CAP journal

Communicating Astronomy with the Public

issue 1 | 2007

The International Year of Astronomy 2009

Background information to get started

Dark Matter

Explained in 60 seconds!

Astronomy in *Second Life*

Get with it! Welcome to the future!

Credibility of Press Releases

An exploratory study

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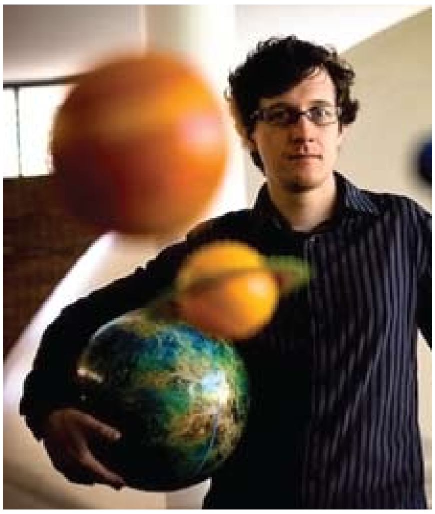
Editorial



THE PUBLIC COMMUNICATION OF ASTRONOMY provides an important link between the scientific astronomical community and society, giving visibility to scientific success stories and supporting both formal and informal science education. While the principal task of an astronomer is to further our knowledge of the Universe, disseminating this new information to a wider audience than the scientific community is becoming increasingly important. This is the main task of public astronomy communication — to bring astronomy to society.

The next few years will be extremely important for astronomy communication and education. The International Year of Astronomy 2009 will serve as a unique platform to inform the public about the latest discoveries in astronomy as well as to emphasize the essential role of astronomy in science education.

However, as the astronomy outreach community expands globally, it becomes increasingly important to establish a community of science communication experts. The three Communicating Astronomy with the Public conferences held so far have had some success in raising the profile of astronomy, but a forum where professional expertise and know-how can be presented and preserved for posterity is needed. We think a peer-reviewed scientific journal can help to achieve that.

The IAU DIVISION XII Commission 55 Communicating Astronomy with the Public Journal Working Group prepared a study assessing the feasibility of the Communicating Astronomy with the Public Journal (CAPjournal). The conclusions were inescapable. The present situation of public astronomy communication shows a clear need for a publication addressing the specific needs of the public astronomy communication community.

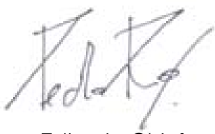
The journal is divided in nine main sections dedicated to: "News", "Announcements", "Letters to the Editor", "Reviews", "Research & Applications", "Resources", "Innovations", "Best practices" and "Opinion". The "Research & Applications" section will contain peer-reviewed science communication 'research' articles. "News" and "Announcements" will present information and updates, such as conference reports from the astronomy outreach community. "Resources" and "Innovation" will provide a repository of outreach ideas and cutting-edge astronomy communication methods respectively. "Best Practices" aims to be a guide, containing case studies, to the techniques that work best in communicating astronomy. "Opinion" provides space for subjective discussions of topics related to astronomy communication.

Public communication of astronomy is a burgeoning field of science communication. We would like to see the astronomy outreach community deeply involved in this journal's evolution and production. Please feel free to send us your articles and reviews on communicating astronomy, as well as suitable books/websites/products for review in the pages of CAPjournal. Submission guidelines are available on the back page. Relevant advertisements are also more than welcome.

We are eager to get your feedback, so please feel free to e-mail us at editor@capjournal.org.

We would like to extend a special thank-you to Andrew Fraknoi and Sidney Wolff from Astronomy Education Review — which in some sense can be seen as the sister journal to CAPjournal on the educational side. We look forward to a warm collaboration and much cross-fertilization.

Happy reading!



Editor-in-Chief

Explained in 60 Seconds

A collaboration with *Symmetry* magazine, a Fermilab/SLAC publication

Dark Matter

Dark matter is, mildly speaking, a very strange form of matter. Although it has mass, it does not interact with everyday objects and it passes straight through our bodies. Physicists call the matter dark because it is invisible.

Yet, we know it exists. Because dark matter has mass, it exerts a gravitational pull. It causes galaxies and clusters of galaxies to develop and hold together. If it weren't for dark matter, our Galaxy would not exist as we know it, and human life would not have developed.

Dark matter is more than five times as abundant as all the matter we have detected so far. As cosmologist Sean Carroll says, *"Most of the Universe can't even be bothered to interact with you."* Whatever dark matter is, it is not made of any of the particles we have ever detected in experiments. Dark matter could have — at the subatomic level — very weak interactions with normal matter, but physicists have not yet been able to observe those interactions.

Experiments around the world are trying to detect and study dark matter particles in more direct ways. Facilities like the Large Hadron Collider could create dark matter particles.

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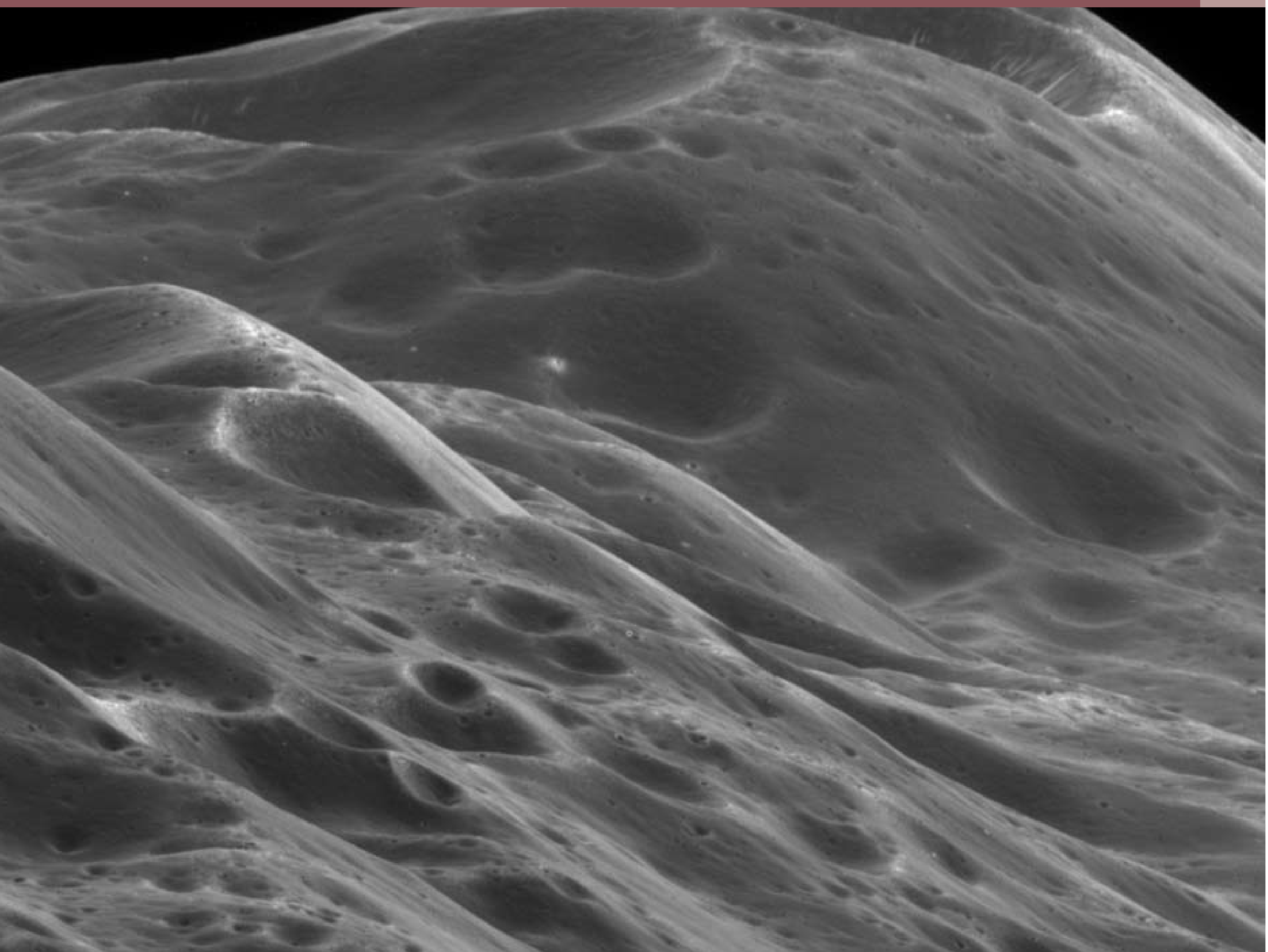
Key Words:

Science Communication
State-of-the-art
Written

At a distance of nearly four thousand kilometres Saturn's moon Iapetus looms into view in this incredible new image from the NASA/ESA *Cassini-Huygens* mission. Bright regions show areas where ice has been uncovered by impacts on the sides of these colossal mountains which rise up a staggering ten kilometres from the icy moon's surface. Credit: NASA/JPL/Space Science Institute



An Exploratory Study of Credibility Issues in Astronomy Press Releases

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Key Words

Credibility
Hype
Science Communication
Astronomy
Visibility
Press Releases

Summary

Current developments in the media marketplace and an increased need for visibility to secure funding are leading inevitably to faster, simpler and more aggressive science communication. This article presents the results of an exploratory study of potential credibility problems in astronomy press releases, their causes, consequences and possible remedies. The study consisted of eleven open-ended interviews with journalists, scientists and public information officers. Results suggest that credibility issues are central to communication, deeply integrated into the workflow and can have severe consequences for the actors (especially the scientist), but are an unavoidable part of the communication process.

Introduction

Science communication operates in the modern media marketplace and competes for headlines with politics, business, sports, crime and large commercial communicators such as the entertainment industry. Science communication is partly a political tool and the pressure on the communicator to deliver is greater than ever. Due to the very nature of public communication, the temptation to overstate the importance of scientific results or to take credit for more than is deserved is great. Two of the more well known examples of credibility problems within astronomy and physics are the "NASA Mars meteorite" case (Kiernan 2000) and the "Cold fusion" case (Gregory and Miller 1998, p. 61).

The extent of the damage done to the public perception of science and scientists by examples like these is very difficult to measure. A recent public opinion survey (European Commission, 2005) has shown that Europeans generally see scientists as being credible and having a positive impact on society. Journalists scored poorly in the survey, but still much better than politicians who were almost at the bottom of the scale.

Many scientists have the impression that science reporting is inaccurate and that science news is often overstated (Shortland and Gregory 1991, p. 8; Dunwoody 1986, p. 11). This perception has, in the case of astronomy, been shown to be false by Shaefer et al. (1999), who found that none of 403 evaluated newspaper articles on astronomy significantly mislead the reader. Furthermore, most errors in the evaluated articles could be attributed to the fact that they were reporting on front-line science, where no reliable conclusion has yet been reached. Scientists and journalists can also have quite different perceptions of the term accuracy, and thus "accuracy" for journalists is usually missing the required level of detail for scientists (Peters 1995).

Credibility in science communication is one of the most actively discussed issues in science communication today: *'How far can we, in the name of science communication, keep pushing, or promoting, our respective results or projects without damaging our individual, and thus also our collective credibility?'* (Robson 2005, p. 162). As science communicator Robert Hurt states (interview 4): *'In public affairs you are pulled between two poles: sensationalizing the results and correctness.'* However, serious studies about this important, but rather elusive, topic are difficult to find in the literature.

How widespread are credibility problems in astronomy press releases? What factors cause these credibility problems? What are their consequences and how can they be reduced? It is the purpose of this exploratory study is to answer these questions.

The topic of astronomy was chosen partly for its inherent fascination for the public and partly as it is a fundamental science — one where credibility issues do not involve risks to human lives or substantial commercial interest as compared with fields such as health care (Madsen 2003).

This paper only examines the credibility of the communication of scientific results, and not the credibility of the actual scientific results themselves. We thus assume that the peer-review process produces credible scientific results, though some scholars question this claim (Russell 1986, p. 93; Nelkin 1995, p. 150; Gregory and Miller 1998, p. 168). The communicated scientific results, by their very nature as cutting-edge information, may of course later be proved wrong, but this is how the scientific process works. The question whether the communicated results are "true" to the actual scientific results is here treated independently of the intrinsic quality and scientific importance of the results themselves.

Study Design

This exploratory study was inspired by the panel discussion, 'Keeping our Credibility: Release of News', held at the Communicating Astronomy with the Public 2005 conference at the European Southern Observatory in Munich in June 2005.[1]

We chose to examine the problem of credibility in astronomical press releases from the perspective of the actors in the science communication process: scientists, journalists and public information officers at large governmental and intergovernmental scientific organizations. According to Madsen (2003) and sources quoted therein, nearly 50% of all reported science news in the media result directly from press releases, making this particular way of communicating science news very important.

A qualitative rather than a quantitative approach was chosen because we, as in parallel studies (Treise and Weigold 2002), wanted to identify and understand the issues as experienced by the actors themselves. The qualitative approach allowed us to adapt to many kinds of responses and to explore uncovered issues in greater detail. Furthermore, we assumed that by conducting face-to-face interviews we could ask more penetrating questions on sensitive issues and so explore the more important issues in greater detail.

Care should be taken if the astronomy-related results presented here are used to draw broader conclusions about science communication in general. However, this paper may serve as a basis for designing quantitative studies of the credibility of general science communication.

Research Questions

Based on our preliminary studies, we posed the following five research questions:

1. How do the communication actors define credibility and credibility problems in science communication?
2. In which situations do the communication actors experience credibility problems?
3. How do the communication actors experience the consequences of credibility problems?
4. When should the dissemination of scientific results to the public take place?
5. Would it be useful to formulate a 'code of conduct' for press releases in astronomy and if yes, how might it look?

These five research questions formed the basis for the topics to be covered during the interviews.

Method

Eleven open-ended, in-depth interviews with a semi-structured interview guide approach (Kvale 1996, p. 129) were conducted with science communication actors[2]. The topics of the interviews were specified in advance, but the sequence of the questions and responses from the interviewees were not restricted to choices provided by the interviewers.

The authors conducted eleven face-to-face interviews in person (one interview was conducted with two persons who are close collaborators[3]) in Munich, Baltimore, New York and Boston and one interview was conducted by telephone. Each interview lasted approximately one hour and was recorded digitally with the verbal permission of the interviewee.

Interviewees were chosen to match one of the following profiles:

- Scientists closely relating to the work of public information officers, either as scientific support in the development of press releases (outreach scientists) or as evaluators of the public information officers' work.
- Science journalists specializing in astronomy.
- Public information officers from large governmental scientific institutions.
- Scientists who are otherwise deeply involved with science communication.

The public information officers and scientists were selected from two of the largest governmental and intergovernmental astronomy research organizations in Europe and the United States of America, namely the European Southern Observatory (ESO) and the National Aeronautics and Space Administration (NASA).

We followed seven steps in the analysis of the interviews:

1. Reduction of raw information (selective transcription): After all the interviews were completed they were each transcribed selectively, i.e. not verbatim, by one of the authors. Statements that were not deemed relevant to the posed research questions were omitted.
2. Re-reduction of raw information (selective retranscription): Each interview was then transcribed again using the same method, but by another of the authors to reduce the risk of missing important information.
3. Identification of interesting themes: Themes in each interview were then identified, meaning that the transcript was examined for descriptions, ideas, patterns, observations or interpretation of phenomena that could shed light on our research questions.
4. Comparison of identified themes: Recurring themes among the different actors were found.
5. Condensation of interviews to statements: Each interview was then further reduced with the aid of the identified themes to a list of statements.
6. Validation of statements: To ensure that the statements did not misrepresent the interviewee the statements were validated against the recorded interviews.
7. Approval of statements: Each list of statements was sent to the interviewee for approval to validate the reduction process described above and to give them a chance to comment.

Results

Finding 1: Credibility is primarily defined as being honest and doing your homework.
Eleven out of twelve of the interviewees largely defined credibility in science communication as being honest and doing your homework well. Interestingly, Heck (interview 3) defined credibility as, *'credibility occurs if the message that you conveyed have been received credible by the receiver'*, which implies that the communicator is responsible for tailoring the message in such a way that it is well received.

Hype and exaggeration was generally defined by all interviewees as taking credit for more than you deserve by overstating importance of science results e.g. by increasing visibility overly.

Finding 2: Credibility issues are ubiquitous and integrated into the public information officer (PIO)-Journalist interaction.
There is a general view that a certain amount of exaggeration of scientific findings in press releases is necessary to reach the general public (science journalist Schilling, interview 9; science communicator Villard, interview 11; scientist/communicator Tyson, interview 10). The media are used to and even expect a certain amount of overstatement, as stated by Schilling (interview 9), *'There is hype everywhere and everybody is doing it ... every serious science journalist knows that press releases are made by public information officers who emphasize their own organization.'* Science journalist Lorenzen (interview 7) goes as far as to say, *'It is the responsibility of the journalist to check the press releases.'*

Even though overstatements in press releases are normally perceived as harmful by the scientific community, the view, especially among science communicators and journalists, is that some overstatement is unavoidable when communicating a technical scientific result to the public. All interviewees agree that high accuracy is vital when communicating to the general public, but *'[...] the level of accuracy is irrelevant if no one pays attention. To make something interesting and glamorous is not* *hype — hype is when you take credit for more than you deserve,'* (Villard, interview 11).

Public information officers are juggling daily to find a sensitive balance between correctness and overstatement, and they constantly need to walk a tightrope to get news out to the media. If press releases are accurate but uninteresting, they will not receive media attention, but if PIOs sacrifice accuracy while injecting colour the press releases lose credibility with journalists and are not used. As science communicator Watzke (interview 1) says, *'[PIOs] end up walking a line, because you want to be as interesting and provocative as possible without being wrong.'*

Although scientific organizations jostle to be heard by the same media and are sometimes in competition for the same funding, all the interviewees agree that if competition between organizations becomes unethical it may damage the credibility of the whole community (science communicator Edmonds, interview 1; scientist Leibundgut, interview 5). Hurt (interview 4) states this clearly: *'Any chink in the armour of credibility can make the entire scientific community vulnerable to attack.'*

It is evident that there is a great interest in, and concern for, credibility among the communication actors in general. As stated by Villard (interview 11), *'once lost [credibility] is very hard to achieve again.'* It is a topic that is known to be very sensitive and of high priority to all involved communication actors. Great effort is put into producing science communication that is as accurate and as credible as possible (Watzke, interview 1; scientist Livio, interview 6; science communicator Madsen, interview 8; Hurt, interview 4).

Finding 3: Credibility problems are most often caused by an intense need for visibility driven by personal or organizational desires for recognition or financial gain.
As stated by scientist/communicator Heck (interview 3): *'Behind hype is the problem of visibility and recognition — the fight of organizations, laboratories or people for money.'* This development inevitably leads to science communication with more spin, more push and a shorter elapsed time from scientific results to publicly communicated results.

The pressure is applied from different sides: from the organization itself — often from management, from PIOs and also from scientists. While many scientists try to be modest when they publish their results, the increased competition in the scientific community may push them to overstate their results to become more visible, thereby attracting more funding and gaining recognition (Leibundgut, interview 5). As stated by Madsen (interview 8), *'in the "conventional wisdom" scenario, the scientist is the guardian of "truth" and objectivity, urging caution and moderation. […] But this is a simplistic scenario. I have seen several cases where the scientist fell into the trap of serious "overselling" or hype and the press officer had to exercise the necessary restraint.'*

Finding 4: At least five separate factors may contribute towards credibility problems in press releases.
When trying to "dissect" the cause of credibility problems, we found that it is possible to list (at least) five different distinct, but related, causes with underlying motivations that generally fall into one of two categories: factors that contribute to making the organization look better than it deserves and factors that make other organizations look worse than they merit. The causes are:

1. Using too high a level of communication effort for the level of scientific importance.
2. Using wording that does not correspond to the level of scientific importance.
3. Letting unscientific factors dictate the timing of the publication of a press release.
4. Omission of references to other scientists' work.
5. Unjust comparisons with other facilities.

1. The level of communication effort

Naturally, all scientific findings are not of equal scientific significance. The PIO has to choose from different levels of communication effort to emphasise the finding and convince the media to run the story given. This decision will be based on a subjective assessment of the scientific importance as determined by the PIO, the scientists and possible internal organizational boards. The chosen communication effort may have a great influence on the resulting visibility of the story in the media.

We have chosen to define the level of effort with which a science press release is communicated and distributed by a "press release visibility scale" (see Figure 1).

When releasing a given result, a PIO will choose a level of effort according to the importance of the given result. The scale, as defined here, consists of seven steps, with magnitude 7 being the highest level of effort an organization can put into communicating a result. If too high a level is chosen relative to the story's scientific importance, credibility problems may occur (Nelkin 1995, p. 161). The higher the level of effort the more solid the science case and the evidence have to be. Equally, the higher the level of effort the greater the need for a corrigendum if the science is later proven wrong — and the actual correction should have a commensurate visibility (Heck, interview 3).

- Magnitude 7 — Live televised press conference with the presence of a high-ranking political figure: Only major scientific discoveries are endorsed by politicians, whose presence will pull the media in even more strongly. Normally this news will be based on an accepted peer-reviewed paper to be published in a prominent science journal like Science or Nature.

The Press Release Visibility Scale	
Magnitude 7:	Live televised press conference with presence of a high ranking political figure
Magnitude 6:	Live televised press conference
Magnitude 5:	Press conference
Magnitude 4:	Media teleconference
Magnitude 3:	Press release
Magnitude 2:	Photo release
Magnitude 1:	Web-only posting

Figure 1. Press release visibility scale.

- Magnitude 6 — Live televised press conference: If a result is released via a live televised press conference this effort tells journalists that the scientific institution believes the scientific finding is of major importance.
- Magnitude 5 — Press conference: Press conferences that are not televised live are likely to receive less attention than their live televised counterpart, mainly because they require journalists to gather in person in one place.
- Magnitude 4 — Media teleconference: The media teleconference allows journalists to be in close contact with the scientist without having to travel. A scientist will give a presentation and journalists may ask questions afterwards.
- Magnitude 3 — Press release: Press releases are the most frequently used way of communicating science news that presents a scientific discovery of significant importance to the general public. Press releases are sent out via distribution lists that cover hundreds of journalists and news media. If a wire service picks up a press release many local newspapers will pick up the story.
- Magnitude 2 — Photo release: Photo releases do not usually represent major scientific discoveries, but contain aesthetic images. Even though the scientific content is relatively low, a photo release may still achieve considerable media attention, and may for instance appear on the front page of the New York Times which happened for an image of Mars[4] taken by the Hubble Space Telescope (Villard, interview 11). There is rarely a scientific paper to back up a photo release.
- Magnitude 1 — Web-only posting: Web stories, posted only on the scientific institution's website, contain news or information from the scientific institution that may only be of interest to a smaller audience. The end user needs to be active to "pull" the material from the scientific institution's website.

It is important to note that the press release visibility scale describes the effort level chosen by PIOs to emphasize a scientific result, and not the level of attention the press release will actually receive in the media, as this is partly determined by a number of additional external factors.

2. The wording of a press release

It is necessary for the public information officer to make science results understandable for the general public by simplifications and analogies (Heck, interview 3; Villard, interview 11; Livio, interview 6; Tyson, interview 10; Hurt, interview 4); Madsen, interview 8; Watzke, interview 1; Edmonds, interview 1). However, the wording can be used to overstate claims and thus increase the visibility of a scientific finding. It can be tempting to omit a question mark in a headline and also to omit the caveats and qualifiers that are really necessary. As Livio (interview 6) says, *'when using words like "may", "could", "possible", etc., the news media does not find these stories exciting enough, and therefore do not print them […].'*

Another aspect of the critical use of wording is seen as "superlative saturation". This is recognized as part of the established process (Tyson, interview 10) and occurs when PIOs focus on the parts of science that contain results that justify superlatives like "biggest", "fastest", "first", etc. The superlatives are often factually correct and are added to catch the attention of journalists working under heavy time pressure and deadlines. It is always possible to find at least one superlative for even the smallest science results. The resulting "superlative saturation" can make it difficult for journalists to separate "big story" press releases from smaller ones.

3. Dictating the timing of a press release

The timing of a press release is a factor that can affect the visibility of a given science story greatly. The timescales of the scientific process and the communication process are vastly different. Science can take years to materialize and the communication of the result can be over in days. As stated by Lorenzen (interview 7), *'Peer-reviewing is a slow process — I think you have to communicate fast.'* Conflict over timescales is one of the inherent potential flashpoints in the scientist-journalist interaction (see Valenti 1999).

The timing of a press release can be the cause of credibility problems in at least three areas:

1. The timing may be used as a political tool: A press release can, for instance, be timed to coincide with a vote on funding for a scientific organisation. As a scientist, Fosbury points out (interview 2): *'When a professional in, I guess, any science sees a press release they think the organization must have a grant application review coming up and therefore they are trying to create some kind of event around this.'* This can raise concern about abusing science results for political motives among the journalists. Heck (interview 3) gives an example: *'Some years ago an announcement that life had been found on Mars made all the headlines and even triggered some words from the then US President (Clinton). Interestingly, this took place shortly before a NASA budget was to be approved by the US House of Representatives or by the Senate. Of course, no life has ever been found on Mars, but the subsequent rectification passed almost unnoticed in the news.'*
2. A press release can be forced out before a peer-reviewed paper exists. This bypasses the scientific process and opens up a whole range of potential credibility problems (Tyson, interview 10).
3. A press release can be timed so as to interfere with a press release or an event from a competing scientific organization. Not only is this unethical and counterproductive for science in general, but, as in case 1 above, it raises concern about the real motives behind the press release.

4. Omission of references to other scientists' work

Giving proper credit to earlier work in the same field is another stress point in the battle between the communicator's need for conciseness and the scientist's need for completeness (Edmonds, interview 1). There is no doubt that this decision is very subjective. Credibility problems may arise if credit is taken for work that has been done by others or a conscious decision is taken to omit references to earlier work where it is obvious that it ought to be acknowledged.

5. Unjust comparisons with other facilities

Comparisons of scientific and technical abilities are a standard part of public communication. It is most probably unavoidable and, to some extent, a healthy part of justifying the funding spent on scientific projects. A newly funded project is supposed to be an improvement, incremental or better, on existing projects. Credibility issues can occur if this is done in an unjust way or so as to diminish other projects (Hurt, interview 4; Villard, interview 11).

Finding 5: Loss of credibility mostly affects the scientist

We find that individual scientists stand to lose more credibility than an entire institution, a reporter or a PIO (Schilling, interview 9). So it is natural to find that scientists are more concerned about this topic than other actors. Scientists know that negative reactions from their peers can have devastating consequences for their career, as it might for instance get harder to publish articles, find collaborators or get better positions (Livio, interview 6; Tyson, interview 10).

Finding 6: Refereeing either by the main scientist, an internal refereeing board or an external refereeing board can reduce the risk of credibility problems.

Interviewees mentioned that the reluctance of scientists to communicate arose from a fear of losing credibility with their peers (Fosbury, interview 2). One way to improve the scientists' view of communication via press releases is to encourage them to collaborate as much as possible and to understand the different priorities operating when communicating with the public. It is also necessary that the main scientist involved approves a press release (Watzke, interview 1).

If a press release is run past an internal refereeing board before its public release, some factors that are known to increase inaccuracy can be eliminated. This means that there is less risk of oversimplified results, incorrect analogies, problems of a political nature and other factors that can harm credibility. Internal refereeing also helps scientists maintain credibility with their peers, which, as mentioned above, is important for the scientist's willingness to communicate Edmonds, interview 1; Hurt, interview 4; Madsen, interview 8; Watzke, interview 1).

Finding 7: The lack of a peer-reviewed scientific paper makes a press release more vulnerable to loss of credibility.

To all interviewees it is important that the result has been peer-reviewed prior to public dissemination, as this is vital to increase the scientific accuracy of the communication. In its most extreme form this principle is implemented by some journals, like *Science* and *Nature*, in the form of the Ingelfinger rule (Toy 2002). The rule says that scientific results must not be published elsewhere (including public dissemination and electronic preprints) before the paper has been published by the journal it was submitted to. The rule was invented partly to protect the (legitimate) commercial interests of the publishers of scientific journals and partly to control the timing of the release of a given scientific result into the public domain as a response to the increasing external pressure. The original intentions of the Ingelfinger rule make some sense, as it seems fair for a publication to protect the newsworthiness of its stories and to put a brake on the accelerating pace of the public dissemination of science results. However, the embargo system also has negative effects (Kiernan 2000; Marshall 1998) that lie beyond the scope of this paper.

The need for a refereed scientific paper backing a press release increases as the claims become more significant. If no paper is available to support significant scientific claims, it makes a press release more vulnerable to loss of credibility, as the claims may more easily be undermined as the normal scientific process has been bypassed. It is risky to use high levels of communication efforts without a peer-reviewed scientific paper in the background (Tyson, interview 10; Fosbury, interview 2).

Conclusions

Credibility issues are found everywhere in scientist-PIO-journalist interactions and are deeply integrated into their workflow. Overstatements are, to some degree, accepted and recognized as a necessity for the communication process.

All actors also recognize the sensitivity of the issue and know that the issue can have severe consequences to the actors. The real reason behind credibility problems is an intense need for visibility that is driven primarily by the desire for recognition or funding.

Credibility problems in press releases can be caused by using too high a level of communication effort, by overstating scientific claims, omitting qualifiers and saturating the text with too many superlatives, by dictating the timing of a release for political motives, by announcing the finding to the public before the peer-reviewing process has had a chance to work or to time the issuing of a release in order to interfere with other press releases, by omitting references to other important work in the same field, or by making unjust comparisons with other projects.

Credibility problems often have the greatest negative implications for the scientists. However, internal refereeing and the peer-reviewing system can reduce the risk of credibility problems for all actors.

To make these findings applicable to practical science communication it is necessary to synthesize them into guidelines that may aid the work. Nine specific recommendations are listed below. These can be seen as a suggestion for a "code of conduct for astronomical press releases" that astronomical organizations could adapt as guidelines, or as an ethical charter, to help to minimize credibility problems and to evaluate cases of questionably aggressive science communication.

Some of these recommendations are aimed directly at ensuring scientific accuracy in press releases announced to the public; others are included to ensure credibility within the scientific community, and among public information officers and scientists. As is natural in such a diverse field as press releases in astronomy, there is much room for interpretation in each recommendation and valid exceptions to these guidelines can naturally also exist.

In conclusion, we recommend that:

1. Scientific results should be peer-reviewed prior to public dissemination.
2. Press releases should be validated by the main scientist.
3. Press releases should be validated by an internal institutional refereeing body.
4. Substantial work by others in the same field should be acknowledged.
5. The incremental nature of the scientific process should be mentioned if at all possible.
6. If the science or the press release turns out to be incorrect a correction of the web version of the release should be posted or if the release contains significant mistakes a correction release should be issued.
7. The level of communication effort should fit the level of importance of the science as determined by the involved scientists, PIO and the internal refereeing board of the organization.
8. The wording in the release text should match the level of importance of the science and include the relevant qualifiers.
9. A press release should not be intentionally timed to counteract press releases from competing organizations.

Appendix

The following individuals were interviewed for this project:

- Dr Peter Edmonds (PIO), outreach scientist at Chandra X-Ray Observatory (NASA), interviewed in person in Boston, on 3 November 2005 (interview 1).
- Dr Robert Fosbury (scientist), head of Space Telescope European Coordinating Facility (ESO/ESA), interviewed in person in Munich, on 7 November 2005 (interview 2).
- Prof. André Heck (scientist/communicator), first-class astronomer at Strasbourg Astronomical Observatory, interviewed in person in Boston, on 3 November 2005 (interview 3).
- Dr Robert Hurt (PIO), imaging specialist at Spitzer Space Telescope (NASA), interviewed in person in Boston, on 4 November 2005 (interview 4).
- Dr Bruno Leibundgut (scientist), head of Office for Science at European Southern Observatory, interviewed in person in Munich, on 25 October 2005 (interview 5).
- Dr Mario Livio (scientist), outreach scientist at Space Telescope Science Institute (NASA), interviewed in person in Baltimore, on 31 October 2005 (interview 6).
- Mr Dirk H. Lorenzen (science journalist), senior science reporter for German Public Radio and major newspapers, interviewed in person in Munich, on 7 November 2005 (interview 7).
- Mr Claus Madsen (PIO), head of ESO Public Affairs Department, interviewed in person in Munich, on 28 October 2005 (interview 8).
- Mr Govert Schilling (science journalist), science correspondent, interviewed by telephone from Copenhagen, on 16 November 2005 (interview 9).
- Dr Neil deGrasse Tyson (scientist/communicator), director of Hayden Planetarium, interviewed in person in New York, on 31 October 2005 (interview 10).
- Mr Ray Villard (PIO), public information manager for Space Telescope Science Institute (NASA), interviewed in person in Baltimore, on 31 October 2005 (interview 11).
- Ms Megan Watzke (PIO), press officer for the Chandra X-Ray Observatory (NASA), interviewed in person in Boston, on 3 November 2005 (interview 1).

Notes

1. A webcast of the panel discussion and the subsequent wide-ranging and lively debate is available at http://www.communicatingastronomy.org/cap2005/programme.html.
2. We would like to thank the interviewees, especially Claus Madsen, for sharing their insight.
3. Edmonds and Watzke (interview 1).
4. http://www.spacetelescope.org/images/html/opo0124a.html

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Communicating Astronomy with the Public 2007

Communicating Astronomy to a Global Audience

http://www.communicatingastronomy.org/cap2007/

Eugenides Foundation / Planetarium

Athens, Greece 8-11 October 2007

Scientific Organizing Committee

Lars Lindberg Christensen (ESA/ESO) (co-Chair)
Dennis Crabtree (Gemini Observatory) (co-Chair)
Ian Robson (UK ATC/ROE) (co-Chair)
Christos Goudis (Nat. Observatory of Athens)
Robert Hurt (SSC)
Tim Slater (AAS)
Jin Zhu (Beijing Planetarium)
Patricia Whitelock (South African Astronomical Observatory)

Local Organizing Committee

Christos Goudis (National Observatory of Athens)
Nikos Matsopoulos (National Observatory of Athens)
Raquel Yumi Shida (ESA/ESO)
Dennis Simopoulos (Eugenides Foundation/Planetarium)
Kanaris Tsinganos (Hellenic Astronomical Society)
Manolis Zoulias (National Observatory of Athens)

Specific goals

- To prepare for the International Year of Astronomy 2009
- To make public astronomical knowledge global and accessible to everyone, adapting communication methods to cross national, political, social and cultural borders and impairment limitations
- To promote international collaboration
- To evaluate current tools and methods and prepare for future developments

Key topics

- Case Studies and hands-on demonstrations
- Communication in the YouTube/MySpace/vodcasting mediascape
- Audiovisual, multimedia & online tools
- Social impact and evaluation of astronomy communication
- Education and communication tools for the visually impaired
- Prospects of IAU Commission 55: Communicating Astronomy with the Public

International Astronomical Union
Commission 55

National Observatory
of Athens

Eugenides Foundation
Planetarium

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The Top Ten Astronomical "Breakthroughs" of the 20th Century

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Key Words

Breakthroughs
Research
20th Century astronomy
Advancement

Summary

Astronomy was revolutionized in the 20th century. The electron was discovered in 1897 and this transformed spectroscopy and introduced plasma and magnetohydrodynamic physics and astro-chemistry. Einstein's $E = mc^2$, solved the problem of stellar energy generation and spawned the study of elemental nuclear synthesis. Large telescopes led to a boom in astronomical spectroscopic and photometric data collection, leading to such cornerstones as the Hertzprung-Russell diagram and the mass-luminosity relationship, and to the realization that the Universe contained a multitude of galaxies and was expanding. Radio astronomy was introduced and the advent of the space age saw the astronomical wavelength range expand into the ultraviolet, X-ray and gamma-ray regions, as well as the infrared and millimetre. We also started wandering around roaming the Solar System instead of merely glimpsing its members from the bottom of our warm, turbulent atmosphere. Astronomical "breakthroughs" abounded. We have asked astronomers to select their "top ten" and these are listed and discussed in this paper.

Introduction

The progress of astronomy leapt forward when astrophysics was added to its sub-disciplines. The science of astrophysics essentially started in the early 19th century and has advanced at a great pace, especially so in the last century. In fact we might suggest that the 20th century was an epoch of enlightenment, in which our understanding of the Universe was revolutionized. As with many of today's sciences, we might wonder whether this rate of progress will continue.

Science advances in two ways. On the one hand we have the gradual accumulation of knowledge and data. There are many examples of this in astronomy. Just think of the slow and painstaking accumulation of accurate stellar distances, masses, luminosities, temperatures and spectra. On the other hand, we have "breakthroughs". These are major paradigm shifts, the realization that we have actually been 'barking up the wrong tree.' Here, our concept of the astronomical Universe changes dramatically over a relatively short period of time. The Earth's cosmic position is a good example. In the 15th century the vast majority of thinkers placed the Earth at the centre of the Universe. By the 17th century our understanding of the cosmos had changed dramatically and Earth was demoted to being a mere planet. The Sun then became the centre of the Universe, but even this view did not last long.

In this paper we aimed to recognize the major astronomical breakthroughs that occurred in the 20th century. These stand out as landmarks in the progress of astronomical history. Our subtext is the implicit suggestion that the breakthroughs of the twentieth century might have been better and more numerous than the breakthroughs of previous centuries. We are also asking the reader to consider whether it is it possible that a similar number of major changes and impressive breakthroughs might also occur in the next century. Perhaps the rate of astronomical advance is slowing down.

Let us start by being pedantic, and define the word "breakthrough". In the context of astronomy this can be thought of in terms of **parameters, processes,** or **objects**. To illustrate this we will provide examples in each category.

(i) Parameters. A typical astronomical parameter would be "the distance between the Earth and nearby stars". Here, we stray away from the 20th century. In the early part of the 19th century we knew the Earth-Sun distance, some 150 x 10^6 km (1 au), but that was the extent of our precise knowledge of the cosmic distance scale at the time. To quote John Michell (1767)

"[T]he want of a sensible parallax in the fixed stars, is owing to their immense distance."

An understanding of the relationship between stellar brightness and apparent magnitude, coupled with an understanding that the flux from a specific star decreased as a function of the inverse square of the distance from that star, would provide a clue as to typical interstellar spacings. The fact that the Sun is about 10^{11} times brighter than the next ten brightest stars in the sky, coupled with a guess that all stars might have luminosities similar to the Sun's (a rather optimistic assumption, given that the median absolute magnitude of the fifty closest stars to the Sun is 11.85, indicating a median luminosity of $L_\odot/640$), leads us to the suggestion that typical interstellar distances in the galactic disc are around $\sqrt{10^{11}} = 300{,}000$ au = 1.5 pc. This means that when we are trying to measure the "sensible" stellar parallax of the nearest stars we are attempting to measure angles that are at best about 1/1.5 arcsecond in size. These parallax angles had been hunted for since the days of Nicolaus Copernicus and his promotion of the heliocentric Solar System in 1543. Only by the 1830s had telescopes improved sufficiently for the first stellar distance to be measured. The star was 61 Cygni, and the measurement was made in 1838 by Friedrich Wilhelm Bessel. (The distance of this star is now given as 3.496 ± 0.007 pc.) This was the astronomical breakthrough, as it confirmed astronomers' suspicions as to the enormity of the Milky Way. As the 19th century progressed, more and more stellar distances were measured, this leading to the assessment of stellar luminosities and stellar masses, and eventually the foundation of astrophysics.

Distance is only one of a host of physical and chemical astronomical characteristics. Think briefly of the parameter "velocity". Albert Einstein regarded the Universe as static. Then along came Edwin Hubble and his discovery that clusters of galaxies have non-random velocities, and that the Universe is expanding. This was a breakthrough; the concept of the Universe was revolutionized.

Consider the age of astronomical objects. Many thought of the Earth as being created in a Biblical fashion some 6000 years ago. Then, we subsequently discover that the Earth is actually around 4,570,000,000 yr old (see for example Faul, 1966; Brush, 1996.) This was clearly a major paradigm shift and thus another breakthrough.

In the early 19th century we had no idea as to the composition of the Sun. Even in the 1920s Sir Arthur Eddington thought that the solar composition was similar to that of the Earth. Along came Cecelia Payne (later Payne-Gaposchkin), who discovered that the solar mass is about 74% hydrogen, 24% helium and 2% metals; another breakthrough. Here, we are reminded of a further episode in the history of our subject, when, like Aristotle, we regarded the heavens as "perfect" and made of some "quintessence" completely unlike the mundane terrestrial earth, fire, air and water. The breakthrough was due to the development of spectroscopy and the discovery that the heavenly bodies consisted of exactly the same elements as the Earth beneath our feet.

(ii) Processes. An example of the "process" breakthrough would be the mechanism of stellar energy generation. As soon as astronomers had been convinced that the constant-luminosity Sun was more than 6000 years old, they started worrying about its energy source. Was it burning? Was it shrinking? Was it gaining mass (and kinetic energy) by cometary and meteoritic accretion? Was it radioactive and thus decaying? All these mechanisms proved to be inadequate. Then in 1905 Einstein introduced $E = mc^2$. Mass, m, could be converted into energy, E, the discovery of this process being a breakthrough. All that then remained was to decide what specific mass was being used. It was soon realized that atoms and electrons were not being annihilated but merely converted from one form into another. Hydrogen was transformed into helium, helium into carbon, carbon into oxygen, and so on. These ideas eventual led to our detailed understanding of the proton-proton and CNO cycles. Stellar energy generation was also transformed from being a mere fuelling process. Not only were we producing energy, we were also manufacturing new, and heavier, elements. The overabundance of stellar helium was explained by processes that occurred in the Big Bang. The metallicity of the Universe was explained by Burbage, Burbage, Fowler and Hoyle (1957), evoking nuclear synthesis in stellar interiors and during supernova explosions. Here we have another breakthrough; the chemistry of the Universe was no longer a complete mystery.

(iii) Object breakthroughs can be divided into "new" and "similar" objects. So you might flag a breakthrough if you discover something completely new, something that you had no idea existed. Examples might be Uranus, white dwarf stars, Cepheid variables, quasars and gamma-ray bursters. Then you have the objects that are predicted theoretically but take a considerable effort to find. Neptune, Pluto, asteroids, pulsars, black holes, the cosmic microwave background and the 21 cm radiation, spring to mind.

In the context of "similar" objects one can think of galaxies. Astronomers spent the first few thousand years of their scientific endeavour being convinced that there was but one galaxy, the one that contained our Sun and Solar System. Then, in 1928, there was a breakthrough. The Universe did not just contain a single galaxy; there were actually huge numbers of them. (1999 Hubble Space Telescope observations led to an estimate of about 125 billion, and more recent modelling programs indicate that the number might be as high as 500 billion.) A second surprise was the realization that our Galaxy was not very special but was rather similar to many other large (non-dwarf) galaxies.

Turn to the Solar System. As soon as the Earth had been demoted from its geocentric cosmic elevation, the normality of the Sun and the profusion of planets led astronomers to suggest that planetary systems were commonplace. The breakthrough came when, in the mid-1990s, other planetary systems were detected, by radial velocity measurements and transit observations. A subsequent surprise was the realization that our Solar System was rather unusual and might be way off the Gaussian mean when it came to the distribution of planetary system characteristics. Many of the newly discovered planetary systems had large Jupiter-like planets very close to the central star (see, for example, Croswell, 1997; Goldsmith, 1997).

Perhaps the term "object" can be stretched slightly. In Newtonian times astronomers were convinced that space was Euclidean, and that light always travelled in straight lines from emitter to observer. We now realize that this is far from the case, and the discovery of gravitational lenses has led to an interesting breakthrough, in essence showing that massive bodies affect the geometry of the surrounding space, this leading to the bending of the rays of light that pass close by. Also in the 19th century, with the exception of the "aether", astronomers were convinced that space was empty. The 20th century discovery that space contained considerable amounts of dust and gas, and the discovery of the influence of missing mass ("dark matter") was a considerable breakthrough.

Notice that we do not count techniques and instruments as breakthroughs, even though new types of instruments and bigger and more sensitive examples of old ones might lead to breakthroughs. The invention of the telescope, the spectroscope, the photographic process and the silvering of glass mirrors are not breakthroughs, and neither is the construction of, say, the 100 inch (2.54 m) Hooker Telescope, or the Lovell radio dish at Jodrell Bank, or the microwave horn antenna at Bell Telephone Company, Holmdel, New Jersey, USA, or the Hubble Space Telescope, or the Saturn rocket that took men to the Moon. The use of these certainly resulted in a number of breakthroughs, such as the discovery of planetary rings, asteroids, external galaxies, stellar composition, interstellar hydrogen and dust, the exansion of the Universe and the cosmic microwave background, but they are not breakthroughs in themselves.

The Time Period

In this paper we restrict ourselves to the 20th century. Let us review a few of the changes that occurred in this 100 year time interval.

In 1900, astronomical calculations were carried out using logarithm tables and slide rules, but by 2000 we had the laptops and supercomputers. In 1900, it took three weeks to calculate a cometary orbit from a limited data set. By the year 2000 the job could be done in less than three minutes. In 1900, we had no idea what was inside the atom. The electron and neutron had not been discovered, quantum mechanics had not laid the foundation for the study of spectroscopy and electromagnetic radiation, there was no special or general relativity, no $E = mc^2$, and no understanding of nuclear fusion or fission.

In 1900, we were still wedded to the refracting telescope, and Lord Rosse's reflecting Leviathan, in the middle of Ireland was regarded as somewhat of an oddity. The great Yerkes refractor, near Chicago, with its 40 inch (1.01 m) lens, was a 'thrusting research tool' when it was commissioned in 1897. The largest reflecting telescope effectively working on astronomical research in 1900 was Ainsley Common's 36 inch (0.91 m) Crossley reflector, this being the telescope that the Lick Observatory had bought in 1885. In the first decade of the 20th century the Americans were hard at work trying to fund and built the 60 inch (1.5 m), Ritchey and the 100 inch (2.5 m) Hooker telescopes at Mount Wilson, California. The former started to be used in 1908 and first light hit the Hooker in November 1917 (Edwin Hubble joined the Mount Wilson staff in 1919). By the year 2000 we had a 2.5 m telescope orbiting our planet, 600 km up, and giant 8 and 10 m telescopes in both hemispheres. Instrumentation had been further augmented by the replacement of the

20th Century Top Ten Breakthroughs

Listed using the Eurovision Song Contest approach to positioning

1. Expanding Universe
2. The multitude of galaxies
3. Cosmic microwave background
4. Exotics (quasars/AGN)
5. Stellar energy sources and evolution
6. Hertzprung-Russell diagram and stellar diversity
7. Exoplanets
8. Stellar chemical composition
9. Dark matter
10. Galaxy mapping and structure

20th Century Top Ten Breakthroughs

Listed using the "horse racing form" approach to positioning

1. The multitude of galaxies
2. Expanding Universe
3. Stellar energy sources and evolution
4. Hertzprung-Russell diagram and stellar diversity
5. Stellar chemical composition
6. Exotics (quasars/AGN)
7. Cosmic microwave background
8. Dark matter
9. Exoplanets
10. Solar probing using neutrinos/helioseismology

photographic plate by the much more efficient charge-coupled device, and by the introduction of adaptive optics.

In 1900, with the exception of a small incursion into the infrared using blackened thermometers and bolometers, all astronomy was restricted to the limited visual wavelength range. By 2000, the surface of the Earth was dotted with radio telescopes and a legion of gamma-ray, X-ray, UV and IR telescopes had been placed above the atmosphere in low Earth orbit.

In 1900, if we wanted to travel, we caught a railway train or a ship. By 2000, everyone was flying and twelve men had walked on the Moon (albeit in the 1969-72 time period). The space age had also seen craft flying by all the planets except for Pluto (although NASA's New Horizon mission is expected to fly by Pluto and its satellite Charon in July 2015), going into orbit around Venus, Mars Jupiter and Saturn, and actually landing and roving about on Mars.

In 1900, the world boasted around 2000 active astronomers, working in around 100 observatories. This dropped to about 1000 after the ravages of the First World War. By the year 2000, the world groaned under the efforts of around 20,000 astronomers, each publishing, on average, 2 research papers a year. Today, the world has 32 telescopes with mirror diameters, D, in the range 2.0 m $<$ D $<$ 3.0 m, fourteen in the range 3.0 m $<$ D $<$ 4.0 m, eight in the range 4.0 m $<$ D $<$ 8.0 m and eleven with D $>$ 8.0 m.

The Process

In our original letter to Astronomy & Geophysics (de Grijs & Hughes, 2006), we overviewed the huge advances in enlightenment and instrumentation that had occurred in the 20th century, and pointed to some of the ways in which the understanding of our planetary, stellar and galactic neighbours had changed between AD 1900 and 2000. We then decided to ask both the readers of Astronomy & Geophysics and our colleagues at the University of Sheffield to produce lists of what they considered to be the significant astronomical and astrophysical breakthroughs that had occurred in this time interval, and to place these breakthroughs in order of significance.

Many contributions were received and the suggested breakthroughs were then analysed and ordered in two ways. All the breakthroughs suggested by all the respondents were considered, even though some respondents put forward fewer than the ten requested. First choices were given ten points, second choices nine, third choices eight and so on. List 1 shows the results using the Eurovision Song Contest approach. Here, the points given to each breakthrough are added up, and the breakthrough with the most points wins, the one with the next highest tally coming in second, and so on. In this approach all the "judges" considered all the "entries".

The second approach is rather like the "betting form" of a horse when entering a new race. Here, we wish to know the position it obtained in the previous races that it entered. And not entering a race does not count. In this method, all the points allocated to a breakthrough are added up, but this number is then divided by the number of times that that breakthrough has been chosen, and the results are then listed in order, giving List 2.

Both lists indicate that galaxies win clearly. The top two places in both lists go to the discovery that the Universe actually contains a huge number of galaxies, as opposed to just the single one (ours!), and the discovery that the galactic distribution was not static, but ever expanding. The galaxy/cosmology party then try to dominate List 1 by having the cosmic microwave background in third place, the emphasis here being on the Big Bang theory and its conclusions as to the age of the Universe. The galactic bias is further underlined by the high position of the astronomical "exotics". Much is made of quasars, active galactic nuclei, galactic accretion discs and galactic central black holes, all of which are powered by a range of highly energetic physical processes, these being observed over a multitude of wavelengths from the gamma- and X-ray end of the spectrum through to the long wavelength radio.

The middle orders of both our final lists are dominated by stellar astrophysics. There is considerable agreement in the ordering of these breakthroughs. The most important was the discovery of the sources of stellar energy. The fact that there is a variety of nuclear "fuels", coupled with the possibility of simply utilizing potential energy, means that there are a range of different star types. So the second major "stellar" breakthrough concerns the division of the stellar population into dwarf stars, giant stars and white dwarf stars, exemplified by their positions on the Hertzsprung-Russell diagram. This advance was extremely fruitful, leading as it did to the recognition of both a mass-dependent stellar evolutionary sequence and a host of subspecies stellar types. The final "stellar" breakthrough concerned composition. Maybe we can couple this with physical state too. Clearly, we are dealing with a triumph for the spectroscopists and a transition from an era when we had no idea what a star was made of or how stellar structure and composition varied from surface to centre to today's deep understanding of elemental nuclear synthesis and stellar interiors.

It is interesting to note the lowly position of planetary astronomy in both Lists 1 and 2. Despite the dawn of the space age, no characteristic of our Solar System makes the top ten. Exoplanets have a somewhat contentious breakthrough status considering that the discovery of well over a hundred planets orbiting stars other than the Sun simply underlines that fact that we really have little idea where our Solar System came from, or how cosmogonical processes fit in with general star birth.

A More Detailed Consideration of the Breakthroughs

1. The Milky Way is not the only galaxy in the Universe. Many of the fuzzy nebular blobs that Charles Messier (1730-1817) charted in the mid-18th century are actually distant star systems just like our own. The breakthrough occurred in 1923, when Edwin Hubble (1889-1953) used the 100 inch Hooker reflector and discovered a Cepheid variable in M31 (later published in Hubble, 1929a). By 1924 he had discovered twelve more. Using the calibrated Magellanic Cloud Cepheid data obtained by Henrietta Leavitt (1868-1921), see Leavitt & Pickering (1912), he realised that M31 was 900,000 light years away, nine times further than the outer edge of our Milky Way galaxy. Soon it was realized that the Universe contained over 10^{11} galaxies and not just the one. This is a marvellous example of an astronomical breakthrough and paradigm shift. Astronomers did not just double the number of galaxies, or change it by a factor of ten. A single unique entity, our Galaxy, suddenly, in the late 1920s found itself to be merely one among over 125 billion. Some change!

2. The Universe is expanding. This entry relies somewhat on the previous one. The stars in the Galaxy are clearly orbiting the centre of mass, and astronomers envisaged a stellar system of a specific size, with a nuclear bulge at the centre and an edge beyond which there were very few stars. It was a great leap to introduce another 10^{11} or so galaxies. And Einstein's view was that the Universe was static. The realization that, on average, the galaxies seemed to be moving away from us was a major paradigm shift. And this was bolstered by the discovery that the recessional velocity increased with distance. Again, the 100 inch Hooker telescope was responsible. This huge instrument had been used to take spectra of galactic radiation. Vesto Slipher (1875-1969) measured redshifts, as did Edwin Hubble. These Doppler velocities were reasonably accurate. Hubble estimated galactic distances using Cepheids, for the close ones, and then magnitude and size comparisons for the more distant. Needless to say, the assumption that galaxies of a specific type all had similar absolute magnitudes and diameters led to errors in the estimated distances. By 1929, however, Hubble had obtained 46 values of both velocity and distance.

A graph indicated that velocity was proportional to distance (see Hubble, 1929b). The gradient was 500 km s^{-1} Mpc^{-1}, this positive value indicating that the Universe was smaller in the past. It was noted at the time that the inverse of the gradient (assuming no retardation) gave the time since the expansion started. Astronomers could thus measure the age of the Universe, or at least the time since it was all "squashed" into a primeval "atom". Initially this worryingly revealed that the Universe was younger than the Earth, but cosmologists speedily reassessed the "Hubble constant", whose present value, combining WMAP with other cosmological data, is around 71 ± 4 km s^{-1} Mpc^{-1} (see http://map.gsfc.nasa.gov/m_uni/uni_101expand.html). So the Universe is about $(13.8\pm0.8) \times 10^9$ yr old, about three times older than planet Earth.

Another breakthrough discovery associated with Hubble's early work was the realization that the Universe looked very similar in all directions. This led to the suggestion that the Universe would look similar from the vast majority of places inside it, and thus that the formative Big Bang must have been amazingly homogeneous and isotropic.

3. The generation of stellar energy. The next three breakthroughs indicate just how little we knew about stars in 1900 and how the first few decades of the 20th century led to a major transformation of our views. In 1900, astronomers realized that stars were old, well over a billion years old, and that they were very luminous for much the greater part of their life. But astronomers did not know how the huge amounts of stellar energy were produced. The breakthrough was triggered by Albert Einstein's 1905 paper on special relativity and the introduction of mass-energy equivalence, this being exemplified by the iconic equation $E = mc^2$. Clearly, mass is not converted into energy under normal physical conditions. Before $E = mc^2$ could be embraced, astrophysicists like Sir Arthur Stanley Eddington (1882-1944) had to show just how extraordinary the centre of a star was. Eddington was one of the first to realize that stars were gaseous throughout, and that stars owed their stability to the balance between the force exerted by gravity and the opposing pressure exerted by gas and radiation. This led to the mass-luminosity relationship, which was vital for the understanding of stellar evolution. For example, the main sequence luminosity of a star is proportional to $mass^{3.5}$ and the main sequence lifetime of a star is proportional to $mass^{-2.5}$. These relationships enabled astronomers to estimate such important characteristics as stellar cluster masses and ages.

Eddington (1926) intimated that the density of the gas at the centre of the Sun was well over a hundred times that of water, and that the temperature of this region was higher than 10^7 K. Stellar interiors were certainly hot enough for the nuclear reaction rate to be non-negligible. But what was the form of the mass that was being destroyed? Luckily, at about the same time (1920), Francis William Aston (1877-1945) was using a mass spectrometer (an instrument that he invented) to measure the masses of certain atoms and isotopes. He realized that four hydrogen atoms were heavier than one helium atom. Others at the time (see later) were hinting that hydrogen and helium were the major components of stellar composition. These factors combined to solve the stellar energy generation problem. But one had to show exactly how it worked. Hans A. Bethe (1906-2005) did this in 1939, when he proposed the carbon-nitrogen -oxygen (CNO) cycle. Later on he introduced the proton-proton cycle. Interestingly, these processes were extremely slow, so stars spent long periods of time on the main sequence, gently converting hydrogen into helium. During this period, their luminosity changed very little.

The recognition of the source of stellar energy led eventually to the general solution of the stellar evolution problem, an endeavour that took about 35 years.

4. There are only two common types of stars. Slightly before our understanding of how stellar energy was gained came the realization that the vast majority of stars are essentially of just two types, the so-called "dwarfs" and "giants". This is rather surprising nomenclature for objects that typically have diameters of around 10^6 and around 20 x 10^7 km respectively. The year 1910 saw certain astronomers drawing up lists of stellar luminosities and surface temperatures (as time went by these lists were extended to included radii and masses). Hertzsprung (1911) plotted graphs showing the apparent magnitude as a function of spectral type for stars in specific open clusters (i.e. nearby "moving groups" of closely related stars), such as the Pleiades and the Hyades. Russell (1914) took full advantage of recent parallax work and plotted absolute magnitude (i.e. luminosity) as a function of spectral type (i.e. log[surface temperature]) for stars in general. Both Hertzprung and Russell found that there were two main types of stars. By far the commonest were the "dwarfs"— approximately Sun-sized stars occupying a "main sequence" along which luminosity was proportional to temperature to the power of approximately 6.7. Less common were the "giants". Here, we had stars with absolute magnitudes of around zero. (As time went by more stellar classes were added. One class was the faint Earth-sized white dwarfs, with absolute visual magnitudes between 10 and 14 and spectral types around B and A, and the other, the rarer supergiants with absolute visual magnitudes in the -5 to -8 range.)

5. We now understand the composition of the baryonic matter in the Universe. In 1900, the general consensus was that stars were made of "earth". Since 1925 astronomers started to realize that stars are predominantly made of hydrogen and helium, this clearly being a major paradigm shift. Cecelia Payne led the way, in her famous Harvard PhD thesis Stellar Atmospheres, A Contribution to the Observational Study of High Temperature in the Reversing Layer of Stars, a thesis that led to her 1925 Radcliffe College (Cambridge, Massachusetts) doctorate. She used the 1920 equation developed by Meghnad Saha (1894-1956) to convert spectroscopic line strengths into atomic number counts and eventually stellar photospheric compositions. A second important breakthrough in this field was the realization that stars come in two main compositional sorts; metal rich Population I and metal poor Population II. This was discovered by Walter Baade (1893-1960) in 1943 (see Baade 1944), using photographic plates that he had taken of the M31, The Andromeda Galaxy, with the Hooker, under the conditions of the wartime blackout. A third breakthrough was the explanation of why the stars actually had the compositions that they did, and how that composition varies with time. There were two components to this breakthrough: first the explanation of the initial 75%:25% hydrogen helium mix produced just after the Big Bang, and second the 1957 breakthrough due to the work of Margaret Burbidge, Geoffrey Burbidge, William Fowler and Fred Hoyle. This takes the nuclear e-process that converts hydrogen into helium and extends the sequence on to the production of carbon and oxygen, silicon, sulphur, argon and calcium, and ending with the iron peak. These four scientists then showed how the r-process takes over in supernova explosions and moves the composition on towards gold, platinum and uranium.

6. Exotics. In 1900, the "Universe" consisted of planets, other minor members of the Solar System, stars and a single Galaxy. The objects known at that time were relatively mundane. But there is a special class of astronomer who yearns for the exotic, and the last century has provided such celestial bodies in abundance. The exotics, by their very nature, stretch cosmic physics to extremes, and it is this that leads to the breakthrough. First one has the stellar exotics. Typical examples are found at the end points of stellar evolution. Low-mass stars evolve into Earth-sized white dwarfs, bodies governed by the laws of degenerate matter. Neutron stars were predicted by Subrahmanyan Chandrasekhar (1910-1995) in 1930 to be the evolutionary endpoint of stars more massive than 1.4 solar masses. Many of these are produced by supernova explosions, as suggested by Walter Baade and Fritz Zwicky (1898-1974) in their joint 1933 paper. The radio wave observations of of Jocelyn Bell (now Bell-Burnell) and Anthony Hewish in 1967, showed that pulsars were just rotating neutron stars. Finally, one has the black holes, these being the endpoints of the evolution of stars more massive than three solar masses.

Another addition to the tally of exotic breakthroughs was the1963 discovery of the quasi-stellar object 3C 273 by Maarten Schmidt. Here, we were confronted by a strong radio source, at a redshift of 0.158, which visually looked just like a 13th magnitude star moving away from Earth at 16.6% of the velocity of light. Subsequently, radio-quiet quasars were found, as well as quasars that varied in brightness over timescales of a few weeks. Soon, quasars were being equated to accreting discs around 10^7 to 10^8 solar mass black holes, these being the very active nuclei at the centre of distant (and thus young) galaxies. Seyfert galaxies (first described in 1943) are thought to be a specific class of quasars with rather low luminosity. They are near-normal spiral galaxies with reasonably active nuclei Quasars/AGN are perfect examples of late 20th century exotics, lending themselves to multi-wavelength investigation.

7. The Microwave Background Radiation. It is one thing to suggest that the Universe started with a "big bang" (a derogatory term coined by Fred Hoyle (1915-2001) in a BBC broadcast, see Hoyle, 1950), but it is another to prove it. It is one thing to measure an expanding Universe, but it is another to work out what made it expand. Robert Henry Dicke et al. (1965) realized that a Big Bang (the term quickly became capitalized) would not only accelerate matter away from a singularity but would also produce extremely hot radiation that would cool as the Universe expanded. If the Universe was 13,000,000,000 yr old it should have a radius of 13,000,000,000 light years, and the radiation should now have a temperature of only a few K. This corresponds to an energy emission maximum at a wavelength of a millimetre or so. Dicke planned to search for this microwave maximum, but was pipped at the post by a serendipitous discovery. Arno Penzias and Robert Wilson of Bell Telescope Laboratories detected the 3.1 ± 1 K background radiation ($\lambda_{max} = 0.93$ mm) in 1965 when trying to eliminate static that was interfering with their satellite communication system. Their 4080 MHz horn antenna was about as big as a house. This breakthrough immediately converted cosmology from a vibrant exciting subject with two flourishing and competing theories, into a boring dirge where everyone sings from the same "Big Bang" hymn sheet and the "steady state" theorists are cast into outer darkness. Interestingly, in whichever direction one looked from Earth, the radiation was very close to the same temperature of 3.1 K. More recent refinements have indicated that this radiation, in the rest-frame of the Universe, is isotropic down to 1 part in 105. Huge amounts of money have been expended in launching satellites such as COBE (1992) and WMAP (2001) to investigate the isotropy on ever smaller scales.

8. Dark Matter. Most of the Universe seems to consist of material that we cannot see. The "luminous", radiating, bodies in our Universe only make up about 4% of the total mass. This strange and still unexplained phenomenon was first discovered by Fritz Zwicky (1937). The application of the virial theorem to the Coma cluster of galaxies indicated that it contained 400 times more mass than that indicated by the visible parts of the galaxies.

Galaxies are more massive than they look. We can count all the stars and add up their masses, and then include the gas and the dust. But it is still not enough. Vera Rubin showed that the velocity curve of a typical galaxy indicated that the velocity of rotation did not decrease significantly as a function of distance from the galactic spin axis (see Rubin, 1978, 1983). Everyone was expecting most of the galactic mass to be in the nucleus. If this were the case, the rotation velocity would decrease as the inverse square root of distance from the massive central body (as happens in the Solar System). The typical spiral galaxy actually has a massive halo, which has a density that decreases as a function of the inverse square of the distance from the spin axis. The composition, or form, of the "missing mass" in this halo is not known. Some of our contributors to the breakthrough listings suggested that the discovery of "dark matter" should only achieve breakthrough status when the actual physical form of the dark matter has been identified. This is somewhat unfair. One of the great joys of modern astronomy and astrophysics is the host of mysteries that abound.

9. Exoplanetary systems. In 1900, there was one known planetary system — the one we inhabit. As the century progressed certain astronomers, such as Peter van de Kamp (1975), hinted that the slight astrometric wobble of the celestial paths of certain nearby stars indicated that they had planetary companions. By the end of the 1900-2000 period, the planetary floodgates had opened. The Doppler shift of a planet's parent star could now be monitored accurately. A profusion of planetary discoveries were reported (see, for example, Mayor & Queloz, 1995, who used the telescope at the Haute-Provence Observatory in France, and Butler & Marcy, 1996, who confirmed the discovery using the telescope at the Lick Observatory in California, USA). Later on, some of these discoveries were confirmed by the observation of stellar transits. This was a fascinating breakthrough. Our Solar System was proved not to be the only one in the Galaxy. Rather unexpectedly, however, the vast majority of these newly discovered planetary systems are nothing like the system that we live in. Instead of having Jupiter-like planets orbiting the central star every decade or so, their "hot Jupiters" are in Mercury-like orbits. The observations of a host of other planetary systems were expected to provide clues as to the origin of our own system. They have not.

A side issue to the breakthrough discoveries of many exoplanetary systems is the realization that we are still alone. Life seems to be rare; and intelligent, inquisitive, communicating life, rarer still. Look though we may, we have found absolutely no evidence of life having broken out on other planets in our system. Even though we listen diligently, we have intercepted no incoming radio signals from "extraterrestrials".

10. Solar neutrinos and helioseismology. We cannot "see" inside a star. Our vision of the solar photosphere extends to a depth of about 500 km, but, in comparison with the solar radius of around 700,000 km, this still leaves a very long way to go. Until recently, the stellar interior was the realm of the theoretical astrophysicist. Two breakthroughs have occurred in the last 50 years. The first was the detection and monitoring of solar neutrinos, these being produced by the host of nuclear reactions that convert hydrogen into helium. Raymond Davis Jr and his huge tank of ^{37}Cl in the mine at Homestake, South Dakota, measured at least a few of the 6.5×10^{14} neutrinos m^{-2} s^{-1} that pass through the Earth. This experiment started in 1968. Detectors using gallium started operation in 1991 (see, for example, Stix, 2002).

The second breakthrough was the observation of seismic waves on the solar surface. As waves of different frequency penetrate to different depths, they can be used to estimate spin rates in the solar interior as well as the position of the region where radiative energy transport changes to convective energy transport. Helioseismic oscillations were discovered in 1960 and reported by Leighton et al. (1962). The detailed structure of the five-minute evanescent oscillations were reported in 1975 (Deubner, 1975) and the lowest wavelength modes were observed in 1979 (see Claverie et al. 1979).

Discussion and Conclusions

The timing of the breakthroughs is rather informative. Those relating to stars occurred rather early on in the 20th century. The stellar energy problem was well on the way towards a solution in 1905; stellar diversity was indicated by the 1911-14 Hertzprung-Russell diagrams; and stellar composition was reasonably well understood by 1925. The two huge extragalactic breakthroughs, the discovery of galactic multiplicity and the expansion of the Universe, both occurred at the end of the 1920s. The year 1937 saw the discovery of dark matter. So six out of ten of our breakthroughs occurred in the first 37 years of the 20th century. Three more occurred in the 1960s: the discovery of quasars in 1963, the cosmic microwave background in 1965 and the detection of solar neutrinos in 1968. The mid-1990s saw the discovery of exoplanets.

With the exception of quasars and the microwave background, the visual portion of the electromagnetic spectrum dominates the breakthrough scene. It is also rather interesting to note that the 100 inch Hooker telescope provided two of the breakthroughs, and larger telescopes have not helped a great deal in providing the remainder. Perhaps there are a host of future breakthroughs awaiting the next generation of large telescopes, but this is rather unlikely. Computers seem to have led to no top-ten breakthroughs at all. Neither has space exploration. The later is rather unexpected. Maybe the discoveries of the planetary flyby probes, orbiters and landers, discoveries such as magnetic fields around Mercury, impact craters on Venus, thick crusts on the non-Earth facing hemisphere of the Moon, great canyons on Mars, smooth sandblasted asteroids, kilometric dirty snowball nuclei at the centre of comets, active volcanoes on Io, huge subsurface water oceans on Europa, lakes of liquid methane on Titan, large blue spots on Neptune, etc. might have crept into the top thirty, but not the top ten. There again, maybe the bodies in the Solar System turned out to be very much as we expected, and there were few major surprises.

Breakthroughs come in two main categories; (i) the completely unexpected, and (ii) the solution to a longstanding problem. Considering lists 1 and 2 it is clear that nobody predicted the existence of quasars before they were found, or had suggested that the vast majority of the material in the Universe was "dark". Also, the expectation was that the space between the stars and galaxies was well behaved, empty and flat. The discovery of interstellar dust and gas by Robert Julius Trumpler in 1930, and the consequent light absorption, together with the discovery of 21 cm radio waves emitted by neutral atomic hydrogen in the Universe, put paid to the second of these assumptions. The gravitational flatness disappeared with the introduction of General Relativity by Albert Einstein in 1916. The "proof" of space curvature came with Eddington's observations of the starlight from the Hyades cluster during the totality of the 29 May 1919 solar eclipse, followed, more importantly, by the detection of the gravitational lensing introduced by super-massive galaxies as observed by Dennis Walsh et al. (1979).

Likewise, if one combs through the research papers of the 19th century the possibility of there being a multitude of galaxies was hardly mentioned, and when this multitude was discovered, again, the expectation was that they would be orbiting their centre of mass as opposed to rushing away from the Big Bang.

These "completely unexpected" breakthroughs sometimes depended on the invention of a completely new type of scientific instrument. Often, the "new instrument" started life having very little to do with astronomy. Just consider these possible statements and consequences.

- *'I have invented a two-lens telescope that brings distant things closer, and reveals bodies too faint for the eye to see, marvellous for army and navy use and for spotting your enemies when a long way away. Blast, an astronomer has usurped the device and used it to show that the Moon has mountains, Venus goes round the Sun, and Jupiter has satellites . . .'*
- *'I have invented a prismatic instrument that splits light into its different colours, and when I look at Sun-light I see lots of dark lines, at specific wavelengths, just the job to help my physicists measure the refractive index variations of glass. Blast, an astronomer has developed the instrument, fitted it to a telescope, and measured the chemical composition of the Universe, stellar surface temperatures, the radial velocities of stars and planetary surfaces . . .'*
- *'I am using a new-fangled millimetre wave radio horn antewweiver to pick up messages from submarines and am trying to reduce the background noise. But I am not going to pass this interesting noise data on to an astronomer. I shall publish the results myself and thus prove that the Universe started with a Big Bang.'*

Those breakthroughs associated with 'the solution to a long-standing problem' usually arose from a combination of instrumental advance, prolific data collection or theoretical enlightenment. The "chemical composition of the cosmos" is a perfect example, relying, as it did, on the invention of the spectrometer, the analysis of spectral lines, the discovery of the electron and the theoretical work of Menghnad N. Saha. The Hertzprung-Russell diagram is another. Here we have a "discovery" whose time had arrived. If Ejnar Hertzprung (1873-1967) and Henry Norris Russell (1877-1957) had not reached for the graph paper, others would have done the job in the next year or so. A similar situation arose with a mini-breakthrough around the same time, this being the discovery of the Cepheid period-luminosity relationship. Henrietta Swan Leavitt's work in 1912 was ground-breaking, as was the calibration and use of the relationship by Ejnar Hertzprung and Harlow Shapley (1885-1972) to measure the 94,000 light year distance to the Small Magellanic Cloud. But again, if these astronomers had not done the job some one else would have, soon after.

Let us conclude by hinting at some of the breakthroughs that we are still waiting for. Some of these concern astronomical bodies that are embarrassingly close to planet Earth. Consider the second brightest object in the sky, our Moon. Do we know where it came from? The short answer is, no. Some contemporary researchers hint that a Mars-sized asteroid simply knocked a chunk off the Earth's mantle and that this ejected material subsequently condensed and accumulated to form our Moon. But it would be most unusual if there was just the one large impact in the history of our planet. In those times there were many asteroids, and many big ones, so similar impacts should have occurred quite a few times. If our Moon were the result of an impact it is rather surprising that we do not have quite a few moons, as opposed to just the one. And Mars, Venus and Mercury should be blessed with satellite families too.

Another serious "yet-to-come" breakthrough concerns cosmogony. It is fair to say that we have a very tenuous understanding of how our planetary system formed, and why there are only eight planets in it, and why it essentially ends at Neptune. The discovery of planets around other stars simply has not helped. The majority of these systems have Jupiter-sized planets in Mercury-like orbits. In fact, many of the new systems are nothing like the system that we live in and were probably formed in different ways.

And then we have the problem of the origin of the Universe. Many astronomers are rather uncomfortable about the *creatio ex nihilo* aspects of the Big Bang. And the addition of the spice of inflation, dark energy and dark matter does little damp down their suspicions that we might not yet be on exactly the right track.

We also worry that angular momentum still seems to be rather too difficult a topic for astronomers. As university lecturers we have always been somewhat embarrassed by being unable to explain to our students why, for example, the Sun and Venus are spinning so slowly and the Universe is not thought to be spinning at all.

One of the great joys of astronomy is the simple fact that, even though breakthroughs abound, and occur at a fairly regular rate, there is a vast amount of evidence indicating that there are still a huge number of breakthroughs yet to come.

Finally, let us mention some general points. Before starting this exercise we thought that different types of astronomers might come up with completely different lists of breakthroughs. Surprisingly, this was not the case. There was considerable agreement between such diverse groups as, for example, the cosmologists, planetary astronomers, stellar theoreticians and astro-historians. Many alluded to the temporal nature of our quest. What we today (in 2007) regard as being the great breakthroughs of the 1900-2000 period might differ somewhat from what astronomers in 2107 would regard as the significant breakthroughs. And clearly the breakthroughs of 1900-2000 bear scant relationship to the breakthroughs of 1800-1900 and 1700-1800.

It was also interesting to compare the speed with which certain breakthroughs became recognized. One can well imagine that the discovery of the cosmic background radiation was realized to be a breakthrough in about half an afternoon. The elevation of the HR diagram to breakthrough status clearly took a couple of decades.

One also feels sorry for the topics that did not quite make it. The 20th century was the era of astronomical ages. At the beginning, we did not like to talk about such a delicate topic as age, such was our uncertainty. At the end, planets, meteorites, stars, stellar clusters, galaxies, and even the Universe itself, had well known ages. It was also the century of interiors. Stellar and planetary interiors were mysterious places in 1900. By 2000, these had been successfully modelled and we had a detailed understanding of the variability of pressure, density, temperature and composition, and the origin of such characteristics as heat and magnetism. Temperature ranges also expanded hugely during the century. The expansion of the observed wavelength bandwidth enabled us to investigate the high temperatures of such places as the solar corona and the surfaces of neutron stars, and such freezing spots as the centres of giant molecular clouds and the midnight regions of Pluto. The century has also been a period when the isolation of the Earth was lessened. In 1900 the only magnetic field that we could measure was the field at the surface of our planet. By 2000, we had measured magnetism in such diverse places as the centres of sunspots and the surfaces of white dwarfs. We were also beginning to appreciate and understand the influence that solar magnetic variation had on terrestrial characteristics. The century, which started only three years after J. J. Thomson discovered the electron, was also a period when the significance of plasma was first appreciated.

The expression 'the textbooks will have to be rewritten' is often overused in modern media discussions of scientific progress. But in the case of "breakthroughs" it often turns out to be true.

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Bios

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The International Year of Astronomy 2009

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Key Words

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Summary

The International Astronomical Union (IAU) has launched 2009 as the International Year of Astronomy (IYA2009) under the theme "The Universe, yours to discover". IYA2009 marks the four hundredth anniversary of Galileo Galilei's first astronomical observation through a telescope. It will be a global celebration of astronomy and its contribution to society and culture, with a strong emphasis on education, public engagement and the involvement of young people, with events at national, regional, and global levels throughout the whole of 2009. IYA2009 has been endorsed by UNESCO, which has recommended it for adoption by the United Nations. The UN General Assembly will vote in late 2007 to endorse 2009 as the International Year of Astronomy.

Vision and Goals of the International Year of Astronomy 2009

Vision

The vision of the International Year of Astronomy 2009 is to help people rediscover their place in the Universe through the sky, and thereby engage a personal sense of wonder and discovery. Everyone should realize the impact of astronomy and other fundamental science on our daily lives, and understand how scientific knowledge can contribute to a more equitable and peaceful society.

The IYA2009 will be a global celebration of astronomy and its contributions to society and culture, highlighted by the 400th anniversary of the first use of an astronomical telescope by Galileo Galilei. The aim of the Year is to stimulate worldwide interest, especially among young people, in astronomy and science under the central theme "The Universe, Yours to Discover".

IYA2009 activities will take place locally, regionally and nationally. National Nodes have been formed in each country to prepare activities for 2009. These nodes will establish collaborations between professional and amateur astronomers, science centres and science communicators in preparing activities for 2009. More than 90 countries are already involved, with well over 140 expected. To help coordinate this huge global programme, and to provide an important resource for the participating countries, the IAU has established a central Secretariat and an IYA2009 website (www.astronomy2009.org) as the principal IYA resource for public, professionals and media alike.

Figure 1. The International Year of Astronomy 2009 Logo.

Goals To:	Objectives To:	Evaluation estimator
1. Increase scientific awareness among the general public through the communication of scientific results in astronomy and related fields, as well as the process of research and critical thinking that leads to these results.	• Make astronomical breakthroughs more visible in the daily lives of billions of people through all available means of communication (TV/radio documentaries, newspapers, web pages, exhibitions, stamps, blogs, web portals, advertising campaigns etc). • Facilitate individual astronomical observing opportunities.	The number of people "touched": • Number of press clippings and readership. • Number of people visiting national, regional and global webpages (webstats). • Number of activities. • Number of new products etc.
2. Promote widespread access to the universal knowledge of fundamental science through the excitement of astronomy and sky-observing experiences.	• Enable as many laypeople as possible, especially children, to look at the sky through a telescope and gain a basic understanding of the Universe.	• Number of laypeople, especially young people and children, viewing the Universe through a telescope at street astronomy events, star parties, professional observatory webcasts etc. • Number of cheap new telescope kits produced, assembled and distributed.
3. Empower astronomical communities in developing countries through the initiation and stimulation of international collaborations.	• Involve astronomical communities of the developing nations in the Year, thereby providing examples of how outreach and education is carried out in different parts of the world.	• Number of participating developing nations as measured by the establishment of National IYA Nodes. • Number of new international partnerships and joint programs formed. • Number of people reached by new initiatives.
4. Support and improve formal and informal science education in schools as well as through science centres, planetariums and museums.	• Develop formal and informal educational material and distribute all over the world. • Conduct focused training of event leaders and presenters.	• Number of participating teachers and schools. • Number of educational materials distributed. • Number of new event leaders and presenters trained.
5. Provide a modern image of science and scientists to reinforce the links between science education and science careers, and thereby stimulate a long-term increase in student enrolment in the fields of science and technology, and an appreciation for lifelong learning.	• Popular talks by scientists of all ages, genders and races. • Facilitate portraits — on TV, in web blogs, biographies — of scientists that break with the traditional "lab coat view" of scientists, showing the excitement of scientific discovery, the international aspect of scientific collaborations and portraying the social sides of scientists.	• Number of popular talks. • Number of scientist portraits. • Public response questionnaires. • Evidence for penetration of astronomy into popular culture (media, web, TV, radio talk shows…)
6. Facilitate new, and strengthen existing, networks by connecting amateur astronomers, educators, scientists and communication professionals through local, regional, national and international activities.	• Connect as many individuals (named "IYA ambassadors") as well as organizations (amateur and professional) in networks;; for instance, by creating of new internal and external electronic communication infrastructures. These networks will become part of the heritage of IYA2009.	• Number of National IYA Nodes. • Number of new networks and partnerships formed.
7. Improve the gender-balanced representation of scientists at all levels and promote greater involvement by underrepresented minorities in scientific and engineering careers.	• Provide access to excellent role models and mentors, formally and informally, and publicize them. • Provide information about the female "dual-career" problem and possible solutions.	• Number of active new role models and mentors. • Number of new international partnerships, projects and activities.
8. Facilitate the preservation and protection of the world's cultural and natural heritage of dark skies in places such as urban oases, national parks and astronomical sites, through the awareness of the importance and preservation of the dark skies and astronomical sites for the natural environment and human heritage.	• Involve the dark-sky community in IYA2009. • Collaborate in the implementation of the UNESCO and IAU "Astronomical and World Heritage" initiative. • Lobby organizations, institutions, and local, regional and national governments to approve preservation laws for dark skies and historical astronomical sites. • Put the issues of natural environment and energy preservation on the agenda of decision makers.	• Number of activities and events related with night-sky protection • Number of countries/cities with laws or guidelines for dark sky preservation. • Areas protected by dark sky laws • Number of historical astronomical sites identified and protected under the UNESCO's World Heritage Convention

The Team behind the Scenes

IAU

The International Astronomical Union (IAU, www.iau.org) is the initiator and international leader of IYA2009. It was founded in 1919 with the mission of promoting and safeguarding the science of astronomy through international co-operation and maintains a small secretariat in Paris. Its individual members are professional astronomers active in research and education in astronomy all over the world. It is a "bottom-up" organization run by its members for the benefit of astronomy worldwide and maintains friendly relations with organizations that include amateur astronomers in their membership.

Currently the IAU has nearly 10,000 individual members in 87 countries worldwide. In addition to arranging scientific meetings, the IAU promotes astronomical education and research in developing countries through its International Schools for Young Astronomers, Teaching for Astronomy Development, and World Wide Development of Astronomy programmes, and through joint educational activities with UNESCO and other bodies.

The IAU acts as a catalyst and coordinator for IYA2009 at the global level, largely, but not exclusively through the IYA2009 website and Secretariat. The IAU will organisze a small number of international events such as the global astronomy web-portal, global image exhibitions and the Galileoscope project. The IAU will be the primary interface with bodies such as UNESCO and the United Nations.

The next triennial General Assembly of the IAU takes place in Rio de Janeiro in August 2009. Some 2500 astronomers from all over the world will attend. Considerable media attention is always given to the General Assemblies, with regular briefings and news releases provided. Naturally, the programme of the General Assembly will be closely linked to the themes and activities of IYA2009, and this will provide a further opportunity for the Global Sponsors of IYA2009 to promote their activities through displays and speakers at dedicated sessions, particularly those devoted to communication and education.

The IAU IYA2009 Secretariat

The central hub of the IAU activities for IYA2009 is the Secretariat established by the IAU to co-ordinate activities during the planning, execution and evaluation of the Year. The Secretariat will liaise continuously with the Single Points of Contact, Task Groups, Global Official Partners, Global Sponsors and Organizational Associates, the media and the general public to ensure the progress of IYA2009 at all levels. A website (www.astronomy2009.org) has been set up and more than 90 member countries have established national committees and appointed "Single Points of Contact". The Secretariat and website are the most important coordination and resource centres for all the

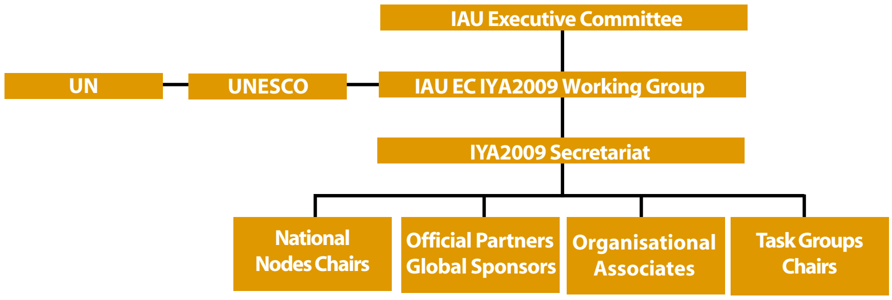

Figure 2. IYA2009 Organisational Structure.

countries taking part, but most particularly for those developing countries that lack the national resources to mount major events alone.

IYA2009 Global Cornerstone Projects

24 Hours of Astronomy

This is a round-the-clock, round-the-globe event, including 24 hours of live webcasts, observing events and other activities connecting large observatories around the world. One of the key goals is to allow as many people as possible to look through a telescope, and see what Galileo saw — the four Galilean moons around Jupiter. The 24 Hours of Astronomy might coincide with a "Dark Sky Event" with a controlled reduction of city illumination in a Wave of Darkness around the globe to raise awareness that the dark sky is a majestic, but often overlooked, cultural resource for everyone (security and safety issues to be considered).

The Galileoscope

Who doesn't remember the first time they looked at the Moon through a telescope and were amazed by the details of the mountains and craters? The same is true for Jupiter's cloud belts and its fascinating Galilean moons, Saturn's rings and a sparkling star cluster.

Observing through a telescope for the first time is a unique experience that shapes our view of the sky and Universe. The IYA2009 programme wants to share this observational and personal experience with as many people as possible across the world and is collaborating with the US IYA2009 National Node to develop a simple, accessible, easy-to-assemble and easy-to-use telescope that can be distributed by the millions. Ideally, every participant in an IYA2009 event should be able to take home one of these little telescopes.

This simple telescope enables people to build and observe with a telescope that is similar to Galileo's. Sharing these observations and making people think about their importance is one of the main goals of IYA2009: Promote widespread access to new knowledge and observing experiences. A do-it-yourself Galileoscope could be the key of pursuing an interest in astronomy beyond IYA2009, especially for people who cannot afford to buy a commercial telescope.

We aim to give 10 million people their first look through an astronomical telescope in 2009. This is achievable if, for example, 100,000 amateur observers each show the sky to 100 people. Millions of small telescopes are sold every year, but anecdotal evidence suggests that most are rarely used for astronomy. A worldwide Telescope Amnesty programme will invite people to bring their little-used telescopes to IYA2009 events, where astronomers will teach them how to use them and offer advice on repairs, improvements, and/or replacements, encouraging more people to stay involved in the hobby.

We encourage the organizers of IYA2009 celebrations in all countries to promote similar activities, with a common goal of giving 10 million people worldwide their first look through an astronomical telescope.

Cosmic Diary

This project is not just about astronomy; it is more about being an astronomer. Professional astronomers will blog in text and images about their life, families, friends, hobbies, and interests, as well as their work — their latest research findings and the challenges that face them in their research. The Cosmic Diary aims to put a human face on astronomy. The bloggers represent a vibrant cross-section of female and male working astronomers from around the world. They will write in many different languages and come from five different continents. Outside the observatories, labs and offices, they are musicians, parents, photographers, athletes, amateur astronomers. At work, they are managers, observers, graduate students, grant proposers, instrument builders and data analysts.

The Portal to the Universe

The science of astronomy is extremely fast moving, and delivers new results on a daily basis, often in the form of spectacular news, images of forms and shapes not seen anywhere else, enhanced by illustrations and animations. Public astronomy communication has to develop apace with the other players in the mass market for electronic information such as the gaming and entertainment industries. The problem today is not so much the availability of excellent astronomy multimedia resources for use in education, outreach and the like, but rather finding and accessing these materials. The public requires better access to information, images, videos of planets, stars, galaxies or other astronomical phenomena. Press, educators, scientists, laypeople need a single point of entry into all the discoveries that take place on a daily basis — a global one-stop portal for astronomy-related resources. Modern technology (especially RSS feeds and the VAMP — Virtual Astronomy Multimedia Project) has made it possible to link all the suppliers of such information together with a single, almost self-updating portal. The Portal to the Universe will feature a comprehensive directory of observatories, facilities, astronomical societies, amateur astronomy societies, space artists, science communication universities, as well as a news-, image- and video-aggregators and Web 2.0 collaborative tools for astronomy multimedia interconnectivity. The global astronomy web portal will enable innovative access to, and vastly multiply the use of, astronomy multimedia resources — including news, images, illustrations, animations, movies, podcasts and vodcasts.

She Is an Astronomer

IYA2009 has the aim of contributing to four of the UN Millennium Development Goals, one of which is to 'promote gender equality and empower women.' Approximately a quarter of professional astronomers are women, and the field continues to attract women and benefit from their participation. However, there is a wide geographical diversity, with some countries having none, and others having more than 50% female professional astronomers. Also, the very high level of female dropouts shows that circumstances do not favour female scientists. Gender equality is of a major concern to the whole scientific community regardless of geographic location. The problems and difficulties are different in all regions and continents. IYA2009's She is an Astronomer programme will offer platforms that address some of these problems. She is an Astronomer will contain the following components:

- The Portal to the Universe global web portal will provide a collection of links to all the existing regional and national programmes, associations, international organizations, non-governmental organizations, grants and fellowships supporting female scientists.
- Part of the programme will appear in the Cosmic Diary featuring the work and family lives of female researchers.
- The project intends to seek cooperation agreement with prestigious already running initiatives, to provide fellowships to female scientists to support their career prospects.
- A Woman Astronomer Ambassador programme will be established to reach girls at school and university level with the messages of the programme.

Dark Skies Awareness

It is now more urgent than ever to encourage the preservation and protection of the world's cultural and natural heritage of dark night skies in places such as urban oases, national parks and astronomical sites, as well as to support UNESCO's goals of preserving historical astronomical sites for posterity. For this cornerstone project, the IAU will collaborate with the US National Optical Astronomy Observatory, International Dark-Sky Association and other national and international partners in dark sky and environmental education on several related themes, including worldwide measurements of local dark skies by thousands of citizen-scientists using both unaided eyes and digital sky-quality meters (as in the successful GLOBE at Night programme), star parties, new lighting technologies, arts and storytelling, and health and ecosystems.

IAU/UNESCO Astronomy and World Heritage

UNESCO and the IAU are working together to implement a research and education collaboration as part of UNESCO's Astronomy and World Heritage project. This initiative aims at the recognition and promotion of achievements in science through the nomination of architectural properties, sites or landscape forms related to the observation of the sky through the history of mankind or connected with astronomy in some other way. The proposed lines of action are: identification, safeguarding and promotion of these properties. This programme provides an opportunity to identify properties related to astronomy located around the world, to preserve their memory and save them from progressive deterioration. Support from the international community through IYA2009 is needed to develop this activity, which will allow us to help preserve this sometimes very fragile heritage.

Galileo Teacher Training Programme

There is an almost unfathomable amount of rich and very useful astronomy educational resources available today — mostly in digital form, freely available via the Internet. However, experienced educators and communicators have identified a major "missing link": the training of the educators to understand the resources and enable them to use it in their own syllabuses. To sustain the legacy of the International Year of Astronomy 2009, the IAU — in collaboration the National Nodes and leaders in the field such as the Global Hands-On Universe project, the US National Optical Astronomy Observatory and the Astronomical Society of the Pacific — is embarking on a unique global effort to empower teachers by developing the Galileo Teacher Training Programme. The Galileo Teacher Training Programme goal is to create by 2012 a world-wide network of certified Galileo Ambassadors, Master Teachers and Teachers. Included in the programme is the use of workshops and on-line training tools to teach the topics of robotic optical and radio telescopes, web cams, astronomy exercises, cross-disciplinary resources, image processing, and digital universes (web and desktop planetariums).

Universe Awareness

Universe Awareness (UNAWE) will be an international outreach activity that aims to inspire young disadvantaged children with the beauty and grandeur of the universe. UNAWE will broaden children's minds, will awaken their curiosity in science and will stimulate internationalism and tolerance. Games, songs, hands-on activities, cartoons and live internet exchanges are devised in partnership with UNAWE communities throughout the world for children from the age of four onwards. UNAWE will enable the exchange of ideas and materials through networking and interdisciplinary workshops.
Universe Awareness is imagination, excitement and fun in the Universe for the very young.

Figure 3. The Universe from the Earth — An Exhibit of Astronomical Images.

The Universe from the Earth — An Exhibit of Astronomical Images

Cosmic images are captivating and have incredibly inspirational power. Astronomy touches on the largest philosophical questions facing the human race: Where do we come from? Where will we end? How did life arise? Is there life elsewhere in the Universe?

Space is one of the greatest adventures in the history of mankind: an all-action, violent arena with exotic phenomena that are counter-intuitive, spectacular, mystifying, intriguing and fascinating. The fantastic images of the Universe are largely responsible for the magical appeal that astronomy has on lay people. Indeed, popular images of the cosmos can engage the general public not only in the aesthetics of the visual realm, but also in the science of the knowledge and understanding behind them. IYA2009 is an unprecedented opportunity to present astronomy to the global community in a way that has never been done before. The Universe from the Earth is an exhibition arranged by the IYA2009 project that will bring these images to a wider audience in non-traditional venues, like art museums, public galleries, shopping malls and public gardens.

The IYA2009 and the UN Millennium Development Goals

IYA2009 is, first and foremost, an activity for everyone around the world. It aims to convey the excitement of personal discovery, the pleasure of sharing fundamental knowledge about the Universe and our place in it. The UN Millennium Development goals form a blue-print agreed by every country and the entire world's leading development institutions. The inspirational aspects of the International Year of Astronomy embody an invaluable resource for humankind and aim to contribute to four of the UN Millennium Development goals.

Help to Achieve Universal Primary Education

IYA2009 intends to add to the quality of primary education by providing access to basic astronomy to teachers and pupils all over the world. The night sky displays its wonders equally above all nations. We just have to provide the guides to understand what we see and discover. Providing equal chances to access knowledge will result in the development of international cooperation in scientific research and relevant applications, and in its broader effect will assist the developing world to match the developed world.

Help to Eradicate Extreme Poverty and Hunger

An increase in scientific wealth has been shown to be associated with an increase in economic wealth in developing countries, thereby contributing to fighting poverty, building capacity and good governance. The IYA2009 programme aims to empower astronomical communities in developing countries through the initiation and stimulation of international collaborations. These small steps can contribute to increasing the scientific and technological knowledge, and economic wealth in developing countries.

Promote Gender Equality and Empower Women

One of the IYA2009 goals is to improve the gender-balanced representation of scientists at all levels and promote greater involvement by underrepresented minorities in scientific and engineering careers. Gender equality is a priority concern of the whole scientific community regardless of geographic location. The problems and difficulties are different in all regions and continents, so IYA2009 has initiated special programmes to meet local needs.

Develop a Global Partnership for Development

Development relies on several factors, including the use of basic science to develop and use practical applications adequately. IYA2009 will connect networks of professional and amateur astronomers and astrophysicists from all over the world, providing an opportunity to share all the valuable sources of knowledge they have. The aim of the Year is to channel the information obtained into the right development projects and applications.

Make it Happen!

How can I participate in the International Year of Astronomy?

One of the International Year of Astronomy goals is to enable as many people as possible to experience the excitement of personal discovery that Galileo felt when he spied lunar craters and mountains, the moons of Jupiter, and other cosmic wonders. It is also meant to encourage citizens to think about how new observations force us to reconsider our understanding of the natural world.

If you're a newbie or an astronomy enthusiast…

If you are a beginner and would like to get some advice, the best you can do is to contact a local astronomy club, planetarium or science museum. A list of organizations worldwide can be found on http://skytonight.com/community/organizations or on http://www.astronomyclubs.com/

If you're an amateur astronomer…

For every professional astronomer, there are at least 20 amateur astronomers. The IAU is encouraging amateur astronomers to pay a major role in the organization of astronomy outreach activities. As an amateur astronomer, you can join a local astronomy club and plan some cool astronomy outreach activities. Lots of ideas can be "lifted" from the IYA activities pages, don't be afraid of replicating and adapting them according to your own country's history and culture. Get in touch with science teachers in the local schools and propose some practical activities for the students involving the observation of the sky.

If you're a professional astronomer…

You can do all the above, and contact your country's Single Point of Contact for getting advice and new ideas on what can be done in order to promote astronomy in your region. You can coordinate activities together with amateur astronomers, help them to publish your results and contribute to science.

I have an idea for an activity that's not listed in the activities pages. How can I submit it?

If you have a new idea and you are sure it is not listed in the national, regional and global activities, pages, you should contact the Single Point of Contact from your own country and propose your ideas to him or her. To contact the Single Point of Contact, please check www.astronomy2009.org, where you will find a list of countries and their national pages.

Bios

Pedro Russo is the IAU Coordinator for IYA2009. He is a member of the Venus Monitoring Camera/Venus Express Scientific Team and has been working with Europlanet, IAU Commission 55: Communicating Astronomy with the Public and EGU Earth and Space Science Informatics Division.

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The International Year of Astronomy 2009 and the Re-enlightenment

Opinion

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Key Words

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In 2009 we celebrate the International Year of Astronomy. The International Year of Astronomy 2009 is, above all, a celebration of the fulfilment, growth and creativity of humanity in its quest to understand the Universe and the life within it. In recent decades the pseudo-sciences seem to have been overpowering science in the public understanding of the world around us (Sagan 1996). As a prominent example, astrology is more widely accepted by the population as truth than alternative scientific explanations (Kelly et al. 1989). This may be due to the dedicated language of science or, more importantly, a lack of public understanding of it. Eventually, this lack of understanding will result in a notable hindrance in the cultural and literal advancement of society's comprehension of science and science subjects. If we are not careful, scientific, cultural, social and economic progress will be impeded and the modernization and prosperity of countries ultimately penalized. Therefore, now more than ever it is pressing to bring scientific and critical thinking back on to the agenda. The engagement of the scientific community, educators and the media is crucial in achieving this most important goal.

Astronomy, as a science, is committed to the use of critical reasoning, factual evidence, and rational methods of inquiry to probe the Universe. The amazement that the public feels toward astronomical images and quantities, together with addressing fundamental and inspirational questions regarding our place in the Universe, make astronomy not only essential for global education but also an excellent way of engaging the public in science, hence the importance of the International Year of Astronomy 2009.

The public feels it should be informed as much as it needs to be, and this should not be neglected. We believe that scientists have a duty to make knowledge accessible to everyone. This will avoid public alienation of science and enhance human well-being and individual responsibility. Scientific knowledge and understanding need not be difficult, and science in general should be demystified. The specificity of the language needed to produce original contributions to science should not be used as an excuse for the scientific community not to communicate the advances in the field and not make basic methods and explanations accessible to the population.

IYA2009 will be a vehicle to highlight and make acknowledgeable the merit of a scientist's role as a valuable contributor to society. Above all, IYA2009 is a celebration of the fulfilment, growth and creativity of humanity in its quest to understand the Universe and life within it.

The IYA2009 will be a good opportunity to reaffirm the place of astronomy in the cultural, artistic, social and scientific order and contribute to the fulfilment, growth, and creativity for both the individual and society. For example, astronomical insights into human existence could be put to use in the arts, philosophy, politics, criticism and democracy.

The itch to explore and the sense of wonder, when approaching existentialist questions, are common to every human. In this respect, astronomy is the key to an examined life. It deals with fundamental questions regarding the origin, location, nature and destiny of our species, our planet and the Universe. We believe that the astronomical perspective (without relegating humans to a peripheral place) can work as a common basis for global equity and peace and be used to change attitudes in an individualistic society towards a greater sense of community, as well as serve as a vehicle for mutual respect.

IYA2009 will clearly play an important role in establishing all of these aspects and it is a unique opportunity to re-enlighten society regarding science. Informed debate, scientific thinking, and tolerance as perceived from an astronomical perspective can be channelled into building a better world for our generation and the generations to come.

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Bios

Carla Gonçalves obtained her first degree in Astronomy at The University of Porto and her M.Sc. in Radiation Physics at University College London. After working as a Clinical Scientist for the English National Healthcare System. Carla is now working towards a degree in Medicine at UCL.

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Astronomy Cast: Evaluation of a Podcast Audience's Content Needs and Listening Habits

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Astronomy Content
Web-resources
Survey

Summary

In today's digital, on-demand society, consumers of information can self-select content that fits their interests and their schedule. Meeting the needs of these consumers are podcasts, *YouTube*, and other independent content providers. In this paper we answer the question of what the content provider can do to transform a podcast into an educational experience that consumers will seek. In an IRB-approved survey of 2257 *Astronomy Cast* listeners, we measured listener demographics, topics of interest and educational infrastructure needs. We find consumers desire focused, image-rich, fact-based content that includes news, interviews with researchers and observing tips.

Introduction

Thirty years ago, US news came from three television networks, music came from a small handful of big labels, and marketers made sure we ate, drank and wore what we were supposed to. Then came cable television, and suddenly content shifted, with new networks catering to consumers' needs and supplying golf, shopping and even soap operas 24 hours a day. With the advent of the Internet, the fractioning of the market has continued to the benefit of the public, who can now find programmes designed around such specific topics as *Grammar Girl's Quick and Dirty Tips for Better Writing* and the *Talking Reef*. In this tail-wags-the-market distribution system, consumers can easily find anything they want and will readily flip from one show to the next if they become bored. Catching and keeping an audience, a goal of every content provider, requires knowing what your audience wants and providing it.

Astronomy Cast, a weekly 30-minute audio podcast that takes its listeners on a facts-based journey through the Cosmos, has sought to educate while entertaining within the competitive podcast market. In doing this type of educational outreach to the public, it has been necessary to consider how to make content competitive within the greater market place. NASA and ESA's many video podcasts (vodcasts), and *Astronomy Cast* sit in the iTunes music store side-by-side with shows produced by the *New York Times*, *Scientific American*, and many public and commercial radio stations. To succeed in educating, we must take an example from the commercial marketing playbook and ask our listeners, 'What do you want?' Rather than teaching them what we think is important from pedagogical standpoints, people working on extreme public outreach — EPO that is more 'edutainment' than education — must find out what is interesting to Joe Public, and use those interests to lure Joe into learning.

To learn about the astronomy-interested audience, *Astronomy Cast* conducted a survey to find out who its listeners are, what they are interested in listening to, and what they need to improve their experience. In this paper we discuss: 1) survey setup, 2) the demographics of respondents, and 3) listener interests and self-identified needs. In the discussion section of this paper we suggest how this information can be applied, and what additional studies are needed.

Survey Administration

In designing *Astronomy Cast*, we looked to other shows to see what was popular. This led us to adopt a conversational style (*Skepticality, Skeptics Guide, IT Conversations*) that centered on science without including skits (*Quirks & Quarks, Science Friday*). This format, combined with our astronomy content, has worked. *Astronomy Cast* has ranked within the top 25 science and medicine podcasts since the third day after its September 2006 release. However, all because something works does not mean it cannot be improved. Additionally, our success is not necessarily something that can be replicated because we don't know if the true reasons for our success in the rankings have been identified. To try to create a recipe for creating popular podcasts and addressing the needs of astronomy-interested listeners, we created a listener survey that asked the listeners a series of questions relating to who they are, what they currently listen to, how podcasts have affected their attitude toward astronomy, and what we can we do to improve their experience. (The full text of this survey is in the appendix).

The listener survey was conducted from 13 to 23 July 2007, after receiving IRB approval. To safeguard the privacy of all respondents we used a secure socket layers (ssl) connection to a secure (https) webpage. We also did not ask for any identifying information and provided the option 'prefer not to answer' for all multiple-choice questions. Every question started with a null response. To allow duplicate surveys to be removed from our sample, we did save the IP addresses of all survey participants; that information was stored in an encrypted form.

The survey was promoted via a special promo podcast as well as in the 16 July episode of *Astronomy Cast*. As a lure to get people to complete the survey we promised survey participants access to a special, hidden, episode of *Astronomy Cast*. The promo episode was downloaded 10,003 times. The survey was completed 2437 times; however, there were 180 duplicate or spurious surveys. In the case of clear duplicates, defined as surveys with the same IP address and same answers to all multiple-choice data, we retained the record with more complete answers to the fill in the blank questions if there were any discrepancies. Spurious entries were defined as entries with multiple entries from the same IP address and randomized results that included the specific contradiction of a US or Canadian state and a non-US or Canadian country being selected as place of origin. An additional fifteen respondents had non-duplicate records, but indicated contradictory residence information. This represents 0.7% of our sample, and indicates we have a potential 'randomized clicks' error of ~1% in our responses.

Our final sample size was 2257 and represents 23% of the audience during that time period. For comparison, the *Slacker Astronomy* (Gay, Price, & Searle, 2006, hereafter GPS06) surveys in 2005 and 2006 only obtained a 4% response rate. They used the potential to win a gift certificate as a lure. We believe our success in obtaining survey respondents is due entirely to providing all participants access to hidden content. This theory is supported by 8 emails from listeners who were upset that they did not get to participate in the survey and obtain access to the hidden show. We strongly recommend using premium content to encourage listener participation, with the caveat that the listener must be able to answer, 'prefer not to respond' to all questions.

While we would like to believe the survey respondents were a representative sample of *Astronomy Cast* listeners, there is no way to prove this is true. Research into non-response bias in surveys is difficult to do. How do you randomly select non-respondents when your target population is anonymous? We have been unable to identify a method to determine the actual bias in our survey. Listeners of *Astronomy Cast* download episodes anonymously. At no point is any information received that would allow us to contact listeners who do not self-identify.

Listener Demographics

To determine who is listening to our episodes, we asked our listeners to self-identify personal characteristics including gender, age and education, as well as socio-economic characteristics such as household income and whether they owned a car. These characteristics are detailed in the appendix (questions 1-16).

1. Listener Personal Characteristics

Much to our frustration, we discovered that our audience is extremely gender skewed, with only 8.43% of the 2255 question respondents indicating they are female. This is a drop from the GPS06 surveys, which had 9% and 13% female respondents. *Astronomy Cast* has worked hard to have no sexual innuendo in its content and to promote women as scientists. Our only explanation for this extreme gender bias is the frequent comment that host Pamela Gay has a sexy voice (four respondents, to the question 'What type of content do you want to see?' commented on Gay's voice. Countless emails on this topic have also been received.). As a result of this survey, *Astronomy Cast* will work with a specialist on women and communications to help make their content appeal better to women.

In terms of age, we had a flat distribution from age 26 to 53 (each year of age had N = 53±7 respondents), with an average age of 40±10 years and a mode of 31 years. Above and below ages 26 and 53 years, there is an expected rapid fall-off in listeners. Our content level is geared toward college level, and many younger listeners will find it pitched too high and turn away. At the older end, the drop is caused both by the drop in population numbers and the lower use of technology by those over 50 (*US Census 2000*; Fox & Madden 2006). That said, we were very surprised to note there were 52 respondents (2% of those responding) aged 70 years and older (Figure 1).

Our listeners also came from all professional areas with only careers related to computers (23% of 2252 responding) contributing a double-digit percentage to our respondent pool. Students make up an additional 7.8% of our listeners, and the combined categories of K-12 and college educators make up 5.9% of our listeners. The only other area to break 5% was health/medicine with 5.4%.

Our listeners tend to be educated, with 33% of the respondents having a bachelor's degree (an additional 10% are graduate students), 30% having a undergraduate degree (an additional 5% are graduate students). It is always hard to understanding what household incomes mean when comparing international survey results; however, there is an undeniable trend to affluence in out survey data, with a strong curve in out data from low incomes to high incomes (Figure 2).

Our listeners also come from all over the world (see appendix, question 6). After removing all data from individuals who indicated a country other than Canada and the US while selecting a state/providence in the US or Canada, we found 58% of our respondents are from the US, 11% are from the UK, 7% are Australian, and 7% are Canadian. No other nations contributed

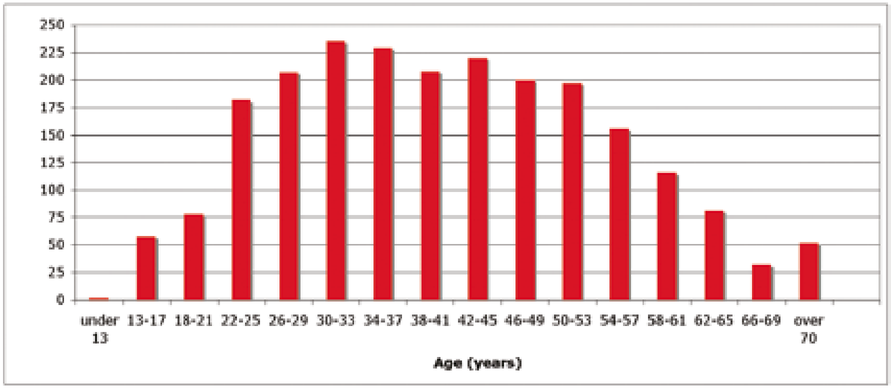

Figure 1. The age distribution of Astronomy Cast listener survey respondents. The average age is 40±10 years and a mode of 31 years.

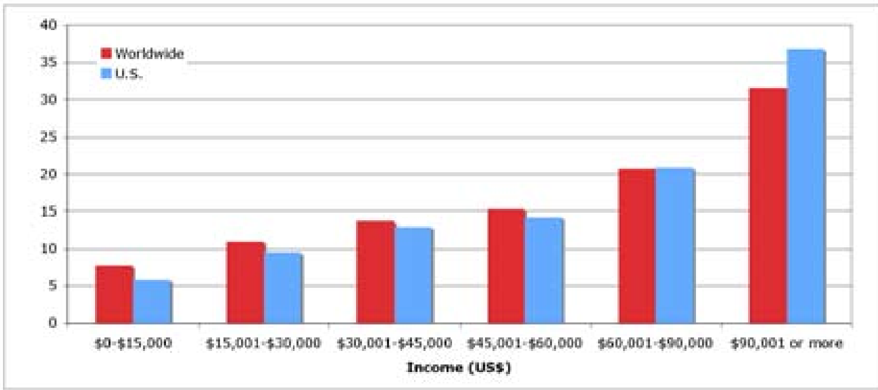

Figure 2. The income distribution of Astronomy Cast listener survey respondents. The total sample (N = 1843) is shown in red, and the sample of US respondents (N = 1122) is shown in blue.

more than 2% of our respondent pool. Together, the respondents represented 72 nations.

2. Listener Socio-economic Characteristics

The average *Astronomy Cast* listener is affluent and surrounded by technology. 99.7% of the respondents have computers in their homes, and 94.9% of those homes are connected to the Internet. Over 85% of them live in homes with portable MP3 players, DVD players, and cell phones. 52% of their homes have video game players, and 56% have Digital Video Recorders. They are not subscribing to satellite radio (only 13% have it in their households), but they are listening to podcasts, with the average respondent listening to 13.11 ± 10.53 podcasts. We do not feel this audience is necessarily typical of all podcasts, and in fact this audience is substantially wealthier than the GPS06 audience and is thus more able to have electronic gadgets.

Audience Impact and Needs

1. Impact of Podcasts on Listener Attitude toward Astronomy

One of the most significant results of GPS06 was documentation of the ability of podcasts to transform individuals from not being interested or only passively being interested in astronomy, to individuals actively seeking astronomy content. In our survey, we replicated their study and found similar results (Table 1). We found that 25% of our listener respondents had no interest or a passive interest in astronomy prior to listening to astronomy-related podcasts. After listening to astronomy-related podcasts, 70% of these individuals had begun to actively seek astronomy content or had become amateur astronomers. GPS06 saw 61% and 63% gains in their surveys.

We also found that while only 31.6% of our respondents had taken astronomy courses in high school or college, 61.2% are now either attending or interested in attending local astronomy lectures and 68.9% are interested in learning how to become involved in amateur astronomy. To understand this result, we need to ask, 'Why didn't you take astronomy before?' and 'What created your interest?' in a future study.

Table 1. Change in listener attitude toward astronomy content after listening to podcasts containing astronomy related content. We consider the first three categories passive content acquires and the last three categories active content acquirers.

Option	% Before	% After	Change
I knew how to spell astronomy	1.1	0.4	-0.7
I thought it was neat when I was a kid	2.9	0.1	-2.7
I will pay attention if it crops up in something I already read/ watch/listen to	20.8	7.1	-13.7
I actively seek and read/ watch/listen to stories about astronomy	56.7	70.0	13.3
I am an amateur astronomer and/or go to local astronomy club meetings	16.7	20.1	3.5
I am a professional astronomer or astronomy major in college	1.9	2.2	0.3

We have clearly identified a population of people who have a growing interest in astronomy content. Through edutainment we have inspired individuals to seek more classical educational experiences, such as attending local lectures.

2. Type of Content Being Listened to

To determine the listening habits of the *Astronomy Cast* audience, we asked our listeners to tell us their favorite podcasts, their favorite science podcasts, and then to list up to ten podcasts they listen to on a regular basis. Listeners could leave any of the questions blank.

When asked to list up to ten podcasts listened to regularly, 1876 people responded by listing a total of 2227 unique podcasts. In their 11,805 responses (37% listed ten podcasts, 15% listed one, and 4-7% listed two-nine podcasts), they demonstrated diverse tastes in topic. We attempted to classify the format and publisher of all podcasts listed by more than twenty people. (Table 2, at the bottom of the article)

While it is hard to clearly distinguish professional podcasts from volunteer efforts, there was clear diversity. 54% were from radio, television, and magazine publishers, 3% were from NASA, and the rest were from individuals with unknown funding sources.

In terms of format 1.4% of the shows were vodcasts. It is unclear if this is indicative of a lack of interest in vodcasts in general, or if it simply reflects that there are fewer vodcasts in the preferred subjects of our audience or fewer players able to play them.

It is clear from this list that we are only reaching one niche — those interested in science and medicine. Of the ten most frequently listed podcasts (representing 29% of responses), only two are not categorized in "Science & Medicine" by iTunes. In fact, in looking at all podcasts listed at least twenty times (61% of those listed), 71% are categorized in "Science & Medicine".

The niche nature of our audience also carries into how listeners responded to the question 'What is your favorite podcast?' Table 3 lists the top ten favorite podcasts. Several trends can be noted in this data. The top ten podcasts (representing 60% of the responses) show listeners are non-discriminatory with regard to show length, but prefer podcasts with more than one host, that operate in a panel format, or with hosts interviewing experts. Interestingly, 2.3% of respondents specifically indicated they have no favorite podcast (14% of survey participants also left this question blank). See appendix, question 21 for a complete list of responses.

Listeners were also asked to identify their favorite science-based podcast (Table 4). Respondents show a clear preference toward science podcasts with only one host (only three in the top ten had more than one host), even though they still prefer interview-style presentations. We believe this reflects a dearth of multi-host science-based podcasts. 22 of the top 25 Science and Medicine shows in iTunes are single-host productions. Of the top ten podcasts, only half are produced from radio shows. This implies that the best science podcasts can compete for listeners with radio shows made available through RSS feeds. (Table 5)

Astronomy Cast listeners are clearly a niche audience, listening to primarily science-based podcasts, while exhibiting interest in podcasts on tech news and current events. In general, most podcasts they listen to are hosted by one person, but they tend to prefer content presented in an interview, lecture or news magazine style. There is a sharp decline in the number of podcasts reported that have an average length of over an hour; by and large our respondents seem to be listening to podcasts between 30 minutes and an hour.

3. Content Sought

Each week *Astronomy Cast* presents a different topic for 30 minutes. Some shows are general (e.g. exoplanets), and others are more specific (e.g. Venus). By throwing out a variety of topics and hitting on both big picture topics and narrow topics we hope to meet the needs of our listeners. This is an uncomfortable strategy, and in the survey we asked the open-ended question, 'What type of content do you want to see?' so that we could provide what is actually wanted rather than guessing at what is wanted. Answers were sorted into 30 different bins to obtain a quantified breakdown of needs. A complete table of our bins and the number of responses fitting in each bin is listed in Appendix B. Full responses from listeners are not

Table 3. 10 podcasts most frequently listed as "favourite podcast" by respondents to the Astronomy Cast listener survey.

Podcast Name	Avg Length (hh:mm)	# Hosts	Topic	Presentation	N
Astronomy Cast	0:15 - 0:30	2	Science & Medicine	Discussion	689
The Skeptic's Guide to the Universe	1:15 - 1:30	6	Science & Medicine	Panel	200
Universe Today	0:05 - 0:15	1	Science & Medicine	Interviews	70
This Week in Tech	1:00 - 1:15	4	Tech News	Panel	48
None					45
BBC: In Our Time	1:30 - 1:45	4	Society & Culture	Panel	32
All					24
This American Life	0:45 - 1:00	1	Society & Culture	Talk Show	22
NPR: Wait, wait... Don't tell me!	0:45 - 1:00	1	News	Game show	21
Mysterious Universe	0:45 - 1:00	1	Science & Medicine	Discussion	20

Table 4. 10 podcasts most frequently listed as "favourite science podcast" by respondents to the Astronomy Cast listener survey.

Podcast Name	Avg Length (hh:mm)	# Hosts	Topic	Presentation	N
Astronomy Cast	0:15 - 0:30	2	Science & Medicine	Discussion	1244
The Skeptic's Guide to the Universe	1:15 - 1:30	6	Science & Medicine	Panel	130
Universe Today	0:05 - 0:15	1	Science & Medicine	Interviews	87
NPR: Science Friday	1:45 - 2:00	1	Science & Medicine	Interviews	43
Science Talk	0:15 - 0:30	1	Science & Medicine	Interviews	34
CBC Radio: Quirks & Quarks	0:45 - 1:00	1	Science & Medicine	Interviews	33
ABC Radio National Science Show	0:45 - 1:00	1	Science & Medicine	News	32
BBC: The Naked Scientists	0:45 - 1:00	1	Science & Medicine	Interviews	31
This Week in Science	0:45 - 1:00	2	Science & Medicine	News	30
None					24
SETI: Are We Alone?	0:45 - 1:00	1	Science & Medicine	Discussion	18
Astronomy Magazine Podcast	0:05 - 0:15	1	Science & Medicine	News	18

being made available to protect the privacy of respondents who opted to give personal information within the open response sections of this survey.

We found *Astronomy Cast* listeners are seeking a wide variety of astronomy-related content in their podcasts. Over 30 different desired topics were identified from the survey responses, ranging from the very complex and theoretical "Relativity" and "Quantum Mechanics", to the more concrete and familiar "Solar System Objects". Our respondents indicated the greatest desire to hear about thought-provoking, deep topics, with "Cosmology" requested in 5.5 % of the responses and "New Theories" following at 4.2%. Other popular requests were for more "Physics" and for more "Cutting Edge Research", at 3.3% and 3.1% respectively.

There was also a large interest in keeping up-to-date with information relating to our own Solar System. In 4.1% of the responses, listeners requested topics concerning the Sun, planets, and other Solar System objects. Another 2.1% wanted updates on the various probe and satellite missions that are under way in the Solar System, including past and possible future missions. This thirst for the latest information was also expressed more generally with approximately 6% of the responses requesting news of various types — discoveries, sky objects to observe, spacecraft missions, and general, brief news updates each week.

These results match with our multiple choice question responses to the question, 'What is your favorite type of show?' Of 2112 responding, 85% prefer the topic shows, 7% prefer shows in which we answer listener questions, and 8% prefer shows in which researchers are interviewed.

As well as asking about what content is needed, we also asked if the show is currently pitched at too high or two low a level on a five-point Likert scale. The overwhelming majority of our listeners (76% of 2154 responding) said the show is pitched just right, very few thought it was a little too hard (3%) or way too hard (two people), and some thought it was a little too simplified (20%) or way too simplified (1%).

4. Desired Web-resources

Currently, *Astronomy Cast* provides on its website the following content: links to mp3 audio files and a web-based audio player, show notes which include summaries of show content with extras such as definitions, expanded explanations, and links, as well as transcripts with embedded images. This content is provided regularly, but the formatting and richness of the content is very ad hoc, and is based on what we find interesting. In order to better meet our users' needs, we asked them the open-ended question, 'What online materials do you want to see with each show?'

Of the 1239 responses, the vast majority fell into two categories: 'Everything is all right as is' (23%) and 'I don't visit the website' (19%). Those not visiting the website consistently stated they listen to our podcast while away from their computer. The remaining 713 respondents (58%) listed specific online content as needed (see appendix). While the majority of their needs, such as images, links and show notes, were expected, three results caught us completely off guard. Specifically 4% of those stating specific needs requested references to original journal articles, 3% wanted us to

Table 5. Top 25 podcasts in iTunes Science and Medicine on Sept 12, 2007.

Rank	Podcast Name	# Hosts	Host(s)	Producer
1	60-second Psych	1	Christie Nicholson	Scientific American
2	Science Friday	1	Ira Flatow	NPR
3	Radio Lab	2	Jay Abrumrad & Robert Krulwich	WNYC
4	BrainStuff: The HowStuffWorks Podcast	1	Marshall Brain	HowStuffWorks
5	Wild Chronicles	1	Boyd Matson	National Geographic
6	Science Talk	1	Steve Mirsky	Scientific American
7	Hidden Universe HD		Dr. Robert Hurt	NASA/SSC
8	Hubblecast HD	1	Dr. Joe Liske	ESA/Hubble
9	60-second Science	1	Karen Hopkin	Scientific American
10	NPR: Hmmm.... Krulwich on Science	1	Robert Krulwich	NPR
11	The Skeptic's Guide to the Universe	1	Dr. Steven Novella	NESS
12	NPR: Environment	1	Varies	NPR
13	NOVA | PBS	1	Varies	WGBH
14	HD NASA's JPL		N/A	NASA
15	Green.tv		N/A	green.tv
16	Science Times	1	David Corcoran	New York Times
17	NASACast Video		N/A	NASA
18	The Naked Scientists	1	Dr. Chris Smith	Cambridge University
19	Food Science	1	Dr. Kiki	ON Networks
20	Astronomy Cast	2	Fraser Cain & Dr. Pamela Gay	Astronomy Cast
21	TERRA: The Nature of our World		Varies 1-2 filmmakers	Montana State University
22	Quirks & Quarks - Segmented Show	1	Bob McDonald	CBC Radio One
23	Skepticality	2	Derek Colanduno & Swoopy	Skeptic Magazine
24	Nature Podcast	1	Chris Smith	Nature
25	National Geographic World Talk	1	Patty Kim	National Geographic

explain the equations behind the concepts, and 3% wanted educational materials or slide shows to accompany the audio. Additionally, eight people asked for quizzes to accompany the shows so they could test their learning. We believe these requests indicate that people want to use these shows to obtain a high level of astronomy understanding and wish to make sure their understanding is correct.

Another unexpected result was that seven respondents indicated they do not listen to the show, but rather read our transcripts to access our content. Reasons stated included being hearing impaired (one person), not understanding English well enough to understand the spoken podcast (one person), and not being able to download large audio files (five people). While these seven people represented less than 1% of those responding, it should be noted that we did not specifically ask if people listen to our show or read our transcripts, so we do not know how large a population these people represent. This is a question that will need to be asked in a follow-up survey. We believe this result indicates that the simple act of providing transcripts to audio and video shows can allow the content to reach into underserved communities, including the hearing-impaired and those with limited Internet access.

Listener survey responses also addressed show format. Currently, *Astronomy Cast*, is an audio-only show processed to 64 kilobytes per second (kbs), and the typical show is 12-15 megabytes in size. Of those listing specific needs, 12% requested enhanced or video podcasts that would show images and/or video of topics being discussed. An additional 1% of those responding requested low-bandwidth versions of shows.

As with many surveys with open-ended questions, this survey did log several responses that were silly or social rather than intellectual in nature. On the reasonable side, nine people requested pictures of the *Astronomy Cast* hosts so they could know what the people they were listening to look like. On the unreasonable side, one person requested email addresses for all scientists mentioned in the show, three people requested images of naked women, one person requested a live band (other information shows, such as *Geologic*, do have this), and one person requested more cowbell. While we now intend to include pictures of the hosts online, the other needs in the area will go unmet.

Discussion

From our survey respondents, we can begin to envision a formula for an ideal show. Specifically, the perfect show should be under one hour, feature two hosts, and include interviews with real scientists, five-minute news updates, and information on any celestial events of interest to amateur astronomers. These shows should, ideally, be available in multiple formats (high-quality 64 kbs audio, low-quality 16 kbs audio, and possible video/enhanced mp4 format). Accompanying shows should be transcripts, links to supplementary materials including educational resources and original journal articles, and as many images and videos as possible. This formula is actually fairly close to the audio format of the existing and highly popular *Skepticality* podcast, although they do not have the requested online content.

In designing shows, our survey seems to indicate that there is a need for high-level content that requires listeners to intellectually reach. *Astronomy Cast* is pitched at a college-level that assumes the listener has had introductory science courses. In fan mail letters (not quantified due to lack of IRB approval to use them in research), listeners often comment that they cannot listen while doing other things because they must concentrate on our show. They also often comment that they must listen to shows multiple times and read the online content to feel confident that they fully understand the content of the shows. In future studies we feel there is a need to address the question how much effort listeners put into learning through the *Astronomy Cast* podcast.

This study allowed us to get an initial, quantified understanding of our listeners' demographics and needs. In also raised some interesting questions. In future studies we wish to ask further questions. What brings passive seekers of astronomy content to an astronomy podcast? How many "listeners" are actually reading our transcripts rather than listening to the show (and why)? And also, what about *Astronomy Cast* do people like most and least? We also need to ask the people who are now interested in astronomy classes why they did not take astronomy before and what created their interest.

After working to make our online content better reflect the needs of our listeners outlined in this paper, we will do a second listener survey to address the questions and to learn what new needs our listeners have discovered they cannot live without.

Conclusion

It's a cliché, but it's true. The Internet really is a revolutionary tool for reaching a highly targeted audience and delivering a comprehensive collection of multimedia resources: audio, video, animation and text. And this road goes both ways, allowing audiences to give nearly instant feedback to educators, allowing them to fine-tune their presentation to the needs of the audience.

The hunger for astronomy information is enormous, and is exemplified by the popularity of photographs from the *Hubble Space Telescope*. Listeners told us they can handle complex subjects as long as they are made understandable. Over time, their understanding and capabilities grow, as they learn to digest more and more complex information.

Perhaps what surprised us most during this survey process is the enthusiasm of the audience. They are learning about astronomy because they enjoy it, not because they have to. They find it intellectually stimulating, and want to know more. Time and time again we hear how our audience appreciates that we do not 'dumb things down.'

Podcasts like *Astronomy Cast* allow educators to deliver on the public enthusiasm for science information; inexpensively and quickly, and bypassing the traditional media gatekeepers that assumed the public is too ignorant or vacuous to handle the wonders of the Universe that nature reveals to anyone who cares to go searching for it.

Through podcasting, initially passive content non-seekers can be transformed into individuals who actively seek public lectures, classes and other astronomy activities. This introduces podcasts as a new tool to bring people into amateur astronomy. Podcasts appeal to a large range of ages, with our show appealing equally to people in their late twenties and early fifties. While the people who interact with podcasts tend to be college educated and affluent, and tend to have a lot of technological gadgets in their households, they are not just people employed in computer-related fields. Our audience includes people from all career fields. The audience is also global, with a podcast being produced in the US by a Canadian — US collaboration reaching 72 nations on six continents. This simple-to-produce communications media is a way to produce globally accessible content that can change attitudes and inspire learning.

Bios

Dr. Pamela L. Gay is an assistant research professor at Southern Illinois University Edwardsville. Her research interests include variable stars and assessing the impact of new media astronomy content on informal audiences. When not in the classroom or doing research, she co-hosts *Astronomy Cast* and writes the blog StarStryder.com.

Rebecca Bemrose-Fetter is an undergraduate majoring in physics at Southern Illinois University Edwardsville. In her free time, she has given volunteer astronomy presentations to Girl Scout groups and run astronomy-based sessions at conferences for gifted and talented children. Rebecca is the assistant producer of *Astronomy Cast*.

Georgia Bracey is a graduate student in Physics & Astronomy Education Research at Southern Illinois University Edwardsville, an experienced elementary school teacher and an amateur astronomer. She is currently interested in science education and public outreach, including the development and evaluation of science curricula and science teaching methods.

Fraser Cain is the publisher of *Universe Today*, a space and astronomy news website. He's also a freelance writer, with several published books, and articles in periodicals such as Wired. Fraser has also held executive positions in software and technology companies in Vancouver, BC. He's also co-host of *Astronomy Cast*.

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- The Skeptics Guide to the Universe, hosted by Steven Novella. http://www.theskepticsguide.org
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Note

1. To view the appendix please refer to the *CAP Journal* online at http://www.capjournal.org

Table 2. A list of all podcasts listed by more than 20 people in the Astronomy Cast listener survey as being regularly listened to. Listeners could listen up to 10 shows and no one listed the same show more than once.

Podcast Name	Avg Length (hh:mm)	# Hosts	Topic	Presentation
60 Second Science (Scientific American)	< 0:05	1	Science & Medicine	Lecture
ABC NewsRadio: StarStuff (Australia)	0:15 - 0:30	1	Science & Medicine	News
ABC Radio National: All in the Mind	0:15 - 0:30	1	Science & Medicine	Interviews
ABC Radio National: Ockham's Razor	0:05 - 0:15	1	Science & Medicine	Interviews
ABC Radio National: The Science Show	0:45 - 1:00	1	Science & Medicine	News
APM: A Prairie Home Companion News from Lake Woebegon	0:05 - 0:15	1	Comedy	Talk Show
Archaeology Channel	0:05 - 0:15	1	Science & Medicine	News
Ask a Ninja	< 0:05	1	Comedy	Video
Astronomy 161	0:30 - 0:45	1	Science & Medicine	Lecture
Astronomy a Go-Go!	0:45 - 1:00	1	Education	Lecture
Astronomy Cast	0:15 - 0:30	2	Science & Medicine	Discussion
Astronomy Magazine Podcast	0:05 - 0:15	1	Science & Medicine	News
Bad Astronomy: Q & BA Vodcast	0:05 - 0:15	1	Science & Medicine	Lecture
BBC NewsPod	0:30 - 0:45	1	News & Politics	News
BBC World Service: Digital Planet	0:15 - 0:30	1	Technology	News
BBC: From Our Own Correspondent	0:15 - 0:30	1	News & Politics	News
BBC: In Our Time	0:30 - 0:45	4	Society & Culture	Panel
BBC: Mark Kermode Film Reviews	0:15 - 0:30	2	TV & Film	Reviews
BBC: The Naked Scientists	0:45 - 1:00	1	Science & Medicine	Interviews
Berkeley Groks Science	0:30 - 0:45	2	Science & Medicine	Interviews
CBC Radio: Quirks and Quarks	0:45 - 1:00	1	Science & Medicine	Interviews
CNET: Buzz Out Loud	0:30 - 0:45	2	Technology	News
Cranky Geeks	0:30 - 0:45	1	Tech News	Panel
Dan Carlin's Hardcore History	0:45 - 1:00	1	History	Lecture
Democracy Now	0:45 - 1:00	1	News & Politics	News
Diggnation	0:45 - 1:00	2	Tech News	News
DL.TV	0:30 - 0:45	1	Tech News	News
Dogma Free America	0:45 - 1:00	2	Other	Interviews
Dr Karl on Triple J	0:30 - 0:45	1	Science & Medicine	Discussion
Escape Pod	0:30 - 0:45	1	Literature	Commentary
FreeThought Radio	0:45 - 1:00	2	Other	Discussion
Futures in Biotech	0:45 - 1:00	2	Science & Medicine	News
GeekBrief	< 0:05	1	Gadgets	Video
Grammar Girl	0:05 - 0:15	1	Language Courses	Lecture
Guardian Unlimited: Science Weekly	0:15 - 0:30	1	Science & Medicine	News
Infidel Guy	1:00 - 1:15	1	Other	Discussion
KCRW: Left, Right & Center	0:15 - 0:30	4	News & Politics	Discussion
Logically Critical	0:30 - 0:45	1	Science & Medicine	Discussion
MacBreak Weekly	1:00 - 1:15	4	Tech News	Discussion
MacCast	0:45 - 1:00	1	Tech News	News & Reviews
MSNBC: Meet the Press	0:45 - 1:00	1	News & Politics	Interviews
Mysterious Universe	0:45 - 1:00	1	Science & Medicine	Discussion
NASA	varies	varies	varies	varies
NASA: Hidden Universe	< 0:05	varies	Science & Medicine	Video
NASA/ESA: HubbleCast	< 0:05	varies	Science & Medicine	Video
NASA: JPL	< 0:05	varies	Science & Medicine	News
NASACast	< 0:05	varies	Science & Medicine	News
NASACast Video	< 0:05	varies	Science & Medicine	Video
National Geographic	varies	varies	varies	varies
Nature	0:15 - 0:30	1	Science & Medicine	Interviews
Net @ Nite	0:45 - 1:00	2	Tech News	News
New Scientist	0:15 - 0:30	1	Science & Medicine	News
New York Times: Science Times	0:15 - 0:30	1	Science & Medicine	Lecture
NOVA	< 0:05	1	Science & Medicine	News
NOVA Science Now	< 0:05	1	Science & Medicine	News
NPR	varies	varies	varies	varies
NPR: Car Talk	0:45 - 1:00	2	Performing Arts	Interviews
NPR: Fresh Air	0:30 - 0:45	1	Society & Culture	Interviews
NPR: Radio Lab	0:45 - 1:00	2	Science & Medicine	Discussion
NPR: Science Friday	1:45 - 2:00	1	Science & Medicine	Interviews
NPR: This American Life	0:45 - 1:00	1	Society & Culture	Talk Show
NPR: Wait, wait... Don't tell me!	0:45 - 1:00	1	News	Game show
Planetary Radio	0:15 - 0:30	1	Science & Medicine	Interviews
Point of Inquiry	0:30 - 0:45	1	Science & Medicine	Interviews
PseudoPod	0:15 - 0:30	2	Literature	Magazine
QuackCast	0:15 - 0:30	1	Science & Medicine	Discussion
Real Time with Bill Maher	0:45 - 1:00	1	News & Politics	Talk Show
Science @ NASA	< 0:05	1	Science & Medicine	News
Science Magazine Podcast	0:30 - 0:45	1	Science & Medicine	News
Science Talk	0:15 - 0:30	1	Science & Medicine	Interviews
Security Now	0:45 - 1:00	2	Tech News	Discussion
SETI: Are We Alone?	0:45 - 1:00	1	Science & Medicine	Discussion
Skepticality	0:45 - 1:00	2	Science & Medicine	Talk Show
Skeptoid	0:05 - 0:15	1	Science & Medicine	Lecture
Slacker Astronomy	0:05 - 0:15	2	Science & Medicine	Discussion
Slackerpedia Galactica	0:30 - 0:45	3	Science & Medicine	News
Slate Daily Podcast	0:05 - 0:15	1	News & Politics	News
Slice of SciFi	0:30 - 0:45	2	TV & Film	Reviews
StarDate	< 0:05	1	Science & Medicine	Lecture
STScI: Sky Watch	< 0:05	2	Science & Medicine	News
TEDTalks	0:15 - 0:30	N/A	Education	Lecture
The Economist Podcast	0:05 - 0:15	2	News & Politics	Magazine
The Jodcast	0:30 - 0:45	4	Science & Medicine	News
The Onion Radio	< 0:05	1	Comedy	News Parody
The Skeptic's Guide to the Universe	1:15 - 1:30	6	Science & Medicine	Panel
This Week in Science	0:45 - 1:00	2	Science & Medicine	News
This Week in Tech	1:00 - 1:15	4	Tech News	Panel
Tiki Bar TV (video)	< 0:05	varies	Comedy	Video
TWiT: The Daily Giz Wiz	0:05 - 0:15	2	Tech News	Reviews
Universe Today	0:05 - 0:15	1	Science & Medicine	Lecture
Windows Weekly	0:45 - 1:00	1	Tech News	Lecture

I Tune, You Tube, We Rule

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Key Words

New media
Videos
YouTube
iTunes
Digital Media

Summary

The website *YouTube* was created in 2005 and has rapidly become one of the most popular entertainment websites on the internet. It is riding the online video wave today like few other online companies and is currently more popular than the video sections of either *Yahoo* or *Google*. *iTunes*, a digital media application created by Apple in 2001, where one can download and play music and videos, has had a similar success. There is little doubt that they both represent important communication channels in a world heavily influenced by online media, especially among teenagers and young adults. As science communicators we can use this direct route to a younger audience to our advantage. This article aims to give a taste of these applications with a few selected examples demonstrating that both *YouTube* and *iTunes* are excellent tools to teach and inspire the general public.

YouTube

There are typically three types of astronomy videos seen in *YouTube*: short clips, most of them recorded by amateurs and distributed free to the world; longer ones, in some cases professionally produced by big companies or organizations, and lastly videos uploaded on the web (often without permission) from previously published productions such as Carl Sagan's beautiful *Cosmos* series. The first are low-cost and can be just as interesting as long productions full of special effects. In this category, the "how to" videos may be among the most appealing ones. These videos have often allowed individual amateurs to share a huge amount of knowledge and information with a large audience. Topics may include the workings of telescopes in general, specific functions, such as how to use a *GOTO* telescope system as well as generic astronomy tutorials. YouTube allows this much sought after information to be quickly disseminated and is becoming an essential tool for the beginner astronomer.

Webcam mod for Telescope is an example of a popular video for beginners in amateur astronomy. It describes how to adapt a cheap webcam and make it work as an astronomical camera to be attached to a telescope in a concise and practical way. With over 20,000 views it is

Figure 1. Webcam mod for Telescope, (Credit YouTube user: jorowi)from http://www.youtube.com/watch?v=9khTIkwNmW8.

easy to see how popular such tutorial-based astronomy videos are.

One can also imagine that videos on how to observe the Sun, eclipses, or comets could be produced, and these would probably go a long way towards enthusing and educating a public that might not otherwise engage in astronomical activities. Similarly, short movies without any narration but with the right visuals can also do the job. One example is *Aurora*, a clip of some time-lapse footage that shows impressive views of the aurorae australis and the sky over Antarctica. Without any spoken information, it is capable of both inspiring and intriguing the public. The user can always find a video which might tell them more about a particular phenomenon by following *YouTube*'s "related" box to the right of the video.

Other videos such as the 3D animation *Orion Nebula 3D* also give an excellent insight into the physics of space. A lay viewer is more likely to absorb the information contained in the video with the aid of an explanatory narration, atmospheric music and excellent visuals. So long as sufficient quality is maintained, this will ultimately result in users watching astronomy

Figure 2. Aurora, (Credit YouTube user: Antzarctica)from http://www.youtube.com/watch?v=icugqEEOgkg.

Figure 3. Orion Nebula 3D takes us on a journey into one of the most famous nebulae in the sky. From http://www.youtube.com/watch?v=PyxOF_8T5hg (Credit YouTube user: Indriq; Animation credit: VisLab SDSC).

content that they might not usually be drawn to. Today, even the big public outreach offices of space agencies and observatories worldwide are using *YouTube* to reach a wider audience. An excellent example of a professionally produced video from a public outreach office is *Black Holes: Tall, Grande, Venti* from NASA's Chandra X-ray Observatory. Users who enjoy these videos can usually also subscribe to the outreach office's *YouTube* channel — as is the case with the Chandra video. But the beauty of *YouTube* is the ease with which such videos can be produced, uploaded and shared. Huge budgets are not always required as even seemingly low-cost productions can have a profound and influential impact. Take the superb video *Ant: Light Pollution* whose anti-light pollution message is as simple as it is eloquent and powerful.

Figure 4. Black Holes: Tall, Grande, Venti is a video produced by NASA's Chandra X-Ray Observatory public information office and is about one of the most intriguing subjects in popular astronomy. (Credit YouTube user: cxcpub) from http://www.youtube.com/watch?v=yPj641uN9Gc

iTunes

iTunes is an application that can be downloaded for free (see references for the link). In the *iTunes Store*, under the "Podcast" and "Science and Medicine" sections, several astronomy video podcasts may be found. Downloads and uploads are free. Submitting videos to *iTunes* rather that *YouTube* may require a bit more time, but the experience is worthwhile. As with *YouTube*, *iTunes* has been used to great effect by many of the world's big science and astronomy public affairs offices and there is no

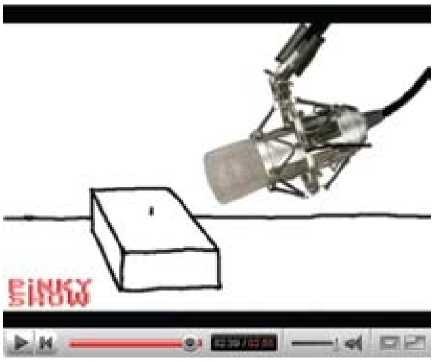

Figure 5. Ant: Light Pollution (Credit YouTube user: pinkyshow) from http://www.youtube.com/watch?v=skKpivApW7E.

Figure 6. Hidden Universe HD is also a great video podcast series with stunning graphical and audio content. (Credit NASA/Spitzer Science Center/Robert Hurt.)

reason why we, as science communicators, should not do the same.

Using These New Technologies to Our Advantage and Avoiding Misconceptions

These media can be used in a fairly broad manner by science communicators either by using the videos in both formal and informal

Bios

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educational situations, during talks to the public, or as an alternative distribution channel for releases and news with a large user base for new or existing video material.

Internet video is the medium of choice today for many people looking for news and information. People watch what they want, and a key step to induce lots of mouse clicks on your video is an interesting title and an eye-catching icon. It is equally important that the content be visually appealing, not too long and factually correct. Bad science and misconceptions in astronomy can be easily disseminated through this medium, so we, as astronomy communicators, are in charge of providing good content for the public.

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- HubblecastHD: http://www.spacetelescope.org/videos/hubblecast.html
- iTunes: www.apple.com/itunes
- YouTube: www.youtube.com

Figure 7. Hubblecast HD is a video podcast series that showcases the latest news and images from the Hubble Space Telescope. Read more about the production details in Christensen & Shida (2007). (Credit ESA/Hubble.)

Astronomy in *Second Life:* A User's Perspective

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Key Words

Communication via social networking
Multi-user virtual environments
Second Life
Outreach, informal education

Summary

Second Life (*SL*) is a multi-user virtual environment that is not limited to adult social entertainment. *SL* is also a 3D playground for innovative instructors and education/outreach professionals in the sciences. Astronomy and space science have a presence in *SL*, but it could be so much more. This paper describes some of the current astronomy themed spaces in *SL* and briefly discusses future innovations.

Second Life[1] (SL) is a multi-user virtual environment (MUVE) owned and managed by a company called Linden Labs in San Francisco, California (USA). Residents use customizable building blocks called *prims* to sculpt and mould their world. Current user metrics[2] indicate that there are 4.3 million individual human users, roughly 8 million 3D avatars, with approximately 40,000 avatars in-world at any given time, and 500,000 repeat visitors. Second Life key metrics (current to May 2007) report that 28% of avatars were aged 18-24, 39% in the 25-34 age range, 21% in the 35-44 age range, and only 12% were 45 or older. This multi-user virtual world is truly international. Self-reported nationality data shows that 25% of users are from the United States as compared to 39% for European countries.

Popular press reports concentrate mostly on the gambling, "griefing"[3] and more adult content of this metaverse. However, at the 2007 Second Life Community Convention Education Track it was reported that 161 colleges/universities have an active *SL* presence and 35-40 classes are taught in the virtual world. The science, humanities, medical, technology, business and law schools are all represented. Innovative faculty and instructional staff continue to develop educational experiences for their students with this bleeding-edge technology[4]. Informal education projects also take advantage of this amazing online program. Replicas of cathedrals, cities, artefacts, and historically significant role-playing sims[5] all exist to educate the general public. Most of the higher education projects are also open to the public to enjoy. Many sciences are represented by the SciLands consortium of 34+ islands: genome research, physics, health sciences, information sciences, nanotechnology, biology, space technology, and astronomy are among those currently represented. In addition, the National Oceanic and Atmospheric Administration (NOAA) has a spectacular build[6] where you can not only see inside a hurricane, but watch a tsunami form and ruin a coastline. But what about astronomy?

Figure 1. The author's avatar, Ourania Fizgig, gazes through a small telescope to see The Eagle Nebula.

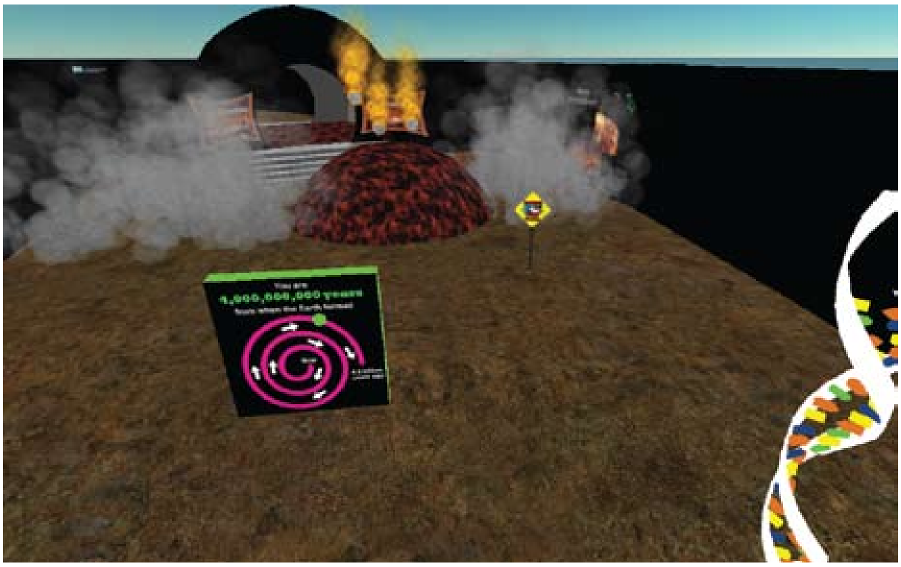

Figure 2. Portion of the Timeline of Earth Exhibit, from 4 million years ago showing a molten Earth leading into the Heavy Bombardment period where avatars have to dodge debris (Primary exhibit builder: David Huber).

Ourania Fizgig (my avatar) was created in December 2006 as I prepared for an undergraduate non-major general science course on "Life in the Universe", taught by Professor Chris Impey at the University of Arizona. I was asked to design, implement and manage an astrobiology/astronomy-related project in Second Life with the students. A handful of students were courageous and innovative enough to participate. We decided to build a scale model showing the timeline of Earth, from 4.6 billion years ago to the present. The exhibit has the timeline stretched along a spiral structure with images, 3D models, movies and Notecards[7] of text to provide content to the audience. The early content revolves around geological and atmospheric processes, but once life emerges, the timeline focuses on biology and chemistry. We

Figure 3. Breathtaking view of the International Space Station and the Space Shuttle Endeavour.

plan to build a "Timeline of the Universe" wrapper for the Earth timeline, placing the Earth in context with the rest of the Universe and thus being able to add beautiful astronomical imagery. This ambitious initial build was completed in August 2007 and is found in the sky of the LivingintheUniverse sim[8].

This project is not the only astronomy-themed sim in Second Life, which also has the Interna-

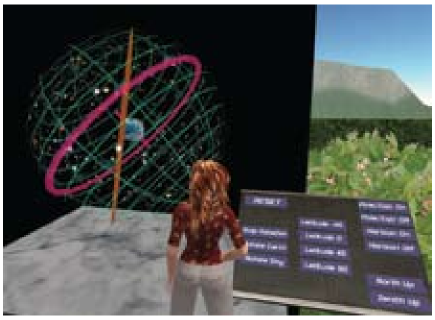

Figure 4. Interactive Celestial Sphere at the SL Science Center.

tional Spaceflight Museum[9], JPL's (Jet Propulsion Lab) Explorer Island[10], *SL* Planetarium[11], *SL* Science Center[12], and NASA Colab[13] . In addition, some astronomy minded avatars have built small telescope models that show limited astronomical imagery. Others play with planet textures to create scale models of the Solar System and decorative orreries. NASA Live TV streams into *SL* at numerous locations for special events like launches or other public programming. In March 2006 the Exploratorium (San Francisco, California) hosted a live video feed of the eclipse from Turkey in Second Life. The accompanying eclipse exhibit built by *SL*

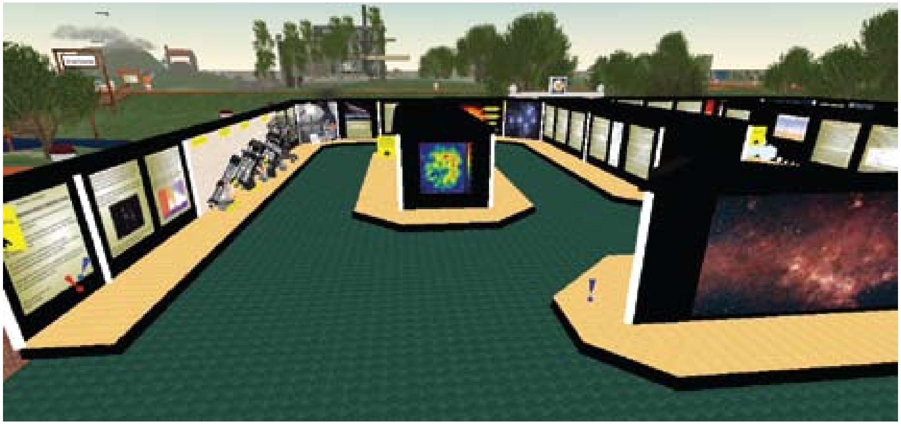

Figure 5. Roger Amdahl's Physics and Astronomy display space in Primrose.

architect Aimee Weber[14] is still well visited and referenced today. They also streamed the rare transit of Mercury into *SL* from observations at Kitt Peak Observatory in Arizona. The popular astronomy podcast, Slacker Astronomy[15], also has a small bit of land in *SL* to visit.

One astronomical adventure in *SL* is a content-rich display space created by avatar Roger Amdahl[16]. He takes us through the basics of electromagnetic radiation, telescope optics, interferometry, spectroscopy and their relation to astronomical objects. Another individual astronomy project is an interactive Celestial Sphere created by avatar Prospero Frobozz[17]. Avatars can manoeuvre their camera or view to be inside The Celestial Sphere and watch. Numerous educational activities can be built around the manipulated views as the controls adjust the projection of the sphere to reflect any latitude on Earth.

The *SL* Planetarium[18] is managed by avatar Chaac Amarula. Anthony Crider, a real-life professor at Elon University, has used the planetarium for instruction. Scripted shows are imagined, designed, and implemented by his students. A working replica of a Meade telescope sits outside the *SL* planetarium. Students can be engaged with the 3D model as they learn how to operate such a telescope in real life.

Science School[19] is a notable higher education project that is located on the SciLands continent and focuses on physics and astronomy education. Their sim houses the Second Life Observatory, modelled on the Mount Evans Meyer-Womble Observatory at the University of Denver. Astronomical imagery can be seen through the eyepieces of the telescope if the camera controls are worked correctly.

The Jet Propulsion Lab (JPL) at Caltech has a strong and growing presence in *SL* and based on Explorer Island with amazing model building of past, present, and future space technology. In one area it appears they are experimenting with stereoscopic images of the lunar and Martian surfaces. One corner[20] of their sim is dedicated to recreating portions of Mars. Avatars should watch for dust devils, rovers, and bouncing Mars airbags. Exhibits under development sit high above Explorer Island. The Victoria Crater model is inspiring and the view of the Space Shuttle Endeavour and the International Space Station (under construction) over Earth is breathtaking. Their sim also hosts the obligatory scale model of the Solar System.

In August 2007 I participated in the *SL* launch event at Explorer Island for the Phoenix Mars Mission. My colleague is a part of the Phoenix Mars EPO (education and public outreach team) and was asked to speak in *SL* on launch day. She was at Cape Canaveral anxiously awaiting the live launch. I was in Tucson and up at 3 a.m. to watch the live launch video feed in *SL*. We collaborated for her interview over the phone as she gave me details and answered

Figure 6. Second Life planetarium and telescope.

Figure 7. View of the International Spaceflight Museum.

questions from the *SL* audience, and I typed the answers through her avatar. Following the actual launch, I updated her on the rocket once it left their view at Cape Canaveral but was still being shown zoomed-in for the video feed. The power of social computing was evident that morning when the sim filled around launch time as many avatars wanted to see the video feed.

Last on the list of astronomy themed places in Second Life is the well-known International Spaceflight Museum, the original driving force of the SciLands consortium. Here models (some working) of various rockets, satellites and vehicles are displayed. There is some specific astronomy content spread throughout the sim and it also contains a scale model of the Solar System.

In general, Second Life seems to lack hardcore astronomy content — all those beautiful images of galaxies, nebulae, and star clusters from the world's telescopes and the rich contextual information that comes from the various education and public outreach offices. Where are they? Why haven't they found Second Life? My sources tell me they have, that it is just a matter of time and development cost. The International Year of Astronomy may also play a role in bringing more astronomy to Second Life. I can imagine installations of images being peppered throughout *SL* at special events and in high traffic sims to mimic the real life cornerstone IYA (International Year of Astronomy) 2009 project, The Universe from Earth[21]. I'd personally like to see an aggregator of astronomical images and contextual information brought into an *SL* exhibit space. This may become possible in the coming year if grant monies are forthcoming. Now that we have Google Sky[22], how can that integrate with Second Life? NOAA may be leading this bleeding edge of development with their Second Earth[23] project that melds Second Life and Google Earth to deliver visualized weather and other data for scientists and the general public. Ponder the possibilities for astronomy, a Second Sky perhaps?

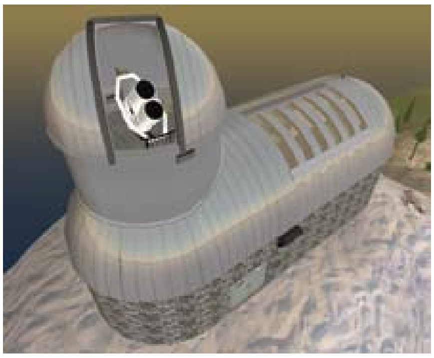

Figure 8. Second Life Observatory modelled on the University of Denver, Mt Evans Meyer-Womble Observatory.

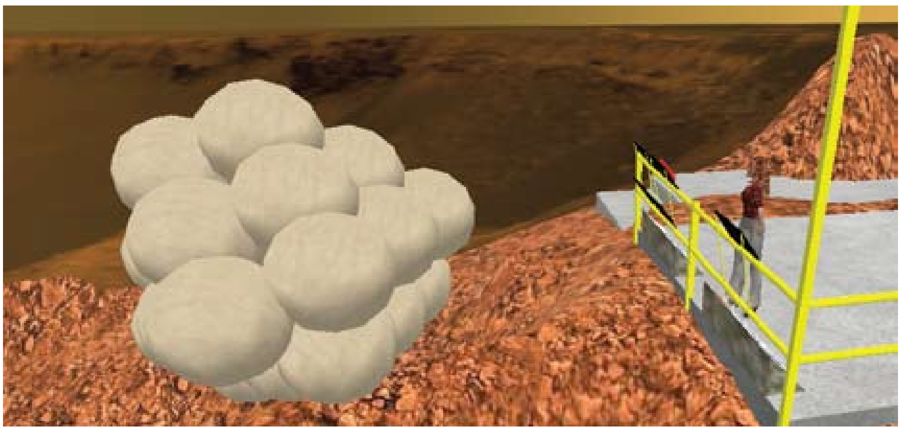

Figure 9. My avatar triggering a re-enactment of the rover airbag landing on Mars.

Bio

Adrienne J. Gauthier, M.Ed. is an Instructional Specialist in Steward Observatory (University of Arizona) and chair of the VAMP project. She specializes in online learning environments, social computing, and innovative uses of technology to enhance learning, and instructional design and development for astronomy education products.

Notes

1. Second Life, a multi-user virtual environment owned by Linden Labs. http://secondlife.com
2. http://blog.secondlife.com/2007/06/12/may-2007-key-metrics-published/
3. Griefing is an act of vandalism in online virtual worlds.
4. Bleeding-edge technology is technology that is at the very forefront of technological advancement, i.e. ahead of cutting edge technology.
5. Sim refers to a 65,000 square meter space in *SL* in which 15,000 prims are available for building.
6. http://slurl.com/secondlife/Meteora/177/161/27/
7. A Notecard is a simple text window shown on the screen. Content creators in *SL* can easily give information to avatars using this method.
8. http://slurl.com/secondlife/LivingintheUniverse/45/190/251/
9. http://slurl.com/secondlife/Spaceport%20Alpha/48/78/24/
10. http://slurl.com/secondlife/Explorer%20Island/182/155/23/
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Press Releases and the Framing of Science Journalism

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Opinion

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Key Words

Science
Journalism
Press Releases
Embargo

In a recent summary of a significant publication, I devoted a few paragraphs to slamming the press release that accompanied the results, since I viewed it as presenting assumptions as established fact with no underlying data to support them. This seems to have happened at a time where a general debate has erupted over the ways science gets presented to the public and the role of journalists in the communication process. I've now viewed the internals of pretty much every step of the pipeline that runs from results to public press, and I've given some thought to what goes wrong along the way to produce press coverage that's misleading and/or inaccurate. So what follows is both a description of the process for the curious, and my take on what the problems are.

In general, most science stories start with a publication. There are exceptions to this — major astronomical sightings and large scientific meetings produce their share of press coverage — but for the most part, scientists like to keep the profile of their results low until they have passed peer review. Mostly, the press is made aware of publications through the embargo system run by the journals or through press releases from the institutions where the researchers work.

There's a number of ways for things to go sour here. The clearest problem is that press officers are dedicated to creating positive coverage of whatever institution they are a part of, be it a university or a journal. Part of that job involves making scientific results as broadly interesting and significant — as newsworthy — as they possibly can. That can often lead them to spin the results in a way that the people who actually produced them may view as inaccurate, over-hyped or oversimplified.

The chances of this happening are probably proportional to the press officer's expertise in the relevant field of research. And that, of course, is going to vary wildly. As a result, press releases vary in quality from something as good as an experienced science writer might produce to borderline incoherence.

Scientists themselves, however, share part of the blame for this wide range of quality. Part of this stems from our willingness to write in jargon that limits our audience to fellow experts in our fields. One article I covered spent much of its introduction discussing the differences between the 'cognition-based perceptual fluency/misattribution theory' and the 'affect-based hedonic fluency model' but didn't define either of these until much later in the paper. The press release announcing the results was (surprise!) difficult to fathom, and the results received almost no coverage beyond Ars: good for Ars, bad for nearly everyone else involved.

Some of the confusion could be avoided if scientists and press offices worked more closely together, but my experience is that their interactions are somewhat limited. A lot of the blame for this falls on the shoulders of the scientists, as they tend to view the press office as a distraction from their work rather than as the first step towards an informed public. My experience has been that researchers are generally cooperative with the press, but they interact very little with their own institution's press office, perhaps because they recognize that there is an unpleasantly high ratio of press releases to press coverage.

So the press releases that reach the hands of journalists can vary widely in quality. Assuming the story gets covered, one of two things tends to happen. Most news outlets no longer have dedicated science journalists (this is especially true of the web-based press), and they hand the story to someone who rearranges the press release and publishes. This is depressingly common and sends any flaws in the release straight on to the public.

Even dedicated science journalists, however, don't always have the time or ability to read and digest the underlying publication. They often end up structuring their reports around the press releases and counting on interviews with the scientists in order to fill out the report. This again leaves the journalists highly dependent on the quality of the press release; if it's bad, the writer may reduced to squeezing a scientist's words into a story that's scientifically unsound. The interviews may give the scientists the opportunity to correct any misinterpretations by the journalist ,but it depends in part on the time and effort that they expend in talking to the press. Any miscommunications between the two may result in the kind of horror stories that started the recent discussions of science/press relations.

The whole process becomes a bit like the game of Chinese whispers, where an original message gets badly distorted as it's passed around the room by word of mouth. To make matters worse, there's a lot of mistrust at both ends of the chain: scientists may view the press as prone to misreporting and sensationalism, while the press probably views scientists as being uncooperative and possessing limited communications skills. I pity the press officers that have to act as a bridge between the two.

To fix this, the scientific community is going to have to do two things. The first is to recognize that press coverage is neither a distraction nor an unseemly display of ego; rather, it is an essential part of maintaining an informed and scientifically literate public. The second is to recognize the central role that the press release now occupies in this process. Scientists can start to improve the situation by making their publications accessible to a broader audience, but they will have to go beyond that. They need to know when a press release about their research is being made, they need to work with the press officer involved to make sure it's right, and they need to recognize that the press officer probably has better communication skills than they do.

Scientists are the first step in the process and, accordingly, they need to be the first to get their act together. Once the scientific community does a better job of ensuring that the press has good material to work with, it'll be in a far better position to recognize when the journalists get things wrong and to work on ensuring that those mistakes don't get repeated.

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Manuscripts should be delivered in MS Word or text (.txt) format, with no formatting apart from bold, italics, super- and subscripts. Hard carriage returns after each line should be avoided, as should double spacing between sentences. If the contribution contains figures, these may — just for the sake of overview — be pasted inline in the Word manuscript along with the caption (Word files below 4 MB are encouraged). However, images must also be delivered individually as Tiff, PDFs, vector-files (e.g. .ai, .eps) in as high a resolution as possible (minimum 1000 pixels along the longest edge).

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