The philosopher of photons

From meeting the Dalai Lama to national media star, Anton Zeilinger is on a mission to bring physics to a wider audience. Quirin Schiermeier listens in.

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Tough talking: Anton Zeilinger (left) discusses quantum physics and philosophy with the Dalai Lama.

Enlightenment is hard work — especially when you mix philosophy with quantum physics. But the Dalai Lama is always keen to investigate areas of science, no matter how complex they seem. And in 1997, when he wanted to delve into the quantum world, one of the men he invited to India was Anton Zeilinger.

Based at the University of Vienna in Austria, Zeilinger is committed to explaining his work to a broad audience. As a student, he was fascinated by both opera and the mathematical beauty of quantum mechanics. And although Zeilinger, who turns 60 in May, has just revived his old student hobby of playing walk-on parts at the Vienna State Opera House, it was fundamental physics that won his heart. Over the years, his scientific achievements, as well as his communication skills, have made him a media star, at least in his native Austria.

"Explaining science to the public is hard work," he says jovially, while clearing a spot on a visitor table that is overflowing with manuscripts. He knows that fellow researchers can be scornful of the media attention he gets. And he admits that he sometimes feels uneasy about popular portrayals of his work. When the leading German news magazine *Der Spiegel* last month featured him on its cover as 'The Sorcerer from Vienna', with a story full of references to time travel, parallel universes and pop culture, he was not too happy.

But we need capable translators. Quantum mechanics so often contradicts our ideas of how cause and effect determine what we see, that many physicists struggle to accept its description of the physical world. Even Einstein felt notoriously spooked by the concept of quantum entanglement, in which independent quantum particles remain mysteriously linked. So journalists appreciate Zeilinger's ability to translate the mathematics into a working philosophy.

Zeilinger is also happy discussing the challenges of quantum mechanics — both technical and philosophical. "I strongly feel that we need to clearly tell the people what we don't understand," he says. For example, quantum physicists have yet to find a satisfying explanation for the randomness inherent in the quantum world. "Mysteries of that kind are among the biggest questions of the twenty-first century," Zeilinger says.

When the Dalai Lama made a return visit to Zeilinger's lab, then in Innsbruck, a year after their first meeting, he confessed to having difficulties with the philosophical implications of quantum physics, especially the role of chance and causality in nature. As the idea of determinism is central to Buddhism, the existence of purely random acts might call into question Buddhist doctrine, he said.

But Zeilinger is keen to stress that his research, and the ground-breaking quantum-optical experiments he has designed, are all explained by the known laws of physics. Less mysterious, perhaps, but equally fascinating.

A tangled tale

When a photon of polarized laser light passes into certain types of crystal, it can generate a pair of lower-energy photons that are 'entangled' in terms of their respective polarization — the vertical or horizontal direction in which they oscillate. In Zeilinger's hands, these entangled particles offer revolutionary ways of communication and computation.

One application, cryptography, has already been demonstrated, and is close to being commercially exploited. Quantum cryptography cannot prevent a spy from trying to decode a secret transmission. But the spy's actions will irreversibly modify a secret quantum key sent from the sender to the receiver, providing cast-iron proof that an unwanted third party is listening in.

As quantum information is so easy to disturb, transmitting entangled photons over useful distances is a considerable challenge. But the technology is making good progress. Last year, for example, Zeilinger's group performed the first real transfer of money from a bank using quantum cryptography.

The possibilities of multiparticle entanglement are endless, Zeilinger says. Until now, entanglement experiments, such as the 'teleportation' of a complete quantum state from one particle to another, have used up to four particles (usually photons). If it were possible to 'connect' even more particles and maintain high-quality entanglement over greater distances, this may open up entire new worlds of quantum communication, he says.

Zeilinger dreams of using satellites for quantum communication between any two spots on the globe. Although transmitting entangled photons on the ground is limited to distances of less than 20 kilometres, in space it is much easier. A feasibility study for supplying satellites with high-precision lasers to produce entangled photons and send them to Earth has already been made. Zeilinger hopes that the European Space Agency will fund a payload of such components to the International Space Station by 2010.

The ultimate goal might be to connect a network of future quantum computers. Zeilinger's group has recently demonstrated the first one-way quantum computer, in which an entangled multi-photon state starts out with all of the possible calculation results, and proceeds by irreversible steps to reach the final answer (P. Walther *et al.* *Nature* **434,** 169–176; 2005). But a future 'Internet' based on the laws of quantum physics is currently pure science fiction.

Something else for the Dalai Lama, and the rest of us, to meditate over. ■

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