Quantum theory: certainty in uncertainty

P. W. Atkins

The Cosmic Code: Quantum Physics as the Language of Nature. By Heinz R. Pagels. Pp.370. ISBN 0-671-24802-2. (Simon & Schuster:1982.) $17.50.

THIS is a book aimed squarely at the general reader with the intention of conveying not only the excitement of modern science but also the revolution in our comprehension of the world that accompanied the introduction of quantum theory. There are three parts: an account of quantum theory; a description of modern particle physics; and a brief personal reflection on the nature of physical laws. The material is presented non-mathematically and will be accessible to anyone who is interested in what the author rightly regards as the nonpareil of this century's social and cultural events. The text itself is characterized by the author's almost boyish eagerness to communicate his enthusiasm, and is sometimes so anxious to please that it trips over its own naivety ("Most physicists enjoy the outdoors") to the point, in one place, of ascribing the well-known allegory of Paley's watch to a speaker at a recent conference.

The most important section is the first, which occupies about half the book. It is woven around the biography of Einstein and his transition from being a revolutionary innovator to one who lost "his hot-line to the Old One" and refused to accept that determinism was dead. The intention of the section, apart from emphasizing a moral, is to present an exposition of quantum weirdness; the loss of objectivity, its replacement by an observer-created reality and the rejection of determinism — "the quantum theory is a theory of an instrumentally detected material reality" (p.99). Underlying (if not stemming from) this intention is an opposition to material reductionism (a programme that "cannot be carried out", p.135). The basis of this view is an acceptance of the Copenhagen interpretation of quantum mechanics with its emphasis on the meaninglessness of a concept until its mode of measurement has been defined. Pagels adopts the party line on this issue, and as such does a very good job. His argument leads, convincingly, to the ultimate quantum weirdness that "human intention influences the structure of the world" (p. 95), and the view that "quantum reality" is statistical.

Convincingly, that is, until one stops to think. In my view, for what it is worth, determinism *entered* physics with the uncertainty principle, and the principal confusion pervading so much interpretative commentary on quantum mechanics (and finding such lucid expression in this book) is the failure to distinguish between measurement and specification. I should explain what I mean. With quantum theory we first encountered a constraint on our description of the world. Classical mechanics attempted unknowingly to be overcomplete in its specification; quantum mechanics is the first theory we have (and possibly the last we shall need) that respects nature by refraining from imposing a description too strong for it to support. Quantum mechanics is fully deterministic in the sense that the evolution of a state under the influence of a hamiltonian is perfectly well-defined; it ceases being deterministic only when we insist upon reverting to an overcomplete discussion by asking questions that classical mechanics has conditioned us to believe are answerable or when, after we have prepared a system in an eigenstate of one observable, we seek to predict the outcome of another observation that classical mechanics has conditioned us to expect but which quantum mechanics proscribes. No wonder our predictions then squirt out in all directions! Quantum "randomness" is nothing more than this reaction to false expectation. Likewise, the strict Copenhagen requirement of "meaningless until measured" is a confusion between a mode of interpretation and a manner of exhibiting self-consistency (or at least of constructing thought experiments to show that there is no inconsistency). This viewpoint is consistent with Einstein's whose views, I suspect, have been overborne by the appeal of an interpretation that hangs on to classical modes of thought. This emphasizes yet again the delicacy of the balance in the dictum (p.67) that "physicists are conservative revolutionaries . . . pseudoscientists lack that commitment to existing principles".

My position then is strict determinism (or better, neodeterminism, because it must not be confused with classical determinism) showing itself as indeterminism only when false, culturally conditioned, classical questions are asked. Hence, in my view, Pagels has focused on a wholly misleading and fallacious interpretation which cannot fail to imbue his readers with a false impression of the nature of "quantum reality". I have to admit, though, that he has the forces of neoconvention ranged on his side (which does not mean he is right), and readers of this engaging book will leave it with a clear grasp of a conventional and widely accepted interpretation.

I have concentrated on a single aspect of the book, but one that lies at its core. There are many other remarks with which the careful reader will probably disagree. For instance, I could criticize at equal length the remarks to the effect that differences between macroscopic and microscopic phenomena are qualitative and not merely quantitative (p.128), that historical events are not reducible to individual acts on the part of human beings (p.131), and that quantum reality is statistical and therefore outside mathematics (p.337). There is also a peculiar blindness to the technical meaning of a "selfish" gene but not to its analogue "charm". There is also much to admire, especially the author's manifest deep concern to communicate. □

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Getting JET off the ground

John B. Adams

A European Experiment: The Launching of the JET Project. By Denis Willson. Pp.181. Hbk ISBN 0-85274-543-5; pbk ISBN 0-85274-549-4. (Adam Hilger/Heyden: 1981.) Hbk £10.50, $23; pbk £6.95, $15.50.

EVERYBODY who is concerned in Western European affairs should be interested in this account of "a European experiment". Opponents of the European Community system will find in it ample confirmation of their criticisms; supporters will see in it a triumph of the European spirit over national self-interest. For those who are convinced that international action is now the only way of carrying out major scientific enterprises in Europe, it will come as a sobering reminder of how very difficult it is to reach agreement at the European level.

The subject of the book is the launching of the Joint European Torus (JET) project, the latest and largest experiment in the world-wide effort which started back in the 1950s to exploit nuclear fusion reactions as a useful energy source. To make this dramatic story (or lamentable comedy as it was once described) intelligible to the layperson, the author has first to explain something about plasma physics, the general history of nuclear fusion research and the complexities of the European Community system, all of which he does with commendable clarity. Having provided the reader with the essential background information, he then describes the specific problems presented by JET.

The principal difficulty that arose in the launching process and the reason for the two-year delay in the approval of the project was the problem of where to locate it. After the failure of the Community to agree to a common nuclear fission reactor programme and the consequent disarray this caused to the Euratom laboratory at ISPRA, which was set up to carry out that programme, the Commission devised a

JET Joint Undertaking

JET takes form — the eight limbs are part of the transformer core of the machine, currently under construction in the Torus Hall at Culham.

different method for pursuing nuclear fusion research in Europe. This was to set up a coordinated research programme using the existing national fusion laboratories rather than to try to bring all the work together in a single European laboratory. This method proved acceptable to the national laboratories and to the Governments concerned, and it worked very well until the JET experiment came along. Because of its large size and the need to engage most of the national laboratories in its design and construction, it did not easily fit into the established pattern. A new system was adopted, called a Joint Undertaking, which made JET a common European enterprise. But there was no European fusion laboratory in which to build it.

The Commission first suggested that JET should be built at ISPRA where there were resources then under-utilized. This proposal was opposed by many of the fusion scientists who feared that the project would be seriously handicapped by the absence of fusion expertise at ISPRA and by its previous history. It was also opposed by several member states, who saw JET as a desirable acquisition and who proposed alternative sites for it on their own territories. The scene was thus set for a first-class battle for the JET site in which all of the many levels of the Community became involved, and it is this battle which forms the main drama of the book.

Denis Willson describes these events, blow by blow, with great objectivity and with refreshing frankness which makes his book a very valuable account of the trials and tribulations of those who have the need — and the courage — to launch international projects in Europe. It may even be used to avoid similar problems arising again in the future but, as the author points out, the Governments in Europe still have no agreed way of resolving such problems and it is difficult to see how they will acquire one as long as they insist on unanimity (which, incidentally, they had finally to forego to reach a decision on JET). But, despite all the difficulties, JET was finally approved and is now under construction next to the British nuclear fusion laboratory at Culham where it appears to be going very well.

Similar dilemmas faced by CERN, the European Organization for Nuclear Research, are occasionally quoted for comparison but it is not mentioned that it took CERN much more than two years to reach a decision on where to build its SPS machine. This problem was finally resolved when the scientists involved agreed to reshape that project and themselves proposed the only site where it could be built — something which the scientists in the national fusion laboratories were apparently unable to do for JET.

This book is a well-written and thought-provoking account of a European experiment in all senses by someone who played a key role in the launching of JET and who had access to all of the documentation. It can and should be read and digested by all serious-minded citizens of Europe — politicians, civil servants, scientists and laypersons — and it will surely be read and noted by similar people in other regions of the world. □

Sir John Adams, currently at CERN, was Director of the Culham Laboratory from 1960 to 1967.

Space for science?

John Noble Wilford

Beyond the Atmosphere: Early Years of Space Science. By Homer E. Newell. Pp.497. ISBN 0-80-607146. (NASA Scientific and Technical Information Branch: 1981.) Hbk $12.50; pbk $9.50.

FROM the start, in 1958, the National Aeronautics and Space Administration and the scientific community have had an uneasy and ambivalent relationship. It was probably unavoidable. For all their shared interests in exploration, they approached the space age with different priorities and expectations. Scientists saw in NASA a new source of research funding and of opportunities to study Earth, the Solar System and the Universe. While NASA was not ungenerous in its early dealings with scientists, its administrators marched to a different drummer. Given their political mandate, which was to establish the United States as the pre-eminent space power, the NASA managers accorded highest priority to projects aimed at "catching up" with and eventually "beating" the Soviet Union. Scientists had no choice but to accept a secondary role in the Apollo Project, for example, and to live with a relatively small share of the space budgets, now as then. Tensions between them and NASA have been an inevitable consequence.

The potential for conflict has, if anything, risen since the Apollo days. Even at the height of the Apollo mobilization, not a year went by without the initiation of a new space-science project. A small share of ample budgets paid for a lot of science. Post-Apollo budget reductions, however, coupled with inflation and the expense of the space shuttle, have now squeezed space science to the point of near-paralysis. New projects are rare, and existing ones are forever being threatened with deferral or cancellation, a fate that recently befell the Venus Orbiting Imaging Radar Mission and the American half of the International Solar Polar Mission. Only desperate lobbying by scientists, led by Carl Sagan, saved the Galileo Project from extinction this year.

In this context of uncertainty verging on despair, scientists will read Homer E. Newell's *Beyond the Atmosphere* with a sense of nostalgia for the early days of space science. Dr Newell, who retired in 1973 as NASA's associate administrator, bore much of the responsibility for mediating NASA's relationship with scientists so that a vigorous space-science programme was possible. He is a scientist himself who brought to his job considerable experience in managing Government science undertakings. His book is another in a series of histories prepared under NASA auspices, which means that it is, in a sense, "official history", though somewhat more candid than most works of this genre.

Much of the book reviews the origins of space science as a part of NASA's operations and the achievements of NASA-financed research from 1958 to the mid-1970s. Space science, the way Dr Newell uses the term, is the multidisciplinary pursuit of a knowledge made possible or significantly aided by rockets and spacecraft. The breadth of the field as it evolved is impressive: geodesy, meteorology, atmospheric and ionospheric physics, magnetospheric research ("a genuine product of the space age"), lunar and planetary science, solar studies, galactic astronomy, relativity and cosmology as well as the life sciences and exobiology.

Dr Newell acknowledges that the expanding perspective afforded by spaceflight has yet to produce any scientific revolution. But he writes with understandable pride of the "continuing harvest" of knowledge from space science, notably in the earth and planetary fields:

> No longer was the geophysicist confined to a study of only one body of the solar system. No longer was the study of the planets solely a venture of the astronomers. The dearth of new data that had led planetary studies into the doldrums and even disrepute . . . gave way to a sudden flood of new information that reawakened the astonomer's interest.

Other exciting developments included the effect on astronomy of space observations in the hitherto hidden wavelengths and the