The pop-star professor

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Profile

The pop-star professor

Research into quantum mechanics has turned **Anton Zeilinger** into something of a celebrity. He spoke to Amber Jenkins about physics, philosophy and popularizing science

Not many physicists can claim to have shared a stage with the opera singer Luciano Pavarotti, the film-maker Steven Spielberg and the entrepreneur Sir Richard Branson. But in 2001 quantum researcher Anton Zeilinger was one of 11 recipients of a "World Award" from former Soviet leader Mikhail Gorbachev to recognize their support for "the cause of peace, freedom and tolerance throughout the world in order to positively influence the attitudes of men".

Zeilinger, based at the University of Vienna and the Austrian Academy of Sciences, has built a scientific reputation by testing many of the basic predictions of quantum theory and showing how the strange quantum properties of particles can be exploited technologically. But a passion for communication has made him far more of a public figure than many of his scientific peers – indeed he is now a household name in his native Austria. What is more, Zeilinger's interest in the wider philosophical implications of his work has brought him into contact with thinkers outside the realm of physics, among them the Buddhist leader the Dalai Lama.

Jacqueline Godany

Passionate communicator Anton Zeilinger.

In person

Born: Ried im Innkreis, Austria, 1945
Education: University of Vienna (degree in physics and mathematics, PhD in experimental solid state physics)
Career: professor at the University of Innsbruck (1990–9); president of the Austrian Physical Society (1996–8); professor at the University of Vienna (1999–present); co-director at the Institute of Quantum Optics and Quantum Information, Austrian Academy of Sciences (2004–present)
Outside interests: music, sailing and philosophy
Homepage: www.quantum.univie.ac.at/zeilinger

A practical bent

Born in Austria in 1945, Zeilinger was destined to be an experimentalist. As a small boy he took great joy in tinkering with anything mechanical – pulling things apart, putting them back together and, as he readily confesses, often leaving them with "at least one piece broken".

This natural curiosity was coupled with an exposure to science from an early age, with his father, a chemist and bacteriologist, taking his inquisitive young son on trips to his lab. After receiving inspiring lessons from his high-school physics teacher, Zeilinger became hooked on the subject and took up a place at the University of Vienna to continue his studies.

> If you have not thought of a counter argument to your scientific ideas, Zeilinger will probably find it

After doing a PhD in solid-state physics under the guidance of top experimentalist Helmut Rauch, Zeilinger emigrated to the US and took up a postdoc position at the Massachusetts Institute of Technology. A brave new world welcomed him on the other side of the Atlantic – one where scientists were more competitive yet had greater freedom to express their ideas. Relishing this freedom, Zeilinger formed valuable relationships with other researchers there, including Nobel laureate Clifford Shull, who taught him the merits of doing more experimental work than appears to be strictly necessary. But in 1983 Zeilinger had to return to Austria for family reasons.

Since then, he has gained international renown. Having held teaching and research positions in Innsbruck, Oxford, Munich and Paris, Zeilinger is now based back in Vienna, with a research group of about 35.

Quantum technology

At the heart of many of Zeilinger's experiments is the concept of entanglement, in which two particles become inextricably linked without actually interacting with each other. In 1997 Zeilinger and co-workers used entanglement to demonstrate the world's first "quantum teleportation", the idea that the full quantum description of a particle can be transferred instantaneously over an indefinite distance. His group has since gone on to teleport photons over several kilometres and to successfully entangle more than two particles.

Zeilinger is also keen to probe the boundary between the classical and quantum worlds. In 2003 he helped to observe the interference pattern created when fluorinated buckyball molecules ($C_{60}F_{48}$) pass through a double slit – the classic signature of wave–particle duality. These molecules have set the record as the most massive single particles to have displayed quantum interference, although they are still much smaller than a true "macroscopic" object.

In addition, the research team has carried out a number of tests of quantum cryptography, which exploits Heisenberg's uncertainty principle to encode an ultra-secure cryptographic key in a string of photons. Zeilinger and colleagues demonstrated the commercial potential of the technology in 2004 by using it to transfer a €3000 donation to their lab from the Bank of Austria in Vienna. This work has gone hand in hand with studies into quantum computers – machines that could in principle far outperform their classical equivalents by carrying out hugely parallel computations – with each bit capable of existing as a superposition of 0 and 1 rather than just a 0 or 1.

Beyond science

Zeilinger's natural interest in philosophy ties in closely with his work. He says that quantum teleportation, for example, raises some very deep questions about the nature of reality. When an object is teleported, it is the properties of that object that are transported rather than the object itself. Zeilinger believes this fact demonstrates that information, or knowledge, can have a more fundamental meaning than a concrete, objective reality, and that, ultimately, reality and information are indistinguishable. According to Zeilinger, when a quantum state is taken to represent the knowledge we have of a system rather than the system itself, the paradoxes that appear to lie at the heart of quantum mechanics disappear.

This tendency to philosophize has taken Zeilinger far and wide. He has met the Dalai Lama twice – in India in 1997 and then in his Innsbruck lab a year later. There, he gave the Dalai Lama a crash course in quantum physics, demonstrated the double-slit experiment using a photon counter and exchanged ideas on the similarities between Buddhist and scientific thinking. It emerged that observation plays a key role in both Buddhism and quantum theory, and the Dalai Lama agreed that there are limits to what we can know in principle, rather than merely in practice. But the Buddhist leader refused to accept that we cannot know which path a photon takes in a two-path quantum interference experiment. "Continuity of existence is very important to Buddhists because it leads to reincarnation," notes Zeilinger.

While he is a keen learner, Zeilinger also loves to teach. He was one of the first academics in Austria to actively engage the public's interest in science, for example teaching quantum physics to kindergarten children on television. This has made him something of a "pop star", says his colleague Markus Arndt, but has earned him disapproval from academic peers who are scornful of such media attention.

Neither the stardom nor the criticism seem to have gone to his head, however. Despite having more than two dozen awards to his name, and notwithstanding the excellence that he pushes for in those around him, Zeilinger's students and postdocs speak of how he openly admits to making mistakes. As he explains to his first-year lab students, "You are allowed to break things. You only find out by trying."

This willingness to try things out, even if it proves fruitless, is allied to an open-mindedness summed up by Arndt. "If you have not thought of a counter argument to your scientific ideas, Anton will probably find it," he says. "If you have not yet identified a vision beyond the next decade, Anton will probably ask you for it. And if you believe you have found a truth, Anton will ask you for an alternative truth."

Energy

Nuclear future for China

Flying the flag for fusion
The EAST reactor, which is about to start operating.

Chinese development of nuclear energy is advancing on two fronts. Last month the country announced that it is to build 32 new fission plants over the next 15 years, taking nuclear's share of electricity generation from just over 2% to about 5%. Later this month, meanwhile, Chinese scientists will finish testing a new fusion reactor, known as the Experimental Advanced Superconducting Tokamak (EAST), the world's first fully superconducting tokamak device.

More than 70% of China's electricity currently comes from coal. But as the country's energy demand rises, it is increasingly looking to nuclear as a less-polluting energy source. The new fission reactors, announced by Shen Wenquan of the China National Nuclear Corporation at the end of February, will cost about $50bn and will add to the country's nine existing reactors. The new plants will probably still be based on conventional pressurized water reactors, but China also plans to build a prototype of an advanced "pebble-bed" reactor in the next five years. In common with several other Asian countries, it is also developing the technology for fast reactors.

As China's energy demand rises, it is increasingly looking to nuclear as a less-polluting energy source

But while China is keen to expand its output from fission reactors, in the longer term it is also looking to fusion as an energy source. It is one of seven partners in the €10bn International Thermonuclear Experimental Reactor (ITER) project, which is due to start up in around 2016 (*Physics World* March pp12–13), and this summer is due to begin operating EAST in Hefei in eastern China. At a cost of under $40m, EAST is cheap compared with ITER, but is likely to be the first fusion experiment to confine the plasma in its doughnut-shaped tokamak using just superconducting magnets.

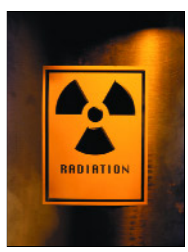
This will make the reactor an important test-bed for ITER, which will also use such magnets, according to EAST project leader Yuanxi Wan. EAST is designed to demonstrate "steady-state" operation by confining its plasma for stretches of up to 1000 s, rather than the roughly 10 s bursts typical of the world's leading fusion devices (although these devices can generate greater power outputs). Steady-state operation is an essential feature of power stations, which must maximize their output to be cost-effective.

Edwin Cartlidge

...but nuclear is not the answer for the UK

Britain should not look to nuclear power to fulfil its future energy needs, says a government advisory body. The Sustainable Development Commission has spent a year analysing the pros and cons of nuclear power as part of a governmental review of energy, and concludes that the UK can tackle climate change and ensure the security of its energy supply without building a new generation of nuclear power stations. The UK currently generates about one-fifth of its electricity from nuclear power, but most of its reactors will have closed down by 2020.

The commission recognizes that nuclear power stations emit very little carbon dioxide, can generate large amounts of electricity and increase the diversity of the UK's energy supply. But it says there are a number of shortcomings. It points out that there is still no long-term solution to the disposal of radioactive waste and believes the public may have to subsidize the construction of new reactors. It also says that the rebirth of nuclear power would prevent the growth of localized electricity generation and undermine efforts to improve energy efficiency. Finally, with an expansion of nuclear power, the UK could not then deny that capability to countries with lower safety standards, the commission adds.



Waste not wanted
A government commission rejects nuclear power.

"There is little point in denying that nuclear power has benefits, but in our view these are outweighed by serious disadvantages," says Jonathon Porritt, the commission chair. The commission concludes that the UK can instead meet its future energy needs through a combination of a "low-carbon innovation strategy" and an "aggressive expansion" of energy efficiency and renewable technology.

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● **www.sd-commission.org.uk**