Institution: University of Portsmouth

Unit of Assessment: UoA 9: Physics

Title of case study: Tactile Universe - Engaging the Visually Impaired Community with Astrophysics Research

Period when the underpinning research was undertaken: 2010-2018

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:
Nicolas Bonne	Public Engagement and Outreach Fellow	14/04/2015 - date
	Visiting Researcher	15/09/2014 - 14/04/2015
Karen Masters	Reader in Astronomy & Astrophysics	01/10/2008 - 30/09/2019
Bob Nichol	Professor of Astrophysics	01/08/2004 - date
Daniel Thomas	Professor of Astrophysics	01/02/2007 - date
Rita Tojeiro	Research Fellow	01/10/2008 - 21/03/2014

Period when the claimed impact occurred: September 2016 - date

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

1. Summary of the impact

The Tactile Universe project makes current University of Portsmouth astrophysics research accessible to people with vision impairments (VI). Since its inception in 2016, the Tactile Universe has reached more than 9,000 members of the public, school children aged 6 to 16, and education and outreach professionals across the world, including over 350 with VI. Participation in Tactile Universe activities has increased interest and engagement in astrophysics amongst VI school pupils, making them feel both included and inspired. Educators across the UK have been trained to use the Tactile Universe resources, increasing their confidence when working with VI people and empowering them to change their science communication practice to be more inclusive.

2. Underpinning research

An important finding about massive galaxies in the Universe is that they come in two basic types: “spirals” and “ellipticals”. Understanding the physics behind these galaxy morphologies has been a key area of research at the University of Portsmouth’s Institute of Cosmology and Gravitation (ICG) since Thomas and Masters joined in 2007 and 2008, particularly through the Sloan Digital Sky Survey (SDSS), and it is this research that underpins the Tactile Universe project.

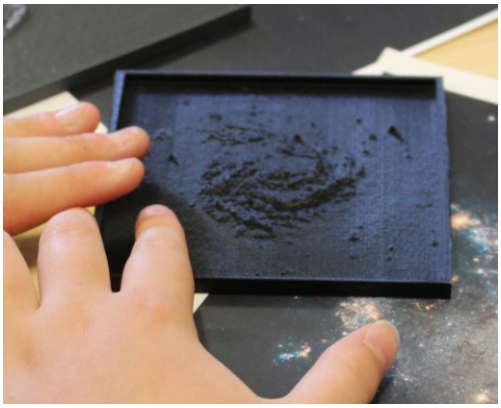
SDSS has revolutionised our understanding of galaxies. In addition to studying individual galaxies in great detail to gain an understanding of their properties, SDSS allows for the study of large numbers of galaxies in a statistical way, allowing for conclusions to be drawn about overall galaxy populations in the Universe. ICG members have played a crucial role in SDSS during the assessment period - in particular, Nichol has been a member of SDSS since 1993 and holds ‘SDSS Builder’ status, Masters is an ‘SDSS Architect’ and the current SDSS-IV Spokesperson (since 2016), and Thomas is an ‘SDSS Architect’ and was the Science Team Chair for SDSS-IV/MaNGA taking place from 2014-2020.

The 13th SDSS Data Release (DR13) in 2016 was the first data release from the fourth phase of SDSS (SDSS-IV) (R2; 13 ICG authors including Masters, Nichol and Thomas). From 2000 to 2009, SDSS imaged “most of the northern high Galactic latitude sky” (R2) in five different optical bands; this imaging dataset was then re-analysed for DR13 and provides the data used in the Tactile Universe project.

We selected 10 morphologically distinct galaxies to create detailed tactile images of, with separate images created using DR13 i-band (red) and DR13 u-band (blue) data. The selection of these galaxies was heavily influenced by research from the Galaxy Zoo 2 citizen science project (R3; 6 ICG authors including Masters, Nichol and Thomas), in which members of the public classified the shapes of 304,122 galaxies in SDSS images over the course of 14 months in 2009-2010. The findings from Galaxy Zoo 2 broadened our understanding of how galaxies of different types populate our Universe. The 10 tactile galaxy images created from this research form the basis of all the educational activities created for the Tactile Universe.

The content of the Tactile Universe school workshops and outreach activities is underpinned by further ICG galaxy morphology research. Research led by Masters (R4) has shown that red spiral galaxies are more prevalent than previously thought and may represent a significant stage in galaxy evolution. This work was built on by Tojeiro (R5) who studied the star formation histories of both red and blue spiral and elliptical galaxies. Bonne joined the ICG in 2014 and worked with Masters to study the properties of the local Universe galaxy population using SDSS data (R1) and has more recently contributed to research describing the underlying physics and evolutionary processes which create red spiral galaxies (R6). To create a more representative selection of tactile galaxy images based on this research, we have included an example of a red galaxy with a clear spiral structure. Drawing on the body of galaxy morphology work carried out at the ICG, we have been able to create a more complete and compelling educational narrative around the process of galaxy evolution, involving discussions of what we know, and what still remains a mystery.

The main resources of the Tactile Universe are 3D 'height map' tactile images (referred to as 'models') created from monochrome galaxy images from SDSS DR13, where the brighter the source image pixel, the higher it is from the base of the model. These physical models can be produced by several techniques including 3D printing. Users of the models can therefore feel the shape of a galaxy by running their hand across the surface, without the need to see it, as shown on the right.



3. References to the research

(R1) **Bonne, N.J.** et al. (2015). The influence of red spirals on the shape of the local K-band luminosity function. *The Astrophysical Journal, 799*(2), 1-16. https://doi.org/10.1088/0004-637X/799/2/160 (4 authors, including **Bonne**).

(R2) Blanton, M.R et al. (2017). Sloan Digital Sky Survey IV: Mapping the Milky Way, Nearby Galaxies, and the Distant Universe. *The Astronomical Journal, 154*(1), 1-35. https://doi.org/10.3847/1538-3881/aa7567 (363 authors including Beutler, Goddard, Gonzalez-Perez, Lian, Maraston, **Masters**, **Nichol**, Parikh, Penny, Percival, Ruggeri, **Thomas**, Westfall).

(R3) Willett, K.W. et al. (2013). Galaxy Zoo 2: detailed morphological classifications for 304 112 galaxies from the Sloan Digital Sky Survey. *Monthly Notices of the Royal Astronomical Society. 435*(4), 2835-2860. https://doi.org/10.1093/mnras/stt1458 (18 authors including Bamford, **Masters**, Edmondson, Melvin, **Nichol**, **Thomas**)

(R4) **Masters, K.** et al. (2010). Galaxy Zoo: passive red spirals. *Monthly Notices of the Royal Astronomical Society, 405*(2), 783-799. https://doi.org/10.1111/j.1365-2966.2010.16503.x (17 authors, including **Masters**, **Nichol**, Edmondson).

(R5) **Tojeiro, R**. et al. (2013). The different star formation histories of blue and red spiral and elliptical galaxies. *Monthly Notices of the Royal Astronomical Society, 432*(1), 359-373. https://doi.org/10.1093/mnras/stt484 (8 authors, including **Tojeiro**, **Masters**, Percival, Bamford, Maraston, **Nichol**, **Thomas**).

(R6) Fraser-Mckelvie, A. et al. (2018). Multiple mechanisms quench passive spiral galaxies. *Monthly Notices of the Royal Astronomical Society, 474*(2), 1909-1921. https://doi.org/10.1093/mnras/stx2823 (5 authors, including **Bonne**).

Evidence for the quality of research

The underpinning research outlined above was published in the foremost international astronomical journals, including robust peer review. The impact factors of these journals range from 5.4 to 8.4.

Grant funding

(G1) Gupta, J., **Masters, K.L**., **Bonne, N.J.**, and Krawczyk, C. *The Tactile Universe: accessible astrophysics for vision impaired school children*. Funded by the Science and Technology Facilities Council, April 2018 - October 2020 (GBP58,400)

4. Details of the impact

The focus of the Tactile Universe is on engagement with visually impaired (VI) groups, and is inspired by Bonne's personal experience. Due to his status as a severely sight-impaired person, he faced extreme difficulties when visual verification of galaxy properties was required for his research. This led to discussions on how this work could have been made easier for a VI researcher and how ICG research could be made more accessible to the wider VI community. From these initial ideas came the Tactile Universe, a public engagement project that makes current ICG galaxy morphology research accessible to the VI community.

Context

Studies by support charities RNIB and Vision UK have shown that VI people experience major barriers to accessing information at every stage of life, from early education through to higher education, employment and beyond. While 0.2% of the UK population aged 25 or younger are estimated to have a visual impairment, only 0.1% of UK higher education students were recorded as having a visual impairment in 2017. Physics-specific statistics are limited but in the most recent Royal Astronomical Society membership survey only 0.3% of respondents reported "blindness" (noting that this includes retired members and the likelihood of vision impairment increases with age) compared to 3.3% of the entire UK population. Increasing the availability of accessible STEM educational materials is key to establishing better routes from school through to higher education and employment for this under-represented population, which is where the Tactile Universe comes in.

Project development

The models were initially co-created with VI adults to best meet their needs via 3 consultation sessions between September and November 2016. The project has had an impact from the start, with one member of the consulted group going from being "scared" of space at the start of our first visit, to asking us when we would come back again by the end.

The change of focus to VI school pupils started in November 2016, when a VI primary school pupil and her teacher attended an outreach event during our initial development phase; we used the prototype 3D galaxy models to adapt an existing activity so she could fully participate. The teacher said: *"...it was a really inspirational session, that had a huge impact on <name>... Realising how [Dr Bonne] had achieved what he had despite visual impairment gave her confidence to aim high... her mum said... "What have you done to her - she's told me she's now going to university to study science when she's 18.""* (S1)

Since 2017 we have collaborated with a primary and a secondary school that both have 'resourced provision' for visual impairment, to develop VI accessible activities that use our 3D galaxy models and are based on ICG galaxy research. Between November 2017 and March 2018, 5 secondary school test sessions were held attended by an average of 15 VI pupils each time, and 3 test sessions were held at the primary school: 2 with whole Year 5 classes (60 children including 4 VI) and 1 with 10 VI pupils and their support staff. These sessions resulted in the creation of 3 (2 primary and 1 secondary) school workshops. All the workshop resources have been made freely available on our website where the resources page has been accessed over 3,000 times since it launched in 2018.

In April 2018 we won a highly-competitive STFC Nucleus Award (G1) to fund a nationwide roll-out of the Tactile Universe, by training people to deliver our school workshops and providing either a ready-made kit or the instructions to create their own resources. 66 educators, including 5 VI people, attended 5 training sessions across the UK in 2019. 20 kits were distributed to attendees and others have indicated that they will create their own kits. The training resulted in changes in attitude towards engaging with visually impaired audiences - following the training sessions in Birmingham and London, 100% of attendees reported an increase in confidence to explain galaxies to a VI audience (S4).

Impact on school children

Our sessions increased student interest in astronomy and also led to changes in behaviour, with a teacher at the secondary school reporting that "*...our pupils with VI have developed a greater*

interest in this aspect of science and STEM subjects generally. Moreover, one of our Year 11 pupils has enrolled on an online teaching course on cosmology to further his interest and knowledge... His intention is to continue with this within post 16 education" (S2). The teacher also stated that "*all of our pupils have engaged in positive questioning and higher-level thinking. Social skills have also been developed*" (S2).

Since 2019 we have delivered 6 workshops to 159 school pupils (6 with VI), with a further 5 school visits cancelled due to COVID-19. Post-visit teacher interviews and pre- and post-workshop pupil questionnaires show the impact of these visits. Overall, pupils enjoyed the novel approach to learning and came away with the clear message that 'anybody can be an astronomer'. For example, 92% of secondary school pupils (n=49) agreed with this statement following participation in a Tactile Universe session, compared with 76% before the session (S10). The VI pupils in particular felt 'included' and 'inspired' by the sessions, with one teacher who observed her VI pupil in a session reporting that *"he talked about it for hours, at the end of the day he was so excited to tell his Mum and Dad"*. Teaching staff also noted that their VI pupils were more involved and engaged, asking questions where they would usually not, and being a more active participant with more of their peers (S9). Beyond our direct delivery, our resources have also been used by our kit holders to deliver workshops to their local schools reaching an additional 120 school pupils (6 with VI).

Internationally, we are affiliated with the International Astronomical Union-funded AstroBVI project which has distributed kits featuring our models to 100 teachers in South America, Spain and Nepal. In the USA, Bonne has used our resources at IDATA (Innovators Developing Accessible Tools for Astronomy) workshops, engaging with over 50 teachers and students (10 with VI), and also ran workshops with 45 VI pupils attending Wisconsin's School for the Blind.

By creating activities that are inclusive regardless of level of vision, our school workshops have also had an impact on the fully-sighted participants. For example, one secondary school pupil said "*It was good because we got to understand how <name> could use certain tools to help him understand what he can not see*" (S3).

Impact on the wider public

The versatile nature of the Tactile Universe resources is something that has been recognised by us as well as the delivery teams and teachers. The Tactile Universe resources have been incorporated into the wider ICG public engagement programme, reaching over 5,400 members of the public since 2017 at events including the ICG's annual public Stargazing at Portsmouth Historic Dockyard event and Victorious Music Festival. An external evaluation in 2020 showed that the kit holders were "adapting the sessions to their own needs with success" (S9) and our resources have been used at a variety of events (both VI and non-VI targeted) including the University of York Astrocampus events (2019-20), the London Science Museum 2019 VIscovery day, and an International Astronomical Union gala in December 2019 attended by the King of the Netherlands, reaching over 3,700 members of the public. Bonne has appeared on national TV and radio to talk about the project, including news pieces for BBC South in February 2019 and January 2020, an interview on BBC The Sky at Night in October 2020 and numerous interviews for RNIB Radio Connect. The open nature of our resources means that they are likely to have been used in many more situations that we are unaware of.

Impact on the education and public engagement sectors

The Tactile Universe is also having a wider impact on educators and public engagement practitioners, and these sectors as a whole. Follow-up interviews were conducted in 2020 with teachers who attended sessions that we delivered in their schools. The interviews revealed an unexpected impact on these teachers - they reported having their confidence raised through participation in the sessions, and the external evaluator who carried out these interviews concluded that the sessions "provide a space for reflection and professional improvement" for these teachers. The teachers also requested help from us with other subjects, showing the value they placed on our approach (S9). Our resources will be included in the State of Ohio science standard model curriculum (S8).

The Kavli Institute for Cosmology in Cambridge has built on our resources in their 'TouchAstro' outreach project and the UK Astronomy Technology Centre in Edinburgh hosted a VI undergraduate summer student in 2019 who created multi-material versions of our models (S5). Bonne has further facilitated this aspect of the project by advising others in the UK and internationally on how best to engage with VI audiences, through direct consultancy activities and collaborations, and presentations at public engagement meetings (S6). These include providing exhibit accessibility advice and training staff at the Jodrell Bank Discovery Centre, collaborating with European Southern Observatory (ESO) Fellow Dr Chris Harrison on a VI-accessible show that premiered at the 2019 British Science Festival (S7) and consulting for the NSF-funded IDATA project in the USA.

In 2017 we initiated a VI physics public engagement consortium, organising a meeting in collaboration with the Royal Astronomical Society to bring together people working on different projects (the first of its kind). This first meeting was held on 14 December 2017 with representatives from 7 projects. A second meeting, this time with more than double the number of attendees, held in Manchester on 15 January 2019. A third meeting scheduled for March 2020 was cancelled due to COVID-19.

In conclusion, the Tactile Universe has reached more than 9,000 people across the world, including over 350 with VI, since 2016. Through this work VI children have increased their engagement with and changed their attitude towards astrophysics, non-VI children have a better understanding of the needs of their VI peers, and public engagement practitioners are more confident and better equipped to engage with this under-represented group. The importance of this work was recognised in 2020 when the Tactile Universe was selected out of 112 worldwide finalists as the winner of the Falling Walls Science Engagement Breakthrough of the Year, recognising achievements that remove barriers to scientific engagement (S11).

5. Sources to corroborate the impact

(S1) Email from Northamptonshire primary school teacher, 10/10/2017

(S2) Email from teacher to NB 17/01/2018

(S3) Email from Hampshire secondary school teacher, 12/02/2019 with quotes from students

(S4) Participant feedback collected at two training events in 2019

(S5) STFC news article about a summer project at UK ATC using our Tactile Universe models https://stfc.ukri.org/news-events-and-publications/whats-happening/undergrad-student-ground-breaking

(S6) List of 26 conferences and workshops attended 2016-2019

(S7) Press release about the European Southern Observatory (ESO) show 2019

(S8) Tweet from STEM coding: https://twitter.com/STEMcoding/status/1045483872803262466

(S9) Evaluation report from Public Engagement and Involvement Consultant, Charlotte Thorley

(S10) Pre and post-session evaluation results from a secondary school visit in February 2020

(S11) Press release for Falling Walls Science Engagement Breakthrough of the Year November 2020