Video: How String Theory scaled up

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In August 1984 two physicists arrived at a formula that transformed our understanding of string theory, an achievement now recognised by a major award. Professor Michael Green of the Department of Applied Mathematics and Theoretical Physics explains how string theory has taken unexpected directions.

In December 2013 Professor Michael Green of Cambridge University and Professor John Schwarz of California Institute of Technology were awarded the 2014 Fundamental Physics Prize, one of a series of annual 'Breakthrough Prizes' set up to raise the profile of the physical and biological sciences. Their shared $3 mn prize was given for "opening new perspectives on quantum gravity and the unification of forces".

Green and Schwarz are known for their pioneering work in string theory, postulated as a way of explaining the fundamental constituents of the universe as tiny vibrating strings. Different types of elementary particles arise in this theory as different vibrational harmonics (or 'notes'). The scope of string theory has broadened over the past few years and is currently being applied to a far wider field than that for which it was first devised, which has taken those who research into it in unexpected directions.

Although the term 'string theory' was not coined till 1971, it had its genesis in a paper by the Italian physicist Gabriele Veneziano in 1968, published when Green was a research student in Cambridge. Green was rapidly impressed by its potential and began working seriously on it in the early 1970s. As he explains in the accompanying film, he stuck with string theory during a period when it was overshadowed by other developments in elementary particle physics.

As a result of a chance meeting at the CERN accelerator laboratory in Switzerland in the summer of 1979, Green (then a researcher at Queen Mary, London) began to work on string theory with Schwarz. Green says that the relative absence of interest in string theory during the 1970s and early 1980s was actually helpful: it allowed him and a small number of colleagues to focus on their research well away from the limelight.

"Initially we were not sure that the theory would be consistent, but as we understood it better we became more and more convinced that the theory had something valuable to say about the fundamental particles and their forces," he says.

In August 1984 the two researchers, while working at the Aspen Center for Physics in Colorado, famously understood how string theory avoids certain inconsistencies (known as 'anomalies') that plague more conventional theories in which the fundamental particles are points rather than strings. This convinced other researchers of the potential of string theory as an elegant unified description of fundamental physics.

"Suddenly our world changed - and we were called on to give lectures and attend meetings and workshops," remembers Green.

String theory was back on track as a construct that offered a compelling explanation for the fundamental building blocks of the universe: many researchers shifted the focus of their work into this newly-promising field and, as a result of this upturn in interest, developments in string theory began to take new and unexpected directions.

Ideas formulated in the past few years, indicate that string theory has an overarching mathematical structure that may be useful for understanding a much wider variety of problems in theoretical physics that the theory was originally supposed to explain – this includes problems in condensed matter, superconductivity, plasma physics and the physics of fluids.

Green is a passionate believer in the exchange of ideas and he values immensely his interaction with the latest generation of researchers to be tackling some of the knottiest problems in particle physics and associated fields.

"The best ideas come from the young people entering the field and we need to make sure we continue to attract them into research. It is particularly evident that at present we fail to encourage sufficient numbers of young women to think about careers in physics," he says. "Scientific research is by its nature competitive and there are, of course, professional jealousies - but there's also a strong tradition of collaboration in theoretical physics and advances in the subject feel like a communal activity."

In 2009 Green was appointed Lucasian Professor of Mathematics at Cambridge. It comes with a legacy that Green describes as daunting: his immediate predecessor was Professor Stephen Hawking and in its 350-year history the chair has been held by a series of formidable names in the history of mathematical sciences.

The challenges of pushing forward the boundaries in a field that demands thinking in not three dimensions but as many as 11 are tremendous. The explanation of the basic building blocks of nature as different harmonics of a string is only a small part of string theory – and is the feature that is easiest to put across to the general public as it is relatively straightforward to visualise.

"Far harder to articulate in words are concepts to do with explaining how time and space might emerge from the theory," says Green. "Sometimes you hit a problem that you just can't get out of your head and carry round with you wherever you are. It's almost a cliché that it's often when you're relaxing that a solution will spontaneously present itself."

Like his colleagues Green is motivated by wonderment at the world and the excitement of being part of a close community grappling with fundamental questions. He is often asked to justify the cost of research that can seem so remote from everyday life, and that cannot be tested in any conventional sense. In response he gives the example of the way in which quantum mechanics has revolutionised the way in which many of us live.

In terms of developments that may come from advances in string theory, he says: "We can't predict what the eventual outcomes of our research will be. But, if we are successful, they will certainly be huge - and in the meantime, string theory provides a constant stream of unexpected surprises."

Provided by University of Cambridge