| | | |
|---|---|---|
| **Institution:** University of Edinburgh | | |
| **Unit of Assessment:** UoA9 – Physics and Astronomy | | |
| **Title of case study:** Astronomy Outreach, Public Engagement, and Education | | |
| **Period when the underpinning research was undertaken:** 2000–2017 | | |
| **Details of staff conducting the underpinning research from the submitting unit:** | | |
| **Name(s):** | **Role(s) (e.g., job title):** | **Period(s) employed by submitting HEI:** |
| Prof. Arjun Berera | Professor | 1999–present |
| Prof. Beth Biller | Professor | 2013–present |
| Prof. James Dunlop | Professor | 1995–present |
| Dr Nigel Hambly | Senior Researcher | 1999–present |
| Prof. Catherine Heymans | Professor | 2008–present |
| Prof. Ross McLure | Professor | 2002–present |
| Prof. John Peacock | Professor | 1998–present |
| **Period when the claimed impact occurred:** August 2013–December 2020 | | |
| **Is this case study continued from a case study submitted in 2014? N** | | |

## 1. Summary of the impact

***Attribution:*** University of Edinburgh (UoE) astronomers have led the world-leading highly-cited research, and have worked directly with outreach staff, educators, and organisations to maximise the potential of astronomical discoveries to promote scientific literacy for all, and act as a springboard into further study and/or careers in STEM.

***Impact on public outreach, education, science engagement and debate:*** Inspiring, informing, engaging and educating the general public, school children, educators and policy makers by communicating and sharing the results of UoE astronomical research through school events and visits, teacher training and production of educational materials, Royal Society and Dark Sky meetings, festivals and public events, TV programmes and films, webinars, blogs and press releases.

***Beneficiaries:*** The public, educators and educational organisations, governmental organisations including recreation and tourism, international organisations.

***Significance:*** Improved awareness and knowledge of astronomical discoveries, and the importance of progress in science. Improved teaching, enhanced motivation of school children to pursue science, supported by heightened enthusiasm/knowledge in the wider public.

***Reach:*** Direct interaction with approximately 100,000 school children and members of the wider UK public over the REF period. Engagement with many more worldwide through events, TV programmes, movies, webinars, and press releases/news stories. Direct training of several hundred school teachers, and extended impact through educational resources. Influence on Public Engagement policy throughout the UK and internationally.

## 2. Underpinning research

This public outreach, engagement and education draws heavily on cutting-edge research led by UoE astronomers. Here we highlight the specific areas of high-quality/high-profile research that are most directly and demonstrably related to the outreach and educational programmes and events developed and delivered at UoE.

**COSMOLOGY** UoE's world-renowned work in **cosmology**, as exemplified by Peacock's leadership of the 2-degree Field (2dF) survey [***R1***], and Heyman's leadership of the CFHT Lensing Survey [***R2***], is central to communicating up-to-date information on such fundamental issues as the age of the Universe, its origin and large-scale structure, and the nature of dark matter and dark energy. The 3-D maps of the Universe produced from the 2dF, and the dark-matter maps produced by the CFHTLS were the deepest and most detailed ever made at the time of their publication, and have featured heavily in public lectures, festival shows, and in the Royal Observatory Edinburgh (ROE) outreach and educational materials.

**ASTRONOMICAL SURVEYS** The UoE's Institute for Astronomy (IfA) hosts the UK's Wide Field Astronomy Unit (WFAU), now housed in the new Higgs Centre for Innovation (HCI). WFAU is

responsible for hosting and serving the **latest astronomical surveys** to the UK and worldwide research communities. WFAU data products have been utilised extensively to introduce the public to modern survey astronomy, and have been fed into secondary school resources and teacher training, as well as displays and demonstrations for public audiences (e.g., at ROE Open Days). Specific use is made of the digitized 'all sky' optical survey, created by WFAU, the near-infrared UKIDSS WFCAM surveys [***R3***], and the latest *Gaia* maps of the Milky Way, with WFAU staff (e.g., Hambly) participating directly in engaging the public with the data products they themselves helped to create.

**FIRST STARS & GALAXIES** UoE astronomers Dunlop and McLure have co-led the deepest Hubble near-IR surveys in the search for **the first stars & galaxies** at the end of the 'Dark Ages'. These programs have yielded the most distant objects known [***R4***], infant galaxies that existed when the Universe was less than a billion years old, highlighted in the 2015 Horizon documentary *Cosmic Dawn*. This work feeds directly into outreach/educational materials on deep space, the origins of the Universe, and the technology involved in modern observatories, and supports new UoE-led outreach work on the James Webb Space Telescope (JWST).

**EXOPLANETS & ASTROBIOLOGY** Much of current public interest in astronomy is directed towards the discovery and study of **exoplanets**, with a special focus on the prospects for discovering potentially habitable earth-like worlds. UoE (Biller) is a world-leader in exoplanet discovery, and in mapping the cloud structures in their atmospheres [***R5***], and is also home to the UK Centre for Astrobiology. UoE (Berera) has also led novel research into the ability of space dust to transport life between planets [***R6***]. This revolution in the study of exo-planets, and the origin of life, feeds directly into public engagement/education, even at primary school level, and features heavily in current ROE public engagement activity.

## 3. References to the research

[***R1***] **J.A. Peacock** et al., *'A measurement of the cosmological mass density from clustering in the 2dF Galaxy Redshift Survey'*, Nature, 410, p. 169. (2001) DOI: https://doi.org/10.1038/35065528 *[564 citations, NASA ADS]*

[***R2***] **C. Heymans** et al., *'CFHTLenS: the Canada-France-Hawaii Telescope Lensing Survey'*, Monthly Notices of the Royal Astronomical Society, 427, p. 146 (2012), DOI: https://doi.org/10.1111/j.1365-2966.2012.21952.x *[546 citations, NASA ADS]*

[***R3***] **N.C. Hambly** et al., *'The WFCAM Science Archive'*, Monthly Notices of the Royal Astronomical Society, 384, p. 637, (2008)
DOI: https://doi.org/10.1111/j.1365-2966.2007.12700.x *[356 citations, NASA ADS]*

[***R4***] **R.J. McLure**, **J.S. Dunlop** et al., *'A new multifield determination of the galaxy luminosity function at z = 7-9 incorporating the 2012 Hubble Ultra-Deep Field imaging'*, Monthly Notices of the Royal Astronomical Society, 432, p. 2696, (2013), DOI: https://doi.org/10.1093/mnras/stt627 *[285 citations, NASA ADS]*

[***R5***] I.J.M. Crossfield, **B. Biller** et al., *'A global cloud map of the nearest known brown dwarf'*, Nature, 505, p. 654, (2014) DOI: https://doi.org/10.1038/nature12955 *[102 citations, NASA ADS]*

[***R6***] **A. Berera**, *'Space Dust Collisions as Planetary Escape mechanism',* Astrobiology, 17, p. 1274, (2017), DOI: https://doi.org/10.1089/ast.2017.1662 *[3 citations, NASA ADS]*

## 4. Details of the impact

***Activities:*** The UoE is involved in a particularly vigorous programme of public outreach, engagement and education, under the auspices of the Royal Observatory Edinburgh (ROE) Visitor Centre, jointly funded by the University and the Science and Technology Facilities Council (STFC). Within the UK university sector, this programme is unusual in its breadth and scope, extending well beyond the normal expectation of public talks, press releases and media interviews. This is in part because university staff, post-docs and students work collaboratively with Visitor Centre staff, but is also due to the unique advantages afforded by the ROE site, with its unusual combination of front-line astronomical research, world-leading instrument and technology development, and astronomical history and heritage.

Activities include the annual ROE open days (exploiting [***R1***, ***R2***, ***R3***]), school visits to ROE, regular public observing, 'Meet The Astronomer' sessions, school visits (with the portable planetarium) with a recent focus (between 2015 and 2017) on the Tim Peake Primary Project, teacher training (CPD, including the development of educational resources for Primary and Secondary teachers, and live online sessions for both teachers and pupils), adult 'continuing-education' certificated evening courses, a strong programme of monthly astronomy talks/podcasts, and the development and operation of the Dark Sky Scotland and now Dark Sky Discovery programmes [***I1a***]. These events have been attended by approximately 50,000 members of the general public during the REF period [***I1b***]. ROE is now also the Scottish centre for the European Space Agency led European Space Education Resource Office (ESERO) [***I1a***], supporting Space Education throughout Scotland. In addition, the UoE is collaborating with the Scottish Schools Education Research Centre (SSERC) [***I1c, I2a***], to bring Research Council-funded researchers together with teachers. Recently, two new demonstration exhibits (on gravitational waves and astronomical spectroscopy [***R1***]) developed by IfA PhD students have been used to engage audiences of hundreds of people both at the ROE and at venues throughout Edinburgh (Figure 1).

***Figure 1:*** IfA PhD student, Joe Kennedy, demonstrating gravitational waves at an ROE Open Day [***I1b, I2e***].

A major recent development has been the creation of a JWST outreach campaign led by Olivia Johnson (Public Engagement Manager at the ROE Visitor Centre) and Alastair Bruce (UoE PDRA). This is a strategic national role, ensuring that key resources and projects are in place, with a focus on the UK role in the mission, to exploit the excitement surrounding JWST launch and early science. The campaign has brought JWST scientists and engineers together with educators, science centres, planetaria, amateur astronomical societies and creative organisations to develop a suite of over a dozen resources, projects and events for schools and public audiences [***I3a-c***]. IfA scientists have featured heavily in this work. A primary school resource ('*Deep Space Diary*') was developed and 15,000 copies were sent to 467 primary schools in 2019 and 2020 (with distribution prioritised to schools in areas of multiple deprivation) [***I3b***]. A secondary school project ('*Cosmic Mining*') was developed in collaboration with the Institute for Research in Schools, and sees school pupils collaborate with scientists in the analysis of existing astronomical data to select potential targets for JWST [***R4***, ***R5***, ***I3c***]. Since its inception in 2018, at least 400 pupils from 48 schools have taken part [***I3c***]. Due to the disruption of Covid-19, an 'At Home' version of the project was launched in March 2020 and has since been completed by 187 pupils from 60 different schools [***I3c***].

Another recent highlight is the completion of a successful pilot of *Creative Space*, a strand of public engagement programming designed to engage new audiences with cutting-edge science and technology at ROE through participation in creative activities. The same activities were offered in separate sessions for families and adults, and the themes include astrometry, exoplanets, coding, instrument testing, and mirror design [***I2b***].

Following the launch of the STFC *Wonder* Initiative, the public outreach programme at ROE has moved focus to engaging with community groups in Edinburgh that live in socio-economically deprived areas of the city. For example, participation in the City of Edinburgh Council's Discover! Programme in 2019 and 2020 (online) has created repeat engagement with local families living with poverty [***I2c***]. Finally, 2019 also saw a new project, *Armchair Astronomy,* run within care homes [***I2d***], as well as engagement with groups that meet in community centres, including the provision of activities as a part of a resettlement project for those from areas such as Syria.

***Impact on the General Public:*** Evidence of *short-term impact* is provided by basic numbers, and immediate feedback from questionnaires etc. For example, the annual ROE Open Days attract approximately 3,000 visitors of all ages each year [***I2e***], while an average of 2,828 school-age children either visit ROE, or receive school visits each year [***I1b***]. Post-event evaluation from the 2018 ROE Open day revealed that 72% of questionnaire respondents rated the event 5/5 and

27% rated it 4/5 and nearly every respondent said they learned a little (44%) or a lot (55%) about science and technology. Qualitative comments also reflect the fun and educational nature of these open days, with one parent at the 2017 event commenting "*We came yesterday with our 2-year-old she loved it so much that we came back. The comet talk was superb very engaging for kids and so informative for adults*" [***I2e***]. Feedback from other initiatives also demonstrates immediate engagement: 72% of Creative Space participants ranked their enjoyment of the event as 5/5 [***I2b***], while a parent who took part in the 2020 Discover! Programme said their kids loved learning all about space and that a "*telescope [is] definitely on the Christmas list*" [***I2c***].

***Figure 2:*** Dunlop and McLure present findings from [***R4***] on "Cosmic Dawn: The Real Moment of Creation" [***I4***].

We can also identify clear evidence of *long-term impact in public outreach*. Our work has featured in widely-distributed long-running documentary movies and television programmes. For example, UoE astronomers (and the ROE) featured prominently in the Horizon and Discovery Channel 2015 documentary "*Cosmic Dawn: The Real Moment of Creation*", based directly on [***R4***] (Figure 2). Total UK viewing figures were 2,258,000, with millions more worldwide [***I4***]. Our research on the seeding of life by space dust [***R6***] generated enormous worldwide press coverage and motivated the creation of multiple YouTube videos with a total of approximately 80,000 hits [***I5***]. The dramatic growth of the Edinburgh-led Dark Sky initiative also provides evidence of long-term impact: building on the success of Dark Sky Scotland reported in the previous REF period, a further 128 educators were trained to run Dark Sky activities [***I1c***]. The current REF period has seen the creation of the UK-wide Dark Sky Discovery project, with a steering group led by Dan Hillier from ROE. This has resulted in the creation of 74 new Dark Sky Discovery sites since 2014, including several notable clusters for tourism/community development: https://www.darkskydiscovery.org.uk/dark-sky-discovery-sites/map.html [***I6, I7***].

***Impact on Teachers and Education:*** UoE's astronomy research has also had a *long-term impact in education*. SSERC's Physics team leader describes the ROE as "*one of our most valued partners in professional learning*" [***I8***]. Over 500 school teachers have attended *Deep Space* and other Continuing Professional Development (CPD) courses provided by the ROE, and have been provided with resources (developed as part of the CPD work at ROE) for use in the classroom [***I1c***]. The *Deep Space* resources (galaxies and exoplanets) are now included in the official Scottish Qualifications Authority (SQA) Course Unit Support document for the National Physics courses in Scotland [***I9***] and teachers in approximately 40% of schools in Scotland have now completed ROE CPD training. These educational resources have also been distributed through four outreach centres in England (Leicester, Oxford, Portsmouth, Warwick), and the Deep Space CPD materials have been used by the Public Engagement teams at Daresbury and Rutherford Appleton Laboratories. They are also available via the National STEM learning centre and have been downloaded 9,949 times, including 634 downloads by teachers [***I10***]. The star-charts on the BBC Learning website, based on an ROE resource, are one of the most downloaded resources.

In 2017, in collaboration with RAiSE (Raising Aspirations in Science Education), we launched a new education initiative focused on science education at transition between primary and secondary schools at national level in Scotland. The initiative uses astrobiology to teach basic and inter-disciplinary science using resources developed by teachers at our Astrobiology Summer Academy, including our *Astrobiology in a Box* resource [***R5***]. In 2018, more than 50 teachers and practitioners were trained in using the astrobiology materials in five school clusters across Scotland, reaching over 2,000 pupils. The material is soon to be shared nationally as part of an Education Scotland STEM Nation online resource [***I11***].

***Impact on Public Engagement Policy:*** During the current REF period, Edinburgh's public engagement (PE) work in Astronomy has influenced PE policy in the UK and internationally, through the development of a clear improved *evaluation framework* for PE activity, and the

expanded implementation of CPD. In addition, it is Edinburgh's leading work in widening participation in science engagement (through Dark Sky Scotland) that seeded the *Wonder* initiative, and members of the ROE Visitor Centre team have given talks on PE policy at several international conferences [***I12***].

**5. Sources to corroborate the impact**

[***I1***] **Information on the ROE: a)** ROE Visitor Centre (VC): https://www.roe.ac.uk/vc; **b)** Visitor, outreach, and event numbers (from VC records); **c)** CPD events (from VC records)
[***I2***] **Feedback, quotes, and visitor numbers from internal reports: a)** SSERC teaching training workshop; **b)** Creative Space report; **c)** "Discover Online Summer 2020" and "Wonder Match final report" describing ROE work with community groups; **d)** Armchair Astronomy project review; **e)** Evaluations from 2017 & 2018 ROE Open Days

[***I3***] **Links for JWST outreach work: a)** JWST resource homepage https://jwst.org.uk/resource-network/, Primary school resources https://jwst.org.uk/resource-network/articles/esero-uk-webb-primary-resources/, Secondary school resources https://jwst.org.uk/resource-network/articles/esero-uk-webb-primary-resources-2/; **b)** Deep Space Diary project https://jwst.org.uk/resource-network/articles/deep-spacediary/ and school distribution list; **c)** Cosmic Mining project homepage https://jwst.org.uk/resource-network/articles/cosmic-mining/, internal report on the project for 2019-2020, and 2019-20 Institute for Research in Schools impact report: https://researchinschools.org/impact-reports/

[***I4***] **Email from the producer of 'Cosmic Dawn'.** Can be contacted for corroboration.

[***I5***] **Example YouTube videos: a)** https://www.youtube.com/watch?v=TtvfCNP5zGA; **b)** https://www.youtube.com/watch?v=TyOLFqImB4A (in Albanian); **c)** https://www.youtube.com/watch?v=xqcoFDJ-xp4 (in Vietnamese).

[***I6***] **Examples of new Dark Sky Discovery sites created in REF period (74 in total):**
**a)** Northumberland National Park https://www.visitnorthumberland.com/darkskies
**b)** North Pennines Area of Outstanding Natural Beauty (AONB) http://www.northpennines.org.uk/exploring/stargazing/dark-sky-discovery-sites/
**c)** Pembrokeshire National Park/National Trust https://www.nationaltrust.org.uk/features/best-stargazing-sites-in-pembrokeshire
**d)** Forest of Bowland AONB https://www.forestofbowland.com/star-gazing
**e)** South Downs National Park https://www.southdowns.gov.uk/communicating-south-downs/dark-night-skies/south-downs-dark-sky-discovery-sites/

[***I7***] **Corroborating contact:** Visitor Development and Marketing Manager at Northumberland National Park Authority. Can corroborate the number of new Dark Sky Discovery sites and clusters for tourism and community development.

[***I8***] **Email from Physics Team Leader at SSERC containing quote cited in case study**

[***I9***] **National 4 Physics Course Support Notes, May 2015, SQA (page 14):** http://www.sqa.org.uk/files_ccc/CfE_CourseUnitSupportNotes_N4_Sciences_Physics.pdf

[***I10***] **Deep Space learning resources available via the National STEM learning centre:** https://www.stem.org.uk/rxybr (Galaxies) and https://www.stem.org.uk/rxybq (Exoplanets). Download statistics provided as a PDF document.

[***I11***] **Support letter from the National Education Officer at RAiSE**

[***I12***] **Conference talks on Public Engagement policy development:**
**a)** Programme evaluation https://web.archive.org/web/20170720183009/http://www.planetariomedellin.org/cap2016/english-version/; **b)** "Evaluation of research infrastructure investment and Public Engagement in the UK" https://indico.frm2.tum.de/event/43/contributions/565/; **c)** "Measuring Success" https://www.isis.stfc.ac.uk/Pages/Measuring-Success.aspx; **d)** "How to Develop a Strategic Approach to Evaluating a Public Engagement Programme" https://www.publicengagement.ac.uk/sites/default/files/publication/engage_2016_programme.pdf ; **e)** "Getting organised for communicating about research infrastructure" https://indico.frm2.tum.de/event/43/contributions/551/