CAP journal

issue 5 | January 2009

Communicating Astronomy with the Public

Astrology and Astronomy
From Conjunction to Opposition

Capturing Heaven
Visualising the Universe

ASTRONET: Public Outreach
A Strategic Plan for European Astronomy Outreach

THE UNIVERSE YOURS TO DISCOVER
INTERNATIONAL YEAR OF ASTRONOMY 2009

IAU

www.capjournal.org

Colophon

Editor-in-Chief
Pedro Russo

Executive Editor
Lars Lindberg Christensen

Editors
Terry Mahoney
Anne Rhodes

Assistant Editors
Lee Pullen
Catherine Moloney

Layout and Production
Mafalda Martins
Pedro Russo
André Roquette
Martin Kornmesser

Contributors
Emily Lakdawalla
Wallace Tucker
Daniel Kunth
Lee Pullen
Pedro Russo
Greg Martin
Rosa M. Ros
Robert Fosbury
Lars Lindberg Christensen
Jose Carlos del Toro Iniesta
Leonarda Fucili
Robert Hill
Dirk Lorenzen
Claus Madsen
Andy Newsam
Alan Pickwick
Veselka Radeva
Ryan Wyatt

Web Design and Development
Raquel Shida

IAU DIVISION XII, Commission 55: Communicating Astronomy with the Public Journal Working Group
Lars Lindberg Christensen
Rick Fienberg
Andrew Fraknoi
Richard de Grijs
André Heck
Terry Mahoney
Steve Miller
Paul Murdin
Pedro Russo
Sidney Wolff

Thanks to
Britt Sjöberg, Mariana Barrosa and Julia Westner

Published by
IAU DIVISION XII Commission 55: Communicating Astronomy with the Public

Sponsored by
ESA/ST-ECF, ESO, Fundação para a Ciência e a Tecnologia, Portugal and Navegar Foundation, Portugal

CAPjournal
Communicating Astronomy with the Public Journal
ESO ePOD
Karl-Schwarzschild-Strasse 2
85748 Garching bei München
Germany

E-mail: editor@capjournal.org
Phone: +49 89 320 06 195
Fax: +49 89 320 2362

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

Contents

Submit articles for one of the following journal sections:

- **Announcements**
- **Reviews**
- **News**
- **Resources**
- **Innovations**
- **Research & Applications**
- **Letters to the Editor**
- **Opinion**
- **Best Practices**
- **Interviews**

www.capjournal.org

Online issues
Free subscriptions
Article submission

Cover: Euphoria Mod II. Credit: artofgregmartin.com

Editorial

WELCOME TO 2009, THE INTERNATIONAL YEAR OF ASTRONOMY!

Assuming you haven't been living in a cave or anywhere equally remote for the past few months, you will be keenly aware of the International Year of Astronomy 2009, a global celebration of astronomy and its contribution to scientific development and cultural enrichment. Organised by the International Astronomical Union and UNESCO, it has been many years in the making. Now is the time to celebrate! However, we astronomy communicators have the responsibility to make this year an example to follow throughout 2009 and beyond.

The European astronomical community has recently put together an unparalleled strategic plan for European Astronomy, the ASTRONET Infrastructure Roadmap. This lays out long-term scientific and investment plans for European astronomy over the next 10–20 years. This time education and public outreach (EPO) were not forgotten, and they play a major role in the document. A group of European experts analysed the current status of EPO in Europe and outlined a list of recommendations to implement over the coming years and decades. Working side by side with research, public outreach will require an effective synergy of resources across Europe and beyond. In this issue we reproduce the subchapter dedicated to Public Outreach. IYA2009 may represent the first real step towards the strategic goals laid down by the ASTRONET panel. The full, and very interesting, report may be found at www.astronet-eu.org.

Winds of change are already blowing across Europe. Last year the European Commission awarded its Science Communication Prizes to three of the most influential astronomy communicators in Europe, Jean-Pierre Luminet, Communicator of the Year, Peter Leonard in the Category of Audiovisual Documentary of the Year for his programme, *Most of our Universe is Missing*, and Nuno Crato, finalist in the category Science Communicator of the Year, a Portuguese mathematician and an astronomy enthusiast. In this issue we have the pleasure of sharing with you some tips from the 2007 Science Communicator of the Year in Europe, in an interview with Jean-Pierre Luminet.

Also in this issue, Daniel Kunth provides useful insights into the long-lived tumultuous relationship between astronomy and astrology, Greg Martin shares with us his know-how in space art, and Emily Lakdawalla summarises upcoming Solar System missions.

Between issues you can stay in touch through our website, www.capjournal.org, where you will find the current issue in PDF format, a job bank, submission guidelines and back issues. You can also post anything you have to say on the site or e-mail me at editor@capjournal.org. I'd like to know what you think!

Happy reading and a successful 2009,

Pedro Russo
Editor-in-Chief

Explained in 60 Seconds

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

String Theory

String theory proposes that the fundamental constituents of the Universe are one-dimensional "strings" rather than point-like particles. What we perceive as particles are actually vibrations in loops of string, each with its own characteristic frequency.

String theory originated as an attempt to describe the interactions of particles such as protons. It has since developed into something much more ambitious: an approach to the construction of a complete unified theory of all fundamental particles and forces.

Previous attempts to unify physics have had trouble incorporating gravity with the other forces. String theory not only embraces gravity but requires it. String theory also requires six or seven extra dimensions of space, and it contains ways of relating large extra dimensions to small ones. The study of string theory has also led to the concept of supersymmetry, which would double the number of elementary particles.

Practitioners are optimistic that string theory will eventually make predictions that can be experimentally tested. String theory has already had a big impact on pure mathematics, cosmology (the study of the Universe), and the way particle physicists interpret experiments, by suggesting new approaches and possibilities to explore.

John H. Schwarz
California Institute of Technology.

Key Words

Written Communication
Case Study

Colour-composite image of Centaurus A, revealing the lobes and jets emanating from the active galaxy's central black hole. This is a composite of images obtained with three instruments, operating at very different wavelengths. The 870-micron submillimetre data, from LABOCA on APEX, are shown in orange. X-ray data from the Chandra X-ray Observatory are shown in blue. Visible light data from the Wide Field Imager (WFI) on the MPG/ESO 2.2 m telescope located at La Silla, Chile, show the background stars and the galaxy's characteristic dust lane in close to "true colour". Credit: ESO/WFI (Optical); MPIfR/ESO/APEX/A.Weiss et al. (Submillimetre); NASA/CXC/CfA/R.Kraft et al. (X-ray).

Neighbourhood Watch: Solar System Exploration during 2009

Emily Lakdawalla
The Planetary Society
E-mail: emily.lakdawalla@planetary.org

Key Words

Solar System Missions
Public Involvement
Engagement

Summary

As the International Year of Astronomy 2009 opens, there are nearly 20 spacecraft exploring our astronomical backyard, and five more are planned for launch in the coming year. Once the province of a few superpowers, Solar System exploration is now being conducted by countries across the world. The Planetary Society[1] strongly believes that the world's public should not only be told about the lessons learned from these missions, but also be invited to ride along for the adventure.

Spaceships in every corner of the Solar System, from every corner of the world

There have never been so many planetary missions active at once as there are today. In 2009, spacecraft will explore the Moon, Mars, Venus, Mercury and Saturn; many others are on their way to explore comets, asteroids, the cold worlds of the Kuiper belt and beyond. The year will also see the launches of three more spacecraft towards Mars and two towards the Moon. The 23 spacecraft that will be active in 2009 are named and their activities summarised in the following tables.

Clearly, more and more nations are seeking to participate in the exploration of the Solar System, and particularly of our nearest neighbour, the Moon. Japan, China, India, the United States, Germany, the United Kingdom and Russia are all now planning or operating missions on the Moon, a confluence of effort that inspired the Society to declare the "International Lunar Decade"[2], beginning with the launch of Japan's *Kaguya* orbiter[3] in 2007. Last year *Kaguya* was joined at the Moon by China's *Chang'e 1*[4] and India's *Chandrayaan-1*[5], and 2009 will see the launches of NASA's *Lunar Reconnaissance Orbiter*[6] and *Lunar Crater Observation and Sensing Satellite (LCROSS)*[7]. The Planetary Society hopes that the Decade will serve as a framework for cooperation among the international organisations and nations conducting lunar missions, and also that it will provide a mechanism for scientists and engineers from developing nations and other countries not directly involved in space missions to participate in science programmes or smaller engineering developments.

Many of the next steps in the exploration of our neighbourhood in the Solar System are so challenging that they seem daunting without the commitment and cooperation of many (if not all) of Earth's space-faring nations. Establishing a permanent presence on the Moon; advancing the scientific study of the mini "solar systems" and moons of Jupiter, Saturn and beyond; returning scientifically useful samples of rocks from the surface of Mars; extending the presence of humans beyond Earth orbit to the Moon, asteroids and Mars — all of these will require billions of dollars and the kind of effort that only seems to be sustainable when departments of state, not just space agencies, commit to working together toward common goals.

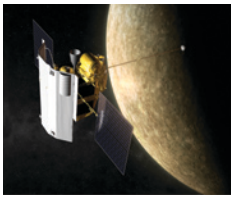
So, to advance international cooperation further, The Planetary Society is supporting the development of the Global Exploration Strategy[8]. Fourteen space agencies (including ESA, NASA, and the agencies of Italy, the UK, France, China, Canada, Australia, Germany, India, Japan, South Korea, the Ukraine and Russia) have signed on to the first Global Exploration Strategy document, published by ESA in 2007. It presents a broad global consensus and concise rationale for human exploration of the Solar System, beginning with our nearest neighbour, the Moon. We hope that by the end of the International Lunar Decade, humans will have returned to the Moon and be looking outward, to the asteroids or Mars.

Opportunities for the public to participate in planetary exploration

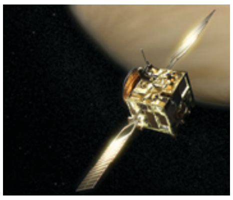
Developing expensive and technologically challenging planetary missions requires broad support by the taxpayers of space-faring nations, and space agencies are increasingly learning that it is not enough to tell the public about their successes; they must invite the public to, in effect, "ride along" with the voyages of discovery. One

Table 1. Planetary exploration missions active in 2009.

Inner Solar System



MESSENGER (NASA)
En route to Mercury orbit insertion in 2011, *MESSENGER* will fly by Mercury for the third time on September 29. Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.

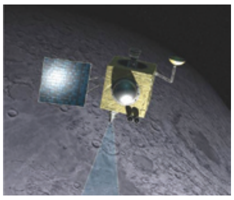


Venus Express (ESA)
Venus Express is currently funded through at least April 2009. ESA has not yet determined its future after that, but the spacecraft is in good health and could continue returning data on Venus's atmosphere. Credit: ESA (Image by AOES Medialab).

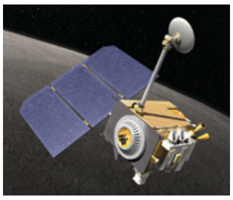
The Moon

Kaguya (JAXA)
Kaguya finished its primary mission in October 2008, but will continue mapping the gravity field of the Moon and capturing high resolution stereo images until May 2009. Later in the summer, it will impact the Moon. Credit: JAXA.

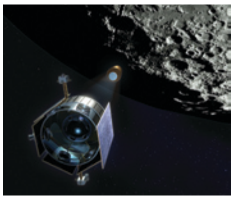
Chang'e 1 (China)
Shortly after the lunar orbit insertion of *Chang'e 1*, Chinese officials announced that the fuel margin should permit them to double the length of its science mission to two years. Credit: CNSA.



Chandrayaan-1 (India)
Launched in October 2008, *Chandrayaan-1's* lunar mapping mission will continue through 2009. Credit: ISRO.

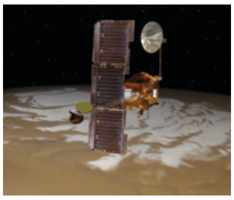


Lunar Reconnaissance Orbiter (NASA)
Lunar Reconnaissance Orbiter is expected to launch in spring 2009 and will spend the rest of the year mapping the Moon; its cameras will be the first since Apollo's to be able to spot human-made artefacts on the Moon. Credit: NASA.



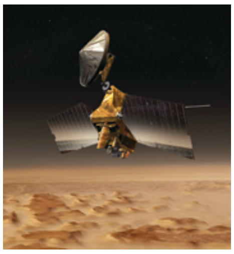
LCROSS (NASA)
Launching with the *Lunar Reconnaissance Orbiter*, *LCROSS* will impact the lunar about two months later, possibly in May. The event will be watched by Earth-based astronomers, including a worldwide amateur community. Credit: NASA.

Mars



2001 Mars Odyssey (NASA)
Although long past the end of its primary mission, 2001 *Mars Odyssey* shows no signs of faltering and will likely still be mapping Mars and serving as a communications relay for the Mars Exploration Rovers. Credit: NASA/JPL.

Mars Express (ESA)
In orbit since 2003, *Mars Express's* mission will likely be extended again to continue its mapping of the surface and subsurface of Mars, as well as the surface of Mars's moon Phobos. Credit: ESA.



Mars Reconnaissance Orbiter (NASA)
Mars Reconnaissance Orbiter's primary mission ended in November 2008, and is now in its Extended Science Phase. Once the Mars Science Laboratory arrives it will serve as the primary Mars telecommunication satellite. Credit: JPL/NASA.

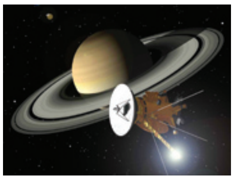
Mars Exploration Rovers (NASA)
Although both *Spirit* and *Opportunity* are showing signs of their advanced age, there is no reason to expect that they will not survive well into 2009, when spring and summer in Mars's southern hemisphere should bring them warmer temperatures and more solar power than they enjoyed in 2008. Credit: NASA/JPL/Cornell University/Maas Digital.

Phobos-Grunt (Russia)
Phobos-Grunt is currently scheduled to launch toward Mars in October 2009 to collect samples from Mars's moon Phobos and return them to Earth. Credit: Paolo Ulivi.

Yinghuo-1 (China)
China's first mission beyond Earth orbit will hitch a ride to Mars with the *Phobos-Grunt* spacecraft, launching in October 2009. Credit: CNSA.

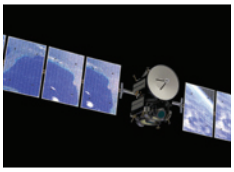
Table 1. Planetary exploration missions active in 2009 (Cont.).

Saturn

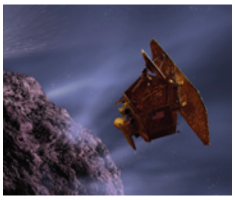


Cassini-Huygens (NASA/ESA/ASI)
Throughout 2009 the *Cassini* orbiter will be in its first extended mission, continuing studies of Saturn, its rings and its moons; highlights will be three exceptionally close flybys of the geyser moon Enceladus, and witnessing the arrival of Saturn's equinox in August. Credit: NASA/JPL.

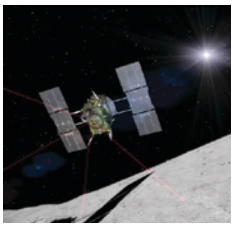
Deep Space / Cruise



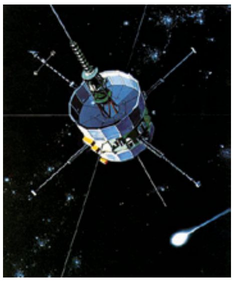
Dawn (NASA)
In February 2009, *Dawn* will fly by Mars, which will supply a gravity assist to boost the ion-powered spacecraft onward to its planned 2011 arrival at the asteroid Vesta. Credit: McREL.



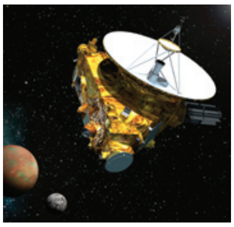
Deep Impact (NASA)
As part of the EPOXI extended mission, the *Deep Impact* spacecraft has completed its observations of extrasolar planets. It is now travelling towards a 2010 rendezvous with Jupiter-family comet 103P/Hartley 2. Credit: NASA/JPL/UMD. Credit: NASA/JPL/UMD.



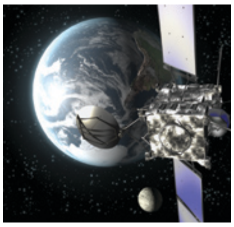
Hayabusa (JAXA)
Although seriously injured during its dramatic touchdown on asteroid Itokawa in 2005, *Hayabusa* in its attempt to return its sample capsule (which may or may not contain a sample) to Earth in 2010. Credit: LiVE Company Ltd.



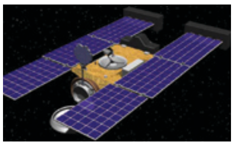
International Cometary Explorer (ICE) (NASA)
After an eight-year hiatus, NASA re-established contact with *ICE* in 2008, which flew through the tail of comet Giacobini-Zinner in 1985. Still in good condition with most of its instruments functioning, *ICE* is on course for a return visit to Earth in 2014, when it may be sent onward to explore another comet. Credit: NASA.



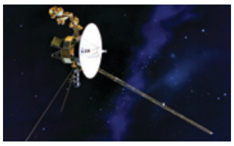
New Horizons (NASA)
New Horizons will spend most of 2009 hibernating while it travels 533.7 million kilometres (3.57 astronomical units) on its way to Pluto. It will not reach Pluto until 2015. Credit: Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute (JHUAPL/SwRI).



Rosetta (ESA)
ESA's flagship mission to a comet will fly by Earth for the third time on November 13, en route to its planned arrival at comet Churyumov-Gerasimenko in May 2014. Credit: ESA/C. Carreau.



Stardust (NASA)
Throughout 2009, *Stardust* will be cruising toward a February 2011 encounter with Tempel 1. Credit: NASA/JPL.



Voyager 1 and 2 (NASA)
The two long-lived spacecraft will hopefully still be returning data from the interstellar medium beyond the Solar System. Credit: NASA/JPL.

very simple method of helping people to feel a sense of ownership over space missions is to facilitate "Messages from Earth" opportunities[9]. These allow the public to send their names and, sometimes, good wishes along with planetary missions. The oldest example is still in orbit around Saturn: *Cassini* carries a DVD[10] with 616 400 handwritten signatures from people living in 81 countries, scanned to digital format. The advent of the internet has made collecting names easier, so two DVDs, each containing four million names, were sent with the Mars Exploration Rovers[11]. With *Phoenix*, a DVD was included containing "Visions of Mars"[12], a collection of Mars-inspired literature, art and personal greetings from leading space visionaries of our time. The *Lunar Reconnaissance Orbiter* will be the next spacecraft to carry names beyond Earth.

But members of the public can do more to actually contribute to the scientific results of space missions. One such opportunity is The Planetary Society's Stardust@home project[13]. After completing a short online training session, members of the public can help examine more than 700 000 microscopic scans of the *Stardust* spacecraft's interstellar dust collection plates, searching for a few dozen micron-sized grains of dust. To date, only a quarter of the collection plates have been scanned, so plenty more work remains for 2009.

There will also be two opportunities for amateur astronomers to contribute to lunar science. On separate dates in the summer of 2009, there will be two missions intentionally crashing into the Moon: the two spacecraft of *LCROSS* in the early summer and Japan's huge *Kaguya* orbiter in the late summer. The *LCROSS* impact will be into a permanently shadowed region of one of the lunar poles; observations of the plume raised by

The year starts with Mars in early northern autumn; Saturn in late northern winter; Uranus in early northern spring; and Neptune in early northern winter.

	Astronomical Events	Spacecraft Events
January	4: Earth at perihelion 11: Full Moon 24: Jupiter at conjunction 26: Annular solar eclipse	14: *Stardust*: Earth flyby (en route to Tempel 1 rendezvous in 2011)
February	9: Full Moon 9: Penumbral lunar eclipse 13: Neptune at conjunction 20: Venus at maximum brightness	2: *Cassini*: Distant Rhea flyby 7: *Cassini*: Titan flyby 18: *Dawn*: Mars flyby (en route to Vesta rendezvous in 2011)
March	8: Saturn at opposition 11: Full Moon 13: Uranus at conjunction 20: Earth at equinox 28: Venus at conjunction	6: *Kepler* planet-hunting spacecraft: Launch 27: *Cassini*: Titan flyby
April	9: Full Moon 29: Venus at maximum brightness	*Venus Express*: End of extended mission 4: *Cassini*: Titan flyby, first of 10 straight with 16-day orbit matching Titan's 20: *Cassini*: Titan flyby 24: *Lunar Reconnaissance Orbiter*: Launch
May	9: Full Moon 22: Mars at solstice (northern winter)	5: *Cassini*: Titan flyby 21: *Cassini*: Titan flyby
June	6: Full Moon 20: Earth at solstice	6: *Cassini*: Titan flyby 22: *Cassini*: Titan flyby
July	4: Earth at aphelion 7: Full Moon 7: Penumbral lunar eclipse 22: Total solar eclipse in Asia	8: *Cassini*: Titan flyby 11: *Cassini*: Distant Dione flyby 24: *Cassini*: Titan flyby 26: *Cassini*: Distant Tethys flyby
August	6: Full Moon 6: Penumbral lunar eclipse 11: Saturn at equinox (northern spring) 15: Jupiter at opposition 18: Neptune at opposition	9: *Cassini*: Titan flyby 11: *Cassini*: Observes Saturn at equinox! 25: *Cassini*: Titan flyby, last of 10 straight
September	4: Full Moon 5: Earth crosses Saturn's ring plane 17: Uranus at opposition 18: Saturn at conjunction 22: Earth at equinox	15: *Mars Science Laboratory*: Launch period opens 20: *Cassini*: Distant Dione flyby 29: *MESSENGER* Mercury flyby #3
October	4: Full Moon 27: Mars equinox (northern spring)	*Phobos-Grunt* and *Yinghuo-1*: Launch 12: *Cassini*: Titan flyby 13-14: *Cassini*: Distant Rhea, Mimas, and Tethys flybys
November	2: Full Moon	2: *Cassini*: Targeted Enceladus flyby (1 of 2 this month) 13: *Rosetta*: Earth flyby #3 (en route to comet rendezvous May 2014) 21: *Cassini*: Targeted Enceladus flyby and distant Rhea flyby
December	2: Full Moon 21: Earth at solstice 31: Full Moon (blue moon!) 31: Partial lunar eclipse	12: *Cassini*: Titan flyby 26: *Cassini*: Distant Tethys flyby 28: *Cassini*: Titan flyby

the impact could confirm the presence or absence of water in these regions. The Planetary Society will be helping to organise and promote a worldwide campaign by amateur astronomers to photograph the impact plume, and hopes to mobilise the same group to watch *Kaguya's* demise. The exact dates of both events will not be known until a couple of months before they occur.

The world's public can also now take science into their own hands, because many missions now provide relatively easy internet access to entire catalogues of raw image data being returned from spacecraft. Data from all active Mars orbiters can be accessed via map-based interfaces after proprietary periods have expired, while some missions (currently, the Mars Exploration Rovers and *Cassini*) provide nearly instantaneous access to "raw" image data. Until recently, such data was only useable by trained experts at research institutions, but the proliferation of digital camera use by members of the general public, in combination with increasing high speed internet access, has resulted in the birth of a worldwide community of armchair scientists who download, process, examine, and then discuss the images being returned by active planetary missions. The joy of discovery of new landscapes on strange worlds, once limited to the few scientists fortunate enough to be on mission science, is now accessible to the world's public via the internet. The Planetary Society is helping this community to grow by converting some planetary datasets from the arcane formats used by researchers into more commonly used formats like JPEG and PNG, and providing guidance on how to find and process images from planetary missions.

We hope that the worldwide events of the International Year of Astronomy in 2009 will focus public attention not only on distant stars and galaxies, but also on our own Solar System. Space is not just what we see at the other end of a telescope; we live in space, too, and it is as important to study our own neighbourhood as it is to examine the Universe beyond.

Notes

1 http://planetary.org
2 http://www.planetary.org/programs/projects/lunar_decade/
3 http://www.selene.jaxa.jp/index_e.htm
4 http://planetary.org/explore/topics/chang_e_1/
5 http://isro.org/Chandrayaan/index.htm
6 http://lunar.gsfc.nasa.gov/
7 http://lcross.arc.nasa.gov/
8 http://www.scitech.ac.uk/Resources/PDF/gesframework.pdf
9 http://planetary.org/programs/projects/messages/
10 http://saturn.jpl.nasa.gov/kids/amazing-dvd.cfm
11 http://www.planetary.org/programs/projects/red_rover_goes_to_mars/dvd.html
12 http://www.planetary.org/programs/projects/messages/vom.html
13 http://stardustathome.ssl.berkeley.edu/

Biography

Emily Lakdawalla is the Science and Technology Coordinator for The Planetary Society. She received a Bachelor's degree in geology from Amherst College and then taught science to fifth- and sixth-grade children in Chicago. She went on to Brown University to study planetary geology. Lakdawalla came to The Planetary Society in 2001, and she now writes for the website and weblog, records the "Q and A" segment on the weekly Planetary Radio show and occasionally contributes to the Society's bimonthly magazine, *The Planetary Report*.

It Is not *Just* a Theory, It *Is* a Theory!

Wallace Tucker
Harvard-Smithsonian Center for Astrophysics
E-mail: wktucker@znet.com

Key Words

Written Science Communication
Scientific Theory

Summary

A theory is not some hunch, or half-baked idea that you come up with while taking a shower, or being under the influence of something or other. A theory, as scientists understand the meaning of the word, is a scientifically tested principle or body of principles that incorporates and explains a significant body of evidence.

My theory on housework is, if the item doesn't multiply, smell, catch fire, or block the refrigerator door, let it be. No one else cares. Why should you?
Erma Bombeck

Every now and then we get into a discussion about the Big Bang theory or the theory of evolution, and the discussion occasionally ends with what is intended as a put-down:

"Well, after all, it's just a theory."

In the same vein, there was a flap at NASA a couple of years ago when someone insisted that the word "theory" be added after every mention of the Big Bang.

Both instances betray a misunderstanding of what a scientific theory is. It is not some hunch, or speculative idea that you come up with while taking a shower, or being under the influence of something or other.

As Michael Peshkin (2006) has said, "I always discuss the words, 'It's only a theory,' by saying that for practical purposes that's the same as saying 'It's only science, and the price we can pay for such contempt for science is high.'"

A theory, as scientists understand the meaning of the word, is a scientifically tested principle or body of principles that incorporates and explains a significant body of evidence. It is an important milestone in the search for knowledge of our Universe that begins with observations, usually followed by a batch of half-baked ideas, most of which are soon proven wrong by further observations. The surviving ideas are formulated into hypotheses that must do more than explain the observations. To be taken seriously, a hypothesis must make predictions that can be tested by further observations.

It doesn't matter how beautiful your theory is, it doesn't matter how smart you are. If it doesn't agree with experiment, it's wrong.
Richard P. Feynman

As a hypothesis matures, and is extended to include complementary hypotheses to explain more observations in a self-consistent way, it becomes a model. Models have a set of assumptions and, in physics, are described by a set of equations. The exploration of the implications of these equations leads to explanations of other phenomena, or to predictions.

Usually, a "model" is used to describe an intermediate step on the way to a "theory" that emerges if the model survives rigorous experimental and theoretical testing. Sometimes, the name sticks even after a particular model is the only one left standing. The Standard Model of particle physics is an example of a model that has become a theory, yet it is still referred to as a model.

It has been suggested that maybe scientists should drop the use of the word "theory" because it can be used in too many ways — Merriam-Webster's dictionary lists nine different meanings — and use "model" instead. Another term used for scientific theories that are well established is "law", as in Newton's laws of motion, and the laws of thermodynamics.

In any case, the transition from hypothesis to model or theory or law seldom goes smoothly. When Isaac Newton was standing on the shoulders of Galileo and Kepler to invent physics, he came up with a model for gravity and three laws of motion, but before he could work out the implications, he had to invent calculus!

Also, one of his main goals, to explain the motion of the Moon, didn't match the observations. It turned out that the observations were wrong — when the data on the radius of the Earth were updated to take into account new measurements, his model matched the observations, and he knew he had a legitimate theory.

With his three laws of motion (inertia, force = mass x acceleration, and action = reaction) plus the universal law of gravity, Newton could explain the orbits of the Moon, the planets and comets, as well as the twice-daily tides on Earth caused by the Sun and Moon, the flattening of the Earth at the poles, etc. These laws were subsequently used by others to discover the planet Neptune, and are still used today to discover planets around other stars. Now, that's a scientific theory!

Another example is the development of the theory of electrodynamics by James Clerk Maxwell. It incorporated the work of Michael Faraday and others into a set of four equations (now known as Maxwell's equations) that explained known phenomena associated with electricity and magnetism, and led directly to the discovery of radio waves a few years later.

Despite its awesome power, Newton's theory was not complete. For example, Newton's laws apply only for relative motion at speeds much less than the speed of light. At speeds approaching the speed of light, modifications provided by Einstein's special theory of relativity were necessary.

Likewise, when gravity becomes extremely strong, special relativity must be modified by Einstein's general theory of relativity. And finally, near the singularity inside a black hole's event horizon, the general theory of relativity must be modified by quantum gravity, although there is as yet no agreement on how to do this.

A similar fate has befallen Maxwell's theory. It has also been modified with special relativity at speeds close to the speed of light, and by quantum electrodynamics to account for the photonic nature of light.

A common misconception among laymen about scientific theories is that when they break down, the breakdown is catastrophic and the entire theory is discarded, that the textbooks have to be rewritten. A good example of this misconception appeared recently in a *Washington Post* article by columnist Charles Krauthammer:

If you doubt the arrogance, you haven't seen that Newsweek *cover story that declared the global warming debate over. Consider: If Newton's laws of motion could, after 200 years of unfailing experimental and experiential confirmation,* ***be overthrown****, it requires religious fervor to believe that global warming — infinitely more untested, complex and speculative — is a closed issue. (Bold italics mine).*

Of course, Newton's laws have not been overthrown. They give the same results as Einstein's theories at speeds much less than the speed of light and moderate gravity. The new theories, such as relativity theory or quantum theory, do not render the prior theories irrelevant, they just incorporate them into a larger domain.

What did change radically was the big picture. Like a scene in a great mural painting, the old theories were seen to be part of a much larger reality.

There could be no fairer destiny for any physical theory than that it should point the way to a more comprehensive theory in which it lives on as a limiting case.
Albert Einstein

Gravity isn't just about apples falling to Earth, the Moon orbiting the Earth, and the Earth orbiting the Sun. It is about matter causing curvature in space and bodies moving in straight lines through curved space. It is about black holes. The theory of relativity allows us to move back for a more comprehensive view of the Universe that is beautiful and magnificent to behold.

And guess what — scientists still don't know what the entire mural looks like. For example, the limits to the Big Bang theory are becoming increasingly apparent and are telling us that there is much more to be discovered.

There is a theory which states that if ever anyone discovers exactly what the Universe is for and why it is here, it will instantly disappear and be replaced by something even more bizarre and inexplicable. There is another theory which states that this has already happened.
Douglas Adams

References

- Krauthammer, C. 2008, *Washington Post*, May 30, A13
- Peshkin, M. 2006, *Physics Today*, July, 46
- Quinn, H. 2007, *Physics Today*, January, 8
- Thorne, K. 1994, *Black Holes and Time Warps*, (New York: Norton) 84

Biography

Wallace Tucker, an astrophysicist, is science spokesman for the Chandra X-ray Center at the Harvard-Smithsonian Center for Astrophysics. He has authored or co-authored several non-technical books on astronomy, the latest of which is *Revealing the Universe*, written with Karen Tucker.

Astrology and Astronomy: From Conjunction to Opposition

Resources

Daniel Kunth
Institut d'Astrophysique de Paris, France
E-mail:kunth@iap.fr

Key Words

Astrology
Society

Summary

As science communicators dealing with astronomy we often find a strong interest amongst the public in astrology — how the stars and planets directly affect our individual lives. Nowadays astrology is at odds with the scientific nature of astronomy, but this has not always been the case. Presented here is a background to astrology, to give a deeper understanding of where it has come from and why it has such an enduring place in all forms of global media.

Astrology has adapted to changes in society throughout history, and as a result it continues to benefit from a positive public image. The commercial and social success of astrology, largely driven by the media, is surprising given the dominance that science enjoys within our society. Its foundations exploit the widely held belief that pervasive connections exist between the *macrocosm* (the Universe as a whole) and our *microcosm* (human society and social relationships). Astrologers aim to decipher the hidden meaning behind planetary movements and positions, which they believe correspond to human personality traits or predict major and minor life events. The lexical ambiguity, with which these predictions are made, however, produces results that can be neither proven nor disproven.

Without an objective method by which a predicted result can be tested, astrology cannot be considered a science. Astrological analysis, while sometimes quite sophisticated, does not utilise any traditional scientific methodology. Astrology even skips the necessary confrontation between hypothesis and proof, the opposite of a rigorous scientific approach. Astronomers oppose not only the astrological assertion that cosmological positioning can directly impact a person's destiny, but also astrology's ignorance of the physical reality, richness and variety of stars and planets.

Moreover, no serious statistical study has been able to establish the reliability of astrological predictions. In modern times, most of its adherents opt for a psychological interpretation of astrology in which the stars have set forth the keys to our destiny, personality and predilections at the very time of our birth. The foundation of a belief in astrology is based upon a deterministic approach and constitutes a psychological alienation that can easily be over-exploited by those interested in financial gain.

Throughout our own civilisation, astrology has had both fervent and casual believers within nearly all social classes or cultures. From ancient times to the present, humans have been challenged to predict and prepare for life events from the joyous to the catastrophic. Faced by disorder on Earth, astrology proposes that an ordered and readable structure exists in the firmament that is intricately involved with the saga of human life. However, this belief does not at all constitute a cosmic science because neither the tools of the astrologer nor their subjective analysis allows the astrologer to deduce facts or test a theory. Is astrology therefore more of a social science? That is to say a mode of knowledge in competition with scientific cosmology?

Some astrologers, discontented by their relegation to the margins of official sciences, request academic recognition that would allow the public financing of astrological research and strengthen the scientific and academic standing of astrology and its followers. The utilisation of computers, statistics and ephemerides of great precision suggests an increasingly scientific practice. However, an overwhelming majority of scientists completely reject the scientific relevance of astrology and remain critical of new superficial uses of technology.

Astrologists have been at the centre of an explosion in both traditional print and electronic media that has bombarded readers with intense (and intensely lucrative) commercialisation of astrology. Astrology in the print media is especially common – today, from the tabloid to the weekly, many newspapers offer an astrology column. Some people read their horoscope as if it were fiction; others rely on it for predictions and advice that will help them manage their personal or professional lives or perhaps how and when to plan a holiday. If so much money is devoted to astrology, perhaps it is because it fulfils an essential need that neither science, nor psychology, nor religion takes into consideration.

Symbolism in astrology

One of astrology's great forces of persuasion lies in its symbolic perception of the world. This symbolism follows, more or less, from observations made since antiquity regarding the lustre or colour of astronomical bodies, the apparent vagaries of planetary movement as well as solar or lunar proximity. These symbols do not have a universal value: each culture elaborates its own.

Most people know their zodiac sign: to be a Cancer sign signifies that at that individual's birth, the Sun (when projected on the sky) was in the position corresponding to the sign of Cancer. In order to be more focused on the individual or to help account for evident differences between those with the same sign, the sign is countered or nuanced by other personalised elements, such as the ascendant sign that rises in the east at the precise moment of birth or the position of the principal planets in the birth chart.

Astrologers are equally interested in planetary transits, when planets pass certain significant points in the birth chart. They consider them to be triggers of events or decisions (marriages, divorces, births…) already predicted within the chart at the time of birth. Transits occupy a key position in astrology because it is considered possible to predict by calculation the principal transitions of a life. Horoscopes often make use of this technique in order to determine the charted angles of a planet with respect to a sign. For example, a person born under the sign of Virgo might have the planet Mars charted in close proximity to their sign; the astrological characterisation of Mars as the planet of war could be interpreted as an indication of impending conflict.

A brief return to the past

Historically, astrology and astronomy were not considered entirely separate fields; much of an astrologer's time was spent working on star charts or taking meticulous measurements. Observations repeated thousands of times allowed the prediction of certain celestial events and, as a result, terrestrial events (the Egyptian calendars were inextricably linked to the life of the Nile). Proceeding from the correlation between celestial and terrestrial events, a control of the latter by the former was imagined. The planets or "wandering stars" were perceived as a coded communication from the deities; hence observation of tiny planetary movements was a way of interpreting the will of the Gods. The Greeks, then the Romans, were convinced of the divine nature of this kind of astrology, also known as *Chaldean*, deriving from its ancient Sumerian origins. In ancient Greece, the regularity and often predictable nature of celestial events gave birth to a *mathematical mysticism*, a singular marriage between mathematics and divination, which western astrology has drawn upon, allowing it to endure to this day. Modern astrology has broken with the concept of gods, but has conserved the belief that a universal will can be perceived through careful evaluation of planetary movements. With the evolution of both knowledge and scientific tools, the gap has widened between the premises of astrology and those of science.

Historically astronomers renounced unproven principles regarding the influence and connection between planetary configurations and terrestrial events. These became sources of disagreement and eventually rupture between astronomy and astrology. Astronomy attempts to explain the cosmos; scientists are objective observers. The astronomer builds upon or rejects a theory based on available evidence, while an astrologer's work is controlled by a doctrine of predetermination.

During this transition, astrologers were confronted by shake-ups they had not foreseen: the Earth was no longer at the centre of the system, the separation between the *sublunar* and *supralunar* worlds was no longer justified and distances exploded. According to the philosopher Alexandre Koyré, our human world, once at the centre of everything was transformed into a tiny player in an infinite Universe.

Astrology face to face with science

So now we have one cosmos to investigate, studied by two wholly different schools of analysis. Many astrologers describe themselves as scientists and insist upon the existence of genuine celestial influences on the individual. They hope to demonstrate its authenticity by using statistical studies that are often ill-conceived and badly executed (Fraknoi, 1989).

In borrowing astronomy's methods of calculation (the ephemerides of astrologers are scientific tables graciously made available to the public by astronomers), this type of astrology recovers a kind of scientific legitimacy that plays a role in its durability. The confusion of genres and the questions of the public are relayed by media debates where astronomers and astrologers confront one another. The most critical arguments of astronomers regarding astrology focus on the misunderstanding of the physical reality of the Universe and its richness. What is the point of invoking the sky and its planets if they are not taken into account for themselves – that is, if the sky is without object?

In essence, the symbolic language of astrology possesses some limits that keep it at a distance from the realities of the physical world. Taking the example of the planet Mars: for the astrologer, the colour red evokes flowing blood, therefore war, and with it, death; for the scientist, the colour red can have multiple causal reasons, which can only be determined by experiment. The first space missions to Mars attested to the presence of iron on the surface of this planet, the colour red was partly due to the oxidation of iron. Oxidation, however, required the presence of oxygen, most notably in the form of water. Water is considered synonymous with life on Earth so the question was then posed about the existence of life on Mars. Did life exist in the past? Such a hypothesis will be explored during future missions to the red planet. Mars-red-war-blood and death, the symbolic chain that functions on analogy has made room for Mars-red-iron-water and life, which comes from strict ties with causality.

Mars, a simple mass of red stone covered with iron oxide, continues to be assigned the virtues of the god of war. We see how a relevant observation – that of colour – can provoke a simple and elementary symbolic interpretation. However, once the *nature* of the planet is known and causal relationships revealed, that this associative game could endure after having lost all real significance does not cease to astonish.

It is certainly not necessary to understand the nature of a phenomenon in order to

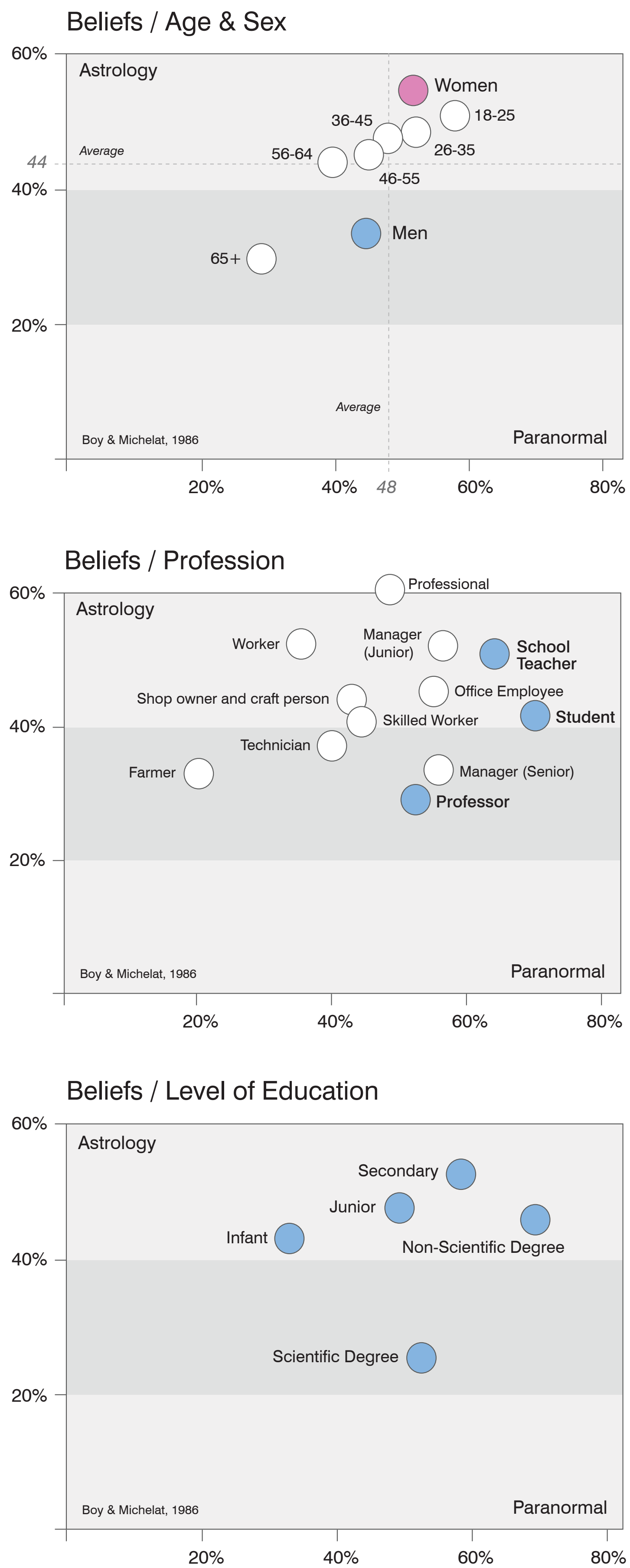


Figure 1. Examining the relationship between beliefs and life factors. Credit: Boy & Michelat.

establish its existence, but the first question, beyond all polemic, is to know if astrological influence is attested to by the facts.

Alas, astrologers hardly worry about submitting their hypotheses to a definitive test of refutation. The exception is the psychological test conducted by Carlson and published in the 1985 review in *Nature*, which tested the precepts and foundations of astrology. They effectively debunked all tested astrological principles.

Astrological predictions of catastrophic events rarely specify the size of disasters, location or precise date of occurrence; because of this they can almost never be contradicted or disproven. Even so, at the beginning of each year we see in the media a wave of predictions that are rarely verified — a fact the public does not seem eager to take into account. A renowned astrologer once predicted a major catastrophe because the August 1999 solar eclipse coincided with the Earth flyby of the *Cassini* probe. A petition was immediately sent to NASA demanding that they modify the date of the mission!

Despite an abundance of evidence that astrology is essentially a non-science, the academic platform of astrology does offer a certain psychological depth. Predictions can be so ambivalent that there are an almost unlimited number of interpretations on any given subject. Scientists regard such profusion as redundant, manifesting when the number of possibilities exceeds the number of unknowns. The astrological lexicon, with numerous possible meanings, allows those who use it a good deal of latitude.

Science is at the same time knowledge, method and proof. It tries to transcend cultures and national affiliations and evolves without demanding any psychic belief as a prerequisite for exploring the nature of the world. On the other hand, the term astrology should merit the plural form; so diverse are its schools. Different and numerous disciplines of astrology often contradict or ignore each other without consensus or even the need for consensus.

Public attitude

- 26% of people questioned in France declare they “believe in the predictions of astrologers”; among these, one third takes horoscopes into account in their lives.
- 41% of people surveyed declare they believe in the explanation of characters by astrological signs.
- About 13% have consulted an astrologer.

The infatuation of the public for astrology moves more and more towards a psychology aimed at liberating the potentialities of individuals. During a session, an astrologer works in the field of affectivity, not rationality. The client finds himself in the position of expectant believer, a mechanism by which he hears only what he wants to hear, and discounts or ignores what does not fit in with his expectations.

Astrology remains at its heart the art of predicting the future, a future written according to the tendencies acquired at birth by the influence of the stars. However, this deprivation of free will engenders alienation and a strong risk of psychological manipulation (it is not uncommon to meet people who consult their astrologer before making any decisions). The determinist nature of astrology leads to the irreducible paradox in which the astrologers work as so-called psychologists. The free will that the psychological astrologer advocates finds itself confronted by the determinism of predictive astrology. How can this personal autonomy be reconciled with the blows of fate or of bad luck that Jupiter or Saturn provokes in passing by the birth sign? The client waits for the answer to be revealed to him. Astrological analysis, in the great majority of cases, is performed for pecuniary gain, which is why an astrologer formulates broad assertions, the opposite of generally prudent interpretations offered by psychotherapists.

The influence of the astrologer is not found solely in the private sphere. It has penetrated the field of politics and civil society. Certain businesses use astrology for recruitment. Astrology is judged sometimes to be more suitable to evaluate potential candidates than their CVs and motivation! A financial astrology, based on the apparent movement of Uranus has been all the rage, even on Wall Street and astrology has even been used in fee calculation for certain insurance companies! In fact, for almost any human activity or phenomena to which a great deal of uncertainty is attached, you will find astrologers eager to impart a sense of cosmic order and to be paid for securing that peace of mind.

Astrological belief is not the sole privilege of those who have access to thorough instruction but thrives in a sort of in-between state (Boy & Michelat, 1986). Statistically, a belief in astrology increases with a declared interest in science, peaking among the salaried middle class holding an intermediate-level degree, then lessens among those with a postgraduate education (notably among scientists) (see Figure 1). The sociologist Theodor Adorno (1994) pointed out that belief in astrology is characterised by a state-of-being that he called semi-erudition. The semi-erudite would borrow some non-scientific shortcuts to find answers to questions regarding their future as a result of an unsuccessful conversion to the system of scientific thought.

The nature of astrology

Astrology is not monolithic, but finds an anchor in a current of common thought linked to tradition. It weaves social connections and allows a group of people to identify themselves with a cultural community.

We can characterise two classes of astrologers. Those who call themselves astrological scientists work under the premise that they live in a world of physical causal influence between people and the cosmos. Such astrology utilises a sort of patchwork scientific analysis, which moulds concepts pulled from other scientific fields to suit the astrological framework. More traditional astrologers consider the sky to be a symbolic template, and willingly use some mythical tales to expand their interpretations rather than expounding on a physical cause and effect methodology. Astrology can equally be perceived as a language that presents words with the use of a specific vocabulary and grammatical technique. The scientific refutations presented by astronomers only fleetingly embarrass these astrologers for whom the object of astrology is not a study of the cosmos but of man, at the same time subject and object.

Fundamentally, the differences are glaring. The astrologer scientist makes his art mathematical. The astrologer metaphysician attaches no importance to a so-called scientific astrology. There is an in-between kind of astrologer, probably the most widespread, for whom the practice comes as close as possible to penetrating intuition, of psychology and clever deductions. It is believed that the cosmos imprints upon the individual at the moment of birth and that the future of the individual is coded within that specific and unique formation. For this community, the astrologer is simply the interpreter who analyses the characteristics of the birth chart. Such astrological discourse is extremely malleable, which explains its capacity to adapt to cultural norms of modern or post-modern societies. This is again due to the rich and symbolic lexicon of astrology; a birth chart can be interpreted in so many ways as to make impartial and unequivocal analysis impossible. Astrology seduces timelessly, not because it carries the scientific weight of fact or provable hypothesis, but because it places the appearance of order upon an unknowable future. The unbridled commercial exploitation of those seeking answers by those adept at the manipulation of a complex lexicon and a societal need for stability can only be condemned.

Some astrologers may be skilled at fitting astrological omens and portents within our perceptions of reality, but the premises and methods of astrology differ fundamentally from those of science or even social science and carry no scientific validity.

References

- Adorno T. W. 1994, *The Stars Down to Earth and Other Essays on the Irrational in Culture*, (London: Routledge)
- Caudron D. et al. 1996, *The Mars Effect*, (London: Prometheus Books)
- Boy D. & Michelat G. 1986, *Croyances aux parasciences: dimensions sociales et culturelles*, Revue Française de Sociologie, 43-1, 35-45
- Carlson, S. 1985, *A double blind test of astrology*, Nature, 318, 419-425
- Fraknoi, A. 1989, *Your astrology defense kit*, Sky & Telescope, 146-150
- Kunth D. & Zarka P. 2005, *Astrologie, Que Sais-je* no 2481, (Paris: Eds. Presses Universitaire de France)
- Peretti-Watel P. 2002, *Sous les étoiles, rien de nouveau?*, Revue Francaise de Sociologie 43-1, 3-33

Notes

Translation from French by Emma-Kate Symons (journalist). English editing by Brooke Sing (writing editor) and the CAPjournal editorial team.

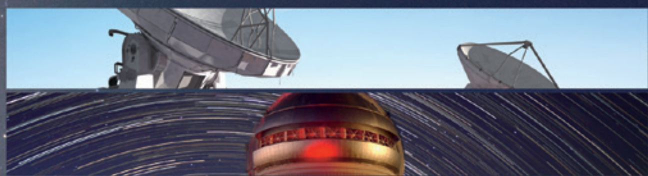
Biography

Daniel Kunth is an astrophysicist, a specialist on extragalactic astronomy, mainly in the study of the evolution and formation of galaxies. He dedicates a significant fraction of his time to develop media outreach, give talks and write articles, in particular on the relation between astronomy and astrology.

INTERNATIONAL YEAR OF ASTRONOMY 2009

THE UNIVERSE, YOURS TO DISCOVER.

The International Year of Astronomy 2009 is a global effort initiated by the International Astronomical Union and UNESCO to help the citizens of the world rediscover their place in the Universe through the day and night-time sky, and thereby engage a personal sense of wonder and discovery.



THE UNIVERSE YOURS TO DISCOVER
INTERNATIONAL YEAR OF ASTRONOMY 2009

UNESCO United Nations Educational, Scientific and Cultural Organization

IAU International Astronomical Union

Partners for the International Year of Astronomy 2009

www.astronomy2009.org

Vision

The International Year of Astronomy 2009 aims to help everyone realise the impact that astronomy and other fundamental sciences have on our daily lives, and understand how scientific knowledge can contribute to a more equitable and peaceful society.

IYA2009 activities will take place locally and globally. Nodes have been formed in over 120 nations to plan activities and establish collaborations between science centres, astronomers, educators, enthusiasts, artists and many others.

To help coordinate this huge global programme and to provide an important point of contact for the participating countries, the International Astronomical Union has established a central Secretariat and website (www.astronomy2009.org) as the principal IYA2009 resource for the public, professionals and media.

Goals

1. Increase scientific awareness.
2. Promote widespread access to new knowledge and observing experiences.
3. Empower astronomical communities in developing countries.
4. Support and improve formal and informal science education.
5. Provide a modern image of science and scientists.
6. Facilitate new networks and strengthen existing ones.
7. Improve the gender-balanced representation of scientists at all levels and promote greater involvement by underrepresented minorities in scientific and engineering careers.
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.

Jean-Pierre Luminet: Renaissance Communicator

Lee Pullen
International Astronomical Union
International Year of Astronomy 2009
ESO ePOD
E-mail: lpullen@eso.org

Pedro Russo
International Astronomical Union
International Year of Astronomy 2009
ESO ePOD
E-mail: prusso@eso.org

Key Words

Interview
Communication
Methods

Summary

Science communication, like other areas of study, features prominent figures who lead the field. One such individual is Jean-Pierre Luminet, a researcher, communicator, artist and author. As recipient of the 2007 European Science Communication Prize for Communicator of the Year, Jean-Pierre is at the forefront of his field. The *CAPjournal* editorial team interviewed Jean-Pierre to discover more about the man, his mission and his methods.

Figure 1. Jean-Pierre Luminet.

How did you begin your career in science? When did the interest in science/astronomy develop?

I was born in the south of France in 1951. My parents were teachers at the local college and had no special interest in science. When I was a schoolboy I was interested by many things, especially music, painting, literature, poetry. I also liked mathematics because it seemed easy to me, so I followed the usual path in the French education system: a scientific degree. In the 1970s I went to Marseille University for my graduate studies in mathematics, without knowing yet whether I would like to become a writer, a musician or a scientist later. Then I read by chance an excellent book popularising cosmology, and I realised that fundamental research could be as creative and imaginative as art or literature. I decided to have a career in science. I had the chance to meet Brandon Carter, a world-renowned specialist in the study of black holes, who became my PhD advisor in a small research group studying relativity at the Paris-Meudon Observatory. My first contact with top-level research was in 1976, when I spent a few months at the famous Department of Applied Mathematics and Theoretical Physics (DAMTP) in Cambridge, UK, where I met Stephen Hawking, S. Chandrasekhar, Roger Penrose, George Ellis and others. Back in Meudon I was awarded my PhD in 1977 at the University of Paris on a very theoretical subject (singularities in spatially homothetic cosmologies). Next, I worked on black hole astrophysics. In 1979 I published the first computer generated image of a black hole accretion disc, which quickly became a classic, and I took up a permanent position at CNRS. I received a Doctorat d'Etat-ès-Sciences in 1985, after studying the tidal disruption of stars by black holes.

Figure 2. Two of Luminet's book covers. Credit: Jean-Pierre Luminet.

What is it about astrophysics and cosmology that you find particularly fascinating?

When I first began to wonder about nature, and more specifically about the size, the origin, the fate of the Universe and of its contents, I did not know that these were some of the questions that humanity has asked itself since antiquity. In nearly every culture, philosophers, scholars or artists have supplied various explanations, which have evolved over the course of history. What is particularly fascinating with modern astrophysics and cosmology is that these disciplines try to respond to these questions by combining mathematical reasoning, physical models and astronomical observations. And they do it rather successfully, with Big Bang models, black holes, high energy physics and so on!

How did it feel to win the 2007 European Science Communication Prize for Communicator of the Year?

It goes without saying that it was a great honour to receive such a prize. But for me it had a special added value for the following reasons. The challenge of science communication is to make very abstract and difficult concepts understandable to a general audience and to young people. I always keep in mind a remark by Erwin Schrödinger, one the fathers of quantum mechanics who devised the famous, but very abstract Schrödinger equation, when he wrote, *"A theoretical science unaware that those of its constructs considered relevant and momentous are destined eventually to be framed in concepts and words that have a grip on the educated community and become part and parcel of the general world picture — a theoretical science, I say, where this is forgotten, and where the initiated continue musing to each other in terms that are, at best, understood by a close group of fellow travellers, will necessarily be cut off from the rest of cultural mankind; in the long run it is bound to atrophy and ossify."* Thus I tried to communicate my own fascination for the hardest concepts of science to the general public and the younger generation via a variety of media such as books, television, exhibitions, music or the plastic arts.

But there is a price to pay. It is not at all easy to pursue so many activities simultaneously in the field of science, communication, public conferences, writing, art, etc., because a large part of the academic community (at least in France) is not very indulgent to or understanding of those who try to explore several ways. To be honest, in recent years I have sometimes felt a bit of inertia or been discouraged, because, in the eyes of many colleagues, my popular science activities tended to mask the value of my pure research work (well recognised abroad). But thanks to the award received from Europe, I feel more confident in quietly continuing my mission for scientific and cultural outreach, although the perception of my work in the French specialised community has not improved since then!

What is the secret of writing successful science communication books?

The description of science began in Greek antiquity. Then natural philosophers such as Democritus, Heraclitus and Plato were both scholars and masters of language. In their studies of nature, physical reasoning and poetic expression went hand-in-hand. Throughout history, this manner of communicating science has seen some success, as well as some virulent criticism. Some "purist" thinkers have proposed that no literary expression can give a proper account of the subtleness and complexity of scientific thought. As for me, I have always thought that there is no contradiction between the scientist's work and the writer's art (although I am perfectly aware of the limits of language, of analogies and metaphors). For instance, I have always tried to apply the idea that the very form of a book can reflect, in one way or another, its content — through its size, its layout, its organisation, its literary construction, and its rhythm. Thus for me, the ideal "recipe" for successful science communication books (not necessarily leading to a short-lived best-seller!) lies in a mixture of enthusiastic passion, a rigorous and always up-to-date scientific content, and a high level of literary achievement.

How can art help with the communication of science?

For me, as for Omar Khayyam, who was an astronomer, a mathematician and a poet in the Persia of the 11th century, science is not the only road to knowledge. I have always believed in the links between the various forms of human creation, and I am deeply convinced that different approaches — whether scientific, artistic, philosophical or others — give rise to different perceptions of the world, but with an underlying common imaginary element. In that sense, art, and more generally an aesthetic approach, can really sustain and help science communication.

Do you use any models for communicating science with the public?

As long ago as the third century BCE, in Syracuse, in the Greek colony in Sicily, King Hiero called on Archimedes to turn his art from purely intellectual issues to concrete objects, to render his reasoning accessible to the senses and tangible to the common man. A high point in science communication was reached by Lucretius. This Latin poet of the first century BCE, a follower of Epicurus and the atomistic philosophy, left a crucial work, *On the Nature of the Universe (De natura rerum)*, which admirably combined an epistemological design with a concern for form. Lucretius constructed his work as a poem whose rhythm and structure fits its content as closely as possible.

Now this is for books. Since I also use other media such as documentaries, exhibitions, audio records, artistic works, novels, etc., each medium has its own specificities, and frankly I have no model other than my passion to make complicated things understandable.

Which aspects of communicating astronomy with the public do you find particularly challenging?

Most of the concepts and results of modern astrophysics and cosmology are in contradiction with what is called "common sense". For instance, the idea (developed by such bright minds as the philosopher Immanuel Kant) that finiteness implies limits. Such an argument is faulty, because it relies on propositions coming from supposed common sense (or mathematical ignorance). Another example is the common belief, shared not only by laymen, but also by most professional cosmologists, that the real Universe is necessarily greater than the observed one. To believe the inverse (and this is quite possible in the framework of "wraparound" universe models that I have developed and worked on a great deal) clearly goes in opposition to common sense. But this is not sufficient for the idea to be dismissed — quite the contrary, as the history of science has often shown! Common sense, whatever it may be, cannot help but be surprised by science on occasion. It is, after all, only an argument of authority for those ideas shared by the greatest number. This is, for me, the greatest challenge for communicating scientific knowledge. As Galileo said, the number of people who reason well in complicated matters is much smaller than those who reason badly! Other challenges are important and simpler to explain: help stimulating interest in science, promote the understanding of scientific progress and its implications in wider society, boost scientific culture, and encourage young people to take on scientific careers.

How do you visualise the future of European science communication, given the difficulties presented by language and cultural barriers?

I am profoundly attached to the idea of the prominent role of Europe in the field of knowledge, both in the past, of course, but also in the present and the future. As a consequence I have always highlighted in my work for the public the intimate presence of European discoveries in the remote and recent past. For instance, the purpose of one of my popular essays in the history of science has been the re-evaluation and promotion, based on extensive historical and scientific research, of the Belgian priest and cosmologist George Lemaître. Lemaître pioneered the application of Einstein's general theory of relativity to cosmology, suggested a precursor of the law now named after the American Edwin Hubble, and proposed the first "Big Bang" theory. Also, in my series of scientific biographies of European scholars (Copernicus, Tycho Brahe, Kepler, Galileo, etc.), I tried to give a clear and historical vision of the fundamental contribution of European scientists to astronomy and our understanding of the Universe over some 25 centuries. In this manner I want to illuminate the richness of European culture and the clear place of science within it. Of course there is the barrier of language and culture. But translations are possible, and my main satisfaction in this field is to see the number of translations of my works into English, German, Italian, Spanish, Portuguese, Greek, Dutch, Polish or Czech.

Biographies

Jean-Pierre Luminet is an astrophysicist at the Paris-Meudon Observatory in France and a leading expert on black holes, cosmology and the new field of cosmic topology – the study of the overall shape of the Universe. He has published numerous articles in the most prestigious journals and reviews in these areas. He has been awarded many prizes for his work in pure science and in science communication. His website address is: http://luth2.obspm.fr/~luminet/.

Lee Pullen puts his astronomy degree and science communication master's to good use, engaging a wide range of hard-to-reach audiences. He specialises in science education and journalism, having taught several thousand people about the cosmos and regularly writing for NASA's astrobiology web magazine. His enthusiasm is legend, as is his website: www.leepullen.co.uk.

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, EGU Earth and Space Science Informatics Division and the IAF Science and Society Committee.

Capturing Heaven

Greg Martin
artofgregmartin.com
E-mail: greg@artofgregmartin.com

Key Words

Visualisation

Summary

We have all seen the spectacular images that the *Hubble Space Telescope* and other such observatories have revealed to the world. Their haunting splendour inspires and compels us as artists. But how can we capture the elusive essence of space in our own work?

Simply put, how does one draw space? To answer this question, it is necessary to move beyond the details of "How do I do such and such in Photoshop?"

I'll say this right up front: this article is not going anywhere near the raw techniques needed to create celestial art. I've discussed this with a number of colleagues, and we've all agreed that the process of self-discovery and learning is a priceless experience. I have no intention of giving anyone the temptation of a shortcut, as I really believe it does more harm than good — providing a crutch and inhibiting an artist's ingrained confidence from developing. The main reason I've written this article is because I dearly love space and all its potential beauty. I also highly respect the community and would like to give those who care to take the time an insight into my own understanding of the elements of space.

To begin, I offer this kernel of knowledge...

Understanding the concept is paramount

The secret to drawing space is to have an intuitive understanding of it. Whether this understanding is the result of research and observation or some spontaneous inspiration, you really must know your subject. A thorough grasp of software and a decent assortment of tricks up your sleeve are important, of course, but even more important is the ability to think about space on a level deeper than simply looking at a *Hubble* image and trying to copy it. You need to be able to appreciate what space is, physically and aesthetically, in order to represent it in a manner that really does it justice.

That being said, I'd like to share with you some of my own research and insights into space. I realise that some of this is common knowledge. My aims are merely to open your eyes and mind to the sheer potential of celestial art, and then sit back and watch what you create.

Stars and space

As Carl Sagan put it, "A galaxy is composed of dust and stars — billions upon billions of stars." It's true, space is not as dark as one might think. In fact, it is often far brighter than anyone imagined, a tapestry of shadow and exquisite lights, a dimensional fabric with a subtle texture of brilliance, stretching back in layer upon layer, plane upon plane.

Points of light with maybe a twinkle here and there, stars can seem fairly unremarkable at

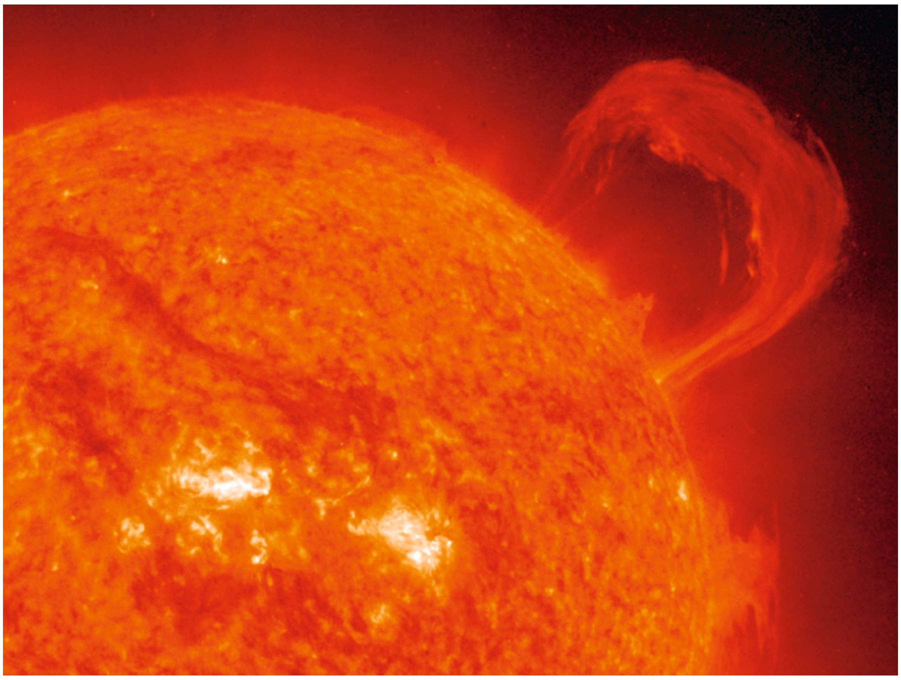


Figure 1. Prominence on the Sun. Credit: NASA/ESA SOHO.

first. Closer analysis, however, reveals that stars are not boring in the least and in fact play a vital role in celestial art. Whether they are seen up close or from afar, these luminous pinpricks provide two crucial elements in a scene: a sense of depth and a source of light. When combined with a healthy dose of variety, stars can convey fathomless depths. Similar to looking into a lake and watching the Sun reflect off particles in the water, stars recede in layer upon layer of tiny specks, diminishing in size and visibility as the distance between themselves and the viewer increases. A simple glance at the night sky illustrates this point, revealing also that not all stars are created equal: they vary in size and composition according to their nature. Like a crowd of random people, the sky reveals stars of different masses and in different stages of their lives.

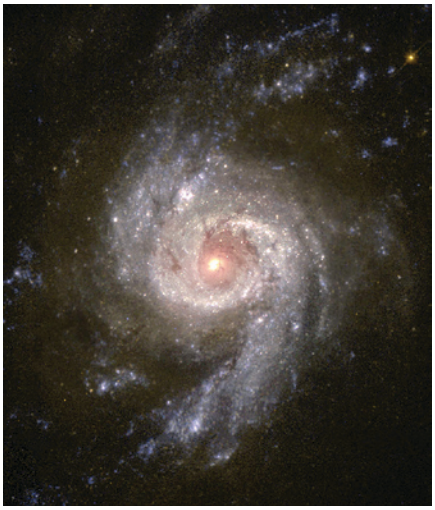


Figure 2. Galaxy NGC 3310. Credit: NASA/ESA/ HUBBLE Heritage Team.

Taking a closer look, the specks of light lose their innocent purity. At close range a raging tempest is revealed: a roiling ball of fusion, light and energy that is held together only by the tenuous balance between energy released and gravity retaining. Suddenly that pinprick of light has a fiery presence and personality that demand recognition. A look at the Sun illustrates this nicely, and easily dispels any notion that stars are simple, perfect spheres of light. Sunspots mar a surface of churning texture, and solar flares leap out into space. The Sun is a caged beast, with a fury unmatched.

There are many different types of stars, broadly categorised by their colour and size. The colour of a star is determined by its temperature, a result of the ferocity of its fusion reactions and often in direct correlation to the size of the star itself. Red stars are generally the coolest in temperature, and white or blue stars are the warmest. Our Sun, for example, is a midsize yellow star, apparently quite common and with a moderate temperature. Like other stars, it is a collection of gases that exist in a state of perpetual turmoil, a giant, ongoing fusion reaction held together by its own gravity. It is our constant friend and benefactor, providing light and heat in a curiously opportune balance that has allowed life to flourish on Earth. When it reaches the end of its lifespan (in several billion years), it will probably swell to become a red giant for a brief time… a stage of development that will result in the incineration of the inner planets, including Earth. At the end of this stage, it will then collapse in on itself to become a white dwarf, eventually burning itself out. This represents a generalised life cycle that most stars will follow, save for those stars that have huge amounts of mass. These may go out a bit more dramatically, with the cataclysmic event known as a supernova, and leave a slowly fading splash of light and colour known as a supernova remnant.

> Stars have been and always will be an important element of space. In point of fact, you don't see a whole lot of celestial artwork without them. They always seem to be included in some form or another, like some unspoken prerequisite for a space image, and can be used as anything from a simple texture to a major character in a scene. Such amazing versatility is not to be taken for granted. It is always worth taking the time for a little experimentation to learn — to know — how you can use these luminous characters in your art and do them justice. One thing you see very rarely is a space image that is only space, only stars. Very few people have taken the time to perfect such a piece, as most are used to seeing stars as merely a task on the road to a larger goal. Personally, I think that stars are worthy objects of study all by themselves, and that there is seldom anything as beautiful — or as peaceful — as a view of deep space filled with stars.

Stars can also be community dwellers. This means that they exist not only as singular specks in the depths of space, but in clusters and galaxies as well. It is also possible that they will not always be shining through pristine space. Some stars may live ensconced within a haze of dust, others amidst full-fledged planetary nebulae. Others fall victim to dark matter (called dark for a reason, apparently) and are partially or even completely obscured. Each star tells part of a story, and together they weave a scene as fully expressive and emotive as any landscape or character study.

That covers the purely physical nature of stars; how they are used in art is a different matter of study altogether. As a source of light and energy, a sun can be an amazingly benevolent character. Stars can be peaceful companions in a night sky, or glittering treasure in pockets of light amidst a diaphanous nebula. Imagine stars as a handful of brightly glowing dust; the uses for such an amazing element are endless, as is the wonder one can evoke in a viewer if they are used well.

Planets

The quintessential characters of celestial art, planets are often both underdeveloped and undervalued. More than just a spherical *cliché* in a celestial scene, planets are jewels of creation and provide a story all on their own. A view from space reveals a tremendous saga of biology, geology and meteorology. Clouds, coastlines, mountains, lakes, rivers, volcanoes, craters, storms... the list of

Figure 3. Earth. Credit: The author.

Figure 4. Phytoplankton blooms in Fox Basin, Canada. Credit: NASA/VISIBLE EARTH

Etymology: Middle English *planete*, from Old French, from Late Latin *planeta*, modification of Greek *planēt-*, *planēs*, literally, wanderer, from *planasthai* to wander.
Merriam-Webster's Collegiate Dictionary

possibilities goes on and on. What's more, planets can easily play multiple roles in celestial art, functioning as an actor in a scene, an extra detail, or even the subject of the piece as a whole. Defined by their sheer size and penchant for detail, planets are essentially enormous layered spheres. Each of their layers encompasses a system of immense complexity and an endless opportunity for detail and exploration.

A look at satellite imagery of our own planet (Figure 4) reveals that, as an artist, nature tends not to disappoint. Each spherical layer on Earth, from the multifaceted atmosphere down to the land and sea, is teeming with detail and activity.

And the Earth is not alone: even the gas giants in our Solar System are permeated to their very depths with detail. A close examination of Jupiter, for example, reveals that, while not possessing a visible ground surface, it is imbued with layer upon layer of colossal and chaotic weather patterns. The Jovian skyscape is rent with lightning, dominated by rank upon rank of towering cloud formations that utterly dwarf their terrestrial cousins. All of this is visible from space, and the largest storm system a planet can produce could very well be no more than a minor detail in the scheme of things. This is the entity known as the planet, not those annoying rendered texture balls that many think they are. A planet is a creation that, when done properly, will convey endless levels of detail from the prominently visible all the way down to the merely implied.

As interesting as they are, it also pays to remember that planets are not always alone. In fact, it is quite common to see them accompanied in their orbits by one or more moons. These often barren brethren are also repositories of exquisite detail, albeit perhaps in fewer layers than the planets if the moon is without atmosphere. But moons carry different elements that may be lacking on a planet — details of their interaction with other space elements: craters, cracks and fissures. All of these things (which may or may not survive the wear of time or weather on a planet surface) tell of the devastating power of impacting asteroids, meteorites and comets. Whereas a green planet with water and air may tell a story of teeming life, a barren moon displays its alternative, opening up the imagination to all sorts of cataclysmic scenarios. Of course, there can be an element of the dramatic without fire and ice (so to speak). Moons are, by their physical as well as aesthetic natures, perfect balances for a planet in a scene. This makes them "free agents" of a sort, extremely welcome to any composition, but not entirely essential.

Figure 5. Crop from Crescent. Credit: Michael Ward (shirosynth.deviantart.com).

More than anything else, planets represent endless possibilities. They are more than a simple texture, more than a glowing orb. Planets are alive, and like any other element of space, deserving of a composition that does full justice to their undeniable beauty and appeal. Incredible visual entities that they are, however, planets are more often than not represented in art as a shaded circle or a simple textured sphere. The idea that a multifaceted, infinitely complex planetary body can be meaningfully distilled down to a simple sphere with a texture mapped onto it is, in a word, obscene. That's akin to saying the elegance of engraved and polished silver can be obtained by wrapping a rock in aluminium foil; it doesn't work that way. Planets are treasure troves of natural splendour, able to carry an image in their own right or provide elegant context as needed. To waste such an artistic element by not taking the time to realise it completely is a terrible loss. A good planet is both a joy to create and a wonder to behold.

Nebulae

Tangled constructs of dust, gas and light, nebulae are among the most beautiful and erratic of space phenomena. These glowing expanses of ionised gases and dust can easily be one of the most enjoyable and free vessels for artistic expression. Beyond a reasonable adherence to physics (often better considered than ignored) nebulae are surprisingly open to interpretation. Since most people have only seen them through

Figure 6. The Rosette Nebula. Credit: T. A. Rector, B. Wolpa, M. Hanna (AURA/NOAO/NSF).

Figure 7. The Orion Nebula and Trapezium Cluster. Credit: Mark McCaughrean (AI Potsdam) et al., ISAAC, VLT ANTU, ESO.

Figure 8. The Helix Nebula. Credit: NASA, WIYN, NOAO, ESA, Hubble Helix Nebula Team, M. Meixner (STScI) & T. A. Rector (NRAO).

Figure 9. Reflection Nebula in Orion. Credit: NASA/ESA Hubble.

Figure 10. The Bug Nebula. Credit: NASA/ESA Hubble.

It is important to note that when the term "light" is discussed here it may transcend the visible spectrum. Since many of the images seen in popular media are created from X-ray or even infrared observations, the term "light" is stretched to cover any energy that can be construed as a lightening element when translated through artwork.

the lens of false-colour photography, just about anything can be made believable — and thereby even more spectacular — with a decent level of detail and at least a nod towards their physical structure. Surprising to some, nebulae are more than just a splash of colour in the night sky. Their very existence is due to intricate interactions between their component parts, a subtle dance of light and energy that results in several types of nebulae. There are many ways to classify these luminous structures, most commonly based on their physical properties or manner of creation. When thinking about them in terms of art, however, a schema that broadly classifies them based on how they deal with light (see box) seems more appropriate.

Emission nebulae

Emission nebulae are luminous entities composed of energised gases. The highly charged state of the gases depends on their surroundings; either the stars near them are exciting the gas in some fashion, or the nebulae themselves are the result of an event of magnitude. Supernova remnants, for example, are emission nebulae, and are usually some of the most exciting in terms of colour and vivacity. When a dying star of sufficient mass collapses inwards in the final stages of its death throes, it sometimes erupts in an explosion known as a nova, or in the case of more massive stars, a supernova. Material is hurled forth in this process, spreading out

Figure 11. Region N11B in the Large Magellanic Cloud. Credit: NASA/ESA Hubble.

When I draw nebulae, I never sketch or plan beyond the most whimsical of lines. I prefer not to define them if I can at all avoid it, instead preferring to let them evolve as I work. No one technique for creating them has ever gained my fancy, and no one type of nebula has ever reigned supreme as "THE nebula for the serious space artist" (a silly consideration to begin with, why limit yourself?). In my experience, nebulae grow, based on playing and deciding for one's self what works for the given composition, truly a gut creation if I ever saw one. And they take time. This is a subject that looks as if it would be fairly easy to create, but oddly enough isn't. If it were, everyone would be doing it and succeeding brilliantly (which isn't saying that some people aren't succeeding brilliantly). Simply put, if there was a quick and easy way to make incredible nebulae, we'd see a lot more of them. But there's more to a nebula than the techniques of its creation. They should tell a story, because in real life each and every one does just that. Take, for example, planetary nebulae. Most often composed of dust and the raw materials for life, these variants of reflection nebulae organise around a star or a system of stars. The story of the beginning of a solar system is there for the taking (or illustrating), and is far more interesting than a simple splash and smear affair that is concerned solely with "looking like space". The human race has long looked at the stars and been in awe, but history maintains that we didn't peer into the night sky for a good show so much as to derive meaning. To look at space any other way is merely skimming the top of a rich subject with the potential to give so much more.

in a wave of highly energised gas. The Helix Nebula is a good example of this (see Figure 8). The Rosette Nebula is also an emission nebula, but also a supernova remnant, a glowing cloud of gas heated by nearby stars to an excited state.

Reflection nebulae

Reflection nebulae, as the name implies, are visible largely due to the reflection of light from their dusty components. Often seen as ghostly apparitions in the sky, reflection nebulae are absolutely fantastic for alluding to depth and volume. Unlike the charged gases in emission nebulae, reflection nebulae deal with their component light sources up front, constructing fantastic inner spaces that are lit or in shadow depending on the position of their light sources. These nebulae are the most dramatic and awe-inspiring of the three because, unlike emission or dark nebulae, they are literally edifices in space, spanning millions upon millions of miles. They are the cumulonimbi of nebulae. One such example, the Bug Nebula (Figure 10), is particularly dazzling. With its wildly energetic veils of light and rich golden hues, the Bug Nebula looks like it would almost be more at home in a renaissance painting rather than in space. On the other end of the spectrum, they can also be the cirrus clouds of nebulae, wispy and diaphanous, like the Reflection Nebula in Orion (Figure 9). This incredible range makes them immensely interesting and, in terms of composition, incredibly versatile subject matter.

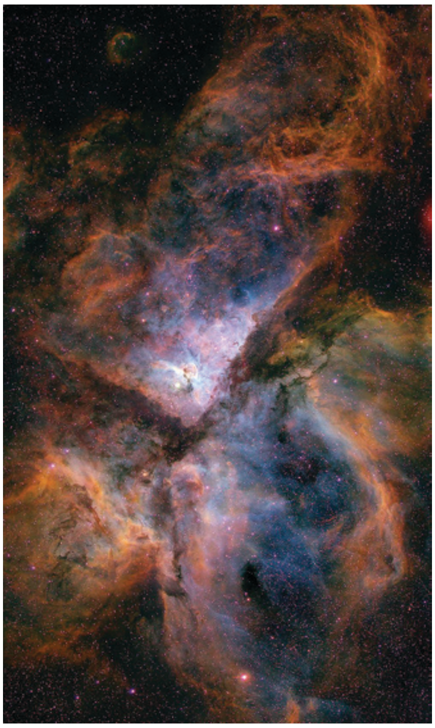


Figure 12. Keyhole Nebula. Credit: Nathan Smith (University of Minnesota), NOAO, AURA, NSF.

Dark nebulae

Dark nebulae are the shadows in space, veils of dust and assorted matter that, rather than reflecting or emitting light, block it entirely (but not uniformly). The Horsehead Nebula (Figure 13) is a perfect example of a dark nebula, its eerie silhouette a sharp contrast to the brilliantly lit gases surrounding it. Whereas the two previous nebula types have celebrated light, dark nebulae celebrate its absence, making them at once both foreboding and enigmatic. These curtains of dust are, by their very nature, alluring, their presence leading viewers to wonder, "What's behind there?" When used with sensitivity in an image, they can provide a powerful boost to the mood of the piece. In another light (no pun intended), they rule supreme as the ultimate element of contrast.

Figure 13. Horsehead Nebula. Credit: NASA

Light

Light flows. Like water, it can gush, bubble, meander and swirl. It functions as a tangible substance, even though it is physically anything but. Light is the crucial element in a piece, able to make or break it depending entirely on the ability of the artist to wield it effectively. As the key element (an important idea in the inherent darkness of space), light is something that every artist should study and attempt to understand. It is by far the most dynamic element of celestial art — or any other art for that matter — and those who master it stand out from the rest with works that exhibit a potent vibrancy.

How light behaves depends largely on the medium it is reacting to. Energised gas, for instance, emits its own light, and so, by extension, becomes light in of itself and has no limits to what it can do. The dust and matter of a reflection nebula, on the other hand, are a little less free, if only by physical definition. Here the light is far more expressive

Figure 14. Crop from Etherlight. *Credit: Gary Tonge (www.visionafar.com).*

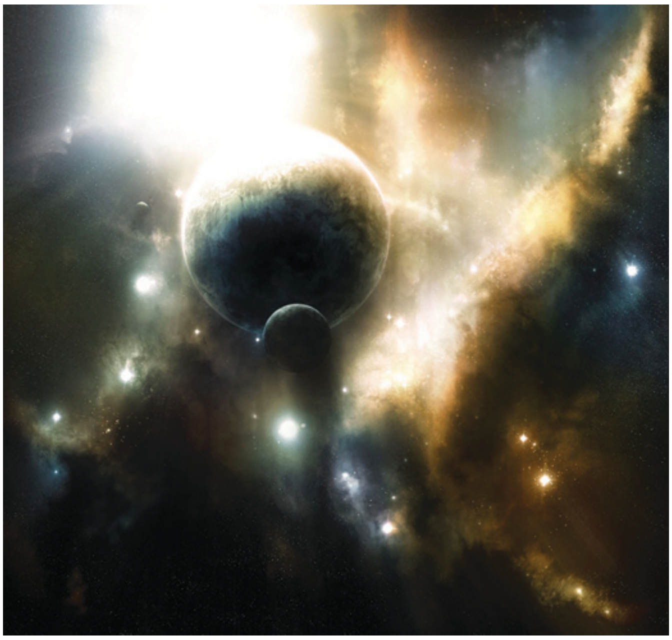


Figure 15. Crop from Euphoria Mod II. *Credit: The author.*

in the form of streams, rays and shadows. A column of dust, for example, may have rivulets of light curling about it as wisps of dust farther from the main mass escape its shadow to catch light on their own. A thin cloud of matter may also allow crepuscular rays (also known as "God rays") of light to flow past, streaming out like a holy beacon. Gary Tonge captures this beautifully in his painting, *Etherlight.* At the other end of the spectrum are simpler light reflections. Planetary surfaces, for example, may reflect light while their atmospheres refract it in such a fashion that they glow brilliantly.

It is important to note also that light is not a two-dimensional creature. Highly receptive to changes in depth and volume, light can be used to emphasise or exaggerate either. A cavern of nebulous dust could become even more dynamic than it is in a merely physical sense by the addition of light (in the form of glowing stars) throughout. Shadows can throw contours into sharp relief, deepening the visual impact of such a structure. A veil of glowing dust between the viewer and a planet can emphasise not only the size of the planet, but its sheer presence and dimensionality as well, drawing attention to the formal contrast between the dust and the magnificent glowing sphere. The list could go on and on — the possibilities of light are endless.

The physical nature of light, too, is something to consider. The luminosity of a light source can provide direct focus for a piece, as it is very hard to ignore a properly rendered (drawn) light of brilliant intensity. The quintessential dawning of the Sun over the Earth would be decidedly lacklustre without the telltale flare and diffraction spike, elements that can be used elsewhere to indicate extreme brilliance far more tactfully than an overexposed glare of white and colour. It has become common to denote brightness by merely upping the levels in a paint program, washing out the object to the point of whiteness. This is not the way to go about things; the best way to show that a light source is incredibly bright is, first, by how it interacts with the subjects of a piece (reflection) and, second, by how it would look to a viewer via delicate diffraction spikes and possibly a subtle flare (see above, right). It is also important to note that a camera flare is easily recognised, and too many of these stand out in a glaring fashion. It is a nice tool, no question about that, but like many filters in paint programs, best used as part of a more refined process and not as a singular means to an end.

The final and most important element of light is its incredible importance to the mood of a piece. Mood plays an important role in the success of the planet and dust veil example mentioned earlier. An excellent example of lighting to affect a mood can be seen in Brandon Hale's *Incandescence.* The image, while simple in its subject matter and technique, is extremely effective in conveying a mysterious, almost brooding mood. The light coming from above makes the planets and moons almost aquatic in nature, as if some higher illumination was shedding light upon a community of celestial bodies. Gary Tonge's *Havona,* also uses light effectively, both as a focus for the piece and to create a feeling of sheer awe.

Light is incredibly important to art. Unfortunately, many people are too caught up with the "how" to understand the "why". There's no easy answer to how one creates and controls light in a scene beyond simply taking the time to understand it and get a feel for it. For a long time, light has been a particular fancy of mine, an element that I seek to control and harness for the betterment of all my works. I don't know why, but the idea of a truly immersive image is so incredibly appealing to me that I find myself working towards that goal in everything I do. Light is an essential key to this, the final piece in setting up a truly dynamic environment. Despite the many years that I've been playing with it, I've not yet fully mastered light. The only way to learn is to do, so I've been practising and improving over time. I urge everyone to do the same.

The impact of a piece is directly related to how effectively it is lit, because one of the main draws for such an illustration is the pervasive mood of mystery and awe that the scene would evoke in real life. This holds true for almost any scene, making it all the more important to understand light and how to use it.

Final thoughts

You may ask what all the fuss is about regarding understanding space. You may think to yourself, "I can always follow a tutorial and get the results I need." In return, I ask you this: are you truly your own artist if you do this, Or are you an extension of the tutorials that govern your creations? Thanks to cookie-cutter tutorials and walkthroughs (which I am at least in part responsible for), the realm of celestial art is now a horrible *cliché* inundated by artists and dreamers who cut corners to get their shiny, mass-produced results. Only a dedication to complete, utter and exquisite excellence will make this genre respectable again. I've hinted at this decline throughout the whole of this article (and tried not to be overbearing, since I'm just as responsible as any for the fate of this genre), but the message is of

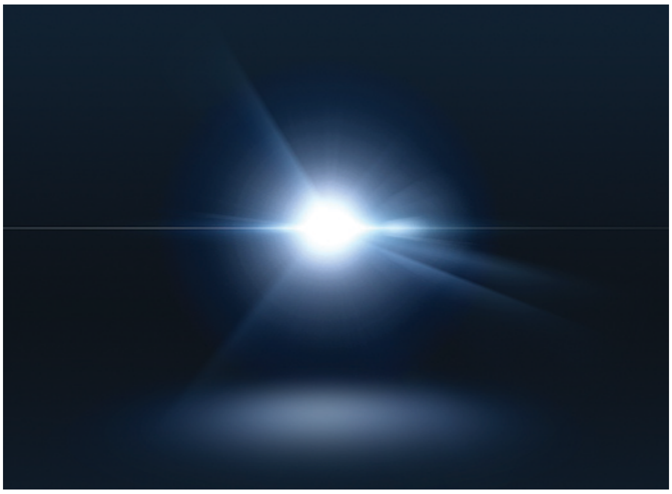


Figure 16. Flare and diffraction spike example. Credit: The author.

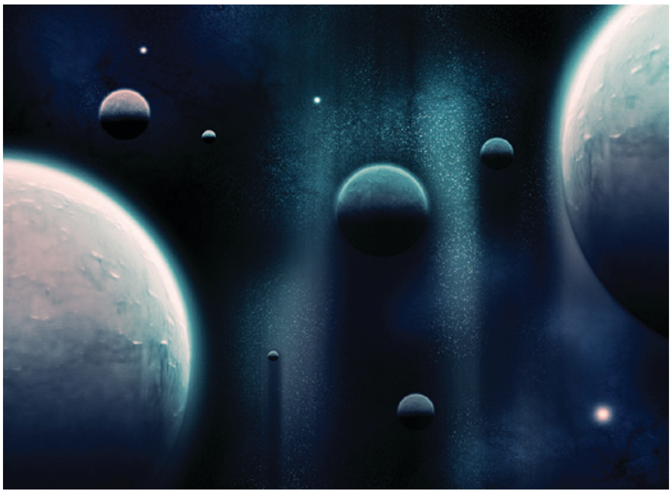


Figure 17. Incandescence. Credit: Brandon Hale (absolutehalo.deviantart.com/).

paramount importance. Space is dying. As a realm free from restraint or rules save those that we make for ourselves as artists, it has suffered the blows of ready-made filters, plug-ins and campy computer-generated shortcuts like none other. I suppose the thing to remember is that, no matter what anyone says, those cheap derivations of space will probably always be there. It is the responsibility of the serious artist to govern his or her own efforts, to exercise discipline and to learn respect for the truly awesome topic that we strive to represent and do justice to.

Figure 18. Havona. Credit: Gary Tonge (www.visionafar.com).

So much of art isn't the program you use, but the understanding your exhibit through whatever you create. The differences between the images created off the cuff or after copious research are dramatic. Personally, whenever I attempt a project without a firm footing in the subject at hand I flounder — badly. I can only imagine how other artists feel about this subject, but for me, to draw something you must know it intimately. In this, an open mind and open eyes are your best tools. Many tend to forget that observation and research are part of the job of being an artist, and that careful analysis — both in terms of the medium (programs) and the physical nature of what is being created — can yield answers far more illuminating than any tutorial or step-by-step instruction.

The road to understanding something can only be travelled by your own two feet. Your personal style and the insights you bring to a subject through art are what make your creations different from anyone else's. Ultimately, that's what keeps art interesting. Certainly, that's what keeps art alive.

I hope this has been some help. Now it's time to draw...

Biography

An artist admired by many astronomy communicators, **Greg Martin** lives in Portland, Oregon. He has been drawing ever since he could pick up a pencil or crayon, and made the transition to computers as his primary mode of artistic expression around 1995 or so. This transition was inspired largely by the fact that it is fairly difficult to draw celestial artwork in pencil or paint (although many have done so with spectacular results). The computer seemed to be a perfect tool for it, and space became his "gateway" into digital art.

ASTRONET: Public Outreach

Extract, with minor editorial changes, from The ASTRONET Infrastructure Roadmap[1] Chapter 7

Rosa M. Ros
Technical University of Catalonia, Spain
E-mail: ros@ma4.upc.edu

Robert Fosbury
ST-ECF, ESA
E-mail: rfosbury@eso.org

Lars Lindberg Christensen
ESA/Hubble/ST-ECF

Jose Carlos del Toro Iniesta
IAA-CSIC, Spain

Leonarda Fucili
SMS Belli Rome, Italy

Robert Hill
Northern Ireland Space Office, Armagh, UK

Dirk Lorenzen
German Public Radio, Germany

Claus Madsen
ESO

Andy Newsam
Liverpool JMU, UK

Alan Pickwick
Manchester Grammar School, UK

Veselka Radeva
Varna Observatory, Bulgaria

Key Words

Public Outreach
Strategic Planning
European Astronomy

Summary

The infrastructures that are built and used for astronomical research are financed by — and therefore must be justified to — our society. Astronomy has an innate appeal for people of all ages, partly because it concerns the fascinating, great questions "of life, the Universe and everything" and partly because much of the data obtained with telescopes can be presented as objects of stunning beauty. These are key facts when considering communicating astronomy with the public.

This native advantage that astronomy has over many other sciences does not, however, relieve us of the obligation to explain what we are doing to the public at large. There are many reasons for doing this. They range from attracting bright young people into the subject to fuel future research endeavours to convincing decision-takers to allocate large sums of money to finance increasingly expensive and ambitious projects.

Introduction

The existence of the International Year of Astronomy in 2009, 400 years after the first use of an astronomical telescope by Galileo Galilei, provides a splendid opportunity to boost worldwide awareness of the subject. Organised by the International Astronomical Union (IAU) and endorsed by the United Nations, this global endeavour with over 125 national nodes will reach hundreds of millions of people who will have had little previous exposure to science. Occurring near the beginning of the Roadmap implementation, it should create a groundswell of public support for the ambitious plans we are making. It is certainly an important time for astronomy communicators, with numerous opportunities to promote how science can have a positive influence on society.

ASTRONET Panel E is concerned with these aspects of the relationship of our subject with society, from teaching in schools, training in universities and recruitment into astronomy-related jobs to the process of communicating astronomy to the public. It also considers the relationship between cutting-edge research infrastructures with the industries that help build them, hopefully to the benefit of the overall economy of the continent.

At the top level of research activity, where international teams of astronomers, including young post-docs, collaborate to utilise

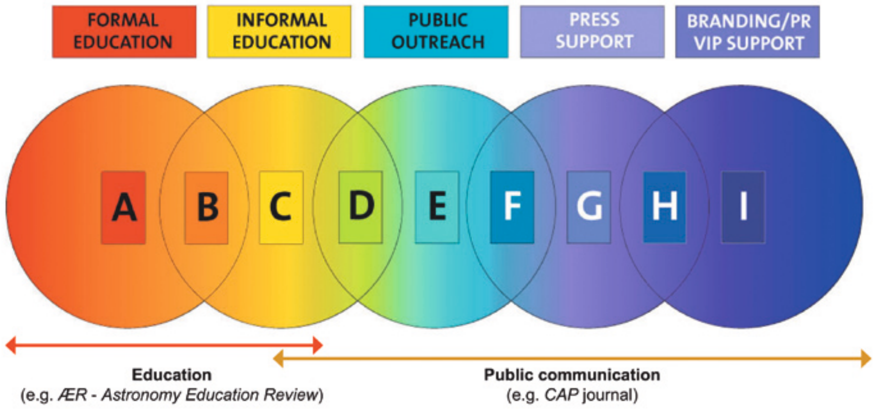


Figure 1. The entire science communication "space" from education to public communication including "PR"[2]. Credits: Christensen & Russo.

the world's most powerful instruments, there must be sufficient funding available to allow European astronomers to exploit the resulting observations on a competitive timescale, thus reaping the full scientific and training rewards of such large investments in facilities.

It is important that the organisations providing the facilities and also individual scientists recognise the importance of explaining what they do to the people who are, ultimately, paying them to do it. By ensuring that public communication is seen as an integral part of a scientist's job and that it is given clear recognition when done well, a culture of high quality communication can be encouraged.

A common theme among the recommendations we make in this article is an urgent need for steps to improve the organisation and the accessibility of the enormous amount of education and public outreach material in today's information mass market. Tools such as common portals to — and organised repositories of — media and materials for these purposes will bring a fruitful order to the existing rich, but widely dispersed, assemblages of data, images, videos and other information.

Background

People's innate curiosity about the world in which they live draws them towards astronomy, providing rich opportunities for outreach and education (see Figure 1). Our task is to gain maximum profit from this situation by stimulating the interest and imagination of people of all ages and backgrounds.

Panel E's report tackles two principal areas:

- Education, including primary and secondary schools, university education and research, and recruitment;
- Communication, aimed at several different target groups.

A set of recommendations has been derived from the Panel's investigations and they are given and described in the following sections. Each recommendation is supported by some background information, a summary of the work carried out by the Panel and, where possible, some pertinent example.

These recommendations can be divided into two groups: those that seek to change the cultural behaviour within astronomy and science education and those that will require some financial support provided by government education ministries, national or international funding agencies or individual research institutions. Effects of such spending might be expected to become apparent on timescales of two to three years. In this article we focus only on the communication side.

A note on terminology. In this document, we refer to both national and international organisations. Amongst the latter are pan-European organisations like the European Space Agency and the European Southern Observatory for which we use the generic term "agency".

Communication

Science museums and planetaria

The opinions of the museum and planetarium operators were polled with a questionnaire (reproduced in the Report Appendix VI.D) sent to addresses from the International Planetarium Society[3], the British Association of Planetaria[4], and the European Hands-On Universe network[5]. This list includes various government-funded organisations, non-governmental bodies and privately funded science outreach operations throughout Europe. From a total of 34 responses, the following general conclusions emerged:

- Formal links with the European agencies involved with astronomy and space are scarce. Less than a tenth of responders indicated that they had any link or direct communication with the agencies in Europe.
- The majority of responders would welcome a central repository of visual material relating to astronomy and space. They are especially interested in images and videos.
- The relationship between planetaria and local amateur astronomical societies is common and should be better understood and utilised. Regional astronomical associations and societies are a powerful dissemination mechanism of astronomy related literature and scientific endeavour. The valuable role that amateur astronomers play, both in the role within society as a communication conduit, and also in real scientific endeavour through observation, is recognised by the Panel. Established relationships with professional astronomers are less common.
- Problems with curriculum integration and the sustainability of formal programmes clearly exist.

The responses exposed a richly diverse programme covering many aspects of classical and modern-day astronomy. The interaction with the public clearly benefits from the stunning visual appeal that astronomy offers and there is some evidence that this has a direct effect on bringing pupils into science subjects in secondary school, although more tracking is required to verify this effect. Many of the facilities questioned offer a formal astronomy education package linked to the curriculum in their respective regions and it may be that the impact that these centres have on student choice should be further explored. It should also be noted that those that do provide formal stimulus also have difficulty in creating synergy with the curriculum providers and that this is partially addressed in Recommendations 1, 2, 3 and 4. See full report on: www.astronet-eu.org.

The planetaria and science centres in Europe are the natural conduits through which the flow of astronomical information is disseminated to the wider public. This leads to our principal recommendation in this area. Although the European Agencies (ESA/ESO) have worked in collaboration with some of the major planetarium associations in Europe, a more systematic collaboration and coherent strategy may be required to further the impact of European astronomy communication to society.

Recommendation 5

Action. *Active steps should be taken to forge links between science museums/planetaria and the European Agencies (ESA/ESO), the principal providers of high quality media and related resources in astronomy.*

Institution. European agency (ESA/ESO) or other stakeholders.

Timescale. Two to three years.

Comment. This could take place via a central portal that could be the same as that referred to in Recommendation 8 below.

It should be noted that the European Space Agency has begun to create a network of European Space Education Resource Offices (ESERO)[6]. The primary task of the European Space Education Resource Offices (see Figure 2) is to encourage and inspire young people to learn more about science and technology by drawing upon their enthusiasm for space exploration. The ESEROs are intended to be the first ports of call for anyone in Europe requiring educational support related to space activities. A network could be created to promote a synergy between European agencies and science centres and planetaria.

Figure 2. ESERO logo. Credit: ESA.

Public communication and outreach

Here we focus on the astronomy communication activities that are not seen as "formal education", especially press support, public outreach and activities of a promotional nature (with the aim of elevating the visibility of a scientific organisation). In addition to using the substantial hands-on public communication experience within the Panel, we have distributed a questionnaire to over 40 of the major players in Europe (see Report Appendix VI.E) and also analysed the answers to the relevant question in the ASTRONET Questionnaire (see question 12 in Report Appendix IV.D and also Report Section 2.3).

It is widely acknowledged that astronomy can play a key role in raising public awareness of science[7]. A vigorous activity in science public communication and outreach in Europe is an absolutely essential investment in the future health of the subject and, indeed, can significantly contribute to the economic and cultural life of the continent. Differences in the attitude towards public communication between scientists and science management in the US and in Europe are often stark. The Panel has identified a need to bolster public awareness of astronomy (and science in general), to convince the scientists of its importance and to equip at least some of them with the knowledge and tools to participate actively in the process.

The European landscape of public communication mechanisms is (not surprisingly) complex and rather fragmented. Different countries have different cultural backgrounds, political systems, technological and scientific levels, and level of general knowledge. The differences naturally make it more difficult to reach the entire continent in an easy way, but the diversity can also be an advantage if taken into account when communicating.

What, from a modern point of view, can only be described as an underdeveloped communication culture and identity in European academia is undoubtedly rooted in its history and linked to the way scientific research has traditionally secured its financial support. Indeed, systematic and sustained public communication about research has not been regarded as indispensable to ensure continued support by public research funders. Public communication is therefore still primarily regarded as a burden on the scientific institutions instead of being seen as a long-term strategic investment. In the US on the other hand the funding loop is much more closed (partly due to federal law) and depends highly on the visibility and results of the individual organisations and research groups.

The claim that Europe has a weak, or in some parts even absent, public communication culture, is strongly supported by the literature and personal experience. As an example Banda (2005) states[8]: "Despite several initiatives in recent years to improve Europe's performance, parts of the research community still do not believe that effective proactive media relations is a priority."

One of the consequences of the Europe/US asymmetry in communication, which is seen over and over again, is that European journalists most frequently quote US sources[9]. One response to the questionnaire states: "European science often appears as second class in the press, even in fields where Europe is leading. The basic communication-cultural differences between the US and Europe are to blame." There may be several reasons for this. Perhaps part of the reason is merely habit with journalists and editors? After all, the media know what they are getting from the US. Perhaps American science stories are more digestible and have a higher standard? Or there are more of them and they are simply more accessible and visible? Most likely all of the above apply, and the best strategy to improve the situation is to consistently produce interesting and high quality communication products in Europe.

This general trend is also apparent in the ASTRONET questionnaire, which provides evidence that there is stronger tendency to include extensive education and outreach programmes in US-dominated facilities. An example is the LIGO Science Education Center in the US (a similar one for GEO600, located in Germany, is not planned as far as we can tell). Naturally there are counterexamples (for instance nearly all radio telescopes in Europe and the US have visitor facilities, as claimed by the European VLBI network).

The lack of communication culture in Europe can also be detected in quite different areas from those discussed so far. An example is the lack of understanding, especially at higher levels, of the scientific hierarchy that astronomical data cannot remain in the ownership of individual scientists or teams beyond a reasonable period. The "ownership" of data streams of potential direct interest to the public by the Principal Investigator of a publicly funded instrument has a destructive impact on the public participation in the science to a degree that should not be underestimated. This is seen for instance for some space-based experiments, with the *Mars Express* High Resolution Stereo Camera data as a notable example (see Figure 3). Instruments operated as "facilities", like most (European) ground-based observatories, tend to have clear data-rights policies. Spacecraft operated as platforms for Principal Investigator experiments produce data that are more under the control of the Principal Investigator.

While most US scientists acknowledge communication as part of their business in order to foster support for future projects, most European scientists don't "get the message". NASA is communicating some of its space missions quite aggressively (actually also quite a few of ESA's and other space agencies' missions) while ESA is very often quite reluctant to communicate the results from its science missions and is sometimes essentially invisible to the press. Without

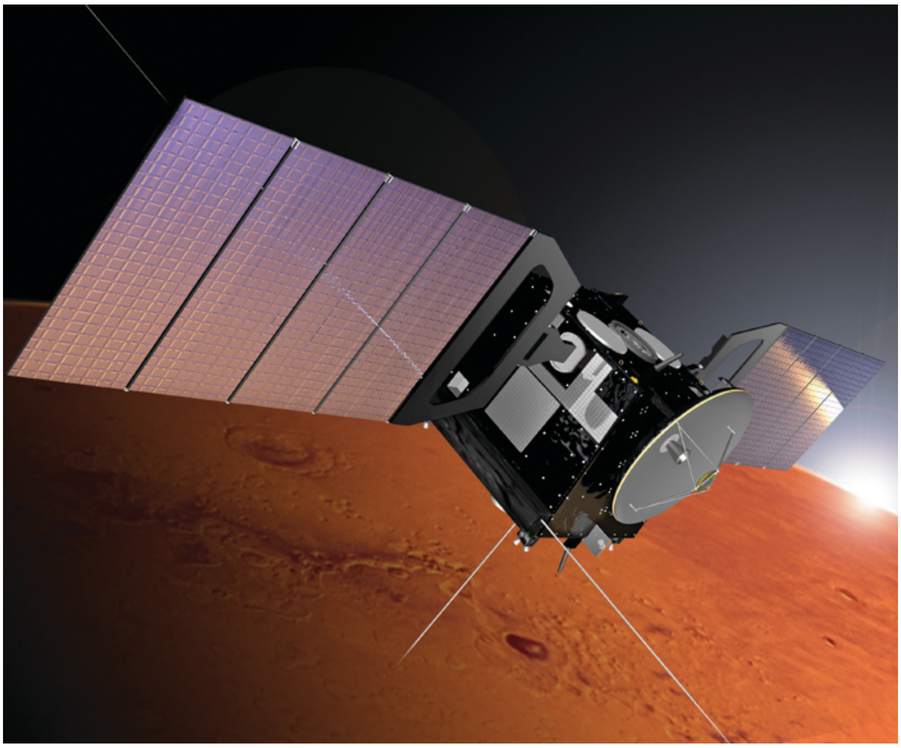


Figure 3. Mars Express*. Credit: Alex Lutkus.*

speculating about the detailed reasons for this finding, one conclusion is unequivocal: the difference in the level of funding for public communication per mission between NASA and ESA can be as much as an order of magnitude or more.

Communication could have a huge impact on the general public and on the decision-makers. The fifth servicing mission to the *Hubble Space Telescope* was saved because of the strong public support, resulting in intense political pressure. The same is true for the *New Horizons* spacecraft en route to Pluto (see Figure 4). NASA's cancellation because of budget problems was withdrawn within months. Could European scientists expect similar public support for their next projects?

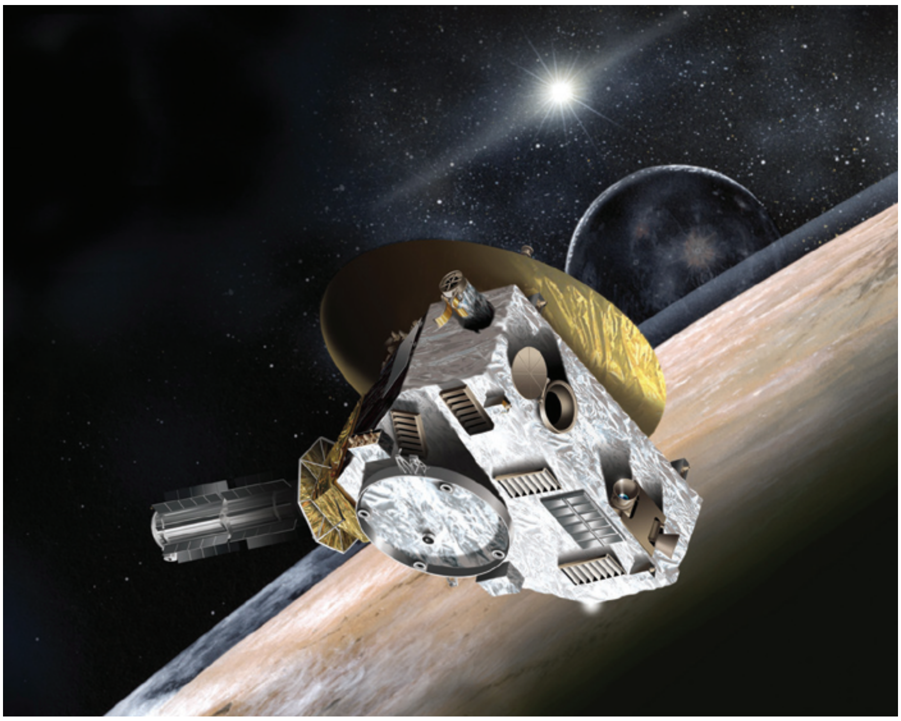


Figure 4. New Horizons *Spacecraft. Credit: NASA.*

The message here is that proper spending on public communication should not be seen as a "cost" but as an "investment" for the future. Returns on this investment may be high. The consequences of not making the investment may be disastrous!

Recommendation 6

Action. *Adequate strategic long-term support must be provided for public communication and education in Europe. Firstly, observatories, laboratories and all facility-funding authorities should allocate sufficient resources for public communication and education.* As a useful benchmark, this would amount to at least a few percent of the overall budget (1–2% is sometimes quoted as a good starting point). For smaller institutes, it should be understood that a threshold investment must be reached to enable a successful communication effort. *Secondly*, public communication of science is subject to the same competitive pressures as all other kinds of public communication. Hence *communication departments must be organised and operated in a professional fashion,* i.e., by professional science communicators, working with active scientists (see Recommendation 7). *Thirdly, as strategic management tools, communication departments must be placed at or directly linked to the highest levels of the institutional scientific hierarchies.*

It goes without saying that results from taxpayer-funded experiments must go into the public domain and be accessible as soon as possible. Where research data are subject to proprietary time rights (typically one year), carefully selected elements of the data should be available for presentation in a suitable form for direct public communication at an earlier stage.

Institution. Agencies.

Timescale. One to two years.

Many of the European projects that have answered the ASTRONET questionnaire aim relatively low in their strategy and mainly target science centres, museums, and teachers' organisations. There is a lack of planning of communication targeting press/journalists, stakeholders, political and industrial opinion formers, etc. Furthermore some European education and outreach programmes lack full-time/professional communicators. As one questionnaire responder says, "There is a lack of professionalism and effectiveness in Europe as compared to the US. We need to learn how to get there 'on time' and 'with a splash'."

In terms of recognition of the importance of public communication in general the Washington Charter[10] is a good starting point and we recommend adherence to it at all levels. The questionnaire confirms the claim that the role and importance of public outreach is still not properly understood in many institutes across Europe. This includes assessing and recognising these activities when young people apply for astronomy positions.

Recommendation 7

Action. *Ensure clear career-relevant recognition for scientists who become involved in public communication. Provide, and encourage scientists to utilise, media training courses.* The Washington Charter should be promulgated at all levels. Proper public communication of astronomy entails the allocation of sufficient resources to secure an adequate, sustained effort executed by professional science communicators.

Institution. Employers of research scientists.

Timescale. One to two years.

Public astronomy communication has to develop apace with the other players in the mass market for electronic information (gaming and entertainment industries, etc). The problem today is not so much the availability of excellent astronomy multimedia resources for use in education, outreach and the like, but rather *access* to these (often digital) materials.

Even for an expert user, locating a particular image invariably requires going to a known resource or relying on the vagaries of existing multimedia search engines, such as Google images or YouTube. One questionnaire respondee said: "Even a simple web page with links to the existing outreach material would be a good start."

Another respondee said: "A central repository with illustrations of any kind in astronomy would be very useful. There are a lot of interesting illustrations on the internet. If these were collected in an archive and allowed to be used for talks etc. it would be very helpful!"

Lately, press release portals such as EurekAlert[11] or AlphaGalileo[12] (see Figure 5 and 6) have emerged and seem to have some success amongst journalists. This kind of syndication service, or one-click portal, seems to be favoured in many parts of the community and is a valuable step in the right direction.

In summary, access to digital education and inspiration materials is getting increasingly difficult due to data management issues, not lack of material. The data management issues can be split into standardisation, metadata tagging, and data exchange/communication. Briefly put, we need standards to know how, where, what, etc. to exchange. We need metadata tags to describe the context of the products (images, videos, etc.). And we need well-described methods for exchanging the products. Some of the existing archives, such as at AthenaWeb[13], rely on physical repositories, where the archive centrally stores and distributes the material. Others advocate an aggregator approach where the material stays with the producers (similar to iTunes) and only the metadata and the location of the data is stored centrally. This method has huge advantages over the former as it is community and needs-driven and hence is more efficient once the archive works. The method is however more cumbersome to set up in the initial phase.

Recommendation 8

Action. *Support the creation of a standardised European science communication portal for media, educators, interested laypeople and others.* This portal should promote best practices and requirements for public communication with a particular awareness of the spectacular image material produced by astronomical research activity (and whose production is currently dominated by the US), on multimedia products (animations, video podcasts, etc.) and engage the community in its continuous growth.

Institution. Agencies.

Timescale. Two to three years.

Comments. Involve IAU Commission 55[14]. This could take place via a central portal, which could be the same as that referred to in Recommendation 6.

Summary and implementation

Following an initial collection of some seventy items, Panel E were able to reduce and condense their deliberations to just ten recommendations directed toward the appropriate European and national bodies. A reasonable time to implement these recommendations is considered to be from one to three years. Note that, due to its somewhat broader nature, Recommendation 10 is considered to be an issue of concern to all the Panels and is not addressed further in this section.

It is recognised that in order for the recommendations in this chapter to be realised, they will need to be carried forward and monitored by a "champion" who has strong connections with funding agencies and other relevant high-level bodies in Europe. The need for continuity over at least two to three years, suggests that this is an activity for ASTRONET to follow beyond the current roadmapping exercise.

The recommendations generated by Panel E divide naturally into two categories. The first of these demand a change in mental attitude and methodology — basically a change of culture — and can be implemented at little or no cost over a period of one or two years. Recommendations 1, 2, 3, 6 and 7 fall within this group.

Given appropriate advice, it is possible for the national bodies responsible for school education to implement changes in a relatively simple way at little if any additional cost (Recommendations 1, 2 and 3). Each country has its own structure for teacher training and it is necessary to ensure that these provide opportunities to instruct teachers to present astronomy to their pupils in an exciting and stimulating manner. If this happens, we can be confident that future European citizens will have an appreciation of the Universe around them and can feel excitement about the progress of science in general. Also, the fact that observations of the sky, while being free of financial cost, do require low levels of light pollution, will contribute to an awareness of the need to care for our planet.

The employers of research scientists need to ensure that there is a clear and effective recognition of the efforts that these researchers make to communicate to the public what they are doing and to convey the excitement they feel about the discoveries they make (Recommendation 7). Such recognition should be significant factor in assessing career development.

A general guideline reached by the Panel is for funding agencies to arrange to invest some 1–2% of their overall project expenditure into public communication and education and also to ensure that the research results are clearly represented and illustrated in the public domain (Recommendation 6).

The second category, including Recommendations 4, 5, 8 and 9, will require a somewhat longer period (two to three years) to realise and carry some requirements for funding. The development of new capabilities such as portals and repositories needs the clear identification of resources and responsible groups charged with their provision and maintenance. It may be that existing groups with short-term funding can be extended in a way that makes full and continuing use of their existing expertise and capabilities.

Although many professional Europe-wide activities can be effectively carried out in

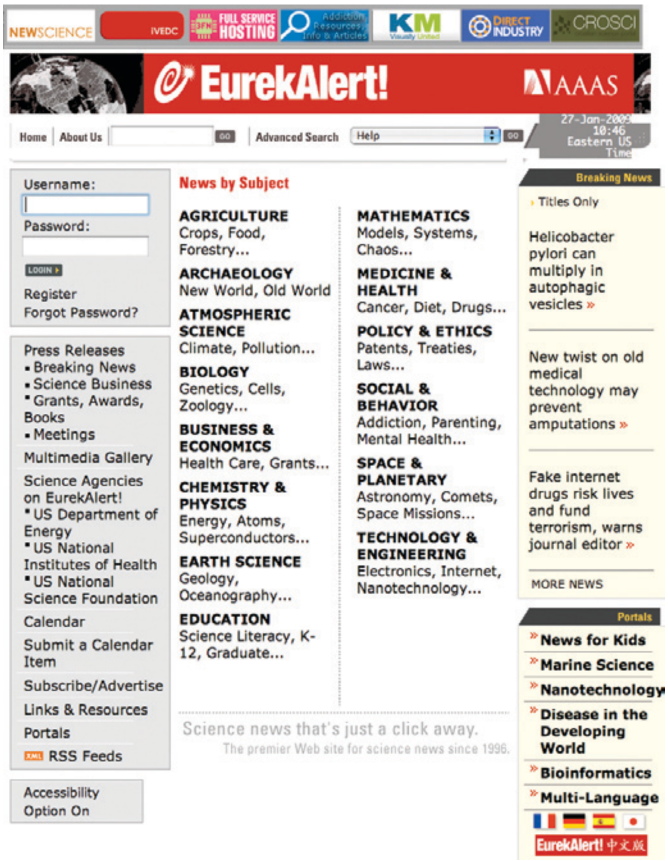


Figure 5. EurekAlert[11] home page.

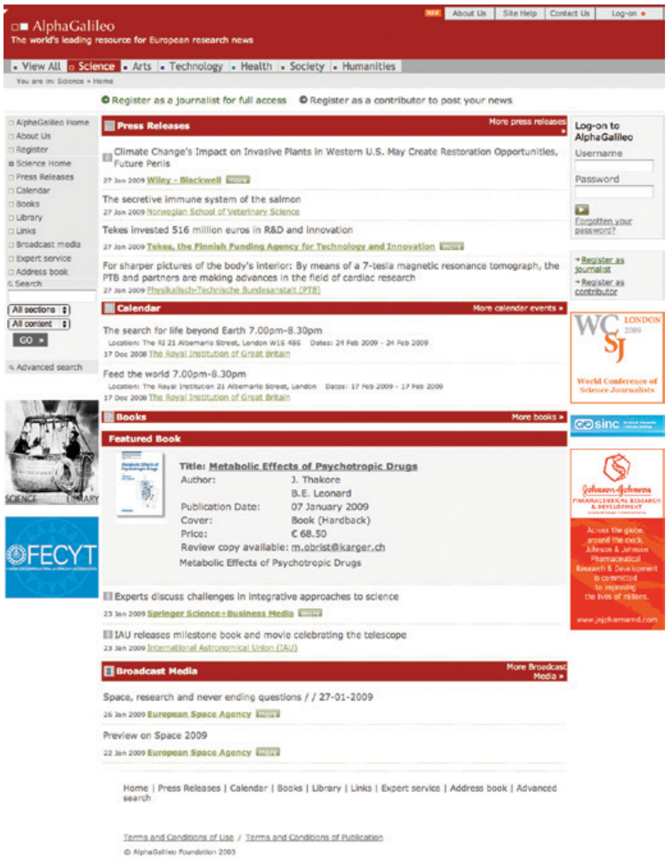


Figure 6. AlphaGalileo[12] home page.

English, the resources aimed at school education have to be made available in the relevant languages. This is particularly pertinent for the portal for primary and secondary schools and for teacher training (Recommendation 4).

A second portal/repository is necessary for non-formal education as recommended in Recommendations 5 and 8. This portal should offer media (including images and videos) for the public and also tailored for science museums and planetaria. While there are already many excellent sources of material, a "one-stop-shop" or aggregator, would greatly increase the efficiency and effectiveness of dissemination.

Many of the contracts offered as part of the development of the cutting-edge facilities in astronomy today are of considerable interest and value to industry in Europe. Some of them can elevate small industries to large ones and/or create new capabilities of relevance to other fields — for example the fabrication of large, high precision optics. The tracking of this process and the recognition of opportunities for technology transfer requires the establishment of an expert group that will increase the visibility of the process (Recommendation 9).

With thorough planning and proper support, astronomy communication throughout 2009 and beyond will be more successful than ever before.

Notes

1 Bode, M.F.,Cruz, M.J. & Molster, F. J. (ed.). 2008, *The ASTRONET Infrastructure Roadmap*, ISBN: 978-3-923524-63-1
2 Christensen, L.L. & Russo, P., 2007, *Communicating Astronomy with the Public*, in Proceedings from Future Professional Communication in Astronomy, ed. André Heck, adapted from Christensen, L. L., 2006, *Hands-On Guide for Science Communicators*, Springer Verlag and inspired by Morrow, 2000, http://www.spacescience.org/education/extra/resources_scientists_cd/Source/Venn.pdf
3 http://www.ips-planetarium.org/
4 http://www.planetaria.org.uk/
5 http://www.euhou.net/
6 http://www.esa.int/esaED/SEMXH8V681F_index_0.html
7 Madsen, C. & West, R. M.,2000, *Public Outreach in Astronomy — the ESO Experience*, in Heck, A (ed.): Information Handling in Astronomy, Kluwer Academic Publishers; Sjøberg, S. 2002, *Science and Scientists: Cross-cultural evidence and perspectives on pupils's interests, experiences and Perceptions*, Acta Didactica, l,
8 Banda, E. 2005, *Communiqué — A road map for the establishment of a European research media service.*
9 Scherzler, D. 2008, *Important for Good Press Relations: Accessibility*, CAPjournal Issue 2, February 2008.
10 http://www.communicatingastronomy.org/
11 http://www.eurekalert.org/
12 http://www.alphagalileo.org/
13 http://www.athenaweb.org/
14 http://www.communicatingastronomy.org/

ImmersiveFilmFestival

IFF'09

Immersive Film Festival

April, 24th – 26th, 2009
Espinho, Portugal

An open invitation to producers, animators, filmmakers, artists, students, teachers and planetarium professionals

Competitive Section
Screenings

Deadline to receive the submissions:
March, 2nd, 2009

Works should be sent by registered mail to:
IFF – Immersive Film Festival
Centro Multimeios de Espinho
Av. 24, n800
4500 Espinho
Portugal

web | iff.multimeios.pt

Visualising Astronomy: “Other Worlds”

Reviews

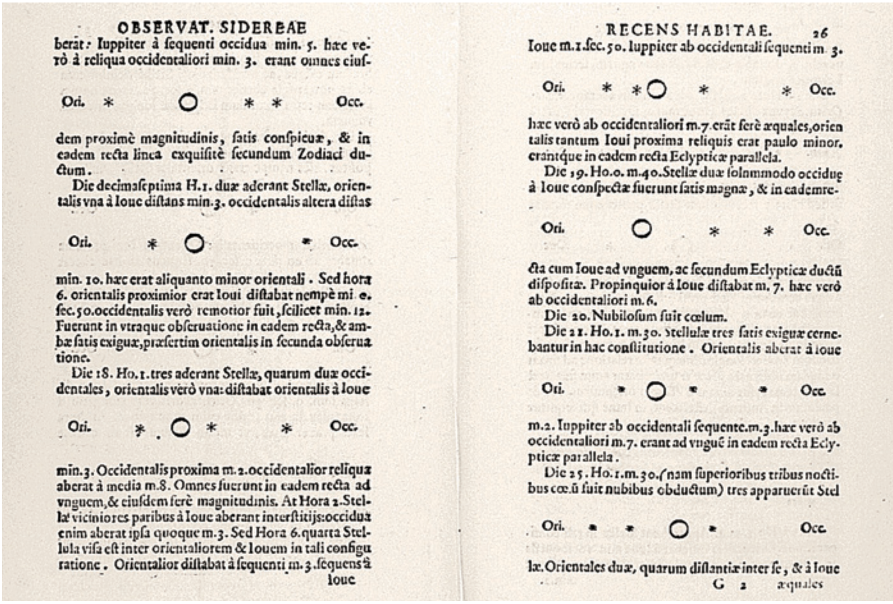
Ryan Wyatt
California Academy of Sciences
E-mail: rwyatt@calacademy.org

Key Words

Visual Communication
Astronomical Images

The International Year of Astronomy 2009 celebrates the 400th anniversary of Galileo’s use of the telescope for astronomical observations; if you’re reading this, you probably know the story by rote, but bear with me...

The discovery of Jupiter’s moons ranks as one of the most famous revelations that Galileo announced in *The Starry Messenger*, and to illustrate his breakthrough, he embedded a sequence of images in the middle of the text (see Figure 1). The series of woodcuts shows these “little stars” moving from night to night, leading to the conclusion that Jupiter must have moons like our own — not one single companion, but four. At this point in the story, the reader is typically reminded that Galileo used the observation of the Jovian satellites to bolster arguments in favour of the heliocentric planetary system. All well and good.


OBSERVAT. SIDEREAE
berāt: Iuppiter à ſequenti occidua min. 5. hæc verò à reliqua occidentaliori min. 3. erant omnes eiuſ-

Ori. * O * * Occ.

dem proximè magnitudinis, ſatis conſpicuæ, & in eadem recta linea exquiſitè ſecundum Zodiaci ductum.
Die decimaſeptima H.1. duæ aderant Stellæ, orientalis vna à Ioue diſtans min.3. occidentalis altera diſtas

Ori. * O * Occ.

min. 10. hæc erat aliquanto minor orientali. Sed hora 6. orientalis proximior erat Ioui diſtabat nempè mi. o. ſec.50.occidentalis verò remotior fuit, ſcilicet min. 12. Fuerunt in vtraque obſeruatione in eadem recta, & ambæ ſatis exiguæ, præſertim orientalis in ſecunda obſeruatione.
Die 18. Ho.1.tres aderant Stellæ, quarum duæ occidentales, orientalis verò vna: diſtabat orientalis à Ioue

Ori. * . O * * Occ.

min.3. Occidentalis proxima m.2.occidentalior reliqua aberat à media m.8. Omnes fuerunt in eadem recta ad vnguem, & eiuſdem ferè magnitudinis. At Hora 2.Stellæ viciniores paribus à Ioue aberant interſtitijs: occidua enim aberat ipſa quoque m.3. Sed Hora 6.quarta Stellula viſa eſt inter orientaliorem & Iouem in tali configuratione. Orientalior diſtabat à ſequenti m.3.ſequens à Ioue

RECENS HABITAE. 26
Ioue m.1.ſec.50. Iuppiter ab occidentali ſequenti m. 3.

Ori. * * O * * Occ.

hæc verò ab occidentaliori m.7.erãt ferè æquales, orientalis tantum Ioui proxima reliquis erat paulo minor. erántque in eadem recta Eclypticæ parallela.
Die 19. Ho.o. m.40.Stellæ duæ ſolummodo occiduę à Ioue conſpectæ fuerunt ſatis magnæ, & in eadem recta cum Ioue ad vnguem, ac ſecundum Eclypticæ ductũ

Ori. O . * * Occ.

diſpoſitæ. Propinquior à Ioue diſtabat m. 7. hæc verò ab occidentaliori m. 6.
Die 20. Nubiloſum fuit cœlum.
Die 21. Ho.1. m.30. Stellulæ tres ſatis exiguæ cernebantur in hac conſtitutione. Orientalis aberat à Ioue

Ori. * O * * Occ.

m.2. Iuppiter ab occidentali ſequente.m.3.hæc verò ab occidentaliori m.7. erant ad vnguẽ in eadem recta Eclypticæ parallela.
Die 25. Ho.1.m.30.(nam ſuperioribus tribus noctibus cœlũ fuit nubibus obductum) tres apparuerũt Stel

Ori. * * O * Occ.

læ. Orientales duæ, quarum diſtantiæ inter ſe, & à Ioue
G 2 æquales

Figure 1. Pages from Galileo’s The Starry Messenger *show his depictions of the moons of Jupiter integrated into the text.*

But other debates raged at the time, and other questions occupied people’s attention. Is the Universe infinite or finite? What is the nature of the planets? Are there other worlds, with other beings? Questions not unlike those that occupy astronomers today! Johannes Kepler showed a much greater tendency to speculate on such topics than Galileo, and indeed, taken together, the two represent complementary perspectives on astronomy at the time. (More than a few people have argued that 2009 should also receive recognition as the 400th anniversary of Kepler’s *New Astronomy*, a tome that offered significant advances in the theory

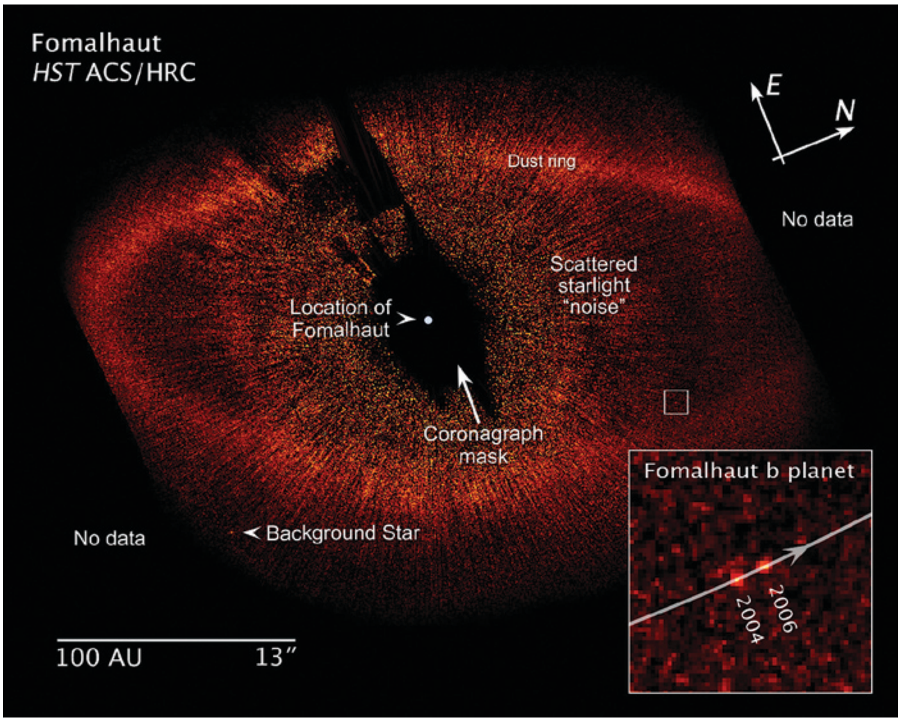


Figure 2. The Hubble Space Telescope *image of Fomalhaut reveals an extrasolar planet observed directly in visible light.*

and mathematics of astronomy. I'm inclined to agree with them, if not for the particular value of that work then for the general recognition of Kepler as an astronomical celebrity on par with his Italian counterpart.)

In response to Galileo's observations, Kepler wrote: "[Giordano Bruno and others] thought that other celestial bodies have their own moons revolving around them, like our earth with its moon... Moreover, they supposed it was the fixed stars that are so accompanied... Now the weakness of his reasoning is exposed by your observations. In the first place, suppose that each and every fixed star is a sun. No moons have yet been seen revolving around them. Hence this will remain an open question until this phenomenon too is detected by someone equipped for marvellously refined observations..."

Who would have guessed that we'd need to wait nearly four centuries for that open question to be resolved?

Over the last decade, marvellously refined observations have revealed the existence of hundreds of such "moons" orbiting other fixed stars... Observations the likes of which Kepler could never have conceived, relying on physical effects (spectroscopy, gravitational lensing) about which he knew nothing. But that remarkably straightforward observation eluded us: an image of another planet, simple reflected light from a distant point in orbit around another star.

In November 2008, two research groups announced independent observations of two extrasolar planetary systems — one planet orbiting the star Fomalhaut (Figure 2) and three more revolving around the much less familiar HR 8799 (Figure 3). Much enthusiastic reporting and blogging ensued. We already know that such planets orbit other stars, so why do we get so excited about a couple of pictures?

Part of the accomplishment lies in the promise it holds for future developments — in particular, acquiring spectra and gathering astrometric data that could yield additional information. But of course, we already have spectra for a few planets, and we can even determine the size of transiting exoplanets. The excitement that surrounds the new pictures goes beyond their scientific merits.

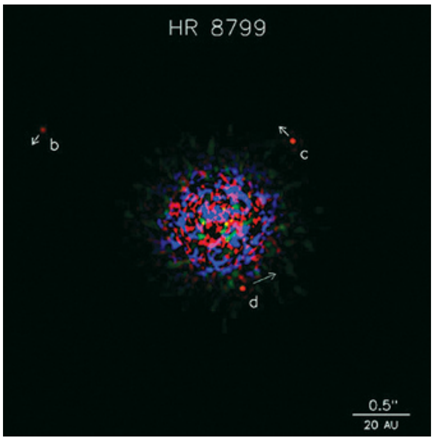


Figure 3. The Keck Observatory used adaptive optics in the near infrared to observe three planets orbiting HR 8799.

Like investigators at a crime scene, we want a snapshot. As Susan Sontag wrote, "Photographs furnish evidence. Something we hear about, but doubt, seems proven when we're shown a photograph of it." Somehow, these digital images are more real to us than the reams of spectra that have been collected on extrasolar systems thus far. A dip in brightness as a transiting planet dims the light of its parent star isn't as real as a snapshot of a tiny dot moving — not from night to night, but from year to year — around another sun. Even in an era of Photoshop and special effects, we accept some photographs as evidence.

Of course, Galileo didn't have recourse to photography (or digital imagery). His tiny woodcuts, dotting his text like frames from an animated film, had to suffice for presenting evidence to his readers. But his images and his eyes could be distrusted. After extolling (with typical verbosity) Galileo's virtues as a scientist, Kepler writes: "Shall he with his equipment of optical instruments be disparaged by me, who must use my naked eyes because I lack these aids. Shall I not have confidence in him, when he invites everybody to see the same sights, and what is of supreme importance, even offers his own instrument in order to gain support on the strength of observations? [...] Consequently I have no basis for questioning the rest of your book and the four satellites of Jupiter."

Criteria for evidence have changed over 400 years, but each generation holds to oddly image-based standards. If any observations qualify as "marvellously refined", the Hubble and Keck accomplishments should, alongside Galileo's pioneering efforts. Beyond the technological differences, the other worlds we discover seem to gain meaning through visual representation. Seeing is, perhaps, believing?

Notes

[1] Kepler, Johannes, *Conversation with the Sidereal Messenger*, as quoted online at https://eee.uci.edu/clients/bjbecker/ExploringtheCosmos/week4e.html
[2] *Sontag, Susan 1977, On Photography,* New York: Farrar, Straus and Giroux, p5, cited not so much for the perspicacity of this observation as for the general value of the work in stimulating thinking about the use of imagery in communication.
[3] *Kepler 1610, op. cit.*

Biography

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

INTERNATIONAL YEAR OF

ASTRONOMY 2009

cornerstone projects

The International Year of Astronomy 2009 is supported by eleven Cornerstone projects. These are global programmes of activities centred on specific themes to help to achieve IYA2009's main goals; whether it is the support and promotion of women in astronomy, the preservation of dark-sky sites around the world or explaining the workings of the Universe to millions, these eleven Cornerstones will be key elements in the success of IYA2009.

www.astronomy2009.org

THE UNIVERSE YOURS TO DISCOVER

INTERNATIONAL YEAR OF ASTRONOMY 2009

United Nations Educational, Scientific and Cultural Organization

International Astronomical Union

Partners for the International Year of Astronomy 2009

100 Hours of Astronomy
An event 400 years in the making

Co-chairs: Douglas Pierce-Price (dpiercep@eso.org) & Mike Simmons (mikes@astronomerswithoutborders.org)
www.100hoursofastronomy.org

The Galileoscope
Millions looking at the sky

Chair: Rick Fienberg (rfienberg@skyandtelescope.com)
www.galileoscope.org

Cosmic Diary
The life of an astronomer

Chair: Mariana Barrosa (mbarrosa@eso.org)
www.cosmicdiary.org

Portal to the Universe
A one-stop universe of news

Chair: Lars Lindberg Christensen (lars@eso.org)
www.portaltotheuniverse.org

She is an Astronomer
Breaking down misconceptions

Co-chairs: Francesca Primas (fprimas@eso.org) & Enikő Patkos (epatkos@eso.org)
www.sheisanastronomer.org

Dark Skies Awareness
Seeing in the dark

Chair: Connie Walker (cwalker@noao.edu)
www.darkskiesawareness.org

Astronomy and World Heritage
Universal treasures

Chair: Anna Sidorenko-Dulom (a.sidorenko@unesco.org)
www.whc.unesco.org

Galileo Teacher Training Program
Teaching the teachers

Co-chairs: Jim Manning (jmanning@astrosociety.org) & Rosa Doran (rosa.doran@gmail.com)
www.galileoteachers.org

Universe Awareness
One place in the Universe

Chair: Carolina Ödman (odman@strw.leidenuniv.nl)
www.unawe.org

From Earth to the Universe
The beauty of science

Co-chairs: Kimberly Kowal Arcand (kkowal@cfa.harvard.edu) & Megan Watzke (mwatzke@cfa.harvard.edu)
www.fromearthtotheuniverse.org

Developing Astronomy Globally
Astronomy for all

Chair: Kevin Govender (kg@saao.ac.za)
www.developingastronomy.org

Global Sponsors

Organisational Associates

Eyes on the Skies

The International Astronomical Union's book and movie celebrating the 400th anniversary of the telescope.

The invention of the telescope has been by far the most revolutionary development in the history of astronomy. For thousands of years, astronomers had to rely on their eyes in unravelling the mysteries of the Universe. The telescope revealed an embarrassment of astronomical riches, and led to a dramatic increase of knowledge about the wider world we live in.

The Eyes on the Skies DVD movie and accompanying book explore the many facets of the telescope — the historical development, the scientific importance, the technological breakthroughs, and also the people behind this ground-breaking invention, their triumphs and failures...

Review copies for the media are available, please contact:
lars@eso.org

More information:
http://www.eyesontheskies.org

CAPjournal submission guidelines

We are keen to encourage readers to submit their own articles, reviews, etc. Some key points are addressed below.

Technical and esoteric language should be either avoided or used with a footnoted explanation if absolutely required. All contributions will be made to conform to British spelling and punctuation practice. Figures and tables should be referred to "Figure n" and "Table n" respectively. Acronyms should be spelt in full once and then parenthesised; henceforth they can then be used as lettered acronyms. Numerals should be used for numbers greater than two words and always for numbers greater than ten.

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).

Copyright

Authors are solely responsible for ensuring copyright clearance to reproduce illustrations, text, etc., for which they themselves do not own the copyright. CAPjournal accepts only original submissions and will only reproduce previously published work by special arrangement.

Contact

Submissions should be sent to the Editor:
editor@capjournal.com

Submit articles for one of the following journal sections:

- **Announcements**
- **Reviews**
- **News**
- **Resources**
- **Innovations**
- **Research & Applications**
- **Letters to the Editor**
- **Opinion**
- **Best Practices**
- **Interviews**

www.capjournal.org

Online issues
Free subscriptions
Article submission

Sponsors

esa
FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR
NAVEGAR FOUNDATION
ESO