A Special Kind of Astronomer

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FRITZ ZWICKY was one of the few survivors - and an unforgettable example - of the scientific individualism of earlier years. He gave the impression of thinking for himself on every subject, of making his own decision on every point.

Born in Bulgaria of Swiss parents, he retained Swiss citizenship to the end of his life. Although he lived and worked in the United States for nearly 50 years, he is quoted as saying "naturalized citizens are second-class citizens," and accordingly he remained his own man.

He obtained his degree and doctorate from the Swiss Federal Institute of Technology, and went to California Institute of Technology during 1927 as a theoretical physicist, with a fellowship from the Rockefeller International Education Board. Assistant professor of theoretical physics at Caltech from 1927 to 1929, he became associate professor from 1929 to 1942. For the next 30 years he was professor of astrophysics there, retiring as professor emeritus in 1972.
His whole career was thus, exceptionally, passed virtually in one institution, but (as will appear) he had many other activities and interests.

Although Zwicky was regarded as an astrophysicist, and probably considered himself to be such in his later years, much of his early work and publications concerned the theory of the physical properties of crystals and liquids.
His name appeared in the astronomical literature in the late 1920's, when he turned his interest to the theory of the redshifts of distant galaxies, a problem then coming into prominence for the first time in connection with relativity. His approach was and remained theoretical and unconventional. He continued to return to this subject in connection with his growing interest in galaxies, clusters of galaxies, and the distance scale and age of the universe.

Zwicky was always awake to the many possibilities of high-energy physics in astronomy, and in the 1930's he joined the growing band of astronomically minded physicists who had begun to explore the implications of cosmic rays - a subject to which Sir Arthur Eddington had called the reluctant attention of astronomers a decade earlier.

Throughout his career, Zwicky was to make insistent claims to priority in this and other controversial fields. The most important outcome of his concern with cosmic rays was his interest in supernovae. Although the idea that supernova outbursts are the direct source of cosmic rays has given way to other interpretations, the practical result was his observational study of supernovae - one of his chief legacies to astronomy. The turn to a search for empirical data was probably due to a fruitful, if brief, collaboration with Walter Baade, that great proponent and producer of observations. Together they made one of the first, and still one of the most significant, studies of supernovae. As Sir Fred Hoyle has remarked: "The early suggestion ... that neutron stars were associated with supernovae ... was an inspired suggestion."

Zwicky's speculations on redshifts led him to undertake his second great work - the study of distant galaxies and clusters of galaxies. Driven by his theoretical ideas, he realized that the great need was for more and more distant objects by which to test them. During the '30's and '40's he used the powerful facilities of Mount

Wilson (and later Palomar) Observatory to detect remote galaxies. He announced the discovery of faint and very distant clusters in Pisces, Pegasus, Cancer, Hydra, and elsewhere.

These findings channeled his efforts in two directions. He continued to speculate on the "intrinsic properties of light and corpuscles from distant galaxies," and he proceeded to apply his theoretical ideas to the observed properties of galaxies and clusters. Our present knowledge of clusters of galaxies stems largely from his observations.
Zwicky's interpretation of the clustering and motions of galaxies was both original and controversial. To the last he denied that clusters of galaxies themselves were gathered in clusters of higher order.

Two massive bodies of data remain as monuments to Zwicky's interest in supernovae and galaxies. He organized, and bore much of the responsibility of executing, a systematic photographic search for supernovae, which is the basis of our present knowledge of these objects. He proposed a classification of them (more detailed than the simple division into Types I and II that still dominates the subject), and in 1942 made estimates of their frequency of occurrence (which, though speculative and based on few data, have hardly been bettered).
Moreover, he examined the relationship between classical novae and supernovae, speculating on the underlying physical processes. The idea that a supernova collapses into a neutron star has had wide consequences and is firmly entrenched.

Zwicky discovered and catalogued tens of thousands of galaxies and clusters of galaxies, leading to the monumental six-volume Caltech catalogue of northern objects. In the course of this work, he made two discoveries of the first importance.

Examining the relationship between neighboring galaxies, he noted faint connecting "bridges," whose spectra showed primarily absorption features and were accordingly interpreted as consisting of stars rather than nebulosity.
Equally significant in the light of present work was his early interest in "compact" galaxies. He realized their relation to the Seyfert and N-type systems, and was alert to the possibility that their continuous spectra might be largely nonthermal in origin.
He was also one of the first to stress that the members of some close groups of galaxies differ greatly in radial velocity and to emphasize the theoretical importance of this fact, as well as the implications of the dispersion of velocities within a cluster.

Zwicky's concern with compact bodies was not confined to galaxies. With the collaboration of Milton Humason, he produced in 1947 a most fruitful catalogue, the list of 48 HZ (Humason-Zwicky) stars. Many of these have proven to belong to a group of objects which, if not new, were at least insufficiently recognized by astrophysics. This search for faint blue stars was later continued in collaboration with W. J. Luyten. Speculations on compact stars were later extended to the so-called pygmy stars, which are still controversial objects.

A survey of Zwicky's many published astronomical works reveals a bewildering variety. Nothing in the universe was foreign to his interest, nothing excluded from his study. Intergalactic bridges led to the exciting topic of intergalactic matter; at one point he suggested that a large part of the mass of the universe consists of undetected molecular hydrogen.
He proposed tests for the rest mass of gravitons.
He wrote extensively on the possibilities of direct lunar exploration and the exploitation of lunar materials.

The best conspectus of his world picture is presented by his 1957 book *Morphological Astronomy* (whose

main ideas had appeared in the Halley Lecture before the Royal Astronomical Society in 1948). It is an extraordinary book, the product of the impact of a resolutely original mind on the multifaceted phenomena of the universe. Every astronomer can read it with profit; the reader's reactions will be enlightenment, astonishment, and occasionally incredulity.
One reviewer happily referred to the book as an "astronomical catharsis." It is an attempt to wrestle single-handedly with the mystery of the universe, and its argument is not confined to the purely astronomical phenomena.

Zwicky's development of many new astronomical techniques should not be overlooked. Notable is his method of composite photography (the combination of a negative taken in one wavelength with a positive taken in another, with revealing and sometimes unexpected results). So are his observations of the Crab nebula in polarized light.

One of the major concerns of Zwicky's life was the applications of rocketry. From 1943 to 1949 he was director of research for the Aerojet Corporation. In 1948 his wartime work on jet propulsion was recognized by the award of the Freedom Medal by President Truman.
Far from being an ivory-tower scientist, he developed some 50 patents, many of them in the field of rockets. He used to talk of his plan (never adopted by the authorities!) for desmogging Los Angeles. When he retired from his Caltech professorship, he intended "to travel ... and to work for international friendship as vice-president of the International Academy of Astronautics."

Fritz Zwicky was one of the last of the scientific individualists, a breed that is dying out in an age of teamwork. Aggressively original, outspoken to the point of abrasion, he seemed to his contemporaries stubbornly opinionated. His ideas were so fertile and his projects so vast that he could have employed all the facilities of a great observatory.

Looking back on his rugged determination and his slightly Renaissance flavor, one is reminded of Tycho Brahe: brilliant, opinionated, combative, a superb observer, and a very human person. For Zwicky was one of the kindest of men, with a deep concern for humanity. To those who knew him only in the scientific arena, it may come as a surprise to learn that he was a former chairman of the board of trustees of the Pestalozzi Foundation, devoted to the support of orphanages.

The man who gave us so much of what is known about supernovae, galaxies, and clusters of galaxies has placed the world in his debt.
Astronomy will never be the same again, and these permanent legacies will be remembered when the superseded theories and battles for priority are long forgotten.
His medal for public service in the field of jet propulsion came to him relatively early in life.
In his old age, when he was 74, Zwicky received the gold medal of the Royal Astronomical Society (which many agree is the highest such award), in recognition of his scientific work. I believe that posterity will consider that he earned it.