Biographical Encyclopedia of Astronomers

Hoyle, Fred

Born Bingley, West Yorkshire, England, 24 June 1915.

Died Bournemouth, Dorset, England, 20 August 2001.

Fred Hoyle applied field theory to cosmology (including a new matter-creation field), proposed an alternative theory of gravitation, and developed time-symmetric electrodynamics. He was thereby an intellectual link, stretching from the theories of Albert Einstein and Paul Dirac, toward modern cosmological theories. A national figure, he was knighted in 1972 for a number of distinguished contributions to astronomy and to the United Kingdom. Hoyle had worked on radar during World War II, founded Cambridge's Institute of Theoretical Astronomy, and chaired the Science Research Council's advisory committee for the Anglo-Australian Telescope. His name became well known to the public following his British Broadcasting Company broadcasts in 1950. Hoyle's 1955 book, *Frontiers of Astronomy*, inspired both astronomers and the public.

Hoyle grew up in industrial western Yorkshire. In his autobiography, he eloquently describes his early "war" with the educational system in Gilstead, a village near Bingley. His family was far removed from the privileged classes that gave England so many noted scientists His mother had worked in the Bingley textile mill but later studied music at the Royal Academy and became a professional singer before she married. At age nine, Hoyle quit school after being slapped by a teacher. His mother strongly supported him in his confrontation with local authorities. Hoyle eventually won a scholarship to Bingley Grammar School, to and from which he walked four miles daily. From there, he gathered financial support to enter Cambridge University's Pembroke College in 1933. At Pembroke, he won half of the Mayhew Prize in the mathematical tripos. Later, he became Dirac's research student because, as Hoyle put it, Dirac could not resist the circular logic of a supervisor who did not want a research student who did not want a supervisor!

Perhaps Hoyle's most successful theory was that of nucleosynthesis in stars. In 1946, he showed that the interiors of massive, evolved stars reached very high temperatures and densities. Under those conditions, the natural dominance of iron in the middle-mass abundance peak could be understood as a consequence of statistical equilibrium. Hoyle and later collaborators called this the "e-process," where "e" stood for "equilibrium." If explosive disruption of the star followed, then the interstellar medium would be enriched with iron. This important result shifted attention toward nucleosynthesis in stars and created the field of galactic chemical evolution

In 1954, Hoyle detailed not only the "e-process," but also the synthesis of all elements between carbon and nickel as a series of successive stages in which the ashes of one reaction became the fuel for the next. Much of that conceptual structure survives intact today. By the late 1960s, radioactive nickel was demonstrated (by others) to be the parent of iron, was demonstrated to be the radioactive power source for a supernova's light curve, and served as a test of the theory through the detection of its gamma rays

Hoyle is perhaps most widely known as the creator of the steady-state theory of the Universe, although Hermann Bondi and Thomas Gold also published a discussion of this idea from a more philosophical viewpoint. Hoyle's approach, however, went straight to the need for an alternate theory of gravitation that included a field for the creation of matter. Hoyle thus introduced a scalar field for that purpose. Many of his publications, co-authored with Jay-ant V. Narlikar over the next 15 years, explored the mathematical implications of this (and other) fields in cosmology. Hoyle's time-symmetric quantum electrodynamics was a Herculean effort in theoretical physics, one that was seen as capable of supporting the steady-state theory. These concepts established Hoyle as a champion of the concept of continuous creation of matter in the Universe, and the field equations that achieved this result will remain associated with his name. Hoyle's field equations led to an exponentially expanding but spatially flat metric that reappeared in a similar guise within the inflationary theory of big-bang cosmology. Philosophical beauty was not Hoyle's only guide, however. From the work of Victor Ambartsumian and others, Hoyle became convinced that high-energy astrophysical processes represented the ejection, rather than the infall, of matter around extremely massive objects.

Hoyle's indignation at premature attacks on the steady-state theory placed him in the position of seeming to be a sore loser in the scientific debate with Big-Bang proponents—a perception that lasted until his death. But in 1964, Hoyle and Roger J. Taylor pioneered nucleosynthesis calculations in either a Big Bang or a series of lesser cosmic explosions that emphasized an elevated cosmic abundance of helium In 1967, with Robert V. Wagoner and William Fowler, Hoyle demonstrated that both isotopes of hydrogen and both isotopes of helium, as well as lithium-7, could be made during the Big Bang. These calculations set the standards for Big Bang nucleosynthesis. Nonetheless, the common image of Hoyle is that of him giving the Big Bang its name sarcastically. Following accurate measurements of the cosmic microwave background radiation, Hoyle acknowledged its possible knockout blow to the simple steady-state model. His monograph, *A Different Approach to Cosmology* (2000), co-authored with Geoffrey R. Burbidge and Narlikar, presented an alternative to the Big Bang by employing an oscillating and expanding steady-state universe.

Hoyle was also a pioneer in computational stellar evolution, specifically physical models of stars becoming red giants and exploding as supernovae. In 1953, Hoyle and Martin Schwarzschild constructed numerical models of the evolution of stars beyond the main sequence that not only explained the physical nature of red giant stars but also introduced many physical ideas that now seem as if they must have always been known. The dimensionless variables q, t, and p that Schwarzschild later used in his book on stellar evolution were all integrated by hand! Innovations included an isothermal helium core, a thin hydrogen-burning shell ("burning" on the C-N cycle), and a deepening surface convection zone owing to failure of the zero boundary condition at the surface. These assumptions are now taken for granted

When Hoyle first visited the Kellogg Radiation Laboratory at the California Institute of Technology in 1953, he argued that the triple-alpha process would be inadequate for both red giants and nucleosynthesis unless carbon-12 were to have an excited state with zero spin and positive parity at 7.7 MeV excitation. Initially, this pronouncement was viewed with incredulity because carbon-12 has very few excited states, but it was soon shown to be precisely true. Hoyle's prediction of this energy state was the most accurate ever achieved, and it had relied on astrophysics rather than nuclear physics! He argued that this excited state of carbon-12 must exist because we ourselves are here an anticipation of the anthropic principle

In 1960 and 1964, Hoyle and Fowler published physical interpretations of the spectroscopically defined Type I and II supernovae. They argued that Type I supernovae were the explosions of degenerate white dwarfs, whereas Type II supernovae were implosion-explosion sequences occurring within massive stars. Today, these are our paradigms, although Hoyle and Fowler did not anticipate the role of neutrino transport in the Type II rebound, but argued that centrifugal barriers prevented further collapse and allowed the star's thermonuclear power to eject matter.

Hoyle's controversial ideas about interstellar biology began in collaboration with Cambridge student Nalin C. Wickramasinghe, who studied the condensation of refractory dust in both the winds emitted by carbon stars and within the interiors of supernovae. A new field of investigation was later envisioned by others if such isotopically anomalous stardust could be found within meteorites The first such stardust in meteorites was isolated in 1987 and has enormously enriched astronomical knowledge. Hoyle's detour into interstellar biology grew from the recognition that the absorption spectra of bacteria resembled that of interstellar dust, together with his conviction that some dominant mechanism was necessary to process interstellar matter into such forms with high efficiency. For this, Hoyle and Wickramasinghe boldly suggested reproductive chemistry. When that idea was attacked by biologists' public comments rather than through published scientific arguments, Hoyle's back stiffened. He thereafter pitched his books directly to the public rather than to scientists.

Hoyle had written imaginatively for the public in his novel, *The Black Cloud* (1957), in which he postulated that cold molecular clouds developed nervous systems and a consciousness that controlled their environments. The physical notion stayed with him Writing primarily for the public, Hoyle and Wickramasinghe argued in *Lifecloud* (1978), *Diseases from Space* (1979), and *Space Travelers: The Origins of Life* (1980) that comets carried the basic chemicals of DNA replication, and even of influenza epidemics. The scorn of the biochemical world was total. It must be added, however, that the role of comets in delivering biochemically sensitive materials remains an open topic, as is the question of whether life emerged first on Earth or another planetary body. Many felt that Hoyle might have shared the 1983 Nobel Prize in Physics (awarded to Fowler and Subramanyan Chandrasekhar), but for Hoyle's embarrassed status over exobiology.

Much of Hoyle's life was spent bucking the establishment and playing devil's advocate against conventional wisdom—traits that seem further reflections of his upbringing and childhood "war" with the Yorkshire educational system.

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Selected References

Arnett, David D. (2002). "Sir Fred Hoyle (1915-2001)." *Publications of the Astro-nomical Society of the Pacific* 114: 262-264.

Burbidge, Geoffrey (2003). "Sir Fred Hoyle." *Biographical Memoirs of Fellows of the Royal Society* 49: 213-247.

Burbidge, Geoffrey and Margaret Burbidge (2002). "Sir Fred Hoyle 1915-2001." *Observatory* 122: 133-136.

Clayton, Donald D. (2001). "Fred Hoyle, 1915-2001." *Bulletin of the American Astronomical Society* 33: 1570-1572

Gregory, Jane (2003). "The Popularization and Excommunication of Fred Hoyle's 'Life-from-Space' Theory." *Public Understanding of Science* 12: 25-46.

Hoyle, Fred (1994). *Home is Where the Wind Blows: Chapters from a Cosmologist's Life*. Mill Valley, California: University Science Books.

Kragh, Helge (1996). *Cosmology and Controversy: The Historical Development of Two Theories of the Universe*. Princeton, New Jersey: Princeton University Press.

Lynden-Bell, Donald (2001). "Sir Fred Hoyle (1915-2001)." *Observatory* 121: 405-408.

McConnell, Craig Sean (2000). "The Big Bang-Steady State Controversy: Cosmology in Public and Scientific Forums." Ph.D. diss., University of Wisconsin-Madison