Shoucheng Zhang

(1963–2018)

Co-discoverer of topological insulators.

Shoucheng Zhang's pioneering work helped to launch a new branch of physics devoted to a class of materials called topological insulators. Like all insulators, these materials do not conduct electricity in bulk, but do so at their surfaces — because of quantum-mechanical phenomena best understood using tools from the mathematical field of topology. He was widely expected to share a Nobel Prize in Physics for his role in the prediction and discovery of the first topological insulator, made of bilayers of the semiconductors cadmium telluride and mercury telluride.

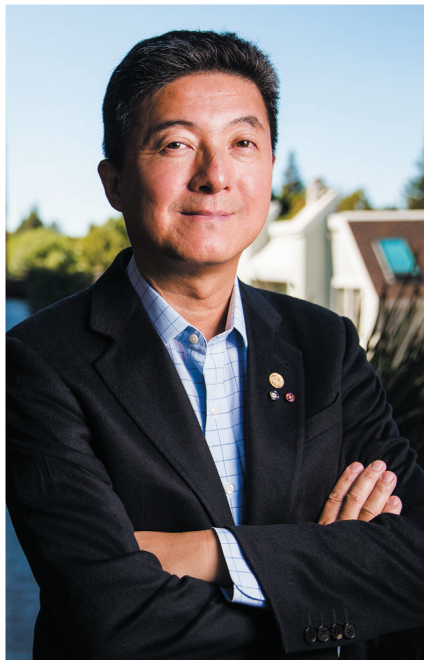
He was 55 when he took his life on 1 December 2018, following a period of depression and insomnia.

Zhang was born in Shanghai. His parents were engineers. He largely skipped high school, entering the physics programme at Fudan University at the age of 15. Selected to finish his undergraduate study abroad, he received his *Diplom-Physiker* from the Free University of Berlin. In 1983, aged 19, he began a PhD on supergravity at the State University of New York at Stony Brook, with physicist Peter van Nieuwenhuizen.

In Zhang's final year, on the advice of his hero (and, later, friend) C. N. Yang, he switched to condensed-matter physics under my supervision. After a postdoc with J. Robert Schrieffer at the Institute for Theoretical Physics at the University of California, Santa Barbara, he moved to the IBM Almaden Research Center in San Jose, California, and then in 1993 to the physics department at Stanford University, where he remained until his death.

Zhang was a theoretician whose work inspired many experiments. Conceptually, he played a leading part in mapping a taxonomy of the various 'species' of topological insulator. He identified a key feature of electronic structure — band inversion — that is central to transforming normal insulators into topological ones under certain conditions.

His studies also guided the discovery of actual materials. In particular, in 2006 Zhang and his co-authors predicted the existence of a topological insulator (B. A. Bernevig *et al. Science* **314**, 1757–1761; 2006), which led to an experimental study the following year (on which he collaborated) that achieved the first observation of such an insulator in nature (M. Koenig *et al. Science* **318**, 766–770; 2007). The topological insulator had near-perfect conduction at its surface edges thanks to a phenomenon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called the quantum spin Hall effect.

Late last year, he was exploring particles called Majorana fermions, which were mooted in 1937 as a (still unconfirmed) theory of the neutrino. 'Emergent Majorana modes' are predicted to occur at the edges of topological superconductors — cousins of topological insulators. Zhang proposed that these exotic particles could be observed in a device made of a conventional superconductor on top of a film of yet another species of topological insulator — one that exhibits the 'quantum anomalous Hall effect'.

Several of Zhang's other works were also foundational. I had the privilege to collaborate with him on the theory of fractional quantum Hall liquids (S. C. Zhang *et al. Phys. Rev. Lett.* **62**, 82–85; 1989). These are states with a form of topological order that results in a single electron breaking up into a set of emergent particles, each of which carries a fraction of the electron charge. The basic understanding of these states, for which our Stanford colleague Bob Laughlin received a Nobel Prize in Physics, ranks among the most important pillars of condensed-matter physics. I vividly recall the 'aha' moment when Zhang, drawing on his background in formal field theory, showed how the basic physics of these states follows simply and intuitively from the resulting field equations.

In 2013, Zhang co-founded the venture-capital firm DHVC, whose motto, 'In math we trust', was characteristic of his thinking. It invested hundreds of millions of dollars in more than 100 technology start-ups, including many working with blockchain technology, artificial intelligence, big data and robotics. In recent years, he was increasingly a public intellectual; many of his lectures can be viewed on YouTube. His numerous awards included a share of the American Physical Society's pre-eminent award for condensed-matter physics — the Oliver E. Buckley Prize — and the 2015 Benjamin Franklin Medal in Physics.

Zhang met his wife, Barbara, in kindergarten in Shanghai. She joined him at graduate school at Stony Brook (to study statistics, in her case), becoming a software engineer at IBM until her recent retirement. The warmth and hospitality of their household was legendary. Dinners were often shared with many family members and myriad close friends from the many communities to which Shoucheng belonged. This personal contact left an indelible impression, in particular, on many of his students and postdocs. Always apparent was the love and mutual pride between Shoucheng and his children, Brian (now doing a PhD in statistics at the University of Oxford, UK) and Stephanie (a master's student in educational technology at Stanford).

Enthusiastic and brilliantly creative, Zhang had a deliberate style that combined mathematical precision and elegance with a close and direct connection to phenomena that were measurable experimentally. He had an uncanny knack for spotting promising scientists, and was generous with his time and thought in mentoring them. He was a key catalyst of the mutually beneficial relationship that has developed over the past two decades between the condensed-matter physics communities in the United States and China.

Shoucheng was infectiously interested in everything — from the philosophy of the Roman poet Lucretius to the seascape in Cabo San Lucas, Mexico. He is sorely missed. ■

Steven Kivelson *is professor of physics at Stanford University and a member of the Stanford Institute of Theoretical Physics, California, USA. He was Shoucheng Zhang's adviser on condensed matter for the final year of his PhD, and collaborated with him on many projects thereafter.*
e-mail: kivelson@gmail.com