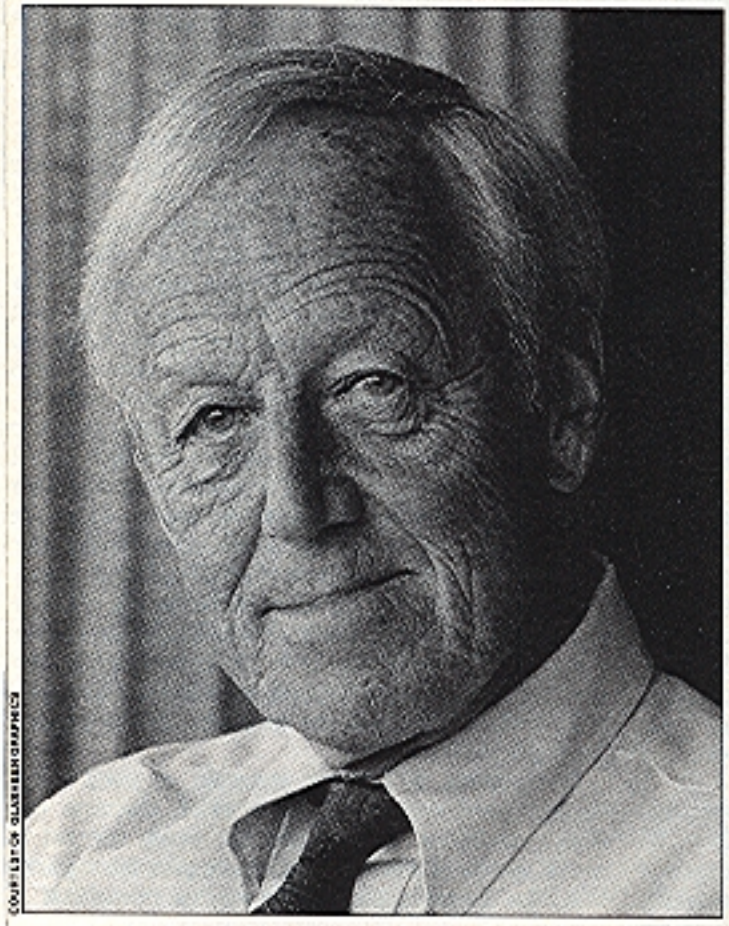
DEAN OF THE PLASMA DISSIDENTS

Having challenged and overcome the prevailing views of the electromagnetic and plasma dynamics of the ionosphere, the solar system, and the galaxy, Hannes Alfven is now challenging the orthodox view of the origin of the universe.

ANTHONY L. PERATT



COURTESY OF OLSSEN PHOTOGRAPHICS

In the world of specialized science, Swedish electrical engineer Hannes Alfvén is an enigma. Regarded as a heretic by many physicists, Alfvén has made contributions to physics that are today being applied in the development of particle beam accelerators, controlled thermonuclear fusion, hypersonic flight, rocket propulsion, and the braking of reentering space vehicles. At the same time, applications of his research in space science include explanations of the Van Allen radiation belt, the reduction of the earth's magnetic field during magnetic storms, the magnetosphere (a protective plasma envelope surrounding the earth), the formation of comets' tails, the formation of the solar system, the dynamics of plasmas in our galaxy, and the fundamental nature of the universe itself.

Hannes Alfvén has played a central role in the development of several modern fields of physics, including plasma physics, the physics of charged particle beams, and interplanetary and magnetospheric phys-

Considered a heretic by many physicists, Hannes Alfvén has keen insight into the natural world and has advanced many innovative and now-accepted theories in diverse fields of physics and astrophysics.

ics. He is also usually regarded as the father of the branch of plasma physics known as *magnetohydrodynamics*.

In addition, Alfvén's contributions to astrophysics have been as important as his contributions to physics. His postulation in 1937 of a galactic magnetic field forms the basis today for one of the fastest growing areas of research in astrophysics. In 1950, together with his colleague N. Herlofson, Alfvén was the first to identify nonthermal radiation from astronomical sources as synchrotron radiation, which is produced by fast-moving electrons in the presence of magnetic fields. The recognition that the synchrotron mechanism of radiation is important in celestial objects has been one of the most fruitful developments in astrophysics, as nearly all the radiation recorded by radio telescopes derive from this mechanism.

In spite of these fundamental contributions to physics and astrophysics, Alfvén, now professor of electrical engineering at the University of California at San Diego, is still viewed as a heretic by many in those very fields. Alfvén's theories in astrophysics and plasma physics have usually gained acceptance only two or three decades after their publication. Characteristically—and also concomitant with his 80th birthday in 1988—Alfvén is to be awarded the most prestigious prize of the American Geophysical Union, the Bowie medal, for his work three decades earlier on comets and plasmas in the solar system. Disputed for 30 years, many of his theories about the solar system have only recently been vindicated through measurements of cometary and planetary magnetospheres by artificial satellites and space probes.

Hannes Alfvén's achievements have earned him worldwide recognition—including the Gold Medal of the Royal Astronomical Society (1967), the Nobel Prize in physics (1970), the Gold Medal of the Franklin Institute (1971), and the Lomonosov Medal of the USSR Academy of Sciences (1971). Several academies and institutes include his name in their membership rosters: the Institute of Electrical and Electronics Engineers (life fellow), the European Physical Society, the Royal Swedish Academy, the Swedish Academy of Engineering Sciences, the American Academy of Arts and Sciences, and the Yugoslav Academy of Sciences. Alfvén also is one of the very few scientists who are foreign members of both the U.S. and Soviet Academies of Sciences.

Alfvén's theories in physics and astrophysics have generally preceded their acceptance by two or three decades, as indicated by this graph. The left-hand side of each bar shows the year a concept was first published; the right-hand side indicates, roughly, when the idea was generally accepted or used by the scientific community. The colored dots indicate the general field of each contribution.

Although Alfvén has received these singular honors from many parts of the world—and at least two scientific journals have scheduled special issues in honor of his 80th birthday—for much of his career Alfvén's ideas were dismissed or treated with condescension. He was often forced to publish his papers in obscure journals; and his work was continuously disputed for many years by the most renowned senior scientist in space physics, the British-American geophysicist Sydney Chapman. Even among physicists today there is little awareness of Alfvén's many contributions to fields of physics where his ideas are used without recognition of who conceived them.

Attempting to explain the resistance to his ideas, Alfvén points to the increasing specialization of science during this century. "We should remember that there was once a discipline called natural philosophy," he says. "Unfortunately, this discipline seems not to exist today. It has been renamed *science*, but science of today is in danger of losing much of the natural philosophy aspect." Among the causes of this transition, Alfvén believes, are "territorial dominance, greed, and fear of the unknown." "Scientists tend to resist interdisciplinary inquiries into their own territory. In many instances, such parochialism is founded on the fear that intrusion from other disciplines would compete unfairly for limited financial resources and thus diminish their own opportunities for research."

COURTESY OF THE ROYAL INSTITUTE OF TECHNOLOGY, STOCKHOLM

Hannes Alfvén at the Royal Institute of Technology in Stockholm, where he has held the Chair of Plasma Physics since 1963 (Photo: c. 1950).

Education

Hannes Olof Gösta Alfvén was born on May 30, 1908, in Norrköping, Sweden. He received his doctor's degree from the University of Uppsala in 1934. His thesis was entitled "Investigations of the Ultrashort Electromagnetic Waves." The same year Alfvén was appointed a docent in physics at both the University of Uppsala and the Nobel Institute for Physics in Stockholm. In 1940 he became professor of electromagnetic theory and electrical measurements at the Royal Institute of Technology in Stockholm, and in 1945 he was elected to a newly created Chair of Electronics at the same institute, which was converted to a Chair of Plasma Physics in 1963.

In 1967 Alfvén issued a stinging condemnation of Sweden's nuclear research program, protesting what he considered to be insufficient funds for projects on peaceful uses of thermonuclear energy, and he left, saying, "My work is no longer desired in this country." He was immediately offered chairs in both the Soviet Union and the United States. After two months in the Soviet Union, he moved to America, testing the professorial waters in the departments of electrical engineering at two universities in Southern California, the University of California at San Diego in La Jolla and the University of Southern California. Having made his peace with the Swedish government soon after he left, Alfvén now spends October to March in La Jolla and April to September in Stockholm at the Royal Institute of Technology.

Alfvén's Approach to Physics

Alfvén's approach to physics is based on insight and intuition. He is quick to understand how nature works and he is able to place new observations into a framework larger than that required to explain the observations themselves. For example, in the early 1930s, cosmic rays were commonly thought to be gamma rays filling the entire universe. However, when they were discovered to be charged particles, Alfvén offered in 1937 the novel suggestion that the galaxy contained a large-scale magnetic field and that the cosmic rays moved in spiral orbits within the galaxy, owing to the forces exerted by the magnetic field. He argued that there could be a magnetic field pervading the entire galaxy if plasma was spread throughout the galaxy. This plasma could carry the electrical currents that would then create the galac-

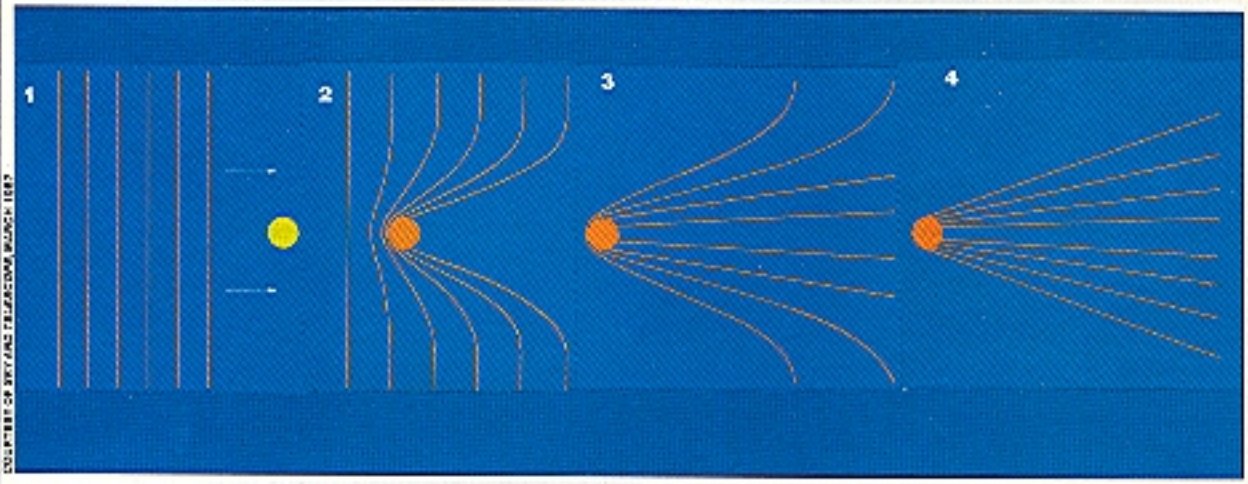
Some of Alfvén's far-reaching concepts on the structure of space have come from his studies of comets. A 1974 photograph of his favorite comet, Kohoutek, is shown here.

tic magnetic field.

Such a hypothesis, based on a great leap of creative intuition but without a grounding in apparent rational thought or inference, left Alfvén's proposal open to much criticism; his theory was dismissed on the grounds that interstellar space was known to be a vacuum and that it certainly could not support the electrical currents and particle beams he was proposing. But Alfvén had started the scientific community thinking about an idea that was to become very fashionable.

Alfvén's discovery of hydromagnetic waves is another example of an original idea having a far-reaching impact on multidisciplinary science. On purely physical grounds, Alfvén concluded that an electromagnetic wave could propagate through a highly conducting medium, such as the ionized gas of the sun, or in plasma anywhere. However, in 1942, when Alfvén published his discovery, Maxwell's theory of electromagnetism was a well-established edifice, a subject for textbook pedagogy and engineering applications. It was "well known" that electromagnetic waves could penetrate only a very short distance into a conductor and that, as the resistance of a conductor became smaller and smaller, the depth of penetration by an electromagnetic wave would go to zero. Thus, with an ideal electrical conductor, there could be no penetration of electromagnetic radiation. But Alfvén was proposing a form of electromagnetic wave that could propagate in a perfect conductor with no attenuation or reflection. Alfvén's discovery was generally dismissed with such remarks as "if such waves were possible, Maxwell himself would have discovered them."

His work was not recognized as both correct and significant until six years later, when he gave several lectures on hydrodynamic waves during his first visit to the United States. An oversimplified statement of what occurred has been provided by Alex Dessler,



This drawing illustrates Alfvén's theory of how a comet's plasma tail is formed. Magnetic field lines move outward from the sun on the left and meet a comet (1). As the field lines encounter the comet, ions in the comet's head begin to be captured and spiral around the lines (2). The comet halts the advance of the field lines, which begin to drape over the head and stretch behind it (3 and 4).

PERSONAL AND PUBLIC LIFE

In counterpoint to his often turbulent scientific career, Hannes Alfvén's home life has been quiescent, a tranquility that has been attributed to his wife of 53 years, Kirsten. They have raised five children: a son who is a physician and four daughters, one a writer well-known in Sweden and one a lawyer.

Besides his scientific papers, Alfvén has written popular science books, sometimes with his wife. These include *World's-Antiworlds: Antimatter in Cosmology* (1966), and *The Great Computer: A Vision* (1968). The latter book, written under the pen name Olaf Johannesson, describes how increasingly sophisticated computers gain control first over government, then the earth. Alfvén's distrust of computers is long-standing, and only recently, when plasma simulations on supercomputers started reproducing the noise measured in real physical systems, did he take an interest in this aspect of analysis. Other popular books include *Atom, Man, and the Universe: A Long Chain of Complications* (1969) and *Living on the Third Planet* (1972).

Alfvén strongly identifies with a variety of social issues. He is, for example, an activist in the worldwide disarmament movement, having served as president of the Pugwash Conference on Science and World Affairs. In addition, his son is the Swedish secretary of the Physicians for Social Responsibility. In his leisure time, Alfvén enjoys studying the history of science and oriental philosophy and religion. He is currently taking lessons to improve his flute-playing.

The green flash, an elusive phenomenon of interest to Alfvén, appears for a brief moment as the sun sets on the horizon.

Known for his sense of humor and for having an anecdote for every occasion, Alfvén also loves to travel, especially to exotic lands such as Sri Lanka and the Fiji Islands. While he claims residence according to the equinoxes—vernal to autumnal in Europe and autumnal to vernal in North America—prior to celebrating his 80th birthday in Sweden he will travel to the Amazon River. Not surprisingly, he is also interested is languages; in addition to his native Swedish, he is fluent in English, German, and French, and nearly so in Russian; and he speaks some Spanish and some Chinese. When not visiting exotic places, he can often be found in Washington, D.C., or the capitals of Europe, attempting to influence the way science is managed.

Physically active, Alfvén enjoys long walks and prefers the stairway to the elevator when going to his third-floor office. He walks to and from the hill top campus from his beachside apartment in La Jolla, a distance of two miles, and accepts rides only if the weather is foul. Entertaining visitors with wine at his apartment in La Jolla, he will hurry them to the beach at sundown in hopes of catching a glimpse of the "green flash," the phenomenon that sometimes occurs as the sun drops below the ocean horizon.

As the years pass, Alfvén's wife, who makes all his travel arrangements, might prefer her husband to slow down and let others carry the torch for the plasma universe and enlightened conduct of science. Yet she acknowledges that her beloved Hannes is probably still the best torchbearer available, and besides, for the moment, he probably would not be happy if he were not leading the way.

—*A.L. Peratt*

now editor of the prestigious *Geophysical Research Letters*. "During Alfvén's visit he gave a lecture at the University of Chicago, which was attended by [Enrico] Fermi. As Alfvén described his work, Fermi nodded his head and said, 'Of course.' The next day the entire world of physics said, 'Oh, of course.'"

Alfvén versus Chapman

Alfvén became active in interplanetary and magnetospheric physics at a time when a contrary viewpoint prevailed. Alfvén's views were consistent with those of the founder of magnetospheric physics, the great Norwegian scientist Kristian Birkeland. At the end of the nineteenth century Birkeland had laid out a compelling case—supported by theory, laboratory experiments, polar expeditions, and a chain of magnetic-field "observatories" around the world—that electric currents flowing down along the earth's magnetic fields into the atmosphere were the cause of the aurora and polar magnetic disturbances.

However, in the decades following Birkeland's death in 1917, Chapman became the acknowledged leader in interplanetary and magnetospheric physics. Chapman proposed, in contradistinction to Birkeland's ideas, currents that were restricted to flowing only in the ionosphere with no downflowing currents. Chapman's theory was so mathematically elegant that it gained wide acceptance over the Birkeland theory. Based on Chapman's theory, closed-form solutions of the ionospheric current system could, with complete mathematical rigor, be derived by any student of the subject. Birkeland's ideas might have faded completely had it not been for Hannes Alfvén, who became involved well after Chapman's ideas gained predominance. Alfvén kept insisting that Birkeland's current system made more sense because downflowing currents following the earth's magnetic field lines were required to drive most of the ionospheric currents. The issue was not settled until 1974, four years after Chapman's death, when earth satellites measured downflowing currents for the first time.

This story is typical of the difficulties Alfvén has faced in his scientific career. Interplanetary space was commonly considered to be a good vacuum, disturbed only by occasional comets. This viewpoint was widely accepted because space "looked" that way, having been viewed only by using telescopes at optical wavelengths. In contrast, the electrical currents proposed by Alfvén generated a telltale signature only in the radio portions of the electromagnetic spectrum, so they had not yet been observed. Thus Alfvén's proposal that there were electrical currents in space was received with great skepticism.

In 1939 Alfvén advanced a remarkable theory of magnetic storms and auroras that has widely influenced contemporary theory of the dynamics in the earth's magnetosphere. He used the notion of electric charges spiraling in magnetic fields to calculate the motions of electrons and ions. This method came to be universally adopted by plasma physicists and remained in use until the tedious task was assigned to computers in the mid-1970s. Yet in 1939, when Alfvén submitted the paper to the leading American journal *Terrestrial Magnetism and Atmospheric Electricity*, the paper was rejected on the ground that it did not agree with the theoretical calculations of Chapman and his colleagues. Alfvén was forced to publish this seminal paper in a Swedish-language journal not readily accessible to the worldwide scientific community. Restrictions such as this have been imposed on several of Alfvén's other key articles as well.

It is usual in science that one or two major discoveries place their author in the rank of leading authorities, with great influence and continuing funding commonly following. This has certainly not been the case with Alfvén. At no time during his scientific career prior to winning the Nobel Prize was Alfvén generally recognized as a leading innovator by those in the scientific community who were using his work.

Dessler has written of his own realization that Alfvén's contributions were being overlooked.

> When I entered the field of space physics in 1956, I recall that I fell in with the crowd believing, for example, that electric fields could not exist in the highly conducting plasma of space. It was three years later that I was shamed by S.Chandrasekhar into investigating Alfvén's work objectively. My degree of shock and surprise in finding Alfvén right and his critics wrong can hardly be described. I learned that a cosmic ray acceleration mechanism basically identical to the famous mechanism suggested by Fermi in 1949 had [previously] been put forth by Alfvén.

HANNES ALFVÉN VERSUS THE BIG BANG

For 30 years, based on plasma physics, Alfvén and his colleagues have proposed an alternative cosmology to both the Steady State and the Big Bang cosmologies. While the Big Bang theory is preferred today by most astrophysicists, it is being challenged by new observations, especially over the last four years. In particular, the discovery of coherent structures of galaxies hundreds of millions of light years in length and the large-scale streaming of superclusters of galaxies at velocities that may approach 1,000 kilometers per second present problems that are difficult, if not impossible, to reconcile with the Big Bang theory.

To Alfvén, the problems being raised are not surprising. "I have never thought that you could obtain the extremely clumpy, heterogeneous universe we have today, strongly affected by plasma processes, from the smooth, homogeneous one of the Big Bang, dominated by gravitation."

The problem with the Big Bang, Alfvén believes, is similar to that with Chapman's theories, which the scientific community accepted mistakenly for decades: Astrophysicists have tried too hard to extrapolate the origin of the universe from mathematical theories developed on the blackboard. The appeal of the Big Bang, says Alfvén, has been more ideological than scientific. "When men think about the universe, there is always a conflict between the mythical approach and the empirical scientific approach." "In myth, one tries to deduce how the gods must have created the world—what perfect principles must have been used."

To Alfvén, the Big Bang is a myth—a myth devised to explain creation. "I was there when Abbé Georges Lemaître first proposed this theory," he recalls. Lemaître was, at the time, both a member of the Catholic hierarchy and an accomplished scientist. He said in private that this theory was a way to reconcile science with St. Thomas Aquinas' theological dictum of *creatio ex nihilo*—creation out of nothing.

But if there was no Big Bang, how—and when—did the universe begin? "There is no rational reason to doubt that the universe has existed indefinitely, for an infinite time," Alfvén explains. "It is only myth that attempts to say how the universe came to be, either four thousand or twenty billion years ago."

"Since religion intrinsically rejects empirical methods, there should never be any attempt to reconcile scientific theories with religion," he says. An infinitely old universe, always evolving, may not, he admits, be compatible with the Book of Genesis. However, religions such as Buddhism get along without having any explicit creation mythology and are in no way contradicted by a universe without a beginning or end. "*Creatio ex nihilo*, even as religious doctrine, only dates to around A.D. 200," he notes. "The key is not to confuse myth and empirical results, or religion and science."

Alfvén admits that his plasma universe theory may take a long time to penetrate the popular consciousness. "After all," he asserts to a group of physicists, "most people today still believe, perhaps unconsciously so, in the heliocentric universe." The group, at first incredulous, quickly nods in agreement as Alfvén continues, "every newspaper in the land has a section on astrology, yet few have anything at all on astronomy."

—A.L. Perall

Alfvén and Astrophysics

Looking far beyond the solar system and even beyond our galaxy, Alfvén has drawn on his intuition to propose a model of the universe itself. Under the tutelage of Swedish physicist and cosmologist Oskar Klein, Alfvén developed a cosmology based on the concept of the British physicist P.A.M. Dirac that the universe is symmetrical, consisting of equal parts of matter and antimatter. Although Alfvén has elaborated on this model of a matter-antimatter universe in 29 papers and 4 books published from 1962 to 1988, the work remains only superficially known to astrophysicists.

While in recent years his work on astrophysics may be highlighted in opening addresses or lead articles in commemorative journals around the world, none of this work has been published in the *Astrophysical Journal*, the information organ and policy setter of the American Astronomical Society, of which Alfvén is a member. One probable reason is that a matter-antimatter symmetric universe is irreconcilable with Big Bang cosmology, currently the dominant model.

Because his ideas often conflict with the generally accepted or "standard" theories, Alfvén has always had trouble with the peer review system, especially as practiced by Anglo-American astrophysical journals. "I have no trouble publishing in Soviet astrophysical journals," Alfvén says, "but my work is unacceptable to the American astrophysical journals." In fact, he has never enjoyed the nearly automatic acceptance generally afforded senior scientists in scientific journals. "The peer review system is satisfactory during quiescent times, but not during a revolution in a discipline such as astrophysics, when the establishment seeks to preserve the status quo," explains Alfvén.

Part of the reason that Alfvén's work is neglected in astrophysics may be that Alfvén considers himself, first and foremost, an electrical power engineer and rather enjoys the accusation of encroachment in astrophysics leveled by other cosmologists and theoreticians. Plasma physics has traditionally been neglected in astrophysics, Alfvén says. "Students using astrophysical textbooks remain essentially ignorant of even the existence of plasma concepts, despite the fact that some of them have been known for half a century," he argues. "The conclusion is that astrophysics is too important to be left in the hands of astrophysicists who have gotten their main knowledge from these textbooks. Earthbound and space telescope data must be treated by scientists who are familiar with laboratory and magnetospheric physics and circuit theory, and of course with modern plasma theory."

DAVID DUNCAN, COURTESY PETER ARNOLD, INC.

The origin of the universe has long puzzled mankind. Alfvén believes neither the Steady State nor the Big Bang theories are adequate. His alternative theory projects a matter-antimatter symmetric universe.

Alfvén clearly has come to enjoy his role as the dean of the plasma dissidents of contemporary cosmology. He remains active in publishing his theories, especially in journals of interplanetary, magnetospheric, and plasma physics. His views critical of the Big Bang theory, especially when ad hoc changes in this cosmology have been used to fit it to some new observation, can be found in recent issues of *Physics Today*, *Nature*, *Science*, and *Scientific American*. Approaching his 80th birthday, Alfvén has yet to slow his relentless quest for understanding the universe or his battle to convey his insights to the world.■

Anthony L. Peratt conducts plasma research at the Los Alamos National Laboratory. He was previously with the Max Planck Institute for Plasma Physics in West Germany.