Institution: Queen Mary University of London (QMUL)

Unit of Assessment: Physics B9

Title of case study: Delivering Astronomy Research into the Classroom

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

Through our unique engagement with school students and teachers, astronomy research conducted by the Astronomy Unit (AU) at Queen Mary has had demonstrable impact on society by influencing, enhancing and enriching science-related education. Our activities contribute to the STEM agenda, providing support for a key government policy related to long-term economic growth. The Cassini Scientist for a Day competitions and our Media Space summer schools have raised aspirations and increased awareness and knowledge of astronomy, and have improved the scientific thinking and writing skills of over 300 school pupils from UK-wide and local secondary schools. Approximately 100 teachers have engaged with the AU's research through our Astrophysics Summer Schools. Teachers' knowledge and understanding of modern research has been developed, transforming their teaching practice by providing them with the motivation, resources and confidence to tackle complex issues in the classroom and through extracurricular activities. In survey responses, 90% of teachers report that their practice has been transformed as a result of engagement with the AU. Some teachers describe plans to introduce GCSE Astronomy into their curriculum and to establish astronomy clubs in response to attending the summer schools.

2. Underpinning research (indicative maximum 500 words)

Our research covers broad areas of astrophysics, allowing us to enhance the knowledge and inspire the interest of school teachers across a wide range of topics. AU research through the Cassini mission to Saturn has provided a powerful means of engaging school students with astronomy research, in addition to contributing strongly to our engagement with school teachers.

Professor Carl Murray is the sole UK member of the Cassini imaging team. He was personally responsible for the discovery in 2005 and 2008 of two new moons of Saturn detected in Cassini images, *Polydeuces* [R1] and *Anthe* [R2], and provided a rigorous analysis of their orbits and interactions with neighbouring satellites. The research demonstrated that *Polydeuces* is an unusual coorbital satellite in a tadpole orbit with *Dione*, and showed that *Anthe* occupies a dynamically important 10:11 resonance with *Mimas*. Murray has pioneered the study of Saturn's F-ring and its interaction with the nearby satellite Prometheus, and provided the first explanation for the complex, time-dependent structures observed in the ring by the Cassini spacecraft [R3]. As a member of the Cassini imaging team, he was involved in the high-profile study of ice-plumes emanating from *Enceladus*, demonstrating the presence of liquid water within the satellite's interior [R4]. This research has underpinned The Cassini Scientist for a Day competitions and the Media Space programmes that are described below, and has been the focus of talks given to teachers during our Astrophysics Summer Schools.

Professor Richard Nelson's research on the formation and migration of planets aims to understand the origin of planet systems. His paper from 2000 was the first to demonstrate how concurrent migration and gas accretion by giant planets operates [R5], and has been highly influential in discussions of how 'hot Jupiter' exoplanets form. Professor David Burgess researches the interaction between the Solar wind and Earth's magnetosphere to understand "space weather". The interplanetary magnetic field is most geo-effective when directed southwards, so observations by spacecraft can provide advance warning. In 2001 Professor Burgess and collaborators were the first to demonstrate that the timing of arrivals of southward field are improved by accounting for discontinuities in the solar wind [R6]. The topics of exoplanets and space-weather are of particular interest to teachers who attend our summer school, and so these research results have featured prominently in our talks and discussions with them.

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

[R1]. Murray, C.D., Cooper, N.J., Evans, M.W., Beurle, K., 2005, 'A new co-orbital companion for Dione', *Icarus*, 179, 222

[R2]. Murray, C.D., Chavez, C., Beurle, K., Cooper, N., Evans, M.W., Burns, J.A., Porco, C.C., 2005, 'How Prometheus creates structure in Saturn's F-ring', *Nature*, 437, Issue 7063, pp 1326
[R3]. Cooper, N.J., Murray, C.D., Evans, M.W., Beurle, K., Jacobson, R.A., Porco, C.C., 2008, 'Astrometry and dynamics of Anthe (S/2007 S4), a new satellite of Saturn, *Icarus*, 195, 765
[R4]. Porco, C.C. et al, 'Cassini observes the Active South Pole of Enceladus', 2006, *Science*, 311, pp 1393
[R5]. Nelson, R.P., Papaloizou, J.C. B., Masset, F., Kley, W., 2000, 'The migration and growth of protoplanets in protostellar discs', *MNRAS*, 318, 18
[R6]. Horbury, T. S., Burgess, D., Fränz, M., Owen, C. J., 2001, 'Prediction of Earth arrival times of interplanetary southward magnetic field turnings', *JGR*, 106, 30001-3001

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

The Cassini Scientist for a Day competition and our Media Space summer schools have increased the interest, knowledge and learning skills of more than 300 secondary school pupils from around the UK. The teaching practice of school teachers has been transformed by engagement with the AU's research through our Astrophysics Summer Schools. These activities support the government's promotion of STEM skills as a key driver of long-term economic growth (e.g. see page 87 of the Treasury document http://cdn.hm-treasury.gov.uk/2011budget_growth.pdf).

Cassini Scientist for a Day

Cassini Scientist for a Day is a competition for 11-18 year old school pupils that inspires participants' interest in science, improves their knowledge of Saturn and increases independent learning and writing skills. It was developed by NASA in 2006, in collaboration with AU scientists who selected competition images. Since 2007 it runs annually in the UK, administered by the AU. Students are given three targets for Cassini to image. After watching introductory films they research each target and provide scientific arguments in favour of observing one of them in a 500-word essay. Professor Carl Murray acts as judge through his Cassini role, and the winning targets are imaged by Cassini. There have been over 240 UK participants, and three annual winners (ages 11-13, 14-16, 17-18). Winners receive the Cassini image of their chosen target. Winners of the senior category have been invited to work on Cassini research with Prof. Murray. The 2010 winner is co-author on a conference abstract (http://rings2011.astro.cornell.edu/absbook.pdf), and will co-author a forthcoming paper. Competition films, supporting documents and winning essays are available on our public outreach webpage [4]. This has been viewed 3760 times since September 2011. Average viewing times are in excess of 3 minutes, demonstrating significant engagement with the material. When asked about the impact on pupils, one teacher responded "*May I take this opportunity to thank Prof Murray for this amazing and life-changing opportunity you have created for our students… Over the last 4 years our students were very keen to participate. It has created a lot of interest among students, teachers and even parents. Last year alone we had 32 students inspired to do research about Saturn and Cassini. Academic impact of this competition should not be underestimated. Doing research for the essays helped our students to gain valuable experience and to improve their independent learning skills. The competition has enriched our teaching curriculum across the year groups*" [1]. We conducted a survey of teachers whose schools participated in the competition, and 100% of responses said they would encourage their students to participate again. Selected comments received from the respondents describing the impact on the pupils who participated include: "*Many of them did gain new knowledge of Saturn and the mission. Many gained skills in scientific writing*" and "*New set of skills (mainly essay writing) and above all else a huge sense of achievement*".

Media Space programme

Our Media Space programme started in 2007 as a collaboration between QMUL, the Ideas Foundation and Venture Thinking (two educational partnership charities), and has increased the scientific knowledge, interest and aspiration of Year 10 students in Tower Hamlets schools. It began as a partnership with Morpeth school and expanded to include St. Paul's Way and Stepney Green Schools. The annual programme consisted of a five-day summer school, attended by 20 students, comprising workshops run by academics and media professionals, allowing students to explore astronomy research and science communication. A key element was the one-day Cassini Science Planning workshops. Students attended talks about Cassini research [R1-R4], and were divided into four "research groups" each with an AU mentor, studying *Atmospheres*, *Rings*,

Surfaces, and *Fields and Particles.* They were provided with a model of the Cassini spacecraft incorporating a camera, a dust detector, a magnetometer and radar, and a segment of the Cassini tour. The spacecraft must rotate for different instruments to take data and downlinks require time segments. Each group was tasked to design an observation sequence using all instruments, maximizing the scientific gain for their particular research topic. The final task involved merging the separate sequences into a single optimal sequence through a process of scientific argument and debate. This mimics how Cassini observations are scheduled, and hones the students' abilities to formulate and debate scientific arguments. The students generated films and magazines relating to space exploration during the Media Space programmes that are available on our public outreach webpage [4]. Over 10,000 copies of the magazines have been mailed to schools nationally and distributed at events such as the Big Bang Fair, generating wider awareness and knowledge of Cassini research.

In 2009 the programme won the London Education Partnership Award for "*Excellent professional practice in curriculum and student support in STEM*" [5]. The Head of Morpeth School said at the time: "*Ten years ago we would never have dreamt that we would be involved in a high profile project on science supported by leading scientists from Queen Mary University and NASA and having parents, teachers and students involved in a live video link with Cassini Mission specialists*". In a later statement he also writes "*The pupils who attend Morpeth come overwhelmingly from disadvantaged backgrounds with virtually no history of Higher Education in their families. For many of the Media Space participants this was a unique opportunity to engage with high profile astronomical research and to interact with professional scientists such as Professor Murray. The experience provided by the Media Space Programme, including the awe-inspiring images of Saturn and its rings that the pupils worked with on their projects, had a massive impact on our pupils. It is always dangerous to exaggerate but for one or two of our pupils it may have been life changing*" [2]. Heather MacRae, Creative Director of the Ideas Foundation and Director of Venture Thinking commented: "*There is no doubt that Media Space achieved its primary aims. The numbers of pupils going on to study A level STEM subjects increased during the time it ran… and the attitudes of the participants towards astronomy and science in general changed markedly – the pupils were genuinely inspired by their experiences… Some have gone onto university to study physics or astronomy, and often cite their experience of Media Space as a prime motivation*" [3]. One student participant has commented: "*I found the project to be extremely insightful, intellectually stimulating and a generally fantastic experience. The project gave me exposure into the world of astrophysics and physics that would have been beyond my realms at the tender age of 15/16, and for that I'm extremely thankful to Professor Murray and all parties involved in making the project happen… I'm currently studying Physics at University College London…*" [6].

In 2011 Media Space became Cosmic Futures, a national essay-writing competition run in partnership with the Metro newspaper, that has had over 300 participants. There were over 20,000 views of the content for the Cosmic Futures competition and it was featured in the Metro newspaper six times (average daily circulation around one million). Media Space attendees and competition winners have participated in teleconferences with Cassini scientists at NASA's Jet Propulsion Laboratory, and their achievements have been celebrated at Parliamentary Space Committee Christmas receptions.

Astrophysics Summer Schools

Our Astrophysics Summer Schools have increased the awareness, knowledge and interest of secondary school teachers. By giving them the confidence to tackle complex issues we have transformed their teaching practice. Since 1998, as part of The Goldsmiths' Company's Science for Society courses, the AU has run a five-day residential course on Astrophysics. Exceptions were 2008, when organiser Prof. Emerson oversaw building of the VISTA telescope, and during the 2012 Olympics. Each year approximately twenty-five secondary school teachers participate in lectures and workshops run by AU academics. Each lecture and workshop is based on an academic's research, and includes background information and material drawn directly from research outputs. Cassini-members lectured on the search for satellites, the dynamics of the rings (with specific focus on the F-ring) and on Enceladus (between 2009-2013) [R1-R4]; Prof. Nelson lectured on planet formation, using his own research insights and material drawn from his research publication in 2000 [R5] to explain the formation of hot Jupiter exoplanets (2009-2013); Prof. Burgess lectured on space weather, and used research insights from his publication in 2001 [R6]

to discuss how spacecraft can predict geomagnetic storms (2009-2013). After attending, teachers have access to presentations online and each other's contact details for sharing of ideas. Attendees give feedback through a questionnaire, and we conducted a follow-up survey in 2012 to gauge impact. The 2012 survey had a 28% response rate and 60% of responses "strongly agree" and 30% "agree" that the course had an impact on their teaching practice. 77% responded to say that they used course content in lessons. Selected comments from the survey include [7]: "*I attended the course because I wanted to strengthen and extend my knowledge about current thinking and research in astronomy*"; "*Some of the lectures which we were given copies of, I have used some slides in my lessons. I felt tremendously valued. I was flattered that Goldmsith's were willing to invest money in me and that the speakers likewise invested their time and knowledge on me. That has left a great impression*."; and "*I have taught and taken the GCSE in astronomy and run it as an after school club."*

The questionnaires distributed at the end of each summer school include a quality rating of the course's utility and training (0=poor to 10=excellent). Averaging responses from 2009 onward, the percentages given for each quality score were: 5 (1.6%), 6 (5%), 7 (8.3%), 8 (16.6%), 9 (38.3%),10 (30%). Questionnaire responses consist largely of written comments about the course impact. Analysis shows that in response to attending the summer schools, five teachers plan to set up a new astronomy club; four teachers plan to expand the activities of existing clubs; four teachers plan to use the National Schools' Observatory; five teachers plan to introduce GCSE Astronomy; 36% indicate that they were motivated to attend to learn about current research, and/or valued the research content of the course; 35% indicated that they gained the confidence required to tackle complex topics in the classroom; 33% indicated that they and/or their students would be inspired/stretched/motivated because of their attendance on the course. Selected answers to questions about the motivation for attending the course and value gained from it include [8]: "*To obtain an overview of the latest research in this field. This objective was wholly met.*"; "*I applied for participation in the astrophysics course in order to gain a deeper understanding of astronomy. I did this primarily to assist my teaching of GCSE physics. I also wanted to have enhanced knowledge of Astrophysics to assist my colleagues who teach A-level. I have without doubt obtained an insight on concepts I previously had little or no understanding of. I also feel I am a better person and teacher for having availed of this wonderful course at QMUL."*; "*To gain a more detailed perspective of the extent of new research and to stretch my own knowledge further. Both of these objectives have been exceeded.";* "*My personal objectives were to develop my knowledge of astrophysics… I have taught the astrophysics element of A-level and am conscious that I needed an update. This course has been superb and has more than exceeded my expectations. Indeed, the course has been inspirational.*" Since 2008 two teachers have followed up their attendance on the summer school by enrolling on our part-time MSc in Astrophysics.

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

1. Ardingley College, Physics Teacher. Corroborating impact of the Cassini Scientist for a Day competition on pupils at his school.
2. Morpeth School in Tower Hamlets, Ex-Head Teacher. Corroborating impact of the Media Space programme on the educational achievements and aspirations of school pupils from Morpeth School who participated.
3. Director, Venture Thinking educational charity. Corroborating impact of the Media Space programme on the educational achievements and life choices of school pupils who participated.
4. Webpage describing Cassini Scientist for a Day competition and Media Space: http://ph.qmul.ac.uk/engagement/space-activities
5. The London Education Partnership Award-winners brochure 2009 can be downloaded from http://ph.qmul.ac.uk/sites/default/files/REF/winners22009.pdf (see page 7 for Media Space info).
6. A transcript of selected comments from pupil-participants in Media Space/Cosmic Futures can be viewed here: http://ph.qmul.ac.uk/sites/default/files/REF/MediaSpaceParticipantComments.pdf
7. Astrophysics Summer School follow-up survey conducted to gauge impact in March 2012 for course participants (2009-2011). A transcript of selected comments may be viewed at: http://ph.qmul.ac.uk/sites/default/files/REF/AstrophysicsSummerSchoolSurvey2012.pdf
8. Astrophysics Summer School questionnaires 2009-2013. Transcript of selected comments: http://ph.qmul.ac.uk/sites/default/files/REF/AstrophysicsSummerSchoolQuestionnaireComments.pdf