The Last of the Old Masters' of Physics

I met him only once in California.

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Hans Bethe, the nuclear physicist whose elegant calculations explained how stars shine and laid the foundation for development of both the atomic and hydrogen bombs, has died. He was 98.

Bethe, who received the Nobel Prize in Physics in 1967, died Sunday at his home in Ithaca, N.Y., Cornell University announced Monday.

A reluctant but crucial participant in the World War II effort to develop nuclear weapons, Bethe later became one of the country's most passionate and persuasive proponents of disarmament. He argued that the use of such weapons would cost not only countless lives, but "liberties and human values as well."

Teller introduces Bethe

A brilliant, prolific and engaging theorist with an encyclopedic knowledge of nuclear physics, Bethe spent more than 60 years working with only a slide rule, a stack of blank paper and his enormous intellect, turning out page after page of mistake-free, complex calculations that fundamentally altered how scientists viewed the microscopic world of the atom.

"He was the last of the old masters," said astrophysicist Edward Kolb of the Fermi National Accelerator Laboratory. "He turned out classic paper after classic paper."

Bethe (pronounced BAY-ta) was the lone survivor of the remarkable group of mostly German physicists of the early 20th century — a group that included Einstein, Dirac, Fermi and Heisenberg — that deciphered the fundamental laws of matter and energy and set the stage for the remarkable technological developments of the last half of the century.

"There's no one of comparable stature alive today," Cornell physicist Kurt Gottfried told The Times in 2003. "I can't think of any physicist who was as productive at the frontier over such a long period."

Bethe was a young man literally fresh off the boat from Europe when he made his first mark on the then-infant field of nuclear physics. With two collaborators, he wrote three massive articles for the American Physical Society's Reviews of Modern Physics that, in effect, compiled everything then known about the field.

The 1936 articles, which later became known colloquially as "Bethe's Bible," clarified the theory of nuclear forces, the structure of nuclei and the theory of nuclear reactions.

They were reprinted multiple times and served as the primary text in the field for decades.

"Bethe systematically laid the theoretical foundations for nuclear physics with such clarity and care that they could be used to support major applications: stars and, later, reactors and bombs," said MIT physicist Frank Wilczek.

Bethe received the Nobel Prize for his explanation of how the sun and other stars are able to pour forth so much energy over long periods of time. Before he began his seminal work in 1938, researchers had speculated that the light and heat emitted by stars were caused either by chemical reactions or the compression of gases by the bodies' massive gravity.

Calculations ruled out both models, however: The mass of the sun was sufficient to sustain such reactions only for a few tens of millions of years, not the billions that astronomers knew our local star had survived.

Bethe was introduced to the problem at the 1938 Washington Conference on Theoretical Physics, where astronomers speculated that perhaps nuclear reactions were involved.

He went back to his office at Cornell University after the meeting and within six weeks had solved the problem. Given the known temperature of the core of the sun — about 20 million degrees Celsius (about 36 million degrees Fahrenheit) — and the proportions of carbon, hydrogen and other elements in its interior, he deduced which nuclear reactions could be responsible for its radioactive fire.

He ultimately developed a six-step cycle in which carbon and nitrogen atoms act as catalysts for the conversion of four hydrogen nuclei (protons) into one helium nucleus. The very slight mass lost in the process is converted into large amounts of energy, according to Albert Einstein's famous equation, E = mc2.

Bethe later remarked with typical modesty that he found the answer by "looking through the periodic table [of elements] step by step. So you see, this was a discovery by persistence, not by brains."

One oft-told story about Bethe recounts the evening after he discovered the secrets of starlight. During a late-night stroll, his fiancee, Rose — daughter of theoretical physicist Paul Ewald — remarked on how beautiful the stars looked. He responded: "Yes, darling, and I'm the only one on Earth who knows how they do it."

Bethe and his Cornell colleagues then verified five of the six steps in the laboratory; the sixth was reproduced by researchers at Cambridge University. The entire six-step cycle takes 5.4 million years to complete.

With the coming of World War II and by then a naturalized U.S. citizen, Bethe joined the war effort, first at MIT's Radiation Laboratory and later as the chief theoretical physicist for the Manhattan Project at Los Alamos, N.M., even though he believed development of the atomic bomb was morally wrong, and that the U.S. — and the world — would be far more secure without it.

"He had a strong sense of duty," said physicist Richard Garwin. "He was an example to many of us in this regard."

Bethe's solid, plow-through-the-problem approach earned him the nickname the Battleship; in contrast, his close colleague and office-mate, physicist Richard Feynman, became known as the Mosquito Boat because he skittered around a problem from all sides at once.

Together, they were a formidable pair; the formula for calculating the efficiency of nuclear weapons became known as the Bethe-Feynman formula.

At Los Alamos, "he was moderate, intelligent, indispensable," MIT physicist Philip Morrison said.

Bethe's contribution was particularly valuable, the War Department's official Smyth Report said afterward, because all aspects of the novel project were being conducted simultaneously based only on theoretical considerations and because of the impossibility of conducting small-scale explosions for study.

His group had to work out the critical size of the fissionable mass — exactly how much was necessary for the bomb to explode — and had to decide in advance the likelihood that a continuing nuclear reaction might destroy the entire world.

Despite his moral qualms about the bomb, Bethe considered it a necessary evil. He felt that its use in Japan was justified because many more Japanese and American lives would have been lost in an invasion of the island nation.

After the war, he became a prominent spokesman against proliferation — arguing without success that atomic bombs should be placed under strict international controls. He made countless speeches throughout the country arguing his case.

He initially opposed Edward Teller's plans to build the hydrogen bomb, arguing that it was unnecessary. "We had enough A-bombs to kill the world," he said later. "Why add an H-bomb and kill the other half? So I said no to Teller.... I would not join him at Los Alamos."

He became the spokesman for 12 physicists who opposed the project, a group that later developed the idea that the United States should publicly declare that it would not be the first to use the H-bomb "since it was not a weapon of war but a means of exterminating entire populations."

Bethe initially thought the point was moot because none of Teller's ideas for producing the bomb seemed likely to work. But in 1951, physicist Stanislaw Ulam conceived a new way to make fission bombs and Teller saw how this could be used to make a fusion bomb — using an A-bomb to trigger the H-bomb.

Bethe recognized that the bomb could be built and could undoubtedly be built by the Russians as well. "If I didn't work on the bomb, somebody else would — and I had the thought that if I were around Los Alamos, I might still be a force for disarmament," he later said.

His role was similar to that in the development of the atomic bomb, providing the theoretical underpinnings for all phases of the project.

"Interestingly, after the H-bomb was made, reporters started to call Teller the father of the H-bomb," he said. "For the sake of history, I think it is more precise to say that Ulam is the father, because he provided the seed, and Teller is the mother, because he remained with the child. As for me, I guess I am the midwife."

While Bethe did not achieve many of his arms reduction goals, he believed that all scientists should take an active role in influencing public policy.

"Whether or not their governments respond to their advice, scientists have an obligation to speak out publicly when they feel there are dangers ahead," he wrote.

Bethe was an advisor to presidents from Truman to Clinton, and served on dozens of advisory committees When the idea of antiballistic missile systems became popular under President Johnson in 1967, Bethe and Garwin published an article in Scientific American arguing that such systems would add to the insecurity of the U.S. as well as the world — a position he held until his death.

Even with the best system, he wrote, there would be too many incoming targets to stop, and it would be too easy for an enemy to avoid our missiles and destroy our satellites. "Even quite feeble blows against orbiting battle stations … could render them useless."

On Aug. 6, 1995, the 50th anniversary of the bombing of Hiroshima, Bethe called on scientists all over the world to stop working on all weapons of mass destruction, and appealed to all nuclear powers to slash arsenals to fewer than 100 bombs each. That way, he argued, even if political leaders went crazy (he used Adolf Hitler as an example), at least they couldn't destroy all of civilization.

Bethe also worried that the U.S. would be seen as hypocritical for urging nuclear nonproliferation while continuing to design and build bombs, and argued that funds should go instead for improved stewardship of the weapons the U.S. already had.

Throughout his life and despite the potential distractions of his forays into the politics of arms control, Bethe continued to produce first-rate physics in an unusually wide range of disciplines. He worked on theories of metals, developed important insights into such exotica as neutron stars, and speculated how neutrinos that appeared to be missing from the sun's nuclear output could be eluding detectors because they were changing into different forms en route to Earth.

"He had enormous breadth," Gottfried told The Times in 2003.

In the 1970s, Bethe returned to his first love: astrophysics. While his earlier work explained how stars lived, he turned after his retirement to the fireworks produced when they die.

When massive stars run out of fuel, they eventually collapse under their own gravitational weight, then explode in colossal fireworks. Physicists knew most of the energy was carried away by wispy neutrinos, but the mechanism was a mystery.

Bethe's insights helped cut through complexities that had stumped much younger minds.

"Other people were cranking out large computer codes and reams of output, but they weren't cranking out understanding," Kolb said. "Hans came in with a pencil and paper and made more sense of what was coming out of the computer than the people who wrote the code."

His style of working never changed. "It was wonderful to watch him write a scientific paper," Morrison said. "He would write steadily, sentence after sentence, without looking anything up. When he got to a place that was hard, he'd go very slowly, but he wouldn't stop. Then he'd give those pages to a typist, and they'd be published as a book — without any correction whatsoever. Hans didn't know about mistakes."

After his retirement in 1975, Bethe became a strong advocate for the development of peaceful nuclear power — along with drastic conservation efforts — as the only realistic short-term alternative to fossil fuels. "The country has to realize that the energy problem is terribly serious and is likely to be permanent," he wrote.

But he never lost his interest in science. At the age of 83, he apprenticed himself to Gerald E. Brown of the State University of New York at Stony Brook to learn lattice gauge theory, which predicts how nuclear matter is transformed at extremely high temperatures into a plasma of particles called quarks and gluons.

"I'm interested in learning new things," Bethe explained. The two scientists subsequently published several papers together.

He began every day with a 45-minute bath because, he said, "You sleep, and things get somewhat [organized] in your mind; then, in the bath, I can become conscious of that."

In his 90s, with his left arm and shoulder wasted by a degenerative muscle disease, he continued to arrive daily at his office. But, he admitted, "not every day do I find anything interesting."

Hans Albrecht Bethe was born in Strasbourg in what was then Germany on July 2, 1906. He was the only child in a prominent academic family; his father was a professor of physiology at the University of Frankfurt, his mother the daughter of a physicist.

Even as a child, Bethe's mathematical ability — along with what Morrison described as his "can-do qualities" — helped him get his family through the severe depression of Germany's Weimar Republic, when currency was often losing half its value in a single day.

Twice a week after school, he would ride his bicycle to his father's bank, withdraw his salary and spend it before 1 p.m., when all stores closed for an hour. When they reopened, everything was twice as expensive. If he was late, the family only had half as much to eat the next day. After receiving his doctorate from the University of Munich, he became a faculty member at Tubingen University, where he studied the newly blossoming field of quantum theory. But because his mother was Jewish, he lost the post because of the anti-Semitism of the Nazi regime.

He emigrated, first to England, where he lectured at the University of Manchester; then to the United States and Cornell University in Ithaca, N.Y., where he became a professor of physics in 1935. Except for his work at Los Alamos, he remained on the Cornell faculty until his death.

He is survived by his wife, Rose; a son, Henry, of Ithaca; a daughter, Monica, who lives in Japan; and three grandchildren.

Remembered as the "ideal" mentor by Morrison, Bethe lured a generation of such top physicists to Cornell. "Of all the people who are so bright and accomplished, few are so sweet of temperament," said Morrison, one of many who followed Bethe to Cornell. "He finds errors in such a way as you're pleased to have the help. He never fights with anyone."

Cornell physicist Edwin Salpeter first encountered Bethe as a graduate student, and recalled how he would go from student to student, giving advice to each in turn. "He reminded me of a master chess player who plays multiple games," Salpeter said. "All great physicists are pretty smart, but very few are broad enough to listen to graduate students each working in different fields. The biggest piece of advice he gave me — and my success is partly due to that — is that you should be able to use mathematics, but don't use more than you need for a particular problem. He always went for simplicity."

For much of his life, Bethe's favorite pastimes included skiing, riding trains, mountain – climbing and travel., But he spent far more of his time simply working, often far into the night as he became engrossed in his current problem, whatever it was.