Institution: University of Surrey

Unit of Assessment: UOA 9 Physics

Title of case study: Communicating Physics through Public Engagement

1. Summary of the impact

The research carried out by Surrey's Nuclear Physics Group and the expertise of its members have informed and stimulated debate on a wide range of scientific areas via broadcasting, the press, science policy, STEM education, and wider public engagement.

Professor Al-Khalili, in particular, has built on his expertise and experience in theoretical nuclear physics, such as his published research on the properties of exotic halo nuclei, to promote and disseminate many fundamental ideas in quantum mechanics, and physics in general, to the wider public. Through his popular science books, such as *Nucleus: A Trip into the Heart of Matter* (the only coffee table book on nuclear physics) and *Quantum: A Guide for the Perplexed*, and his numerous television and radio programmes (such as BBC Four's *Atom*, which is widely seen as having broken new ground in the way science documentaries are presented), he has played a vital part in the resurgence of interest in physics in popular culture and in inspiring the next generation of scientists, impacting millions of people around the world.

2. Underpinning research

The Nuclear Physics Group at Surrey, with nine academic staff and two emeritus Professors, has activities encompassing both theoretical and experimental work. Their research focusses on the study of exotic nuclei produced at radioactive ion beam facilities around the world.

On the experimental side, high-resolution gamma-ray spectroscopy is used to measure radiation emitted from radioactive atomic nuclei. The nuclear physicists at the University of Surrey, particularly Prof. Regan, have led a series of experiments at the GSI facility in Darmstadt, Germany, which utilises such measurements to identify and to characterise individual nuclear species. In this fundamental research, they identify the presence of unique gamma-ray fingerprints, which are particular to a given isotope. The team characterises the internal structure of nuclei with unusual numbers of protons and/or neutrons, compared to the 286 radioactively-stable nuclear species that exist in nature [1,2]. On the theory side, Prof. Al-Khalili's main research interests are in nuclear reaction theory and in modelling the scattering and reactions of light exotic nuclei, particularly those short-lived very neutron-rich nuclei with neutron halos. These strange entities owe their existence to Heisenberg's Uncertainty Principle. Al-Khalili and Tostevin were the first researchers to implement successfully a 'four-body' scattering model that took fully into account the few-body correlations (the Borromean characteristics) in halo nuclei, without which its properties, such as binding energy, size and lifetime, could not be predicted with any degree of accuracy [3].

Together with Prof. Johnson and a PhD student (Cunningham), Al-Khalili has recently completed the first full calculation to describe proton-nucleus scattering when the nuclear target has non-zero spin. Including the spin of both projectile and target in the reaction model leads to new tensor terms in the potential and predicts novel observables to probe nuclear structure [4]. This research is of interest to many reaction studies at experimental facilities around the world.

3. References to the research

1. *Nuclear Structure 'Southeast of ^{208}Pb: Isomeric States in ^{208}Hg and ^{209}Tl.* N. Al-Dahan, Zs. Podolyak, P.H. Regan, W.Gelletly, P.M.Walker et al., *Physical Review C Rapid Communications* (2009) 80, 061302 (5 pages) doi: 10.1103/PhysRevC.80.061302

2. *β⁻-delayed spectroscopy of neutron-rich nuclei: Shape Evolution in neutron-rich Tungsten Isotopes*, N.Alkhomashi, P.H. Regan, Zs. Podolyak, …., W.Gelletly, P.M.Walker *et al*., *Physical Review C*, 80 (2009) 064308 (12 pages) doi: 10.1103/PhysRevC.80.064308

3. *Matter radii of light halo nuclei*, J.S. *Al-Khalili and J.A. Tostevin, Phys. Rev. Lett. 76 (1996) 3903-3906*. doi: 10.1103/PhysRevLett.76.3903 (cited >230 times)

4. *Effect of spin-spin interactions on nucleon-nucleus scattering*, E.S. Cunningham, J.S. Al-Khalili, and R.C. Johnson, *Phys. Rev. C* 87 (2013) 054601. doi: 10.1103/PhysRevC.87.054601

Gamma-ray spectroscopy research was funded by STFC rolling grants, the Qatar Ministry of the Environment, the Kuwait Environment Agency. Al-Khalili's research was funded by EPSRC (1994-2007) and STFC (2008-2015).

4. Details of the impact

The Nuclear Physics Group's world-leading research on the structure of exotic nuclei and expertise in techniques, such as gamma-ray spectroscopy, has led to a wide range of public engagement activities and media work, which have raised their impact far beyond the confines of the international nuclear physics community.

Much of the impact of the Group's research has derived from their being world-leading authorities on nuclear and radiation issues. For example, when news of the Fukushima nuclear incident broke in March 2011, Professor Regan and colleagues were called upon to take part in more than 50 TV and radio interviews by discussing the measurement and biological effects of radiation. Regan made a number of appearances on BBC Breakfast News and BBC World News, both of which have a viewership of millions [see Section 5, Source S1]. They informed the public by drawing on information provided by research results, such as the characterisation of radioactive isotopes using gamma-ray spectroscopy (ref. 1). Six months later, Prof. Al-Khalili presented a Horizon programme filmed in Fukushima, entitled 'Is Nuclear Power Safe?', reaching over two million viewers. It informed the general public and stimulated an on-line debate.

While this activity was prompted by a major news story, Prof. Al-Khalili's on-going and wide-ranging science communication and public engagement activities have had an even greater and more lasting impact. He has just written his fifth popular science book (*Paradox: The Nine Greatest Enigmas in Physics* [S2]) and is currently writing his sixth, on quantum biology. His highly successful book, *Quantum: A Guide for the Perplexed* (first published in paperback in 2004), which was instrumental in his winning the Royal Society Michael Faraday Medal in 2007, as its youngest ever recipient [S3], is linked to his body of research in nuclear reaction theory and related quantum mechanics. In collaboration with other nuclear physicists, he wrote *Nucleus: A Trip into the Heart of Matter* (revised and updated in 2012), which is the only 'coffee table' book on nuclear physics ever published. The link between this book and Al-Khalili's research is seen explicitly in a section of Chapter 4, which describes his research on the structure of exotic halo nuclei [ref. 3]. In total, Al-Khalili's books have sold over 100,000 copies and have been translated into 20 languages [C2]. Reviewers of his books note their societal impact in informing, inspiring and stimulating the public.

Al-Khalili's television career began in the late 90s, but his big break came in 2007 when he presented the BBC Four series *Atom.* [S4] (First broadcast on BBC Four in 2007, it has since been repeated on both BBC Four and Two within the REF period, as well as in many countries around the world.) Many observers at the BBC, including the then Director General, Mark Thompson, have commented that the series marked a watershed in the way science documentaries are now made. The second hour of the series was devoted entirely to nuclear physics and drew on Al-Khalili's research on halo nuclei while at the Niels Bohr Institute. Reviewers on public websites have

described how the programme amazed them (*e.g.* 'blew my socks off') and inspired physics study.

Since then, Al-Khalili has gone on to make nine more science documentaries. As evidence of the impact of his work in science communication, his programmes have had three Grierson Trust nominations and one BAFTA nomination, and have won the Athens International Science Film Festival prize and an Association of British Science Writers prize for best science documentary. The total number of viewers for Al-Khalili's most recent four BBC programmes is estimated to be over 10 million. Audience surveys (internal to the BBC) reveal that his programmes consistently achieve an Audience Appreciation Index of 88±1%, which is considerably higher than the average.

Al-Khalili now has a weekly programme on Radio 4: *The Life Scientific*, which runs for 24 weeks of the year [S5]. The programme has an average weekly audience of 2.2 million. Feedback obtained from an internal BBC 'Pulse Survey' from March 2012 indicates its format has been extremely successful [S6]. Radio 4 controller, Gwyneth Williams, has stated that Al-Khalili is an excellent communicator "but fundamental to his role in such a high profile programme is his research expertise and his locus as a working physicist." [S7]

The new Editor of BBC Four, Cassian Harrison, has explained how Al-Khalili's experience as a researcher is necessary for his programmes to have a maximum impact on audiences: "Professor Al-Khalili has shown a consistent ability to encapsulate and to communicate some of the most complex principles and theories in contemporary physics with a clarity and insight that is clearly born not only from years of study but also from his ongoing work and research." [S8] The previous controller for BBC Four, Richard Klein, has emphasised the importance of Al-Khalili being an active scientific researcher when presenting programmes: "I have no doubt that Jim Al-Khalili's research - his willingness to re-consider and re-think the big ideas in physics - has been a huge contribution to his standing as one of BBC Four's principal science presenters."

Al-Khalili's media work has been credited with contributing to the sharp increase in the number of students applying to study physics at University.[S9] Peter Main, Director of Education and Science at the Institute of Physics, has said: "There is no doubt that his thoughtful and intelligent contributions to public engagement have had a major impact, not least in improving the public's perception and understanding of science, and physics in particular, but also in encouraging more young people to study the subject at school and at university. A particular feature of Jim's media work is the way that he draws upon his own research experience as a nuclear physicist."

Al-Khalili has also achieved impact on science policy and culture. In 2012, he was invited by a House of Lords All Party Parliamentary Group to deliver a keynote speech on thorium-fuelled nuclear reactors. He has represented the world of science as a judge on several cultural awards panels (such as the Art Fund Prize) and has helped to develop science and science education policy through his contributions to learned societies and organisations, including the Royal Society.

Al-Khalili actively promotes his research through regular blogs on his website and Twitter (with *ca*. 50k followers) [see http://jimalkhalili.com/ Twitter: @jimalkhalili]. His blog-post on the OPERA 'faster than light' neutrinos experiment was read by more than 13,000 people in a single weekend in 2011. He stimulates public debate with his regular comments in the media about scientific issues [S10].

5. Sources to corroborate the impact

S1. See the BBC News web-site for examples of TV interviews at http://www.bbc.co.uk/news/world-asia-pacific-12744973 ; http://www.bbc.co.uk/news/12734910 and http://www.bbc.co.uk/news/world-asia-pacific-13352227

S2. A list of Jim Al-Khalili's popular science books on Amazon:

http://www.amazon.co.uk/Jim-Al-Khalili/e/B001HD1W88/ref=ntt_dp_epwbk_0

Relevant reviews include: *Nature* (2003) **424**, 997

http://internetreviewofbooks.blogspot.co.uk/2012/07/nucleus.html

http://www.amazon.com/Complete-Series-Hosted-Professor-Al-_Khalili/dp/B004EFSHUC

S3. Faraday Prize committee member, Professor Richard Dawkins FRS. Contact details provided.

S4. BBC Website for Atom: http://www.bbc.co.uk/programmes/b007x243/episodes/guide

S5. The Life Scientific website: http://www.bbc.co.uk/radio4/features/science-discovery/jim-al-khalili/#intro Profile as a broadcaster on BBC Radio 4 website: http://www.bbc.co.uk/radio4/people/presenters/jim-al-khalili/

S6. BBC internal document; Information available from BBC Marketing and Audiences.

S7. Controller of Radio4. Contact details provided.

S8. Editor of BBC Four. Contact details provided.

S9. http://www.telegraph.co.uk/science/9796578/The-Brian-Cox-effect-presenter-rescued-physics-from-disaster.html ; Director of Education and Science at the Institute of Physics. Contact details provided.

S10. Newspaper articles on science: http://journalisted.com/jim-alkhalili?allarticles=yes