DIFFICULT CONCEPTS

Bob Fosbury

ESA/ST-ECF, Munich, Germany

ABSTRACT

Beautiful colour images of the sky are both a blessing and a curse for the communication of astronomy to the public. While undoubtedly attractive, they can obscure the fact that discoveries are often made in astrophysics using techniques and measurements that are much more difficult to grasp and certainly less appealing to view. Should we try to explain such concepts as spectroscopy, polarimetry and interferometry, or is it a lost cause? The most effective approach to this problem may be to lead the audience to ask the question themselves: "But how do you know that?"

INTRODUCTION

Astrophysics is 'hard science'. Astronomy has a tremendous advantage over most other hard sciences in that pictures of the sky are naturally appealing and can be appreciated and enjoyed by the lay viewer without the necessity of complex explanation. Following pioneering photographic work—most notably by David Malin—around 30 years ago, the technique of producing more-or-less true colour representations of astronomical objects and fields has flowered into the digital imaging age where now both amateur and professional astronomers can produce stunningly beautiful images from digital archives using the power of the FITS Liberator software.

Important discoveries in astronomy, however, are generally made by employing a broad range of observational, experimental and theoretical techniques that are subtle and/or intrinsically difficult for a non-scientist to understand. The use of such techniques can often reasonably be ignored or by-passed when presenting and explaining a result but sometimes their application is so crucial that explanation must be attempted. Some outreach operatives teach: "never, ever show a spectrum!" Such a dictum was voiced at this conference. I do not agree. How should it be done? Are there any general rules or guidelines? How do audiences react: is it a 'turn-on' or a 'turn-off'?

SPECTROSCOPY: THE JOY OF COLOUR

Spectroscopy is the science of colour. People react to colour; it can be beautiful and it certainly carries information. A greyscale image of M51 (Fig. 1, top) carries a great deal of information about what a galaxy is, but a colour image (middle) opens the door to understanding physical processes and the nature of the different components of such a complex structure. The addition of a colour image from outside the visible spectrum (perhaps a difficult concept itself) adds yet more insight into how things work. With this sequence of images we have already started doing spectroscopy without even mentioning prisms, gratings or slits!

Figure 1. *The path to spectroscopy. The monochrome image of M51 (top) from Hubble's Advanced Camera for Surveys (ACS) gives a wonderful insight into galactic structure. Foreground stars, luminous clumps tracing the spiral arms and dark regions of obscuration are clear. The addition of (roughly true) colour coding (middle) adds an enormous amount of information that can be interpreted quite directly in terms of the physical processes in young star clusters, the distributions of stars of different types and the absorption in dust lanes along and between the spiral arms. Moving to a different waveband, this time using the IRAC on Spitzer in its four filters from 3 – 8 microns (bottom), complements the optical physics by showing the dust in emission (fluorescence) and coding almost all the stars as the same shade of blue which represents the invariant 'Rayleigh-Jeans' part of the stellar spectrum. Just by using and explaining these beautiful pictures, we are well on the way to doing real spectroscopy! [credits: NASA, ESA, S. Beckwith (STScI), and The Hubble Heritage Team (STScI/AURA); NASA/JPL-Caltech/R. Kennicutt (Univ. of Arizona)/DSS]*

What about 'hard-core' spectroscopy: the source of the real information? There are many analogies of course (rainbows, radio dials etc.) and some of them are overused, but all are effective in the right context. Contrary to most prejudice, some spectra have their own intrinsic beauty and immediately convey the idea of richness of information. A high resolution representation of the Solar spectrum, e.g., http://www.noao.edu/image_gallery/html/im0600.html, is visually stunning and a high redshift quasar showing a resolved Lyman forest will convince anyone that the Universe is trying to tell us something profound.

Try taking your audience back to the second half of the 19th century when the spectroscope was first being turned towards the Sun and the brighter stars and nebulæ. Imagine the orgy of intellectual excitement when it was realized that mankind had a means to analyse the physical state and chemical composition of remote, inaccessible objects throughout the visible Universe. The discovery of helium in the Sun and the first steps taken to interpret the signals from other objects gave us the science of astrophysics.

So, yes, do be ready to show spectra and explain what they mean. Science without spectroscopy is like civilisation without TV and radio (pause for the obvious response…).

OTHER TECHNIQUES

What else is encoded in a stream of photons? Polarization is a property that is not impossible to explain; but it is difficult, even for physicists (read the first chapter of Paul Dirac's "Principles of Quantum Mechanics). When Polaroid sunglasses were common, we at least had a chance to demonstrate what we meant. Polarization really tells us about the orientation in space of a source of photons or it can reveal something of the path the photons took to reach our telescope, i.e., it is a property that can be imprinted by 'reflection' (read scattering) from mirrors that allow us to see around corners. As for spectroscopy, there are analogies and easily visible demonstrations in nature: one just has to choose an appropriate one.

Figure 2. *Polarization of the blue sky. Sunrise on Hawaii looking south. The Sun is rising behind Mauna Kea on the left and a polarizing filter in a fisheye lens (the 30mm lens on a Hasselblad with a diagonal FoV of 180°) reveals the directional imprint of Rayleigh scattering: the process that creates the splendour of the clear blue sky.*

Figure 2 is an example of the kind of demonstration that I so often find useful in explaining astronomy. There are many sky phenomena visible with the (almost) naked eye that are directly related to the processes we study as astronomers. In this case, the use of a polarizing filter to photograph a clear sky at sunrise (it could be sunset with equal effect) reveals the next layer of depth in our understanding of why the sky is blue. The dark band arching through the zenith shows us the relationship of polarization with direction and orientation. You can explain how the filter is oriented and why!

Interferometry is also a challenge: there are fewer useful analogies and the process is intrinsically complex. We are driven to use it because of our desire to see fine detail in images and the physics behind it is one of the two reasons we are always trying to build larger telescopes. If you can explain this reason, you are halfway there. If we reach the stage of sketching fringes and talking about equalising paths, we may be stepping into quicksand.

So, having mastered spectroscopy, polarimetry and interferometry, where do we go next? These techniques all concern the properties of single quanta. Once we start bothering ourselves with the arrival times of individual photons, we get into the whole new game of quantum optics. We can see if they come in bursts or as a spatter of more evenly distributed events. We will need large telescopes to do this for faint astronomical sources, and we will need to count photons pretty fast, but it will tell us about natural lasers, phenomena close to black holes and the intricacies of the photon's journeys to us.

CONCLUSIONS

I believe that what we do as astronomers is explicable to lay audiences. In my experience, people love to hear about what we actually do: even if they don't understand the gorier details. I have no fear of showing (and explaining) spectra or polarization maps. But the audience have to be prepared first; they need to formulate the questions themselves. They should be ready to ask: "But how do you know that?"

We are fortunate as astronomers in having the Universe as our canvas. We have the intrinsic beauty of the night (and daytime!) sky above us. When we look closer with our expensive toys we can, unlike many scientists, convert our digital data streams into the most stunning images that everybody loves to see. Given this bonus of public interest, we can afford to put a little effort into revealing glimpses of a deeper understanding. But we have to tread gently: it is all too easy to kill interest.