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CAP journal

Communicating Astronomy with the Public

Tactile Sun

Bringing an Invisible Universe to the Visually Impaired

Reaching for the Stars in your Golden Years

The Importance of Outreach for Senior Citizens

A Do-it-yourself Guide

The University of Washington Mobile Planetarium

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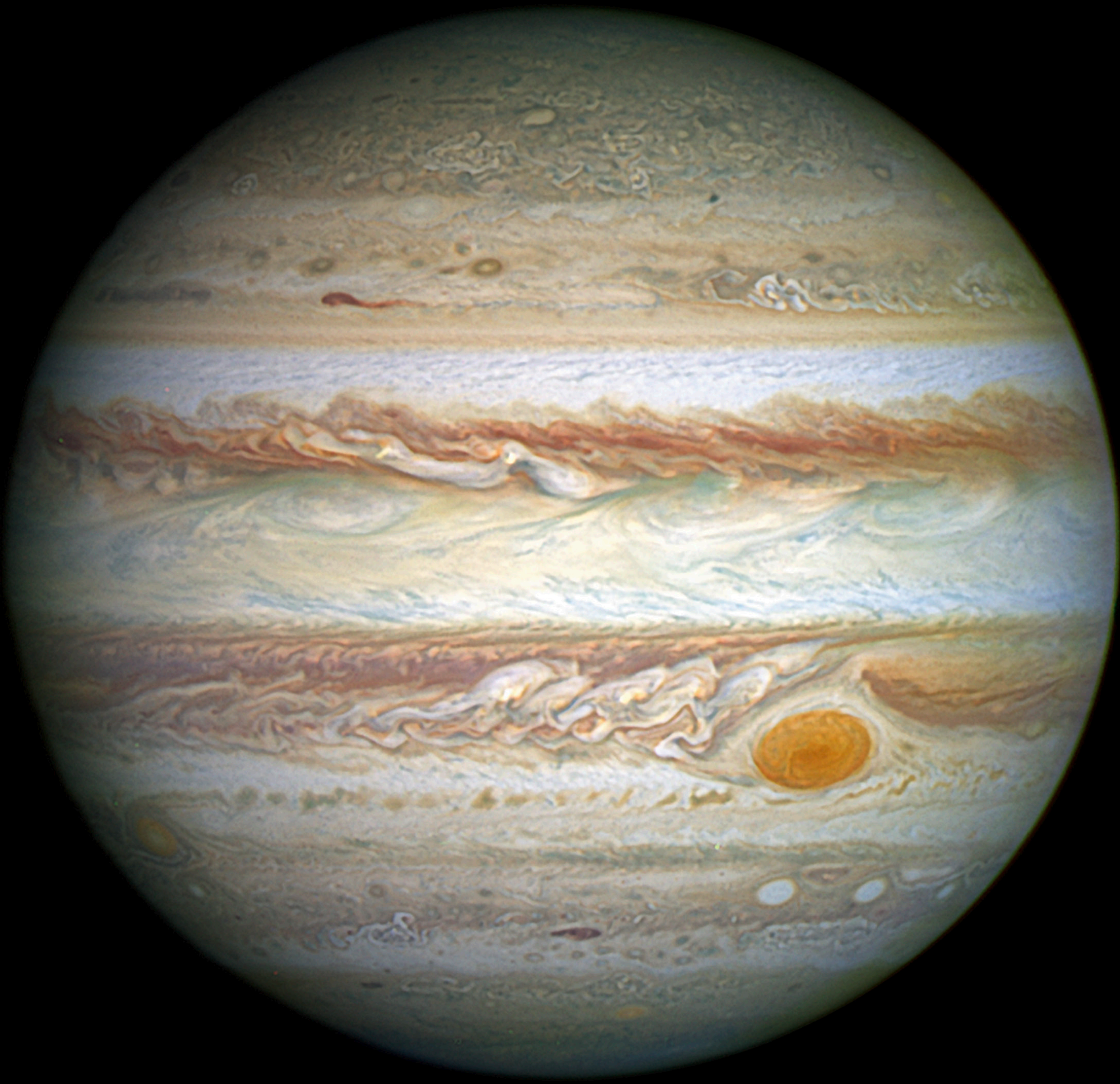
IAU

This image shows Jupiter's famous Great Red Spot at its smallest ever observed size. The Great Red Spot is a churning anti-cyclonic storm and is one of the most widely known and popular planetary features in the Solar System.

The Great Red Spot shows up in images of the giant planet as a conspicuous deep red eye embedded in swirling layers of pale yellow, orange and white. Winds inside this Jovian storm rage at immense speeds, reaching several hundreds of kilometres per hour.

This NASA/ESA Hubble Space Telescope image shows the spot at just under 16 500 kilometres across, significantly smaller than the 23 335 kilometres of 1979.

Credit: NASA, ESA, and A. Simon (GSFC)



Editorial

It is once again my pleasure to introduce the *CAPjournal*, as it reaches its 15th issue.

Earlier this year I was lucky enough to visit the Chilean Atacama Desert, an arid and unforgiving environment that is home to some of the clearest skies on the planet — not to mention some of the world's most impressive ground-based telescopes. Viewing the night sky with such clarity — very different from the orange skies of home — was unlike anything I had seen before and highlighted to me how important it is to do what we do. To bring those skies to people all over the world.

The commitment that this community has to engaging the public with astronomy and astrophysics never ceases to astound me, and neither does the enthusiasm of the public to engage with it. Even in a remote desert town — 106 kilometres from the nearest city with a population of under 5000 — I waited four days for a place on a "star tour". The appetite for knowledge about the Universe is phenomenal.

So, I would like to thank the authors of the papers and articles found in this journal for helping us to share knowledge on communicating astronomy with the public and to expand and improve upon the field. Not to mention the team of people at the IAU and ESO ePOD who make this journal happen, alongside countless other outreach initiatives.

In this issue you will find articles that outline best practice for astronomy outreach with the visually impaired, with the elderly, with children and with audiences from around the world — from rural Mexico to downtown Tokyo, Japan. Amongst the research articles there are resources on designing your own spectroscopy lab, building a do-it-yourself portable planetarium programme and using new analogies to bring the Universe down to a scale that can be better understood.

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

Many thanks for your interest in CAPjournal and happy reading,

Georgia Bladon
Editor-in-Chief of CAPjournal

Contents

Cover: On the cover of this issue is an image from the Ultraviolet Coverage of the Hubble Ultra Deep Field (UVUDF) project. It is the most comprehensive picture ever assembled of the evolving Universe — and one of the most colourful. Credit: NASA, ESA, H. Teplitz and M. Rafelski (IPAC/Caltech), A. Koekemoer (STScI), R. Windhorst (Arizona State University), and Z. Levay (STScI).

Submit articles for one of the following journal sections:

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

Explained in 60 Seconds: Timescales of Stellar Oscillations

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Keywords
Asteroseismology, Pulsating Stars, Stellar Time Scales, Stellar Oscillations

For the most part the stars are constants in our lives and are often perceived as only changing on timescales of billions of years. However, the brightnesses of stars can vary over a period of time that you could measure on your watch.

The hour hand: it takes half a day to complete one full revolution — in other words it has a frequency of two cycles per day. This is roughly the same timescale as the brightness variation in a red giant star five times the diameter of the Sun.

The minute hand: it completes one cycle in an hour and illustrates the time it takes for a red giant twice the diameter of the Sun to vary in brightness.

The Sun is oscillating with a period of five minutes — a typical coffee break.

The fast-moving second hand can be a good proxy for the variability of a white dwarf. These densely packed objects are about one tenth of the Sun's size, and have brightness variation periods of 100 to 1200 seconds.

Variability timescales give a good indication of the density of a star. Periods can range from between a few hundred seconds in very dense objects to several hundred days for stars with a low density like Mira, a red giant with a diameter one hundred times that of the Sun.

Figure 1. *Comparing stellar time scales to something known by everyone: a watch. Credit: Chris Roach.*

Tactile Sun: Bringing an Invisible Universe to the Visually Impaired

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Keywords
Science Literacy, Public Outreach, Adapted Materials, Visually Impaired, Braille

Summary

A tactile model of the Sun has been created as a strategy for communicating astronomy to the blind or visually impaired, and as a useful outreach tool for general audiences. The model design was a collaboration between an education specialist, an astronomy specialist and a sculptor. The tactile Sun has been used at astronomy outreach events in Puerto Rico to make activities more inclusive and to increase public awareness of the needs of those with disabilities.

Introduction

The University of Puerto Rico is currently pursuing strategies to adapt its Descriptive Astronomy course for students who are visually impaired or blind (Isidro, 2013). Making elective science courses available and accessible to all college students is very important as a means to improve science literacy and give a foundation in the scientific method and in general scientific concepts (Hobson, 2008). Astronomy in particular is a course that attracts the interest of many students and can serve to inspire them to learn about science and technology (IAU, 2010).

The resources typically available for presenting astronomical concepts to the visually impaired are limited to three-dimensional figures, tactile plane figures and some Braille lessons. Some academic institutions, public places and museums have a limited selection of adapted materials that can be used to elaborate astronomy concepts, and are available to be used by visually impaired visitors and students.

Learning to present astronomy concepts according to individual needs in this way not only enhances the individual's appreciation of the concepts and access to scientific knowledge, but also promotes a culture of respect for the differences of others.

Figure 1. The artist Luis Felipe Passalaqua working with the tactile Sun during the sculpting workshop Hands that See (2014). Credit: Isidro.

From the Moon to the Sun

The tactile model of the Sun was developed after collaborating with the design and evaluation of the 3D tactile model of the Moon, a project directed by Dr Amelia Ortiz Gil from the Astronomical Observatory of Valencia, Spain[1]). This experience highlighted the importance of listening to the visually impaired when working with tactile models.

To design a tactile model of the Sun with an appropriate level of detail the team at the University of Puerto Rico were advised by the blind artist–sculptor Luis Felipe Passalacqua[2] and the group of blind participants at the sculpting workshop Hands that See (*Manos que Miran* in Spanish). Passalacqua was a medical illustrator and

Figure 2. *The artist Luis Felipe Passalaqua exploring the tactile comet (Kowal et al., 2010) and a blind participant of the Hands that See workshop exploring the tactile Sun (2013). Credit: Isidro.*

Figure 3. *Tactile Sun model with an approximate indication of the size of the Earth with the head of a pin stuck in cork at the left side. Credit: Isidro.*

artist before losing his sight several years ago. In addition to his work as a sculptor he is actively engaged in introducing diverse audiences to the arts and increasing public awareness of people with disabilities.

Isidro worked as a volunteer for the Hands that See workshop at the Museum of Art, Puerto Rico. The workshop was developed with the assistance of five volunteers and a member of the museum staff. The participants included totally blind, visually impaired and paraplegic individuals. The tactile Sun project was developed over a period of ten weeks and concluded with a display of the students' creations[3] at the museum in May 2013.

Designing a tactile model of the Sun

The tactile Sun was created on a styrofoam sphere coated with a metal mesh screen. The texture of the Sun was made using cold porcelain and it was then painted with acrylic paint. Cold porcelain is an easy-to-prepare and inexpensive material that is used in crafts.

The tactile Sun consists of a sphere with a radius of 10.9 cm and its rough texture represents the granular appearance in the visible images of the Sun. The grains in the tactile Sun correspond to the movement of gas in the convection zone of the Sun. In visible images, the bright areas of the Sun represent gas that is ascending and the dark areas are the descending gas. In the tactile Sun, the high reliefs represent the ascending gas and the low reliefs represent the descending gas.

The surface of the sphere has two arcs that are protruding from the surface. These arcs represent two prominences — jets of gas ejected from active regions on the Sun's surface with the shape of arcs. In addition, the tactile Sun has three flat surfaces representing three solar flares — jets of gas ejected from active regions of the Sun's surface shaped as flames.

In the centre of the sphere, there is a small hole that represents a sunspot — a region where the temperature is lower than adjacent areas. Some sunspots are comparable in size to the size of Earth.

Some uses of a tactile model of the Sun

The team have used the tactile Sun model at different events[4] developed in consultation with blind people. It was displayed at an exhibit during the celebration of White Cane Day[5]: *Dare to See the World with Your Eyes Closed*, at the University of Puerto Rico (15 October 2013). The model has also been used at teacher workshops with science and mathematics teachers and with special education teachers, as a resource with sighted students at all levels in an activity about the scale of the Solar System, and to present concepts and at the same time display different resources developed to make astronomy more accessible.

When discussing the Sun at outreach events it is very important to remind the public to never look directly at the Sun without proper protection because direct sunlight may cause permanent damage to our eyes.

Conclusion

The design and development of tactile materials as an education strategy offers blind students or students with special needs the opportunity to become interested in learning science and mathematics. The tactile Sun is an example of how to create tactile resources in the classroom and at astronomy outreach events that are made using easy-to-find materials.

It is very helpful to include the blind during the process of design and elaboration of the models to be used with this community and to synchronise activities with events already organised by the community. This strengthens the activity's relevance to the community, enhances the quality of the output in communicating key concepts and helps to establish stronger bonds with the blind community.

Other resources for engaging the visually impaired with astronomy

- A printed guide (in large print and Braille) to using the tactile model was created by the University.
- The tactile Sun can be complemented with images from the book *Touch the Sun* by Noreen Grice (2005).
- There are several Braille books with tactile images available. These include *Touch the Earth, Touch the Sun, Touch the Universe, Touch the Invisible Sky, Touch the Stars, The Little Moon Phase Book* and *Our Place in Space* (Grice, 2006).
- There is a tactile/Braille exhibit that was developed during the International Year of Astronomy 2009 (Arcand et al., 2010).
- At events where the setting allows for the use of computers, assistive technology with software such as JAWS[6], or Earth+[7] can be used alongside other tactile-adapted materials to allow the blind to participate actively and independently in the demonstration.

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Notes

1 http://astrokit.uv.es/downloads/The-MoonatYourFingertips_Guide.pdf (retrieved on (19.3.2014)

2 http://www.youtube.com/watch?v=fBpNNeh1NzA (retrieved on 18.2.2014)

3 http://www.youtube.com/watch?v=rznx1GxHTQo (retrieved on 18.2.2014)

4 http://materialdidacticoparaciegos.blogspot.com/ (retrieved on 3.6.2012)

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7 http://prime.jsc.nasa.gov/earthplus/ (retrieved on 20.2.2014)

Biographies

Gloria M. Isidro obtained her PhD from the Education Faculty of the University of Puerto Rico, San Juan campus. Dr Isidro is from Colombia. She completed her undergraduate studies in Mathematics at the Universidad Industrial de Santander in Colombia. She completed a Masters degree in Mathematics at the University of Puerto Rico. She has worked on developing strategies to make the learning of mathematics and astronomy accessible for blind students.

Carmen A. Pantoja is the first Puerto Rican woman astronomer. She completed her Bachelor and Master's degrees in Physics at the University of Puerto Rico (UPR), and obtained a PhD at the University of Oklahoma using the Arecibo Observatory for her research. She is an Associate Professor of Physics at the Department of Physics of the Natural Sciences Faculty (UPR, San Juan). Dr Pantoja is interested in the large-scale distribution of galaxies in the Universe and in the emission properties at radio and infrared wavelengths of galaxies. She has worked in the development of strategies to make astronomy accessible for persons who are visually impaired or blind.

Best Practices

Here, There & Everywhere: Science through Metaphor, Near and Far

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Keywords
Metaphor, Science Communication, Physics, Astronomy

Summary

The use of metaphors in teaching and learning has a long-standing history. Metaphors can be an effective way to make something new seem less daunting by comparing it with something more familiar. This technique of equating different or disparate things can help complex concepts become more understandable and accessible. The power of the metaphor is discussed in this article, which explores a recent public science project from the Chandra X-ray Center called Here, There and Everywhere. This project attempts to utilise analogy in effective science communication, as well highlighting the dangers that come alongside the use of metaphor and analogy. The article will also look at other areas where metaphors may be usefully implemented in astronomy communication, such as for upcoming programmes, including the International Year of Light 2015.

Introduction

A common refrain heard by those in astronomy communication, whether from students or the greater public runs along these lines: "What does space have to do with me?", "The Universe seems too complicated for me to understand", or "Why should I care about things so far away?" (Rosenberg et al., 2013).

Research strongly suggests that the knowledge and reasoning of people is situated within a context (Osborne, 2007; Brown, Collins & Duiguid, 1989; Carraher, Carraher & Schliemann, 1985; Lave, 1988). By helping to make cosmic phenomena easier to relate to by the use of metaphors, we can perhaps chip away at some of the barriers to the scientific content of astronomy and astrophysics. To that end, the Chandra X-ray Center science communications group created the project, Here, There, and Everywhere (HTE).

At the core of the HTE project is the idea of grouping familiar happenings in our day-to-day experiences on Earth with those on larger scales across the planet and ultimately with objects and events in space. A non-expert might not realise that a solid scientific connection exists between seemingly different scenes and so HTE materials attempt to convey that science can connect things across vast scales and in many different environments.

When we see a wet dog creatively twisting her body back and forth to shake off the water, our thoughts might not drift to the conversion of rotational energy into outflows. Furthermore, most of us probably do not think of how this could in turn be related to energetic winds powered by rapidly rotating pulsars. But why not? With the dog, we are observing something that we can grasp, whose underlying physics we understand from experience. However we often miss the universality of physical laws and the connection between our everyday world and the larger environment.

Figure 1. Example of the HTE concept, from rotation to outflows: a dog, a windmill, and the Crab Nebula pulsar. Credits: Dog - Stock Photography; Windmill - Stock Photography; Crab Nebula - NASA/CXC/SAO/F. Seward et al.

Metaphor development

The HTE team of scientists, science communicators and educators paid particular attention to metaphor creation. Research and development was done through key stages of prototype creation, response to formative evaluation sessions with non-expert volunteers and final content refinement.

Some of the preliminary metaphors or science concepts early in the project had to be altered, diminished or discarded. Either because it became clear during content creation that the storyline was not scientifically accurate enough, or because during formative evaluation the metaphor failed to connect the dots from the non-expert perspective.

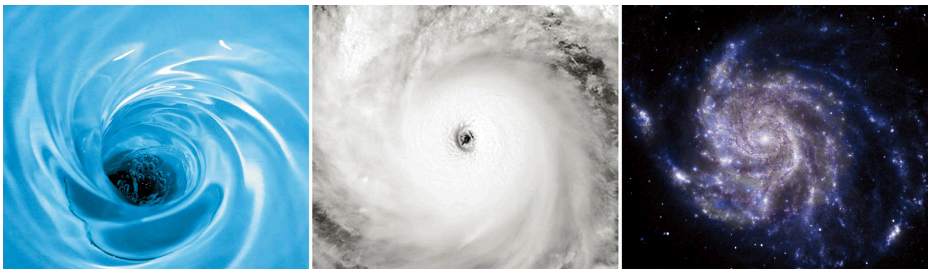

Figure 2. *Example of a more problematic HTE concept on spirals: water going down a drain, a hurricane, and a spiral galaxy. Credits: Water draining - Stock Photography; Hurricane - NOAA; M101 - X-ray: NASA/CXC/JHU/K. Kuntz et al.; Optical: NASA/ESA/STScI/JHU/K. Kuntz et al; IR: NASA/JPL-Caltech/STScI/K. Gordon - See more at: http://hte.si.edu/more_topics.html#spirals*

Take for example, Figure 2 where draining water, a hurricane and a spiral galaxy show the progression of a physical process from “here” to “there” to “everywhere”. In the original concept the “here” was a nautilus as opposed to draining water. However, during the creation process this caused confusion as the processes of the three objects were not the same, and so the shell was replaced with draining water.

The spiral-based approach did not test as strongly as other metaphors, so it was not one of the main topics featured in the programme, but rather served as a further example in nature to consider.

The challenge therefore is to find the right elements for each metaphor so that together:

a) They have a strong scientific connection.
b) The scientific thread between them is easily explained in relatively few words, with clear and attractive illustrative images.
c) The science described is relevant enough to engage viewers.

The final collection of topics discusses atomic collisions, electric discharge, blocked light, lensing, bow waves, wind, and other concepts[1]. The resulting metaphors created for HTE were stronger than those originally conceived, thanks to the iterative process.

Results and conclusion

HTE has primarily visited public science locations (Arcand, 2011), including public libraries, school libraries, and community spaces. Each hosting location, chosen from an application process that was oversubscribed by 250%, plans supplementary activities that expand on the provided content, including children’s arts events, science book clubs, discussions with local meteorologists and sidewalk astronomy.

Evaluation of the HTE programme showed that the use of metaphor positively affected the learning gains and interest levels of the participants. Approximately 75% of evaluated participants self-rated their astronomy knowledge as “nothing” to “some”, with the remainder rating their knowledge from “quite a bit” to a “great deal”. These randomly surveyed volunteers demonstrated learning gains, increased interest in astronomy, and increased interest in attending future science events.

Further research on how best to use metaphors and the benefits of those that heavily feature visual representations of the concepts to enhance the metaphor is certainly needed. Looking ahead, we plan to implement the use of metaphors in other public science projects, including an exhibit Light: Beyond the Bulb for the upcoming International Year of Light in 2015[2].

Acknowledgements

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Notes

1 More information on Here, There and Everywhere: http://hte.si.edu

2 More information on Light; Beyond the Bulb: http://iyl.cfa.harvard.edu

Biographies

Kim Kowal Arcand is the visualisation lead and media coordinator for NASA’s Chandra X-ray Observatory and principal investigator for the International Year of Light 2015 public science project, Light: Beyond the Bulb. She co-authored *Your Ticket to the Universe: A Guide to Exploring the Cosmos* from Smithsonian Books in 2013.

Megan Watzke is the press officer for NASA’s Chandra X-ray Observatory and a co-investigator in such Chandra-led public science projects as From Earth to the Universe; From Earth to the Solar System; Here, There, & Everywhere; and Light: Beyond the Bulb. She co-authored *Your Ticket to the Universe: A Guide to Exploring the Cosmos* from Smithsonian Books.

Using Survey Data to Inform Best Practice of Engagement with New Audiences

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Astronomy Outreach, New Audiences, Audience Survey, Gender, Age, Public Opinion

Summary

The main purpose of this article is to discuss how survey findings concerning the audiences for astronomy and space science outreach could help science communicators to foster public interest and participation in space activities among larger audiences. The article draws on findings from a large survey carried out in the UK, based on the responses of 744 respondents attending astronomy and space outreach events. The results of this survey, including interests, preferred means of exploration, beliefs and rationales for exploration, and the relationship with age and gender, could help practitioners reach new audiences who are not often targeted by conventional outreach efforts.

Introduction

Space science and astronomy are recognised by many as being particularly attractive subjects for both students and the general public. Contact with these subjects has a positive effect on students' interest in science and scientific careers, as well as public support for science and technology. As a result, communication of these subjects is regarded as an important activity to be undertaken by individuals, governments and research institutions dealing with space research (e.g., Barstow, 2005; Washington Charter, 2003; BNSC, 2008; Space IGS, 2011; RAS, 2004; Global Exploration Strategy, 2007; National Space Technology, 2011).

The International Astronomical Union Commission 55 developed the Washington Charter in 2003, which highlights principles of action for individuals and organisations involved in astronomical research, stating that they "have a compelling obligation to communicate their results and efforts with the public for the benefit of all".

However, the social scientific literature on these audiences is still relatively limited (Bell & Parker, 2009). Audience characteristics are usually studied in general surveys of public attitudes towards science and technology. The National Science Foundation (NSF), for example, started surveying Americans' opinions on science and technology in 1979, but it was not until 1981 that they introduced questions on attentiveness to space exploration (NSB, 2002, 2010; Miller, 1987). Although undoubtedly a valuable source of information about public interest, knowledge and attentiveness, these surveys do not provide an in-depth characterisation of the public. Practitioners of science communication often stress the lack of quantitative data about their audience, which leaves them to guess the characteristics of the groups that they are meant to be addressing (Entradas, 2011).

A careful analysis of survey data may provide a useful framework for thinking not only about audiences that are already being targeted by practitioners' communication efforts, but also about new audiences to reach and communication strategies to carry out.

The study presented here empirically examines the characteristics of the British audience attending astronomy and space outreach events and focusses on some of those characteristics to discuss how survey findings may assist in understanding audiences and planning outreach strategies.

This study is part of a broader analysis that examines the public support for space exploration (Entradas, Miller & Peters, 2011).

Methods

The study was conducted at two space outreach events in the UK: the Royal Society Summer Exhibition in London and the National Space Centre in Leicester, in the summer of 2008.

Questions designed as indicators of the concepts "beliefs", "attitudes", "rationales for exploration", and "political references" were included in a short questionnaire distributed to visitors to the exhibitions and returned immediately. All questionnaires were anonymous. 744 visitors returned the questionnaires; 249 respondents from the Royal Society and 495 from the National Space Centre. The response rate at the Royal Society Exhibition was 62% and at the National Space Centre was 71%.

The variables discussed here are: socio-demographics such as gender, age and professional activity, means of exploration, rationales for exploration, and beliefs in extraterrestrial life. All variables were measured at the nominal level, except age which was measured at the ordinal level. The relationships between variables were measured using contingency tables, non-parametric tests (χ^2), Cramer's *V* (for nominal and ordinal variables), and Gamma (for ordinal variables). Relationships between both age and gender with the variables "means of exploration", "rationales for exploration", and "belief in extraterrestrial life" were tested to determine correlations. A significance value of $p = 0.05$ was used to reject/accept the hypotheses about the relationships being tested.

Audience for astronomy and space exploration outreach events

1. Socio-demographic factors

The principal finding that comes out of the data is that the frequency distribution of the socio-demographic factors in both sub-samples — the Royal Society Exhibition and the National Space Centre — were largely the same. Both sub-samples were equally characterised in terms of gender, age and professional activity. This suggests that these characteristics are typical of the audiences who attend astronomy and space exploration outreach events.

Moreover, the distribution of responses to survey questions by respondents at both survey locations was also quite similar ($p > 0.05$). χ^2 was used for each question to test the similarity of distribution of answers in both sub-samples.

This finding indicates that the location did not influence the distribution of answers in the two sub-samples, reinforcing the idea that not only socio-demographic characteristics, but also the other characteristics surveyed, should be typical of audiences for astronomy and space events. Due to the similarity between the two sub-samples ($p > 0.05$), they are not treated separately in the statistical analysis and an aggregated data analysis is presented.

Respondents	Number of respondents	Total %
Gender		
Male	408	55.5%
Female	327	44.5%
Total	**735**	**100%**
Age		
≤ 15	170	23.2%
16–24	68	9.3%
25–39	208	28.4%
40–54	182	24.8%
55	105	14.3%
Total	**733**	**100%**
Professional activity		
Secondary student	127	18.8%
Undergraduate	36	5.3%
Post-graduate	113	16.7%
Researcher	15	2.2%
Other*	384	56.9%
Total	**675**	**100%**

Table 1. Demographic profile of respondents.

Table 1 shows that a majority of the public attending astronomy and space exploration outreach events were male, that young adults (16–24 years) were the most under-represented and that almost half were either students or had a professional connection to science. The latter is likely to be below the actual percentage as some of the children aged 15 or under, if not yet secondary students, might have considered themselves to fall into the category "others" as no other option was provided.

These data thus suggest that those not being reached by practitioners' communication efforts are more likely to be female, young adults aged 16–24 years, and people who do not have a professional connection to science.

2. Preferred means of exploration

When asked "How do you think we should explore the Solar System?" respondents showed positive support for space exploration with 98% of respondents agreeing that we should explore space. Yet, they held differing views on the preferred means of exploration. While the majority tended to agree with multiple means (55%), 43% had varying opinions on favoured means, with robotic and manned missions ranking higher (16%) than observation from spacecraft (9%) and observation from Earth (6%). Only a small number (2%) thought we should stop exploring space (Figure 1).

A small percentage of respondents (5.3%) ticked more than one response. A separate analysis looked in more detail at this portion of the sample and reflected in this analysis were concerns about manned space missions: a majority (3.5% out of 5.3%) ticked the three answer options that did not involve human exploration.

As one of the main discussions around space exploration, not only in the UK but also elsewhere, is whether it should involve humans, this finding is not surprising. It is to be expected that individuals who did not agree with "all means of exploration" and chose more than one answer would

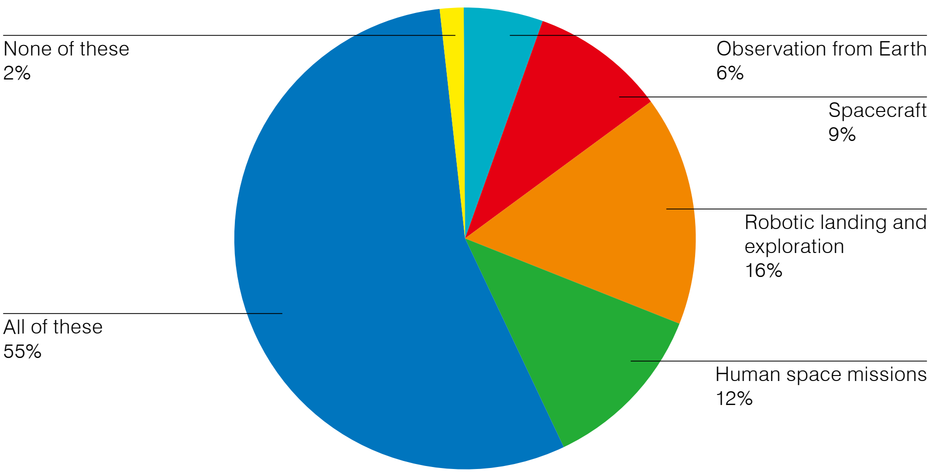

Figure 1. Respondents' preferred means of exploration. (Total number of respondents: n = 725)

be likely to have concerns about human space missions.

Statistical analysis of the relationship between means and demographic factors shows that while spacecraft exploration and manned space missions were more likely to be favoured by men than women, observation from Earth was more likely to be favoured by women than men (Cramer's $V = 0.19$).

The analysis also shows significant relationships between age and means of exploration (Cramer's $V = 0.14$). When compared with older age groups, children aged 15 and younger were the most likely to support human space missions, followed by the group aged 16–24. By contrast, individuals aged older than 55 were more likely to support less "adventurous" means of exploration (Figure 2).

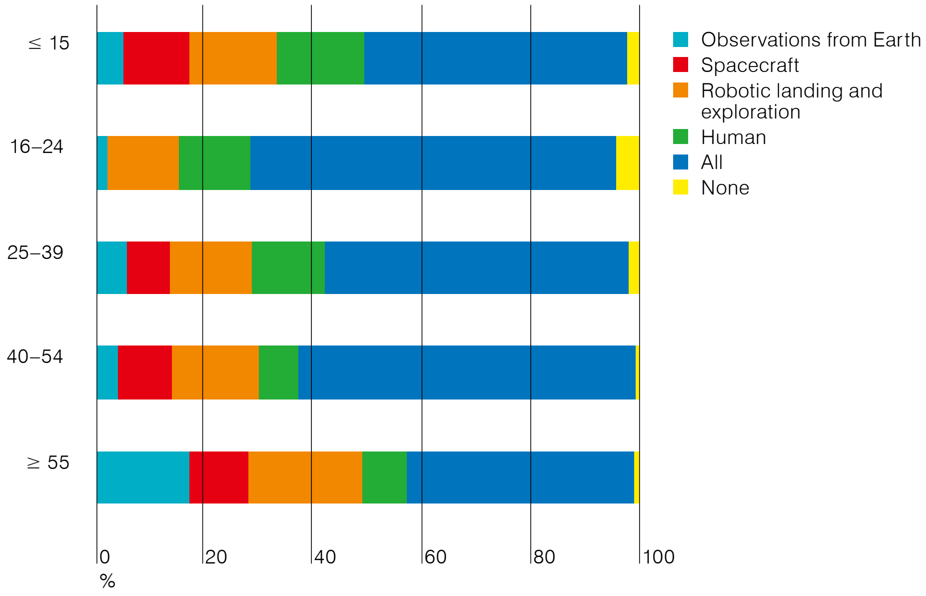

Figure 2. Preferred means of exploration by respondents' age. (Total number of respondents: n = 725)
Note: A sum of the response "all of these" with each of the four preferred means of space exploration would read as: 71% agreed with robotic landing and exploration; 67% agreed with human space missions; 64% observation from spacecraft; and 61% observations from Earth.

3. Rationales for exploration

When asked about rationales for exploration, the most common response was "generating new scientific knowledge and advancing human culture" (69%). "Inspiring new generations" was the second most common reason (16%), while "creating international cooperation" (3%), "engaging British society in the full excitement of space exploration" (6%), and "returning value to the UK economy" (6%) did not appear to be strong preferences for the justification of space exploration. This seems to suggest that people think of space exploration as a science whose aim is to generate new knowledge about the Universe, rather than thinking about the practical applications of technologies derived from space exploration. Applications that have included mobile phones, GPS, and weather forecasting.

This suggests a lack of awareness of the benefits that space exploration can bring to our lives, and is supported by other information in the data regarding respondents' attitudes towards value for money.

Respondents were asked to what extent they agreed with the statement "Space exploration is good value for money" using a five-point rating scale ranging from 1 (strongly disagree) to 5 (strongly agree). Just over a quarter of respondents agreed with the statement (31%), a similar number disagreed with the statement (28%), and almost half of respondents were ambivalent (41%).

Associations were not found between respondents' demographics and rationales for exploration ($p > 0.05$). This is not at all surprising as the great majority of respondents mentioned the same reason to explore space.

4. Beliefs in life beyond Earth

4.1. Is there life out there?

When asked "Do you think life has ever existed on other planets in the Solar System?" the majority of respondents said they believe that life has existed elsewhere in the Solar System (63%), either as primitive (47%) or higher forms (16%). However, around a quarter of the respondents said "don't know" (24%). A further 12% did not believe that other planets in the Solar System have held life (Figure 3).

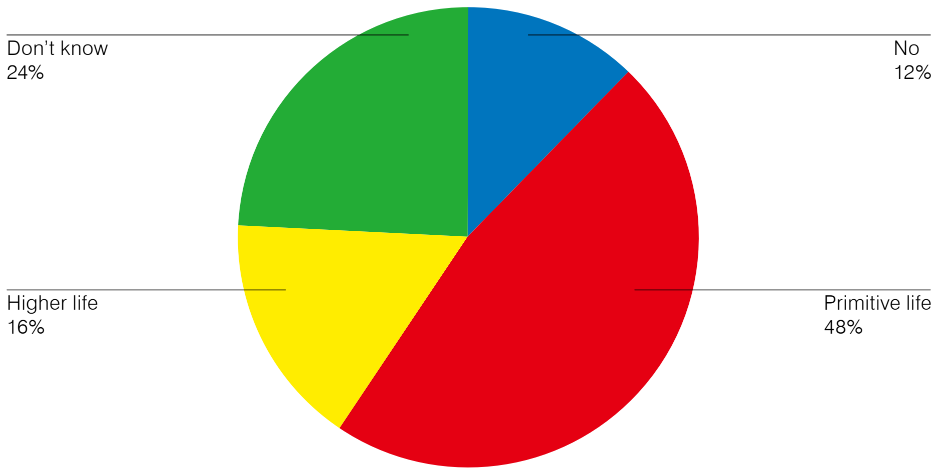

Figure 3. Respondents' belief in the existence of life on other planets in our Solar System.
(Total number of respondents n = 718)

The statistical analysis shows rather interesting relationships between people's belief in the existence of life beyond Earth and gender and age. Females were less likely than males to believe in the existence of life on planets other than Earth. In contrast, males were more likely to believe in the existence of higher forms of life on other planets than females (p = 0.003). Regarding age, respondents older than 55 were the least likely to think that life has existed outside Earth, when compared with other age groups. And, of the 16% who believed in the existence of higher forms of life, the majority were younger than 16 years old. Those aged between 40–54 years old were the strongest believers in the existence of primitive life.

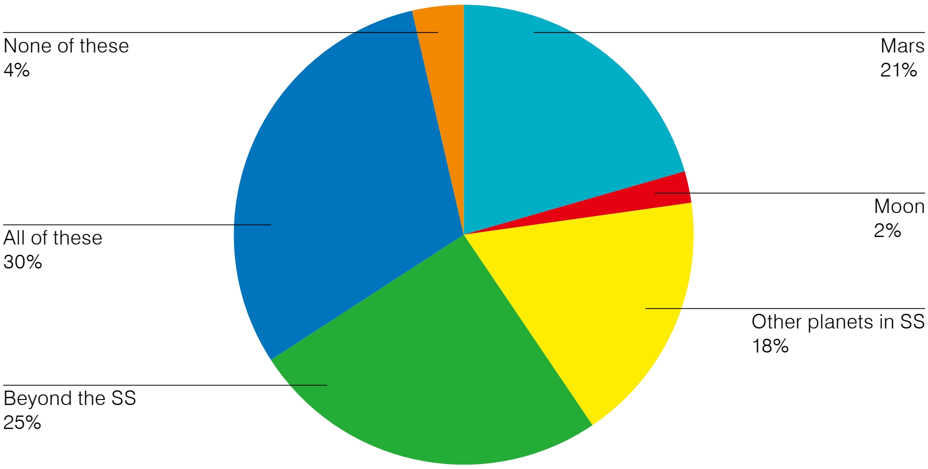

Figure 4. Respondents' preferred targets for exploring for traces of life. (Total number of respondents n = 739) *Note: A sum of the response "all of these" with each of the four preferred targets for exploration for any traces of life would read as: 52% agreed with exploration on Mars; 33% agreed with exploration on the Moon; 49% agreed with exploration on other planets in the Solar System (SS); and 56% agreed with exploration beyond the Solar System.*

4.2. Where to look for life beyond Earth

Regarding targets for exploration of extraterrestrial life, when asked "Where do you think we should explore for any traces of life?" — Mars; Moon; other planets in the Solar System; beyond the Solar System; all or none of these, the most common response was "all of these" (chosen by almost a third of the respondents — 31%), and there was a strong expectation of the existence of life beyond the Solar System (25%), on Mars (21%) and other planets in the Solar System (18%). The Moon was almost disregarded as a possible host to life (2%) (Figure 4).

The younger age groups were more likely to believe that life exists on Mars than older age groups (p = 0.001). In fact, the younger age groups appeared to be more excited about looking for life on more distant targets than older age groups, who preferred exploring the Solar System (Figure 5).

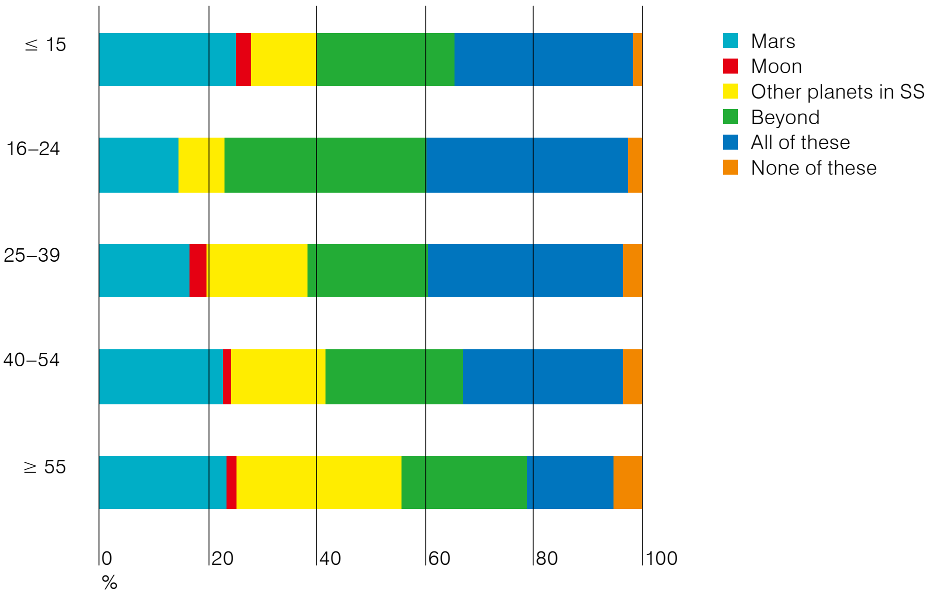

Figure 5. Respondents' preferred targets for exploring for traces of life by age.

Discussion: Reaching new audiences for astronomy and space

The main purpose of this article is to discuss how surveys of audiences for astronomy and space could benefit the role of science communicators in stimulating public interest and participation in space activities amongst larger audiences. This discussion is based on a UK survey of 744 respondents attending astronomy and space outreach events, as well as other studies, including previous detailed analysis of these data. Drawing on analysis of responses from this group and the relation of these responses with age and gender factors, practitioners could reach new audiences who have not been targeted by their outreach efforts.

The main findings presented here show that the group most certainly interested in space and astronomy is mainly composed of male adults aged 25–54 years whose professional occupation relates somehow to science. As for the other characteristics of respondents, a majority of them reported to believe that life may exist, or may have existed outside Earth (63%) in either primitive (37%) or higher forms (16%). In addition, audiences showed a strong positive attitude towards exploring space beyond the Solar System (56%), on Mars (52%) and on other planets in the Solar System (49%).

The audiences that have been less well reached by practitioners' communication efforts are likely to be female young adults, aged 16–24, who do not have a professional link to science.

In particular, the poor attendance of young adults seems to be of particular concern. The absence of this age group at outreach events, combined with their limited awareness of astronomy and space-related issues (Ottavianelli & Good, 2002; Saftwat et al., 2006), shows a younger stratum of people with whom it is critical to engage. It might be of particular interest to attract this cohort since ESA and NASA's long-term space programmes, the Aurora Programme and the Vision for Space Exploration (VSE), respectively, have ambitious aims that call for human exploration of the Solar System and will certainly require support from these individuals. Moreover, reaching younger age groups means recruiting more students for scientific careers and combating the decline in the number of young people studying science and engineering subjects (PISA, 2009; Barstow, 2005).

The survey shows that members of the younger age groups express excitement about manned space missions and reported themselves as believing in the existence of life on other planets. These groups appeared to be particularly supportive of the exploration of life on Mars and beyond our Solar System. The belief that life may exist on other planets seems to be connected with supporting space exploration (Entradas et al., 2011) making it reasonable to argue that communicating the goals of ESA's Aurora Programme, which has the search for signs of extant or fossil life on Mars as a key driver, might attract new audiences to space events. This idea is supported by the strong public expectations of the existence of life on Mars (52% of respondents agreeing that we should explore Mars for any traces of life).

Another important result shown by the survey is the limited attendance of a female audience when compared to males, as well as a female lack of interest in and support for more "adventurous" means of exploration. While these differences in gender are not surprising, concerns about reaching female audiences are shared among practitioners (Entradas, 2011). Many state that such differences are due to the way in which formal education and science communication is pitched. Practitioners may want to think about more attractive ways of communicating to females, which could be based on females' beliefs, interests and attitudes towards space and astronomy as shown here. For instance the survey suggests that a way of reaching new audiences might be through communicating the more tangible technological benefits of space exploration.

Deep analysis of these data (Entradas, Miller & Peters, 2011), shows that the more the public valued space exploration science, the more they tended to support higher levels of government spending on space activities. However, as the results here show, only 30% of the respondents surveyed believed that space exploration is good value for money, suggesting a deficit in public knowledge of the benefits that might come from space research. Therefore, it is reasonable to argue that discussing and communicating the benefits of space exploration to overall quality of life, and to society at large, rather than concentrating on immediate economic returns, may contribute to attracting the more "difficult" audiences.

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Biography

Marta Entradas is a postdoctoral researcher in science communication at Lisbon University Institute, and a visiting scholar at the London School of Economics and Cornell University. Her research interests lie in science communication, public understanding of science and public attitudes towards science and technology.

Reaching the Remote: Astronomy Outreach in Rural Mexico

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Keywords
Outreach, Remote Communities, Traditions

Summary

This article reports on a visit to Victoria, a small village in central Mexico, and the star party conducted there. We wanted to share our experience of the outreach programme because this was one of the most remote places we have ever visited. We emphasise in particular the importance of respecting local culture and traditions, a respect highlighted by making a visit to a ritual centre in the region.

Introduction

A couple of kids share the dusty soccer field with the astronomy students from the University of Guanajuato. It is five in the afternoon, and the Sun is about to set. A few eight-inch telescopes are lined up in front of a small mountain while curious people begin to appear expecting a good show. It has been two years since the staff from the Astronomy Department last came to this town. Two years that the people of Victoria have had to wait to see through a telescope again.

A tradition of star parties in Mexico began during the International Year of Astronomy in 2009, including the nationwide Noche de las Estrellas[1]. These events include naked eye and telescope observations of the night sky, lectures, open-sky talks to describe the constellations and activities designed for children. Together with the Cultural Institute of the State of Guanajuato, the Astronomy Department of the University of Guanajuato hosts around ten travelling astronomy events per year in different towns across the state. These events take place in archaeological sites or in what are called Pueblos Mágicos (Magic Villages) — towns with special historical value. The average event reaches 2000 people unless it is a particularly remote community that is visited on demand, in which case it would be only a few hundred.

In December 2013 the village of Victoria, formerly known as Xichú de Indios became the host of a travelling astronomy event. Located 144 kilometres east of the capital Guanajuato, in a highly underdeveloped region away from the federal roads, Victoria has 2564 inhabitants[2] and was an important place for the Chichimeca people, a hunter-gatherer group who refused to surrender to the Spanish colony. In this particular case, the local authorities of the municipality contacted the staff from the Astronomy Department requesting an event that was called Noche de Estrellas en Victoria (see Figure 1).

The facilities in the town are basic and the events were carried out in a local sport complex composed of an open football field, a basketball court and a small gym. Six eight-inch aperture telescopes were erected along the field with two people in charge of each one. In this way one person moves the telescope while the other explains to the people in the queue what they are about to see. Most of this work is conducted by postgraduate students from the Astronomy Department (see Figure 2).

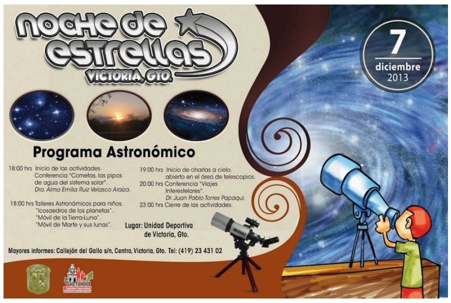

Figure 1. *Poster of the event in the town of Victoria.*

Figure 2. *People looking through the telescope. The big light in the background is the Moon.*

Other activities

- Two talks were presented; one on comets and the other on space travel.
- There was a children's activity called *icosaedros de los planetas* where the children trim off and assemble a mosaic of pictures of a planet surface and glue it back to get a 3D representation.
- Another two activities undertaken were to create mobiles to show different orbits. The first — *móvil de la Tierra y de la Luna* — showed the orbit of the Moon around the Earth, and the second — *móvil de Marte y sus lunas* — which shows Mars and its moons.
- 300 people, most of them adults over 40 and children below ten years old, took part in these activities.

Respecting regional cultures

Staying with the local community, eating with them and drinking with them helps to strengthen the relationship with the community and the outreach with it. In addition it is important to engage with local traditions. In Victoria the team visited a rock painting site known as Arroyo Seco[3], a place that used to be a ritual centre and still hosts ceremonies during the solstice when the Sun rises between the rocks.

Visiting the site required understanding and respect for local customs by asking permission of the guardians, which are impressive rock formations that look like standing people, and leaving tributes in the cavities of rock that represent the nursing Mother Earth.

The paintings themselves included representations of astronomical icons such as the Sun (Figure 3).

Figure 3. *Rock paint representing the Sun.*

Lessons learnt

When visiting remote places the people are always grateful and hospitable. The events usually take place in open facilities, like stadiums or town squares and include archaeological sites and marginalised neighbourhoods. Because of the variety of locations, technical difficulties are common so relying on only a projector or computer for presentation slides is not advised.

One of the main challenges is light pollution. Even in Victoria, where the location had reasonably low light pollution, the lights from passing cars and buildings complicated the night-sky observations.

Planning lectures for these events is a difficult task as attendees range from children to elders. Slow or technical talks lose children's attention and a child's level of talk would bore adults and send elders to sleep. A fast-paced talk with more figures than text is usually a good start.

In Victoria and places like it, despite a very basic educational background, there is always an eagerness to learn. So, it is very important to give enough time for questions and to reward this curiosity. The children received glowing stars for raising their hands, building confidence and encouraging questions to the point that the supply of rewards ran dry.

Telescopes get most of the attention, but with unpredictable weather, alternatives are essential. These can include organised activities, board games with astronomical themes — astronomy bingo and memory card matching game for example — or just taking advantage of the time to ask for questions or discuss a particular topic.

In general events are more likely to succeed during the dry season, but sometimes if invited to festivals right in the middle of the hurricane season, this is not possible. These offers must be considered carefully. A few University of Guanajuato events have been cancelled because of heavy rain.

Collaboration

Victoria was first visited in 2011 as part of an ongoing development project from professors of the Faculty of Social Sciences, University of Guanajuato. During this collaboration a good relationship was formed with the local authorities of the communities visited, including Victoria. Our project benefited from these pre-existing contact as less effort was needed to develop the project.

Trading knowledge

It is important for communication not to present ourselves as wise scientists bringing wisdom to the ignorant, but as humble human beings who are eager to learn; breaking down the educational barrier and showing that our own knowledge is limited in many other fields.

Figure 4. *The group hikes to the sacred mountain in Arroyo Seco.*

Opening a dialogue creates a bond, enriches interactions and creates more awareness about progress in science and technology. For some people, this will ameliorate any ingrained feeling of unease about a form of progress which they may see as a threat to ancient myths, traditions and belief systems.

Showing respect for these local traditions supports the cultural heritage, improves the relationships needed to engage with a community and can enrich our own lives.

We went to Victoria thinking we had something to teach, but we came back with a better understanding of our own roots, knowing we still have so much to learn.

Acknowledgements

We would like to thank the town council of Victoria and our hosts for their kindness and hospitality. J. P. Torres-Papaqui also acknowledges CONACyT-FOMIX for support grant GTO-2012-C03-195186.

Notes

1. Noche de las Estrellas http://www.nochedelasestrellas.org.mx/
2. Instituto Nacional de Estadística y Geografía (http://www.inegi.org.mx/)
3. An article about the rock paintings in the magazine *México Desconocido*. http://www.mexicodesconocido.com.mx/los-ciclos-del-sol.-pinturas-sobre-roca-en-arroyo-seco-victoria-guanajuato.html

Biographies

Alma Ruiz-Velasco graduated from the astrophysics postgraduate programme from the University of Guanajuato, collaborates with the Astronomy Department's outreach activities. She writes an astronomy blog, available online at http://elespinazodelanoche.com.

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Juan Pablo Torres Papaqui teaches at the Astronomy Department of the University of Guanajuato. His research focusses on the extragalactic astronomy, starburst–active galactic nuclei connection and he is also interested in the Virtual Observatory.

Best Practices

Reaching for the Stars in your Golden Years: The Importance of Outreach for Senior Citizens

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Keywords
Senior Citizens, Outreach with the Elderly

Summary

Astronomy outreach is often geared towards young children, but rarely towards senior citizens. This article shares the author's experience of conducting astronomy outreach activities at senior living communities and discusses why senior citizens are an equally important demographic to educate about astronomy.

Introduction

Astronomy outreach is often conducted in science classrooms, museums, observatories, and even at the local park. The intended audiences are usually families with young children, who we are training to be the next generation of scientists, inventors and world-changers.

But what about the other end of the spectrum, the senior citizens of our community? Astronomy outreach is rarely geared towards this demographic, and yet this group can be the most receptive audience, willing to share past experiences and engage in learning. Educating our seniors about astronomy, especially current discoveries, upcoming technology, and funding challenges, is of the utmost importance. One of the easiest ways to educate a large number of seniors is to give talks at senior living communities.

Many senior living communities have adopted a lifelong learning initiative, in which the community holds educational programmes on a variety of topics, including exercise routines, cooking classes, history lessons and science lectures. These hour-long programmes often consist of lessons and/or hands-on activities that are designed to be fun and engaging as well as educational. Recently, many seniors in communities around Rochester, New York, USA, requested the inclusion of science- and astronomy-related topics in their enrichment programme, and thus astronomy lifelong-learning lessons began.

Teaching astronomy to senior citizens

This programme of teaching astronomy at senior living communities in Rochester, USA began three years ago. The programme originally consisted of a set of four one-hour presentations covering the basics of, and different fields within, observational astrophysics. The lessons were very non-technical and filled with many pretty pictures from the well-known NASA/ESA Hubble Space Telescope. These lectures were presented on a weekly basis at the Highlands at Pittsford Senior Living Community and they were very well received. Roughly forty members of the community attended each lesson and were very excited to learn about astrophysics at a level that was understandable to them. After the session many people shared stories about their experiences observing the sky with their children or grandchildren, or their recent visits to NASA centres. Some residents had even worked on the NASA/ESA Hubble Space Telescope's back-up primary mirror at the Kodak headquarters in Rochester, USA.

Since then, the programme has been expanded to monthly lessons at three different senior living communities in Rochester and sporadically (1–2 times per year) at three others. The topics covered have included NASA's Great Observatories, the possibility of life beyond Earth, galaxies and black holes, recent astronomical discoveries, and even Einstein's theories of relativity.

During the summer months, seniors are further engaged through star parties at each of these communities. They are given the opportunity to observe Solar System objects through a telescope and learn which constellations are visible. The lessons and star parties attract anywhere from 5–50 people, depending on the topic, and there is usually a 50/50 mix of men and women. Many seniors attend the lessons regularly, and often suggest new topics that they would like to be covered at upcoming events.

Why it is important to engage seniors with astronomy?

Most astronomy outreach conducted today is geared towards the next generation of scientists. We want to promote astronomy to children so that they grow up wanting to become scientists, and continue the ground-breaking research that is occur-

Figure 1. *Residents at the Highlands at Pittsford Senior Living Community in Rochester, New York, USA observing the Sun during a daytime star party. Credit: Valerie Rapson.*

Figure 2. *Residents of St. Ann's Community at Cherry Ridge in Rochester, USA enjoying an astronomy lesson. Credit: Valerie Rapson.*

ring today. This is wonderful, but we can't forget about the current generation, whose choices today govern whether or not our children will live in a science-friendly future.

Seniors have a love and appreciation for astronomy that is unmatched in today's society. They lived through the space race and watched man set foot on the Moon for the very first time. Our seniors lived in a time when space science flourished, and they understand the importance of providing government funding for telescopes and space programmes. By conducting outreach in senior living communities, we can keep seniors up to date on current astronomical endeavours and help keep their passion for space alive; a passion that we hope they will pass on to future generations.

Senior citizens are also a very vocal group and likely to have a strong influence on whether astronomy and other science research will be well-funded in the future. In 2008 and 2010, senior citizens 65 and older made up 19% and 23% of the total voting population in the USA, respectively[1]. In both years they also had the largest percent of eligible voters in their age bracket to actually vote. If we include adults age 45 and older in the former statistic, the total percentage of voters increases to 58% and 66%, respectively.

It is clear that our elders have a strong influence on which politicians hold office and, ideally, we want them to choose representatives who support the advancement of science and astronomy. Therefore, we need to take the time to share with our elders the most recent astronomy discoveries and advancements in space-related technologies. They will be the ones who ultimately decide whether or not our children live in a world that provides funding for astronomy research. Focussing all our efforts towards training young people to become astronomers and scientists will be fruitless if there is little government funding and thus few jobs for them to fill in the near future.

Last but not least, seniors truly enjoy learning about astronomy. Many seniors in these communities did not have the opportunity to go to college or, if they did, they may not have studied what they were truly passionate about. Often the men's college degrees or careers were interrupted by war and financial crisis, and many of the women opted to stay home and raise children instead of going to college. Now that they have reached retirement, seniors have the time to study any topic they like, and astronomy seems to be a popular choice. By conducting outreach at senior living communities, we enrich the lives of many people by presenting enjoyable lessons, as well as increasing the visibility of astronomy within the general public.

Extension of the project elsewhere

Astronomy outreach at senior living communities has been an incredibly beneficial experience in these cases. These communities offer a wonderful venue for astronomers of all ages to conduct outreach and share their own love of astronomy with a group of people who are often equally passionate about the subject. Many senior living communities throughout the country have their own life-long learning programmes that would likely be very willing to host astronomy lessons or activities. I encourage all astronomers to visit their local senior living communities to help educate the public and create a more astronomy-friendly world.

Notes

1. https://www.census.gov/compendia/statab/2012/tables/12s0399.pdf

Biography

Valerie Rapson is a PhD candidate in Astrophysical Sciences and Technology at the Rochester Institute of Technology, USA specialising in star and planet formation. She is also the president of the Rochester Academy of Sciences Astronomy Chapter, runs star shows at the Strasenburgh Planetarium, and participates in astronomy outreach in Rochester, New York, USA. When she has completed her degree Valerie hopes to either become a college professor or work in the field of astronomy outreach.

Camping Under the Stars: The ESO Astronomy Camp 2013

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Keywords
Camps, Spectroscopy, Multicultural, Didactics of Astronomy, Astronomical Observatory of the Aosta Valley

Summary

The end of last year saw the first ESO Astronomy Camp take place, held at the Astronomical Observatory of the Autonomous Region of the Aosta Valley. The aim of this report is to give a short overview of the camp programme and focus on one of its workshops — the stellar spectroscopy laboratory — as a case study.

Introduction

From 26 to 31 December 2013, the picturesque alpine village of Saint Barthélemy in the Italian Western Alps, played host to 56 secondary school students keen to learn more about astronomy. This was the first ESO Astronomy Camp, held at the Astronomical Observatory of the Aosta Valley.

The winter astronomy school explored the theme of the visible and the invisible Universe through lectures, hands-on activities, and night-time observations with telescopes and instruments. One of these activities was a laboratory on stellar spectroscopy which will be further explored through this report, looking at its aims, challenges and achievements.

The observatory

The location of the first ESO Astronomy Camp was chosen based on several factors, with the favourable conditions for night-time observations being among the most important. The sky in Saint-Barthelemy has almost negligible light pollution. The nearby city of Aosta is relatively small and its lights are concealed by the nearby mountains, and the larger but much more distant city of Turin — which lies 70–80 kilometres away — has little effect, as, although it causes some slight light scattering in the lowest atmospheric layers, it is hidden by the 3000-metre peaks in the south-eastern area of the Aosta Valley. The alpine location also means that crystal-clear weather is a common occurrence, especially during the winter season.

The extensive experience of the observatory staff was also a considerable factor. They have developed and implemented educational activities that make use of the seven 25-centimetre reflecting telescopes placed on the panoramic didactical terrace of the observatory. In addition, the location is well connected, with a handy motorway connection running from the international airport of Milan Malpensa to Nus, a town 20 minutes from the observatory.

The participants

The camp brought together 56 students — 29 girls and 27 boys — aged 15 to 18 years and from 18 different countries. Most were from the ESO Member States, but not all. The international aspect was greatly appreciated by the participants who had the opportunity to meet their peers from different countries and cultures with the same interests and passions. The command of

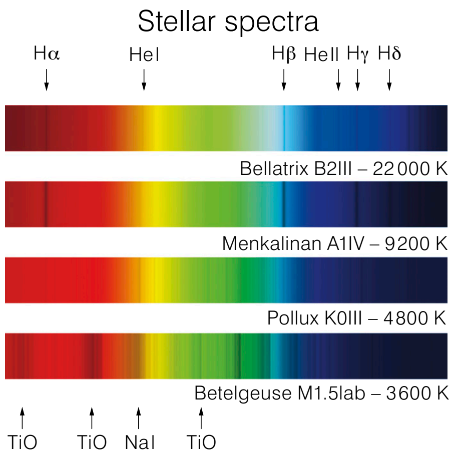

Figure 1. Spectra taken at the Camp arranged along the Harvard spectral sequence. Below each spectrum the name of the star and its spectral classification are indicated. The suffix "I" after the symbol of an element means "neutral", the suffix "II" means "singly ionised". The main lines and bands are highlighted.

Figure 2. The students at the ESO Astronomy Camp 2013.

English as the common language at the camp was quite good and did not pose any problems to the team.

The challenges

The main challenge for the organisers was to tune the level of the activities and lectures to make them enjoyable and challenging for everybody, notwithstanding the different backgrounds with regard to school curricula, age and personal interest. For this reason, students were invited to give continuous feedback to help the organisers to adjust the activities based on suggestions and expectations. Lecturers used appropriate, but simple terminology, provided full explanations of all physical concepts which were introduced — even the most basic ones — and illustrated the concepts with examples from everyday experience.

Visiting astronomers, observatory staff and supervisors spent all their time at the camp with the participants. This meant that the participants with the most advanced knowledge of physics and astronomy could go further with some specific topics and discuss them with the astronomers during lunch or free time.

The programme

The programme aimed to introduce the students to activities related to research processes in astronomy and science in general. Besides leisure and sport activities (about three hours per day), the schedule included:

- Lectures and theoretical exercises led by visiting astronomers and observatory staff: 45%;
- Sky observations with naked eye and telescopes: 25%;
- Data analysis including stellar spectroscopy and measurement of the angular response of an antenna: 15%;
- Laboratory activities for measuring the angular response of an antenna: 10%;
- Group presentations on art and science and the measurement of the angular response of an antenna: 5%.

The theme of the camp, The Hidden Universe, was explored by lectures and activities dedicated to optical, infrared, radio, ultraviolet and X-ray astronomy plus an introduction to the multi-wavelength Universe.

The stellar spectroscopy activity

The stellar spectroscopy laboratory covered the topic of optical astronomy from different perspectives: theoretical, including simple calculations and exercises; practical, through night-time observations with telescopes and use of a spectrograph and associated software; data analysis and discussion of errors. The objectives of the laboratory were to introduce the students to the importance of spectroscopy in astrophysics and to learn both how to take a spectrum and how to extract information about the star's temperature by analysing its spectral lines.

Stellar spectroscopy is strictly related to stellar colours and so can be appreciated at the telescope and, to some extent,

Figure 3. Telescope observations at the observatory.

Figure 4. The astronomical observatory of the Aosta valley at night.

even with the naked eye. So, the laboratory began with the observation of late autumn and winter constellations, identifying stars of different colours. Students were then organised into small groups and instructed how to operate a spectrograph and a CCD camera attached to one of the didactical telescopes. They could then capture the spectra of several "favourite" stars, among which were Aldebaran, Betelgeuse, Dubhe, Mirphak and Sirius.

These spectra were wavelength-calibrated thanks to the prominent Balmer lines visible in the spectrum of one star — Menkalinan in the constellation of Auriga — used as a calibrator. The students could appreciate the differences between spectra and learnt to pick out diagnostic lines in order to relate them to stellar temperatures.

The morning after the observation was devoted to the stellar classification contest. Teams of students competed to classify the spectra according to the Harvard Classification Scheme. There were no awards for winners, except for the deserved acknowledgement, but instead there was a special prize for the team finishing last — the so-called Antares prize. The award involved the losing team taking the spectrum of the red supergiant Antares, which by the end of December rises a couple of hours before sunrise. In the end the prize was not awarded, even though some of the more enthusiastic students would have loved to wake up in the night for this very special observation.

Conclusion

The first ESO Astronomy Camp had some very positive outcomes. There were 170 applications from 24 countries, the informal and formal feedback from participants and their families has been very good, as were the lecturers' comments. We feel that the camp has been a highly formative learning experience for the participants, facilitated by the enthusiasm of the students, the excitement of the international environment and the quality of the social and sporting activities.

Students greatly appreciated the variety in the professional staff, both visiting and resident, and of the activities, which were not limited to face-to-face lessons and simple telescope observations. We feel as well that the number of practical activities and sky observations should increase, and the challenge for future similar experiences will be to reduce the number of hours of theoretical lessons — which are nonetheless fundamental to appreciate and actively contribute to practical activities — and invest in technical equipment to work in smaller groups, thus giving everybody the opportunity to spend more time on the instruments.

We hope that future camps will build on the success and lessons learnt from this first case. The ESO Astronomy Camp 2014 is already being planned and will take place from 26 December to 1 January 2015 in Saint Barthelemy, Italy. The theme of the camp will be Distances in the Universe.

Acknowledgements

Besides the main organisers ESO (www.eso.org), Sterrenlab (www.sterrenlab.com) and the Observatory of the Aosta Valley (www.oavda.it), several partners contributed to the success of the camp by offering bursaries to selected participants: Instituto Nazionale di Astrofisica and University of Milan (Italy), Polish Astronomical Society and Urania — Postępy Astronomii and Urząd Marszałkowski Województwa Kujawsko-Pomorskiego (Poland), Ciência Viva (Portugal), Sociedad Española de Astronomía (Spain) and Université de Gèneve (Switzerland).

Special thanks go to the camp supervisors: Emily, Koen, Lorenzo and Mariona; to the camp resident and visiting astronomers: Davide Cenadelli (Astronomical Observatory of the Aosta Valley), Enzo Bertolini (Astronomical Observatory of the Aosta Valley), Lars Lindberg Christensen (ESO), Andrea Bernagozzi, Paolo Pellissier and Paolo Recaldini (Astronomical Observatory of the Aosta Valley), Anna Wolter (ESO/INAF), Juan Fabregat (University of Valencia), Aniello Mennella and Paola Battaglia (University of Milan); and the 56 students who impressed us with their motivation, intelligence and enthusiasm.

Links

Sterrenlab website: http://www.sterrenlab.com/camps/eso-astronomy-camp-2014/

Biographies

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Cristina Olivotto graduated in physics at the University of Milan and was awarded a PhD in the history of physics. After graduation, she started to work in the field of science communication and education at the Astronomical Museum of Milan and as a lyceum teacher of physics and mathematics. She worked at the European Space Agency for four years before founding Sterrenlab in 2011.

Oana Sandu works as the 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 in Eastern Europe.

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Streaming Astronomical Events for Public Viewings: The 2009 Total Eclipse in Japan

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Keywords
Eclipse, Outreach, Public Viewings and High-definition Streaming Video

Summary

We describe our outreach activity to make high-quality images of the 2009 total solar eclipse freely available to the public and inspect the impact of events allowing public viewing of high-definition (HD) streaming video of the eclipse.

Introduction

A total solar eclipse is one of the most gorgeous astronomical phenomena known and attracts numerous viewers, including those who do not usually engage with astronomy. On 22 July 2009, the longest total eclipse of the century was visible in East Asia and Japan. The timing of the total eclipse meant that for some isolated Japanese islands it occurred when the Sun was high in the sky, making them an excellent location for viewing the eclipse.

However, from most locations in Japan, only a partial eclipse could be observed. This drove the decision to broadcast high-definition (HD) streaming images of the total eclipse from the islands, via the internet, to a much larger public audience. This audience may otherwise have missed this rare and beautiful phenomenon and the project aimed to use the total eclipse to generate interest in nature, science and, in particular, astronomy.

HD images were transmitted to selected science museums, universities and television stations. In addition, the HD images were converted to Windows Media Video (WMV) format and transmitted to 35 locations, which included community centres, public halls, science museums and public astronomy observatories.

The public-viewing events attracted 34 300 people. By the end of 2009, views of our videos — and those of the Japan broadcasting cooperation Nippon Housou Kyoukai (NHK) who used our images — on YouTube and other sites totalled over 770 000. The images appeared 72 times on 28 television programmes on 22–23 July and if cable television and communication satellite programmes were also considered, for which data could not be collected, it is estimated that the images were used in over 100 televised programmes.

To better understand the impact of such public outreach efforts, the public viewings were assessed to see whether they provided an effective way of sharing the experience of an astronomical phenomenon. Although other studies on outreach efforts have indicated that providing streaming videos for viewing on personal computers (PCs) is effective, the effectiveness of providing high-quality streaming for a large screen has not been sufficiently discussed.

In this paper we explain our methods of data transmission and preparation, present the results of the questionnaires taken at the events, discuss unexpected reactions of potential organisers of the public viewings and consider possible countermeasures.

This project was proposed by experts in large-capacity data transmission at the National Observatory of Japan (NAOJ), whose participation was essential to bring the project to fruition.

1. Project outline

1.1. Collaborations

From the beginning, it was clear that collaboration with other organisations outside NAOJ would be key. To publicise the project alone, collaborations were formed with the press, internet broadcast stations, video websites and other media sources, these being the experts in the wide distribution of content. Science museums and communication experts were also part of the collaboration to ensure that the contents were put to best use.

1.2. Choice of observation point

To obtain high-quality images it was important to observe the eclipse from land. After studying several potential observation sites the list was reduced to isolated islands and after comparing the probabilities of having good weather, the decision was made to film the eclipse from Iwo Island. Another advantage of Iwo Island was that no project or tour planned to observe the eclipse from it.

However, the Japanese Self-defence Force controls Iwo Island and access to it is not normally allowed. In fact, nobody outside the team thought that it would be possible. But, after interagency collaboration between the Self-defence Force, the Ministry of Internal Affairs and Communications and the Ministry of Education, Culture, Sports, Science and Technology (MEXT) the observations were given the go-ahead, as was permission to use the local infrastructure, such as lodging facilities and transport. The film team consisted of staff from several different organisations, including NHK, MEXT and NAOJ.

1.3. Transmission

Satellite communication was used to transmit real-time images of the total eclipse because no wired communications network system connects Iwo Island to the Japanese mainland. Figure 1 schematically displays the transmission strategy used to broadcast the eclipse images.

The video footage taken on Iwo Island with HD cameras by the NAOJ and NHK staff was transmitted by wireless communication to WINDS — a Japanese communication satellite. Since WINDS supports multipoint casting, the data were communicated to several receiving stations (the main and backup stations). At the main receiving station, the data were converted from radio to packet and then sent to NAOJ's server via the JGN2plus network — an extension of the Japan Gigabit Network 2, an open testbed network.

Between the receiving stations and the points of display a wired network communication system was used. The NAOJ server broadcast the live HD images via the internet to large museums and public halls. In addition to HD images, WMV-formatted data was delivered to smaller museums, community centres and public halls.

Figure 1. *Schematic showing the transmission strategy for total eclipse images. The picture of Japanese communication satellite WINDS is courtesy of the Japan Aerospace Exploration Agency (JAXA).*

1.4. Procedure for live broadcasting

The procedure to receive the real-time images and copyright statement was complicated and was the source of significant negative feedback from users.

Applicants first sent in their forms, then submitted a signed covenant stipulating the terms of use of the live video and the copyright notice. This rather complicated procedure evolved from the fact that WINDS transmitted the real-time images. WINDS is operated by JAXA and the National Institute of Information and Communications Technology (NICT). The WINDS project team insisted that the credit should be stated clearly in images of the real-time streaming, and that each receiver had to submit a contract.

Upon approval, users obtained a URL with which they could view the live images and were advised to test the connection to confirm that they could watch the webcast. NAOJ provided a server to broadcast a test video. Due to the decision to distribute high-quality WMV data the server capacity limited the number of receivers and so 35 receivers were accepted, based on a first-come-first-serve basis.

Some facilities abandoned the real-time WMV data coming from NAOJ's server. Although we reduced the quality of HD video when converting it to the WMV format, the required transmission rate was still too high for some facilities. These facilities were provided the real-time images by NICT, which had set up a new server for this project.

2. Results

To the best of our knowledge, ten TV stations, a news agency, four science museums and a university primarily obtained HD images, which they distributed over their broadcasting networks. The WMV video was delivered to 35 facilities. We restrict the following discussion to the facilities to which we (NAOJ) provided the data, and exclude the facilities that obtained images from the NICT server.

Because public viewing was free of charge and staff working at the viewing points could not count attendance, the total number of public-event viewers is not accurately known. However, based on the capacities of the various viewing facilities, we estimate that over 5000 people viewed the event via HD images on large-screen displays (Figure 2). The public WMV displays were viewed by at least 29 300 people. Some facilities reported that the number of participants quoted could be an underestimate as the numbers at their events exceeded the venue capacity.

Figure 3 shows transmission rates for the facilities that received the WMV broadcast. Thanks to the connection test, most users enjoyed live video of the total eclipse. As Figure 4 shows, most facilities that received WMV video made it available for public viewing. Public viewings at museums, community centres and public halls were particularly popular and effective as the staff were acquainted with astronomy and could give lectures before, during and after the public viewing. Facilities with science communicators were also likely to have provided public lectures accompanying the total eclipse video.

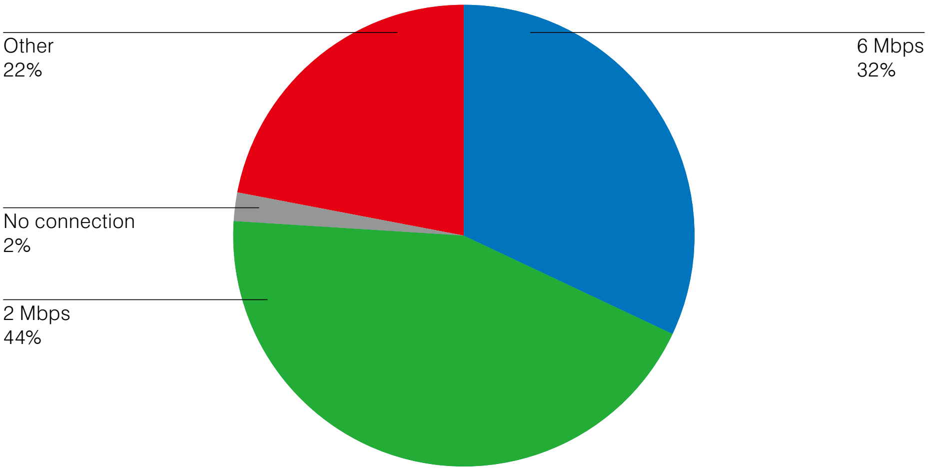

Figure 2. *Percentage of WMV receivers who obtained the given transmission rates. "Other" means users who did not respond to our questionnaire.*

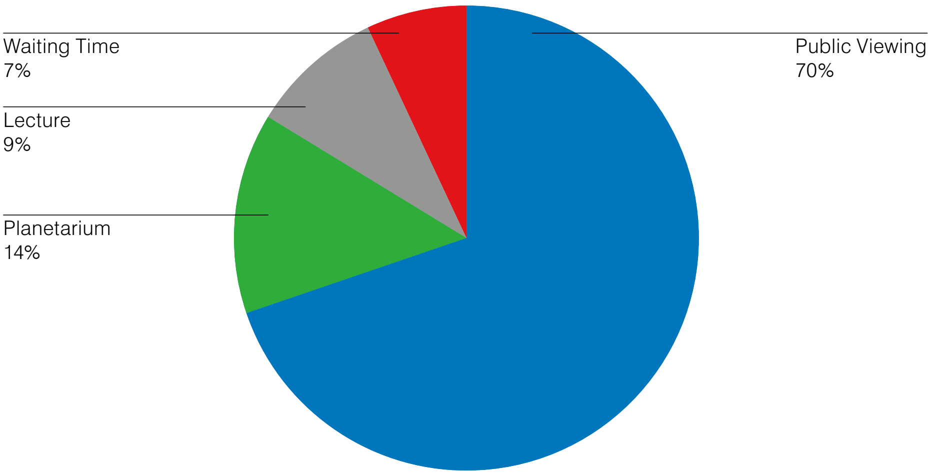

Figure 3. *Use of WMV real-time video.*

Based on feedback from staff working at the viewing facilities, we determined that, because the total eclipse was observable in Japan, public facilities that previously were not sensitive to astronomy were motivated to show the real-time images, despite the locations being limited and far from the mainland.

Members of the public who attended the events commented in the questionnaires distributed that:

"The images showed the total eclipse with so much presence that we had the illusion of actually observing it."

"It was a good opportunity; listening to the explanation of the phenomenon, observing the partial eclipse with our eyes and watching the total eclipse on screens."

Several comments mentioned the sense of presence — something that the small screen of a PC would struggle to achieve. This is one advantage of having public viewing events. The real-time images also served as a backup for eclipse-observation events. Unfortunately, clouds covered a large fraction of Japan on the day of the eclipse, so observing the partial eclipse was difficult. However, even in these bad weather conditions, facilities were able to show our images of the eclipse to the participants and visitors.

3. Lessons learnt

Providing a variety of delivery methods is important. For the sense of presence and to share the excitement with other people, large-screen public viewing of high-quality images is effective. However, watching images on a PC is more convenient and so is also an option worth offering.

As previously noted the copyright and permissions procedure for the live broadcasting was poorly received and the main source of negative feedback. These demands were relaxed after the recorded tapes arrived in Tokyo because, at this point, we no longer needed to transmit the images via WINDS. At present, the recorded images are freely available with only a short copyright notice. Experience from this project and from exchanging the videos and images with many science communicators showed that, to maximise propagation effects, recorded video and images should not be highly protected by copyright but should be made freely available to the public.

Projection of real-time images on a large screen requires wideband communication

Figure 4. *Participants at a public viewing. Credit: JIJI Press Ltd.*

Figure 5. *Participants enjoy a collaboration combining the movie of the eclipse with a musical performance. Credit: Keio University.*

network systems. Today's network capacity limits the amount of data we can transmit to personal terminals. Thus, choosing the appropriate data quality is important; images that can be browsed comfortably should be provided for individual use, whereas transmitting HD images is more suitable for museums and public halls, which could use them to conduct various outreach and educational activities. In other words, for today's outreach activities, both the images and the delivery methods must be optimised for either large screen or personal display.

4. Recommendations

We recommend preparing a beginners' manual or question and answer document before any public announcement of this kind of project. After we announced our intent to deliver images of the total eclipse from Iwo Island, groups that did not know how to connect to the internet asked us to provide real-time images. We realised that a phenomenon such as the total eclipse attracts people from outside astronomy, or even the natural sciences. People who have no experience of public outreach activities for astronomy and little knowledge of the internet. This resulted in an unexpected workload for us, because our manual was not written with this target audience in mind, so we had to answer each group individually and on a very basic level. In particular, those designing the HD images requested aid in providing lectures and setting up network systems. The level of support we could provide depended on the organiser's resources. If the staff at all the groups that planned to receive our streaming images had been sufficiently educated in information technology (IT), our workload would have been much lighter. These problems may have been avoided and the workload reduced if a frequently asked questions document or manual for beginners had been produced. A step beyond this would be to organise a help desk or call centre, if possible.

5. Conclusion

Although the number of YouTube viewers was much larger than the number of public-event participants, we do not feel that this justifies total reliance on the individual communication method. Because science communicators were usually present at the public viewing events to explain the astronomical event, these outreach activities proved important for providing a deeper understanding of the astronomical phenomenon and astronomy in general.

To organise a successful public viewing event using HD video streaming, we recommend preparing a detailed manual for IT beginners in advance. To maximise the use of the recorded video and images, they should not be highly protected by copyright but be made freely available, and both the images and the delivery methods must be optimised for either large screen or personal display.

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Biographies

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The Fingerprint of the Stars: An Astronomy Lab On Spectroscopy

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Keywords
Secondary School, High School, Experiment Activities, Spectroscopy, Activities for Young People

Summary

Many Portuguese schools are not equipped to carry out the mandatory experimental activities covered by the school curriculum. In order to remedy this deficiency, the Centro de Astrofísica da Universidade do Porto (CAUP) has developed hands-on laboratories, offering schools several different experimental activities. This article will focus on one of these experiments, in which students build a spectroscope and use it to analyse different spectra. Pupils learn not only the practical methods of science but also the astronomical and everyday applications of spectroscopy.

Introduction

Although the Portuguese school curriculum places considerable emphasis on experimental activities, many schools lack the materials and facilities required to carry them out. Thus, schools are often forced to bypass these activities, resorting instead to textbooks, PowerPoint or video presentations of the experiments they were supposed to conduct, and teaching the results that should have been obtained experimentally rather than completing the practical work. In recent years, some effort has been made by the Portuguese government to improve the conditions under which public schools operate (Almeida, 2009), but these programmes can only reach a handful of schools[1].

Since its creation in 1989 the Centro de Astrofísica da Universidade do Porto (CAUP) has set science outreach and promotion, and the teaching of astronomy at undergraduate level as two of its main goals. It became clear that CAUP could play an important role in providing the opportunity for students to perform the experimental activities that — according to the guidelines provided by the Ministry of Education — they were expected to conduct, and in particular those related to astronomy.

CAUP began to develop several experimental activities in 2006, activities which covered themes from the school curriculum, and forged a direct link to astronomy and space sciences. Today, six experiments covering different topics and catering to different age ranges are available at the Planetarium of Porto. These can be used as stand-alone activities, or to complement regular planetarium sessions. The experiments are guided by CAUP's outreach staff, all of whom have a high level of astronomy education.

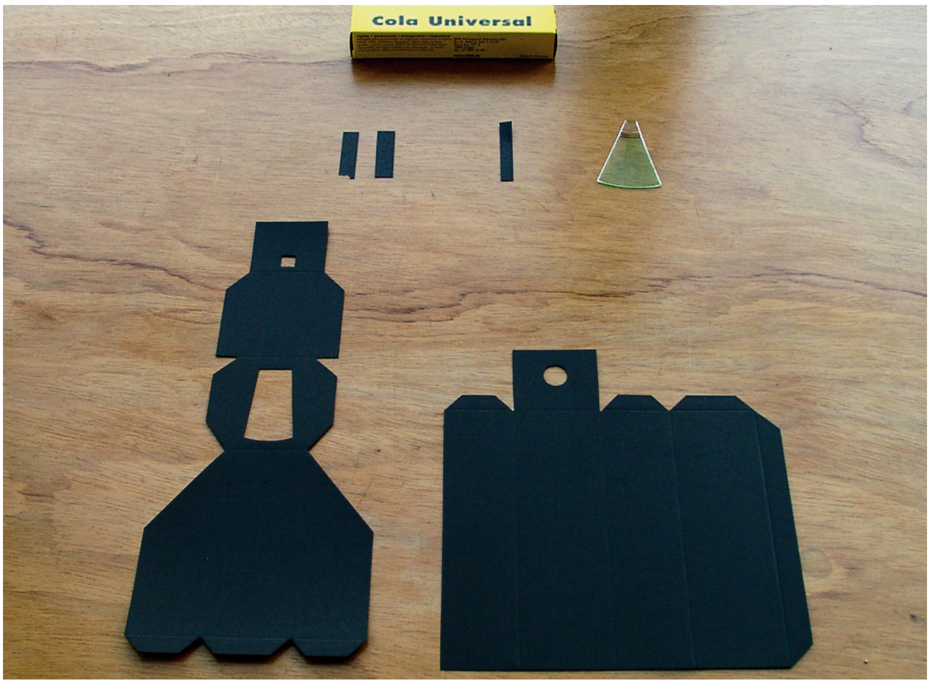

Figure 1. The material needed to assemble the spectroscope. Credit: Ricardo Cardoso Reis.

In the latest published results from the OECD Programme for International Student Assessment, which tests the general competence in reading, mathematics and scientific literacy of 15–16 year old students, Portugal ranked 34th in science[2], and is one of the worst performers among the OECD member countries. Although there is some controversy around what should be the exact role of experimental teaching in science learning, most researchers agree that experimental teaching is very important for at least some aspects of science education (Atkina, 2002)[3]. Therefore, if used appropriately, experimental activities may become a powerful tool for improving Portuguese students' scientific literacy.

The first activity, entitled "The Fingerprint of the Stars", debuted in 2007 and is targeted at students of around 15 years old. At this point in the Portuguese school system the topics covered in the physics and chemistry curricula, taken by high students in science and technology programmes include: the Universe, the nature of light, spectra and atomic structure.

Figure 2. *A group of students observes the solar spectrum. Credit: Ricardo Cardoso Reis.*

Figure 3. *A student uses a spectrometer to observe the spectrum of a gas-discharge lamp. Credit: Ricardo Cardoso Reis.*

Experiment description

This activity begins with an informal talk between the presenter and the students where a broad overview on the nature of light is presented. This checks that students have the necessary prerequisite knowledge and, if not, introduces them to the missing concepts. This talk also explains to students why spectroscopy is of the utmost importance for astronomy.

Students then proceed to build their own spectroscope from very simple materials: pre-cut pieces of cardboard, all-purpose glue and a slice of a compact disc (CD) with its reflective layer removed (Vieira, 2004; Figure 1). With this simple spectroscope, which students take home at the end of the experiment, students can observe spectra with a reasonable resolution (Figure 2), and, if the slit is carefully assembled, they can even observe the Fraunhofer lines in the solar spectrum.

Students are then asked to use the spectroscope they have built to observe several spectra from gas-discharge lamps containing a range of substances, from simple chemical elements like hydrogen or helium, to complex mixtures such as air or water vapour. A more accurate graduated spectrometer is also used as they are expected to perform some basic tasks of spectroscopic analysis, for example identifying the wavelength of a given hydrogen line (Figure 3).

Through their observations students see that different elements present different spectra, helping them understand one of the major applications of spectroscopy: the identification of the chemical composition of distant objects. Depending on the background knowledge of the target audience, some other applications of spectroscopy in astronomy may also be discussed, such as the Doppler effect and the redshift of distant galaxies; the radial velocity method for discovering exoplanets and the determination of gas pressure and temperature in a stellar atmosphere (Figure 4).

Considerable efforts have been made to make these sessions highly interactive, as students take the lead role in the experiments being conducted. Furthermore, throughout the entire session, they are encouraged to participate, by posing and answering questions, some of them requiring complex reasoning.

All this is done in an informal setting to encourage students to pose questions that they may not feel comfortable asking their teacher in a regular classroom setting. Furthermore, as these sessions are presented by people with formal university training in astronomy, students can get up-to-date and highly specific answers, which some teachers may not be able to offer.

In order to further cover the contents of school curricula, a few other related topics are also discussed during the experiment. For instance, the atomic structure of matter is easily brought into the discussion in order to explain how a gas-discharge lamp emits light.

Conclusion

With a growing number of visitors, The "Fingerprint of the Stars" experiment has been providing students with the chance to improve their knowledge and understanding of some major topics in their physics and chemistry curricula. This is done by experimenting first hand with the physical phenomena being studied, and interactively seeking further information. In turn, the presenter poses several questions and challenges that lead students to think about both the astronomical and everyday implications of the physics they are investigating, and also develop their scientific reasoning capabilities.

For most students who visit CAUP, this is the only chance they will get to perform an experiment on any spectroscopy-related subject. Thus, with this activity CAUP ensures that students from less well-equipped schools also have the opportunity to improve, through experimentation, their understanding of these subjects, which are apparently disconnected from everyday life, and potentially harder to grasp.

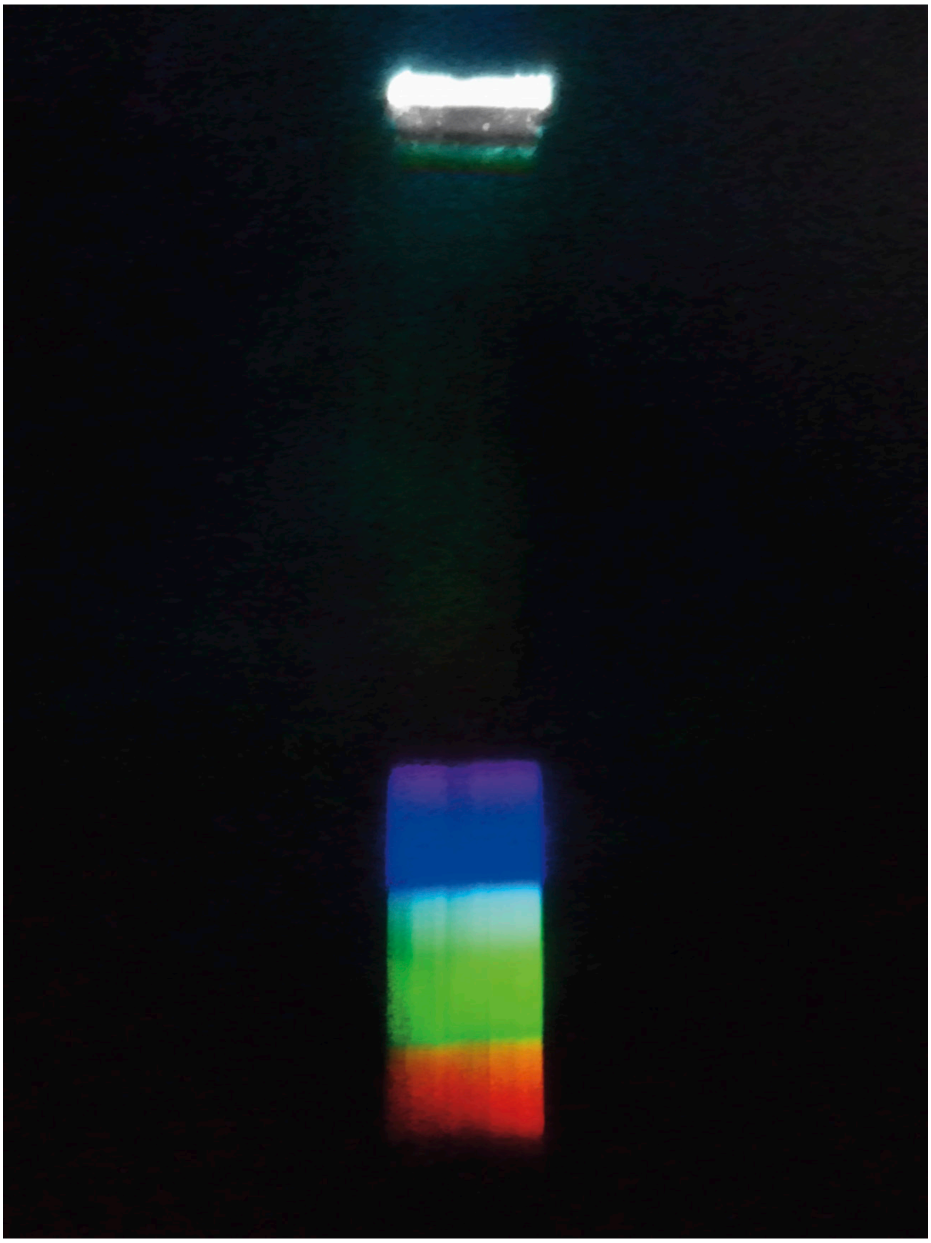

Figure 4. *The solar spectrum observed with a student-built spectroscope. Credit: Ricardo Cardoso Reis.*

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Notes

[1] Parque Escolar, E.P.E., Schools included in the modernisation programme; available at www.parque-escolar.pt/pt/escolas/escolas.aspx, retrieved on 2012/10/12

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Biographies

Pedro Mondim works in the Outreach Unit of CAUP, and is involved in many astronomy outreach activities for the general public and, especially, for students. He regularly presents planetarium sessions, develops new experimental activities and guides students in the hands-on laboratories.

Ricardo Cardoso Reis is an outreach assistant at CAUP, Ricardo works on most aspects of its strategy for astronomy outreach and promotion of scientific culture, by producing and presenting shows in the Planetarium of Porto, writing astronomy related news and press releases, presenting telescope observing nights (and days), and supervising hands-on activities. During the International Year of Astronomy 2009 (IYA2009) he was the coordinator of the global project Dawn of IYA2009 and a member of the task groups of Solar Physics, 100 Hours of Astronomy and Galilean Nights.

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City–City Correlations to Introduce Galaxy–Galaxy Correlations

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Keywords
Large-scale Structure, Cosmology Lab, Galaxy Distribution, Baryon Acoustic Oscillation, Galaxy–galaxy Correlation Function

Summary

The large-scale structure of the Universe, vividly displayed by the spatial distribution of galaxies, is characterised quantitatively by the two-point galaxy–galaxy correlation function. But the meaning of the correlation function is somewhat abstract because it does not have a ready analogy. This work computes the two-dimensional, two-point city–city correlation function for three populous regions of the United States, demonstrating that the city–city correlation function is analogous to the galaxy–galaxy correlation function determined from Sloan Digital Sky Survey data. City radii are analogous to galaxy cluster radii, and city-to-city distances are analogous to distances between galaxy clusters. Part of this work has been adapted for a lab suitable for non-experts.

Introduction

The large-scale structure (LSS) of the Universe — essentially the distribution of galaxies — is characterised by the two-point correlation function (Peebles, 1980). Its applications include determining the percentage of dark matter (Peacock et al., 2001; Hawkins et al., 2003) and demonstrating baryon acoustic oscillations (Eisenstein et al., 2005) as predicted by the dark energy–cold dark matter (ΛCDM) model of the Universe. However, the concept of the correlation function might seem obscure to the uninitiated. This motivated the current work to calculate, for three groups of cities in the United States of America, a two-dimensional, two-point correlation function that can be easily interpreted because of readily available city data.

This provides a tool for non-experts to interpret the three-dimensional two-point galaxy–galaxy correlation function calculated from Sloan Digital Sky Survey (SDSS) data or from other surveys. The question posed and answered in this work is the following: in what sense, mathematically, does the clustering of galaxies in Figure 1 resemble the clustering of cities in Figure 2?

Two-point correlation function

If galaxies were randomly distributed in the Universe, there would be a certain probability of finding two galaxies near each other. That probability is enhanced by the gravitational attraction between two galaxies, an enhancement called the two-point correlation function, represented by the dimensionless ξ. The method for calculating the two-point correlation function is clear in theory, if not in practice. First, generate a random catalogue of galaxies with the same spatial extent as the galaxy catalogue under analysis. Then determine the degree to which galaxy clustering of the actual catalogue is enhanced over that of the random catalogue.

City–city two-point correlation function

A method for calculating the galaxy–galaxy correlation function (Zehavi et al., 2002) was adapted to the problem of determining the city–city two-point correlation function for three groups of cities. The composite satellite image poster, *North America at Night* (Sullivan, 1993), was digitised, and cities represented by a blob of light were identified by comparison with a standard geographical map.

Three regions were chosen as representatives of clusters of cities. The criteria for choosing a region were:

1. That its shape must be square, for ease of analysis.
2. That two other non-overlapping regions could be chosen of the same size and approximate light density.

The Midwest, Southwest, and Southern regions of the United States chosen (highlighted squares in Figure 2) are approximately 414 000 square kilometres in area.

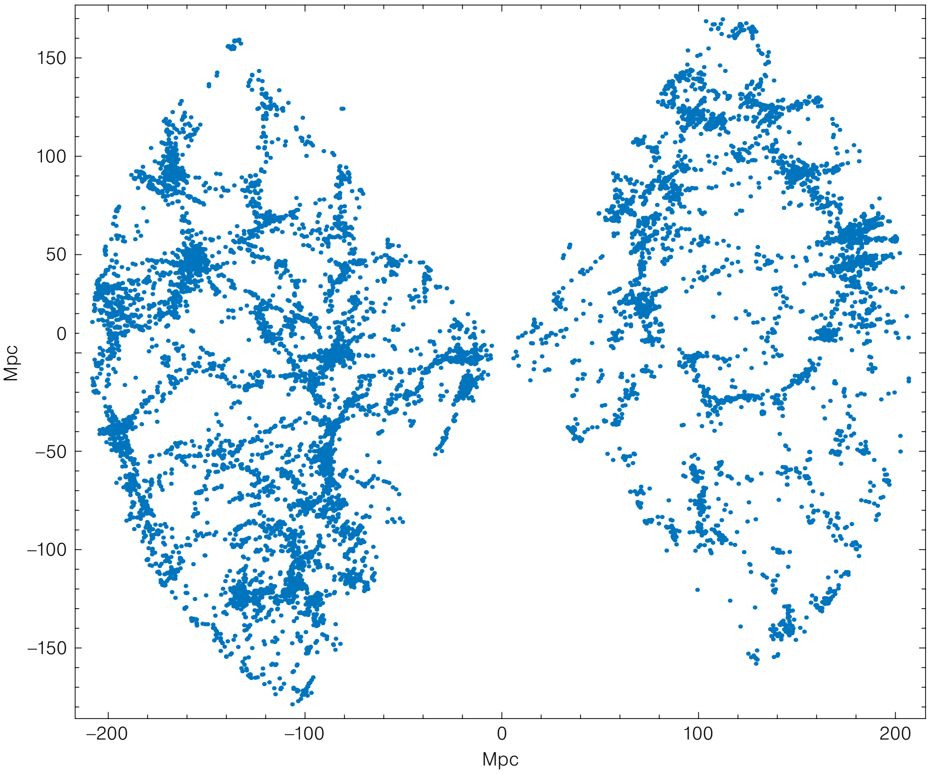

Figure 1. Plot of 9659 galaxies from the SDSS Data Release 7 for 0 < z < 0.05 and –3° < dec < 3°.

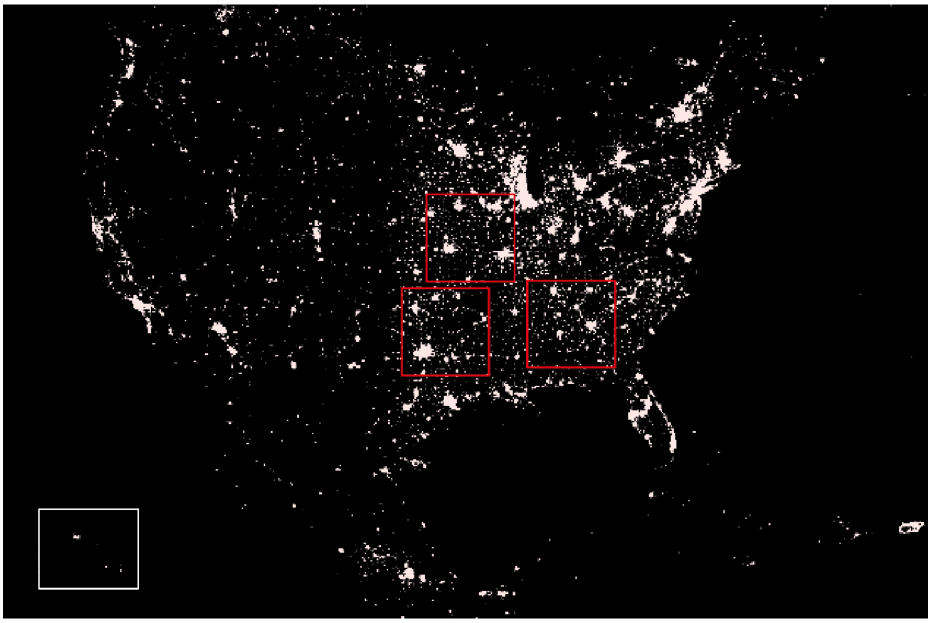

Figure 2. North America at Night *with the three squares indicating the cities grouped for analysis. Credit: Sullivan 1993.*

The correlation function is calculated for the Midwest cities, shown in Figure 3. The result is displayed in Figure 4 and is readily interpreted when compared to independent measurements.

City lights are initially positively correlated, a correlation that decreases and becomes negative as the distance from the city centre increases, but becomes positive again, reaching its peak ($\xi = 0.12$) at 389 ± 10 km when another city is encountered.

This value compares favourably to the 367 ± 132 kilometres determined by simply averaging all of the possible distances between all of the cities, using geographical data. Furthermore, a fit of the initial points of Figure 4 to a power law reveals that the correlation function decreases initially over a characteristic distance of 33 ± 0.8 kilometres, comparable to the average radius (32 ± 8 kilometres) of all of these Midwest cities as determined by making on-screen pixel measurements then converting to kilometres.

The same correlation function analysis is performed for the Southwest cities (Oklahoma City, and Tulsa, Oklahoma; Fayetteville and Little Rock, Arkansas; Dallas, Texas; and Shreveport, Louisiana), and Southern cities (Nashville, Knoxville, and Chattanooga, Tennessee; Birmingham and Montgomery, Alabama; and Atlanta, Georgia). Just as before, for each group there is a peak in the correlation function

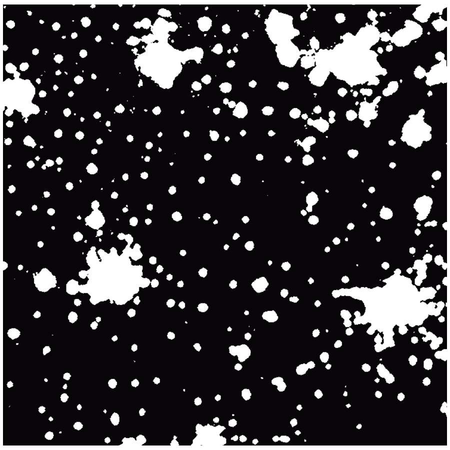

Figure 3. The correlation function is calculated for this group of Midwest cities, the top-most square in Figure 2. Clockwise, from the upper-left corner: Omaha, Nebraska; Des Moines, Cedar Rapids, and Davenport, Iowa; and St. Louis, Springfield and Kansas City, Missouri.

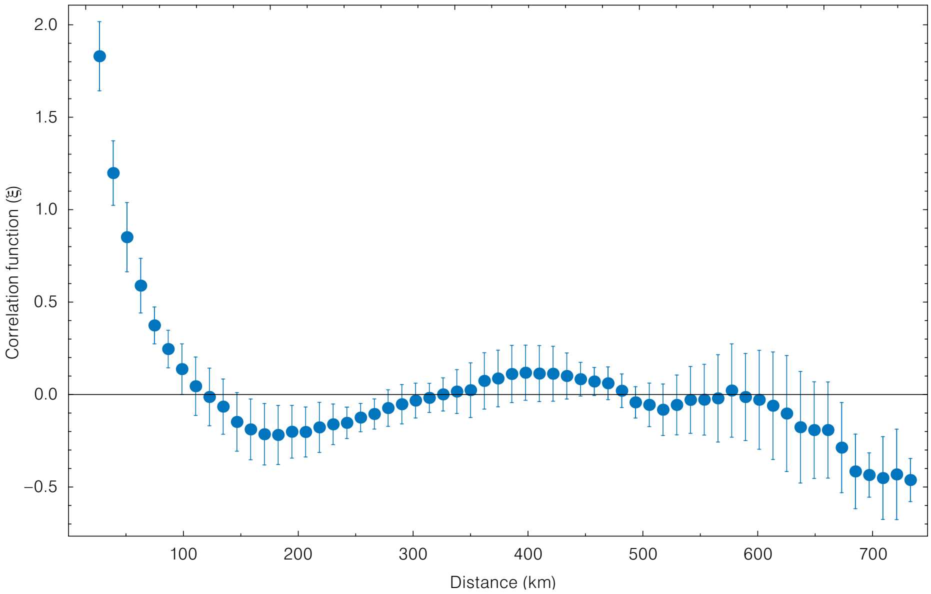

Figure 4. *Two-point correlation function for the Midwest cities in Figure 3.*

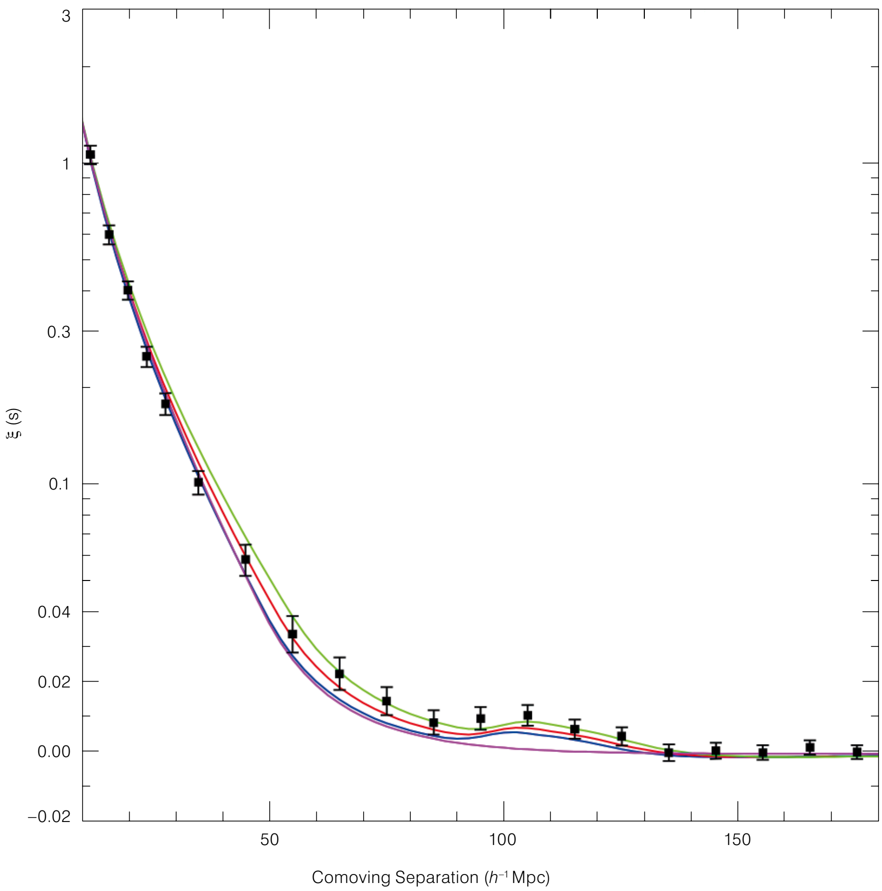

Figure 5. *Two-point correlation function for Luminous Red Galaxies from the SDSS survey. Curves are predictions for various fractions of dark matter. Adapted from Eisenstein et al. (2005).*

that corresponds to the average city–city distances, and the characteristic distance over which the correlation function decreases is the same as the average of the city radii. Average distances between cities, and average city radii for the three groups are summarised in Table 1.

Galaxy–galaxy two-point correlation function

Following the above interpretations, with a couple of caveats, the peak in the galaxy–galaxy correlation function of Figure 5 (Eisenstein et al., 2005) reveals an average distance between galaxy clusters of about 100 h^{-1} Mpc (≈ 143 Mpc for a Hubble parameter $h = 0.7$). And a galaxy cluster's average radius is approximately 8 h^{-1} Mpc (≈ 11 Mpc), according to the correlation function of Zehavi et al. (2002). Both values are from analyses of the Sloan Digital Sky Survey (SDSS) catalogue. Zehavi et al. (2002) includes a summary of correlation functions from other surveys.

The first caveat is that the correlation function peak in Figure 5 is for Luminous Red Galaxies (LRGs), which are particularly suited for galaxy clustering studies, but the galaxy cluster radii value is from a more general catalogue of galaxies. Zehavi et al. (2005) also gives the correlation function for LRGs.

The second caveat is that these galaxy–galaxy correlation functions do not represent real-space distances, but the comoving distances used by cosmologists to give a meaningful measure of distance in an expanding Universe. These distances expand in step with the expanding Universe and depend on the redshift and the choice of the underlying cosmological parameters. These caveats are not detrimental to the analogy between the city–city and galaxy–galaxy correlation functions.

The peak of Figure 5, called the baryon acoustic peak, is of cosmological importance because it is an imprint of the oscillating plasma of baryons (protons, neutrons — essentially ordinary matter) that was coupled to photons in the young Universe via photon–electron scattering (Eisenstein & Bennett, 2008). When the Universe became cool enough, 380 000 years after the Big Bang, the baryons and

City Group	City–City Distance from ξ	Geographical City–City Distance	City Radius from ξ	Pixel Measure of City Radius
Midwest	389 ± 10 km	367 ± 132 km	33 ± 0.8 km	32 ± 8 km
Southwest	423 ± 10 km	346 ± 109 km	38.9 ± 1 km	35 ± 13 km
Southern	240 ± 6 km	249 ± 93 km	23 ± 0.5 km	23 ± 13 km

Table 1. City distances and radii as determined from the correlation function, ξ, and compared to direct pixel measurements converted to kilometres.

electrons combined, forming atoms, dominated by neutral hydrogen. The photons were now decoupled from matter and the Universe became transparent. The imprint of this event is carried by photons streaming freely to observers and is known as the Cosmic Microwave Background (CMB). The neutral atoms retained a frozen pattern of sound waves formed in the presence of dark matter. The resulting pattern of the density variations in both the dark matter and ordinary matter is reflected in the galaxy cluster distribution. So, in addition to the 100 h^{-1} Mpc cluster–cluster distance, the correlation function analysis also gives an independent estimate of the dark matter fraction of the Universe (Eisenstein et al., 2005).

Student laboratory

Some aspects of this work have been adapted to a lab in introductory astronomy (Smith Jr., 2012). Students are first introduced to astronomical distances by having them consult the web for typical distances to stars, and typical distances to galaxies. They are led to determine that galaxies are roughly a million times further away than stars.

Next, students are given the appropriate Structured Query Language (SQL) for downloading SDSS data sufficient for a wedge plot in Excel, consisting of about 9600 galaxies. This enables a visual comparison between the students' galaxy clustering plot and city clustering with images provided by the instructor.

Finally, students are given the data for the Midwest cities that enable them to plot the two-point correlation function so that it can be compared to the correlation function for galaxies provided by the instructor.

Summary

The two-point correlation function, used by cosmologists to describe the large-scale structure of the Universe, is explained by drawing an analogy between city clustering and galaxy clustering.

The analogy is demonstrated by calculating the two-point correlation function for night satellite images of three groups of cities in the USA, and comparing the results with geographical distances, and with direct pixel measurements of city radii, converted to kilometres. The comparison reveals that the characteristic distance of a correlation function can be interpreted as the average radius of a city group, and the correlation function peak is the average city–city distance.

Then similar features in the galaxy–galaxy correlation function can be similarly interpreted by non-experts: the characteristic distance is equivalent to the average radius of a galaxy cluster, and the peak's position, the baryon acoustic peak, is the distance between galaxy clusters. This cosmologically important peak is a relic of an oscillating plasma of coupled photons and baryons in the presence of dark matter just after protons and electrons combined to form neutral hydrogen and photons decoupled to form what became the CMB.

Acknowledgements

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Biography

Daniel M. Smith, Jr. is a Professor of Physics at South Carolina State University with an interest in developing interactive labs and simulations to explain the results of cosmological research to non-science University students. His work can be found on the website Cosmology for Non-Science Majors: http://physics.scsu.edu/~dms/cosmology/home2.html

The University of Washington Mobile Planetarium: A Do-it-yourself Guide

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Summary

The University of Washington mobile planetarium project is a student-driven effort to bring astronomy to secondary schools, and the community, in Seattle, USA. This paper presents the solution that was designed and built in order to use the World-Wide Telescope — a computer program created by Microsoft that displays the astronomical sky as maps, the 3D Universe, and earth science data — from a laptop and an off-the-shelf high-definition (HD) projector located in an inflatable planetarium.

In the first six months of operation, undergraduates at the University of Washington presented planetarium shows to over 1500 people, and 150 secondary school students created and presented their own astronomy projects in our dome, at their school. This paper aims to share the technical aspects of the project so that others can replicate the model or adapt it to their needs. This project was made possible thanks to a NASA/ESA Hubble Space Telescope education/public outreach grant.

Introduction

Digital planetariums are becoming a mainstay in astronomy education. They allow the presenter to enhance their lessons with the incredible imagery that has become commonplace in the modern age and to use visualisations of astronomical systems from moons to galaxies.

Free software, in particular WorldWide Telescope (WWT)[1] has brought high-quality, up-to-date astronomical imagery to the screens of anyone with an internet connection. Furthermore, the WWT contains its own image-warping software, putting do-it-yourself planetariums with HD imagery within the reach of smaller budgets. In fact, the method described here costs roughly $14 000 in parts (all purchased new). The costs would have been about $1500 less had the laptop and projector already been available. The largest costs are the planetarium dome and the first-surface mirror ($12 000).

The mobile planetarium project grew from an existing planetarium outreach programme. The graduate students at the University of Washington Astronomy department maintain a weekly outreach programme where they organise and present free planetarium shows to any school or astronomy group that makes a reservation. In 2009, organisers noticed that over a three-year period, this outreach programme had served, on average, 1000 students per year. However, in the same period, no public secondary schools in Seattle had made reservations, despite being located within 16 kilometres of the planetarium. It was decided that a proactive solution to the lack of engagement with these schools was to bring the planetarium shows to the schools.

With WWT software it quickly became clear that there was no need to lecture, and that the planetarium presentations could be flipped. In other words, the students could create and present their own planetarium shows. The initial plan to turn the planetarium outreach programme into a road show became simplistic and outdated in the face of new technology. Now the project engages students not by presenting to them, but by helping them to produce their own planetarium content and providing a mobile planetarium for them to stage their astronomically themed presentations.

Below is a description of the technical decisions made and the advice that we wish

Figure 1. The University of Washington mobile planetarium dome.

had been available when starting the project from scratch. A very useful starting point is to become a member of the Yahoo groups full_dome and small_planetarium. There is a lot to be learnt by diving into their archives.

1. Timeline

This project was planned over nine months of part-time work to gather equipment, design and build optics housing, and test the optical alignment. Three months were also allocated to offer a seminar to train undergraduates in setting up and operating the planetarium. Finally, two meetings with a pilot classroom were set up before launching into full operation.

2. Budget

2.1. Equipment

This project received a Hubble Space Telescope education/public outreach grant of $40 000 to increase access to the University of Washington planetarium and build a mobile planetarium. This was limited to spending no more than half of the funding on mobile planetarium equipment. In total, the mobile planetarium cost $14 000 in parts, including the purchase of a $1500 laptop.

2.2. Insurance

Insurance is an important element to remember to include in a longer-term budget.

2.3. Transportation

We rent a minivan for the project members to travel in groups of at least three people, but we have transported our entire planetarium and a passenger inside a four-door sedan. Depending on the range over which you expect to travel consider budgeting for rental vehicles and mileage costs.

2.4. Personnel

This project never occupied anyone full time. The initial overhead is the highest concentration of labour. This is the period when the planetarium is built, the first team of undergraduates is trained in the WWT software and the technical details of the planetarium are planned and implemented. For this initial ramp-up a graduate student was hired for approximately 300 hours in total, during the nine-month period, and one undergraduate assistant was hired for approximately 240 hours total, over a one-year period.

The hired graduate student ordered and led the planetarium assembly as well as mentoring the undergraduate assistant. The undergraduate assisted by leading the building and design of the optics housing, writing lessons, and training prospective undergraduate presenters at the seminar.

There is now a team of approximately ten undergraduate volunteers who are capable of transporting the planetarium. One full-time lecturer is in charge of the mobile planetarium, although we recommend keeping this position as an advisory role and funding 1–2 undergraduate assistants to manage scheduling and communication with the schools.

3. Essential equipment

3.1. Projection type

At the time of ordering equipment, a fish-eye lens solution would have been prohibitively expensive as a single purchase and difficult to replace. In addition we wanted a projection system that would sit on an edge of the dome, rather than at the centre, where the students entered the dome. In the end two first-surface mirrors, one convex, and one flat, were purchased to project imagery on to the dome.

3.2. Inflatable dome, fan and hemisphere mirror

The biggest equipment cost is the inflatable dome. The decision of which size dome and which company to use should be made with care. We will not reproduce the clearinghouse of knowledge and experience in the Yahoo groups, *small_planetarium* and *full_dome*. We made heavy use of their email archive as well as asking specific questions of the group at large.

Listed below are the main concerns and solutions arrived at with the help of the Yahoo groups. Advice from the experiences of members in the Yahoo groups positively mentioned Go-Dome, Digitalis, and Stargazer. In the end, a standard sized Go-Dome was purchased through eplanetarium.com[2], which came with an inflating fan and the hemisphere mirror.

3.3. Concerns and solutions

3.3.1. Dome size

Concern: The dome must be transportable by 2–3 undergraduate students, able to fit a class of around 30 students inside, and be able to fit within a classroom.

Solution: Limiting the search to domes no more than three metres high.

New issues raised by the solution: The horizon will be low, most students will need to sit on the ground, some chairs or perhaps two wheelchairs can be placed around the back and sides of a dome this size.

Why constrain the presentations to a classroom?

A taller dome could have been purchased, requiring the set-up to be in a gym, cafeteria, or theatre. Outside is not an option as any wind will cause the dome to lose its shape. The choice not to do this was based on the following two issues:

1. The assumption was made that there would be no internet access outside the classrooms. In fact, it transpires that there is rarely internet access in schools.
2. The assumption was made that it would be more difficult for a science class to take over the other locations and one aim was for the imprint on the school to be as small as possible. For example, the presentation could be too loud to share a space in a library, even though librarians are often very happy to share their space. However, it was very helpful to have the option of using a classroom.

The recommendation would be to phone different schools to see what options are available. In the end, we would have made the same decision on the dome size, and purchased the standard Go-Dome.

3.3.2. Dome entrance

Concern: Needs to comply with the Americans with Disabilities Act (ADA).

Solution: We have not found an excellent solution for inflatable domes. The best option seemed to be to purchase a standing dome (one that does not require constant inflation) that has an open entrance. In our research, these domes were well beyond our equipment budget. Advice from experiences of members in the Yahoo groups positively mentioned Go-Dome, Digitalis, and Stargazer as ADA-compliant options.

Figure 2. The optics box in the mobile planetarium. The do-it-yourself guide to building the above optics box is available on our website[4].

3.3.3. Dome material

Concern: Will the dome let in outside light? Is it safe to bring into schools? Has it been fire tested?

Solution: All the above domes are light-tight. The three companies listed above all seemed to have dark domes and the necessary documentation.

3.3.4. Mirror costs

Concern: First-surface hemisphere mirrors are expensive, and seem to be only produced in Australia. How can we limit the cost as we are based in the USA?

Solution: First-surface mirrors are a must. Coated mirrors produce blurry images as some of light from the projector is reflected by the interior surface of the coating back to the mirror, and travels to the dome at a new angle. This is only made worse if more than one mirror is used. ePlanetarium ships a first-surface hemisphere mirror for an additional cost with the Go-Dome.

3.3.5. Dome fan

Concern: How portable is the fan, given how much other equipment there is?

Solution: It is simple to purchase a small-wheeled attachment for the fan, or a two wheeled luggage accessory. It was not found necessary to purchase them for this project.

Fan speed, fan control, and fan noise are important factors. The fan speed needs to be turned up while people enter and exit the dome, since the fan control is often found on the fan itself, one must control the fan speed from inside if giving the show alone. In practice, there was always someone on the outside to assist with crowd control, and they were able to adjust the fan speed to communicate to the presenter. The fan is turned up when it is time to wrap up the show.

In a small room, a large fan can create a lot of background noise. Look closely into the specifics of the dome fan to make sure it fits your needs.

3.3.6. Projector

Concern: Need a projector that is good for high dark–light contrast (stars and nebulosity), easily portability, has small replacement costs, and all on a small budget.

Solution: An off-the-shelf, 1920 × 1080 p (16 × 9) HD, high-lumen projector was purchased. The website *projector central*[3] is a powerhouse of information when it comes to choosing projectors. The search for this project was limited to 1920 × 1080 p (16 × 9) HD projectors under $1000. High-lumen projectors were found to be better suited for mobile planetarium purposes. Large planetariums can make use of dark adaption in conjunction with a low-lumen projector, so the eye can better pick out details like constellations after seeing a bright image. However, in the portable planetarium the line of sight to the image is never more than 15 ft, and usually around 10 ft. Dark adaption of students' eyes cannot be depended upon after, for example, flashing an image of the Hubble Space Telescope's mosaic of the Crab Nebula spread on the entire dome. Finally, no attention was paid to the quoted contrast ratio, since dynamic irises and other technologies make the quantity non-uniformly defined from projector to projector.

3.3.7. Laptop

Concern: A HD video card, large hard drive space, and a Windows PC or Mac running Windows on a dual boot or as parallels (for WWT) was needed.

Solution: Any laptop with a video card capable of extending an HD display and dedicated hard drive space for WWT to cache imagery is fine. Look for one with a backlit keyboard so the presenter can type in the dark (a USB powered reading light would be an affordable workaround to a backlit keyboard). Based on personal experience (and not industry comparison) we have been happy with a near top-of-the-line NVIDIA GeForce video card. In simpler terms, the laptop should have a built in (mini) DV or HDMI output. For lower quality imagery, VGA can be used, but is not recommended.

3.3.8. Optics assembly

Concern: Mainly durability, size, cost and a preference to limit the handling of the first surface mirror(s).

ePlanetarium.com sell their own Transport Security Approved (TSA) optics solution, which was beyond this project's budget, and may have limited the projector choice to a projector with a lens in its centre.

Solution: To save money, an optics solution was built from scratch by the project team. Full details of the solution are posted on the website[4] and are available from the authors.

4. Essential accessories

4.1. Power

The laptop, the projector, the lights, and perhaps other accessories such as speakers and public address (PA) systems, require power. It is often against fire code regulations to connect a power-strip to an extension cord, so it was important to purchase a single unit.

4.2. Display

Not all HD projectors come with Digital Visual Interface (DVI) or High-Definition Multimedia Interface (HDMI) cables, and some laptops need a cable to convert HDMI. Using only the Video Graphics Array (VGA) cable that comes with an HD projector is like buying a sports car and never taking it out of second gear.

5. Non-essential equipment

5.1 Secondary mirror

A secondary flat first-surface mirror comes recommended. It allows the projector to be safely placed underneath the hemisphere mirror, and thus takes up less physical space in the planetarium, meaning more places for people, and a smaller chance of being bumped and jostled. However, it adds more variables to the alignment.

5.2. Equipment cases

5.2.1. Dome

A rolling equipment bag made for hockey goalies was used for this project. It is large enough to fit extra smaller equipment and does not require expert dome repackaging. With some extra budget, we would have had a logo option!

5.2.2. Mirrors

The hemisphere mirror is the most delicate and difficult to replace item, as there is no repair for scratches. For this project the housing was built as part of the box it was transported in, to avoid the number of times it would be handled.

The secondary mirror is less than 20.5 cm in diameter and kept in a picture frame, which is covered and sealed with rubber bands, so that nothing touches the mirror surface.

5.2.3. Laptop

A simple laptop backpack is enough to hold the laptop, lots of cables, a mouse, an Xbox controller, non-essential accessories, and any paperwork (such as the fire retardancy certificate and contact information). A laptop cooling pad is a good idea.

5.2.4. Projector

Most off-the-shelf projectors come with a carrying bag. In light of the amount of travel — in and out of cars and schools while carrying other equipment —a heavy-duty pelican case was purchased for the projector. We included the cost in the projector budget.

6. Non-essential accessories

6.1 Audio and public address equipment

WWT can play pre-recorded tours with audio, which requires some sort of amplified speaker system. Speakers placed outside the dome work well, as do higher quality computer speakers placed near the presenter.

6.2. Tickets and seating

Tickets are particularly useful when presenting at school science nights, which typically involve doing many short shows in a row. They let people know when to return and aid crowd management.

6.3. Lighting

For effect, rope lights were placed around the edge of the dome with a small switch so that the presenter has easy access to turn the house lights on and off. A battery-powered camping lantern is useful for setup and takedown.

7. Non-essential equipment and accessories for WWT

7.1. Internet access
WWT caches imagery from servers around the world. A 30-ft-long Ethernet cable was used as back up for internet access. Another possibility is using a wireless card in the laptop. Neither were found to be essential. If weak or no internet is available, see the WWT documentation housed on their website.

8. Initial assembly

8.1. Optics box construction
Justin Gaily, who designed and led the building of our optics box, has written a separate do-it-yourself guide, posted on the website and available from the authors.

8.2. Testing and alignment
With the optics box ready, it was great to have high-ceilinged rooms to align and test the system and train undergraduates. The Dance and Theatre Departments of the University of Washington graciously provided these spaces. WWT makes warping very easy in several scenarios, including a 16 × 9 mirror dome (see WWT documentation for details). The rest of the setup involves adjusting the components of the optics box, positions of the projector and angles of the mirrors until the entire dome is filled with light. It is helpful to project a grid during this process.

9. Presentation

9.1. Flipping the planetarium
It seems that the one measure of a successful education or public outreach project is how well it can be adapted to the specific needs of the target market. We wrote our grant with the simple idea of bringing our successful planetarium programme directly to the Seattle schools and community, but we have discovered that students can create their own tours of the Universe in the planetarium.

The model is to support teachers during a planetarium presentations unit lasting one or two weeks. The unit begins with small groups of students choosing a topic in astronomy and creating a storyboard for a short (3–5 minute) presentation using imagery from WWT. If the teacher is not trained in WWT, an initial visit is made to the classroom to demonstrate WWT tour creation and check in with each student group. After this visit, students work together to create WWT tours. Finally, the team returns with the mobile planetarium and the students present their work to their peers.

Students create a story as they research their topic, and then practice their communications skills to present it. On the presentation day, everyone gets to see their tour projected inside the dome.

Students were found to have no problem creating tours that showed well in the planetarium, as long as they avoided projecting text. They were advised to consider that only the middle third of their computer's screen will be in front of them when they are inside the dome and there is no reading from scripts inside the dome, so they could either record a voiceover or memorise what they wanted to say.

9.2. Creating tours
General information on creating tours and teaching WWT in the classroom is available on the excellent WWT Ambassadors' site[5].

Conclusion

Digital planetariums are immersive spaces that have the potential to increase students' enthusiasm for learning science. We have described the path we chose in designing and creating the University of Washington mobile planetarium in the hopes that others will adapt it to suit their needs. The main components are a laptop, a projector, a dome, a hemispherical mirror, and software that will warp the projected image (we recommend WorldWide Telescope). Our equipment budget was under $15 000 with everything purchased new and 80% going to the inflatable dome and first-surface hemisphere mirror. Our initial aim was to bring planetarium shows to local classrooms. We are excited to report that our mobile planetarium has gone beyond this and become an undergraduate-driven stage for secondary school students to teach their peers about the wonders of the Universe.

Contact

Email our team: uw.mobile.planetarium@gmail.com

Find us online: http://www.astro.washington.edu/groups/outreach/mplanetarium/

Links

1 www.worldwidetelescope.com
2 www.eplanetarium.com
3 www.projectorcentral.com
4 http://www.astro.washington.edu/groups/outreach/mplanetarium/about.html
5 https://wwtambassadors.org/

Biographies

Philip Rosenfield is a postdoctoral researcher at the Univeristá degli Studi di Padova, Italy, focussing on constraining stellar evolution models using NASA/ESA Hubble Space Telescope observations. As a graduate student at the University of Washington, USA, he led the digital upgrade of the planetarium and was a co-principal investigator of the mobile planetarium project.

Oliver Fraser is a lecturer in astronomy at the University of Washington, USA. In addition to serving as faculty advisor for the University of Washington Mobile Planetarium group, Dr Fraser teaches introductory astronomy classes, along with classes that focus on how to write in the natural sciences.

Justin Gailey is a recent graduate of the University of Washington, USA, with a double major in Physics and Astronomy, and minors in Music and Mathematics. He designed and built the optics box for the mobile planetarium, and is currently teaching mathematics as a Peace Corps volunteer in Mozambique.

John Wisniewski is an assistant professor in the Homer L Dodge Department of Physics and Astronomy at the University of Oklahoma, USA. He was a co-principal investigator of the mobile planetarium project and currently serves as co-principal investigator of Oklahoma University's new "Sooner-tarium", a similar mobile planetarium project to the one reported here.

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