

Biographical Encyclopedia of Astronomers

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Bethe, Hans Albrecht

Born Strasbourg, (France), 2 July 1906

Died Ithaca, New York, USA, 6 March 2005

German-American theoretical physicist and astrophysicist Hans A. Bethe received the 1967 Nobel Prize in Physics for his 1939 work that clarified the sequences of nuclear reactions that provided the energy sources for the Sun and other stars engaged in hydrogen fusion (the vast majority of stars). His later significant contributions to astrophysics included providing arguments for a solution to the solar-neutrino problem drawn from weak interaction physics (rather than the details of solar models) and for work on the explosion mechanism of core-collapse supernovae

Bethe's father was a physiologist and his mother a musician and writer of children's plays. The family moved to Kiel, Germany in 1912 and to Frankfurt in 1915. He graduated from the Goethe Gymnasium in 1924 and spent 1924–1926 at the University of Frankfurt, before moving on to the University of Munich where he received a Ph.D. in 1928 for work with Arnold Sommerfeld in theoretical physics. Bethe was a physics instructor in Frankfurt (1928/1929) and at the University of Stuttgart (1929), where he worked with Paul Ewald, whose daughter Rose he married in 1939. He spent time in Rome (with Enrico Fermi) under a Rockefeller fellowship, and also held positions in Munich and Tübingen (1930/1933). His work in Germany included discussions of the behavior of electrons in metals and of one- and two-electron atoms

The son of a Jewish mother, Bethe left Germany in 1933, holding temporary positions at Manchester (1933/1934) and Bristol (1934/1935), and working with Rudolph Peierls on the structure of the deuteron (a hydrogen nucleus with a neutron as well as a proton and a vital intermediate stage in the fusion of hydrogen to helium in stars). Cornell University appointed Bethe to an assistant professorship in 1935, and he remained there, retiring as the John Wendell Anderson Professor in 1975, with portions of the cold Cornell winters spent in California. His contributions to the early development of nuclear physics were summarized in a series of 1936/1937 review articles with Robert F. Bacher and M. S. Livingston. These were, in effect, a complete text of the field as it then existed and guided experimental work into the war years and beyond

A pair of papers from 1938/1939, one (on the proton-proton chain) with Charles Critchfield, explained the two possible reaction sequences by which stars might convert hydrogen to helium with the release of energy. Bethe initially thought that the CN cycle (also called the carbon cycle, and, later, CNO tricycle) would operate in the Sun and the proton-proton (p-p) chain only in smaller stars. Later work by others made it clear that the Sun actually runs on the p-p chain, with the CNO cycle dominant in stars with more than about 1.1 solar masses. A very similar set of reactions was written down in the same time frame by Carl von Weizsäcker.

Early in World War II, Bethe (based on an encyclopedia article indicating that the armor-piercing mechanism of grenades was not understood) formulated a theory that became the foundation for research on the problem. He was a member of the staff at the Radiation Laboratory at the Massachusetts Institute of Technology (which focused on radar and related studies) in 1942/1943 before becoming chief of the Theoretical Division of Los Alamos

Scientific Laboratory (1943-1946). Bethe remained a consultant to the lab for more than 30 years.

Following World War II, Bethe's interests turned increasingly to astrophysics (though he was not, in fact, one of the authors of the short 1948 paper on cosmological nucleosynthesis on which his name appears euphoniously as Alpher, Bethe, and Gamow). He contributed to the equation of state for white dwarfs with Robert Marshak and wrote texts on atomic and nuclear physics relevant to astrophysics with Cornell colleague Edwin E. Salpeter. In the 1970s (following the discovery of neutron stars), Bethe turned his attention to studying the properties of nuclear matter. In 1979, in collaboration with Gerald E. Brown, postdocs, and students, he focused on understanding the mechanism of core-collapse supernovae, where the elements necessary for life as well as neutron stars are produced. Bethe's first key insight was that the entropy was very low and thus neutrons would be confined within atomic nuclei, allowing the collapse to reach and exceed nuclear matter density. Later, analyzing the numerical results of James R. Wilson, he suggested that neutrino energy deposition would be important in the production of a successful supernova explosion. Work on this mechanism continues today.

As early as 1934, Bethe and Peierls had wondered whether the neutrino, first hypothesized by Wolfgang Pauli and named by Enrico Fermi, might ever be observable. They concluded that the answer was probably no, but Bethe closely followed the research undertaken by Raymond Davis, Jr., for the detection of solar neutrinos. The detected flux hovered at about one-third of the predicted flux for more than 15 years, while astrophysicists, nuclear physicists, and weak-interaction physicists blamed each other for the discrepancy. In 1986, Bethe quickly saw the implications of a series of papers by S. P. Mikheyev and A. Yu. Smirnov (and related earlier publications by Lincoln Wolfenstein) concerning the possibility that the "flavor" of neutrino (electron) produced in the Sun might rotate into another flavor (the muon neutrino) that would not be detectable by Davis's experiment. A sequence of later observations and experiments in Japan and Canada have definitively shown that this is the right answer, but Bethe's stature in the community was such that most astrophysicists had come around to his point of view well before the definitive 2001 data appeared.

Bethe was a classic example of the scientist-statesman. He was one of the founders of the *Bulletin of Atomic Scientists* (devoted to not use the bombs that its founders had helped to develop), and he donated a portion of his Nobel Prize to help establish the Aspen (Colorado) Center for Physics, which he continued to visit and use as a base for both science and hiking for many years. He served as a member of the US delegation to the first, 1958, International Test Ban Conference in

Geneva and, with Richard Garwin, wrote an influential article in *Scientific American* that contributed to the adoption of the Anti-Ballistic Missile (ABM) Treaty. When it was later threatened, Bethe wrote several popular and technical articles explaining why several proposed forms of missile defense were unlikely to be successful. He was also an advocate of the Comprehensive Test Ban Treaty.

In addition to the Nobel Prize, Bethe received 10 honorary doctorates, the United States National Medal of Science, and other awards from American and German organizations. He was elected to the United States National Academy of Sciences in 1944 and as a foreign member to the Royal Society (London) in 1957. Bethe served as president of the American Physical Society in 1954.

Edward Baron

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