BIOGRAPHICAL MEMOIRS

Figure 1 Shoucheng Zhang. *Oil on canvas, by Pamela Davis Kivelson (2024).*

Shoucheng Zhang

February 15, 1963 – December 1, 2018
Elected to the NAS, 2015

A Biographical Memoir by Steven A. Kivelson and Xiaoliang Qi

This is a personal biography. Shoucheng Zhang was a dear friend of both of ours, a brilliantly creative and deep physicist, and a widely curious intellectual with an irrepressible joy in exploring all aspects of life. It is difficult for us to accept that this vibrant person is no longer with us. His numerous awards included a share of the American Physical Society's 2012 Oliver E. Buckley Prize, the pre-eminent award for condensed-matter physics, and the 2015 Benjamin Franklin Medal in Physics.

Shoucheng was born on February 15, 1963, in Shanghai. His parents were engineers. In 1977, immediately following the end of the Cultural Revolution, the National Higher Education Entrance Exam of China was restarted. Without attending high school, Shoucheng took the first exam and got admitted to the Physics Department of Fudan University in Shanghai. He was fifteen years old—the youngest student in his class. A few months later, on the basis of his outstanding academic performance, he was accepted to an exchange program to finish his undergraduate study abroad at the Free University of Berlin, from which he received his *Diplom-Physiker*.

In 1983, aged nineteen, he began a Ph.D. on supergravity at the State University of New York at Stony Brook, under the direction of Peter van Nieuwenhuizen. In Shoucheng's final year, on the advice of his hero C. N. Yang (also a professor at Stony Brook), he switched to condensed-matter physics under the supervision of one of us (SAK). (On these grounds, SAK continues to boastfully count Shoucheng among his students; Yang remained a lifelong friend and mentor of Shoucheng's.) After a postdoc with J. Robert Schrieffer at the Institute for Theoretical Physics at the University of California, Santa Barbara, Shoucheng moved to the IBM Almaden Research Center in San Jose, California. In 1993, he was hired as a faculty member in the Department of Physics at Stanford University, where he later became the J. G. Jackson and C. J. Wood Professor in Physics.

Zhang was a theoretician with a unique style that emphasized both simple fundamental physical principles and concrete predictions that were verifiable in experiments. One of us (SAK) had the privilege to collaborate with him on his first significant work in condensed matter physics, on the theory of fractional quantum Hall liquids.[1] These are states with a form of topological order that results in a single electron breaking up into multiplets 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 the Nobel Prize, ranks among the most important pillars of condensed-matter physics. Zhang's paper offered a new perspective on this problem, starting from a precise reformulation of the quantum Hall problem in terms of a complex scalar field (representing "composite bosons") coupled with an emergent "statistical gauge field," governed by a Chern-Simons action. SAK vividly recalls 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.

Zhang's subsequent work had a profound effect on multiple distinct and manifestly important areas of condensed matter physics, including high-temperature superconductivity, the theoretical investigation of four-dimensional quantum Hall effects, the intrinsic spin Hall effect in semiconductors, and topological insulators. His works in each of these fields was deeply important and conceptually inspiring. Among these works, probably the most notable contribution was his pioneering work in the discovery of the quantum spin Hall effect and of topological insulators. One of us (XLQ) was fortunate to be a collaborator of his during this exciting period. Since the discovery of the integer and fractional quantum Hall effects in the early 1980s, there had been long-standing efforts to explore other categories of topological states of matter—states that are distinct from ordinary phases of matter and often support novel quantization of physical quantities. A particularly significant aspect of these studies, as Zhang often emphasized, is that "topological distinctions" are precise despite the daunting ways in which real-world materials display complexity. In 2004–05, roughly concurrent papers by Charles L. Kane and Eugene J. Mele[2] and by B. Andrei Bernevig and Zhang[3] marked the discovery of new topological states, now referred to as quantum spin Hall states.

The following few years witnessed a sequence of breakthroughs, including the generalization of quantum spin Hall states to the much larger class of new states known as topological insulators and topological superconductors, and the experimental realization of many ensuing theoretical predictions. Zhang's contribution in this "new topological state revolution" was pioneering and fundamental. In particular, in 2006, Zhang and his then students Bernevig and Taylor L. Hughes made the first realistic material prediction for a quantum spin Hall state in a HgTe/CdTe quantum well.[4] This led to an experimental study the following year (on which he collaborated) that achieved the first observation of such an insulator in nature.[5] In the next few years, Zhang's group continued to make pioneering contributions, including some of the earliest proposals of three-dimensional topological insulators, topological superconductors, and quantum anomalous Hall effects. On a historic note, the early examples of topological states (Haldane spin chain and quantum Hall states) occur in strongly correlated electron systems, whereas research on spin-orbit coupling was mainly carried out in the context of semi-conductor physics, in which interaction effects are often weak. The corresponding two research communities largely remained separate until 2003, when work on the intrinsic spin Hall effect by Zhang, in collaboration with Shuichi Murakami and Naoto Nagaosa and in concurrent work by Jairo Sinova and collaborators, connected the two subfields and successfully motivated people to begin conversations across the border.

One of us (XLQ) began working with Zhang in 2004, first as a visiting student and then as a postdoc. XLQ clearly remembers how he, in common with many other of his contemporaries with interests in the physics of strongly correlated electrons, was attracted by the conceptual beauty of Zhang's 2003 work. But it is characteristic of Zhang's philosophy of science that, despite his native inclination to focus on elegant and abstract theoretical issues, he always maintained an essential commitment to relate theory to observable phenomena. After the discovery of quantum spin Hall effect, Zhang played a pioneering role in convincing people with different research backgrounds, both theorists and experimentalists, to work on this new field, and indeed he actively participated in several such research collaborations. His visionary theoretical insights and remarkable leadership in gathering different talents was essential in the rapid transition of this new research field from abstraction to realization in real-world materials. He was the catalyst for the collaborations between theory and experiment that enriched this field.

Without pausing his research program, 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 the succeeding years, he increasingly became a public intellectual; many of his lectures can be viewed on YouTube.

Shoucheng met his wife, Barbara, in kindergarten in Shanghai. She joined him while he was in graduate school at Stony Brook (to study applied mathematics and statistics, in her case). She then worked as a software engineer at IBM until her retirement in 2014. The warmth and hospitality of the Zhang 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 (a computational biologist) and Stephanie (an education technology researcher).

Enthusiastic and brilliantly creative, Shoucheng had a deliberate style that combined mathematical precision and elegance with a close and direct connection to phenomena that were experimentally measurable. He had an uncanny knack for spotting promising scientists and was a strong advocate for opening educational opportunities to international students. Zhang was a key catalyst of the mutually beneficial relationship that developed over the first quarter of the twenty-first century between the condensed-matter physics communities in the United States and China. (This is a legacy that is currently under attack and should be vigorously protected.) Zhang's own study-abroad experience in Germany formed the basis of a decades-long collaboration with colleagues at the University of Würzburg, and he retained a lifelong fascination with German history and culture.

Shoucheng's intellectual and aesthetic interests were broad and joyful. He also took great delight in exuberantly sharing his latest enthusiasm—from the mathematics underlying blockchain to an avid interest in the history of U.S. democracy and from the philosophy of the Roman poet Lucretius to descriptions of the seascape in Cabo San Lucas, Mexico. SAK recalls that one of the pleasures of being Shoucheng's friend was looking forward to being grilled on what was interesting in whatever book he was reading at the time. Some of this wholehearted joy is reflected in the accompanying portrait of Zhang, now on display in the Geballe Laboratory for Advanced Materials at Stanford, where Zhang worked. It was painted by the artist Pamela Davis in 2023.

Shoucheng took his own life on December 1, 2018. It is hard to accept that this joyful, successful, beloved person could do something so tragic. Shoucheng had for years shouldered stresses without any outward sign of a lessening of his joy and optimism. Moreover, his family life—which was central to his identity—was exceptionally loving and supportive; his beloved children, Brian and Stephanie, were (and are) thriving. Yet those of us who knew Shoucheng realize that there was a convergence of many sources of anxiety at the time of his death, and that he had for years privately struggled with depression and insomnia. Although the search for explanations by the survivors is strongly instinctual, we have to accept that the precise reasons for this tragedy can probably never be fully understood. We are left wishing there had been something we could have done—some intervention or some indication of how much we treasured his friendship—that could have averted this enormous tragedy. Absent that, we continue to keep his memory alive among family, friends, colleagues, and students, with deep gratitude for the brilliance he shared, for the friendships he fostered, and for the humanity he never stopped showing. He is sorely missed.

References

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