Institution: University of Hertfordshire

Unit of Assessment: Panel B (9): Physics

Title of case study: Inspiring public engagement in astronomy

1. Summary of the impact (indicative maximum 100 words)

The university's Bayfordbury Observatory is a working observatory that engages with the public via six Open Evenings and approximately 50 group visits a year, offering access to a wide range of facilities. Many of the 4,000 visitors annually report that they develop a first or renewed 'enthusiasm for astronomy', or become 'inspired to learn more' about what they have seen or heard from our researchers; some young people enthuse about 'now wanting to be a scientist'. Science teachers taking an RCUK 'cutting-edge' CPD astrophysics course also say that they have gained an 'increased understanding of the subject', and 'increased confidence in its delivery to pupils'.

2. Underpinning research (indicative maximum 500 words)

Astronomy research has been carried out at the University of Hertfordshire since the early 1970s. This was based initially on the construction of private optical and near-infrared polarimeters, used extensively on the United Kingdom Infrared Telescope Hawaii (UKIRT) and the Anglo-Australian Telescope, Australia (AAT), and – in addition – on developing polarimetry options for these facilities' instruments. The Centre for Astrophysics Research (CAR) was established in 2003, and now comprises over 60 researchers, with research strengths that include exoplanets, bioastronomy, brown dwarfs, star formation, galaxy structure and galaxy evolution over cosmic times. Inter alia, CAR staff lead several very large-scale international surveys: exoplanets on UKIRT, the Magellanic Clouds on the Visible and Infrared Survey Telescope Chile (VISTA), the Milky Way on the Isaac Newton Telescope La Palma and the VLT Survey Telescope (VST) Chile. For more targeted observations, CAR astronomers make extensive use of major ground-based and space observatories covering wavelengths from radio to X-ray. Imaging, photometry, spectroscopy, polarimetry and radio interferometry are all techniques regularly deployed by CAR staff.

The range and strength of astronomy research is of great benefit in public engagement programmes, as expertise can be provided that covers most of contemporary astronomy, the latest discoveries, and the many techniques used.

Two examples of the many research projects undertaken since 1993 are:

(i) Using the polarimeters developed by CAR for the AAT and UKIRT infrared imagers, the first circular polarisation images of the Orion star-forming complex unexpectedly showed very high degrees of circular polarisation; detailed modelling was then able to explain how this was being produced. This discovery led to a possible explanation for one of the long-standing problems in the development of life on Earth, namely the origin of homochirality which occurs for all Earth life-forms. It was proposed that the highly polarised circular polarisation produces, through asymmetric photolysis, an enantiomeric excess in prebiotic material, and this is delivered to Earth during its heavy bombardment phase. This raised, and continues to raise, considerable interest in the scientific community and at many public talks. Laboratory follow-up to determine whether homochirality could be used as a universal biomarker has been carried out in collaboration with the National Institute of Standards & Technology (NIST) and the Space Telescope Science Institute (Baltimore, USA), and at CAR.

(ii) CAR's high-energy astrophysics research includes the study of relativistic jets from compact objects such as black holes and neutron stars, particularly focusing on particle acceleration and the large-scale dynamics of the jets and the shocks that they drive through the external medium. Observational work spans all wavelengths from the gamma-ray and X-ray (Fermi, Chandra, XMM-Newton) to the radio (JVLA, LOFAR), while theoretical work involves both analytic studies and numerical simulations using CAR's powerful computer facilities. The recent proposal that the ultra-high-energy cosmic rays mapped by the Pierre Auger Observatory can be generated in the giant lobes of Centaurus A and other radio galaxies has been influential in both the cosmic ray and active galaxy communities. In public talks, a direct link is there to be made between phenomena easily observable, even in school laboratories (cosmic rays) and cutting-edge research on powerful, cosmically-distant radio galaxies.

3. References to the research (indicative maximum of six references)

The following outputs came from the two research examples outlined in Section 2. CAR researchers' names are in bold. ***** *Denotes the three publications that best exemplify the quality of the research.*

Example (i):

Chrysostomou, A., Gledhill, T.M., Menard, F., **Hough**, J.H., et al., 2000, Polarimetry of young stellar objects – III. Circular polarimetry of OMC-1, *Monthly Notices of the Royal Astronomical Society*, 312 (1), 103–115. doi: 10.1046/j.1365-8711.2000.03126.x

Hough, J.H., Bailey, J.A., **Chrysostomou, A., Gledhill, T.M., Lucas, P.W**., et al., 2001, Circular polarisation in star-forming regions: possible implications for homochirality, *Advances in Space Research*, 27 (2), 313–322. doi: 10.1016/s0273-1177(01)00063-1

***Lucas, P.W., Hough, J.H**., Bailey, J.A., **Chrysostomou, A., Gledhill, T.M**., McCall, A., 2005, UV circular polarisation in star formation regions: The origin of homochirality?, *Origins of Life and Evolution of Biospheres*, 35 (1), 29–60. doi: 10.1007/s11084-005-7770-6

Example (ii):

***Hardcastle, M.J**., Cheung, C.C., Feain, I.J., Stawarz, L., 2009. High-energy particle acceleration and production of ultra-high-energy cosmic rays in the giant lobes of Centaurus A, *Monthly Notices of the Royal Astronomical Society*, 393 (3), 1041–1053. doi: 10.1111/j.1365-2966.2008.14265.x

– REF2 Output

Hardcastle, M.J., 2010, Which radio galaxies can make the highest energy cosmic rays? *Monthly Notices of the Royal Astronomical Society*, 405 (4), 2810–2816. doi: 10.1111/j.1365-2966.2010.16668.x

***Hardcastle, M.J**., Krause, M.G.H., 2013. Numerical modelling of the lobes of radio galaxies in cluster environments, *Monthly Notices of the Royal Astronomical Society*, 430 (1), 174. doi: 10.1093/mnras/sts564

4. Details of the impact (indicative maximum 750 words)

The Centre for Astrophysics Research encourages its lecturers and researchers to develop public engagement skills through delivering talks, supporting national astronomy-related magazines, and assisting at events such as the Open Evenings held at the university's Bayfordbury Observatory, which receives around 4,000 visitors each year.

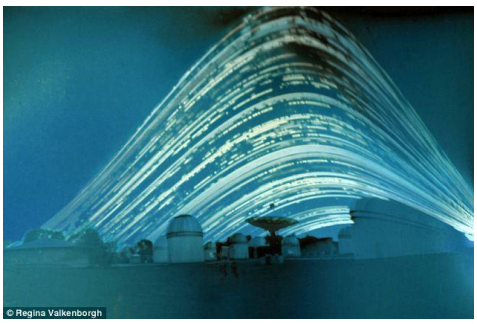
The Observatory's programme of inspiring public interest in astronomy began in the late 1970s. Starting with a single 0.5m telescope, it now has seven domed telescopes, typical aperture 0.4m, a

4.5m radio dish and a three-dish interferometer. The recent automation of five of the seven optical telescopes, providing remote control over the Internet and queue-scheduled observing, permits increasingly efficient use of the telescopes and people's time, thereby continuing to nurture practical astronomy in the UK. Observations include some of the extra-solar planet candidates from Rocky Planets around Cool Stars (RoPACs), the Hertfordshire-led, €3.2m EU-funded Marie Curie Initial Training Network, and RoPACS has led to a significant stake in the European Space Agency's potential exoplanet mission Echo, whose likely target list is also being monitored at Bayfordbury. In public engagement terms, such observations emphasise that Bayfordbury is a working observatory to which the public have access, increasing its attraction for visitors.

There are six Open Evenings a year. There is a small charge (£4 adults; £2 concessions) and they are always oversubscribed, with 400 first-time and repeat visitors aged 5–70+ at each event. Each evening is supported by about 20 lecturers, researchers and research students, and is centred around a single theme chosen from one of CAR's research strengths, with talks given by one or more staff actively involved in the research. Examples are: exoplanets, brown dwarfs, life on other planets, radio astronomy, planetary nebulae, and supermassive black holes.

Visitors can also use the telescopes. All optical telescopes have CCD cameras, some with lucky-imaging to improve image quality – but on Open Evenings eye-pieces are often used: seeing images with 'your own eyes' offers visitors direct, personal enjoyment of the night sky. Even on cloudy evenings people visit the domes, and a researcher is stationed in each one to explain the facilities and the nature of the objects viewed. The radio telescopes are controlled from the adjacent Patrick Moore building, where a talk on radio astronomy is repeated several times.

The Science Learning Centre, the national astronomy specialist centre next to the Observatory, is thrown open during open evenings, allowing access to a lecture theatre, small planetarium, computer suite, laboratories and cafe. Several activities are held there, including talks, planetarium shows, using the web to access astronomy databases and images, and hands-on demonstrations, many of them child-centred. For example, Artist-in-Residence Reggie Valkenborgh was inspired by our work to use a pinhole camera, made from a drinks can, to take images of the sky above the Observatory, with a six-month time exposure. She explained her technique at open evenings and provided material for children to try it themselves. One of her images was chosen as NASA's Astronomy Picture of the Day in 2012, which generated local and national interest. (Section 5, References 1–3)



Visitors remark on the knowledge and enthusiasm of the staff, and how this makes their visit 'enjoyable', 'interesting', 'informative', 'varied' and 'excellent'. Feedback forms from just one Open Night reveal visitors inspired to buy a telescope, consider studying physics at university, join an astronomy society, or 'look at the stars with family and friend in the garden'. Some people leave 5* comments on Tripadvisor, do blog writeups, or send appreciative letters. One blogger said that her son had been 'inspired . . . to find out more and now he is talking about wanting to become a scientist!' (Refs 4–7)

The Observatory hosts about 50 group visits annually, including private parties, brownie and scout troops, and schools. The programme is similar to the open evenings, and feedback is good. For example: 'I have heard some very positive accounts this morning and it seems to have been a very popular, enjoyable and informative visit for all concerned. Given the popularity of the visit and the wonderful show case that it is for UH . . . it would be excellent if we could arrange a trip every semester.' (Ref. 4)

At the Science Learning Centre, CAR staff run a wide-ranging presentation for around 20 schoolteachers annually. This 'cutting-edge' course ('Astrophysics', originally 'From Hydrogen to Humans') is supported by a £60,000 RCUK grant and is often run in twilight hours, giving teachers

the opportunity to use the telescopes. Although pioneered and still led locally, it is now offered at other centres. The course is also offered annually to around 30 teachers as part of a Subject Knowledge Enhancement course (SKE) for teachers whose initial training was not in physics. As the RCUK requires its cutting-edge courses to be continually updated and to involve Council-funded researchers, CAR staff use this opportunity to present their research within a broader context than the narrowly academic. Participant feedback is encouraging: teachers report a 'much improved knowledge of the Big Bang and exoplanets', or a 'better understanding of the formation of the universe'. Importantly, course content is shared with school colleagues, so that newly learned tools and techniques are 'filtering down to the other teachers of physics'. Participants also feel that 'more confidence and enthusiasm for Astrophysics from me means [my] students are more motivated', and that their students are 'stimulated to find out more for themselves'.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Artist in Residence Programme

Press Coverage

1. Ted Thornhill, 'Six months' worth of Sun photos in one incredible shot (and all done with a pinhole camera made from a beer can)', *Mail Online*, 23 January 2012:
   <http://www.dailymail.co.uk/sciencetech/article-2090658/Six-months-worth-Sun-photos-incredible-shot-pinhole-camera-beer-can.html>

2. Simon Wesson, 'Six months of the Sun: an image taken by a Hertfordshire student using a cider can,' *Welwyn Hatfield Times*, 3 February 2012:
   <www.whtimes.co.uk/news/six_months_of_the_sun_an_image_taken_by_a_hertfordshire _student _using_a_cider_can_1_1198122>

Nasa's Astronomy Picture of the Day

3. Reggie Valkenborgh, '**Days in the Sun'**. Pinhole photograph awarded NASA's Astronomy Picture of the Day, 21 January 2012: <http://apod.nasa.gov/apod/ap120121.html>

Representative visitor feedback from Open Evenings and Group visits

4. Bayfordbury website feedback page: <http://bayfordbury.herts.ac.uk/visit/visitor-feedback.htm>

5. A batch of Open Evening feedback forms (in hard copy or PDF form), with representative visitor comments, is available.

6. Tripadvisor: <www.tripadvisor.co.uk/Attraction_Review-g186305-d3579336-Reviews-Bayfordbury_Observatory-Hertford_Hertfordshire_England.html>

7. 'Astronomy in Hertford', blog post (January 2013), Family Fun at Hertford website. This events website is now defunct, but hard copy of the blog posting is available.

Education Outreach (High School Teachers)

8. Feedback from the Science Learning Centre's Astrophysics Course (formerly known as 'H2H') for teachers is available in hard copy/ PDF form; a selection of the comments can also be found on Bayfordbury website feedback page:
   <http://bayfordbury.herts.ac.uk/visit/visitor-feedback.htm>

Independent Sources

The Observatory Director can confirm visitor numbers; contact details are supplied separately.