deduction from their data: "The fact that most participants in our study considered the academic boycott as an irritant and inconvenience, rather than a significant obstacle to scholarly research, does indeed suggest that it was more a symbolic gesture than an effective agent of change." □

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Distant attraction

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The Force of Symmetry. By Vincent Icke. Cambridge University Press: 1995. Pp. 338. £35, \$54.95 (hbk); £13.95, \$24.95 (pbk).

IN a letter to a contemporary about gravity, Isaac Newton wrote that the idea that "one body can act upon another at a distance, through a vacuum, without the mediation of anything else, by and through which action and force may be conveyed from one to the other, is to me so great an absurdity, that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it". As is evident from this extract, Newton was clearly deeply uneasy about the mechanism for transmission of the gravitational force between two distant bodies, but the experimental success of his action-at-a-distance force law was undeniable. James Clerk Maxwell had to grapple with the same problems as he struggled to formulate the force laws of electromagnetism. In Maxwell's equations, action-at-a-distance is replaced by an electromagnetic field pervading all space. One of the greatest triumphs of classical physics was Maxwell's prediction of the existence of electromagnetic waves — oscillating electric and magnetic fields travelling with the speed of light. Indeed, light itself was shown to be a form of electromagnetic wave. The world of classical physics now seemed clear: all could be decomposed into charged matter and fields, with the electron as the paradigm of a point-like charged particle.

In this book, the Dutch physicist Vincent Icke takes up the evolution of these concepts in the twentieth century. Less than 50 years after Maxwell first formulated his fundamental equations came disturbing evidence that supposedly classical electromagnetic waves could somehow display particle-like properties. At the same time, our intuitive understanding of the nature of matter also began to fail: supposedly particle-like things such as electrons were shown to display wave-like behaviour. On top of these blows to the self-confidence of classical physics came Einstein and his theories of relativity which forced a radical

change of our ideas about space and time.

This book is about the interplay between quantum mechanics and relativity and about the guiding role played by symmetries in formulating our present view of matter, forces and fields. It is a great challenge that Icke undertakes and one that encompasses explanations not only of the fundamentals of quantum mechanics and relativity but also of the theory of the strong and weak nuclear forces at the frontier of our current understanding. The subject is undeniably fascinating and Icke's emphasis on symmetry and forces is a novel approach in a popular physics book. The only question is whether Icke really succeeds in his ambitious task of covering most of the fundamentals of modern physics at a level suitable for non-physicists.

Let me begin by saying what I like about the book. Icke is clearly an enthusiast whose love of physics is evident throughout. This enthusiasm together with his direct, non-academic style of writing will clearly attract many casual readers with an interest in modern physics. Chapter titles ranging from "Maybe I'm Heisenberg" (for an introduction to the quantum uncertainty principle) to "The physics of a tablecloth" (for an introduction to global and local symmetries) and section headings such as "The dizzy world of spin" and "Strawberry fields forever" give an accurate impression of the style. The early chapters also contain some nice exercises for the reader with a "Feynman diagram scanner" and an experiment with interference fringes. But the more I read, the more unhappy I became with both Icke's approach and style of writing. Part of this unhappiness is no doubt due to my determinedly academic upbringing, but some of my worries seem more than just prejudice. I do not find it helpful to find statements such as "Physics is not difficult; it's just weird", nor do I find it reassuring to be told that physics is "not particularly hard to explain" when there is ample evidence to the contrary. I am also unhappy to find statements such as "Because it is required that $c + c = c - c = c$, speed cannot be a simple algebraic number for which the normal rules of addition and subtraction hold" — I know what Icke is trying to explain but believe it unhelpful to write down 'equations' that are patent nonsense.

It was not, however, until his section on "Superposition and quantum sorcery" that I really parted company with his approach. In attempting to explain the difficult and subtle concept of quantum superposition, Icke introduces what he calls a "quantum chimaera, which may be considered simultaneously as one thing and as another". His example of superposition is that of a chimaera made from a pure lion state and a pure goat state. Measurement is described in terms of the chimaera either biting a cabbage or a zebra steak. It is difficult for me to gauge the reactions of a reader not

familiar with quantum mechanics on encountering this analogy, which Icke refers to repeatedly. Suffice it to say that I believe that his lion-goat chimaera is both confusing and unhelpful.

The level of mathematical sophistication required of the reader seems both variable and demanding. The concepts of vectors and vector addition are introduced in a single short paragraph. Phases and amplitudes are reassuringly introduced in the context of wave motion, but Icke then leads the reader on rapidly to complex numbers and Argand diagrams. Despite a footnote reassuring readers that they need not worry in detail about how to 'square' a complex number, a footnote two chapters on gives explicit instructions on how to multiply two complex numbers. It is for pedagogic reasons such as these that I wonder about the audience for the book. Stephen Hawking recounts that he was told that each equation he included in *A Brief History of Time* would halve the sales. In the end, Hawking compromised by including just one equation: Einstein's famous mass-energy relation. Icke includes many equations as well as academic-style footnotes, all of which I suspect will deter all but the most determined seeker after truth.

For the more serious physicist there are several worrying short-cuts taken by Icke in his presentation of quantum physics. I like his tablecloth analogy to explain local and global symmetries, but I am still trying to understand his footnote explaining the use of half-angles for spin-half doublets. His explanation of how to arrive at SU(N) symmetries makes it seem that theoretical physicists were breathtakingly stupid in not realizing this for 30 years or more. His dismissal of the problem of "collapse of the wave packet" as "a frightful misnomer" ignores problems that great quantum physicists such as John Bell spent a lifetime taking seriously. There are many other examples of such misleading oversimplifications, but one last one will make the point. His discussion of Heisenberg's uncertainty principle suggests that the momentum-position and energy-time uncertainty relations are on the same footing: Icke then goes on to talk about conjugate variables and operators. Energy and time are not conjugate variables in quantum mechanics. The famous Russian physicist Lev Landau was fond of illustrating that there was no restriction on the accuracy of their simultaneous measurement by saying: "There is obviously no such limitation — I can measure the energy and look at my watch; then I know both energy and time!" The correct interpretation of the energy-time uncertainty relation requires careful discussion: such care is unfortunately often lacking in this book. □

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