Gen Shirane

1924–2005

BIOGRAPHICAL *Memoirs*

A Biographical Memoir by Stephen Shapiro, John Axe, Haruo Shirane, and Tatsuo Shirane

NATIONAL ACADEMY OF SCIENCES

GEN **SHIRANE**

May 15, 1924–January 16, 2005

Elected to the NAS, 1989

By Stephen Shapiro, John Axe, Haruo Shirane, and Tasuo Shirane

He was simply a man on a mission,

To use neutrons, a product of fission

To put on display the games crystals play

And he swept us along in addition.

—John Axe

Gen Shirane, who pioneered and became one of the world's leading experts in the use of neutron-scattering to study the properties of materials, received a Bachelor of Engineering degree in 1944 and his Ph.D. in Physics in 1947 from the University of Tokyo. His doctoral thesis was on ferroelectricity—the study of materials that exhibit a spontaneous electric polarization—a subject he never left and to which he made major contributions throughout his career. Gen immigrated to the United States in the early 1950s and took a position at Pennsylvania State University, where he continued his work on ferroelectricity. It was from there that he published his first neutron-scattering paper, based on experiments he had performed using the graphite research reactor at the Brookhaven National Laboratory (BNL). Gen formally joined the BNL when its High Flux Beam Reactor was being built, and he remained based at the laboratory for the rest of his scientific career.

Early Japanese years

Gen Shirane was born in Nishinomiya, Japan, a town east of the present-day city of Kobe, to Jiro and Sawano Shirane. The youngest of four children and the only boy, he was affectionately called "Gen-bō" (Gen boy) by his parents and sisters, who doted on him. As a result, he became quite spoiled, but the family recognized that he was also very talented. His oldest sister, Kiyoko, said that all the brains of the family went to the last child.

Gen moved to Tokyo to enter the First High School, equivalent to first two years of college, in 1942 at the age of 18. He then attended the University of Tokyo, where he

Gen Shirane at age 6.

majored in aeronautical engineering. Pursuing this specialty probably saved Gen's life—he was spared from being drafted into the Army, like many other young men his age, in the waning stages of World War II. Gen retained his interest in aeronautics after graduating, but he switched to physics in 1947 because the U.S. Occupation banned the design and fabrication of airplanes in Japan. This was an enormous gain for physics!

Gen entered graduate school at the University of Tokyo and rented a room with his best friend at a large house that had miraculously escaped the massive firebombing of Tokyo two years earlier. The widowed owner of the house had a talented piano-playing daughter, Sakae, who was enamored by the two male graduate students. She eventually chose Gen and they were married in 1950. Their first son, Haruo, was born in 1951, and the second son, Tatsuo, in 1955.

Gen Shirane and family in Pittsburgh, PA 1961.

Gen became a research associate at the Tokyo Institute of Technology, where he began his lifelong interest in ferroelectricity. His studies included the use of X-ray diffraction to measure the structures of perovskite compounds exhibiting ferroelectricity. This interest ultimately led to his immigration to the United States.

Early years in the United States

Gen first came to the United States in 1952 to work with Raymond Pepinsky, the world's leading scholar in ferroelectricity, at Penn State University, where they did X-ray studies of ferroelectric structures and came to recognize the need for neutron scattering to definitively determine the different structural models.

Gen continued these efforts at the Westinghouse Research Laboratory, which had a small research reactor, and after six years he moved to Brookhaven in order to take advantage of the most advanced such facility, the High Flux Beam Reactor (HFBR). He brought along one of his colleagues at Westinghouse, David Cox, and the two of them joined forces with Chalmers Frazer, already at BNL. This move demonstrated two of Gen's tendencies: to "go where the action was" and to collaborate with exceptionally competent people.

But even though he spent most of his career in the United States, Gen's affinity for Japan persisted throughout his life. In the early days of the HFBR he invited influential Japanese physicists to visit Brookhaven, where he demonstrated the role of neutrons in solving problems in condensed-matter physics. He continually trained Japanese scientists at the HFBR by inviting them as visitors or hiring them as postdoctoral fellows. In the 1980s, Gen was instrumental in establishing a U.S.-Japan Collaboration on Neutron Scattering, whereby young Japanese physics students would come to the United States to "learn the trade" with him and then return home to continue their research and train others in the field. Many of these "graduates" of Gen's program became scientific leaders in Japan.

The BNL years

Gen Shirane made his most significant contributions in the area of neutron scattering after his arrival at Brookhaven. Beginning in the early 1960's he published over 700 scientific papers, many of them seminal in nature.

The underlying theme of Gen's work was the study of phase transitions, by which solids undergo changes of symmetry as the temperature, pressure, or field (electric or magnetic) is changed. It is worth noting that prior to the 1950s, physicists generally studied solids in terms of single-particle effects, but from that period on they began to view interactions in solids in terms of cooperative, many-body phenomena. Neutron scattering had already been shown to be uniquely capable of measuring collective effects in solids, and Gen's early experiments in phase transitions provided many convincing examples of cooperative behavior of atoms in solids.

His first studies, in collaboration with Chalmers Frazer, focused on phase transitions in ferroelectric materials, which have important technological applications because the lower symmetry in the ferroelectric phase allows for piezoelectricity and nonlinear optical properties. Based on this work, Gen coauthored a book titled *Ferroelectric Crystals* (Jona and Shirane, 1962), which is considered a classic and still used extensively by researchers.

Gen Shirane and Julius Hastings on the floor of HFBR in 1986.

These studies led to Gen's experimentation, during the mid-1960s and '70s, on other structural phase transitions. The soft mode theory of P. W. Anderson and W. Cochran predicted that (a) the frequency of a lattice vibrational mode would tend to zero as the transformation temperature was approached and (b) the solid would distort to a new state of lower symmetry. Gen, working with John Axe (BNL), Yasusada Yamada (Institute of Solid State Physics, Japan), and others, performed elegant experiments that confirmed this theory on a wide variety of systems (Shirane and Yamada, 1969; Shapiro et al., 1972) and discovered new features that were not envisioned in the theory, such as incommensurate structures (Hastings et al., 1977). For the efforts documented in 1969 and 1972, Gen was awarded the Buckley Prize by the American Physical Society and, shared with John Axe, the American Crystallographic Association's Warren prize in 1973.

Recognizing, in the early 1960s, that the magnetic properties of the neutron were conducive to studying magnetic materials, Gen performed definitive measurements on the magnetic structure of solids and the collective motions of "magnetic moments" in a magnetically ordered solid such as iron. These excitations, called spin waves, revealed information about the magnetic interactions within that solid. His experiments on Fe, Ni, and Co formed the basis of our present understanding of magnetism in these elemental solids.

Gen returned to this field in the mid-1980s, when questions were raised about the nature of the paramagnetic state, which exists at temperatures high enough that the thermal energy destroys the ordered arrangement of the magnetic moments. In this research endeavor, as well as in others, Gen interacted closely with the BNL solid-state theory group, most notably Martin Blume and Victor Emery.

Another theme of Gen's work was the magnetic and structural properties of lower-dimensional systems. Although we of course live in a three-dimensional world, anisotropic interactions can affect certain solids' properties such that they resemble a one- or two-dimensional material. This can enhance research outcomes, as detailed calculations are much easier in one or two dimensions than they are in three dimensions. In the 1970s, Gen and his collaborators extensively studied one- and two-dimensional magnets under diverse types of interactions (Birgeneau and Shirane, 1978). For example, they performed some of the seminal experiments on structural analogs of lower-dimensional systems where the electron-lattice interactions are fundamental (Axe, Iizumi, and Shirane, 1980).

Around the same time, Gen, Robert Birgeneau (MIT), and Roger Cowley (Oxford) performed important experiments on random magnetic impurities in antiferromagnetic systems (Yoshizawa et al., 1982). These efforts showed that when a nonmagnetic atom is placed in an ordered magnetic solid, the magnetic properties are altered in a very surprising way—that is, a random staggered field is generated.

Another important part of Gen's body of work involved the study of the properties of superconductors. He performed the first measurements, using neutrons, on the effect of the energy gap on phonon linewidths in strong-coupling superconductors. This direct measure of electron-lattice coupling was one of the key parameters in the Bardeen-Cooper-Schrieffer theory of superconductivity. Gen subsequently collaborated on neutron studies of the interplay of superconductivity and magnetism in rare-earth ternary solids, in which the magnetism and the superconductivity result from different electronic states (Moncton et al., 1977). These experiments demonstrated that magnetic order and superconductivity are not always incompatible, contrary to prevailing wisdom.

When high-temperature superconductivity burst upon the scene in 1987, Gen and his collaborators were well positioned to address it. His past experiences in magnetism, structural-phase transitions in perovskites, lower-dimensional phenomena, and superconductivity came together nicely in the series of experiments he performed in this rapidly advancing and exciting field (Birgeneau and Shirane, 1989). This was perhaps the pinnacle of Gen's long and distinguished career. Gen and his collaborators succeeded (while others failed) in detecting magnetic fluctuations in the $YBa_2Cu_3O_7$ (Tranquada et al., 1988) and the La_2CuO_4 (Shirane et al., 1987) superconductors. The significance of his results was that they essentially defined the nature of the charge carriers, and possibly the mechanism of the superconductivity, in these high-Tc materials. In addition, Gen's studies of magnetism in the above compounds provided the first information on the role of quantum mechanics in the dynamics of lower-dimensional solids.

Toward the end of his career, Gen returned to his first love—ferroelectricity—by studying compounds, now ubiquitous in devices for manufacturing, automobiles, medical instrumentation, telecommunications, and other electronics applications, that exhibited piezoelectricity (whereby an applied strain will induce an electrical charge, or vice versa). At that time it was still a puzzle why the size of this effect was so material-dependent. But Gen, along with his early collaborator Dave Cox and others, used X-rays and neutrons to study PZT ($PbZr_{1-x}Ti_xO_3$), a material that had one of the highest piezoelectric responses. The researchers found a peculiarity of the temperature-composition phase diagram that was responsible for PZT's exceptional degree of piezoelectricity (Guo et al., 2000).

Gen loved competition, whether at home, or in the laboratory, or wherever; and he liked to win. He would stimulate his colleagues by offering to bet on almost anything, especially on the best approach for an experiment. On one occasion, after debating with some of his younger colleagues/trainees over how to perform a neutron experiment, he said, "Okay, you do it your way, I'll do it my way, and when we present our results at a neutron group meeting, they will determine the winner." To Gen's surprise, however, when the time came the trainees were declared the winner! Always reluctant to lose, he saw a way to save face, stating triumphantly, "This [contest] showed what a truly great teacher I am."

Over the whole of his scientific career, Gen's output was thorough and consistent. His energy never lagged, nor were his standards ever compromised; only superior science was acceptable to him. Gen's scientific rigor, together with his dedication to pursuing a problem until it was solved, were imbued in many of the neutron-scattering community's younger scientists from around the world, given that he often mentored them when they made their pilgrimages to the profession's Mecca—the BNL. Gen's legacy is that many of these scientists are now leaders of major research centers, including those at some of the top universities.

It is important to emphasize the consistency of Gen's scientific output over his career, only superior science was acceptable to him. He once said, "Remember in the end there are only two experiments that matter, the first and the best, and the ultimate is when they are one and the same." Gen served as head of the neutron scattering group within the physics department at Brookhaven National Laboratory for many years. He mentored many of the current leaders in the physics and neutron scattering community through their visits to BNL.

Personal life

Gen's home life supported and helped energize his scientific career. Invariably, visitors to Brookhaven were entertained at Gen's Bellport (Long Island, NY) home. Sakae, his wife of 55 years, who was known for her kindness and hospitality, was an especially thoughtful hostess. Aside from being a marvelous cook, she was so organized that she kept records of what she had served to guests; in that way, repeat visitors were not served the same dish unless they had enjoyed it. She also strived to prepare their favorite dishes.

Sakae played the piano beautifully; she in fact had been a concert pianist in Japan before immigrating to the United States. In Bellport she accompanied many local musicians and also taught piano. She undoubtedly imparted her love of music to Gen, and together they regularly attended performances at New York's Lincoln Center; he became a particular fan of the New York City Ballet.

Time with his family was important to Gen. They all went on numerous hiking and camping trips together, and often ventured into the city to enjoy the museums and concerts. His wife and sons accompanied him on many of his work trips to various parts of the world. It was in large part through this time spent with their parents that Gen's sons acquired the curiosity, integrity, persistence, and other qualities that enabled them to achieve successes in their lives. When they had their own families, Gen cherished the occasions when he could be with his grandchildren.

Gen and Sakae in Nikko, Japan.

Gen was a lifelong sports and games enthusiast. He was a black-belt judo champion in high school and college, and participated in the BNL judo club well into his 50s. While visiting his colleagues in Germany, he often played on their soccer team. And after moving to BNL he took up tennis, a sport he was still playing regularly when he passed away at the age of 80.

Gen was particularly fond of doubles; he played men's doubles with his BNL work colleagues, and mixed doubles (with Sakae) outside work. He initiated a summer "Whoosh" tournament for visitors and staff, named after the noise he would make while serving to unnerve his opponents. As he grew older, he increasingly and successfully used psychology and physics to compensate for his declining athletic ability.

Gen Shirane [r], Maurice Rice [c], and Jun Akimitsu [l].

Gen was highly competitive in everything he did, whether it was performing a neutron experiment or playing tennis—or poker. An enthusiastic poker player, he invited many a visiting scientist to participate in a "friendly" game at the Shirane residence. An integral part of an interview of postdoctoral candidates was the question of whether they played tennis or poker. Even if they said no to poker, his eyes would twinkle if they added that they were willing to learn. He would then present them with a copy of *The Education of a Poker Player* by Herbert O. Yardley, a stack of which he kept in his office.

The only person Gen could not successfully bluff was his wife. For example, Sakae had steadfastly refused to get air conditioning for their house in Bellport because she felt it was an unnecessary expense for a summer home with so many windows and fans. However, when she wanted him to retire full-time at age 75, he made her an offer that he figured she would never accept: "When you get air conditioning," he said, "I will retire." She called his bluff and had air conditioning installed. (But he never retired.)

Gen was very traditional in many ways. Long after the advent of computers, he continued plotting things by hand on graph paper, while sitting in his favorite armchair. Substance was important; style and status were not. One of his family's favorite anecdotes illustrates Gen's priorities in life. In the early 1980s he had cable TV installed in the house so that he could get better coverage of his beloved New York Yankees' baseball games. The cable technician spent hours working on the installation and fiddling with the television set. Finally, he went to Gen and sheepishly admitted, "I've never had a problem like this before. I've tried everything. The TV gets all the channels and a picture, but I can't get a color picture." To which Gen replied, "That's because it's a black-and-white TV!" To Gen, the beauty of the plays, the intricacy of the game's strategies, and the final score were important; the color of the uniforms and the grass were not.

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