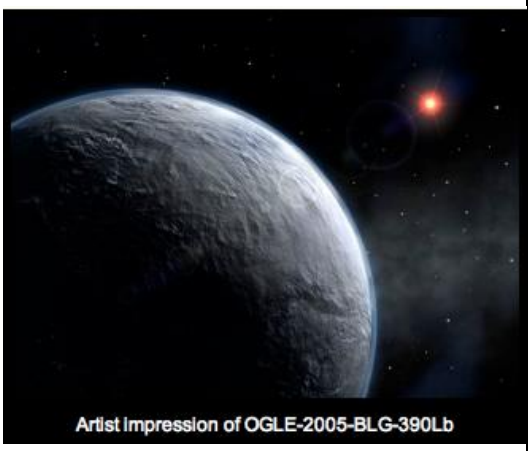
Institution: PHYESTA

Unit of Assessment: UoA 9 – Physics

Title of case study: Astronomy Outreach, Public Engagement, Policy Development and Education

1. Summary of the impact

Impact: *Public outreach, education, science engagement, debate and policy development*:
Inspiring, informing and educating the general public, school children, educators and policy makers by communicating the results of PHYESTA astronomical research through events, movies visits and training. Influencing worldwide policy makers through the stimulation of new debates.


Artist impression of OGLE-2005-BLG-390Lb

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

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

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

Attribution:
PHYESTA astronomers have both led the highly-cited research and have worked directly with outreach staff, educators, and organisations (e.g. Royal Society and STFC) to publicise and promote the impact and relevance of astronomical discoveries.

2. Underpinning research

This Public Outreach, Engagement and Education draws heavily on the latest research led by PHYESTA 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 at, and delivered by PHYESTA.

- PHYESTA's work in **cosmology**, as exemplified by John Peacock's leadership of the 2-degree Field (2dF) survey [R1], is central to communicating up-to-date information on such fundamental issues as the age of the Universe, its origin and its large-scale structure. The 3-D maps of the Universe produced from the 2dF were the deepest and most detailed ever made at the time of their publication, and feature in much of the Royal Observatory Edinburgh (ROE) outreach and educational materials.

- PHYESTA astronomers have been searching for **exoplanets** with Earth-like compositions since 1995. Using gravitational microlensing to detect small, cool planets and more recently HARPS-N to measure the densities of transiting super-Earths from the *Kepler* mission, we

are finding rocky planets both outside and inside their host stars' habitable zones. [R2] outlines the breakthrough discovery by microlensing of what was, at the time, the lowest mass exoplanet known, using a monitoring strategy developed in and led by PHYESTA. The planet was spotted in the data by Martin Dominik supported by the RoboNet-1.0 project led by Keith Horne. The wider implications of this significant step towards the discovery of potentially habitable planets have been actively promoted by PHYESTA, generating strong public interest.

- PHYESTA hosts the UK's Wide Field Astronomy Unit (WFAU), responsible for making the **latest astronomical surveys** available to the UK and worldwide research communities. Our Open Days exploit the WFAU data products to introduce the public to modern survey astronomy. Specific use is made of the digitized 'all sky' optical survey [R3], and the near-infrared UKIDSS WFCAM surveys [R4], with WFAU staff participating directly in engaging the public with the data products they themselves helped to create.

- In recent years PHYESTA astronomers have co-led the deepest ever Hubble near-IR imaging surveys in the search for **the first galaxies and stars** at the end of the 'Dark Ages'. These programs have yielded the most distant objects known [R5], infant galaxies that existed when the Universe was less than a billion years old. This feeds directly into outreach/educational materials on deep space, the origins of the Universe, and the technology involved in modern observatories.

Personnel:
Key PHYESTA researchers involved were Dr Martin Dominik (Royal Society University Research Fellow 2006-Present), Dr Nigel Hambly (1999-Present), Professor Keith Horne (1994-Present) Dr Ross McLure (2004-Present), Professor John Peacock (1998-Present)

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: 10.1038/35065528, URL: tinyurl.com/qxyugsj, *[402]*
[R2]	J.-P. Beaulieu et al., *'Discovery of a cool planet of 5.5 Earth masses through gravitational microlensing'*, Nature, **439**, p. 437 (2006), DOI: 10.1038/nature04441 , URL: tinyurl.com/qzwg8xk, *[314]*
[R3]	N.C. Hambly et al., *'The SuperCOSMOS Sky Survey - I. Introduction and description'*, Monthly Notices of the Royal Astronomical Society, **326**, p. 1279, (2001), DOI: 10.1111/j.1365-2966.2001.04660.x, URL: tinyurl.com/oc6ryxz, *[310]*
[R4]	N.C. Hambly et al., *'The WFCAM Science Archive'*, Monthly Notices of the Royal Astronomical Society, **384**, p. 637, (2008) DOI: 10.1111/j.1365-2966.2007.12700.x , URL: tinyurl.com/nucjcl3, *[175]*
[R5]	R.J. McLure et al., *'Galaxies at z = 6-9 from the WFC3/IR imaging of the Hubble Ultra Deep Field'*, Monthly Notices of the Royal Astronomical Society, **403**, p. 960, (2010), DOI: 10.1111/j.1365-2966.2009.16176.x, URL: tinyurl.com/pdu3t4g, *[156]*

The quality of the underpinning research is best indicated by R1, R2 and R5. *[NASA ADS citations]*

4. Details of the impact

PHYESTA is involved in a particularly vigorous programme of Public Outreach, Engagement and Education. A major aspect of this is the ROE Visitor Centre (www.roe.ac.uk/vc). 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 have the opportunity to 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/technology development,

and astronomical history/heritage.

Activities **i**nclude the annual open days, weekly public observing, 'Meet The Astronomer' sessions, school visits, blogs, teacher training (including the development of educational resources for Primary and Secondary teachers) [F1], adult 'continuing-education' certificated evening courses, and the development and operation of the Dark Sky Scotland and Dark Sky England programmes [F2]. ROE is now also the Scottish centre for the European Space Agency led European Space Education Resource Office (ESERO) [S1]. Over the last year, PHYESTA has also collaborated with the Edinburgh College of Art to produce a film on exoplanets (*Wish You Were Here? Searching for Exoplanets*), which won an honourable mention in the 'Scientific Merit Award' at the Imagine Science Film Satellite Festival in Dublin, leading to it being shown in the official Imagine Science Film Festival in New York in Nov 2012.

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 PHYESTA Open Days attract ~3000 visitors of all ages, while ~6000 school-age children either visit PHYESTA institutions, or receive school visits each year. In addition, more than 50 community Dark Sky events have now been held throughout Scotland, and more than 800 teachers and educators have been trained to run Dark Sky activities. PHYESTA makes a major contribution towards this direct people contact. For example, in 2010, ten post-graduate students contributed a combined total of over 300 hours to outreach activity.

The **short-term impact** of PHYESTA's exoplanet work can also be demonstrated. PHYESTA's exhibit "*Is there anybody out there? Looking for new worlds*" [S2] was a highlight of the 2008 Royal Society Summer Science Exhibition, and was selected to be shown at Techfest 2009 at the IIT (Mumbai, India). The Royal Society exhibition attracted 3069 visitors (including 894 students and 109 teachers), as well as 1197 invited VIP guests in two evening sessions [S3]. Exhibitors and visitors were able to exchange views regarding detecting life beyond Earth, our role within the cosmos, and how research on exoplanets relates to a better understanding of our home planet. It is this link that explains the particular appeal of extra-solar planets to the wider public. An analysis of the media coverage of the UK's National Astronomy Meeting found that *"the public interest in the topic of extra-solar planets seems to be insatiable"*. 86% of the public visitors of the exhibition who provided feedback stated that their *"interest in science had increased*", while 62% of the students declared that they are *"more interested in a career in science"*, 68% were *"more interested about science in general"*, and 58.5% were *"more likely to read about science outside of school"*.

We can also identify clear evidence of **long-term impact in public outreach**. Our work has featured in widely-distributed long-running documentary movies, as well as television programmes such as "*Wonders of the Universe*". The film "*Wish You Were Here? Searching for Exoplanets"* has now been widely viewed at UK Science Festivals, and is currently showing in New York. PHYESTA's exoplanet research also triggered and enabled the widely viewed March 2010 "*Life*" episode of the BBC series "*The Sky at Night*" [F3] as well as a docu-fiction "*The visit – a documentary from outer space*" (being produced by Lise Lense-Møller, 2010 Academy Award "Oscar" nominee for "Best Documentary") [F4]. In addition, the PHYESTA work on the James Webb Space Telescope has featured in the award winning "*We are Astronomers*" film [S4], showing at Dynamic Earth in Edinburgh, and six other science centres across the UK. As one final example of long-term public impact, our efforts to take astronomy outreach to the more remote regions of Scotland have been formative in motivating and helping Galloway Forest Park to successfully apply for Dark Sky Park status. [F2]

Impact on Teachers and Education
PHYESTA's astronomy research has also had a **long-term impact in education**. Over 200 school teachers have attended our *Deep Space* Continuing Professional Development (CPD) courses, and have been provided with *Deep Space* resources for use in the classroom. These resources are now included in the official SQA Course Unit Support document for the new Nat 4 Physics (replacing Standard Grades (= GCSEs) in Scotland), and the exoplanet resource has been expanded into a Researching Physics topic for the new Higher Physics. These educational

resources are now being distributed through four outreach centres in England (Leicester, Oxford, Portsmouth, Warwick). ROE also supplies resources to the BBC Learning website, and the star-charts have proved to be one of the most downloaded resources. Commenting on PHYESTA's contributions to secondary education, the Head of Section Physics and Technology of the SSERC states *"…few, if any, university-funded organisations have quite the impact on my work and indeed on Scottish school physics education in general…*". [F1]

Impact on Policy Development and Public Debate

Our exoplanet work has also had **long-term impact in fostering debate** on the societal implications of the detection of life beyond Earth. To encourage the involvement of relevant stakeholder organisations, PHYESTA astronomer Martin Dominik proposed and co-organised a Royal Society Scientific Discussion Meeting on the detection of extraterrestrial life and its consequences [S2]. This meeting was chosen to open the Royal Society meeting series in its 350th anniversary year, and hosted the first ever pro-and-contra debate about the benefits and risks of communication with extra-terrestrial civilisations. This is now being followed up by a new study group **"***Active SETI: Scientific, Technical, Societal & Legal Dimensions*" of the International Academy of Astronautics. The meeting received world-wide media coverage and has stimulated new debate in the field [S5]. Following this meeting PHYESTA has contributed to an agenda for policy development, involving the United Nations Office of Outer Space Affairs (UNOOSA), which supports the Committee on the Peaceful Uses of Outer Space (COPUOS). The Director of OOSA states the importance of the PHYESTA work: *"The activities carried out under the study led by Dr Martin Dominik have, indeed, increased public awareness of the United Nations Office for Outer Space Affairs (OOSA) and the United Nations Committee on the Peaceful Uses of Outer Space. Whilst at times there were objections to having the United Nations debate the issue of aliens, the publicity did trigger discourse on the processes and procedures for decision-making should extraterrestrial life be detected….In addition, the exchanges and views of information that occurred during those activities did lead to a better understanding among the SETI and extraterrestrial life community on the best way forward to engage the United Nations."*

5. Sources to corroborate the impact

[F1]	Factual statement by Head of Section, Physics and Technology, Scottish Schools Education Research Centre.
[F2]	Factual statement by Head of Tourism, Recreation & Communications, Galloway Forest Park
[F3]	Factual statement by presenter of "The Sky at Night"
[F4]	Factual statement by Magic Hour Films.
[F5]	Factual statement by Deputy Director General United Nations Office at Vienna and Director Office for Outer Space Affairs.
[S1]	www.esero.org.uk/teacher-support/activity/royal-observatory-edinburgh-roe *Corroborates PHYSETA's role in the European Space Education Research Office.*
[S2]	royalsociety.org/news/anybody-out-there/ *Corroborates the Royal Society discussion meeting on extra-terrestrial life.*
[S3]	Review of the Summer Science Exhibition and Soirées 2008, PDF document. *Corroborates attendance figures and ratings for Royal Society Summer Exhibition 2008.*
[S4]	nsccreative.com/filmlibrary/weareastronomers/ *Corroborates "We are Astronomers" film and gives details of awards.*
[S5]	www.nytimes.com/2010/10/09/world/09nations.html?_r=0 *Corroborates New York Times coverage of increased UN debate on extraterrestrial life on the basis of a meeting initiated by PHYESTA researchers.*