Biographical Encyclopedia of Astronomers

Zwicky, Fritz

Born Varna, Bulgaria, 14 February 1898

Died Pasadena, California, USA, 8 February 1974

Swiss-American physicist and astrophysicist Fritz Zwicky is remembered as more or less the first:

(1) to point out the very large amounts of dark matter in rich clusters of galaxies;

(2) to show that gravitational lensing of one galaxy by another is much more likely than star-star lensing; and

(3) with Walter Baade to associate the supernova phenomenon with the formation of neutron stars and the acceleration of cosmic rays.

Zwicky was born into a family of Swiss merchants working abroad and returned with them to the village of Mollis, in the home canton of Glarus (where he was eventually buried) in 1904. Though employed for nearly his entire career in the United States, he remained a Swiss citizen, returning home to vote, and remarking that "a naturalized citizen is always a second-class citizen." Zwicky was educated at the Eidgenossische Technische Hochschule [ETH] (Swiss Federal Institute of Technology), completing a diploma thesis (first degree) under mathematician Herman Weyl and a Ph.D Dissertation in the theory of crystals under Peter Debye (winner of the 1936 Nobel Prize in Chemistry) and Paul Scherrer in 1922. Following a three-year period as an assistant at ETH Zurich, Zwicky moved in 1925 to the California Institute of Technology (Caltech) at the invitation of its president, Robert Millikan, receiving a Rockefeller Fellowship from the International Education Board to support two years' work there.

Zwicky remained at Caltech for the rest of his professional career as an assistant (1927–1929), associate professor of physics (1929–1942), and professor of astrophysics (1942–1968), the first person to hold such a title there. Millikan had expected Zwicky to work on the quantum theory of solids and liquids, and he did indeed publish in these areas, but his primary interests gradually turned to astrophysics, beginning with cosmic rays and ideas for how they might arise In 1929, very shortly after Edwin Hubble's announcement of the expansion of the Universe, Zwicky suggested that the data (a linear correlation between distance and redshift) might be equally well explained by "tired light," that is, the idea that photons simply become less energetic after traveling very long distances. This alternative was finally ruled out only about 60 years later, with the discovery of supernovae in distant galaxies and their time-dilated light curves, showing that the expansion is real. Zwicky himself remained suspicious of large redshifts and carefully referred to "symbolic velocities," although much of his work in fact assumed the standard redshift-distance relation.

In 1933, Zwicky measured redshifts for galaxies in the Coma cluster and found that they were not all quite the same. Instead, there was a spread in velocities of the cluster members, which required a very large mass for the cluster to hold it together The effect was confirmed in 1937 by Sinclair Smith's discovery of a similarly large velocity spread in the Virgo cluster. Zwicky's paper was published in a German-Swiss journal, so he spoke of "*dunkle materie*" rather than "dark matter," and suggested that it might consist of some combination of small, faint galaxies and diffuse gas (perhaps molecular hydrogen). Modern work has shown that both of these are present (though the gas is very hot and ionized rather than molecular), but that an even larger quantity of mass is some other form of dark matter. Zwicky's results implied that the average mass of a galaxy must be much larger than that advocated by Hubble, and he originally suggested that gravitational lensing of one galaxy by another would be a good way to decide which was correct, and that it would also allow the study of galaxies too distant and faint to be seen otherwise. These 1937 ideas both proved to be correct, but with the first such lens identified only in 1975 and mass measurements and Zwicky telescopes in the 1990s.

Zwicky did live to see the confirmation of another of his seminal ideas. Baade had come to Mount Wilson Observatory in the early 1930s. He was interested in novae, and Zwicky had begun to think that these stars might be sources of cosmic rays. Together in 1933/1934 they put forward the ideas that a small subset of novae were actually much brighter supernovae—Knut Lundmark had said the same thing a year or two earlier: that the energy source was the collapse of a normal star to a neutron star, that some of the energy would go into accelerating cosmic rays, and that the Crab Nebula was an example of the remnant of such an event and that one should look for a neutron star in it Because the neutron had only been discovered in 1932, these were remarkably prescient ideas, which were confirmed by the discovery of pulsars in 1968 and a pulsar in the Crab Nebula in 1969. The Russian theoretical physicist Lev Landau also conceived the neutron star idea, probably independently, but somewhat later, and the first serious calculations were done by Julius Robert Oppenheimer and George Volkoff in 1939. Zwicky was never convinced that an object too massive to form a stable neutron star would collapse into a black hole (as implied by work by Oppenheimer and Hartland Snyder in the same year), and advocated a hierarchy of more compact objects, beginning with pygmy stars and the object Hades beyond neutron stars.

Zwicky had begun deliberate searches for supernovae using a small camera mounted atop Robinson Laboratory at Caltech in 1934, soon after his 1932 marriage to Dorothy Vernon Gates, daughter of a wealthy California family. The marriage ended in divorce, but not before Gates had paid a large fraction of the cost of the first telescope erected on Palomar Mountain, an 18-inch Schmidt in 1936, with which Zwicky began finding new supernovae for systematic study. Both supernova searches and a desire for a wide field of view to study clusters of galaxies motivated Zwicky to be a strong supporter of the 48-inch Schmidt, which began operation at Palomar in 1948. He personally discovered 122 supernovae (more than half of those known at the time of his death). Images from the Palomar Observatory Schmidt Survey also yielded a six-volume catalog of galaxy clusters, completed by Zwicky and several collaborators in 1968 and still very much in use. Following the 1963 discovery of quasars, he also compiled a catalog of compact galaxies and compact parts of galaxies, noting their connection with Seyfert

galaxies. His catalog, with Milton Humason, of high-latitude B stars (HZ objects) turned out to include both a variety of highly evolved stars and some quasars.

During and after World War II, Zwicky worked on rocketry and propulsion systems with Aerojet (later Aerojet General) Corporation, for which he received a high civilian award, the United States Medal of Freedom in 1949. He was for many years vice president of the International Academy of Astronautics, and many of his more than 50 patents were in rocketry, although his 1957 attempt to put a small mass into cislunar space (with a secondary firing of a projectile tile off a rocket as it ascended) was probably a failure

Zwicky was, in fact, a very hands-on scientist who developed not only telescopes but also ways of handling photographs, for instance the subtraction of a negative image from a positive image (in a different color, taken at a different time, or with a different polarization) to reveal aspects of galaxies and nebulae that would otherwise have been missed. Others of his ideas were extremely theoretical, for instance the possibility of estimating the mass of the particle that carries the gravitational force (the graviton) from the non-existence of structures in the Universe larger than, perhaps, 100 megaparsecs on the distance scale then in use. The absence of larger structure turns out to be correct, the finite mass of the gravity probably not.

Zwicky had a number of nonastronomical interests, including alpine climbing, the rebuilding of ravaged European libraries after World War II, and the housing of war orphans through the Pestalozzi Foundation, whose board of trustees he chaired for a number of years. Reminiscences of Zwicky (invariably attempting to reproduce his Swiss-German accent—he is said to have spoken seven languages, all badly) point out that, late in life, he became inclined to mention that he had been working on some astronomical problems for many decades, and to quote one or more of his uncomplimentary remarks about colleagues, most often "spherical bastards" (meaning from whichever way you look at them). On the other hand, his claim that a particular Mount Wilson colleague was color blind in his description of stars turned out, upon application of the Ishihara test, to be literally true This irascibility (though he could be very kind as well) is probably responsible for the paucity of honors Zwicky received, despite his enormous accomplishments. Apart from the Medal of Freedom, these were limited to the 1948 Halley Lecture (in which he presented

the concept of morphological astronomy) and the 1972 Gold Medal of the Royal Astronomical Society.

Zwicky was survived by his second wife, Margrit Zurcher, whom he met and married in Switzerland, and their three daughters.

Oliver Knill

Selected References

Arp, Halton (1974). "Fritz Zwicky." *Physics Today* 27, no. 6: 70-71.

Müller, Roland (1986). *Fritz Zwicky: Life and Work of the Great Swiss Astrophysicist, Rocket Scientist, and Morphologist (1898-1974).* Glarus: Baeschlin Publishing House

Payne-Gaposchkin, Cecilia (1974). "A Special Kind of Astronomer." *Sky & Telescope* 47, no. 5:311-313.

Thorne, K. S. (1994). *Black Holes and Time Warps*. New York: W. W. Norton Co.

Wild, Paul (1989). "Fritz Zwicky." In *Morphological Cosmology*, edited by P. Flin and H. W. Duerbeck, pp. 391-398. Berlin: Springer-Verlag.

Zwicky, Fritz (1966). *Discovering, Inventing, Researching in the Morphological Worldview*. Munich: D. Knaur. (Reprint, Glarus: Verlag Baeschlin, 1989.)

—— (1971). *Everyone a Genius*. Bern: H. Lang, 1971. (Reprint, 1992.)