**Institution: Heriot- Watt University**

**Unit of Assessment: 8 Chemistry**

**Title of case study:** *Stars 'r' Us! Engaging the Public with Astrochemical Research*

## 1. Summary of the impact

Stars 'r' Us! (SRU) is a touring exhibition conceived in 2004 by Professor Martin McCoustra to engage the public with astrochemistry. SRU has been updated frequently, most recently in 2010 to include on-going work at Heriot-Watt University (HWU). SRU has contributed regularly to major science festivals, with independently corroborated strong impact on public attitudes. Over its lifetime, active researchers have interacted directly with an estimated 11,000 visitors, most of whom were teenagers. SRU has further indirect reach through a widely distributed teacher's pack. It is also a valuable element of the public engagement programme at HWU which has seen demonstrably improved recruitment to chemistry programmes over recent years. SRU has engaged with the EU Commission through an ESF co-sponsored event: laboratory astrochemistry has recently achieved preferred status in a Horizon 2020 foresighting exercise.

## 2. Underpinning research

Stars 'r' Us! (SRU, http://www.stars-r-us.org ) can trace it roots back to the early 2000s and the publication of a short popular article by McCoustra, Fraser and Williams in the Royal Astronomical Society (RAS) house magazine Astronomy and Geophysics [DOI http://dx.doi.org/10.1111/j.1365-2966.2009.15144.x ] and to the astrochemical science behind a publication for teachers in the Royal Society of Chemistry (RSC) journal Education in Chemistry. The activities of SRU are underpinned and informed today by the wide-ranging science originating from within the HWU Laboratory Astrochemistry Group (http://www.astrochemistry.hw.ac.uk) and from other members of the Framework 7 Initial Training Network (ITN) Laboratory Astrochemical Surface Science In Europe (LASSIE). SRU is broadly based and draws on the activities of all its partners. The key themes that SRU explores are:

- The role of spectroscopy in observing the chemical composition of the local and more distant universe;
- The importance of small molecules in controlling the formation of small, long-lived stars;
- The interplay between chemistry in the gas phase and on dust grains;
- The role of surface and solid state chemistry in developing a rich organic chemistry in star-forming regions;
- The importance of that rich organic chemistry in seeding the galaxy and the universe with the chemical potential for life.

The work of the HWU Astrochemistry Group focuses on the broad theme of the role of surface and solid-state physics and chemistry in evolving the chemical complexity of the regions where stars and planets are formed towards the chemical progenitors of life; this has a direct impact on the final three bullet points listed above. That complexity can be observed to a very limited extent in the solid state, but infrared spectroscopy is insufficiently sensitive and characteristic to provide information on anything but the most abundant chemical species in the solid state. However, desorption and release of complex organic molecules into the gas phase allows many more of the chemical species present in these distant environments to be detected. The on-going development of sensitive new observational platforms such as ALMA is revealing the details of the complex molecular inventory of the Universe. The key publications from the activities of McCoustra and the HWU Astrochemistry Group that are relevant to the development and implementation of SRU are listed below. The work listed highlights the role of laboratory measurements of both thermal [1 – 3] and non-thermal desorption [4 – 6] of molecules under conditions that mimic the interstellar medium. The first set of three publications relate to the development of an understanding of the thermal desorption of icy grain mantles [1 - 3], a process that is crucial to the chemical control of the star formation process. On the basis of this work at HWU, these processes are better described in physicochemical models of such environments. The latter three papers describe recent and on-going work on desorption processes induced by light and charged particles [4 - 6]

that are crucial in returning complex organic species to the interstellar gas and compete effectively with chemical evolution within radiation-rich environments. These discoveries and the understanding they provide of the processes that enrich the interstellar gas with complex organic molecules directly inform our discussion of the chemical evolution of the Universe when engaging with the public.

**3. References to the research** (* = best indicates the quality of the underpinning research )

*[1] Applying Laboratory Thermal Desorption Data in an Interstellar Context: Sublimation of Methanol Thin Films. S. D. Green, A. S. Bolina, R. Chen, M. P. Collings, W. A. Brown and M. R. S. McCoustra Mon. Not. Roy. Astron. Soc., 2009, 398, 357-367.

[2] Laboratory Investigations of the Interaction between Benzene and Bare Silicate Grain Surfaces. J. D. Thrower, M. P. Collings, F. J. M. Rutten and M. R. S. McCoustra, Mon. Not. Roy. Astron. Soc., 2009, 394, 1510-1518.

*[3] Thermal Desorption of $C_6H_6$ from Surfaces of Astrophysical Relevance. J. D. Thrower, M. P. Collings, F. J. M. Rutten, and M. R. S. McCoustra, J. Chem. Phys., 2009, 131, 244711.

*[4] Desorption of Hot Molecules from Photon Irradiated Interstellar Ices. J. D. Thrower, D. J. Burke, M. P. Collings, A. Dawes, P. J. Holtom, F. Jamme, P. Kendall, W. A. Brown, I. P. Clark, H. J. Fraser, M. R. S. McCoustra, N. J. Mason and A. W. Parker, Astrophys. J., 2008, 673, 1233-1239.

[5] Photon- and Electron-stimulated Desorption from Laboratory Models of Interstellar Ice Grains. J. D. Thrower, A. G. M. Abdulgalil, M. P. Collings, and M. R. S. McCoustra, D. J. Burke, W. A. Brown, A. Dawes, P. J. Holtom, P. Kendall, N. J. Mason, F. Jamme, H. J. Fraser and F. J. M. Rutten, J. Vac. Sci. Technol. A, 2010, 28, 799-806

[6] Highly Efficient Electron-stimulated Desorption of Benzene from Amorphous Solid Water Ice. J.D. Thrower, M. P. Collings, F. J. M. Rutten, and M. R. S. McCoustra, Chem. Phys. Lett., 2011, 505, 106-111.

To support the operation of SRU, we have utilised funding from RCUK sources both directly and indirectly. Since 2010, SRU is has been supported by the LASSIE ITN under Framework 7. The awards that have supported SRU activities are listed below;
[A] Stars R Us! An Exhibit at the Royal Society Summer Exhibition. 2004, PPARC PP/B5Q1017/1 to McCoustra (HWU, PI) with Brown and Viti (UCL), Mason (OU), Fraser (Leiden) and Massey (RGO); £4,000.

[B] AstroSurf: A Network in Surface Science Applications in Laboratory Astrophysics. 2004 – 2007; EPSRC GR/T05004/01 and GR/T05004/02 to McCoustra (HWU, PI) with Brown and Viti (UCL), Mason (OU) and Darling (Liverpool); £66,934.

[C] Stars 'r' Us!; The Cosmic Chemistry Connection. 2006, EP/E022693/1 to McCoustra (HWU, PI); Linked to EP/E022413/1 and EP/E022081/1 awarded to Brown (UCL) and Fraser (Strathclyde); £2,598.

[D] Laboratory Astrochemical Surface Science in Europe (LASSIE). 2010, Framework 7 PEOPLE Work Programme 2008 Grant Agreement Number 235258 to McCoustra (HWU, coordinator) with colleagues from 12 other centres; 6, 053,548 Euro.

**4. Details of the impact**

Stars 'r' Us! uses highly interactive exhibits to show how information obtained from telescopic observations, laboratory experiments and computer modelling is used to infer clues about the possible chemical origins of life. McCoustra led the development of the exhibition, with contributions from UCL, the OU, Leiden Observatory and Royal Observatory Greenwich. Over £25,000 was initially secured from various sources to fund the exhibition including grant [A] above. However this initial investment was supplemented by addition funding in 2006 ([B] and [C] above to

an estimated total of £10,000) and most recently in 2010 (from [D] to a value estimated at £7,500). Operating costs for SRU activities come from sources including the British Council, RSC, ESF and SRU partners.

Resources created to accompany SRU include a comprehensive teacher's pack which has been distributed to hundreds of schools. The team has also developed a session for school engagement. Stars 'r' Us! is a key plank of Heriot-Watt University's public engagement strategy, during a period which has seen annual applications for undergraduate places on Chemistry degree programmes increase from 547 in 2004 to 734 in 2013. There has also been a commensurate rise in quality of students accepted into our Chemistry courses, demonstrated by the increase in UCAS tariff by fifty points over the same period.

**4.1 In depth engagement with adults of all socioeconomic groups**

The Stars 'r' Us! team has actively sought engagement with audiences from a wide range of different demographics. With this in mind, we have toured the exhibition around shopping centres as part of an RSC programme, and took it to the International Scout Jamboree. More recently the exhibition has featured at Our Dynamic Earth (ODE) three times during the REF period as part of the Edinburgh International Science Festival (EISF) and once at Cheltenham Science Festival. A senior UK academic astronomer states:

"*Stars 'r' Us! has been a highly effective piece of work with an enduring life and one that works for diverse audiences of all ages and backgrounds*".

***EISF at Our Dynamic Earth Science Centre in 2008, 2009 and 2011***

Exhibiting at ODE offers a great opportunity for scientists to engage with families and independent adults across the social spectrum (a quarter of ODE's visitors are from socioeconomic group C2DE). For example, in 2009, this included a group of Hibernian football fans! The SRU team invites experts to collaborate in the exhibition and programme. Over the weekend of operation in ODE in 2011 some 1000 visits were recorded (an average of 330 per day for the Friday to Sunday period). Taking this as a realistic average footfall per day at each of our activities then a total footfall of 11,000 can be estimated, excluding the additional auditable earlier figures from the Royal Society Summer Exhibitions and more recently (see below) at the Cheltenham Science Festival. The Public Astronomer, from the Royal Observatory Greenwich comments:

"*The Stars 'r' Us! activity has been an amazingly effective piece of public engagement and I've enjoyed helping to present it on a number of occasions. As an astronomer and a professional science communicator I've been very impressed by the excellent mix of exhibits, pictures, interpretation and live demos that comprise Stars 'r' Us! This variety and flexibility has … allowed it to engage a huge number of people in a wide range of different venues. One of its great strengths has been the way in which it has been used to bring together researchers from a variety of different institutes and fields of expertise and it has also proved itself as an excellent training ground for students and young researchers, allowing them to hone their creativity and public engagement skills*."

One former SRU helper has gone on to join the staff of the Royal Observatory Greenwich as an assistant to the Public Astronomer.

***Cheltenham Science Festival 2013 (Area 42 – for over 14s)***

Over 900 people visited Stars'r'Us! at Cheltenham Science Festival. The Festival attracts a broad social mix with approximately half of visitors coming from socio-economic group C2DE. SRU visitors enjoyed in-depth interactions (6-7 minutes on average) with researchers that led to a wide range of new learning from specific details on complex theories such as gravity waves to how different colours of light relate to the composition of stars.

Visitors reported particular appreciation for being able to talk directly to researchers and discovering subjects that would not be covered by mainstream media. They felt strongly that giving young people the opportunity to meet researchers informs and influences their education and career choices. Having visited SRU, visitors also voiced clear support for publicly-funded, curiosity driven research (57% expressed a positive attitude; 30% had no strong opinion; 13% expressed

support with caveats). The Programme Director, Cheltenham Science Festival, said:

"*Cheltenham Science Festival really values the contribution that exhibitions such as Stars 'r' Us! make to Times Area 42. These exhibitions offer a fantastic opportunity for visitors to discuss cutting edge contemporary research with the scientists who are undertaking the work and are a rare opportunity for an in-depth exchange of information and views on everything from fundamental scientific principles to funding*."

**4.2 Engagement with schools**

Stars 'r' Us! has provided information about contemporary science and science careers to thousands of young people. In recent years, this has included participation in HWU's Get SET widening-participation days. These popular events are an exciting and stimulating opportunity to inspire girls to consider study and careers in science and engineering.

McCoustra has also run Stars 'r' Us! schools' sessions with over 600 students in Scotland and northern England. Feedback from teachers shows that these activities have encouraged numerous young people, including many in remote geographical locations, to change their perceptions of science and has influenced their educational choices.

- "*[Our students] thoroughly enjoyed it and some were more motivated to go on and study ..[science]... at a higher level*" Teacher, James Young High School, Livingston
- "*They were more aware of other courses (rather than just physics or chemistry) to study at university and not just the same three as at school*". Teacher, Earlston High School
- "*We are a small island school. We very much benefit from programmes where visiting speakers can show our students a little of the opportunities that exist on the mainland*." Teacher, Islay High School

**4.3 Engagement with EU policy makers - Astrochemistry – The Cradle of Life event**

In 2011, Stars 'r' Us! was invited by the European Science Foundation (ESF) and European Cooperation in Science to take part in an astrochemistry event organised for the EU Commission and Parliament and held at the Natural History Museum in Brussels. EU politicians and civil servants attended a reception to raise awareness of astrochemistry at a trans-national level.

"*Bringing Stars 'r' Us! to an audience of European Commissioners and the general public helped to raise the profile of astrochemistry in the EC. I believe that activities of this kind are an important contributory factor to the favourable discussions regarding astrochemistry in the development of Horizon 2020/Framework Programme 8*." Chair of European Science Foundation

In February 2013, The European Commission Consultation On Possible Topics For Future Activities For Integrating And Opening Existing National Research Infrastructures Report cited (page 24) European Laboratory Astrophysics as a topic with high potential and with merit for future Horizon 2020 actions for integrating and opening existing national research infrastructures.

**5. Sources to corroborate the impact**

[1] A senior Astronomer within the UK will state Stars 'r' Us! has been a highly effective piece of work with an enduring life and one that works for diverse audiences of all ages and backgrounds
[2] The Marketing Manager from Our Dynamic Earth for numbers of visitors and their perception of the impact of SRU when it ran at the Edinburgh International Science Festival.
[3] Public Astronomer at the Royal Observatory in Greenwich can confirm the effectiveness of the approach in SRU, and its impact on participants
[4] Chair, European Science Foundation, on the impact of the event in Brussels in 2011.
[5] Final Report to PPARC PP/B5Q1017/1.
[6] Final Reports to EPSRC EP/E022081/1, EP/E022413/1 and EP/E022693/1.
[7] Evaluation of Stars 'r' Us! at the 2013 Cheltenham Science Festival, Graphic Science Ltd 2013