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Teaching and Communicating Astronomy – JENAM'04
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COMMUNICATIONS TO THE PAST: ASTROLABES TO ZODIACS

V. Trimble[1]

Abstract. In past centuries, astronomers have used a very wide range of techniques to explain what they are doing, how, and why it was worth doing to their equivalents of sponsoring agencies, voters, and students. We here examine an inital set of seven examples of seemingly successful communication, each with lesson to offer, and then, more briefly a wider range of examples, some apparently very good for their purpose and a few that were perfectly awful.

1 Introduction: Motivations, Audiences, and Media

Before starting out to do something, it is perhaps wise to ask why, who, and how. "What" will be dealt with in the following sections. It is actually a little difficult to describe the motivations, past to present, for explaining science to the rest of the world. It tends to come out sounding very much like, "we want more funding". This is, of course, true and not unique to our generation. But anyone who worries about the future of the world also wants an informed electorate, and this is clearly also part of our motivation.

Who should we be trying to reach? It is a long list, beginning with the sponsoring agencies, from the Emperor Rudolph to PPARC. The second-order sponsors, voters and taxpayers, are a more recent audience. One can describe various parts of the public as "interested" –the traditional educated layman and (at one time at least perceived as a separate audience) women, children, and amateur astronomers. There is also the uninterested public, at whom one gets an occasional brief chance through moments like eclipses and meteor showers and the appearance of naked-eye comets. There is the future educated public, reached in medieval times through the quadrivium and more recently (at least in the USA) through compulsory science courses taken by college students aiming at medical, business, legal, and other careers. Special techniques will be needed to reach scientists in other disciplines, who can be our allies, and the pipeline of future scientists, who

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may appear as students in our "serious" courses and as observing and research assistants. Finally, there are those with a practical need for sky lore of various kinds. This once included the astrologers (perhaps it still does) and navigators, most of whom now rely on GPS devices.

How shall we reach them? Live speech comes firts to mind – one-on-one or a few to large audiences at public talks, There are both formal and informal modes for both. Most astronomers have stories to tell about random encounters with taxi drivers, bagagge screeners and all that clearly led to information transfer. If you have none of your own, read those of Tyson (2004) and try to do likewise! Radio talks began in the 1920s and those by Fred Hoyle in the 1950s are famous for launching the phrase "big bang" upon the world. Television began its life with education programs, but astronomy may very well have peaked with Carl Sagan's Cosmos. And there are of course also recorded versions of some radio and many television presentations available.

Books that can (or should) communicate include those written specifically for the interested lay person, introductory textbooks, and encyclopedias, all of which have multi-century histories. Encyclopedias, I think, tend to be under-rated by us as reachers-out. They are very widely used, once as paper, now online, by students at all levels dealing with the problem of "the term paper". Magazine and newspaper articles have addressed science from the mid-19th century onward, and letters (nominally addressed to one person but actually intended for wider audiences) are even older.

Mechanical devices can communicate astronomy. Star finders, eclipse glasses, and telescopes with a "go to" feature come to my mind as recent examples. You may well feel that science fiction is a two-edged sword, in that one can easily learn things that are not and cannot be true –faster-than-light travel, galaxies long ago and far away where the laws of physics are different, and so forth. But if a reader comes away thinking that science is likely to be important in his future, that cannot be all bad. Astrology gets even worse press. But the astrologers of the past at least knew their ways around the night sky and their clients were likely to come away with some of the same knowledge.

Finally, literature and the other arts sometimes incorporate a certain amount of astronomical information. Gustav Holst comes to my mind (though you will need to add sections for Earth and Pluto, the latter not yet known when he composed The Planets), along with paintings of the nativity and illuminations at the beginnings of pages in prayerbooks. Some of my favorite "literary" examples come from detective fiction. Sherlock Holmes my have refused to remember "the Copernican hypothesis", saying it would make no difference to him if the earth went around the moon, but the reader is likely to remember. There is some correct cosmology in Dorothy sayer's Gaudy Night (and first rate organic chemistry in Documents in the Case). And the fictional Charles Ranier in James Hilton's Random Harvest heard the very same lecture by Arthur Eddington that the real Cecilia Payne heard (Haramundanis 1996) and was greatly influenced by.

All e-modes of communication obviously belong to the present and are outside the scope of this discussion. It is always a bit difficult to say when "history" ends and "current events" begin, but perhaps somewhere around 1950, when I began to be aware of several different sorts of deliberate effort to communicate astronomy to children.

2 Seven Salutory Examples

Each fo the following illustrates a different mode of communication and, I think, a different lesson that can be applied to current communication schemes.

2.1 Lesson One: Hands-On

The astrolabe comes to us from the traditions of Arabic astronomy. Perhaps the oldest in existence dates from 1090 and is in the Smithsonian Institution collection in Washington DC. It was made in Valencia for use at latitude $33^{x}o30'$ (very close to Granada) by Muhammad ben as-Sahli. Like many such instruments, it is made of bronze, must have involved many hours of skilled labor, and was very possibly constructed for the 11th century equivalent of a sponsoring agency, the Moslem ruler of al-Andalus at the time. Although astrolabes were used by professional astronomers to observe positions of stars and planets, they also served the function of a "go to" telescope for amateurs who did not want to start with the Toledan tables of Al-Zarqali and calculate for themselves when Sirius would rise or when Mars would pass through Scorpio. The lesson here is that many, perharps most, people learn best with some physical, hands-on involvement with a topic. At any rate, this is what we suppose when we require a laboratory component in science courses for arts and business students!

2.2 Lesson Two: Use the Vernacular

Galileo convinced so many people of the correctness of the Copernican, sun centered solar system and of the foolishness (anyhow simplicity!) of those who opposed it that the authorities of the time thought it necessary to discourage him from teaching or even from wandering around the streets engaging in Socratic-style dialog (a specialized form of one-on-one verbal communication). His Dialogo of 1632 was published in Italian, rather than the then-customary Latin of scholarly communication. Conceivably this is just a bit of a red herring, because the number of early 17th century Italians who could read Itlaian but not Latin must have been rather small. Nevertheless, viewed as moral, that we should abjure jargon and obfuscation in our popular writings, Dialogo carries an important lesson. Kepler earlier and Newton later produced their best-known works in Latin. Again this may not have mattered a great deal because in both Harmonia Mundi (1619) and Principia (1687) the level of mathematical argument was probably more of a barrier to popular understanding than any choice of language (short of Cretan Linear A) could have been. Indeed for Principia it still is, one of the reasons that Chandrasekar devoted much of his late career to recasting it in modern notation.

2.3 Lesson Three: Start Where They Are

During the discussion, session organizer Vicent Martinez mentioned a cartoon by Sydney Harris, well known at least in the USA, which shows Kepler attempting to explain his laws to three contemporaries, whose thought bubbles wonder "what is an orbit"?, "what is a planet?", and "what is an ellipse?" This was probably not a successful communication or appeal for future funding. My example of starting in the right place (Parker 1941) is a pamphlet on the moon, widely available at planetaria in the 1940s and 1950s which suggests a number of projects for children to carry out. These involve using balls, clay, and kitchen chairs to clarify size and distance scales and to show what it means to have a rotation period equal to your orbit period. Aimed at somewhat older children, the Scouting Handbooks of the same period (*e.g.* Girl Scouts of the USA, 1953) assume that the learner will have expert assistance with the ideas of magnitudes, navigation, and angular measure.

2.4 Lesson Four: Fine Tune for your Audience

Sir Arthur Eddington was particularly keen on a 1919 solar eclipse expedition to test general relativity against Newtonian theory of light propagation. An important motivation for him was to bring the "central Powers" (Germany, Austria, Hungary, and all) back within the community of scientists as quickly as possible after the end of World War I (Stanley 2003), and his Quaker, pacifist convictions were, in turn, an important driver for scientific reunification. This meant that he had to "sell" general relativity to a very wide range of audiences, from mathematicians to merchants. His succes can be judged from the expeditions having taken place (and, nominally at least, finding the desired Einstein result). His methods can be examined in (a) Eddington 1923) addressed specifically to the mathematical community, whose support from within the Royal Soceiety had been essential (it is rife with tensor equations in nearly modern notation, of which the simplest on p. 185 seems to be $g_{33} = -r^2 \sin^2 \theta$), (b) Eddington (1916) which is an appeal to the amateur astronomical community (which then included a number of members of the House of Lords) as well as the professional, saying "I think that astronomers in this country realize the disaster to progress which would result from dissolution of partnership... the pursuit of truth, whether in the minute structure of the atom or in th vast system of the stars, is a bond trascending human differences", and (c) Crommelin (1919), a report of the expedition to the readers of Illustrated London News (not now perhaps widely known, but 40–140 years ago a home for accurate, non-technical discussion of archaeology and many other topics), speaking of a verification of "Professor Einstein's theory that light is subject to gravitation". The illustration manages to show the observatory station, the path of the eclipses of May 28–29, and the phenomenon of deflection of light both face on and in profile, with the extent of exageration accurately described.

Both this lesson and the previous one have to include acceptance of your audience as it is. A sage of the communicating community once remarked that "it is no use saying that we don't like the public we have; we want a better public". What you have is what you get.

2.5 Lesson Five: Sneak It In

Cyrano de Bergerac was not just a character in the play by Edmund Rostand but also a real person who, in 1687, published a (fictional!) account of a voyage to the moon. His frontipiece manages to show both his propulsion mechanism and his views on what would be found by the first lunar landers. Both were, not surprisingly, wrong but the attentive reader would have come away with the idea that natural processes (in this case the rising of dewdrops in morning sunlight) might eventually carry us beyond the earth and that there might be life on the moon, resembling that on earth but rather better organized – the same idea that had got Giordano Bruno into trouble about 90 years before.

2.6 Lesson Six: Carpe Diem

A 1577 woodcut shows an impromptu star party responding to the opportunity presented by a naked eye, very spectacular come (not Halley, to save you the trouble of subtracting 76 from 1758 several times). A senior learned gentleman is making a drawing of the comet while several young assistants hold the drawing board and lanterns. But, in addition, a small procession of the burghers and burgheresses of Prague are being shown the sight. The various European activities centered around the transit of Venus and described in the symposium show that this lesson has been well learned. The US will have a similar opportunity in 2012, and it is not too eraly to start planning for the second transit of the pair!

2.7 Lesson Seven: K.I.S.S.

This acronym, for Keep It Simple, Stupid, carries the idea that one should not try to communicate more than is actually needed for a specific purpose. A nice example of getting this right is the time ball. Once ship's chronometers existed, there was a need to reset them (or, in fact, write down the current correction to the chronometer in the log book). Starting 1829 in Portsmouth, England, this was accomplished with a time ball, dropped precisely at noon and visible from all the ships that anchor in the port. The New Year's Eve Time Balls dropped in Times Square, New York and elsewhere are modern descendents, but no longer fulfill a specific need.

3 Variants, Additional Modes, Models, And Lessons

3.1 Astronomy for Women and Children

"The Universe for Women" was a distinct genre of popular writing through the 19th century and into the 20th (Ten Ros 2001). The motivation appears at least partly to permit the author to phrase things less technically than he knows how without himself being suspected of lack of sophistication. Neither the genre not the motivation is unique to astronomy. George Bernard Shaw's The Intelligent Woman's Guide to Capitalism, Socialism, and Communism was, he himself proclaimed, really meant for all who wanted to know about such things or should want to. The astronomical foundations of this approache go back at least to Fontenelle, who couched his presentation of the Copernican hypothesis, Newtonian gravity, and all in the form of instructional "Conversations on the Plurality of Worlds" with a certain "Marquise de G", in 1686. The woman in his frontispiece is quite properly looking at her instructor, not the sky. By the late 1800s at Harvard College Observatory, the senior women, like Fleming, were instructing the more junior ones, with little need of intervention by E.C. Pickering.

Some difference in content is also to be found in astronomy textbooks meant for beginning students in college and in monographs meant for serious scholars. From at least the mid-1800s right down to the present, this has meant more solar system for the young; more stars and galaxies for the serious student, see Hoffleit (1992) on the earlier years, and compare your favorite introductory text with, say, Shu (1982) or Karttunen *et al.* (1996) for the current situation.

The idea of a course of lectures "adapted to a juvenile auditory" is perhaps rather optimistic, though the Royal Institution had already been doing it for a century before James Jeans (1934) presented Through Space and Time that way and described the actual audience as ranging from under 8 to over 80. Lecturers at modern planetaria, faced with onslaughts of school groups through the week can at least ignore the over 80s.

The Encyclopedia Britannica has always been addressed primarily to the intelligent adult, and the post World War I edition has its articles on stellar structure, stellar evolution, and cosmogony by Henry Norris Russell, Arthur Eddington, and James Jeans. A slightly earlier edition (the moons of Mars are described as "recent" discoveries) of Winston's Cummulative Encyclopedia was meant primarily for school children. It does, I think, not at all badly, saying that "the objects with which astronomy has chiefly to deal are the earth, the sun, the moon, the planets, the fixed stars, comets, nebulae and meteors" and providing separate articles on each of these and more. Vulcan is called hypothetical and the connection between meteors and comets advanced as a supposition. The Trimble copy was purchased for father's older brother Jack at age 10.

3.2 Practical Astronomy

Here we look at a range of tables, books, and devices intended to allow non-astronomers to find their way around the sky when they need to. The phrase was once a common textbook title, and the works were aimed, for instance, at civil engineers who needed to start by knowing their latitude and longitude (Hosmer 1910 *e.g.*) and at navigators who needed to end up that way.

A happy, early example of an ephemeris (arguably the first) that communcicated well enough is the 1474 Kalendar of Regiomontanus. A copy accompanied Columbus on his last, 1504 trans-Atlantic voyage, and he was able to use his foreknowledge of a lunar eclipse on 29 February to pry loose food supplies from the indiginees. The calendar is in the German that was current at the time (a modest challenge to the modern reader, as Canterbury Tales would be to a 21st century speaker of German). A collateral conclusion is that Columbus was probably rather better educated than the popular impression of the only guy in all of Europe who didn't know the radius of the earth. An account of the story is to be found in Hoskin (1996) along with many of the other items mentioned here.

A 1533 woodcut of the teaching of navigation distinguishes by dress (a) the scholar, (b) the apprentice navigator, and (c) some surveyors in the field using a similar instrument (the cross-staff) for surveying. The apprentice would seem to be learningn how to measure longitude from the instantaneous position of the moon, one of the few choices before the development of transportable timepieces.

The diagrams in Kepler's 1596 Cosmographic Mystery were meant primarily for the use of astrologers. He himself cast horoscopes (being thus arguably the last astronomer to earn an honest living!) without having enormous confidence in the methods, but his charts of, for instance, the conjuctions of Jupiter and Saturn could be used by anyone, including Jewish mystics of his time and later who called the 60–61 year intervals a "Great Year" and devised prayers to be used only at the beginning of these cycles. The first Gregorian ephemeris of 1582 also devoted many tables to the positions of planets relative to the zodiacal constellations. Thus horoscopes could be cast with confidence even if the sky happened to be cloudy on the birthnight of the relevant prince (horoscopes for ordinary folk belong to a later era).

The 1679 ephemerides of the first volume of La Connaissance des Temps specifically abjure astrology, and the tables were meant for navigators and those who wanted to plan observing runs without having to start from scratch with a theroy of planetary orbits. Such volumes were, therefore, the astrolabes of a later era, though not so pretty. Artistic merit as part of communication was not, however, entirely lost. The chart prepared by Delisle for his assistant to use in beginning the search for the 1758 return of what we call Comet Halley sports traditional animals and heros arranged in the right general part of the sky, though with little regard for the actual positions of the brighter stars. The assistant, by the way, was Messier, and his reputation has eclipsed that of his initial employer.

A Ptolemaic armillary sphere is, in effect, a three-dimensional astrolabe. Many were made of bronze or other metals and constructed at least partly for nobles with an interest in astronomy (the sponsoring agencies of their day). They were, however, also useful for navigation and the teaching thereof, horoscopes, and the planning of professional observations. A Copernican armillary spehere, in contrast, is pretty useless, and these were often made of wood or cardboard. In truth there are also 19th century astrolabes. But the "impress the sponsor" function was largely taken over by orreries. These are models of the solar systems, with distances and sizes to scale (but different scales) in bronze etc. and with cranks and gears so that they can be set in motion to display, for instance, Kepler's third law of periods and distances and the rapid motion of the inner moons of Jupiter (4) and Saturn (5) as known between 1750 (when the first was made by Lord Orrery) and 1800. A particularly spectacular one (with some extra circles needed for it also to function as an armillary sphere) was constructed in about 1780, probably for George III of England, by James Ferguson, the best known popularizer of astronomy in the 18th century. It was one of his books that William Herschel first read as his interest in the subject developed.

3.3 Miscellany

Some of the more attractive "sneak it in" communications, for instance in illuminated books of hours, are wrong by modern standards. On the other hand, a 14th century manuscript of the "Dream of Macrobious" (a 5th century scholar) shows night illuminated not only by the usual Ptolemaic arrangement of planets with a sphere of stars outside, but also by a nearly perpendicular band of discrete stars representign the Milky Way. The idea that the Milky Way consists largely of unresolved stars is thus very old, and hints or sketches of the idea in poetry or artwork from the late 16th century need not, therefore, imply the use of optical instrumentation for astronomical purposes before the 1609-10 flowering associated with the name of Galileo.

Talking back to the author is something we have all wanted to do and may now persue by email. But in the 16th century writing in the margins of books, at least your own, was customary practice, and many astronomers, most notably Erasmus Reinhold, thus communicated in a way with Copernicus (Gingerich 2004, *e.g.* Plate 8b).

Programs for the public on the night sky taking place in national parks may well be unique to the USA (and should be counted as an important kind of communication not done by EPO officers!). But one of the world's most beautiful, and oldest (1437) armillary spheres is in a public park in Beijing.

Finally, one might think of communicating across long time intervals (*cf.* Benford 1999). One of my favourites is a cunneiform tablet surviving from October-November 164 BCE (NOT the date on the table). It records the appearance of Halley's comet with sufficient information that we can be sure neither the orbit period nor the brightness has changed enormously over the ensuing 28 orbits. But "la plus ça change, la plus c'est la même chose". The 1686 visit of Louis XIV to the Paris Observatory (which in those days also housed skeletons of animals other than old professors) reminds one both of Vice President Bush, living with his family on the grounds of the US Naval Observatory and bringing his kids to look through the telescopes under the directorship of Gart Westerhout, and of a 1445 Italian prayer book, undoubtedly illuminated for a wealthy sponsor, which shows the perpetuum mobile of stars being turned by cranks manned (?) by angels.

Anyone who saw the illustration would surely have been persuaded by it. And this also is a lesson to be learned for communication today –don't take your own words (spoken, written, or blogged) too seriously. You are inevitably simplifying and need to remember this.

I am greately indebted to David DeVorkin of the National Air and Space Museum for an introduction to the 1090 Andalucian astrolabe and for the image of it shown at the conference. Many of the images and associated descriptions not otherwise credited come from Hoskin (1997) and a few others from Stephenson *et al.* (2000) and Brashear & Lewis (2001), these last two both catalogues of museum exhibits. The late Philip Moddel first told me about the significane in Jewish lore of the recurrence time for Jupiter-Saturn conjuctions.

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