Biographical Encyclopedia of Astronomers

Alfvén, Hannes Olof Gösta

Born Norrköping, Sweden, 20 May 1908

Died Djursholm, Sweden, 2 April 1995

Swedish plasma physicist and astrophysicist Hannes Alfvén is commemorated in Alfvén waves and the Alfvén velocity at which they travel. He shared the 1970 Nobel Prize in Physics for his contributions to plasma physics, especially magnetohydrodynamics, and can be regarded as the founder of the field of cosmic electrodynamics. Hannes Alfvén was the son of Anna-Clara Romanus (a physician) and Johannes Alfvén. He and his wife, Kerstin Erikson (married: 1935), had five children.

Alfvén developed an early interest in astronomy, reading Camille Flamarion's *Astronomie Populaire* as a teenager, andberschelp. Vol. 1, pp. 417-487. Turnhout: Brepols

in radio communication, building his own receiver. He was educated in mathematics and physics at the University of Uppsala, receiving a Ph.D. in 1934 for work on ultra-high frequency electromagnetic oscillations. In 1940, Alfven was appointed professor of electromagnetic theory and electrical measurements at the Royal Institute of Technology in Stockholm, where he established a vibrant school of electronics, partly directed toward technical applications. In 1945, he was appointed to a personal chair of electronics, renamed plasma physics in 1963, from which he retired in 1973. From 1967 onward, Alfvén held joint appointments at Stockholm and at the University of California at San Diego as research physicist until 1973, as professor during 1973-1975, and as professor emeritus of electrical engineering and computer science during 1975-1988, when he returned permanently to Sweden.

Alfvén created the research field of cosmical electrodynamics, using his knowledge of experimental and theoretical physics to establish that, in addition to gravity, electromagnetic forces play a significant role in a variety of astrophysical processes. His first contributions were collected in the first edition (1950) of his book Cosmical Electrodynamics, with four chapters on general methods followed by three chapters on applications to specific astrophysical problems. A later edition, Cosmical Electrodynamics - Fundamental Principles by Alfvén and Fälthammar (1963), has been extensively used in graduate education. Alfvén's cosmogonic work was presented in his 1953 book Origin of the Solar System, and greatly extended in the 1976 book Evolution of the Solar System, written jointly with the chemist Gustaf Arrhenius.

Alfvén's earliest astrophysical interests were directed toward the theory and observations of cosmic rays In 1933, he published a paper on the electromagnetic origin of cosmic rays, a subject to which he repeatedly returned during the following 25 years. Alfvén (1940) introduced the method of separating the motion of a charged particle in a magnetic field into a fast gyration transverse to the magnetic field and a slower drift of the center of this gyration, which he called the "guiding center." This led to a drastic simplification that has become a fundamental tool in the entire field of plasma physics, from cosmic plasmas to laboratory plasmas and controlled fusion research. A number of scientists developed the highly sophisticated adiabatic theory of charged particle motion, which is now indispensable in modern plasma physics. The rapid transverse motion gives rise to synchrotron radiation, which was predicted in cosmic contexts by Alfvén and Nicolai Herlofson in 1940 and discovered in the 1940s and 1950s in solar radio emission and optical radiation from supernova remnants.

Alfven noticed that in our Galaxy the energy density of cosmic rays is about the same as that of starlight (the Sun excluded). Considering reasonable sources and sinks of these two energies, and the isotropy of cosmic radiation, he predicted in 1937 the existence of a galactic magnetic field due to electric currents carried by the interstellar plasma—a prediction later amply verified by the polarization of starlight scattered by interstellar dust (discovered by John Hall and William Hiltner) and by the synchrotron nature of galactic radio emission.

In addition to his theoretical work, Alfven characteristically conducted careful observations of cosmic rays. Throughout his career he emphasized the importance of laboratory experiments as a check on theories, including theories of cosmic phenomena, because "the same laws of nature should apply everywhere."

Directing his attention to electromagnetic aspects of solar physics, Alfven developed a theory of sunspots and the sunspot cycle in 1943. In the course of this work, he discovered, in 1942, the existence of a new kind of wave, now known as Alfven waves. Studying fluids of high electrical conductivity, such as solar or interstellar plasma, Alfven showed that a combination of electromagnetic theory and fluid dynamics opened up a whole new field of physics: magnetohydrodynamics. Although many decades of new observations have revealed much more complicated magnetic fields in the Sun, and theories of sunspots are correspondingly different, Alfven waves and the Alfven velocity remain indispensable concepts

From the existence of solar magnetic fields, Alfven concluded that beams of charged particles emanating from the Sun during magnetic storms and aurorae must carry magnetic fields. He made this the basis of a new theory of magnetic storms and aurorae (1939). Decades later, this radical and much-contested prediction was verified by in situ measurements in space.

A persistent problem in cosmogony has been that the major planets in their orbits carry 98% of the angular momentum in the Solar System, and the massive Sun only 2%. In 1942, Alfven showed that a new process of electromagnetic braking during the formation of the planetary system would very efficiently transfer angular momentum from the rotating Sun to the orbits of the nascent outer planets

To emphasize the significance of electromagnetic forces, Alfvén coined the term Plasma Universe to represent a "new paradigm" in cosmical physics. The astronomical community gradually came, by about 1965, to accept that Alfvén had been essentially right about the importance of magnetic fields in astrophysical contexts. Curiously, he then turned around and advocated large-scale electric fields to account for properties of galaxies and diffuse matter in the Universe. This has not been generally accepted

In addition to receiving the Nobel Prize, Alfven received numerous awards, including the Gold Medal of the Royal Astronomical Society, the Lomonosov Medal of the USSR Academy of Sciences, the Gold Medal of the Franklin Institute, the Bowie Gold Medal of the American Geophysical Union, and the Dirac Medal of the Australian Institute of Physics. He was a member of the Royal Swedish Academy of Sciences, the Royal Swedish Academy of Engineering Sciences, the USSR Academy of Sciences, the Royal Society of London, the National Academy of Sciences, Washington, D.C., and the American Academy of Arts and Sciences, Boston, as well as of the Yugoslav and Indian academies. He received honorary doctorates from the universities of Newcastle upon Tyne, Oxford, and Stockholm.

Carl-Gunne Fälthammar

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