Quantum Revolution

The Birth of Quantum Mechanics

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The Breakthrough - Quantum Revolution 1
G Venkataraman
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This is an age of great popularisations and the practitioners of science at the highest levels, who till now formed an esoteric priesthood, have suddenly shown a willingness to emerge into the dust and tumble of the world and talk about the arcana of their art. A trend that began with *The Double Helix* by Watson, now enlists names like Murray Gell-Mann (*The Quark and the Jaguar*) and Roger Penrose (*The Emperor's New Mind*). In the life sciences, where it has traditionally been easier to maintain such a dialogue, there have been outstanding books in this genre - to mention just two : Richard Dawkins' *The selfish gene* and Stephen Jay Gould's *River out of Eden*. Then there is that colossus of the coffee table, Stephen Hawking, whose *A brief history of Time*, canonized him into a cult figure. In this country, sadly, with the honourable exception of J V Narlikar and Jagjit Singh, this variety of science writing has largely been neglected. It is this lacuna which Venkataraman has addressed with a superb series of books which he calls *The Junior Feynman series*. The work under review, which belongs to this series, is a conducted tour of the quantum kingdom. But like all good popularisations, it is also much more.

Lagrange once remarked that there was a mysterious pulse which beat under the superficial exterior of an algebraic equation; that in some significant sense an equation was wiser than its creators. Presumably he was referring to a fact recognized by those who have worked at the highest levels of scientific research, that information - once encoded into an equation - begins to have a life of its own. And this sense of a mysterious life is especially enhanced when the equation captures a piece of phenomenological reality, as in physical theory. Venkataraman has very effectively communicated this mystery in this excellent little book.

Like the third volume of the Feynman lectures on which it is modelled, the book opens with one of those abiding landmarks of quantum theory, the double slit experiment. (Venkataraman, like his professed ideal, Richard Feynman, apparently eschews that 'lumber of the schools', philosophy. We are therefore spared the conventional curtain raiser, de rigueur with some writers, who open any text on atomic theory by tracing it back to Democritus and Lucretius). In a detailed discussion of this experiment, in which the classical picture is contrasted with the quantum scenario, the scene is set for what is to follow. The plot gets thicker in the second chapter. Quantum Mechanics' conceptual framework is established through the introduction and discussion of ideas like transition amplitude, spin and the probabilistic interpretation of the Schrodinger equation. There is a discussion of Hamilton's principle of least action, via a brief digression through the calculus of variations.

In connection with the mathematical nuts and bolts with which the theory of the quantum is erected in this book, a remark becomes necessary. A respectable amount of mathematics would, if it is not an absolute prerequisite, definitely come in useful for anybody who would aspire to get down to the nitty gritty of the arguments. In fact, in the reviewer's opinion, two semesters' worth of mathematical analysis - including operator theory, the geometry of complex Hilbert spaces, advanced calculus, Fourier series - should be in the tool kit of the aforementioned aspirant. The Feynman lectures, it should be borne in mind - especially the parts of it relating to quantum mechanics - were originally designed for the sophomore students of Caltech. With the prevailing university standards in this country this would correspond roughly with the final year of our B.Sc. On the other hand the Feynman lectures had for audience a classroom full of very bright, extremely motivated students, who moreover, had the inestimable advantage of an inspired instructor standing before them, who also happened to be one of this century's greatest physicists. Under these conditions, occasional deficiencies of working knowledge might not be very serious. But it is very difficult to imagine anybody without a formal training in some fairly highbrow mathematics attempting to grasp the mathematical parts of Venkataraman's book. That throws up the interesting question of what the book's ideal audience is. Here we run into some difficulties. Where is the reader who needs complex numbers to be explained to him, but not operators? Or who is prepared to transit from the notion of a derivative to that of a partial differential equation in the course of a single page (page 47, 48)? For such a reader, an ability to hack his way undaunted through a thicket of squiggly hieroglyphs of partial differentials and Dirac's bra and ket notations would also come in handy. On the other hand, it would not have been out of place for the author to have amplified through a brief discussion, some physical concepts like the intensity of spectral lines or moment of inertia. Here, as in the earlier case, the author's attempt to address an audience which is as wide as possible, occasionally makes him overreach himself.

The third chapter, the longest in the book taking up nearly a quarter of its length, introduces few new ideas beside the Poisson bracket. On the other hand there is a full discussion of a few topics like Heisenberg's matrix mechanics, the Hamiltonian and the operator. A short section near the end presents, in rapid slide show sequence, three topics in quantum mechanics - scattering, normalization and tunneling. The chapter closes with the Dirac equation and the story of the positron.

The following short chapter which marks the half way point of the book is a literary equivalent of the seminar coffee break. In this excellently timed interregnum, the narration pauses with thumbnail sketches of some of the Titans of physics' heroic age - Einstein, Bohr, Born, de Broglie, Heisenberg, Schrodinger and Dirac. Incidentally, in a curious aside on Einstein, Venkataraman claims that "Einstein did not make any discovery that directly related to quantum mechanics". This must surely be defended only by an idiosyncratically narrow definition of quantum mechanics. At least, one that must be prepared to overlook his work not only on the photoelectric effect (which won him the Nobel prize), but also his 1916 paper which according to John Gribbin "laid the statistical ground rules for quantum theory". Apart from this there was that historic 1935 paper with Podolsky and Rosen - the EPR paradox - which finally led to Aspect's 1982 experiment that established non-locality.

The next chapter is a detailed account of dispersion theory and the matrix algebra underlying the Heisenberg formulation. The ideas are pursued from their inception through their evolution, by tracing the landmark papers that highlighted their development. The inevitably technical nature of the presentation is lightened at strategic points by an anecdotal repertoire that ranges from biographical notes to delightful little causerie columns. Incidentally, this custom of punctuating the narration by the insertion of boxed asides is commendably effective in banishing the tedium of long footnotes in fine print or worse, end-of-the-chapter references.

The following chapter presents some more historical overviews - especially the impact on quantum theory of the attempt by Schrodinger which generalized and integrated Hamilton's theory into quantum mechanics to develop wave theory and secondly, Dirac's equation which imported relativity into it. A certain amount of possible confusion over terminology could perhaps have been avoided by a more conventional use of standard symbols - e.g., *n* which is used to designate an integral variable in mathematics is now used for the refractive index, while the term *commutation* is apparently called in to pinch hit for the more reliable *commutativity*. The Bohr-Einstein debates form the substance of the next short penultimate chapter, while the last - an epilogue, really - promises to take up in the second part of the trilogy, what the trends discussed in the book foreshadow.

A major source of irritation in the book is the complete lack of references for any of the quotations with which the text is liberally strewn. Surely the author would not mind sharing his sources with his readers. A similar observation might perhaps be made about the bibliography, which could have been more extensive. But these lapses in no way mar the impression on closing the book, of a lucid style backed by uniformly high standards of expository skill. The scientific community in India - especially its more youthful members - should consider themselves indebted to G Venkataraman for this offering.

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The Rest of the Series

The second book of Venkataraman's series is entitled "QED - the jewel of physics". The three letters refer to Quantum Electrodynamics which is the formal name for the theory which describes charged particles – (in particular the electron) and the photons that they can emit and absorb. While the basic rules of the game were in place by 1930, it took till almost 1950 and the efforts of three extraordinary theorists – Tomonaga, Schwinger, and Feynman - for the full picture to emerge. Not only was there accurate agreement with experiment to a level never seen before in physics, but a whole new language of "quantum field theory" and "Feynman diagrams" was created which has served physicists for nearly half a century since then. Deep mathematical questions on apparently infinite results at intermediate steps of the calculation were thrown up as well - which are swept under a carpet of "renormalisation". QED is indeed the jewel of physics and a worthy second stage in the quantum pilgrim's progress.

In the third and last of his books on the Quantum Revolution, Venkataraman considers the philosophical underpinnings of Quantum Mechanics and their implications. The book is organized around the EPR paradox and the experimental set-up of Aspect, which finally administered the *coup-de-grace* to the "hidden variable" theories. What the Aspect experiment of 1982 achieved was much more than merely upholding the merits of one theory over its rivals. It has enthroned the outrageously counter - intuitive notion of non-locality as a fundamental feature of the architectonics of the universe. Since then, the weight of steadily accumulating evidence (vide *New Scientist*, June 1st, p 118, 1996), has tended to confirm the outcome of the Aspect experiment. The book reviews briefly the current status of the contending hypotheses in the field. The discussion is presented with all the crisp clarity and the expository skill which the readers of the earlier books would have learnt to expect. While the jury is still out over the final shape of QM's postulates, the readers of Venkataraman's books would be hoping that he would be pursuing some of the later developments of QM, in its post modern phase, so to speak - like string theory, for instance - in what Douglas Adams (in the *Hitchhiker* series) described as "a trilogy in four parts".

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