

Institution: The University of Manchester		
Unit of Assessment: 9 (Physics and Astronomy)		
Title of case study: Jodrell Bank astronomy research inspires millions of people from a wide range of backgrounds to be more engaged with science		
Period when the underpinning research was undertaken: 2000 – 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:
Tim O'Brien	Professor	1999–present
Robert Beswick	Reader	2002–present
Rene Breton	Professor	2014–present
Clive Dickinson	Professor	2009–present
Simon Garrington	Professor	1993–present
Michael Kramer	Professor	1999–2008
Period when the claimed impact occurred: August 2013 – July 2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact		
<p>Using public interest in Jodrell Bank's world-leading research, researchers at The University of Manchester (UoM) developed a broad and innovative programme of activities with a focus on educating, inspiring and reaching previously underserved audiences. Activities are primarily run from the Jodrell Bank Discovery Centre (JBDC), a purpose-built facility run as a social enterprise. Since August 2013, the Centre has attracted 1,017,015 visitors (including 141,292 school pupils) to engage with UoM's cutting-edge research, in areas ranging from pulsars to cosmology. This has had measurable impacts on education (94% of visiting teachers agreed their pupils were inspired about STEM), tourism (exceeding estimates of GBP21,000,000 economic impact in the REF period) and wider culture (the award-winning annual Bluedot festival attracted new audiences to celebrate science, music and art). The significance of Jodrell Bank's research output and engagement resulted in its designation as a UNESCO World Heritage site in 2019.</p>		
2. Underpinning research		
<p>The impact is based on a wide body of research carried out at UoM's Jodrell Bank during the past 20 years. Over this time, Jodrell Bank astronomers have made a number of seminal contributions to astrophysics, particularly in radio astronomy, and to the technical development of observing techniques. A few selected research highlights are listed below with key staff in each area identified. These few examples are drawn from the wide-ranging research programme carried out by the researchers named above, as well as a very broad group of additional researchers from Jodrell Bank. This research regularly features in the material presented at the JBDC through exhibits, workshops, talks and Bluedot festival activities.</p> <p>Paper [1] reported the discovery of the Double Pulsar, a unique system allowing unprecedented tests of fundamental gravitational physics such as that reported in Paper [2]; the first to measure precession in a strong gravity environment. These papers epitomise the significant volume of ongoing world-leading work on pulsars at Jodrell Bank using the Lovell Telescope and others, which comprises over 300 refereed publications in the REF period.</p> <p>Paper [3] describes e-MERLIN, the array of seven radio telescopes developed and operated at Jodrell Bank, and providing sensitive, high-resolution radio images. This paper represents Jodrell Bank's long-standing and continuing development and use of radio interferometers also including the European Very Long Baseline Network of telescopes and the Square Kilometre Array (whose global HQ is at Jodrell Bank). The e-MERLIN/VLBI National facility has contributed to at least 595 research papers just since 2010 – research across a wide range of areas including star formation, gravitational lensing, active galaxies, and more.</p> <p>Paper [4] reports the analysis of Planck spacecraft observations of the cosmic microwave background (CMB) with specific reference to Galactic foregrounds. The Jodrell Bank group's work on the CMB has included developing the Very Small Array in collaboration with the</p>		

University of Cambridge, making early observations of the power spectrum, building ultra-low-noise amplifiers for the Planck spacecraft and leading on the analysis of foregrounds.

3. References to the research

Examples of underpinning research cited in Section 2 are listed below (UoM authors in bold font) and should be taken as representative of the significant volume of ongoing world-leading research undertaken by the Jodrell Bank group. Paper [1] resulted in the group being awarded the 2005 Descartes Prize. Paper [3] contains the technical description of the instrument used by >300 astronomers from >100 institutions, which led to the Jodrell Bank team being awarded the 2015 Royal Astronomical Society Group Achievement Award. Work on the Planck spacecraft, some of which is described in Paper [4], led to the award of an OBE to R. J. Davis in 2011. Citation data is from Scopus, and accurate as of 8 March 2021.

[1] **Lyne, A.G.**, Burgay, M., **Kramer, M.**, Possenti, A., Manchester, R.N., Camilo, F., **McLaughlin, M.A.**, **Lorimer, D.R.**, D'Amico, N., Joshi, B.C., Reynolds, J., Freire, P.C.C.; "A double-pulsar system: A rare laboratory for relativistic gravity and plasma physics", *Science*, **2004**, 303, 1153-1157. DOI: [10.1126/science.1094645](https://doi.org/10.1126/science.1094645) [568 citations]

[2] **Breton, R.P.**, Kaspi, V.M., **Kramer, M.**, McLaughlin, M.A., Lyutikov, M., Ransom, S.M., Stairs, I.H., Ferman, R.D., Camilo, F., Possenti, A., "Relativistic Spin Precession in the Double Pulsar", *Science*, 2008, 5885, 104- DOI: [10.1126/science.1159295](https://doi.org/10.1126/science.1159295) [117 citations]

[3] **Garrington, S.T.**, **Anderson, B.**, **Baines, C.**, **Battilana, J.A.**, **Bentley, M.N.**, **Brown, D.**, **Burgess, P.**, **Diamond, P.J.**, **Kitching, G.J.**, **McCool, R.**, **Muxlow, T.W.**, **Noble, R.G.**, **Roddis, N.**, **Spencer, R.E.**, **Thomasson, P.**; "e-MERLIN", in "Ground-based Telescopes", eds. Oschmann, Jacobus M., Jr., *Proceedings of the SPIE*, **2004**, 5489, 332-343 DOI: [10.1117/12.553235](https://doi.org/10.1117/12.553235) [17 citations]

[4] The Planck Collaboration, 239 authors including 11 UoM authors, **Bonaldi, A.**, **Davies, R.D.**, **Davies, R.J.**, **Dickinson, C.**, **Leahy, J.P.**, **Noviello, F.**, **Peel, M.**, **Remazeilles, M.**, **Vidal, M.**, **Watson, R.**, **Wilkinson, A.**; "Planck 2015 results XXV. Diffuse low-frequency Galactic foregrounds", *Astronomy & Astrophysics*, **2016**, 594, 45, DOI: [10.1051/0004-6361/201526803](https://doi.org/10.1051/0004-6361/201526803) [35 citations]

4. Details of the impact

The breadth and depth of this programme, coupled with the wider long-term appeal of Jodrell Bank and the operation of its iconic telescopes, attracts a large number of people to JBDC. This has helped Jodrell Bank to play a leading role in public engagement with astrophysics research, and deliver impact across a range of areas.

Economic impact: The JBDC opened in 2011 with two new buildings. The funding (from the Northwest Regional Development Agency, European Regional Development Fund and UoM) was awarded following an independent analysis by consultancy firm EKOS, which calculated an additional GBP27,000,000 economic impact to the region over the decade from opening in 2011 *i.e.* ~GBP21,000,000 over the current REF period [A]. This assumed that the site would attract 189,620 new visitors (over a baseline of GBP80,000 *p.a.*) up to 2016/17, safeguarding nine existing jobs and creating six more. In actuality, JBDC attracted 306,254 new visitors up to 2016/17 and as of February 2020 employed 32 staff (at 27 FTE) [B]. This success led to the addition of a third building costing GBP1,400,000 which opened in 2015, and a GBP1,800,000 upgrade and expansion of the car park in 2019. In 2019, JBDC's economic impact was recognised through the receipt of Marketing Cheshire's Special Contribution to Tourism Award [C].

JBDC visitor demographics: Over the current REF period there have been a total of 1,017,015 visitors (including 141,292 school pupils on educational visits) [B]. In 2016/2017, Jodrell Bank commissioned a major external survey conducted by marketing consultants Morris Hargreaves McIntyre (MHM). The survey found that, excluding school visits, nearly half of all visits to Jodrell Bank (47%) are family groups, and nearly one third of all visitors are children (just under one in five are aged between 5 and 11 years old) [B]. This significant proportion of family-group and under-18 visitors shows that JBDC is succeeding in engaging with young audiences, and works towards our goal of inspiring the next generation of scientists and engineers. There is an even gender split, and 37% visit from outside the North West (NW)

region. However, JBDC has historically struggled to engage certain demographic groups; the 16-24 age group were under-represented in the visitor profile, making the fewest visits at just 3%, whilst 97% of visitors were from white ethnic groups. Likewise, in academia, women and people from economically disadvantaged backgrounds have low levels of representation in the fields of physics and engineering. To expand the audience engaged by Jodrell Bank's outreach, and to help address these low levels of representation, we developed several additional programmes, some of which are described in the sections below [B].

JBDC general visitor motivation, satisfaction and learning impact: Visitors are attracted to Jodrell Bank because of its scientific research. For those that visit (285 responders in the MHM survey excluding schools), the biggest attractor is the Lovell Telescope (77%) whilst 54% wish to 'improve my own knowledge' and 40% to 'stimulate my own/children's imagination' [D]. This survey also shows visitors' expectations are exceeded: 95% are likely to recommend a visit to others, 70% thought they had improved their knowledge, whilst half said the visit gave them something to think or talk about compared with 20% who said this was a motivation to visit. The high proportion of return visits (44%) also demonstrates this satisfaction. The MHM survey also found that of 2,117 adults across the UK, 37% were aware of Jodrell Bank (compared with, for example, 77% for Chester Zoo, 27% the National Space Centre and 11% At Bristol Science Centre) and that 70% of these know that it is a centre for world-leading scientific research [B].

Non-school visitors to JBDC engage with our research in a number of ways, including:

- An interactive exhibition – supported by on-gallery explainers and guided tours around the Lovell Telescope explaining its work. The exhibition contains elements directly discussing pulsars, Planck/CMB and e-MERLIN research conducted at Jodrell Bank [1–4].
- *Meet the Scientist:* 48 active researchers from Jodrell Bank have taken part in sessions describing their research and answering questions about it, engaging with >16,113 attendees to date. A survey during the 2017 May school half-term attracted 63 responses representing 73 adults and 62 under-16s [D]. 55% of adults were aged 35-50, 48% of u-16s were aged 10-14. 54% had not visited Jodrell Bank before. When asked 'Why did you visit Jodrell Bank today?', the two most popular responses were 'We're interested in science done at Jodrell Bank' and 'We wanted to see the Lovell telescope' [D]. 100% agreed that they had learnt something new, 76% agreed that they were now more interested in science as a result of attending the event, with only 1% disagreeing [D]. Some of the regularly featured presentation themes are pulsars and cosmology and often directly showcases results about the Double Pulsar and the Planck Mission [1, 2, 4].
- *Lovell Lectures:* 39 evening events, half delivered by Jodrell Bank staff on their research, with a total of 5,954 attendees. An evaluation in 2017 found 87% of the audience are over 45, 56% are regular attenders, 94% learnt something new and 66% agreed they will find out more about the subject as a result [D]. Lectures featured the Double Pulsar/pulsars, e-MERLIN and the Planck [1–4].
- *Girls Night Out:* a female researcher-led series of evening events promoting women in STEM, 11 events over REF period with 1,369 attendees. From 33 survey returns in 17/18, we find they were rated excellent by 70% and very good by 30%, whilst 36% strongly agreed and 52% agreed they would find out more about science as a result of the event [D].

Educational impact on schools: Over the REF period, 141,292 school pupils have visited JBDC on formal educational programmes. The programme extends from Early Years to post-16 with a majority (62%) at Key Stage 2 [E].

- From 102 post-visit evaluations in 18/19, 100% of teachers agreed that their learning objectives were met (72% strongly agreed) and that students learnt something new (83% strongly), whilst 94% agreed that the visit inspired their learners about STEM (48% strongly) [E]. This positive impact leads to an increasing number of return visits (45% in 17/18) [E].
- JBDC also takes part in the UoM widening participation (WP) programme, attracting 2,506 pupils over 15/16-18/19 [E].

- JBDC estimates (assuming learners are representative of their schools) that in 18/19, for example, 22% of those visiting were eligible for free school meals (NW average 18%), 39% had English as an Additional Language (NW 28%), and 13% were non-white British (NW 14%) [E]. This demonstrates that JBDC's school-focused outreach has successfully engaged with young people who are typically underserved by science outreach and under-represented in astronomy.
- Research from Jodrell Bank, including real data, is specifically used in several workshops. The Pulsars workshop [1, 2] has attracted 905 A-Level students in 42 school visits since it was developed during 2016/2017; the Radio Telescopes workshop [3] has attracted 2,107 A-Level students in 108 visits over the REF period; and the Exoplanets workshop 1,179 GCSE students in 38 visits [E]. From 31 post-event responses between 2017 and 2019, 100% of teachers would recommend the workshops to others, 58% felt their students' learning at the workshops was outstanding and 39% good [E]. Teacher comments included: "*One of the best educational workshops I have taken students to*", "*Really good workshop. Our students enjoyed using the real data and discussing pulsars*". In a survey of 99 students taking the pulsar workshop, 28% said they were now more likely to study physics at university, 27% were now more interested in becoming a physics researcher and 86% said they now had a clearer idea of what scientists do [E].

Bluedot festival: As outlined above, JBDC activities have engaged and inspired people from many different demographics but has historically struggled to engage people from certain backgrounds. To try and engage people from these groups with science, and with Jodrell Bank's research in particular, UoM developed the annual Bluedot festival. Launched in 2016 and held on the Jodrell Bank site, Bluedot festival combines music and cultural activities typical of festivals with science engagement events. The four Bluedot festivals held in 2016, 2017, 2018 and 2019 have had 72,649 attendees.

The programme includes multiple talks by Jodrell Bank researchers, several stands and bespoke sci-artworks featuring our research on pulsars, technology development and cosmology/Planck mission [1–4]. As with JBDC, Bluedot visitors are attracted by the work of Jodrell Bank and the science engagement offered. From onsite and post-event surveys for the 2019 festival (306 and 2,166 respondents):

- 81% knew Jodrell was an active research site and 80% agreed they had learnt something about science at Bluedot, 59% said they were likely to visit another science centre in the next 12 months and 74% said they would return to JBDC as a general visitor [F]. This demonstrates that visitors to Bluedot festival were drawn by its scientific track record and were successfully inspired by their visit.
- A 1,339-respondent sample were asked to mention anything they had learned whilst at Bluedot, 92% mentioned something scientific without being prompted [F]. 18% of the facts mentioned were identifiably related to Jodrell Bank research. For example, 44 mentioned pulsars [1, 2] and 15 mentioned the Square Kilometre Array [F]. Comments included: "*Black widow spider pulsars!*", "*The talk around the Lovell telescope was super, and I learnt about pulsars and quasars*", "*Understanding why pulsars emit a narrow, intense beam of electromagnetic radiation*", "*The networking, timing and computing challenges around the SKA are huge!*", "*SKA radio telescope project development, scope and size of the project, and what we will learn with it*" [F]. A further 34% of the responses were relating to astronomy and space but not necessarily Jodrell, 12% were about other physics, 17% environmental science, and 12% other general science [F].

With Bluedot festival, UoM researchers successfully engaged with a greater number of people from demographics underserved by science outreach, including by JBDC. Survey analysis by MHM found that 63% of attendees at Bluedot were in the 16-44 age range, compared with 35% at JBDC [F] and 13% of attendees were in the range 16-24, compared with only 3% at JBDC [F]. Additionally, 9% were from a non-white ethnic group, compared with only 3% at JBDC, and that 55% had travelled from outside the North West of England, whereas only 37% of visitors to JBDC came from outside this region. Taken together, this demonstrates that Bluedot successfully engaged with a broader and more diverse audience than JBDC activities.

Bluedot also has an impact on the scientists taking part. For example, in the 2019 exhibitor survey, from 90 responses, 97% either agreed or strongly agreed that they felt their participation had inspired others, 55% developed new skills, 85% learnt something new and 47% made new professional connections [F]. Comments included: “Audience feedback suggested enthusiasm about being able to talk directly to/ ask questions of scientists about their research”, “We got a real sense of engagement and interest from groups who don’t normally engage with science”, “It gives our young leaders an excellent platform to demonstrate and improve their communication skills face-to-face” [F].

In 2019, Bluedot won the Best Medium-Sized Festival Award (daily capacity 10,000 - 39,999) at the industry’s UK Festival Awards [C].

Wider outreach & citizen science: To widen their reach beyond visitors, the JBDC Education team visits WP schools, engaging with 3,189 students over 2016-19 [E].

Three series of BBC’s Stargazing Live (each with 3 episodes) were broadcast from Jodrell Bank during the REF period (2014 – average 2.6 million viewers per episode, 10.8% audience share; 2015 – 1.8 million, 8.6%, plus eclipse special 4.1 million viewers, 55%; 1.4 million, 6.2%) [G]. These strongly featured Jodrell Bank research, including two citizen science projects: Space Warps (searching for new gravitational lenses) in January 2014 and Pulsar Hunters in January 2016. The former inspired tens of thousands of viewers to make 7.5 million classifications online leading to the discovery of a new Einstein Ring imaged by e-MERLIN during the programme and published in a refereed journal in 2015 [G]. This project was directly underpinned by e-MERLIN [3], which was used to detect the Ring during the TV programme. Pulsar Hunters, developed by Jodrell Bank researchers, similarly attracted over 10,000 people to make around 3 million classifications leading to the co-discovery of a new pulsar which was observed with the Lovell Telescope during the TV broadcast [G]. Pulsar Hunters has since been used in a number of events (including Bluedot, Mozilla Festival and Manchester Science Festival).

World Heritage Site: Jodrell Bank Observatory was designated a UNESCO World Heritage Site in 2019, recognising the significant impact of its research on a wide international stage and bringing our scientific research to a new global audience whose primary interest is in heritage [H]. This followed a 10-year process of developing a case, which was peer reviewed by UK Government, UNESCO and ICOMOS.

5. Sources to corroborate the impact

- [A] Independent consultant report on the economic impact of JBDC developments from 2010 commissioned by North West Development Agency.
- [B] Visitor numbers/profile to JBDC, including postcode analysis, repeat visits and evaluation of their response to the visit. Includes independent consultant reports.
- [C] List of awards for JBDC.
- [D] Report on JBDC activities: exhibition, telescope tours, Lovell Lectures, Meet the Scientist, Girls Night Out – includes description, numbers and evaluation.
- [E] Report on JBDC schools workshops, including Widening Participation programmes, numbers, activities and evaluation.
- [F] Report on Bluedot festival(s), including programme content, demographics, visitor numbers, evaluation (audience and exhibitor, including independent analysis), media coverage, testimonial from external festival company.
- [G] Report on other non-JBDC activities, including the Jodcast and the Space Warps and Pulsar Hunters citizen science project.
- [H] UNESCO World Heritage Site decision/report (July 2019) – see [UNESCO website](#).