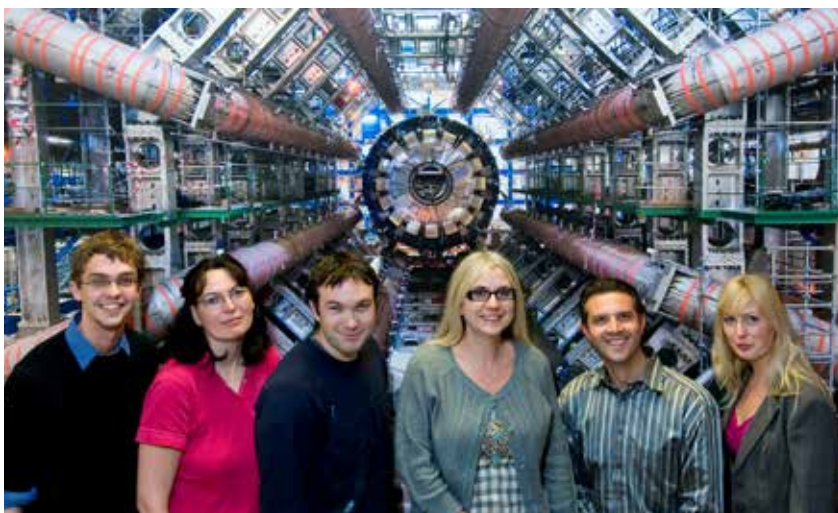


Fundamental physics inspires, entertains and stimulates the public



A team of researchers led by Professor Antonella De Santo (third from right), participated in the discovery and characterisation of the new particle, the Higgs boson. The discovery has generated exceptional public interest, inspiring and entertaining people worldwide and challenging our perceptions of the foundations of the universe. Background image courtesy of Maximilien Brice.

There has been widespread public interest in physics research in recent years, not least due to the ground-breaking research at the Large Hadron Collider at CERN and the discovery of the elusive Higgs boson. The contribution of Sussex researchers to such high-profile fundamental physics, through media stories and cultural interpretation of this work (including television broadcasts and theatrical productions) and their involvement in multi-participant projects that involve the public, has led to popular engagement in an area of research that might otherwise seem inaccessible to lay audiences.

Overview

Three strands of physics and astronomy research at Sussex have led to greater public engagement in fundamental science research. The European Organization for Nuclear Research, known as CERN

(Geneva), is a multinational research organisation whose purpose is to operate the world's largest particle physics laboratory. Since the switching on of the Large Hadron Collider (LHC) – the most powerful particle accelerator in the world, which allows scientists to recreate and study the conditions thought to have occurred within a billionth of a second of the Big Bang – a wealth of new fundamental physics data has been generated. The ATLAS experiment is one of two experiments at CERN that announced in 2012 that they had detected a Higgs-like boson. Researchers at the University of Sussex, Professor Antonella De Santo, Dr Fabrizio Salvatore, Dr Iacopo Vivarelli and Dr Alessandro Cerri, participated in the discovery and characterisation of this new particle, which is consistent with the Standard Model Higgs boson. In doing so, they have helped achieve one of the primary goals of the LHC, tentatively completing the Standard Model, sometimes regarded as the 'theory of almost everything'.

Neutrons are an elemental part of the nucleus of the atom. Although electrically neutral overall, neutrons are made up of charged particles. The neutron electric dipole moment (nEDM) is a measure of the distribution of positive and negative charge inside the neutron; just as a magnet has north and south poles, so a neutron with an EDM would have one end somewhat negative, and the other somewhat positive. However, this can only happen if certain symmetries in the laws of physics are slightly broken – by exactly the same mechanisms that were responsible for the dominance of matter over anti-matter in the universe at the time of

the Big Bang. These mechanisms are not understood, but by measuring (and putting limits upon) the nEDM, we put extremely tight constraints upon new models of physics that attempt to explain the origin of all of the matter in the universe. Professor Philip Harris (Head of the Department of Physics and Astronomy, University of Sussex) and Dr Clark Griffith are working with a Europe-wide collaboration based at the Paul Scherrer Institute, Switzerland, with apparatus that has made the world's most precise measurement to date of this fundamental quantity.

In observational astronomy, Professor Sebastian Oliver, founding Associate Investigator of the European Space Agency's Herschel SPIRE Instrument, leads the largest Herschel project, HerMES, which has helped discover thousands of distant star-forming galaxies. The XMM Cluster Survey, led by Dr Kathy Romer, analyses data from the XMM-Newton X-ray observatory to search for galaxy clusters, and Dr Jonathon Loveday is one of only two UK astronomers to be awarded 'builder' status for the Sloan Digital Sky Survey (SDSS), an international project that systematically photographs the sky and catalogues galaxies. While the human eye is the best tool for classifying galaxies, the number of images from the SDSS are too numerous to be covered by professional astronomers alone. Thus, the Galaxy Zoo project enlisted more than 200,000 non-academic volunteers to classify SDSS images on a massive scale. These public contributions have subsequently been used in further research at Sussex, for example, the study of unusual red spiral galaxies by Dr Romer's group.

Achieving impact

The Higgs discovery has generated exceptional public interest, inspiring and entertaining literally millions of people worldwide, generating global front-page coverage and challenging our perceptions of the foundations of the universe.

The awe-inspiring pictures from the Herschel Space Observatory and a highly proactive effort in public engagement in the UK has had wide-reaching impact, with 47 million audience contacts, 27 distinct press stories and many more international

press releases that have been picked up, for example, by the BBC's web pages. There have been extensive media appearances, including *The Sky at Night* and Radio 4's *Today Programme*, reaching wide audiences. Romer and Baskill's audio slideshow covering highlights of 10 years of the XMM-Newton laboratory was accessed over 100,000 times from the BBC website within the first day of its availability.

Sussex research has also achieved widespread impact by contributing to a leading example of 'citizen science'. In the Galaxy Zoo project, one million SDSS images were made available, via their website, in July 2007. Within 24 hours of its launch, almost 70,000 classifications per hour were being received. By 2009, over 100 million classifications had been contributed by more than 200,000 people, all of whom are individually acknowledged on the website. These classifications have led directly to some substantial new scientific findings – a prime example being the discovery of a new class of galaxy, first noted by volunteers. The ground-breaking nature of the project has subsequently become the focus of academic research into the motivations and benefits of science to volunteers. A study from Johns Hopkins University demonstrated that volunteers' motivations range from fun and interest in the beauty of the pictures to the excitement of contributing to original scientific research. One interviewee noted the importance of the 'slight probability that I may point out the one object that will completely shock our current understanding about the universe'. As a pioneer in the field of 'citizen science', the Galaxy Zoo project featured prominently in Michael Nielsen's book *Reinventing Discovery: The New Era of Networked Science*, which argues for an 'open science imperative' to reinvent discovery.

Sussex scientists have also been engaged as consultants in various arts projects, bringing science to new audiences. Dr Romer and Professor Andrew Little were chief scientific advisors on the play *Constellations*, which is expected to become a feature film and where the lead character is a Sussex astronomer. In addition, the Herschel SPIRE influenced a scene in



Professor Sebastian Oliver discusses the Herschel satellite project with Sir Patrick Moore for *The Sky At Night*.

The Big Bang Theory (CBS Network), reaching 14 to 20 million viewers. In 2009, Professor Harris worked with the Adur Festival and composer-performer Richard Durrant to create a musically and visually accompanied lecture on the search for the nEDM and its implications, allowing the audience to 'experience science in a completely new way'.

Future impact

The identification of the long-anticipated Higgs boson is not the end of its story. Its discovery now provides a testing ground for new physics, beyond the Standard Model, through precision study of its branching fractions, angular decay distributions and production in associations with other particles such as the top quark.

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