

## *AstroSurf: A Network in Surface Science Applications in Laboratory Astrophysics*

### **Background**

Over the last decade, events have highlighted to the chemical physics, surface science, astronomy and molecular astrophysics communities the potential for a highly synergistic relationship to develop between these apparently disparate scientific activities. Extremely successful workshops such as that on *Solid State Astrochemistry of Star Forming Regions* (2003) and *Molecular Databases for Herschel, ALMA and SOFIA* (2007) organised by the Lorentz Centre for International Workshops on Science in Leiden pointed to increased activity in this interdisciplinary area of science. On the national level, increasing activity was illustrated by the presence of substantial sessions in almost every Royal Astronomical Society *National Astronomy Meeting* since Bristol in 2002 and in 2005 by the establishment of an annual *Young Astrochemists' Meeting*, under the auspices of the Royal Society of Chemistry/Royal Astronomical Society Astrophysical Chemistry Group, which the AstroSurf network has supported from its inception. These highly successful activities proved to be the springboard from which further activities were launched to consolidate the interactions between surface science and molecular astrophysics and astronomy in the UK, and more widely. The *AstroSurf network* [1] has built on the success of the *UCL Centre for Cosmic Chemistry and Physics (CCCP)* [2], which is a platform for highly successful interactions between scientists at UCL working on problems of relevance to astrophysics [3]. Researchers within the UK are central to this rapidly developing field and therefore the aim of the AstroSurf network was to extend the fruitful collaborations established at the UCL CCCP to the UK as a whole, and beyond. An open and inclusive network in the application of laboratory surface and thin film science, both empirical and theoretical, to problems rooted in the realm of molecular astrophysics and astronomy was therefore established.

### **Defining the Network Activities**

For sometime it has been widely recognised by astronomers and molecular astrophysicists that understanding the chemical processes which produce the rich chemical soup observed in active star forming regions of the interstellar medium is the gateway to understanding key aspects of the physics of star and planetary formation [4] and, possibly even to understanding the origin of life [5]. Crucially, much, if not all, of this work, depends on having an accurate knowledge of the chemical and physical interaction of the gaseous components of clouds with interstellar grains. Surface science, both experimental and theoretical, provides a means of investigating the gas-grain interaction in a well defined and controlled manner. Indeed, the environment within an ultrahigh vacuum chamber equipped with cryogenic sample cooling provides a realistic model of the conditions within a dense molecular cloud in terms of both the pressure and temperature. Such is the potential for surface science methodologies and techniques to contribute to our understanding of the gas-grain interaction that three major review articles in a special issue of the journal *Surface Science* were dedicated to this topic [6]. Numerous other articles have appeared since to support this contention. It is with this in mind that the AstroSurf network was established to encourage collaborations between surface scientists and molecular astrophysicists both within the UK and further afield. The specific objectives of the AstroSurf network were, and remain, as outlined in the supporting case to our proposal:

- To bring together surface scientists (both experimental and theoretical) and molecular astrophysicists to encourage the application of surface science techniques to problems that are of relevance to astronomy.
- To stimulate future research directly relevant to astronomical systems.
- To provide a forum for the exchange of ideas and expertise.
- To encourage collaborations between research groups, thus allowing access to a wider range of experimental and theoretical techniques.

- To promote the AstroSurf network, and the research of the constituent members, both to other members of the AstroSurf network and to the wider scientific community and to the general public.
- To promote the inclusion of additional AstroSurf network members whose research is relevant to the topics of interest, or who are moving into suitable areas.

These objectives are unchanged and were met through a combination of actions including regular scientific meetings and workshops, a dedicated website and exchange visits. From an initial membership of some 25 to 30 academic and industrial partners, representing the then core of laboratory surface astrochemistry in the UK, the AstroSurf network has grown to encompass nearly 100 UK, EU and international members (academics, research fellows, postgraduate students and others) as detailed on the network website <http://www.chem.ucl.ac.uk/astrosurf/home.html>.

### **Management of the Network and Activity Review**

The day to day management of the AstroSurf network has been undertaken by the investigators on the original network proposal. A management team was formed comprising a chairman (McCoustra), a secretary and website coordinator (Brown) and meetings and visits organisers (Mason, Viti and Darling). This team together arranged the scientific meetings organised by the network and coordinated the other network activities. The grant for the network was originally awarded to Nottingham University, where a part-time secretary was appointed to assist with administration. When McCoustra moved to Heriot-Watt in July 2006, the network grant also moved and administrative support since then has been provided by paid post-graduate students as and when required (*e.g.* when organising scientific meetings).

The AstroSurf network was formally launched in April 2005 with a two day meeting at UCL entitled *New Astronomical Challenges in Surface Science*. Attracting nearly 50 attendees from across the UK and Europe, the meeting combined aspects of a tutorial workshop and regular scientific meeting. The plenary presentations by Professor Paola Caselli (INAF-Osservatorio Astrofisico di Arcetri, Italy, now at Leeds) entitled *Surface Chemistry in Interstellar Clouds* and by Professor Theodore E. Madey (Rutgers University, New Jersey, USA) entitled *Far-out Surface Science - Relevance to Surface Processes in Space* sought to address both the astronomical and surface science backgrounds of the remit of AstroSurf for the respective audiences. Some 16 contributed papers and 14 posters then expanded the horizons of the meeting beyond the broadly-based plenary material and highlighted the range of activity within astronomy and surface science relevant to astrochemistry within the UK.

The second major network meeting reiterated the title of our launch meeting, but proved much larger than our previous meeting. Held at Heriot-Watt University in June 2007, this three day meeting attracted over 50 participants. Again, the meeting consisted of a combination of plenary lectures to highlight key astrochemical topics, in a tutorial manner where possible, and contributed presentations from across the globe. Indeed, at least 40% of the contributions during the meeting were from international speakers. The plenary speakers on this occasion included Professor Glenn White (Rutherford-Appleton Laboratory and the Open University), Professor Eric Herbst (Ohio State University, USA) and Professor Maria Elisabetta Palumbo (INAF-Osservatorio Astrofisico di Catania, Italy) with presentations on observational astronomy (*Ices and Molecules – From Dust to Exoplanets*), astrochemical modelling (*Models of Interstellar Chemistry: the Tug-of-War Between Astronomical and Chemical Complexity*) and laboratory studies of the processing of ices (*The Role of Energetic Processing on Interstellar Icy Grain Mantles*) respectively. There were also a range of contributed oral presentations from researchers based in the UK and Europe. A poster session with contributions from UK students and postdoctoral researchers in astrochemistry and lively discussions supported the main oral sessions.

In addition to our headline meeting series, we have, as promised, contributed to a series of student-centred meetings. These are the series of *Young Researchers in Astrochemistry* meetings, developed in collaboration with the Royal Society of Chemistry (RSC)/Royal Astronomical Society (RAS) Astrophysical Chemistry Group and launched in September 2005 with an inaugural meeting at UCL, with subsequent annual meetings at UCL (2006) and Cardiff (2007). These one day meetings provide PhD students and early stage post-doctoral researchers with a supportive environment in which to present their work and have become rapidly established in the UK astrochemistry scene as the annual student event. To quote one of the attendees at the most recent of these meetings “*The meeting as a whole was not only informative, giving an excellent introduction and overview of astrochemistry, but was also immensely enjoyable and excellently organised. I have attended the meeting for two years and would recommend that all new PhDs and Post-Docs not only use the meeting as an excellent introduction to the field but as an opportunity for the inexperienced among us to present their work to a friendly, pleasant and most importantly interested audience!*”

We are confident that with these two fascinating meeting series (*New Astronomical Challenges in Surface Science* and the *Young Researchers in Astrochemistry*) we have helped to establish important new platforms for the exchange of ideas in astrochemistry. There is little doubt in our minds that these meetings are worth maintaining and we are planning to continue to organise the network meeting, *New Astronomical Challenges in Surface Science*, with the next in the series scheduled for 2009. The RSC/RAS Astrophysical Chemistry Group will also continue to maintain the sequence of *Young Researchers in Astrochemistry* meetings.

In addition to the above mentioned meetings that have been directly organised by the AstroSurf network, we have also supported a range of activities related to the research areas covered by the network. AstroSurf support has been given to the following meetings through the provision of bursaries to reduce the costs of younger scientists (PhD students and postdoctoral research assistants) attending these meetings:

- IoP Thin Films and Surfaces Group meeting on Ice Surfaces and Interfaces, Cambridge, April 2005.
- RSC/RAS Astrophysical Chemistry Group Annual Meetings in Glasgow, January 2006 and Belfast, 2007.
- RSC Faraday Discussion No. 133 - Chemical Evolution of the Universe in Brittany, April 2006.
- Surface and Interface Processes at the Molecular Level, Il Ciocco Conference Centre, near Lucca in Italy, August 2008.

In addition to arranging meetings, a website was also designed and built (<http://www.chem.ucl.ac.uk/astrosurf/home.html>) to advertise the activities of the network and to provide a method of communicating information to the members of the network. The website is used to advertise a range of scientific meetings in astrochemistry and also gives an up to date list of the network members and some of their current grants and publications. In addition, the web-site provides links to our public understanding of science activities (see below) and to other sites where information about astrochemistry can be obtained.

Our original proposal intended to use research exchanges as one of the mechanisms to encourage further collaboration and a small fund for that purpose was advertised *via* the network website. Unfortunately, this proved to be the least successful of our activities. Only two small awards were made over the lifetime of the network grant, one to encourage knowledge transfer in the use of closed-cycle helium refrigerator systems from Nottingham to UCL and the second, between Liverpool and Strathclyde, aimed at developing theoretical models of the successive hydrogenation of carbon monoxide as the mechanism for methanol synthesis in and on interstellar ice mixtures.

We did, however, provide many bursaries for students to attend scientific meetings related to the work of the AstroSurf network as already detailed above.

The final area of activity of the AstroSurf network was extensive public outreach activities, as discussed in the dissemination section below. These activities were extremely successful and it is planned to continue with public understanding of science activities.

### **Explanation of Expenditure**

The grant was originally held at Nottingham and then moved to Heriot-Watt when McCoustra moved there. A small amount of the awarded money was contracted out to UCL to allow for the building and maintenance of the network website. Other than the move between institutions, expenditure on the grant was largely as planned and is detailed in the accompanying summary of expenditure.

### **Dissemination**

Dissemination of information amongst the network community has been undertaken *via* email and *via* the network web site. The email dissemination is currently operated from UCL by Brown; AstroSurf plans to migrate this activity to the JISCMail system shortly. Dissemination to the wider scientific community has been achieved *via* publication of the research of the network members in the scientific literature and by the presentation of talks and posters at conferences. Full details are given in the section on “Network Achievements”.

In addition to providing networking activities for our community, we identified public outreach as one of our important goals in the original proposal. As detailed in the original proposal, we successfully applied to participate in the 2004 Royal Society Summer Exhibition. This exhibit arose from a collaboration between McCoustra (currently HWU, then Nottingham), Brown (UCL), Viti (UCL), Mason (OU), Massey (currently RAS, then National Maritime Museum and Royal Greenwich Observatory) and Fraser (currently Strathclyde, then Lieden) and our successful proposal was developed into the now well-established and recognised “Stars ‘r’ Us!” (SRU) exhibit (<http://www.chem.ucl.ac.uk/cosmicdust/starsrus.html>) [7] which has been presented at a number of public events since 2004:

- London – Royal Society Summer Exhibition, July 2004.
- London – National Science Week, National Maritime Museum, Greenwich, March 2005.
- Athens – Einstein Year, June 2005, (at the invitation of the British Council, Athens).
- Chelmsford – International Scout Jamboree, July 2005, (invited by Scout Association following a visit to the Royal Society Summer exhibition 2004 by the organiser of the Scout Jamboree).
- Paris – Village des Science, October 2005, (at the invitation of the British Council, Paris).
- Shopping Malls in Newcastle, Manchester, Brighton, Nottingham – UK Chemistry Week Shopping Centre Tour, November 2005 (on behalf of the RSC).
- London – National Science Week, National Maritime Museum, Greenwich, March 2006.
- Glasgow – Royal Society Summer Exhibition, September 2006.
- Edinburgh – International Science Festival at The Dynamic Earth Centre, April 2008.

Over the course of these events, the exhibit has been seen by an estimated 70,000 members of the public across Europe. SRU is about to enter a new phase with a recently submitted proposal under the EPSRC Partnerships for Public Engagement (PPE) scheme. This substantive PPE proposal will see the science of astrochemistry described in the SRU exhibit developed into real and useful resources for teachers in the UK through a partnership of the SRU team with schools and learned societies (IoP, RAS and RSC).

The success of “Stars ‘r’ Us!” is an integral part of the success of AstroSurf. Both the outreach activities of the network and its scientific activities in general contribute to the success of the network by widening the participation within science in general (*via* SRU activities) and more specifically (*via* AstroSurf activities).

### **Network Achievements**

What metrics should we consider to establish whether or not AstroSurf has been successful? In the first instance, expansion of the network membership is essential. In our original case, we listed some 25 to 30 potential members in the UK. *Today, our membership stands at nearly 100 (academics, research fellows, postgraduate students and others) of whom at least 25% are international members.* In our opinion this proves that the AstroSurf network has had a substantial impact both nationally and internationally and that we have been taking steps to promote UK leadership in laboratory surface astrochemistry across Europe. Indeed to quote Professor Jean-Louis Lemaire (Observatoire de Paris et Université Cergy-Pontoise, France) *“I admire, since its beginning, the way you are organized in the UK through the AstroSurf project. I was sure that one day or another you will try to extend it, for the best benefit of all the participants, through a European network, seizing the opportunity of the next FP7. I have also very much appreciated your presentation talk last December in Leiden, showing again how efficiently organized and coordinated is Surface and Solid State Astrochemistry in the UK. Now that you are trying to extend it to the European level, I must confess that I am, in the name of my research group, fully enthusiastic about the project and that we would like very much to be involved. I was myself nurturing such a project, but the different communities are not very well organized in France... ”.* Similar statements have come from colleagues across Europe and, indeed from across the Atlantic. The success of the AstroSurf network led to our involvement in an as yet unsuccessful COST Action proposal entitled *The Cosmic Chemical Connection* and to our co-ordination of a FP7 Integrated Training Network (ITN) proposal in February 2007, in the area of astrochemistry, in collaboration with several European colleagues. The development of this latter proposal reflects our commitment to continuing the collaborations established by the network goal and also shows the support of our European colleagues in this aim. While unsuccessful in the first call, we and our colleagues from across Europe will be revising and resubmitting this proposal to the next ITN call. Details of this proposed ITN, *LASSIE – Laboratory Astrochemical Surface Science in Europe*, are to be found on the AstroSurf website at <http://www.chem.ucl.ac.uk/astrosurf/lassie.html>.

While membership increase is an immediate and obvious success of the network, our long term goal was to encourage an increase in collaborative activity in the application of surface science to astronomical problems. This would ultimately be measured by increased collaborative grant activity and jointly authored publications. Such activity is just coming to fruition as the EPSRC funding for AstroSurf draws to a close. We can at present point to the following activities that have grown out of the interactions initiated by contacts made at AstroSurf events:

- Collaboration between McCoustra and Professor M. E. Palumbo (INAF Observatory, Catania) has resulted in a study of the infrared spectra of CO ices on water ice surfaces. This work has led to a publication in a refereed journal [8].
- An international collaboration between Mason and Professors R. W. McCullough (Queens, Belfast) and Palumbo has been initiated and initial publications are in press and preparation [9-11]. McCullough and colleagues are now in the process of developing new surface science experiments to probe ion-ice interactions for which a proposal will soon be submitted to the EPSRC.
- A collaborative programme of research has been established between McCoustra, Brown, Mason, Fraser and colleagues at the STFC Central Laser Facility (Clark and Parker). This programme of work focuses on photon-induced processes in astrophysical ices and has resulted in publications in the CLF Annual report [12] and in refereed journals [13, 14].

- A collaborative programme between McCoustra, Brown, Mason, Fraser and theoretically orientated colleagues at Heriot-Watt and Strathclyde has been developed to obtain a comprehensive picture of photon- and electron-induced physics and chemistry in simple molecular ices. A proposal for this research will also shortly be submitted to the EPSRC.
- As mentioned above, participation in on-going attempts to seek support for the establishment of a COST Action entitled *The Cosmic Chemical Connection* aimed at the astrochemical community across Europe.
- As detailed above, an ITN proposal in the area of laboratory astrochemical surface science was submitted under the FP7 framework in February 2007. This was a collaborative proposal between McCoustra, Brown, Viti and several European colleagues who are all AstroSurf network members. Although the proposal was unsuccessful, it is planned to resubmit this proposal in the future.

This combination of activities, past, present and on-going, and the strong community spirit that has grown out of the activities of AstroSurf is, we feel, a measure of our considerable success in bringing to the table two essentially disparate communities to address a common “big question”, *i.e.* the role of surface physics and chemistry in astronomical environments, in a spirit of open scientific collaboration.

### The Future of AstroSurf

It is our intention to continue with the very successful activities of the network. Indeed, there is considerable expectation from our colleagues in the network that it will continue. In particular we will continue to organise scientific meetings and will maintain the network web-site and mailing list. As per our original proposal, if we are to continue we will redefine the role of the Steering Group and seek to establish a more democratic management with a regularly elected management committee. We have, over the period of the EPSRC support for the AstroSurf Network, established good relationships with a number of instrument suppliers and learned society subject groups who would be willing to continue to offer their support for meetings and other events operated under the auspices of AstroSurf. This will supplement the small surplus we have been able to accumulate from such sources over the last couple of years. We are confident that there is a continued demand for the activities of AstroSurf and will seek to continue and expand on these activities in the future.

### References

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