David Talbott

The Plasma Universe of Hannes Alfvén

In the 20th century no scientist added more to our knowledge of electromagnetism in space than Hannes Alfvén (1908–1995). His insights changed the picture of the universe, revealing the profound effects of charged particle movement at all scales of observation. But recognition never came quickly, and never easily, and mainstream journals typically regarded Alfvén as an outsider, often rejecting his submissions. In retrospect, Alfvén's difficulties in gaining acceptance can only highlight the inertia of institutionalized ideas in the sciences, reminding us of the obstacles faced by all of history's great scientific innovators.

Awarded the Nobel Prize in 1970 for his contribution to physics, Alfvén emerged as a towering critic of directions in astronomy, cosmology, and astrophysics. Though he was surely not correct on everything he proposed, decades of space exploration eventually confirmed a lifetime of observations and hypotheses, often with implications that many space scientists did not want to hear. "In the world of specialized science," wrote plasma scientist Anthony Peratt, "Alfvén was an enigma. Regarded as a heretic by many physicists, Alfvén made contributions to physics that today are being applied in the development of particle beam accelerators, controlled thermonuclear fusion, hypersonic flight, rocket propulsion, and the braking of reentering space vehicles."[1]

But Alfvén's impact reached far beyond new technologies. He devoted much of his life to the study of plasma, a highly conductive, elementary form of matter characterized by the presence of freely moving charged particles, not just electrically neutral atoms. Normal gases become plasma through heating and partial ionization as some percentage of the atoms give up one or more of their constituent electrons. Often called "the fourth state of matter" after solids, liquids, and gases, plasma is now known to constitute well over 99 percent of the observed universe.

Alfven is the acknowledged father of "plasma cosmology," a new way of seeing formative processes in the heavens. Proponents of plasma cosmology suggest that vast but invisible electric currents play a fundamental role in organizing cosmic structure, from galaxies and galactic clusters down to stars and planets. The Big Bang hypothesis, black holes, dark matter, and dark energy are only a few of today's popular cosmological themes disputed by scientists working with this new perspective. Many central tenets of plasma cosmology emerged from laboratory experiments with plasma and electric discharge, and it was Alfvén himself who showed that plasma behavior in the laboratory can be scaled up to galactic dimensions: vast regions of plasma in space behave similary to plasma on earth.

Hannees Alfvén with necklace of feathers from Fiji. Courtesy Carl-Gunne Fälthammar

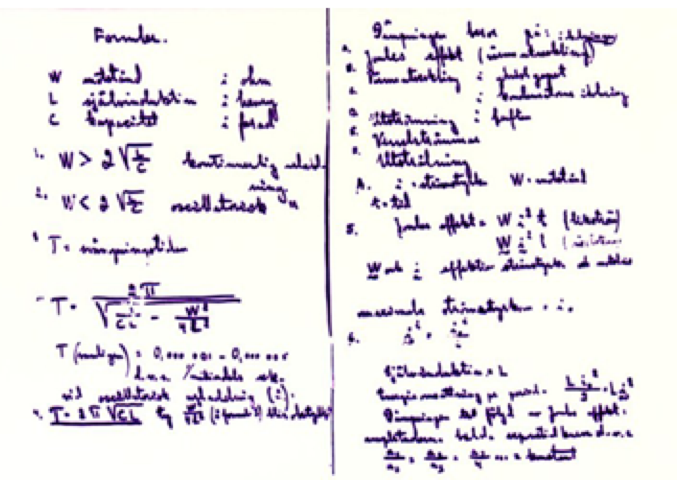
Underscoring the enormity of ignoring cosmic electromagnetic effects in cosmology is the fact that the electric force between charged particles is some 39 orders of magnitude (a thousand trillion trillion trillion) times stronger than the gravitational force. In comparative terms, gravity is incomprehensibly weak; a hand-held magnet will raise a small metallic sphere against the entire gravity of the Earth.

Alfvén's documentation of laboratory plasma experiments eventually made it impossible to ignore the role of electricity in space. He explained the auroras based on the work of his predecessor Kristian Birkeland; correctly described the Van Allen radiation belts; identified previously unrecognized electromagnetic attributes of Earth's magnetosphere; explained the structure of comet tails; and much more.

Early Life

Hannes Olof Gösta Alfvén was born on May 30th, 1908, in Norrköping, Sweden. Astrophysicist Carl-Gunne Fälthammar, perhaps Alfvén closest colleague, notes two childhood experiences influencing the pioneer's intellectual development and eventually his scientific career.[2] One was a book on popular astronomy by Camille Flammarion, sparking a lifelong fascination with astronomy and astrophysics. The other was his active role in a school radio club, a role that included building radio receivers. His natural facility for electronics can be seen at an early age and continued through his formal education. "...As a scientist," writes Fälthammar, "Hannes was inclined to look at astrophysical problems from an electromagnetic point of view, and this turned out to be very fruitful."

A young Hannes Alfvén reading a popular astronomy book by Camille Flammarion. Image credit: Carl-Gunne Fälthammar



Pages from 15-year-old Hannes Alfvén's notebook.
Image credit: Carl-Gunne Fälthammar

While a graduate student Alfvén wrote a paper interpreting the source of cosmic rays. He submitted the article to the distinguished scientific journal *Nature*, which published it in 1933. In this first peer-reviewed article by Alfvén, one sees his early confidence in laboratory experiments as pointers to events in space.

Alfvén received his PhD in theoretical and experimental physics from the University of Uppsala in Sweden in 1934. Early highlights of his academic career, beginning the year of his PhD, include teaching physics at the University of Uppsala and at Sweden's Nobel Institute for Physics. He later served as professor of electromagnetic theory and electrical measurements at the Royal Institute of Technology in Stockholm. For many years he served as Chair of Electronics, a title changed to "Chair of Plasma Physics" in 1963. He also spent time in the Soviet Union before moving to the United States, where he worked in the departments of electrical engineering at both the University of California, San Diego, and the University of Southern California.

In 1937 Alfvén observed that the charged particles of a rarified plasma appear to pervade interstellar and intergalactic space. And he suggested that these particle motions were responsible for the detected magnetic fields. A few years later, in the early 1940s, Alfvén proposed that the Sun and planets emerged from a cloud of ionized gas and that, in such processes, "electromagnetic forces have been more important than mechanical forces." The latter claim, together with other emphases on electric currents, would place Alfvén's work in direct conflict with a cardinal tenet of astronomy at the beginning of the space age—the assumption that only gravity can perform "real work" across interstellar or intergalactic distances.

Magnetohydrodynamics

Alfvén's interest in magnetic fields laid the foundations of today's magnetohydrodynamic theory, a theory widely employed by astrophysicists. In the original formulations of the theory, Alfvén spoke of magnetic fields being "frozen" into neutral plasma, and the magnetohydrodynamic equations he formulated implied that the electric currents that create magnetic fields could be effectively ignored. Hence, the plasma activity on the Sun and in more remote space could be analyzed without reference to any larger domain of electric currents or electric circuits.

To this notion astronomers were readily attracted, and for a time they thought they had an ally in the brilliant electrical engineer. Although his "fundamental work and discoveries in magnetohydrodynamics" led to his Nobel Prize in 1970, the background to this occasion is paradoxical.

Through much of the 19th and 20th century, most astronomers and cosmologists had assumed the "vacuum" of space would not permit electric currents. Later, when it was discovered that all of space is a sea of electrically conductive plasma, the theorists reversed their position, asserting that any charge separation would be immediately neutralized. Here they found what they were looking for in Alfvén's frozen-in magnetic fields and in his magnetohydrodynamic equations. Electric currents could then be viewed as strictly localized and temporary phenomena—needed just long enough to create a magnetic field, to *magnetize* plasma, a virtually "perfect" conductor.

The underlying idea was that space could have been magnetized in primordial times or in early stages of stellar and galactic evolution, all under the control of higher-order kinetics and gravitational dynamics. All large scale events in space could still be explained in terms of disconnected islands, and it would only be necessary to look *inside* the "islands" to discover localized electromagnetic events—no larger electric currents or circuitry required. In this view, popularly held today, we live in a "magnetic universe" (the title of several recent books and articles), but not an electric universe. The point was stated bluntly by the eminent solar physicist Eugene Parker, "…No significant electric field can arise in the frame of reference of the moving plasma."[3]

But the critical turn in this story, the part almost never told within the community of astronomers and astrophysicists, is that Alfvén came to realize he had been mistaken. Ironically—and to his credit—Alfvén used the occasion of his acceptance speech for the Nobel Prize to plead with scientists to ignore his earlier work. Magnetic fields, he said, are only part of the story. The electric currents that create magnetic fields must not be overlooked, and attempts to model space plasma in the absence of electric currents will set astronomy and astrophysics on a course toward crisis, he said.

In accord with Alvén's observations, American physicist, professor Alex Dessler, former editor of the journal *Geophysical Research Letters*, notes that he himself had originally fallen in with an academic crowd that believed electric fields could not exist in the highly conducting plasma of space. "My degree of shock and surprise in finding Alfvén right and his critics wrong can hardly be described."[4]

In retrospect, it seems clear that Alfvén considered his early theoretical assumption of frozen-in magnetic fields to be his greatest mistake, a mistake perpetuated first and foremost by mathematicians attracted to Alfvén's magnetohydrodynamic equations. Alfvén came to recognize that real plasma behavior is too "complicated and awkward" for the tastes of mathematicians. It is a subject "not at all suited for mathematically elegant theories." It requires hands-on attention to plasma dynamics in the laboratory. Sadly, he said, the plasma universe became "the playground of theoreticians who have never seen a plasma in a laboratory. Many of them still believe in formulae which we know from laboratory experiments to be wrong."

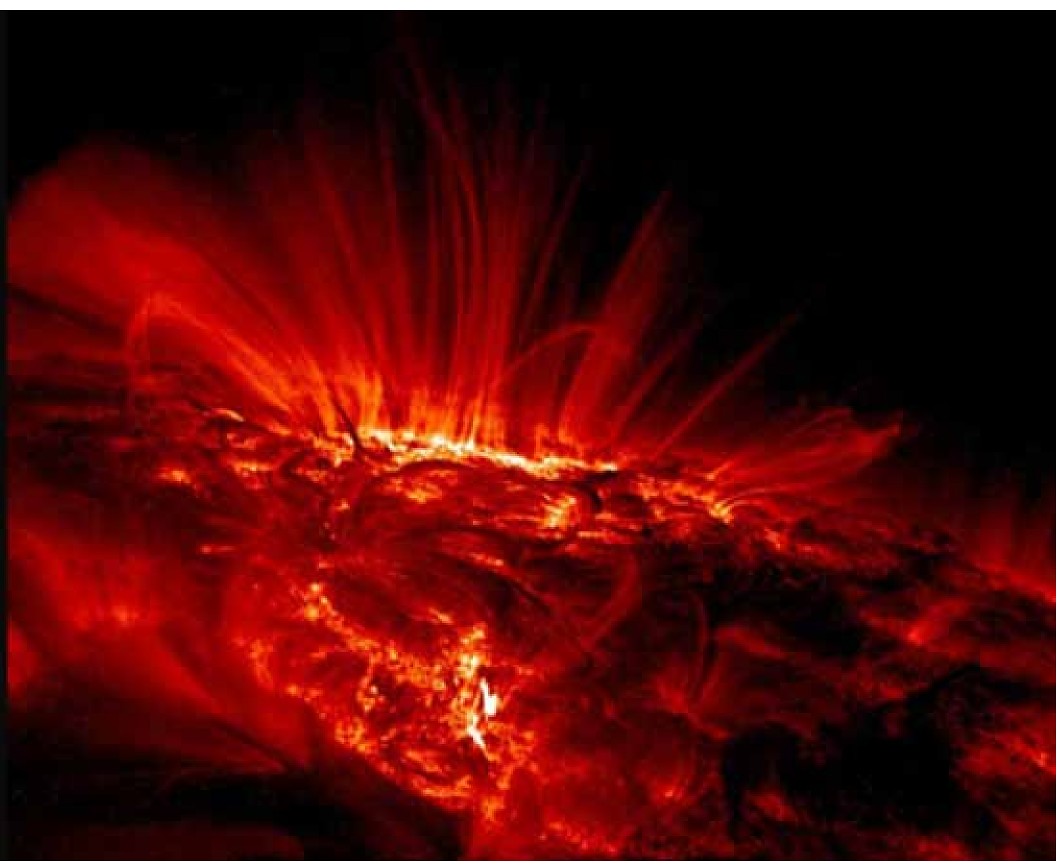
Again and again Alfvén reiterated the point: the underlying assumptions of cosmologists today "are developed with the most sophisticated mathematical methods and it is only the plasma itself which does not 'understand' how beautiful the theories are and absolutely refuses to obey them."

Cellular Structure and Filamentation of Space

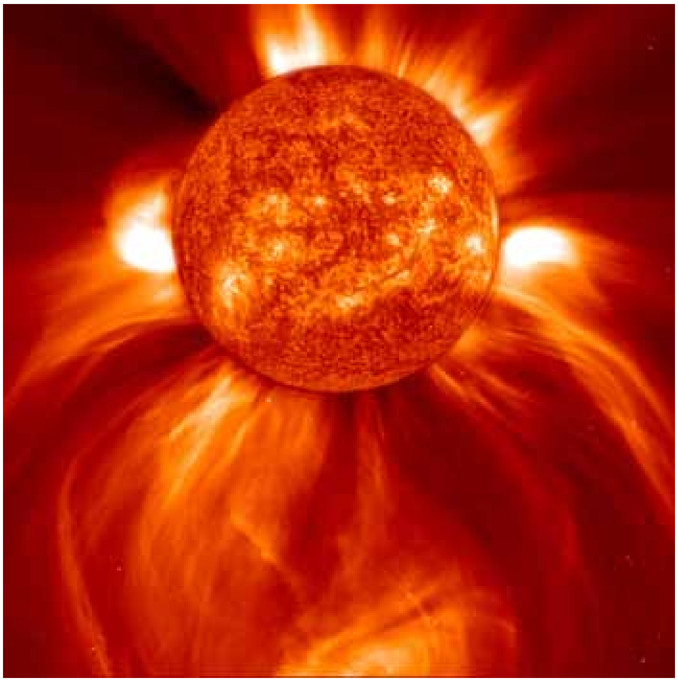
The fundamental truth discerned by Alfvén, but ignored by proponents of his "magnetohydrodynamic" model, is that plasma in space cannot have a magnetic field permanently "frozen" in to it. In space plasma environments, electric currents are required to create and sustain magnetic fields. "In order to understand the phenomena in a certain plasma region, it is necessary to map not only the magnetic but also the electric field and the electric currents. Space is filled with a network of currents that transfer energy and momentum over large or very large distances. The currents often pinch to filamentary or surface currents. The latter are likely to give space, interstellar and intergalactic space included, a *cellular* structure."[5]

Of course when Alfvén discussed these issues, electric currents and cellular plasma configurations in space were simply off the grid of theoretical astrophysics: "...Space in general has a 'cellular structure,'" he wrote, observing that the cellular walls are not visible and could only be measured by sending a space probe through those inaccessible regions. Based on his own laboratory research and backed by the work of Nobel Laureate Irving Langmuir and others, he noted that the plasma cell boundaries, called "double layers," tend to insulate the regions inside these cells from the regions outside.

Plasma experiments show that strong electric fields can be present across the walls of these cellular sheaths (double layers), and the presence of the these fields is essential to understanding plasma behavior. To ignore this cellular structure in the cosmos, Alfvén observed, is to assume that deep space plasmas "have properties which are drastically different from what they are in our own neighborhood. This is obviously far more



A "typical day on the Sun," showing the energetic loops and prominences that trace out the complex magnetic fields carpeting the Sun's surface. But what is the contribution of external electric fields to these events? Credit: NASA/TRACE



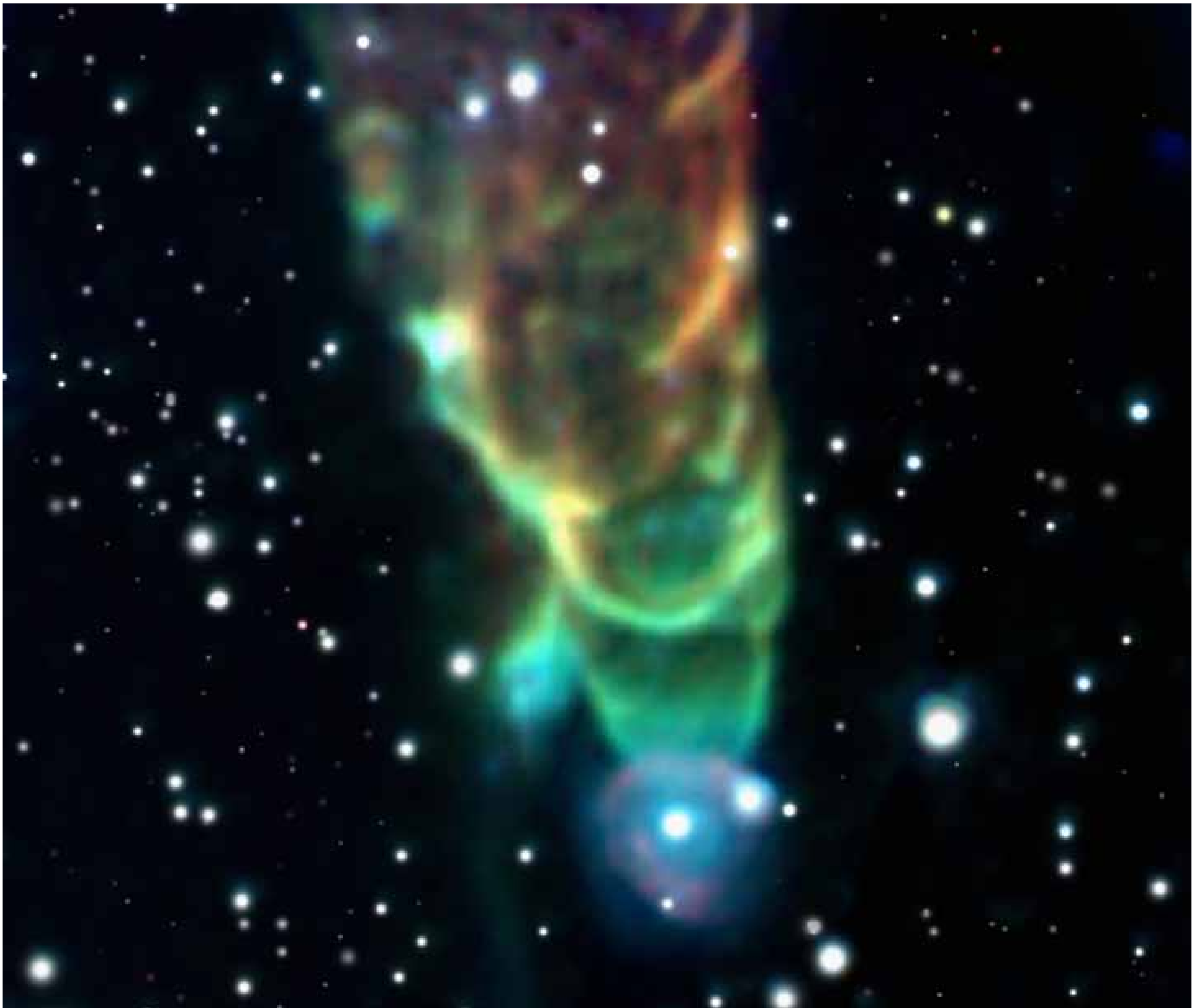
unpleasant than our inability to detect distant 'cell walls.' Hence, a thorough revision of our concept of the properties of interstellar (and intergalactic) space is an inevitable consequence of recent magnetospheric discoveries."[6]

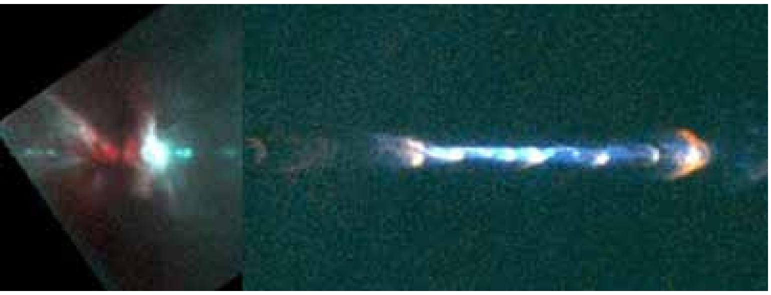
Stellar Jets

Even before the space age, Alfvén had come to realize that, for stars, the electrical circuitry will show up in equatorial current sheets and polar current streams. Based on laboratory plasma experiments, Alfvén noted that electromagnetic energy could be stored in a star's equatorial ring until a critical juncture when that energy switched to a polar discharge. The resulting

LASCO C2 image, recording a coronal mass ejection. Astronomers continue to offer "explanations" for such events, based on the interplay of magnetic fields, with no regard for the external electric fields that are required for the acceleration of charged particles away from the Sun. Credit: SPHO/LASCO consortium

The energetic stellar jet of HH (Herbig Haro) 49/50, as seen through the Spitzer Space Telescope. Credit: J. Bally (Univ. of Colorado) et al., JPL-Caltech, NASA





Herbig Haro 111, displaying a jet *12 light-years long* with charged particles accelerated to speeds approaching 500 kilometers per second. The finely filamentary and knotted jet spans three times the distance from the Sun to our nearest star. By what means are these jets confined to a narrow stream across such unfathomable distances? Credit: NASA and B. Reipurth (CASA, University of Colorado)

jet would be energized by a particle-accelerating double layer: the gravity of a star would then give way to the incomparably more powerful electric force, accelerating matter away from the star.

And now, thanks to more powerful telescopes, we see exactly what Alfvén envisioned. One noteworthy form is the Herbig Harro (HH) object; such objects are now counted in the hundreds and observed in sufficient detail to invalidate all early, non-electric theories of such formations.

The unsolved mysteries confronting mainstream astronomy were popularized in the "Astronomy Picture of the Day" (APOD) on Feb 3, 2006. The caption identified this stellar jet as a "cosmic tornado" light-years in length, with gases moving at 100-kilometers per second.

Of course, gravitational models featured in twentieth century astronomy never envisioned narrow jets of *anything* streaming away from stellar bodies. Neither gravity nor standard gas laws would allow it. The Hubble Space Telescope website compares the whirling, pulsating, and oscillating jets to the effects of lawn sprinkler nozzle: "Material either at or near the star is heated and blasted into space, where it travels for billions of miles before colliding with interstellar material."[7] Does a star have the ability to create collimated, high energy jets across *billions* of miles by merely "heating" material in its vicinity? The matter in the jet is *hot* and it is moving through a *vacuum*. If one is to use an analogy with water, the better example would be a super-heated steam hose. But it will not form a jet of steam for more than a *few feet* before the steam disperses explosively.

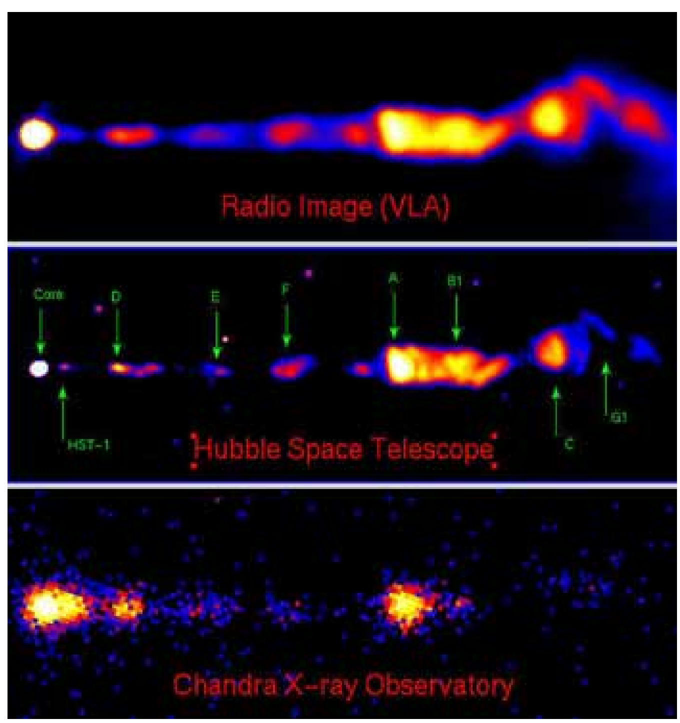
The Hubble page poses two additional questions: "What causes a jet's beaded structure?" and "Why are jets 'kinky?'" Ironically, the questions point directly to two of the most prominent features of electric discharge in plasma—"beading" and "kink instabilities." Both occur not just in laboratory discharge experiments but in everyday lightning on earth.

Herbig Haro objects do not just defy all traditional astrophysics; they explicitly confirm Alfvén's vision of the polar discharging of stars. Axial currents, confined by a current-induced, toroidal magnetic field, flow along *the entire length of the jet*, in precise accord with Alvén's expectations. Only an electric field can accelerate charged particles across interstellar space. There is no canon-like explosion, and there is no "nozzle" on one end. The jet is defining astrophysical objects in fundamentally new terms, confirming Alfvén's suspicions more than 60 years ago, that interstellar space is alive with electric currents.

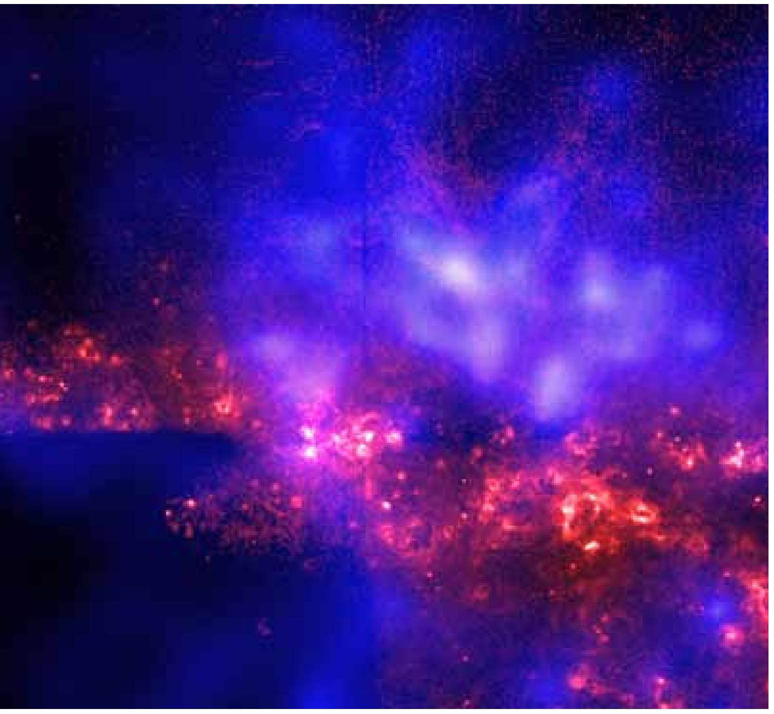
X-Rays and Synchrotron Radiation

Alfvén's view of space was radically different from that of mainstream astronomy before the electromagnetic spectrum became a door to discovery in space. In the first years of the space age astronomers were generally satisfied with seeing objects in visible light alone. Earth's upper atmosphere shielded the surface of our planet from most emissions at the higher end of the spectrum, and there was little reason to expect a broader spectrum of electromagnetic emissions from space. That all began to change in the 1930s, when an engineer named Karl Jansky accidently discovered the existence of radio waves from space. The eventual interest in space telescopes detecting ultraviolet, X-ray, and gamma-ray wavelengths came largely through incremental surprises such as Jansky's.

The intense electromagnetic activity across the cosmos requires a vast complex of electric fields and electrical circuitry, just as Alfvén confidently predicted decades before the new telescopes were launched into space. Prior to the launch of the X-ray telescope Uhuru in 1970, for example, astronomers knew of only two X-ray sources in the heavens—Scorpius X-1 and the Crab Nebula. But the Chandra and XMM-Newton X-ray telescopes, more recently launched into space, began to reveal X-ray activity in virtually every corner of the universe, even in the deepest vacuum *between* galaxies. X-rays require



Energies along the jet of Galaxy M87 confirm the presence of synchrotron radiation. Credit: VLA/Hubble/Chandra



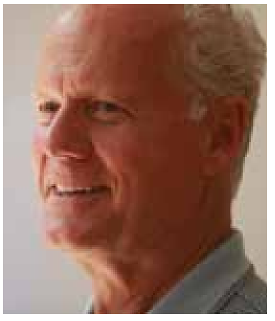
Chandra's observations of NGC 4631 reveal a giant halo of electrified plasma, with X-ray emissions seen in blue and purple, animating this spiral galaxy. We now know that X-ray emissions are ubiquitous in space. Credit: NASA/Chandra

an acceleration of charged particles up to speeds far beyond the capabilities of thermal expansion or gravitational acceleration. So it's understandable that most astronomers did not anticipate an X-ray universe. Of course, we routinely employ electric fields today to produce X-rays, and if Hannes Alfvén had lived to see the recent results, he would have not been surprised at all.

Then at the upper limit of the electromagnetic spectrum, just above X-rays, lie the wavelengths of Gamma-rays. The name for a full complex of electromagnetic emissions—including Gamma-rays—is "Synchrotron radiation," a radically new phrase in the astronomer's lexicon. Such radiation is produced by electrons moving at close to the speed of light while spiraling along magnetic fields. Magnetic fields *require* electric currents—of this fact no reasonable dispute is possible. Ironically, it was in 1950, well prior to the space age, that Hannes Alfvén *predicted* synchrotron radiation in space, based on an electrical interpretation of galactic activity. Astronomers could not imagine such a thing at the time. But in 1987, astronomer Geoffrey Burbidge detected synchrotron radiation emitted by a spectacular jet along the axis of a galaxy called M87. And the fact that these frequencies have now been detected abundantly in space is perhaps the greatest surprise of all.

As every electrical engineer knows, charged particle acceleration is routinely achieved by electric fields. The ubiquitous synchrotron radiation from space simply confirms that the isolated islands envisioned by traditional astrophysics do not exist. But the specialized training of astronomers had suggested no need for electricity. As a result, the discovery of intensely energetic events in space have provoked exotic and untestable amendments to traditional theory—from "black holes" to "dark matter" and "neutron stars"—all based on phenomena unknown in our practical world and disconnected from any verifiable behavior of nature.

Though the history and practice of science is often cluttered with dismissals of scientific "outsiders" and obstructive allegiance to dogma, it can at least be said that in the last 40 years astronomers have grudgingly come to accept an entirely different view of the universe from the one they started with. And for this, no one deserves more credit than the cosmic electrician, Hannes Alfvén.



DAVID TALBOTT is the founder of the Thunderbolts Project (http://thunderbolts.info), an internet collaboration on behalf of the "Electric Universe." He was the founder and publisher of *Pensée* magazine's ten issue series, "Immanuel Velikovsky Reconsidered," bringing international attention to the Velikovsky issue from 1972 through 1974. His book *The Saturn Myth* was published by Doubleday in 1980 and helped to inspire the continuing research of scholars and scientists now involved in the Thunderbolts Project. He has co-authored two books with Australian physicist Wallace Thornhill: *Thunderbolts of the Gods* and *The Electric Universe*, and his work was the subject of the 1996 documentary, "Remembering the World." More recently he served as editor-in-chief of an e-book series, *The Universe Electric* (*Big Bang, The Sun*, and *The Comet*) and has written and narrated two DVDs of a planned series called *Symbols Of An Alien Sky*.

ENDNOTES

1. Anthony L. Peratt, "Dean of the Plasma Dissidents," *The World & I*, May 1988, pp. 190-197.
2. Comments made in a Hannes Alfvén "birth centennial celebration" pictorial tribute: http://www.bibhasde.com/Alfven100.html
3. Eugene Newman Parker, *Conversations on Electric and Magnetic Fields in the Cosmos* (Prineceton, 2007), p.1.
4. Quoted in Anthony L. Peratt, "Dean of the Plasma Dissidents," *Washington Times*, supplement: *The World & I* (May 1988), p. 195.
5. Alfvén, H., Nobel lecture 1970, emphasis ours.
6. Alfvén, H., *Cosmic Plasma*, Chapter II: "Electric Currents in Space Plasmas."
7. "Hubble Observes the Fire and Fury of a Stellar Birth," NASA News Release, June 6, 1995: http://hubblesite.org/newscenter/archive/releases/star/1995/24/background/results/50/