

Institution: University of Hull		
Unit of Assessment: 9 – Physics		
Title of case study: Astrophysics outreach to widen participation for the socio-economically disadvantaged		
Period when the underpinning research was undertaken: 2014 – 2019		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Brad Gibson Marco Pignatari Kevin Pimblett	Role(s) (e.g. job title): Head of Dept., Centre Director Reader Senior Lecturer	Period(s) employed by submitting HEI: 06/15 – present 03/16 – present 03/14 – present
Period when the claimed impact occurred: 2014 – present		
Is this case study continued from a case study submitted in 2014? No		
1. Summary of the impact Our research impacts by facilitating creativity, building skills, and ultimately enhancing society via outreach activities that target under-represented groups and socio-economically disadvantaged regions. Our award winning Changing the Face of Physics initiative doubled the number of women studying Physics at Hull. We supported more than 100 school teachers, and provided over 30 work experience opportunities to under-represented groups. In total, the Milne Centre (a research, teaching and outreach unit within the Department of Physics and Mathematics) ran more than 500 Education and Public Outreach (EPO) events during the REF period, creating long-term relationships across and beyond Northern England. This activity contributes to the UK's Industrial Strategy by inspiring, engaging and, for some, training a STEM- and digitally-literate workforce. Our science communication has reached nearly 3,000,000 people and our influence is designed to stretch long into the future.		
2. Underpinning research Space science has an almost unique power to entrance and engage across the full spectrum of society. We use its stunning visual nature to engage audiences with the most fundamental of human questions in order to spark their curiosity and inspire them to excel. The themes of our outreach activities reflect this (e.g. "Are we alone in the Universe?", "What are we made of?", "What are the most extreme environments in the Universe?"). Consequently, such EPO engagement is ideally positioned to inspire and animate potential students to opt for education into STEM. The students who pursue STEM learning and research will become scientifically, digitally and numerically literate. All of our EPO activities are underpinned by this ethos, and to this end they deliberately mobilise research from our specialist fields of galactic archaeology (2.1.), the origin of the chemical elements (2.2.), and the physics of extreme objects (2.3.). 2.1. Galactic Archaeology (Gibson – Milne Centre) Professor Brad Gibson, who leads the Milne Centre at Hull, is a pioneer in the field of Galactic Archaeology, particularly in the development of some of the earliest codes to marry chemical evolution with cosmological hydrodynamical simulations. Those synergies helped define the Galactic Habitable Zone. Specifically, simulations showed that the steeper, negative, radial metallicity gradients seen in the mid-plane flatten with increasing height away from the plane. Furthermore, Gibson's PDRAs and students led the MaGICC [Ref1] and RaDES [Ref2] teams, creating in total 50+ Milky Way-like simulations, which have underpinned much of Gibson's EPO activity since 2014. Going forward, Gibson has now co-leadership (w/KIAS) of the Horizon Run 5, an unprecedented 350M+ core-hr computational experiment, and recently completed at KISTI. 2.2. The Origin of the Chemical Elements (Pignatari – Milne Centre) Dr Marco Pignatari's research focuses on the nucleosynthesis of chemical elements [Ref3]; from the building blocks of life, via the mineralogy of terrestrial planets, to the chemical tagging which underpins the Galactic Archaeology work [Ref4]. Dr Pignatari's research is embedded throughout our EPO, particularly in relation to answering the question "Are We Alone in the Universe?" because the mineralogical structure of potential life-sustaining terrestrial planets is shaped by the relative ratios of carbon-to-oxygen and magnesium-to-silicon that he researches [Ref5].		

2.3. Extreme Physics (Pimbblet – Milne Centre)

Another Milne Centre member's research that features prominently in the EPO is Dr Kevin Pimbblet's extreme physics of supermassive black holes (SMBHs) [Ref6]. This research has shed light on the growth of SMBHs and the link to their host galaxies' baryonic components. The Milne Centre team was the first to implement the energy feedback from elliptical galaxies' SMBHs within a cosmological hydrodynamical framework. At Milne Centre EPO events, when discussing the "Wonders of the Universe" and "How the Universe Will End", the extreme physics of SMBHs features prominently. Equally, the mystery of black holes never ceases to engage the public and school children especially. Consequently, linking SMBH studies to "Societal Contributions of Astronomy" (e.g., WiFi, x-ray scanners, GPS/SatNav/Google Maps) has proven to be an extremely powerful inspiration for our audiences.

3. References to the research:

1. Miranda, M.S., Pilkington, K., Gibson, B.K., et al. 2016, A&A, 587, [A10](#)
2. Ruiz-Lara, T, Few, C.G., Gibson, B.K., et al. 2016, A&A, 586, [A112](#)
3. Pignatari, M., et al. 2016, ApJS, 225, [24](#)
4. Gordon, Y.A., Owers, M.S., Pimbblet, K.A., et al. 2018, MNRAS, 465, [2671-2686](#)
5. Pignatari, M., ..., Gibson, B.K., et al. 2015, ApJ, 808, [L43](#)
6. Molla, M., et al. 2015, MNRAS, 451, [3693-3708](#)

4. Details of the impact

The Milne Centre for Astrophysics is an academic research and teaching centre that is also the regional leader for Education and Public Outreach (EPO) in its field. It utilises the lure of space to engage and build sustainable partnerships with the public, schoolchildren and teachers. We deliver a series of EPO events including specialist lectures, school-visits, hands-on activities, and demonstrations from our mobile planetarium. We present at science outreach events and science festivals, and offer summer placements and internships for pupils and students. In total, we have logged 500 EPO activities in the REF period (with 94 in 2020, despite the Covid-19 pandemic).

At the broader, national-stage, we have delivered outreach at venues such as the Royal Institution, the British Science Festival, the Cheltenham Science Festival, Pint of Science, TEDx, the National Media Museum, and the Museum of Science and Industry. Milne members have presented Award Lectures including the IOP's John Porter Memorial Lecture, Hampshire's Ray Bootland Memorial Lecture, Glasgow's Leon Davies Lecture, and Manchester's Bexwyke Lecture. We have a media presence in The Conversation, and a monthly spot on BBC Radio highlighting space science. Gibson was also interviewed by National Geographic on the top 10 News Stories of the Year that most excited audiences [Evid1]. As above, this range of activities has engaged almost 3,000,000 people members of the public in this period, including 40,000 students [Evid2].

The following quotes represent a brief selection of anonymous feedback from various audience members (we use this feedback to inform, improve and update our EPO activities).

- *"I absolutely loved your talk so much. Especially your recognition that it's not all about the 'A' students, but how you empower those with lower grades to realise they have opportunities in STEM. [...] I honestly can't tell you how great it is to see someone doing something with real impact for real people."*
- *"You have done more in this region than you realise: Research challenges the way we think about a specific subject. Your approach is challenging the way many will think across a broad range of subjects in your field...AND MAKING IT ACCESSIBLE FOR WOMEN. Keep shining a light, I've seen the ripples you make with the younger children I've worked with. Sparks take a while to catch".*
- *"Learning about the cutting edge research in particular fields and how the students' skills they are already developing apply. Also, simple ways to explain or expand on topics in the national curriculum."*
- *"Can I just say on behalf of everyone at Hilderthorpe Primary School a huge thank you. This afternoon was amazing. The children really enjoyed your talk and were really buzzing back in class. We would definitely like to invite you back again next year."*

Our Education and Public Outreach strategy revolves around three key objectives that will deliver our engagement and impact across the English North through the REF2014-21 period.

- i. We have widened participation in our region by engaging students with cutting edge research in Astrophysics (4.1).
 - ii. We have upskilled students' coding ability and data science literacy through participation in computational physics problems, introducing students to the possibilities of careers in STEM-related occupations (4.2)
 - iii. Finally, following strategic guidance of professional bodies and learned society for physics, we pioneered the inclusion of women in Physics in Higher Education (4.3).
- The case concludes with a brief outline of future ambitions (4.4).

4.1 Widening participation

A key element of our strategy aims to increase participation in STEM learning and our EPO activities specifically targeted areas of weak socio-economic attainment. We have delivered a sub-total of 200 events with 35 schools and colleges across the country since 2014, and we have built long-term, sustained relationships with many due to multiple, re-occurring visits. These activities take the form of lectures/talks, planetarium demonstrations, interactive observing sessions, junior school workshops and work experience opportunities. Consequently, the Milne Centre's reputation makes it the go-to authority for the local region when questions around astronomical events arise [e.g. **Evid3**]. Our concerted efforts to sustain these events lead to lasting local impact by building medium- and longer-term partnerships with schools and venues, and by raising aspirations and widening participation in physics. **Fig 1** illustrates our targeted approach with a heat map showing a selection of the EPO activities in the period, overlaid onto the geographical location of the most deprived areas in England in 2015 (according to the Office for National Statistics Index of Multiple Deprivation, IMD).

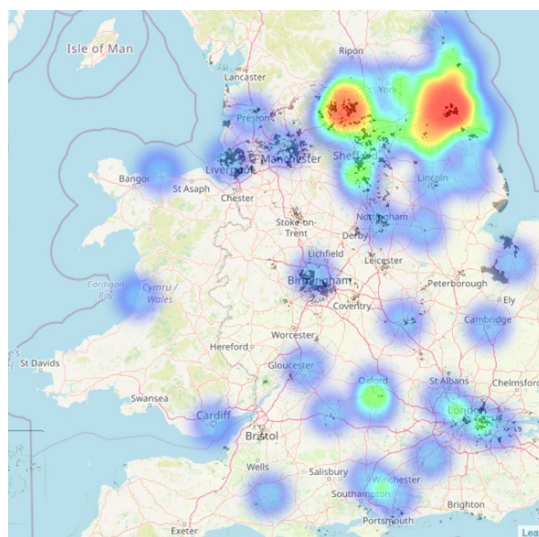


Fig 1: Sub-set of the EPO 435 events delivered since 2014 (excluding 66 interviews), given by the Milne Centre for Astrophysics (heat map) overlaid on the map of most deprived areas in England (black dots, source ONS).

2015 (according to the Office for National Statistics Index of Multiple Deprivation, IMD). A Science/STEM/Careers Lead, Y3 teacher-Burlington Junior School, Bridlington, writes:

"The University of Hull's outreach activities have had such a hugely positive and very valuable impact at our school in encouraging an interest in space and science. [The focus on] 'Extreme astrophysics' has encouraged far greater enthusiasm for STEM fields and changed career ambitions for many. [...] Many of the pupils do not have a chance to attend museums or have much discussion of an educational nature at home. Children have therefore benefited hugely with a positive and lasting effect on their mind-set, attitude, attainment and ambition." [**Evid4**]

Our public talks and planetarium demonstrations are built around the simulations and observational surveys of our research programmes. This exposes audiences to our research: we make it accessible, but explain the potential of this work. We also introduce our audiences to Hull University's research infrastructure such as VIPER (our high-performance computing facility). One indicator of the reach of our activities is the growth of astrophysics groups and societies in the local region. The Hull and East Riding Astronomical Society has seen a 25% increase in attendance and membership since 2014. A second indicator of our reach and impact are surveys that reveal the impact of our events. Assessing the impact of EPO on a short, temporal baseline is complex, but our immediate impact can be evidenced through pre- and post-event surveys: e.g., (i) when queried about the most immediate and pressing astrophysical concern for humanity's survival before a public lecture, 66% of the public believed "the Sun's evolution" was the primary concern, with 25% supporting "mass extinction through impact events." After the lecture respondents had switched to 19% still regarding the Sun as the threat, whereas 70% identified impact events. E.g. (ii) when Upper KS2 students were asked pre-talk whether

astrophysics played an important role in the development of WiFi and Smoothed Particle Hydrodynamics (SPH), 53% and 40%, respectively, said “yes”; post-talk, the numbers were dramatically altered to 93% (WiFi) and 100% (SPH). **[Evid5]**. This is engagement and widening participation by communicating research.

Finally, Hull and its region are a nationally recognised zone of high-deprivation (see **Fig.1**). Yet through a systematic EPO approach focussed on widening participation, the intake to Hull Physics programmes has maintained a steady level overall, with a doubling of students arriving to study astrophysics and numbers from the HU postcode tripling in the REF2021 period. A East Riding of Yorkshire Council Teaching and Learning Officer writes: “*The Science Leaders across the region were unanimous in their praise for the support you provide and the inspirational job you are doing. Thank you for being passionate enough to want to make a difference in the region. You are doing it!*” **[Evid6]**

4.2 Training in computational skills and STEM literacy

The Milne Centre provides Career Professional Development (CPD) training to both regional (100+) and international (20+) school teachers, via the RCUK Teachers scheme, IOP Regional Days, and our relationship with East Riding of Yorkshire Council’s Education Team (Primary and Secondary Science Leaders and Heads of 6th Form Colleges Forum). Our mobile planetarium supplements these CPD events and we demonstrate how our research can be used to enhance their curriculum provision. We also support six regional schools directly, and 12 more through targeted events such as Big Bang Hull and the Scarborough Science and Engineering Week (where over 3,000 students used the planetarium during their Space Weeks). For 2020 we had planned a regionally-focussed series of CPD workshops for KS4 students and teachers; we will run these when conditions allow.

The impact of our EPO extends beyond school children. One teacher (whose school works with us) is now doing a part-time PhD as a direct offshoot of our engagement. Likewise, some of our undergraduates who have delivered our EPO work have been so impacted by the experience that they have changed career plans to study PGCE Physics to become teachers (aligning perfectly with the ethos of the UK Industrial Strategy). We also provided 30+ work experience opportunities in our Department to under-represented groups from the region: they engage with data-mining simulation suites - providing a powerful added value to their career development. Finally, we have also extended our outreach internationally with CPD workshops for 20 Thai teachers and 60 schoolchildren through our Python Workshops project (ThaiPASS (STFC)) **[Evid7]**. Our Galactic Archaeology and Origin of the Chemical Elements research underpins workshops that deliver an astrophysics-driven approach to Python software training to KS4-equivalent students.

4.3 Women in Physics

In a region where girls can be diverted from STEM subjects, we are working with schools to change preconceived images of Physics and to redress the gender balance in the discipline. The national baseline for women entering 1st year Physics programmes is 22%, and the demographics and socio-economics of Hull produced a lower uptake of 10-14% in the pre-2016 period. To address this we have linked with regional colleges (e.g., Wyke; New College Doncaster and Pontefract; Hessle; Beverley Joint 6th Form; Woldgate; Longcroft), to recruit girls from the lower IMD quintiles into intensive work experience opportunities (the focus is on B/C/D students with a passion for space sciences, but who may have struggled with traditional A-level schooling). More than 30 girls from across the region have taken this opportunity and it resulted in a doubling of women entrants into Physics at Hull (with a 25% increase post-2017). The work experience used data from our underpinning research (simulations and observations).



Fig 2: Representative poster of our “Changing Face of Physics” campaign

Momentum is building behind our “Changing Face of Physics” campaign. It was named “Best Practice in the UK” by the UK Equality Challenge Unit and resulted in our Athena Swan Award. Our lead student in the campaign, Kiri Newson, works in schools with Gibson and is one of the inaugural Jocelyn Bell Burnell Graduate Scholarship Fellows (allowing her to pursue a PhD at Hull). Our follow-up campaign - “Breaking Barriers” - aims to widen participation with a focus on LGBTQ+, racial, religious, and socio-economic diversity. More than £10,000 from alumni donations support these initiatives, and Helen Sharman (CMG, OBE), first Western European woman in space and a public engagement champion writes: *“Through the events that I have had the pleasure of participating in at Hull, including the Spacelink Schools Day with 150+ students from a dozen regional schools and colleges, I have experienced first-hand how the Milne Centre approach to outreach really creates a long-term impact on the participants. In particular, the focus on raising aspirations in the most deprived regional areas and work towards redressing the gender balance in the UK Physics and STEM landscape is of prime importance and echoes both national and international priorities.”* [Evid8]

4.4. Impact going forward

The “Changing Face of Physics” and “Breaking Barriers” campaigns are central to our strategy. The success of our STFC ThaiPASS programme demonstrates that astrophysics-driven software training works. When conditions allow, we will pursue a parallel model in the UK with KS4/5 students from the lower two quintiles of the IMD scale to increase the uptake of computing-focussed STEM careers in the region (and our leadership of the OfS-funded WRIPA+ project on emergent computer technologies [Evid9] will support this initiative). Our research already supports the curriculum at a dozen primary schools with our involvement in KS2/3 Space Weeks. We are working with the East Riding of Yorkshire Council Education Team to extend that provision across all levels from Early Years to KS5. Our widening participation programmes will continue to promote our activities to wider audiences.

5. Evidence to corroborate the impact

[Evid 1] “Discover the 10 most exciting space projects right now” by Mark Bailey, 11th of December 2018, National Geographic

<https://www.nationalgeographic.co.uk/space/2018/12/discover-10-most-exciting-space-projects-right-now>

[Evid 2] Engagement and Public Outreach, spreadsheet log:

https://docs.google.com/spreadsheets/d/1iPcYvbAXI1XT8Z8Usm0_tZdWfLs-z5uhViPQZmwJSOQ/edit#gid=0 [Full accounting of Milne Centre post-2014 EPO activities: including The Conversation reads, 2.16m; YouTube views, 0.68m].

[Evid 3] East Riding of Yorkshire Council Teaching and Learning Officer - testimonial

[Evid 4] Hull space experts have their say on strange fireball that lit up the skies

<https://www.hulldailymail.co.uk/news/hull-east-yorkshire-news/hull-experts-meteor-fireball-sky-4060842>, 14:11, 21 APR 2020

[Evid 5] Survey of 300 Upper KS2 students from 4 primary schools across Hull and the East Riding of Yorkshire (Thoresby, Woodmansey, Molescroft, Hilderthorpe).

[Evid 6] East Riding of Yorkshire Council Teaching/Learning Officer, testimonial

[Evid 7] Newton STFC-NARIT: Thai-UK Python+Astronomy Summer Schools (ThaiPASS): A STEM outreach project on Python with applications to data-driven astronomy
<https://gtr.ukri.org/projects?ref=ST%2FR006547%2F1>

[Evid 8] Helen Sharman (CMG OBE) - first western European woman in space and public engagement champion - testimonial

[Evid 9] “£1m funding win for University of Hull as it plays central role in EU future computing projects”

<https://www.business-live.co.uk/technology/1m-funding-win-university-hull-19590606>