers is given.

Figure 4. The Astronomy Week exhibition during the IYA2009: a sample of the best constructions in made Hands-On Universe activities by some of the 900 students who have attended our Laboratory over the years.

The future format (2011 onwards)

After our great IYA2009 regional experience, we have established relevant contacts with local authorities and we are now exploring possibilities for future events. *A necessidade aguça o engenho* (Necessity sharpens the tool), as we say in Portugal. So, we have moved out of the University and gone closer to the people, as we did during the IYA2009. We are now in the process of completely revolutionising the Astronomy Week. Starting in 2011, we plan to organise it in a different *concelho* (borough) every year. There are 11 in Madeira, including the other inhabited island, Porto Santo. For 2011 we have arranged a "contest", open to all *concelhos* to select the one which would like to host all our activities, including the AstroParty (the site for this will be selected from the darkest in the borough, which will likely be among the highest sites). The runner-up might be then automatically selected as hosts in 2012, when a new competition will be opened up for 2013, and so on. So far, the local authorities are surprising us and showing a lot of interest in taking part in this challenge.

Conclusions

Our *Semanas da Astronomia* programme has been running for eleven years. There has been coverage in the news in the local press/TV/radio every year, and is the astronomical highlight of the year in Madeira. It has become a regular feature of the calendar, and is well attended by the public. Some global statistics on the past ten versions of the Astronomy Week show that we had 40 talks by nine different speakers, ten Sun-observing sessions, and nine AstroFestas. By numbers, these were the major events. We believe these informal education activities for the society might change the way Madeirans see culture, and broaden their perspective so that science is included.

The main conclusion is that it is worth "pushing" astronomy to the general public. People are clearly receptive, even if the impact varies from year to year. Local authorities might be more receptive to these activities than universities (at least in Portugal).

Our hope is that soon, Madeira, with its UNESCO World Heritage Forest, will become a reference point with respect to observational astronomy, just as McInnes (1981) suggested. And, as a consequence, that some of the million tourists a year will be of the scientific type.

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Biographies

Pedro Augusto is Aggregate Professor at the University of Madeira, Portugal, currently on leave. He arrived on Madeira in 1997 and devoted all the time left from maths/physics teaching and administration to setting up an Astronomy Group. Intensive teaching on astronomy and the beginning of large scale Public Awareness of Astronomy at Madeira followed, culminating in IYA2009.

Laurindo Sobrinho is an Assistant Professor at the University of Madeira, Portugal. He has been a member of the Astronomy Group since its founding in 2000 (and the head of the group since September 2010). Over the years he has participated in many outreach activities within the areas of astronomy and science in general (lectures, observing sessions, exhibitions). In particular he was active on the organisation of IYA2009 in Madeira.

Cerberus: The Mars Crowdsourcing Experiment

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Summary

This article discusses the use of crowdsourcing in a serious game. A computer game, called Cerberus, which allows players to tag surface features on Mars, has been developed. Developing the game has allowed us to investigate the effects of different help levels in supporting the transfer of knowledge, and also how changing the game features can affect the quality of the gaming experience. The performance of the players is measured in terms of precision and motivation. Precision reflects the quality of the work done and motivation is represented by the amount of work done by the players. Games with an explicit help function combined with a "rich gaming experience" resulted in significantly more motivation among the players than games with an implicit help function combined with a "poor gaming experience". There was no significant difference in the precision achieved under different game conditions, but it was high enough to generate Martian maps exposing aeolian processes, surface layering, river meanders and other concepts. The players were able to assimilate deeper concepts about Martian geology, and the data from the games were of such high quality that they could be used to support scientific research.

Introduction

Crowdsourcing science uses many individuals (the crowd) to process scientific data and is mainly used with datasets where human perception exceeds the capabilities of computers. Humans are still often better and faster than automatic devices at recognising shapes and objects (Hoffmann, 2009). This project investigates whether the crowd can recognise and apply high level semantic concepts to features in photos of the Martian surface and thus support scientific research. In this research project, crowdsourcing was conducted using a serious game. Different types of help function were investigated to establish the level required to provide players with enough knowledge for them to identify surface features on Mars. Another research goal was to investigate which game features are needed to motivate players.

Gaming for science

Because crowdsourcing demands a certain effort from its contributors, the players must be motivated to participate. Two methods are utilised: 1. Small financial rewards are offered for processing data units. 2. The computer game environment is made sufficiently entertaining that players will process data for free.

The concept of crowdsourcing has proven itself in serving science. The quality of the data analysis performed by crowds within certain fields of research is superior to the results obtained by individuals and even sometimes to those of the experts involved (Hoffmann, 2009).

An example of a serious crowdsourcing game used for science is Foldit, a game in which players create new protein chains. The goal is to contribute to cancer research. Players are encouraged to play the game by earning points and the chance to earn "scientific glory" (Viñas, 2008; *The Economist*, 2008). Another example is Galaxy Zoo, an initiative in which galaxies and their behaviour are classified by users (Darg et al., 2009). Astronomers can only cover a small portion of the amount of data that needs to be analysed, so the data is prioritised, and new discoveries may remain hidden in the lower priority data. This is where Galaxy Zoo comes in. The players analyse the photographs collectively, so that each time a photograph is analysed the reliability of the classifications in the galaxy database increases. The results prove to be just as accurate as if the analysis had been carried out by expert astronomers. By the end of the year 2009 over 220 000 people had participated in this project and they had contributed to the discovery of a new type of object (Charles, 2009).

Exploring Mars

Since November 2006 NASA's Mars Reconnaissance Orbiter (MRO) has used the High Resolution Imaging Science Experiment (HiRISE) to acquire data about the surface of Mars. The MRO transmits colour imaging data back to Earth, covering objects with sizes down to 25 centimetres. This high level of detail generates a vast amount of data that needs to be analysed (McEwen, 2010). The first research phase, or Primary Science Phase (PSP), ran until December 2008 and has photographed approximately 0.55% of the planet's surface, consisting of 8 terapixel of data (McEwen et al., 2009). The scientific research covers 18 themes, such as different types of erosion, with each theme processing specific surface features to learn more about Mars.

The non-academic world can participate in HiRISE via an Education and Public Outreach (EPO) initiative (McEwen et al., 2009). The Clickworkers project is an example. This was a "citizen science" initiative whereby internet users had to classify and annotate geological objects such as dunes and craters to generate a searchable database (McEwen et al., 2009). NASA's researchers assumed that the average person had enough commonsense knowledge to accurately screen photographs for craters. Starting in November 2000, over 80 000 people measured two million craters and classified the age of 300 000 craters in a year (Szpir, 2002).

Become a Martian

In November 2009, the website, *Become a Martian* (BaM), was launched on Microsoft's Developers Conference as a cooperation between Microsoft and NASA. Two games are offered through this interface and which allow users to simultaneously learn about Mars and contribute to planetary exploration. Microsoft and NASA emphasise that BaM does not only inform people about Mars and NASA's activities, but that it enables large groups of people to analyse data in a field where computers still lag behind (Brown, 2009; Microsoft, 2009). An introductory movie is shown in the Martian Map Room and then the first game introduces the user to measuring and counting craters. In the second game photographs have to be aligned; a task that is difficult to do automatically because Mars does not have a GPS network. Fragments of satellite images are overlaid to generate a rich Martian map. As a reward the user earns experience points and rewards in the form of medals, badges and "inside" NASA information (NASA & Microsoft, 2009).

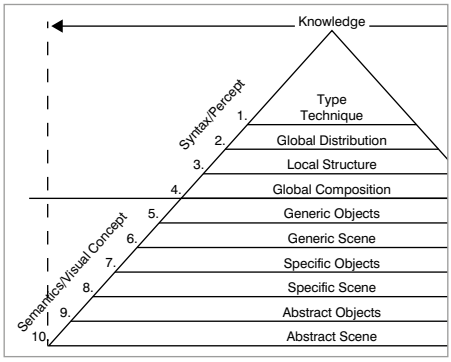

Figure 1. Ten-level model (Jaimes, 2000).

Knowledge levels

Jaimes (2000) presented a model which describes images in terms of ten different levels of perception and semantics. The model is shown schematically in Figure 1, with the first four perceptual levels at the top of the pyramid. The topmost level describes the image in terms of its most basic properties, such as the JPEG 2000 file format of the HiRISE images (HiRISE, 2009). The next three perceptual levels go deeper into the superficial features of the image and describe colour, shape and texture, distinguishing between characteristics of the image as a whole, its distinguishable elements and the composition of these elements (Hollink, 2004; Jaimes, 2000). The general image characteristics described by these perceptual levels show a strong resemblance to the way in which the types of feature that have to be picked out and annotated in Galaxy Zoo and Be a Martian are categorised. Whether crater counting or classifying galaxies the user has to recognise circles or varieties of them. The user also has to align patterns, and both these tasks can be carried out without specialist knowledge (Charles, 2009; NASA & Microsoft, 2009).

The six "lower" semantic (or conceptual) levels are divided into generic, specific and abstract levels, each of which is further subdivided into "object" and "scene" categories. Working down through this hierarchy, within the generic level, objects and actions are generally tagged; within the specific level these objects and actions are named individually; and within the abstract level contextual information or symbolism is added. These levels are derived from Panofsky's (1962) and Shatford's (1986) models, but each differentiates between individual objects and the scene as a whole. In order to describe these six conceptual levels, from general to specific, an increasing level of knowledge about the subject is required (Hollink, 2004). The annotations for BaM are confined to the perceptual levels (levels 1 to 4, Figure 1) with the occasional cautious foray into the first conceptual level (NASA & Microsoft, 2009), as, for example, a crater would be categorised as a generic object within Jaimes's model.

However, when we look at the HiRISE research themes, annotations that are confined to the perceptual levels are no longer sufficient. The themes, for example, describe specific geological processes and therefore demand a deeper level of knowledge to be able to recognise and describe them (McEwen, et al., 2009). In terms of Jaimes's model (2000) the HiRISE research themes would position themselves within the specific and abstract conceptual levels (levels 7–10 in Figure 1). The specific levels could describe processes like wind erosion, while the abstract levels could concern hidden craters buried beneath the planet surface, which cannot be seen directly with the eye (HiRISE, 2009).

The current generation of Mars games created by NASA and Microsoft (2009) only extends to the generic levels (levels 5 and 6 in Figure 1), which do not go deep enough to make annotations within the HiRISE (2009) research themes. But can users reach a deeper semantic level without possessing expert knowledge? (Darg, 2009; Bulletin of the Atomic Scientists, 2001)

The problem

The investigations into whether crowdsourcing using a game can be used to make annotations within the specific levels (levels 7 and 8 in Figure 1) or even within the still higher abstract levels (levels 9 and 10 in Figure 1), and using the HiRISE research themes, have covered three aspects.

Motivation

Firstly, it is important to define how a player can be motivated to apply knowledge to the HiRISE photo data. How important are the game elements in motivating the player? In BaM and the other examples

described above, the motivating elements are point counts, a share in the scientific glory, winning medals and having objectives (NASA & Microsoft, 2009). But are all these elements required or would a single element suffice to motivate the players?

Providing the user with enough knowledge

Secondly, it is important to provide the player with enough specialist knowledge to make annotations within the specific levels (levels 7 and 8 in Figure 1). Can someone acquire the necessary knowledge, i.e., without explicit instruction by just playing the game? In this situation knowledge is transferred implicitly with minimal support and a player is then expected to be able to apply the acquired knowledge correctly. The alternative is to transfer knowledge explicitly by instructing the player, as in the BaM games, where the player is offered educational movies and other kinds of help (NASA & Microsoft, 2009).

Validity of the results

During the game players annotate MRO photos, and it is important that the data (the annotated photos) can be used in the context of the HiRISE research themes (McEwen et al., 2009). The validity of the results depends on the reliability and significance of the annotations (factors). The reliability is measured by the precision of the annotations made by the players. The significance relates to the number of players who make similar annotations on the same objects. Both reliability and significance are important if the generated data is to be used for scientific research.

The research questions

The primary research question is:

- Is crowdsourcing in the form of a serious game applicable for annotation in a semantically-rich research domain?

The secondary research questions are:

- Are the players motivated enough by a poor game experience, or is a rich game experience essential?
- Can we transfer the domain specific knowledge in an implicit manner, or is explicit instruction essential?
- Will the annotations made by the players be usable for science?

The hypotheses

Based on the research questions the following hypotheses can be derived:

- H1: Motivation of the players will be higher given a rich game experience than given a poor game experience.
- H2: Precision of the players will be higher given explicit knowledge transfer than given implicit knowledge transfer.
- H3: The validity of the crowdsourcing results will be highest where knowledge transfer is explicit with a rich game condition.

Method

A two by two factor design was created resulting in four possible game conditions shown in Table 1. The independent variables were implicit or explicit knowledge transfer and a poor or a rich gaming experience. The dependent variables were the levels of motivation and precision the players were able to achieve, while validity indicated the performance as a collective.

A computer game was constructed matching the four game conditions and their independent variables (Table 1). Other than these differences all the game conditions were identical in every aspect. This section will first describe which data were analysed, then it will discuss the game functions that were similar for each game condition, and it will conclude with a description of the differences between the conditions.

A. The dataset and knowledge to be applied

The dataset consisted of photos that had been pre-processed and described by researchers using criteria related to the 18 HiRISE research themes. The photos then had to be annotated with Mars features by the players and compared to expert descriptions to test how the players had performed both collectively and individually. Specifically, players were asked to recognise four important types of feature occurring within the 18 themes on the Martian surface (McEwen et al., 2009).

The first type of feature, Aeolian Processes, covers the study of landforms formed by wind. The players were asked if they could find two different types of these structures: Transverse Aeolian Ridges (TARs) and honeycomb bedforms. TARs describe three levels of linear wind erosion in the form of ripples and dunes, while the three levels of honeycomb bedforms are circular (Zimbleman, 2009; Bridges, 2010). The second type of feature, Gullies and River Meanders, relates to places on Mars where there could have been water in the past and thus could have been caused by water erosion (Berman, 2010; McEwen, 2006; NWT, 2010). The third type, Layers, relates to vertically ordered ground. Layers are often created by sediments that have been laid down by water, dust storms, volcanic eruptions or crater impacts (Grant, 2010; Beyer, 2009). The fourth category, Anomalies, is different from the other three because it is not specifically defined, but caters for the case when a player recognises something strange that does not fit into any particular category, but which could still be interesting, such as, for example, strangely coloured mountains, strange shapes or even Mars landers like the Phoenix lander (Bridges, 2006).

The photos annotated by the players covered all four types of feature and were carefully preselected. Eight photos were extracted from the HiRISE database and a ninth photo was created manually which functioned as a training map. This photo was a synthesis of all the other photos welded together using photo editing software. Each photo had a resolution of 25 cm^2 per pixel, covering a surface of 300 m^2. Each was downloaded in colour (better for context) and infrared (better for detail). The players could shift between these two views using a slider.

	Poor gaming experience	**Rich gaming experience**
Implicit knowledge transfer	−−/−−/−− (condition 1)	++/+/+ (condition 3)
Explicit knowledge transfer	−−/++/+ (condition 2)	++/++/++ (condition 4)
Notation: Hypothesis: Motivation/Precision/Validity (condition#)		

Table 1. Factor table for testing the hypotheses.

Figure 2. Game interface.

Each photo was divided into 144 squares which the players had to annotate with the features they had discovered. Figure 2 demonstrates the interface containing the annotation tools (bottom). Each tool is arranged by type and represented by its own icon. The tools are from left to right: ripples, dunes, draas honeycomb levels 3, 2 and 1, river meanders, layers and anomalies.

When a player annotates a feature he gains a point and this point is added to the total number of annotations previously made by others for that feature on that square. This new total is then the amount credited to the player's individual score. So for example, if a player marks a dune and eight other players had previously marked the dune then the player is rewarded with nine points, and the next player to mark the dune would get ten points, and so on. Thus the game rewards good behaviour and encourages players to do their best.

Figure 3 shows the player's view with some annotated features. In these example grid squares the player can see the points assigned to the ripple (RI) and dune (DU) annotations he has made. Note the only negative feedback is the low score received when an error is made, while a high score represents positive feedback. Each of the features to be marked in the game was represented by one or more tools that the player could select. Each new annotation was transmitted to a database and the set of accumulated annotations formed the dataset used in this research.

B. The main game

The dataset, the annotation module used to mark features and the basic scoring system were identical for all four game conditions. Also each condition started with a training phase so players could become familiar with the interface and with Mars. This phase differed in the way it was built up for the poor and the rich game conditions. The poor game conditions only required players to score a total of 3380 points before proceeding to the main game, while the rich game conditions included short missions that had to be completed and a total score of 3380 points as prerequisites. The training photo was pre-annotated using information from the scientific literature, so players experienced the game as if other players had previously annotated the photo. In this way new players were rewarded for making correct annotations as they would be in the game. Completion of the training unlocked the real Mars photos so that players could begin annotating in earnest.

C. Explicit versus implicit

The explicit and implicit game conditions had different help functions. The implicit game condition only had a first level "mouse-over" help function which very roughly described what each tool did. It did not give any examples nor did it supply the knowledge needed for players to know where to look. The explicit game condition added two additional levels of help. The second level help function was shown when a player clicked on a tool and displayed a brief description of what to look at and was always in scope. The third level was the most detailed help level and was accessible by clicking on the question marks. This level showed what to do and what to look for in great detail. The help texts used information from the scientific literature, but were written specifically for the game.

Figure 3. Annotated ripples and dunes.

D. Poor game experience versus a rich experience

Section 2 described several motivational functions in existing games, including counting scores, rewards for certain achievements, a share in any scientific glory and an active social network (NASA & Microsoft, 2009; Hoffmann, 2009; Charles, 2009; Dartnell, 2009). The conditions with a poor game experience only had a simple scoring system to provide the player with minimal feedback. The rich game experience had an additional extra palette of game-stimulating functions inspired by existing games, including the selection of a personal avatar, promotion in a fictitious operational hierarchy on Mars, rewards for certain actions such as using the infrared tool, and the missions used in training.

E. The test group

Each player was randomly assigned to a game condition during registration to generate a uniform distribution of players in age, gender and pre-knowledge about Mars over the four conditions. Players were recruited via direct mailing and by starting community topics in internet forums related to games, science and Mars.

Results

The game, called Cerberus, after the mythological dog, was launched on 17 July

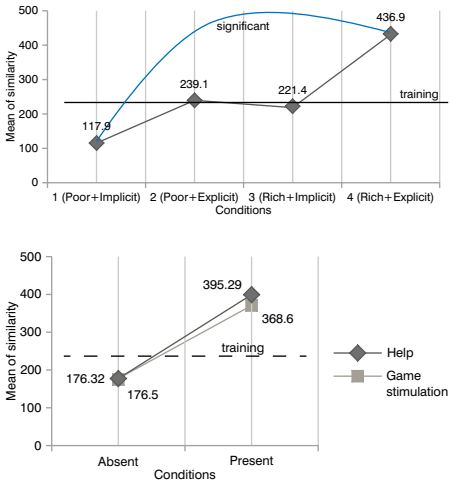

Figure 4. Mean of motivation.

Condition	N	Prop.	Passed Training (n and prop)		Age (mean)	Age (sDev)	Male	Female	Male (prop)	Female (prop)	Motivation (mean)	Motivation (sDev)	Precision (mean)	Precision (sDev)
1	27	20.8 %	4	17.8 %	26.89	13.08	19	8	70.4 %	29.6 %	117.9	131	0.483	0.432
2	26	20.0 %	6	23.1 %	29.81	14.36	21	5	80.8 %	19.2 %	239.1	471	0.407	0.359
3	35	26.9 %	9	25.7 %	27.79	6.24	31	4	88.6 %	11.4 %	221.4	336.4	0.39	0.293
4	42	32.3 %	22	52.3 %	33.21	16.28	35	7	83.4 %	16.6 %	436.9	513.7	0.626	0.176

Table 2. Numerical breakdown by condition.

2010. On 18 August 2010 the database containing data from 151 players was extracted. After removing test accounts, spam and people who never logged in, the group was reduced to 130. The composition and some results of the research groups and its corresponding conditions are shown in Table 2. In this section the results measuring the motivation, precision and the validity, which indicates whether the data could be used for scientific research, will be discussed.

A. Motivation

Motivation is about the eagerness of the players to play Cerberus. It is measured by the total number of annotations, or clicks, made by the players. The more annotations a player makes the more time and effort they have spent playing. A one-way ANOVA was conducted to test whether the mean motivation differed among the conditions. In this measurement each annotation per photo per player was counted, including the training photo. The motivation (m) for each individual player is calculated as follows (f = feature):

$$m = \Sigma\,(\text{photo}\,(\Sigma\,\text{tile}\,(\Sigma\,f)))$$

Motivation results

Figure 4 shows all the motivation results. The horizontal line marks the training threshold, which is the minimum required sum of 194 annotations to pass the training mission. There was a significant difference between condition 1 and condition 4 (see Table 1), i.e. players were more eager to participate in crowdsourcing using a serious game with extended help in combination with rich game elements. The two intermediate game conditions in between (2 and 3) showed no significant differences with either condition 1 or condition 4. So adding either a rich game experience or explicit help does not add enough to be significantly different from condition 1.

Precision

Precision is measured by comparing each individual annotation with the expert annotation. The expert annotation is based on descriptions in the literature about Mars's geological features. Each photograph is pre-annotated by the experts to test the players' precision. Table 2 in the column Precision shows the results from each condition. A mean score of 1.0 implies maximum precision (no errors) while a score of 0.0 implies the player is wrong. To test which condition performed better a One-Way ANOVA is conducted. No training photographs were included in this calculation. Precision (pr) is calculated by testing each player-annotated feature (f_{pl}) per square (sqr) with the expert annotated feature (f_{exp}). Note each square can have a maximum of eight different annotated features. Each feature is marked as 1 or 0 (annotated or not annotated) in the database. The formula is as follows:

$$pr_{sqr} = \frac{\Sigma\, f_{pl} + f_{exp}^{-1}}{\Sigma\, f_{pl}}$$

The results show that for this data, there is no significant difference in precision between the implicit and the explicit gaming conditions.

Validity for science

Until now motivation and precision were discussed as measurements based on an individual basis. However, this approach does not give any insight into the performance of Cerberus as a crowdsourcing initiative, and thus into how players performed as a collective.

To check for validity, all the player results for each condition are now taken together and their similarity (sl) is calculated. Similarity is a measurement comparing the collective data with the expert annotation. Because the number of annotations per feature per player varies from 0 to 15 (15 meaning that 15 players made the same annotation independently) with a mean of 0.789 for the entire data collection, all marked expert features are assigned a target of ten annotations. This means that ten players need to make an identical annotation agreeing with the expert to gain a similarity of 1.0, and for 15 player annotations the similarity would be 1.5. Similarities greater than one indicate that the collective (crowd) has outperformed the expert (Hoffmann, 2009). If neither the collective nor the expert made any annotations for a particular feature the similarity was also 1.0 as the collective was not in error. For this reason all eventual calculated similarity means for each condition will be rather high because the largest portion of all possible annotations is no annotations at all. This is different from the precision calculation where each individual click was tested for right or wrong.

Summarising the similarity calculation for each square, (sl_{sqr}) is calculated by testing each collective annotation (f_{col}) with the expert annotation (f_{exp}) and can be any posi-

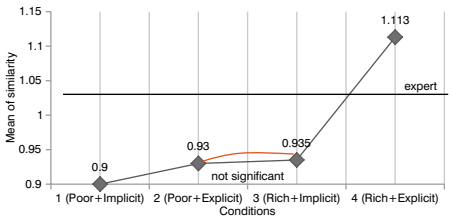

Figure 5. Similarity.

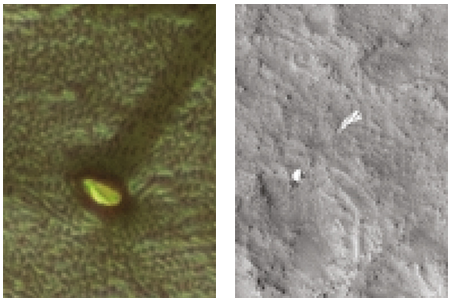

Figure 6. The possible tower and the Phoenix.

tive value when there is similarity, and is 0 when there is no similarity. Before applying this formula to the dataset, each feature where there was neither an expert nor a collective annotation was upgraded to 10 manually. This ensured that the formula calculated a similarity of 1.0 for all the unmarked features. The formula is:

$$sl_{sqr} = \frac{\sum \frac{f_{col} \cdot f_{exp}}{100}}{8}$$

Qualitative results

The anomaly tool was available in all game conditions and it was used for a total of 67 annotations. Most of these annotations were for craters, strange spots, sediments and rocks, but some rarer objects were found, and which were "marked" objects by the expert. The first object is the strange yellow rock, of which some unknown expert annotated as an outgassing tufa tower. The other object is the Pathfinder lander (Bridges, 2006). People have described it as a white spot, a pod or a balloon. Figure 6 shows the possible tufa tower (left) and the Pathfinder lander's pod and its balloon (right).

Discussion

Motivation was significantly higher in condition 4 where there was explicit help and a rich game experience. Precision did not show any significant differences between any of the conditions although there was a noticeable increase in conditions with explicit help, perhaps because in the conditions where players were not motivated enough most gave up long before completion of the training phase due to boredom or the lack of clear goals, and so did not contribute to the final dataset. This meant there were very few players whose results could be used to calculate the precision in the poor game conditions, and so the results in these cases might be biased. It is remarkable that the precision standard deviation tended to narrow in the explicit help and rich game conditions, implying a higher consensus among players in making annotations. Condition 4 showed the highest mean of precision and had the lowest standard deviation. When investigating the similarity results of the collective, condition 4 also demonstrated a significantly higher similarity than any other condition.

Conclusion

While it cannot be proven that the level of instruction had any effect on precision, and thus on the acquired knowledge of the players, it did show a significant effect on the players' motivation. The collective results did show a significantly better similarity with the expert data for the explicit game conditions, so for overall success, explicit instruction is essential. The rich game conditions scored significantly better for motivation than the poor game conditions. Yet the rich game condition without explicit help did not motivate the players significantly better or worse than any other condition. The rich game with explicit help does score significantly better than the condition with implicit help and a poor game experience. Therefore we conclude that a rich game condition is indeed essential, but it must be combined with explicit help to be effective. The annotations made under condition 4, explicit help and a rich game experience showed a high similarity to the expert annotations. Moreover the players generated more results collectively because the expert missed some features. Some players did actually re-discover the Phoenix lander — somewhat of a needle in a haystack task. In conclusion, we can say that the annotations performed by the players are indeed of use for science.

The answer to the main question, whether crowdsourcing in the form of a serious game used for annotation in a semantically-rich research domain is possible, is positive. While there still can be discussion about the implicit or explicit learning conditions and the effects on individual precision, the players did manage to generate an accurate map of the Mars photographs as a collective and thus were able to apply deeper semantic knowledge.

Cerberus has not come to an end with this study. Cerberus as a game has a lot of functions per game condition, but it is not yet clear what the effects of each separately are. For example the explicit help function adds a second and a third help level, so claims can only be made about these functions combined, but not separately. The same applies to the rich game conditions. Cerberus has avatars, rewards, rankings and more enriching game elements, but it is not yet clear what the effects are of avatars or any other of these functions in isolation. Cerberus as a platform is being developed further and meanwhile is participating in the European Space Agency (ESA) business incubator programme. With technological aid directly coming from ESA, Cerberus is now being professionally developed and directly targeted at crowdsourcing, e-learning, gaming and outreach. Other applications where Cerberus could be used are being explored, such as assisting climate-change research or in any field where satellite photographs could be translated into Geographical Information System data. More about Cerberus's current progress, along with the most recent playable version can be found at www.cerberusgame.com.

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Biography

Hans van 't Woud (1983) was born in Leiden, the Netherlands, and studied Human Centred Multimedia at the University of Amsterdam where he was awarded his MSc degree for this research. Before this he graduated with a Bachelor's degree from Rotterdam University, and in part also, the Willem de Kooning Academy of Arts, in Communication and Multimedia Design. After this he worked a period as product manager for a company involving healthcare software. During his Master's study at the University of Amsterdam he participated in a project regarding learning with mobile devices, where he was responsible for the general interface design. Nowadays he is a fulltime entrepreneur for his company, BlackShore — creative, where he is taking Cerberus to the next level. For this he is collaborating closely with and participating in the ESA business incubation centre in the Netherlands.

Reviews

Carbon Based Lifeforms @ Cosmonova: A Concert in Sight and Sound for IYA2009

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Keywords
International Year of Astronomy 2009, Arts, Music, Lightshow

Summary

Replacing its conventional analogue planetarium with a digital fulldome system, the Cosmonova theatre at the Swedish Museum of Natural History sought to come up with a variety of public offerings for the International Year of Astronomy 2009. Besides several fulldome shows it was decided that a concert of live music would both celebrate the year as well as attempt to attract a new audience.

Originally planned as a conventional planetarium, Cosmonova opened in mid-October 1992 as a combined ImaxDome 15/70 large-format film theatre and an Evans & Sutherland Digistar I video planetarium, both operating within the same 23-metre dome. With a 30-degree tilt the dome covers a large part of the audience's peripheral vision, making for a very immersive experience. Besides showing "off-the-peg" large-format IMAX films, a number of original planetarium shows were created that involved both Digistar and analogue media, such as 35 mm slides, videos, custom-built all-sky projectors that cover the dome and offered spectacular special effects, and even astronomy-themed IMAX film clips. While Cosmonova was one of the most technically advanced facilities in the world when it opened, by 2006 it was obvious that an upgrade was needed to bring the theatre into the 21st century.

After the renovation, Cosmonova planned to show a selection of astronomy-related fulldome video shows during the International Year of Astronomy 2009, as well as featuring a small mini-exhibit with some historical telescopes outside the theatre's entrance. It was also thought that a

Figure 1. Kokopelli, the humpbacked rain god and muse of music for a number of Native American tribes from southwestern US states, descends from the summer skies over the ruins of Wukoki, a structure built by an ancient pueblo people in Arizona, south of Flagstaff. Credit: T. Callen and Cosmonova.

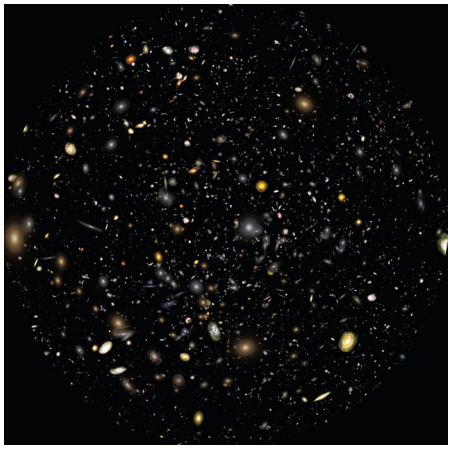

Figure 2. Hundreds of galaxies fill Cosmonova's dome in this image from the Hubble Space Telescope. Transformed into a three-dimensional video, it was possible to travel through them just as if one were travelling through the real Universe. Credit: NASA/ESA, T. Callen and Cosmonova.

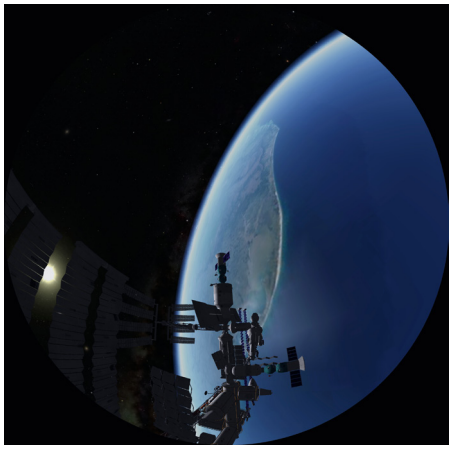

Figure 3. SCISS AB's Uniview™ *rendition of the International Space Station (ISS) hangs in orbit some 350 kilometres above Earth's surface. Since the members of Carbon Based Lifeforms were so taken with a demonstration of the ISS in Cosmonova one whole song in the concert,* MOS 6581*, featured it. Credit: T. Callen and Cosmonova.*

live concert in the theatre with an astronomical and/or space theme would go over well. Cosmonova had hosted several live concerts in the past and produced appropriate visuals to show on the dome overhead. A general call for suggestions to the whole Museum staff bore fruit in the form of an idea from Hanna Taylor, who worked in one of the research departments. She knew of a Swedish ambient electronic music group, Carbon Based Lifeforms (CBL), whose music might be suitable. CBL was also a group that had performed live in a variety of different types of venues so playing under a planetarium dome would not be a problem for them.

CBL formed in 1996 and at the time of the concert consisted of members Johannes Hedberg and Daniel Segerstad. Based in the western coastal city of Göteborg they had three albums to their credit and a wider global following, although much of this was based in Europe. After a meeting in May 2009, it was decided to hold a live concert in Cosmonova late in the year, with CBL to provide the music and Cosmonova to provide the visuals. To make the concert even more special to their fan base CBL wanted to include three tracks from an as-yet unreleased album to mix in with others that were considered to be "classics". A total of seven tracks were decided on, making the whole show 45 minutes long.

Using copies of all seven live concert tracks for inspiration and reference I set about producing the visuals. Having worked with creating musical light shows as far back as the late 1970s when I was a graduate student at Michigan State University's Abrams Planetarium in the US, this was going to be both a challenge and a lot of fun. CBL hadn't set any restrictions, so the concert's visuals could go in any direction that seemed appropriate. Since I was now working in a completely digital domain, production techniques had changed significantly in the years since I had made the visuals for Cosmonova's previous live music concerts. Instead of having to use Digistar, 35 mm slides, videos and all-skies synchronised via an automation system I had a whole new palette of digital tools at my disposal on the fulldome video system's production workstation.

SCISS AB's Uniview is the software used for Cosmonova's new digital planetarium and it was to provide any original astronomically-based video clips. Three-dimensional camera paths manually "flown" with the workstation's mouse could be recorded and rendered out of Uniview at 3200 × 3200 pixel resolution for later processing. Some examples of clips created in Uniview were flybys of planets, tours between galaxies, a view of the slowly turning band of the Milky Way changing through various parts of the electromagnetic spectrum, a scintillating night sky seen from the Arizona desert and the cosmic background radiation that pervades the Universe.

Adobe Photoshop CS3 was used to create and/or process digital photographs that I had taken, as well as to prepare scanned all-sky images that had originally been shot on 120 roll or 4 inch × 5 inch sheet film with special ProDome all-sky cameras. Wondertouch's particleIllusion 3.0 software was used to generate a video clip of a dome full of microscopic parameciumlike life scurrying around. One original video clip had its origins in a film I made of sunlight obliquely reflecting off of the tops of waves on the bay in front of my house on the island of Rindö in the Stockholm archipelago.

Adobe AfterEffects CS3 was then used to compose all the various visual elements against each of the seven individual music tracks. In order to check the synch between audio and visuals, low resolution test renders were made as needed. Once the visuals were completed for all the music tracks the whole concert was rendered out in high resolution. From there the 132-gigabyte file was copied onto a portable hard drive and turned over to Cosmonova's technicians for a process colloquially known as "carving" (or "slicing and dicing" in some fulldome circles).

The standard for image files in a fulldome video show is circular and known as the dome master format. The centre of each dome master image represents the zenith of the planetarium's dome while its circular edge marks the 360-degree horizon with the bottom of the image south and directly in front of the audience. In our system 30 images are shown per second,

Figure 4. Carbon Based Lifeforms, Göteborg, a Swedish ambient electronic music group, and then (November 2009) band members Johannes Hedberg (left) and Daniel Segerstad. Credit: M. Fredriksson and Carbon Based Lifeforms.

which means that there are 1800 images displayed per minute. Since there are six projectors that present a fully blended image on the dome of a fulldome video show, each individual dome master image (some 81 000 for the 45-minute concert!) must be split into six pieces (for a total of 486 000 pieces); one complete set for each video projector's associated file server. In order to do this, a special program "carves" the images into these six video streams while taking into account the target and blending areas on the dome for each of the six projectors.

A copy of the concert's audio was also transferred to Cosmonova's audio servers as a back-up in the event that CBL's equipment had a technical malfunction, although this was thought to be highly unlikely. Unfortunately, there could be no such back-up in the improbable event that the fulldome video system developed a problem.

In order to make sure that CBL's final performance would match the visuals, a 720 × 720 pixel low-resolution version of the whole concert was sent to the group and happily enough they found it to agree to within a fraction of a second with the music track they would play at the concert. This was a major relief as the audio work in *After Effects* was new to all of us.

We had first planned on only one concert on Friday, 28 November 2009, but the demand for tickets — even from European-based fans outside Sweden — was so great that it was decided to add a second concert the following night. As it turned out the first night sold out completely, while the second night was just short of doing the same. CBL arrived in Stockholm from Göteborg on Thursday and after setting up their equipment and integrating it with Cosmonova's sound system we had a dress rehearsal to check out the audio and visual elements together on the dome for the first time. Considering the vastness of CBL's musical soundscape there was only an office tabletop full of their synthesisers, laptops and audio equipment, plus Johannes Hedberg's electric guitar, which was fed through outboard sound processors. After several run-throughs to ensure that the live version of the concert would work, everyone sat down together and watched the concert while the so-called "just in case" emergency back-up soundtrack provided the music.

Friday night's audience was definitely made up of hardcore fans as CBL got a lively response when they entered and took up their positions in the front stage area of the theatre. At the end of the concert they received a standing ovation, and, based on people's reactions as they left the theatre, the concert was a success. A special area just outside Cosmonova's exit, and within a Museum exhibit area, was set up so that the band could "meet and greet" their fans afterwards, which also saw a lot of CD signing and lively conversations with the band.

Saturday night's audience, while not made up mostly of fans, was just as eager with anticipation. I was standing up front in the stage area keeping an eye on the band's equipment as the audience took their seats when I recognised an elderly woman who I had seen accompanied by a friend of hers from the night before. As she passed by she recognised me and (with a different person in tow that evening) came over to tell me that: "There were tickets left for tonight and I just had to come again." And she was not the only person who I saw attending both concerts. Clearly this was music that appealed to a variety of ages, as there were people present from grade school and up. As on Friday night the "meet and greet" area outside Cosmonova was set up again.

With two successful nights of concerts, Cosmonova fulfilled at least two goals; having a live astronomy-related musical performance during the International Year of Astronomy 2009 and introducing people who might not normally come to Cosmonova to the types of things that they do. Listening to the audience as they left the theatre it was evident that there were people in attendance who were in this latter category, and some made a point of coming up to Cosmonova staffers to tell them that they would be back to see some of their other show offerings.

Figure 5. Astronomer/Programme Producer Tom Callen in Gamla Stan (Old Town), Stockholm. Credit: C. Russo.

Could it be done again? I think that both Carbon Based Lifeforms and Cosmonova were pleased with the final results and there is no doubt — based on the positive comments and the pirate video clips shot from out in the theatre that were later posted on YouTube (www.youtube.com/watch?v=LokHAcHIiVQ, www.youtube.com/watch?v=9DEpyze0Zs8 and www.youtube.com/watch?v=rgMN9UEH4Zc) — that the audience would do it again too!

Biography

Tom Callen is the former Astronomer and Programme Producer at Cosmonova, the ImaxDome, digital fulldome video planetarium and 3D theatre at the Swedish Museum of Natural History, Stockholm. Prior to coming to the Museum in 1991 he was at the Albert Einstein Planetarium at the Smithsonian Institution's National Air and Space Museum in Washington, DC., for 13 years. He has also worked at three other planetariums in the United States. Today Callen is Managing Director of *eyemmersive*, a newly formed company that specialises in scientific visualisations with an emphasis on space and astronomy applications. Long interested in all types of music he currently finds a more personal music outlet playing "Pratt," his hybrid digital/analogue drum set.

Visualising Astronomy: Visualising Exoplanets

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Keywords:
Visual Communication, Astronomy Visualisation

In my previous column[1], I described some of the varied means of diagramming the data about exoplanets and exoplanetary systems. Frankly, however, those methods don't do justice to the bigger picture: we need a wider range of tools to help people grok[2] (to understand intuitively) what astronomical observations have revealed. (Normally, I use the term "visualisation" to refer to the visual representation of data, but I'm going to relax that a little in this context; instead, I'll interpret the word in its more commonplace usage of creating a mental image.) How can we help people comprehend the scope, the breadth, and the impact of the spectacular observations of planets around other stars?

When it comes to imaging other worlds, space art blazed the trail more than fifty years ago.... The term applies to a variety of content from highly imaginative covers of science fiction paperbacks of the last century to deeply informed recreations of astronomical objects. The International Association of Astronomical Artists (IAAA) website[3] offers a glimpse at the range of work, as well as a peek into the history of the medium.

In his 1978 essay, "The Archeology of Space Art," Ron Miller wrote, "*Contemporary artists certainly have more factual material to draw upon, yet this abundance also limits them. [...] The phrase 'artist's impression' attached to a space painting no longer means an imaginary guess.*"[4] When Miller wrote those words more than three decades ago, he applied his thinking to objects in the Solar System — consider how radically the *Voyager* and *Pioneer* missions transformed our view of other planets — and his words date to a period when actual spacecraft imagery had started to approach artists' representations in terms of quality. And as Miller specifically notes, discoveries made by those spacecraft put constraints on the artists' work (e.g., the Moon doesn't have mountains the likes of which Chesley Bonestell painted in his famous *Colliers* series from the 1950s) that remove them from occasionally more fanciful work of their predecessors. Furthermore, by the time of Miller's writing, the space programme had shifted from human exploration (always a staple of space art) to robotic voyages: a transition from the aspirational ("we will go there") art of the 1950s and 60s to the inspirational ("wouldn't it be nice to be there") art of the 1970s and 80s.

Established space artists including Lynette Cook and David A. Hardy (to choose just two examples) have lent their images to press releases about exoplanets. Indeed, Hardy's image of tau[1] Gruis (Figure 1) strikes me as an almost prototypical example of the genre: the viewer, placed on the surface of a solid body (in this case, the hypothetical moon of an exoplanet discovered by the Anglo-Australian Planet Search), takes in a dramatic vista that incorporates the rugged (exaggerated) terrain of the moon, the visual counterpoint of the ringed planet and the angular foreground, and the highly expressive whorls of the giant planet's clouds.

Coming at the challenge from a different direction, I personally have helped visualise two different exoplanets (and one exoplanet's hypothetical moon) for public planetarium shows, most recently Gliese 581d for the California Academy of Sciences opening show, *Fragile Planet* (Figure 2). Dimitar Sasselov, Director of the Harvard Origins of Life Initiative at the Harvard-Smithsonian Center for Astrophysics, advised on the ratio of water to land, the amount of cloud cover, and the distribution of ice on the surface of the "super Earth." Based on his input, we used an array of animation tools to create the sequence, with particular reliance on Terragen™[5], software originally designed for digital matte painting in the film industry. The final images appeared mapped onto a sphere with appropriate atmospheric effects generated by Uniview software[6], integrated into a Keplerian planetary system with orbits based on the observed characteristics of the Gliese 581 system, then placed into the Hipparchos star catalogue at the star's proper location.

That type of process exists firmly within the realm of science visualisation, albeit driven by a more subjective set of criteria than a typical project, which usually has fewer degrees of freedom in terms of conveying a concept. (I often joke that the challenge of visualising astronomical data boils down to deciding what colour to make the invisible gas.) And like much contemporary visualisation, the scene exists as part of an animated sequence — in this case, fulldome video.

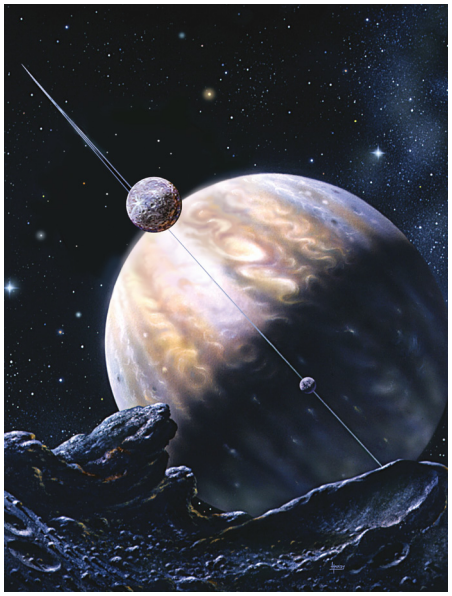

Figure 1. *Artwork from a 2002 press release describing the "detection of a Jupiter-mass planet orbiting tau[1] Gruis" exists squarely within the space art tradition of imagined landscapes. Credit: PPARC and David A. Hardy.*

Most contemporary exoplanet illustrations owe a bit to both space art and visualisation. For example, in Greg Bacon's depiction of HR 8799b (Figure 3), we view a ringed planet from the surface of a hypothetical moon, but the moon takes on an appearance reminiscent of the Galileo images of Ida or the Deep Impact images of

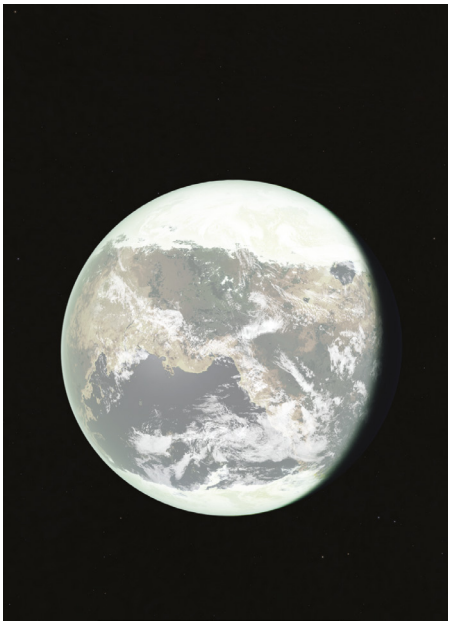

Figure 2. A still image from the planetarium show Fragile Planet illustrating a chilly but water-covered Gliese 581d, based on input from an exoplanet specialist and integrated into the three-dimensional Hipparchos database. Credit: California Academy of Sciences.

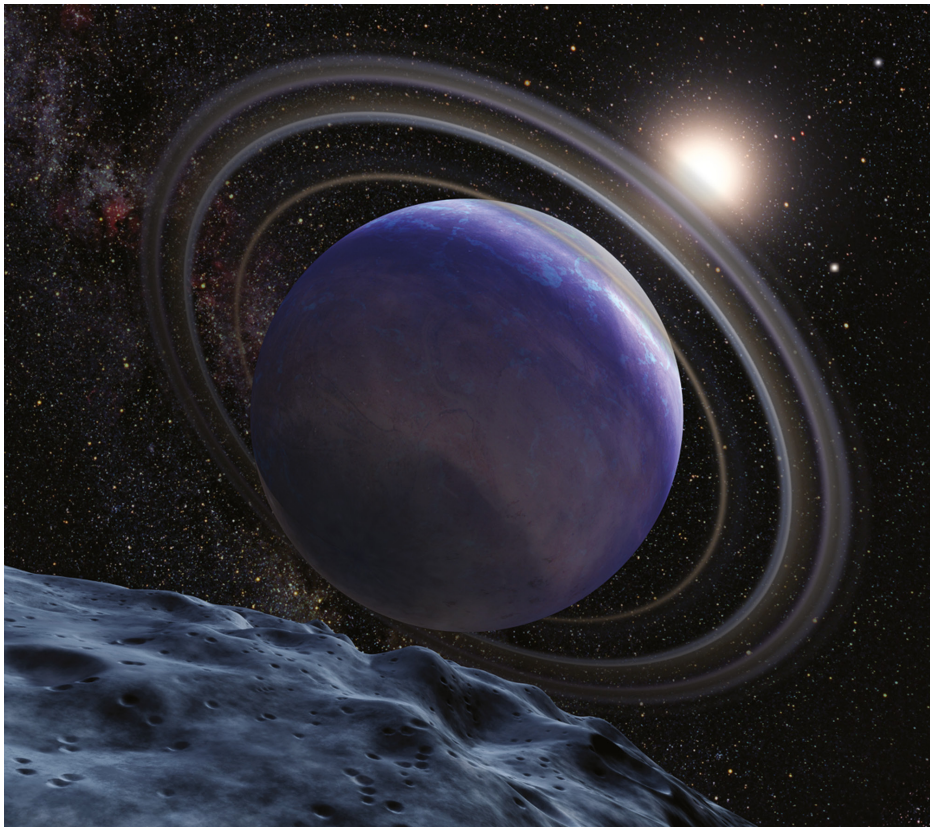

Figure 3. The "artist's concept" that accompanied the Hubble press release about archival data refining our knowledge of HR 8799b. Credit: NASA, ESA, and G. Bacon (STScI).

Tempel 1. But the whole scene sits in front of a photorealistic Milky Way, with the other planets in the system visible as points of light against the background stars[7].

(A detail I can't resist addressing ... Hardy favours a bit of accuracy over drama by depicting a moon that lies in the ring plane of its parent planet, as one would expect. Bacon chooses a more sensational perspective on his ringed world by placing the moon outside the ring plane — a less plausible configuration, but the asteroid-like appearance of the moon suggests a captured body that could exist in an inclined orbit.)

Most of the images that illustrate exoplanet press releases actually involve many more constraints than those Miller decried. The artwork often needs to communicate a specific concept tied to the discovery (e.g., the derived characteristics of the planet, the multiplicity of planets in the system) and sometimes needs to avoid suggesting a potential future discovery (e.g., the existence of an exomoon). As Robert Hurt, of the Spitzer Science Center, puts it, "As the science advances, a second paper can completely overturn the ideas in the previous one, so a carefully constructed visualisation based on one result is often later superseded by a radically different image ... perhaps a reminder that spending weeks to match the science carefully may be overthinking the problem."[8]

I find it intriguing that exoplanet artwork — er, visualisations — reside in this overlap between new and old ways of imagining other worlds. It should come as no surprise, really, since we operate in a blissful state of combined ignorance and imagination. And we can expect this situation to persist for some time, because we can never visit these exoplanets, never subject ourselves to the same kind of specific constraints that the space artists of the 1970s faced with the rapidly-returning results from spacecraft missions throughout the Solar System. Instead, the exoplanet images that accompany press releases will continue to play the role that space art once played for a generation of enthusiasts, fuelling the excitement for discoveries about the Universe around us.

Notes

[1] Wyatt, R. 2011, Visualising Astronomy: Visualising Exoplanet Data, CAPjournal, 11, 32

[2] Heinlein, R. 1961, Stranger in a Strange Land, (London: New English Library Ltd)

[3] http://iaaa.org/

[4] Miller, Ron 1978, Space Art, p. 10 (retrieved from http://dreamsofspace.nfshost.com/spaceart.htm on 12 February 2012)

[5] http://www.planetside.co.uk/

[6] http://scalingtheuniverse.com/

[7] http://hubblesite.org/newscenter/archive/releases/2009/15/image/d/

[8] Hurt, R. 2012, Private correspondence, 15 Feb 2012.

Biography

Ryan Wyatt is the Director of Morrison Planetarium and Science Visualization at the California Academy of Sciences in San Francisco, California, USA. He writes a sadly irregular blog, Visualizing Science, available online at http:// Visualizingscience.ryanwyatt.net/.

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