The making of *Stars 'R' Us!*

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The team behind a successful project to broaden the understanding of astrochemistry – **Serena Viti, Wendy Brown, Martin McCoustra, Helen Fraser, Nigel Mason** and **Robert Massey** – recount how they went about it and what benefits resulted.

Abstract

Say "astrochemistry" and many people imagine something remote, irrelevant and, well, pretty dull. Yet to someone working in the field this is exciting science that delves into the origins of life itself. Astronomical observations have already identified more than 120 different molecules in space. Chemists and astronomers are now working together to understand how these molecules are formed. But how can we probe reactions occurring light years from our labs? This is where astronomy, chemistry and physics come together to generate exciting and cutting-edge science that helps us understand the evolution of the cosmos. At the 2004 Royal Society Summer Exhibition, the leading annual showcase for fundamental science in the UK, we won the opportunity to show to the public how such science is performed, in an exhibit called *Stars 'R' Us!* In this article we set out how we approached the challenge of making our science as interesting to members of the public as it is to us.

The motivation behind our exhibit was to highlight the role of spectroscopy and chemistry in unravelling astronomical wonders. We aimed to show how the new discipline of astrochemistry is combining the clues gleaned from telescopes with sophisticated laboratory experiments and computer modelling to understand the evolution of chemical complexity to the verge of life itself. With the next generation of telescopes now being designed to specifically seek out the molecular markers of life, the importance of molecules, as markers and progenitors for star and planet formation, is paramount. The new science of astrochemistry combines the astronomers' need to understand the chemical evolution of the universe with the chemists' desire to investigate chemical reactions in the extreme environments found in the atmospheres of stars and in the cold, dark depths of the interstellar medium.

The idea for the *Stars 'R' Us!* exhibit was originally developed by Martin McCoustra, who then enlisted the help of the rest of the team to create what proved to be a highly successful exhibit. The exhibit combined the frontier research of astronomers, chemists and physicists from Nottingham, University College London, the Open University and Leiden, with the public understanding of science expertise of the Royal Observatory, Greenwich. The material in the exhibit had to be accessible to a wide audience: schoolchildren, the general public, leaders from industry and the government as well as Fellows of the Royal Society and their guests all visited the exhibition at various times during the week. This fact was brought home to all of us very clearly during the exhibition itself – at one time we might be explaining the exhibit to a retired couple with only a minimal knowledge of science, while the next minute we found ourselves faced with a PhD student in astrophysics.

When designing our exhibit, the main aim was to make a contribution to widening general scientific literacy and supporting lifelong learning. However, at events such as the Royal Society Summer Exhibition, the public also has the rare opportunity to see the enthusiasm and passion with which we scientists pursue our scholarship. The Royal Society Summer Exhibition is an ideal environment in which scientists of all ages can hone their skills in communicating with the public and fulfil the lifelong learning agenda. For this reason, we ensured that the exhibit was staffed throughout the period of the exhibition by a team combining scientists of all levels from our groups in Nottingham, UCL, the Open University and Leiden, plus active science communicators from the Royal Observatory in Greenwich.

The structure of the exhibit

It was decided that the best way to make this science accessible to as wide an audience as possible was to show how important it is for astronomy. Astronomy has great public appeal, from the beauty of the night sky to the awe-inspiring scale of the cosmos; we hoped that by putting our work in this context, people would appreciate what we are trying to find out.

We decided that our exhibit (see figure 1) should be eye-catching and should combine scientific information with hands-on experience. We designed a series of posters that told the story behind the exhibit in a manner accessible to a non-specialist. We also accompanied the posters with a video, telling the story of how chemistry and astronomy are coming together to give a better understanding of how stars form.

The main parts of our exhibit were four hands-on experiments that gave visitors a chance to see for themselves how some of the science worked. The first exhibit, Seeing Stars, illustrated how visible spectroscopy allows us to detect atoms and molecules in stars. We made a series of glass "stars", containing He, Ne and Ar, to be viewed through a hand-held spectroscope. We gave people a series of spectra and asked them to identify which gas was in each star. Almost universally, visitors were amazed that it was possible to identify different elements so easily. This exhibit also had a plasma globe, of the type often found as interactive exhibits in science museums. The plasma globe appeal was two-fold: it attracted visitors, who could not help but touch it, and it could also be viewed through the spectroscopes, allowing the viewer to see the distinct emission from the different atoms in the plasma.

Our second hands-on exhibit, Seeing the Unseen, compared images of a model interstellar cloud in the visible and in the infrared. It allowed us to demonstrate how using the infrared allows us to see inside star-forming regions that appear opaque to the human eye. To achieve this effect we used a simple Sony digital camcorder, equipped with a NightShot mode that converts the camera into a near-infrared camera. Our astronomical object, Barnard 68, was printed onto an acetate film, behind which was located a printed circuit board onto which the logos of our universities were etched. This was then illuminated from behind by an array of near-infrared light-emitting diodes. Light from the diodes, transmitted through the logos and the image of Barnard 68, was only visible with the camera in NightShot mode. Switching between the normal operating mode of the camera and its NightShot mode thus allowed us to illustrate the principle of using infrared astronomy to see the unseen.

Reproducing Space was our third exhibit and consisted of a simple, static ultra-high vacuum chamber illustrating the type of experimental apparatus used in our laboratory surface-science studies. Although this exhibit was simple, it was highly effective as people were able

1 (right): *Stars 'R' Us!* in place at the Royal Society. As well as a series of posters, it included four hands-on exhibits: from left to right, Seeing Stars, Reproducing Space, Seeing the Unseen and Life in a Bottle.

2 (below): The exhibit proved popular throughout the week.

to see the lengths to which it is necessary to go in order to achieve the very low temperatures and pressures that are present in the interstellar medium. The chamber itself was cut away and we filled it with sweets. Needless to say, this move was very successful – and not only with our younger visitors.

Our final hands-on exhibit was Life in a Bottle. This was the exhibit most modified from our original intention. We had planned to develop this as a working Urey–Miller experiment with online infrared spectroscopy to probe the evolving liquid phase. However, considerations of electrical and chemical safety led us to simplify this idea considerably. A straightforward experimental format was designed in which a water-based reaction mixture was excited by a spark from a high-voltage discharge circuit. The chemical evolution of the mixture in the reaction cell was monitored in advance of the exhibition and we presented these observations on materials supporting the exhibit. Although the discharge operated during the exhibition, the effect was illustrative rather than real.

The science behind the exhibit

In summary, we told a story that focused on the star cycle and the chemistry that controls this process. The first part of the story described how stars form from vast clouds of gas and dust and how the cosmos evolves through a continuous cycle of star birth, life and death. In particular, our story stressed how chemistry plays a crucial role in controlling the star cycle.

We underlined how the cosmos formed from the simplest atom, H, along with small amounts of He and Li. Early stars took these elements and began the process of nuclear synthesis to form heavier and heavier atoms: in the first hands-on exhibit, Seeing Stars, we described how one can see this process occurring in the Sun by studying how atoms absorb and emit light that is characteristic of their structure.

The spectra of stars become more complex as the star gets older and, in the infrared, we can even see evidence for the formation of molecules in some stellar atmospheres. In the Seeing the Unseen exhibit we showed how infrared spectroscopy allows us to see objects not observable in the visible spectrum.

The next part of our story explained that in certain areas of the space between the stars, we find dense clouds that are rich in molecules and also in dust particles. Our visitors were surprised to hear that more than 120 different molecules have been identified in space so far. This fact then led us on to why chemistry is important in the star formation process: the conditions in these dense clouds are extremely harsh with very low temperatures and extremely low pressures, meaning that many chemical reactions are not possible. Although some gas-phase reactions do occur, for some molecules they cannot account for the observed abundances and chemical reactions on the surface of dust grains must occur. This fact forms the basis of the research of several of the members of our team. The chemists and physicists in our consortium are involved in investigating the rates of formation of molecules on surfaces and in ices and their release into the gas phase. We explained how we use special equipment to simulate the low temperature and pressure conditions of the interstellar medium and were able to show the visitors the apparatus that is used in the Reproducing Space exhibit.

The final part of our story focused on the origins of life itself. We explained the different theories about how life began on Earth and our Life in a Bottle exhibit illustrated one of these theories. We concluded by pointing out that we are all made of the simple atoms and molecules that are formed and processed into more complex molecules in stars – *Stars 'R' Us!*

Funding the exhibit

Of course, building an exhibit such as this did not come cheap and we were aware, right from the start, of the high cost of such a venture. Following a briefing session organized by the Royal Society and discussions with previous exhibitors, it became clear that we had to take a professional approach to assembling our exhibit. As a first step, we drew up a realistic budget for both the preparation of the exhibit and the running costs associated with the week of the exhibition itself. Sponsorship was then sought from several sources. We received generous funding from our universities: University College London, the University of Nottingham and the Open University. We also received support from several external sources including the Royal Astronomical Society, the EPSRC, PPARC and the Royal Society of Chemistry, who all gave generously. Additional, smaller, amounts of funding were received from the CCLRC, from the Astrophysical Chemistry group of the Royal Society of Chemistry, and from the Thin Films and Surfaces Group of the Institute of Physics. We were also able to secure sponsorship from various companies: VTS, Caburn Vacuum Science, Thermo Electron, SHI-APD, Oxford Applied Research, VAT Vacuum, Leybold, Hiden Analytical and Oxford Scientific all gave generous contributions.

The Royal Society Summer Exhibition

The afternoon of Sunday 4 July and morning of Monday 5 July were given over to assembly of the exhibit at the Royal Society's Carlton House Terrace building. Figure 1 shows the exhibit fully assembled and in place there. The Royal Society Summer Exhibition 2004 ran from 6 p.m. on the Monday until after 10.30 p.m. on Thursday 8 July. It was open to the public from 6–9 p.m. on the Monday, 11 a.m. – 4.30 p.m. on the Tuesday, and 10 a.m. – 4.30 p.m. on the Wednesday and Thursday. The Tuesday evening from 6.30 to 9.30 p.m. was given over to a session for invited educational professionals, while the Wednesday and Thursday evenings from 6.30 to 10.30 p.m. were the Royal Society Soirees.

The Summer Exhibition itself was very busy (figure 2) but incredibly rewarding. All those we talked to were enthusiastic about our exhibit and the exhibition overall. In fact, ours was voted among the top three exhibits by visiting schoolchildren. From the moment the doors opened to each public session, there was a continual stream of members of the public and school groups to meet. Their enthusiasm and thirst for knowledge was infectious. The evening sessions were more formal, but also busy. The Tuesday evening session in particular provided a considerable amount of interest in our exhibit and in the possibility of using the science in lessons in schools.

Our team of exhibitors was extremely effective in communicating our science to as wide a range of people as possible and all of us benefited enormously from communicating our science to an enthusiastic audience.

Beyond the Royal Society

It was always our intention that this exhibit would be made available to the members of the consortium who developed it for use after the Royal Society Summer Exhibition, and a legal framework has been drawn up and signed by the parties involved to ensure the future of the exhibit. It has already been used at a University of Nottingham open day in June and at a UCL chemistry open day in early July. Part of the exhibit, Seeing Stars, also made an appearance at the Science Museum in August this year. Further local events within our universities, for example undergraduate and postgraduate open days, and local public awareness events are planned. As a direct result of the Summer Exhibition, we have also received several requests for schools lectures and for further information about the science behind our exhibit.

Our participation in the Summer Exhibition has been reported in our various university newsletters and Helen Fraser was interviewed for the BBC Radio 4 programme *The Material World* on 12 August 2004. Beyond this, it is planned to exhibit *Stars 'R' Us!* in the new exhibition space being developed at the Royal Observatory, Greenwich, during Science Week next March, at an event at the Open University next April and at the annual meeting of the British Association for the Advancement of Science in September 2005. It will also form the focus of the public appreciation of science activities of a recently funded EPSRC Network being co-ordinated by members of the Stars 'R' Us! consortium, and may be shown at the network launch meeting in April. The Royal Society of Chemistry is also looking into mechanisms to capitalize on the positive view of chemistry put forward by *Stars 'R' Us!* (and the other chemistry-focused exhibits at the Summer Exhibition) through events in their Chemistry Week in November 2005.

On a wider scale, we have developed a website to accompany our exhibit (http://www.chem.ucl.ac.uk/cosmicdust/starsrus.html). This site makes our materials available to a wider audience, provides links to the various research groups involved and aims to promote further our public awareness activities. The information on this website is also linked to the website for the new EPSRC network in "Surface Science Applications in Laboratory Astrophysics" – AstroSurf.

In conclusion, *Stars 'R' Us!* was a successful exhibit at this year's Royal Society Summer Exhibition. We feel that the exhibit projected a positive image of chemistry working closely with physics and astronomy to attempt to answer fundamental questions of importance in understanding the evolution of the universe and life. We believe it has had a positive impact on the public, our colleagues in the wider scientific community, funding agencies (both public and charitable) and the political establishment. This can only be of benefit to science as a whole.

Finally, this exhibit would have not been possible without the help of the many sponsors listed above, and without the help of the various postdoctoral fellows, research students and summer vacation students who ably supported us at the exhibition itself, and we would like to extend our thanks to all of them. ●

Serena Viti, Dept of Physics and Astronomy, University College London, Gower Street, London, WC1E 6BT, UK; Wendy Brown, Dept of Chemistry, University College London, 20 Gordon Street, London, WC1H 0AJ, UK; Martin McCoustra, School of Chemistry, University of Nottingham, University Park, Nottingham, NG7 2RD, UK; Helen Fraser, Raymond and Beverly Sackler Laboratory, Leiden Observatory, PO Box 9513, 2300 RA, Leiden, The Netherlands; Nigel Mason, Dept of Physics and Astronomy, The Open University, Milton Keynes, MK7 6AA, UK; Robert Massey, National Maritime Museum and Royal Observatory, Park Row, Greenwich, London, SE10 9NF, UK.