At Home on the Cusps of Controversy; Hoyle on Hoyle's Life and Time

Home Is Where the Wind Blows: Chapters from a Cosmologist's Life

Fred Hoyle
University Science Books, Mill Valley, Calif., 1994.
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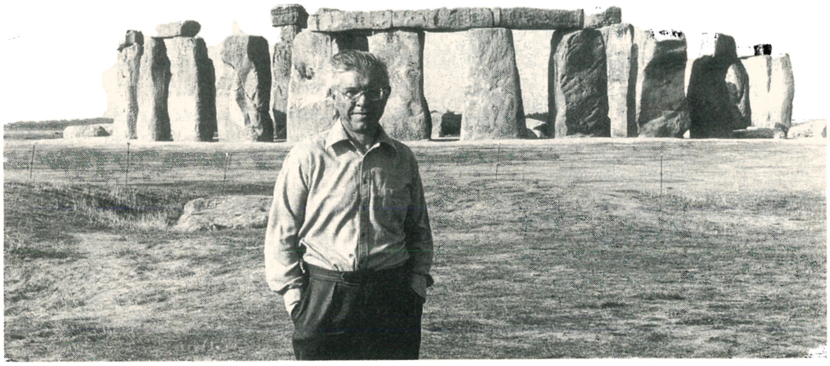
Reviewed by Stephen G. Brush



ASTRONOMER Fred Hoyle at Stonehenge. (From *Home is Where the Wind Blows*, courtesy of University Science Books, Sausalito, California.)

Fred Hoyle is the tragic hero of modern cosmology. Hero because he invented the first quantitative, empirically testable theory of the evolution from hydrogen of a world in which carbon-based life could exist. Tragic because the successful part of that theory has been overshadowed in the public mind by the failure of his desperate attempt to develop an alternative (the steady-state universe) to the dominant Big Bang theory. Like Albert Einstein, who could not control the growth of the indeterministic quantum theory he had created, Hoyle is haunted by the success of the explosive cosmology he named and helped to establish.

Dramatic words like "heroic" and "tragic" are entirely appropriate to describe a career that Hoyle himself has repeatedly advertised as a struggle between reason and mysticism, integrity and chicanery, individual enterprise and bureaucratic conformity. Many scientists see themselves as underdogs fighting against an entrenched establishment that suppresses new ideas or as victims of mendacious administrators and incompetent referees. But few have Hoyle's remarkable ability to reach the public through radio broadcasts, popular science books and science fiction.

Home Is Where the Wind Blows, Hoyle's venture into book-length (though curiously incomplete) autobiography, grabs the reader with its opening chapter on his father's experiences as a machine gunner in World War I. It recounts the author's progress from rebellious schoolboy to Cambridge University undergraduate, moving from the bottom of the "slow stream" in mathematics to the top of the "fast stream" and finally being able to compete with a classmate he characterizes as "one per 30 million population per year." The first half of the book, which describes Hoyle's painfully self-conscious evaluations of his own status and his attempts to gain recognition in the world of science, is fascinating. The second half, which tells what he did after winning that recognition, is somewhat less enchanting: Hoyle brags about his triumphs, downplays his failures and denounces his enemies.

Since Hoyle chooses not to give much space in this book to his role in the development and defense of the steady-state cosmology—he has discussed that role elsewhere in several articles—I will also ignore it. Let's turn instead to what he considers, quite rightly, to be a major achievement: the explanation of how carbon and heavier elements are formed by nuclear reactions in stars.

In the 1930s Hans Bethe and other physicists had shown that the energy of the stars could come from two cycles of nuclear reactions, one resulting in the fusion of protons into helium nuclei, the other resulting in the formation of nitrogen, oxygen and other nuclei from carbon. This work raised the tantalizing possibility that one could account for the synthesis of all the elements from hydrogen, either in stars or in the high-temperature, high-density conditions just after the Big Bang. But before 1953 there was no satisfactory explanation of how carbon could be formed from lighter elements. Edward E. Salpeter (and, in an earlier but forgotten paper, Ernst J. Öpik) had proposed that three alpha particles (helium-4 nuclei) could combine to form carbon 12, but calculations based on the known properties of the carbon-12 nucleus seemed to rule out this process.

Hoyle's contribution was to predict a hitherto unknown energy level (7.65 MeV above the ground state) in the carbon-12 nucleus. This would allow the combination of three alphas (otherwise very difficult because of the instability of the intermediate beryllium-8 nucleus) to proceed under appropriate conditions. The prediction was confirmed experimentally by William A. Fowler's group at Caltech. Hoyle then collaborated with Fowler and Margaret and Geoffrey Burbidge to develop a general theory of the synthesis of elements in stars, the famous "B^2FH" paper published in *Reviews of Modern Physics* in 1957.

Hoyle now suggests that his prediction was an early application of the anthropic principle as he formulates it: In order for the universe to be a home for humans, it must have

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certain physical properties. In particular, for Hoyle (and us) to exist there must be carbon. For carbon to exist there must be a nuclear process that forms it from hydrogen. For that process to work the carbon nucleus must have an energy level at about 7.65 MeV.

Home for Hoyle is not a cozy cottage with an overstuffed chair in front of the fireplace. Not for him the comforts of academic tenure and the polite respect of colleagues. He is at home on the tops of mountains, at the cusps of controversies, where the winds blow fiercely and even God is not omnipotent but, as Hoyle says, just "doing His best" to make an adequate universe.

The Essence of Chaos

Edward N. Lorenz
U. Washington P., Seattle, 1993. $19.95 hc
ISBN 0-295-97270-X

Although the flapping of a butterfly wing in Brazil might influence a tornado in Texas, its effect should not be confused with that of the fabled nail on the shoe of the horse of the rider, the loss of which caused the battle and the kingdom to be lost. Unlike the failure of a small but critical component, as Edward N. Lorenz indicates in a previously unpublished 1972 talk included as an appendix to *The Essence of Chaos*, the sensitivity of chaotic phenomena to initial conditions is democratic: Slight differences in each and every coupled variable can influence subsequent behavior on a large scale at distant points.

For the development of dynamical systems, the influences that helped shape Lorenz himself resemble effects on the fabled messenger's blacksmith, not on Amazonian breezes. How different would that history have been if Lorenz the Harvard mathematics student had not been assigned to weather forecasting in the US Army during World War II? If he had not been selected to head a statistical weather forecasting program in the 1950s? If he had not recognized early the importance of computing machinery and recognized and tracked down the consequences of round-off error? If he had not abstracted and analyzed the simple three-mode model that served as the paradigm of chaotic behavior through the 1960s and 1970s?

The book serves readers—from hungry passers-by to discerning gourmets—a selection of palate-whetting *hors d'oeuvres*: Using easily visualized examples involving pinball machines and bumpy ski slopes, Lorenz gives the novice the flavor of dynamical systems sensitively dependent on boundaries, and he offers quantitative scientists expertly selected vintage sips of Poincaré maps, strange attractors, Cantor sets and Smale horseshoes (from which the equations have been carefully decanted).

In keeping with his mathematical pedigree, however, he explains to literal-minded folk, who have never thought about experiments, that noiseless theories can be subjected to quantitative experimental study even though every real-world chaotic system is subject to some unspecifiable noise. To all he gives a thoughtful account of the intellectual development of dynamic meteorology over the past 40 years and an appreciation of what may be—and what will never be—feasible in forecasting the behavior of a five-million (or more) variable dynamical system. He also gives a very readable and interesting account of the investigations of chaotic dynamical systems with relatively few dynamical variables—first the conservative systems, to which Poincaré made so many contributions, and then the dissipative systems, where Lorenz's own contributions have played such an important role.

To savor culinary delights, one need not know how they were prepared. Likewise, Lorenz observes, to understand and appreciate chaos one need not be an expert on the routes to chaos (bifburcations and other phenomena that appear as values of parameters for which the system behaves more simply—often but not always prior to the occurrence of chaos). As excellent "where to eat" books do not dwell upon the deep and far-reaching chemical processes discovered in the process of cooking, Lorenz does not concentrate on the deep and universal phenomena associated with certain types of transitions to chaos (the phenomena of period-doubling, Arnold's tongues and so forth). This point is valid and worth making, but it may discomfort some physicists whose interest in and understanding of chaotic systems are linked to their analyses of phase transitions and whose natural inclination would be to devote more attention to discoveries in the kitchen.

Over the past few decades, because of the work of Lorenz and others, we have come to appreciate that even simple systems can exhibit behavior once considered exotic. This book tells that story well, apart perhaps from too few words of caution: that the complicated pictures and