Institution: King's College London (KCL)

Unit of Assessment: 9 (Physics)

Title of case study: Using science research to engage new audiences through the 'art' of dark matter

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

Dr Malcolm Fairbairn has worked alongside visual artist Carey Young to inspire contemporary artwork that have exhibited internationally and been viewed by ca. 100, 000 people. Fairbairn's research into dark matter and cosmology led to the collaboration and the artwork has engaged audiences in the UK, the USA and France, prompting visitors to contemplate scientific facts and issues they might not otherwise have considered and leading to a greater public awareness of our knowledge of the universe. Fairbairn has also used his research into dark matter to engage the general public and inspire schoolchildren in science. Since 2008 he has given around 35 talks at which the general public and schoolchildren have learned about dark matter and cosmology, directly impacting pupils who, teachers report, have been inspired by their experience and are reporting an increased aspiration to pursue science.

2. Underpinning research (indicative maximum 500 words)

Malcolm Fairbairn's primary research activities focus on the intersection between particle physics, astrophysics and cosmology. This area covers primordial inflation, dark energy and astroparticle physics, although he has concentrated mainly on the subject of dark matter since joining the Department of Physics, King's College London (Lecturer 2007-11, Senior Lecturer 2011-13, Reader 2013 - present). This large component of the energy density of the Universe is thought to be in the form of massive particles which do not couple to electromagnetism such that they are effectively invisible – hence the title dark matter.

In his research, Fairbairn has looked in detail at various aspects of dark matter [1-3]:

- The quantity and nature of dark matter in galaxies;
- Attempts to detect the dark matter through its own self annihilation;
- Interpretation of the results from direct detection experiments such as DAMA and XENON;
- Understanding the interaction between baryonic matter and dark matter in galaxies;
- The possible effects of the accretion of dark matter onto stars and compact objects.

This wide range of research activities in the field has given him a comprehensive understanding of the subject. Research conducted at King's College London since 2007 has informed his outreach since 2008.

Work by Fairbairn and Schwetz [3] has focused on the analysis of conflicting results from two different dark matter direct detection experiments. The DAMA dark matter detection experiment in Gran Sasso has long claimed evidence for an annual modulation in its event rate which is consistent with a dark matter particle of mass 10 GeV. This is in conflict with the larger XENON-10 and XENON-100 experiments which claim to have ruled out the same region of parameter space. Fairbairn's research re-analysed the DAMA data and showed the importance of studying the energy dependence of the direct detection rate. This research recast the nature of the discrepancy between the two experiments, informing possible particle physics scenarios which could explain both experimental results.

Another experimental anomaly presented to theorists around this time was the discovery of many high energy positrons by the PAMELA experiment in orbit above the Earth. While dark matter self-annihilation does predict the production of anti matter, the large number of positrons observed seems too great in comparison with the required self annihilation rate in the early Universe which explains the relic abundance today. A paper by Fairbairn and Zupan [2] proposed an entirely new particle physics theory of dark matter in order to explain this observation, where there were two

different dark matter species, one of which decays into the other at late times after the relic abundance has been set. The dark matter today can therefore self-annihilate more readily than would be expected given its relic abundance and explain the anomalous origin of the positrons.

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

[1] "Quantifying Astrophysical Uncertainties on Dark Matter Direct Detection Results", M. Fairbairn, T. Douce & J. Swift. Astroparticle Physics **47**, 45 (2013) DOI: 10.1016/j.astropartphys.2013.06.003

[2] "Dark matter with a late decaying dark partner", M. Fairbairn, & J. Zupan, JCAP **0907**, 001 (2009). DOI: 10.1088/1475-7516/2009/07/001

[3] "Spin-independent elastic WIMP scattering and the DAMA annual modulation signal", M. Fairbairn & T. Schwetz, JCAP **0901**,037 (2009). DOI: 10.1088/1475-7516/2009/01/037

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

In 2010 Carey Young, a contemporary visual artist, approached Fairbairn to consult him on a project she was developing in which she planned to explore issues around law which was established to apply to outer space. Young's idea was to create artistic works which featured legal agreements but which also explored ideas in theoretical physics such as dark matter. She turned to Fairbairn for scientific advice and guidance in order to make them scientifically credible. Over several meetings in 2010, conversations between Young and Fairbairn about his research into dark matter and cosmology led to the development of two artistic works which featured Fairbairn's calculations and advice.

In particular, "Missing Mass*"* is a sculptural work, of an open-top perspex container, said to contain 5,461 dark matter particles, the number calculated by Fairbairn to be present within the 18 x 18 x 18 inches volume, based upon a 10GeV WIMP dark matter particle which Fairbairn and Schwetz showed was predicted by the DAMA experiment. As with a number of the artist's works, the piece uses "a legal disclaimer which proposes the particles as the only truly free entities in existence, since they can pass through any material entity on the planet".[1] This work focuses on the fact that since the dark matter constantly flows through the Perspex, it is both ephemeral and unobtainable, yet it is also physical; as indicated in the disclaimer, "any collector of this work should not expect to own the same 5,461 dark matter particles at any one time".[2]

The second piece, "Terminal Velocity*"* informs the observer how quickly the Earth is moving through the Universe. It shows vinyl text of the wording '1,404,000 miles per hour' on the gallery wall with a spotlight, this representing the speed (calculated by Fairbairn) of the gallery in space relative to the Big Bang.

These works inspired by Fairbairn's research are a tangible demonstration of the increasing concern to examine the interrelation between art and science and explore their mutual impacts. They have been exhibited in a number of high profile galleries around the world including the Paula Cooper Gallery in New York, Marianne Boesky Gallery (New York), Cornerhouse (Manchester) and Le Quartier (Quimper, Brittany). Young's exhibition in Manchester attracted around 12,000 visitors and she estimates that in total the works have been viewed by 50,000 to 100,000 visitors so far, a number which is still rising.[1]

Gallery visitors have shown considerable engagement with the pieces and, from the positive feedback Carey Young has received, she considers that the resultant impact has demonstrated that "the works made people aware of scientific and legal issues they would not normally consider".[1] Through the medium of her artistic work, and the associated gallery marketing publications and press exposure, Fairbairn has been able to reach members of the public who normally might have little or no exposure to some of the contemporary ideas of astrophysics and cosmology.

Fairbairn's commitment to public engagement is integral to his academic endeavour. Following his arrival at KCL, he launched a number of activities to engage school pupils in London and developed outreach activities specifically aimed at members of the public. The majority have related to the subject of dark matter, with the aim of increasing public interest in physics research and to make lay audiences feel less distanced from it. A key aim is to motivate students to go on to study Physics at university.

Since 2008 Fairbairn has given around 35 dark matter talks in various forums. Fairbairn began by giving talks in individual schools but this soon evolved into him instigating physics evenings at the KCL Strand campus in central London, where school parties of enthusiastic students come from all over the South East. Using contacts built up through Fairbairn's administration of the department's University Ambassador Scheme, between 120 and 160 students attend each of these events, which now run two or three times a year. At Physics taster days, when students deciding what to study at University visit King's College London, students often report in feedback forms that Fairbairn's talk on Dark Matter was the highlight of their visit.[3] Fairbairn has worked to engage members of the public giving evening courses on cosmology at the Royal Institution, presenting six evening lectures over the course of two months to communicate the basics of current, cutting edge research into cosmology, dark matter and dark energy.

Testimonies from school teachers report that Fairbairn's talks have fired their students' imaginations, providing them with significant inspiration and aspiration and made many think seriously about Physics as a degree subject, when previously they had not considered this.[4,5] As one Head of Science has stated: "It is always possible to judge the success of talks like [that given by Fairbairn] from the discussion that takes place afterwards, and the range and sheer number of questions was a powerful indicator of how successful the talk was ... Those of us who work in schools are always very grateful when people like Malcolm appear, who are working physicists at the cutting edge of their subject and who are not only willing to share their enthusiasm and expertise with young people but do so with such insight, interest and energy." [4] Another has written that the talks, "have provided an enormous amount of inspiration and aspiration to the students from Ilford County High School and is one of the factors leading to a general increase of interest in Physics and university applications at the school." [5]

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

1. Letter and email from Carey Young, Artist.

2. Carey Young's web-site of her works: http://www.careyyoung.com/past/missingmass.html

3. Feedback forms from a 'Physics Taster Day'.

4. Letter from the Head of Science and Technology, Westminster School.

5. Letter from the Head of Physics, Ilford County High School.