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Their Higgs numbers – inspiration for young people around the world

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How does the most fundamental physics benefit humanity? In an earlier paper we followed the surprisingly short connections that link a Higgs boson – a fundamental discovery of no apparent practical value – to inventions that have revolutionized human society: the World Wide Web, digital cameras, and all of modern electronics. Here we emphasize *inspiration* rather than invention – how a Higgs is connected to inspirational themes like international cooperation, harnassing Big Data to improve the human condition, and understanding our place in the universe. The role of science in inspiring young people is directly connected to a programme administered by the first author, in which school girls are encouraged to pursue scientific and technical careers.

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In an earlier paper [1], we illustrated the interconnectedness that links the most fundamental physics to the most visible technologies. By defining a "Higgs number" through overlapping activities, and then following three different paths, which end respectively in applications of the World Wide Web, digital photography, and all modern electronic devices, we found that most people have a Higgs number of no greater than 3.

Figure 1: Twelve prizewinning Swedish school girls and outreach organisers from Uppsala and Umeå Universities in Sweden and Warwick University, UK, on a visit to the Institut Laue-Langevin in Grenoble. Their guide, centre front, was from Gabon. The girls' parents were born in Finland, Iran, Iraq, Poland and Sweden. During their visit they met or were accompanied by English, French, Icelandic, Italian, Russian, and Swedish scientists. Photograph by Max Alexander. Copyright: Uppsala University.

The concept of a Higgs number echoes that of the Erdös number, which traces the number of steps to reach Paul Erdös through the authors of mathematical publications. Erdös was a particularly prolific mathematician; he was assigned an Erdös number of zero; the 511 authors who are currently known to have collaborated with him on a publication were assigned an Erdös number of one. The coauthors of these people, totalling 11002, were then assigned an Erdös number of two – unless they were coauthors of Erdös themselves – and so on. This idea has been mirrored in the Kevin Bacon number and the degrees of separation from Black Sabbath. More information on this topic and the mathematics can be found at Oakland University's website [http://wwwp.oakland.edu/enp/readme/].

Here we again consider the connection of the Higgs discovery to important themes in the daily lives of human beings around the world, but this time with an emphasis on inspiration rather than invention. Since the first author of this paper has organised a programme which encourages young

Figure 2: The flag of Israel is raised at CERN in 2014. Iran, the Palestinian Authority, Saudi Arabia, Qatar, and other Arab nations are also participants in the science being done at CERN. Credit: Maximilien Brice/CERN

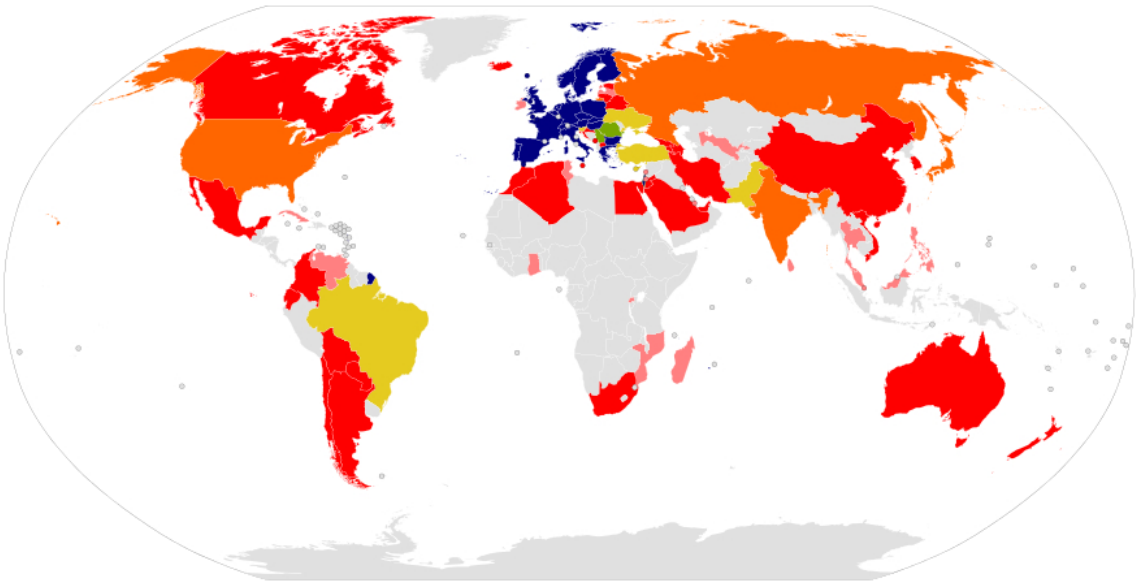

Figure 3: Founded by 12 European nations in 1954, CERN now has relations with the nations shown in various colours. Credit: https://en.wikipedia.org/wiki/CERN).

Figure 4: The flags of many nations fly in front of Wilson Hall at Fermilab. Credit: Ben Galan, AD, and Fermilab.

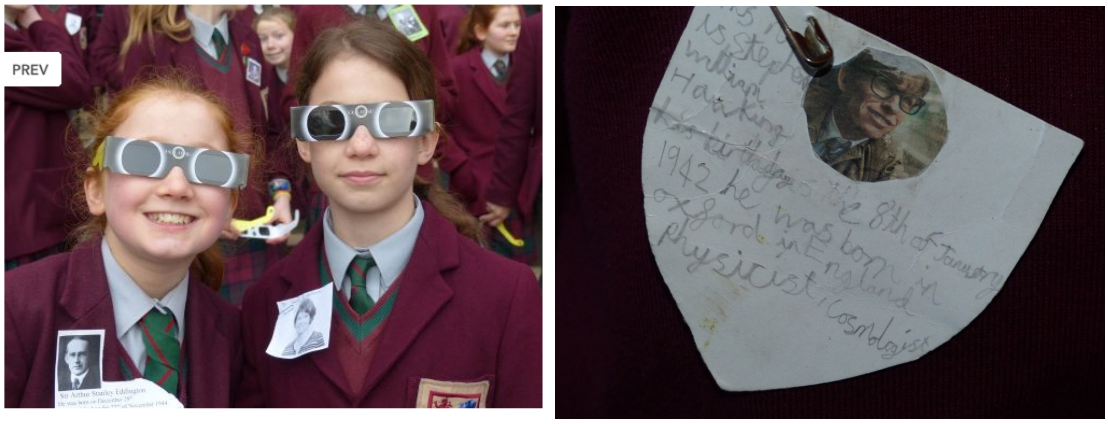

Figure 5: Science week at Ashfold School, United Kingdom. Inspired by the opportunity a solar eclipse offered, the science teacher at Ashfold School arranged a science week for the pupils. In a celebration of science, over two hundred children were invited to produce and sport a badge of a famous scientist. The girl on the left produced a badge showing Sir Arthur Stanley Eddington, while the one on the right chose the considerably less well-known first author! A seven-year-old pupil's badge featured Stephen Hawking, physicist and cosmologist. Hawking has the lowest Erdös-Bacon-Sabbath number recorded, 8, with an Erdös number of 4, and Bacon and Sabbath numbers of 2. Photographs by Anna Senior. Copyright: Ashfold School, Buckinghamshire.

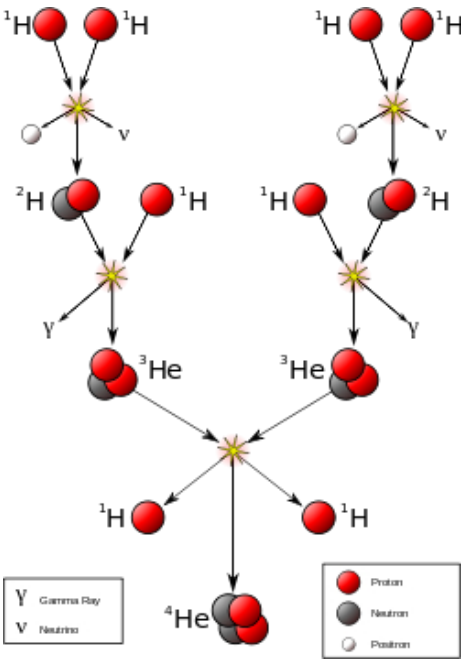

Figure 6: The proton-proton chain by which hydrogen burns to form helium in the Sun and stars of a similar size. If there were no Higgs condensate, the W boson would be massless, making the weak nuclear force much stronger, so that the first step at the top would proceed much more quickly and stars would burn much faster. Credits: Borb, https://commons.wikimedia.org/wiki/File:FusionintheSun.svg.

people (school girls in Sweden) to pursue scientific and technical careers, the emphasis will also be on the potential of fundamental physics to inspire young people like those shown in Fig. 1, who are currently in the programme. The backgrounds of these young people – see the figure caption – makes it clear why the first of our themes is international cooperation, in a time when international instability and conflict are major threats to their futures.

The relevance of the Higgs boson to this theme is made apparent by Figs. 2-4. As seen in Fig. 2, the Israeli flag was raised at CERN on Jan. 15, 2014 – a dramatic fact given that scientists from Iran, the Palestinian Authority, Saudi Arabia, Qatar, and other Arab nations also contribute to the science being done at CERN.

Of course, the ability of science to transcend national boundaries, rivalries, and even deadly conflicts is a very old story. There were at least two prominent examples a century ago, when an English astronomer (Eddington, featured in the badge of the girl on the left in Fig. 5!) confirmed the theory of a German physicist (Einstein) immediately after a world war that killed millions. During this same period of time, the science of X-ray crystallography was being launched by both German and English scientists (von Laue and the Braggs). But the global effort that led up to the Higgs discovery is also a model of international cooperation at its best.

Another inspirational theme is Big Data, which extends into many areas including bioinformatics, but which has been pioneered by the high energy physics community in various respects. And Big Data does not get bigger than the current one petabyte per second! The reduction in the data by first four orders of magnitude, and subsequently another two orders of magnitude, while losing as little information as possible, is an unsurpassed challenge, as are the procedures for anal-

ysis in a distributed global computing network. The sophisticated methods used for filtering and analyzing data in high energy physics – which played a role in the Higgs discovery – should eventually provide inspiration for treating even messier problems in areas like medicine, economics, and allocation of resources.

Finally, the Higgs discovery is relevant to everyone who looks up at the Sun or stars – see Fig. 5 – which would burn very differently if W bosons were massless – see Fig. 6 – or who wants to understand our place in the universe.

In summary, the Higgs is a paradigm of how science can inspire everyone, and the young in particular: (1) The global effort to find a Higgs is a model of international cooperation. (2) The highly sophisticated analysis of enormous amounts of data, required for this discovery, is a model for those areas with a relatively new interest in Big Data. And (3) the role of the Higgs in physics and astronomy is a rather awe-inspiring example of how Nature works, and of our place in the universe.

References

[1] Roland E. Allen and Suzy Lidström, "Your Higgs number – how fundamental physics is connected to technology and societal revolutions", Physica Scripta 90, 028002 (2015).