Institution: Aberystwyth University

Unit of Assessment: 9: Physics

Title of case study: Bringing solar system astronomy to the forefront of Welsh cultural life

Period when the underpinning research was undertaken: 2007- 2020

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:
Professor Eleri Pryse	Reader; Chair	10 October 2007- present
Dr Huw Morgan	Lecturer; Reader	1 October 2011- present

Period when the claimed impact occurred: 2015- 2020

Is this case study continued from a case study submitted in 2014? N

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

Astronomy has become a central theme for several aspects of Welsh culture through the activities of the RAS200 project: 'Astronomy and Geophysics through the Traditional Culture of Wales'. The project reached members of the public who generally would not otherwise have access to science events. It introduced astronomy to schools and cultural events through numerous workshops, competitions and creative events, reaching thousands of active participants, and audiences of tens of thousands. The project had an impact on national organisations, artists, musicians, school teachers and others. This continues past the project lifetime with plans for future activities and has left a legacy of several science-themed artistic publications including music, artwork, and published books.

2. Underpinning research (indicative maximum 500 words)

The research underpinning this impact is observational solar system astronomy of international standard, specifically the solar atmospheric physics, space weather, and planetary ionospheric physics that is conducted by the Solar System Physics (SSP) research group. Pryse and Morgan have research expertise in ionospheric physics and solar physics respectively, and both have leading roles in developing a Welsh-medium academic framework for Physics. This enabled them to speak with authority on this subject area to a wider audience and to secure the relevant funding, which were key to the success of this public engagement project.

Ionospheric physics

Pryse is an expert on Earth's ionosphere, and her studies have been instrumental in developing tomographic techniques to find the total electron content of the ionosphere using satellite and ground-based data [3.1], enabling modelling of features such as the ionospheric trough. Recently, this work has been conducted in collaboration with Qinetiq, and it has implications for communication and GPS accuracy [3.2]. Pryse leads on a major outreach project funded by the RAS 200 Sky & Earth project [3.8], on which this case study is based. She has been a leading advocate for developing a Welsh scientific research community in the past decade, holding roles such as Chair of the Editorial Board of the Welsh academic journal *Gwerddon*, Chair of a national higher education steering panel for Mathematics & Physics, and an organiser of the annual Welsh science conference. She has also published research through the medium of Welsh [3.3].

Solar physics and space weather

Morgan is head of SSP at Aberystwyth University (AU). His research is dedicated to improving the understanding of the solar corona and space weather through the development of new instrumentation and data analysis methods [3.4; 3.5]. Morgan is a Co-I on a NASA medium explorer mission (PUNCH), and is PI of an STFC PRD grant for instrument development [3.9], an STFC consolidated grant [3.10], a Leverhulme Research Project Grant [3.11], and an STFC grant to develop space weather forecasting software for the Met Office [3.12]. He has over 30 peer-reviewed publications between 2014 and 2019, including a large study of how the properties of the solar corona change over a solar cycle [3.6]. He maintains an extensive record of media activity including interviews on Radio 4's 'Inside Science', the *Guardian*, *New York Times* and many others. He has had key roles in developing a Welsh scientific research framework, including roles on national higher education steering panel for Mathematics & Physics, and organiser of the annual Welsh science conference. He has published through the medium of Welsh [3.7], and supervises two Welsh-medium PhD students funded through the Coleg Cymraeg Cenedlaethol.

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

3.1 Wood, A; Shahtahmassebi, G; **Pryse, E** (2015). *Modelling large-scale structures in the high-latitude ionosphere using 15 years of data from the EISCAT Svalbard Radar.* EGU General Assembly 2015, held 12-17 April, 2015 in Vienna, Austria. URL: https://ui.adsabs.harvard.edu/abs/2015EGUGA..1710573W/abstract

3.2 Parker, J., **Pryse, S**., Jackson-Booth, N., & Buckland, R. (2018). *Modelling the main ionospheric trough using the Electron Density Assimilative Model (EDAM) with assimilated GPS TEC*. Annales Geophysicae, 36, 125-138. DOI: 10.5194/angeo-36-125-2018

3.3 S. Eleri Pryse, Helen R. Middleton, & Alan G. Wood, *Llif yr atmosffer drydanol dros begwn y gogledd: Arsylwadau tomograffi radio a SuperDARN*, *Gwerddon*, Vol 2, (2007). Trans: *Atmospheric current flows over the north pole: radio tomography observations and SuperDARN.* URL: www.gwerddon.cymru/cy/rhifynnau/rhifyn2/erthygl2/ [Lang. Welsh]

3.4 Morgan, H., *An Atlas of Coronal Electron Density at 5R⊙ I. Data Processing and Calibration*, The Astrophysical Journal Supplement Series, vol. 219, no. 2, 2015. DOI: 10.1088/0067-0049/219/2/23

3.5 Morgan, H. and Druckmüller, M., *Multi-Scale Gaussian Normalization for Solar Image Processing*, Solar Physics, vol. 289, no. 8, 2945–2955, (2014). DOI: 10.1007/s11207-014-0523-9

3.6 Morgan, H. & Taroyan, Y. *Global conditions in the solar corona from 2010 to 2017.* Science Advances, vol. 3, issue 7, p. e1602056, (2017). DOI: 10.1126/sciadv.1602056

3.7 Morgan, H., *Corona'r Haul: Astudiaeth o strwythur atmosffer yr haul*, Gwerddon (Welsh Academic Journal), vol.10, (2012). Trans: *The solar corona: a study of the structure of the solar atmosphere.* www.gwerddon.cymru/cy/rhifynnau/rhifyn10/erthygl3/ [Lang. Welsh]

Research Grants

3.8 Pryse, E. (PI); Royal Astronomical Society; *Astronomy and Geophysics through the traditional culture of Wales*; 2015-2020 (extended to 2021); GBP100,000 (funder contribution)

3.9 Morgan, H. (PI); STFC ST/N002962/1; *A High-Resolution Imaging Spectrometer For Visible Coronal Emission Lines;* 2016- 2019 (extended to 2021); GBP240,000 (funder contribution)

3.10 Morgan, H. (PI)**;** STFC ST/S000518/1; *Solar System Physics at Aberystwyth University;* 2019- 2022; GBP340,000 (funder contribution)

3.11 Morgan, H. (PI); Leverhulme RPG-2019-361. *An empirical solution to space weather technology;* 2020- 2023; GBP220,000 (funder contribution)

3.12 Morgan, H. (PI); STFC ST/V00235X/1; *SWEEP: Space Weather Empirical Ensemble Package;* 2020- 2023; GBP455,000 (funder contribution)

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

AU Physics staff embarked on an ambitious project to use Welsh cultural events as a vehicle to deliver scientific themes to a wider audience, through leading the *Astronomy and Geophysics through the traditional culture of Wales* project, funded by the RAS 200 Sky & Earth scheme in 2015 [5.1.1]. The Urdd Eisteddfod (attendance approximately 90,000 annually) and the National Eisteddfod (attendance approximately 150,000 annually) provided platforms for the project, including artist-led activities for audiences not normally engaged in science. Both Eisteddfodau are cultural festivals that reach a demographically broad audience. Outside of Cardiff, Swansea, and the northeast, the public's access to science activities within Wales is limited.

Impact on organisations

The National Eisteddfod's Chief Executive commented that:

> *The numbers of competitors involved in new scientific themes are very encouraging, and have conditioned us as an organisation to continue some of these themes in some of the competitions long term. The number of relevant scientific stands offering practical development of knowledge and learning is growing following the success* [5.2]

The project team have achieved their initial goal in bringing science to the forefront of Welsh cultural life. The former Eisteddfod Science pavilion (2015-2018) has grown to become a Science Village (2019-present). The *"scientific activities bring a fresh and new dimension to the Eisteddfod's image, attracting a wider cross-section of society: this was evident from the number of people attending some of the project's activities"* [5.2]. Eisteddfod staff have *"…developed their confidence in discussing science with children and young people and members of the public, in schools and on the field. With the additional publicity, the profile of the Festival was raised as an event of interest to everyone…."* [5.2]. The previously low-key Science Medal prize is now presented in the main pavilion. Scientists have become prominent within the Eisteddfod organisation, with Professor Eleri Pryse and Professor Andy Evans (AU Physics HoD) being current members of the National Eisteddfod's Central Committee. *"This relationship is one that will survive the RAS project…"* [5.2].

The Urdd youth organisation found that the project provided *"…more opportunities to introduce STEM subjects through the medium of Welsh to new audiences …"* [5.3]. The collaboration helped the Urdd forge new links and:

> *...has proven that presenting STEM subjects through a variety of media such as Literature, Dance and Music is appealing to a new audience….Science was deeply embedded across the activities of the festival, raising the profile of astronomy and geophysics and increasing staff awareness and knowledge of the important aspects of the subject...The growth of scientific events on the Eisteddfod Maes, and the growth of scientific themes at cultural events, have been important in attracting a new audience to the Eisteddfod* [5.3]

Astronomy has become central to many Urdd Eisteddfod performance and Craft Design & Technology (CDT) competitions as a direct result of this project [5.1.1; 5.1.2]. This entailed weeks of preparation in hundreds of schools and youth organisations, focusing on several astronomical themes. Approximately 25,000 children and adults took part in these activities. According to Urdd:

There has been an increase in the CDT section since 2016, from 12,000 registered in 2016 to 15,000 in 2019. The AU-led RAS project has certainly contributed to the growth in CDT activities, by expanding the themes of the competitions into the field of astronomy [5.3]

Winning entries of the CDT and staged children's competitions are also viewed by Eisteddfod visitors and many are broadcast on TV and radio. According to the Urdd, *"These activities have a great impact on individuals... enabled us as an organization to reach a new audience in disadvantaged communities, by presenting STEM themes in an interesting and exciting way to the children"*. This is mirrored by the response of teachers to workshop activities and reflects the observation that the children involved gained *"pride, empowerment and confidence".* [5.3].

Impact on learners

Themed workshops were held in schools, led by artists, musicians or poets, with underlying science support from project members [5.1.2]. Eight different workshops, held in 26 schools for more than 1,000 children, produced creative works for performance or exhibitions at the Eisteddfodau [5.1.2], with significant media attention. The workshops were:

…successful in introducing the science to ... children who would often not experience scientific themes, in an exciting and creative way ... stimulate[d] children's interest in astronomy and science in general, affecting their attitude to the subjects at school in a very positive way" [5.4];

and changed attitudes by *"...capturing the imagination of children who take part, and conditioning them to think of science as part of their daily lives, exciting and fun, and relevant to their life and future* [5.4].

The project has also provided on-line resources for HE students via the Coleg Cymraeg Cenedlaethol [5.8].

Impact on professional artists

The project has commissioned many creative works based on astronomical themes: installation art, music concerts, and poetry [5.1.2]. New works by leading musicians, dancers and poets based principally on themes developed in discussion with Pryse and Morgan, have reached large audiences. The culmination of the project was the main theatrical musical concert of National Eisteddfod *Lloergan (Moonsong)* [5.5], which melded the cultural and scientific richness of Wales. Lead director Fflur Dafydd (musican, playwright and novelist) states that:

…astronomical and scientific themes became central to the creative process. …… scientific thinking has reached many people including singers (the Eisteddfod Choir), musicians, the artistic management team, and administrative managers. …From the outset, discussions with scientists at AU's Physics department were crucial to the project. Initial ideas for the show's narrative were derived directly from discussions with Huw Morgan and Eleri Pryse. [5.6.1]

Musical director Griff Lynch (singer, composer, and TV producer) acknowledges:

The input of AU scientists was crucial in creating the framework for the show's musical vision. The discussions with them led directly to artistic inspiration which was based on current science. The purpose of the RAS project was to bring Astronomy alive to a Welsh audience through culture. Without argument, Lloergan succeeds in this. [5.7]

Further impact includes a recent novel, *Lloerganiadau,* by Fflur Dafydd that uses astronomy as a framework for the narrative and contains many astronomical themes. She says:

Collaboration with Aberystwyth astronomers ...has given my creative work a new impetus, leading directly to Lloerganiadau. In addition, Huw Morgan has given me detailed scientific guidance on a number of aspects. This gives me confidence to present the science accurately and credibly [5.6.1]

She included astronomy themes in a new television drama, *Amgueddfa* [5.6.4] noting that:

There are very few scientific characters in plays in Wales, so this new play is a step forward in transforming the profile of science in our culture. The impulse to include the scientific characters came from my contact with the scientists at Aberystwyth……I was opened to the richness of science in Wales - current through the research of the Physics department at Aberystwyth, and historically through the work of some of the giants of astronomy and science in Wales. This heritage is often hidden, and is secondary to us as Welsh people compared to music or poetry. [5.6.1]

This project has set the foundation to reverse this imbalance.

"The legacy of the RAS200 project will be to continue to introduce new topics to members using the arts as a vehicle for realisation" [5.3].

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

5.1 Research reports
5.1.1 RAS200 'Astronomy and Geophysics through the traditional culture of Wales' reports
5.1.2 RAS200 'Astronomy and Geophysics through the traditional culture of Wales' activity tables:
Table 1: Summary of workshops organised as part of RAS200 project
Table 2: Summary of Eisteddfod competitions arising from the RAS200 project
Table 3: Summary of concerts, lectures, commissioned artworks, and science exhibitions organised as part of RAS200 project

5.2 Testimonial: Chief Executive, National Eisteddfod of Wales
5.3 Testimonial: Section Organiser for the Urdd
5.4 Testimonial: Head of Science,Ysgol Glan Clwyd
5.5 Online performance of song from Lloergan: eisteddfod.cymru/amgen-encore-ystrad-fflur

5.6 Evidence relating to impact on Fflur Dafydd
5.6.1 Testimonial: Fflur Dafydd (musican, playwright and novelist)
5.6.2 Lloerganiadau: www.waterstones.com/book/lloerganiadau/fflur-dafydd/9781784618735
5.6.3 Fflur Dafydd and Huw Morgan discussion: eisteddfod.wales/adfent-lloerganiadau
5.6.4 *Amgueddfa* (in production)

5.7 Testimonial: Griff Lynch (singer, composer, and TV producer)
5.8 Coleg Cymraeg Cenedlaethol: On-line Resources www.porth.ac.uk/cy/collection/ras200