Fred Hoyle

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Basic Information

Name: Fred Hoyle
(Jun 1915–Aug 2001)

Birth Location:	Gilstead, Bingley, West Riding of Yorkshire, England
Title:	Astronomer
Affiliation:	Institute of Astronomy, Cambridge
Honor:	Unknown

1. Introduction

Sir Fred Hoyle FRS (24 June 1915 – 20 August 2001)[1] was an English astronomer who formulated the theory of stellar nucleosynthesis. He also held controversial stances on other scientific matters—in particular his rejection of the "Big Bang" theory, a term coined by him on BBC radio, and his promotion of panspermia as the origin of life on Earth.[2][3][4] He also wrote science fiction novels, short stories and radio plays, and co-authored twelve books with his son, Geoffrey Hoyle. He spent most of his working life at the Institute of Astronomy at Cambridge and served as its director for six years. He was one of the authors of the influential B^2FH paper.

2. Early Life and Career

Hoyle was born near Bingley in Gilstead, West Riding of Yorkshire, England.[5] His father, Ben Hoyle, who was a violinist and worked in the wool trade in Bradford, served as a machine gunner in the First World War.[6] His mother, Mabel Pickard, had studied music at the Royal College of Music in London and later worked as a cinema pianist.[6] Hoyle was educated at Bingley Grammar School and read mathematics at Emmanuel College, Cambridge.[7]

In 1936 he won the Mayhew Prize (jointly with George Stanley Rushbrooke).

In late 1940, Hoyle left Cambridge to go to Portsmouth to work for the Admiralty on radar research, for example devising a method to get the altitude of the incoming aeroplanes. He was also put in charge of countermeasures against the radar guided guns found on the *Graf Spee*.[8] Britain's radar project employed more personnel than the Manhattan project, and was probably the inspiration for the large British project in *The Black Cloud*. Two key colleagues in this war work were Hermann Bondi and Thomas Gold, and the three had many and deep discussions on cosmology. The radar work paid for a couple of trips to North America, where he took the opportunity to visit astronomers. On one trip to the US he learned about supernovae at Caltech and Mount Palomar and, in Canada, the nuclear physics of plutonium implosion and explosion, noticed some similarity between the two and started thinking about supernova nucleosynthesis. He had an intuition at the time "I will make a name for myself if this works out." Eventually (1954) his prescient and ground breaking paper came out. He also formed a group at Cambridge exploring stellar nucleosynthesis in ordinary stars and was bothered by the paucity of stellar carbon production in existing models. He noticed that one of the existing processes would be made a billion times more productive if the carbon-12 nucleus had a resonance at 7.7 MeV, but the nuclear physicists did not list such a one. On another trip he visited the nuclear physics group at Caltech, spending a few months of sabbatical there and persuaded them against their considerable scepticism to look for and find the Hoyle state in carbon-12, from which developed a full theory of stellar nucleosynthesis, co-authored by Hoyle with some members of the Caltech group.[9]

A blue plaque at Bingley Grammar School commemorating him. https://handwiki.org/wiki/index.php?curid=1891614

After the war, in 1945, Hoyle returned to Cambridge University, as a lecturer at St John's College, Cambridge. Hoyle's Cambridge years, 1945–1973, saw him rise to the top of world astrophysics theory, on the basis of a startling originality of ideas covering a very wide range of topics. In 1958, Hoyle was appointed to the illustrious Plumian Professor of Astronomy and Experimental Philosophy at Cambridge University. In 1967, he became the founding director of the Institute of Theoretical Astronomy (subsequently renamed the Institute of Astronomy, Cambridge, where Hoyle's innovative leadership quickly led to this institution becoming one of the premier groups in the world for theoretical astrophysics. In 1971 he was invited to deliver the MacMillan Memorial Lecture to the Institution of Engineers and Shipbuilders in Scotland. He chose the subject "Astronomical Instruments and their Construction".[10] Hoyle was knighted in 1972. Hoyle resigned his Plumian professor position in 1972 and his directorship of the institute in 1973, with this move effectively cutting him off from most of his establishment power-base, connections and steady salary.

After leaving Cambridge, Hoyle wrote many popular science and science fiction books, as well as presenting lectures around the world. Part of the motivation for this was simply to provide a means of support. Hoyle was still a member of the joint policy committee (since 1967), during the planning stage for the 150-inch Anglo-Australian Telescope at Siding Spring Observatory in New South Wales. He became chairman of the Anglo-Australian Telescope board in 1973, and presided at its inauguration in 1974 by Charles, Prince of Wales.

3. Decline and Death

After his resignation from Cambridge, Hoyle moved to the Lake District and occupied his time with a mix of treks across the moors, writing books, visiting research centres around the world, and working on science ideas that have been nearly-universally rejected. On 24 November 1997, while hiking across moorlands in west Yorkshire, near his childhood home in Gilstead, Hoyle fell down into a steep ravine called Shipley Glen. Roughly twelve hours later, Hoyle was found by a search dog. He was hospitalised for two months with pneumonia and kidney problems (both resulting from hypothermia), as well as a broken shoulder from the fall. Thereafter he entered a marked decline, suffering from memory and mental agility problems. In 2001, he suffered a series of strokes and died in Bournemouth on 20 August of that year.

4. Origin of Nucleosynthesis

Hoyle authored the first two research papers ever published on the synthesis of the chemical elements heavier than helium by nuclear reactions in stars. The first of these[11] in 1946 showed that the cores of stars will evolve to temperatures of billions of degrees, much hotter than temperatures considered for thermonuclear origin of stellar power in main-sequence stars. Hoyle showed that at such high temperatures the element iron can become much more abundant

than other heavy elements owing to thermal equilibrium among nuclear particles, explaining the high natural abundance of iron. This idea would later be called the e Process.[12] Hoyle's second foundational nucleosynthesis publication,[13] published in 1954, showed that the elements between carbon and iron cannot be synthesized by such equilibrium processes. He attributed those elements to specific nuclear fusion reactions between abundant constituents in concentric shells of evolved massive, pre-supernova stars. This startlingly modern picture is the accepted paradigm today for the supernova nucleosynthesis of these primary elements. In the mid-1950s, Hoyle became the leader of a group of very talented experimental and theoretical physicists who met in Cambridge: William Alfred Fowler, Margaret Burbidge, and Geoffrey Burbidge. This group systematized basic ideas of how all the chemical elements in our universe were created, with this now being a field called nucleosynthesis. Famously, in 1957, this group produced the B^2FH paper (known for the initials of the four authors) in which the field of nucleosynthesis was organized into complementary nuclear processes. They also added much new material on the synthesis of heavy elements by neutron-capture reactions, the so-called s process and the r process. So influential did the B^2FH paper become that for the remainder of the twentieth century it became the default citation of almost all researchers wishing to cite an accepted origin for nucleosynthesis theory, and as a result, the path-breaking Hoyle 1954 paper fell into obscurity. Historical research in the 21st century [14][15] has brought Hoyle's 1954 paperback to scientific prominence. Those historical arguments were first presented to a gathering of nucleosynthesis experts attending a 2007 conference at Caltech organized after the deaths of both Fowler and Hoyle to celebrate the 50th anniversary of the publication of B^2FH. Ironically the B^2FH paper did not review Hoyle's 1954 supernova-shells attribution of the origin of elements between silicon and iron despite Hoyle's co-authorship of B^2FH. Based on his many personal discussions with Hoyle [16] Donald D. Clayton has attributed this seemingly inexplicable oversight in B^2FH to the lack of proofreading by Hoyle of the draft composed at Caltech in 1956 by G.R. Burbidge and E.M. Burbidge.[17]

The second of Hoyle's nucleosynthesis papers also introduced an interesting use of the anthropic principle, which was not then known by that name. In trying to work out the routes of stellar nucleosynthesis, Hoyle calculated that one particular nuclear reaction, the triple-alpha process, which generates carbon from helium, would require the carbon nucleus to have a very specific resonance energy and spin for it to work. The large amount of carbon in the universe, which makes it possible for carbon-based life-forms of any kind to exist, demonstrated to Hoyle that this nuclear reaction must work. Based on this notion, Hoyle therefore predicted the values of the energy, the nuclear spin and the parity of the compound state in the carbon nucleus formed by three alpha particles (helium nuclei), which was later borne out by experiment.[18]

This energy level, while needed to produce carbon in large quantities, was statistically very unlikely to fall where it does in the scheme of carbon energy levels. Hoyle later wrote:

> Would you not say to yourself, "Some super-calculating intellect must have designed the properties of the carbon atom, otherwise the chance of my finding such an atom through the blind forces of nature would be utterly minuscule. A common sense interpretation of the facts suggests that a superintellect has monkeyed with physics, as well as with chemistry and biology, and that there are no blind forces worth speaking about in nature. The numbers one calculates from the facts seem to me so overwhelming as to put this conclusion almost beyond question."
>
> —Fred Hoyle[19]

His co-worker William Alfred Fowler eventually won the Nobel Prize for Physics in 1983 (with Subrahmanyan Chandrasekhar), but for some reason Hoyle's original contribution was overlooked by the electors, and many were surprised that such a notable astronomer missed out.[20] Fowler himself in an autobiographical sketch affirmed Hoyle's pioneering efforts:

> The concept of nucleosynthesis in stars was first established by Hoyle in 1946. This provided a way to explain the existence of elements heavier than helium in the universe, basically by showing that critical elements such as carbon could be generated in stars and then incorporated in other stars and planets when that star "dies". The new stars formed now start off with these heavier elements and even heavier elements are formed from them. Hoyle theorized that other rarer elements could be explained by supernovas, the giant explosions which occasionally occur throughout the universe, whose temperatures and pressures would be required to create such elements.
>
> — William Fowler[21]

5. Rejection of the Big Bang

While having no argument with the Lemaître theory (later confirmed by Edwin Hubble's observations) that the universe was expanding, Hoyle disagreed on its interpretation. He found the idea that the universe had a beginning to be pseudoscience, resembling arguments for a creator, "for it's an irrational process, and can't be described in scientific terms" (see Kalam cosmological argument).[22] Instead, Hoyle, along with Thomas Gold and Hermann Bondi (with whom he had worked on radar in the Second World War), in 1948 began to argue for the universe as being in a "steady state" and formulated their Steady State theory. The theory tried to explain how the universe could be eternal and essentially

unchanging while still having the galaxies we observe moving away from each other. The theory hinged on the creation of matter between galaxies over time, so that even though galaxies get further apart, new ones that develop between them fill the space they leave. The resulting universe is in a "steady state" in the same manner that a flowing river is—the individual water molecules are moving away but the overall river remains the same.

The theory was one alternative to the Big Bang which, like the Big Bang, agreed with key observations of the day, namely Hubble's red shift observations, and Hoyle was a strong critic of the Big Bang. He coined the term "Big Bang" on BBC radio's *Third Programme* broadcast on 28 March 1949. It was popularly reported by George Gamov and his opponents that Hoyle intended to be pejorative, and the script from which he read aloud was interpreted by his opponents to be "vain, one-sided, insulting, not worthy of the BBC".[23] Hoyle explicitly denied that he was being insulting and said it was just a striking image meant to emphasize the difference between the two theories for the radio audience.[24] In another BBC interview he said "The reason why scientists like the "big bang" is because they are overshadowed by the Book of Genesis. It is deep within the psyche of most scientists to believe in the first page of Genesis".[25]

Hoyle had a famously heated argument with Martin Ryle of the Cavendish Radio Astronomy Group about Hoyle's steady state theory, which somewhat restricted collaboration between the Cavendish group and the Cambridge Institute of Astronomy during the 1960s.[26]

Hoyle, unlike Gold and Bondi, offered an explanation for the appearance of new matter by postulating the existence of what he dubbed the "creation field", or just the "C-field", which had negative pressure in order to be consistent with the conservation of energy and drive the expansion of the universe. This C-field is the same as the later "de Sitter solution" for cosmic inflation, but the C-field model acts much slower than the de Sitter inflation model.[27] They jointly argued that continuous creation was no more inexplicable than the appearance of the entire universe from nothing, although it had to be done on a regular basis. In the end, mounting observational evidence convinced most cosmologists that the steady state model was incorrect and that the Big Bang was the theory that agreed better with observations, although Hoyle continued to support and develop his theory. In 1993, in an attempt to explain some of the evidence against the steady state theory, he presented a modified version called "quasi-steady state cosmology" (QSS), but the theory is not widely accepted.

The evidence that resulted in the Big Bang's victory over the steady state model included the discovery of the cosmic microwave background radiation in the 1960s, and the distribution of "young galaxies" and quasars throughout the Universe in the 1980s indicate a more consistent age estimate of the universe. Hoyle died in 2001 never accepting the Big Bang theory.[28]

> "How, in the big-bang cosmology, is the microwave background explained? Despite what supporters of big-bang cosmology claim, it is not explained. The supposed explanation is nothing but an entry in the gardener's catalogue of hypothesis that constitutes the theory. Had observation given 27 Kelvins instead of 2.7 Kelvins for the temperature, then 27 kelvins would have been entered in the catalogue. Or 0.27 Kelvins. Or anything at all."
>
> —Hoyle, 1994[29]

6. Theory of Gravity

Together with Narlikar, Hoyle developed a particle theory in the 1960s, the Hoyle–Narlikar theory of gravity. It made predictions that were roughly the same as Einstein's general relativity, but it incorporated Mach's Principle, which Einstein had tried but failed to incorporate in his theory. The Hoyle-Narlikar theory fails several tests, including consistency with the microwave background. It was motivated by their belief in the steady state model of the universe.

7. Rejection of Earth-based Abiogenesis

In his later years, Hoyle became a staunch critic of theories of abiogenesis to explain the origin of life on Earth. With Chandra Wickramasinghe, Hoyle promoted the hypothesis that the first life on Earth began in space, spreading through the universe via panspermia, and that evolution on Earth is influenced by a steady influx of viruses arriving via comets. His belief that comets had a significant percentage of organic compounds was well ahead of his time, as the dominant views in the 1970s and 1980s were that comets largely consisted of water-ice, and the presence of organic compounds was then highly controversial. Wickramasinghe wrote in 2003: "In the highly polarized polemic between Darwinism and creationism, our position is unique. Although we do not align ourselves with either side, both sides treat us as opponents. Thus we are outsiders with an unusual perspective—and our suggestion for a way out of the crisis has not yet been considered."[30]

Hoyle and Wickramasinghe advanced several instances where they say outbreaks of illnesses on Earth are of extraterrestrial origins, including the 1918 flu pandemic, and certain outbreaks of polio and mad cow disease. For the 1918 flu pandemic, they hypothesized that cometary dust brought the virus to Earth simultaneously at multiple locations—

a view almost universally dismissed by experts on this pandemic. In 1982 Hoyle presented *Evolution from Space* for the Royal Institution's Omni Lecture. After considering what he thought of as a very remote possibility of Earth-based abiogenesis he concluded:

> If one proceeds directly and straightforwardly in this matter, without being deflected by a fear of incurring the wrath of scientific opinion, one arrives at the conclusion that biomaterials with their amazing measure of order must be the outcome of intelligent design. No other possibility I have been able to think of...
>
> —Fred Hoyle[31]

Published in his 1982/1984 books *Evolution from Space* (co-authored with Chandra Wickramasinghe), Hoyle calculated that the chance of obtaining the required set of enzymes for even the simplest living cell without panspermia was one in $10^{40,000}$. Since the number of atoms in the known universe is infinitesimally tiny by comparison (10^{80}), he argued that Earth as life's place of origin could be ruled out. He claimed:

> The notion that not only the biopolymer but the operating program of a living cell could be arrived at by chance in a primordial organic soup here on the Earth is evidently nonsense of a high order.

Apparently, Hoyle had not heard of the RNA world or the evolution of proteins from simple peptides,[32] hence his calculations were not compatible with modern molecular evolution.

Though Hoyle declared himself an atheist,[33] this apparent suggestion of a guiding hand led him to the conclusion that "a superintellect has monkeyed with physics, as well as with chemistry and biology, and ... there are no blind forces worth speaking about in nature."[34] He would go on to compare the random emergence of even the simplest cell without panspermia to the likelihood that "a tornado sweeping through a junk-yard might assemble a Boeing 747 from the materials therein" and to compare the chance of obtaining even a single functioning protein by chance combination of amino acids to a solar system full of blind men solving Rubik's Cubes simultaneously.[35] This is known as "the junkyard tornado", or "Hoyle's Fallacy". Those who advocate the intelligent design (ID) belief sometimes cite Hoyle's work in this area to support the claim that the universe was fine tuned in order to allow intelligent life to be possible.

8. Other Controversies

While Hoyle was well-regarded for his works on nucleosynthesis and science popularization, he held controversial positions on a wide range of scientific issues, often in direct opposition to the prevailing theories of the scientific community.[2] Paul Davies describes how he "loved his maverick personality and contempt for orthodoxy", quoting Hoyle as saying "I don't care what they think" about his theories on discrepant redshift, and "it is better to be interesting and wrong than boring and right".[36]

Hoyle often expressed anger against the labyrinthine and petty politics at Cambridge and frequently feuded with members and institutions of all levels of the British astronomy community, leading to his resignation from Cambridge in September 1971 over the way he thought Donald Lynden-Bell was chosen to replace retiring professor Roderick Oliver Redman behind his back.[37] According to biographer Simon Mitton, Hoyle was crestfallen because he felt that his colleagues at Cambridge were unsupportive.[2]

In addition to his views on steady state theory and panspermia, Hoyle also supported the following controversial hypotheses and speculations:

- The correlation of flu epidemics with the sunspot cycle, with epidemics occurring at the minimum of the cycle. The idea was that flu contagion was scattered in the interstellar medium and reached Earth only when the solar wind had minimum power.[38][39][40][41]
- Two fossil *Archaeopteryx* were man-made fakes.[42] This assertion was definitively refuted by, among other strong indications, the presence of microcracks extending through the fossils into the surrounding rock.
- The theory of abiogenic petroleum, held by Hoyle and by Thomas Gold, where natural hydrocarbons (oil and natural gas) are explained as the result of deep carbon deposits, instead of fossilized organic material. This theory is dismissed by the mainstream petroleum geochemistry community.[43]
- In his 1977 book *On Stonehenge*, Hoyle supported Gerald Hawkins proposal that the fifty-six Aubrey holes at Stonehenge were used as a system for neolithic Britons to predict eclipses, using them in the daily positioning of marker stones. The use of the Aubrey holes for predicting lunar eclipses was originally proposed by Gerald Hawkins in his book of the subject *Stonehenge Decoded* (1965).

8.1. Nobel Physics Prizes

Hoyle was also at the centre of two unrelated controversies involving the politics for selecting the winner of the Nobel Prize for Physics. The first came when the 1974 prize went, in part, to Antony Hewish for his leading role in the discovery of pulsars. Promptly Hoyle made an off-the-cuff remark to a reporter in Montreal that "Yes, Jocelyn Bell was the actual

discoverer, not Hewish, who was her supervisor, so she should have been included." This remark received widespread international coverage. Worried about being misunderstood and by British libel laws, Hoyle carefully[44] composed a letter of explanation to *The Times*.[20]

The second controversy came when the 1983 prize went in part to William Alfred Fowler "for his theoretical and experimental studies of the nuclear reactions of importance in the formation of the chemical elements in the universe." The controversy arose because Hoyle had been the inventor of the theory of nucleosynthesis in the stars with two research papers[45] published shortly after WWII. So some suspicion arose that Hoyle was denied the third share of this prize because of his earlier public disagreement with the 1974 award.[46] British scientist Harry Kroto later said that the Nobel Prize is not just an award for a piece of work, but a recognition of a scientist's overall reputation and Hoyle's championing many disreputable and disproven ideas may have invalidated him.[20][47] In *Nature*, editor John Maddox called it "shameful" that Fowler had been rewarded with a Nobel prize and Hoyle had not.[47]

9. Media Appearances

Hoyle appeared in a series of radio talks on astronomy for the BBC in the 1950s;[48] these were collected in the book *The Nature of the Universe*,[49] and he went on to write a number of other popular science books.

In the play *Sur la route de Montalcino*, the character of Fred Hoyle confronts Georges Lemaître on a fictional journey to the Vatican in 1957.[50]

Hoyle also appeared in the 1973 short film *Take the World From Another Point of View*.[51]

In the 2004 television movie *Hawking*, Fred Hoyle is played by Peter Firth. In the movie, Stephen Hawking (played by Benedict Cumberbatch) publicly confronts Hoyle at a Royal Society lecture in summer 1964, about a mistake he found in his latest publication.

10. Honours

A statue of Fred Hoyle at the Institute of Astronomy, Cambridge. https://handwiki.org/wiki/index.php?curid=1229392

10.1. Awards

- Elected a Fellow of the Royal Society (FRS) in 1957[1][52]
- Gold Medal of the Royal Astronomical Society (1968)
- Bakerian Lecture (1968)
- Bruce Medal (1970)
- Henry Norris Russell Lectureship (1971)
- Jansky Lectureship before the National Radio Astronomy Observatory
- Knighthood (1972)

- President of the Royal Astronomical Society (1971–1973)
- Royal Medal (1974)
- Klumpke-Roberts Award of the Astronomical Society of the Pacific (1977)
- Balzan Prize for Astrophysics: evolution of stars (1994, with Martin Schwarzschild)
- Crafoord Prize from the Royal Swedish Academy of Sciences, with Edwin Salpeter (1997)

10.2. Named after Him

- Hoyle Building, Institute of Astronomy, Cambridge
- Asteroid 8077 Hoyle
- *Janibacter hoylei*, species of bacteria discovered by ISRO scientists[53]
- Sir Fred Hoyle Way, a stretch of the A650 dual carriageway in Bingley.[54]
- Institute of Physics Fred Hoyle Medal and Prize

10.3. Fonds

The Fred Hoyle Collection at St John's College Library contains "a pair of walking boots, five boxes of photographs, two ice axes, some dental X-rays, a telescope, ten large film reels and an unpublished opera" in addition to 150 document boxes of papers.[55]

11. Bibliography

11.1. Non-fiction

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- *Frontiers of Astronomy*, Heinemann Education Books Limited, London, 1955. The Internet Archive. HarperCollins, ISBN:978-0060027605
- Burbidge, E.M., Burbidge, G.R., Fowler, W.A. and Hoyle, F., "Synthesis of the Elements in Stars", *Revs. Mod. Physics* **29:**547–650, 1957, the famous B^2FH paper after their initials, for which Hoyle is most famous among professional cosmologists.
- *Astronomy, A history of man's investigation of the universe*, Crescent Books, Inc., London 1962, LCCN 62-14108
- *Of men and galaxies*, Seattle University of Washington, 1964, ASIN B0087VKR70
- *Galaxies, Nuclei, and Quasars*, Harper & Row, Publishers, New York, 1965, LCCN 65-20996
- *Nicolaus Copernicus*, Heinemann Educational Books Ltd., London, p. 78, 1973
- *Astronomy and Cosmology: A Modern Course*, 1975, ISBN:0-7167-0351-3
- *Energy or Extinction? The case for nuclear energy*, 1977, Heinemann Educational Books Limited, ISBN:0-435-54430-6. In this provocative book Hoyle establishes the dependence of Western civilization on energy consumption and predicts that nuclear fission as a source of energy is essential for its survival.
- *Ten Faces of the Universe*, 1977, W.H. Freeman and Company (San Francisco), ISBN:0-7167-0384-X, ISBN:0-7167-0383-1
- *On Stonehenge*, 1977, London : Heinemann Educational, ISBN:978-0-435-32958-7; San Francisco: W.H. Freeman and Company, ISBN:0-7167-0364-5 pbk.
- *Lifecloud – The Origin of Life in the Universe*, Hoyle, F. and Wickramasinghe C., J.M. Dent and Sons, 1978. ISBN:0-460-04335-8
- *Diseases from Space* (with Chandra Wickramasinghe) (J.M. Dent, London, 1979)[56]
- *Commonsense in Nuclear Energy*, Fred Hoyle and Geoffrey Hoyle, 1980, Heinemann Educational Books Ltd., ISBN:0-435-54432-2
- The big bang in astronomy, *New Scientist* **92**(1280):527, 19 November 1981.
- *Ice, the Ultimate Human Catastrophe*,1981, ISBN:0-8264-0064-7 [57] Snippet view from Google Books
- *The Intelligent Universe*, 1983
- *From Grains to Bacteria*, Hoyle, F. and Wickramasinghe N.C., University College Cardiff Press, ISBN:0-906449-64-2, 1984
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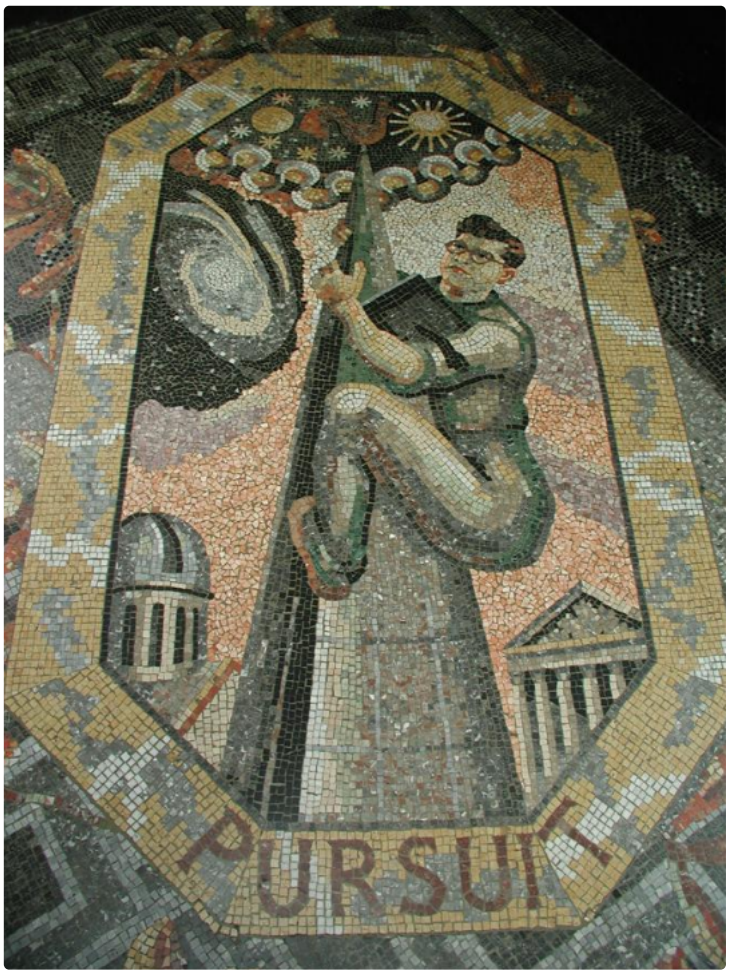
11.2. Science Fiction



A mosaic by Boris Anrep depicting Fred Hoyle as a steeplejack climbing to the stars, with a book under his arm, in the National Gallery, London. https://handwiki.org/wiki/index.php?curid=1676119

Hoyle also wrote science fiction. In his first novel, *The Black Cloud*, most intelligent life in the universe takes the form of interstellar gas clouds; they are surprised to learn that intelligent life can also form on planets. He wrote a television series, *A for Andromeda*, which was also published as a novel. His play *Rockets in Ursa Major* had a professional production at the Mermaid Theatre in 1962.

- *The Black Cloud*, 1957
- *Ossian's Ride*, 1959
- *A for Andromeda*, 1962 (co-authored with John Elliot)
- *Fifth Planet*, 1963 (co-authored with Geoffrey Hoyle)
- *Andromeda Breakthrough*, 1965 (co-authored with John Elliot)
- *October the First Is Too Late*, 1966
- *Element 79*, 1967
- *Rockets in Ursa Major*, 1969 (co-authored with Geoffrey Hoyle)
- *Seven Steps to the Sun*, 1970 (co-authored with Geoffrey Hoyle)
- *The Inferno*, 10/1973 (co-authored with Geoffrey Hoyle)
- *The Molecule Men and the Monster of Loch Ness*, 1973 (co-authored with Geoffrey Hoyle)
- *Into Deepest Space*, 1974 (co-authored with Geoffrey Hoyle)
- *The Incandescent Ones*, 1977 (co-authored with Geoffrey Hoyle)
- *The Westminster Disaster*, 1978 (co-authored with Geoffrey Hoyle and Edited by Barbara Hoyle)
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- *The Planet of Death*, 1982 (Ladybird Books, co-authored with Geoffrey Hoyle)
- *The Giants of Universal Park*, 1982 (co-authored with Geoffrey Hoyle)

Most of these are independent of each other. *Andromeda Breakthrough* is a sequel to *A for Andromeda* and *Into Deepest Space* is a sequel to *Rockets in Ursa Major*. The four Ladybird Books are intended for children.

Some stories of the anthology *Element 79* are fantasy, in particular "Welcome to Slippage City" and "The Judgement of Aphrodite". Both introduce mythological characters.

The Telegraph (UK) called him a "masterful" science fiction writer.[28]

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