Graham Farmelo: The Strangest Man: The Hidden Life of Paul Dirac

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There have been a number of excellent reviews of this truly outstanding biography of the great physicist Paul Dirac, notably by John Gribbin, Louisa Gilder, and Freeman Dyson. The last one is, in my opinion, the best and is highly recommended (The New York Review of Books, Febr. 2009). Dyson begins his review by asking: “Why should anyone who is not a physicist be interested in Paul Dirac?” Unlike Einstein, with whom one could compare him, he is virtually unknown by the general public. As Farmelo reports about his experience in Bristol where Dirac was born and grew up:

> During my many visits to Bristol, over the last five years, I have met scarcely half a dozen people outside the university who have heard of him. In the Records Office, the best way of finding out about Dirac’s early school years is to ask to see the well-fingered documents about his fellow pupil, Archie Leach, aka Cary Grant. (p. 14).

Farmelo is to be congratulated for having attempted an almost impossible task of writing a highly readable biography about the life and work of arguably the greatest British physicist of the twentieth century. Before this wonderfully written biography appeared most people (including scientists) knew about Dirac through his difficult mathematical physics or and the many anecdotes circulated about his eccentric behavior and comments. Most articles about Dirac report his scientific achievements but imbedded in a plethora of anecdotes exploiting his eccentric personality.

Even among my students at the Faculty of Education who are preparing to become physics teachers most have only a vague recollection that he predicted the existence of antimatter and that he was a strange man, unapproachable and distant. When pressed further they might be able to give a cursory explanation of his reasoning based on one of Einstein’s equations that the solution for the energy of an electron involves a positive and a negative quantity. Dirac believed that the positive solution referred to the energy of the electron and the negative solution to a new particle later called the positron and discovered only a few years after the prediction studying cosmic rays. Very few of my students who want to become future physics teachers could give even this minimal explanation. What is interesting is that Dirac first thought the antiparticle was a negative proton!
Niels Bohr called him “the strangest man”, the comment used by Farmelo as the title for his book, and Einstein said to a friend: “I have trouble with Dirac, This balancing on the dizzying path between genius and madness is awful”.

My rationale for writing yet another review of this book is to provide information about the scientific thinking of one of the greats in physics for an audience of science (physics) educators. What was Dirac’s fundamental belief about how ideas in physics evolve? What are the implications for science education in general and for physics education in particular? Elsewhere I have argued that the spectrum of scientific activity ranges from specifiable mechanical procedures to the scientific activities of “normal” science, to the high-grade activity of scientists working on the “edge” of a paradigm. This activity cannot be captured by “method” (Stinner 2007). Einstein and Dirac certainly belong to those who work in the third region.

Gerald Holton wrote in 1979 (Einstein’s centenary) in the Physics Teacher (Holton 1979):

…it seems to be an impossible undertaking (to present a picture of Einstein’s way of thinking to students) His work was carried out at the very frontiers of physics and of human ability. And his mind was not open to easy study from the outside, but Einstein’s mind was accessible from the inside, since he was interested in the way the scientific imagination works and wrote about it frankly. (p. 157)

Holton recommends that students read his “Autobiographical Notes” of Einstein that he published in 1947 at the age of 67. This essay is an account of his intellectual development. He asks at the very beginning of the essay: “What, precisely, is thinking? For the essential of the being of a man of my type lies in precisely in what he thinks and how he thinks, not in what he does or suffers” (p. 157). In spite of this statement we have many biographies that discuss in great detail the life of Einstein.

As Freeman Dyson points out, both Dirac and Einstein were “unique human beings with strong opinions and strong passions”. Both won the Nobel Prize, each had two children of their own, both were deeply involved in the community of physicists, at least at the beginning of their work, both emigrated to the United States but found themselves isolated from the scientific community when they were old.

Nevertheless, Einstein was one of the most famous people in the world while Dirac was relatively unknown. It is interesting to note that Einstein’s Nobel Prize came 16 years after his revolutionary papers of 1905 but Dirac’s work in quantum mechanics was immediately recognized as outstanding and the Nobel Prize was awarded to the 31 year old Dirac three years later. One could argue that Einstein’s work in both relativity theory and quantum mechanics (the photoelectric effect) took a long time to be recognized because it was too revolutionary to be accepted into the classical paradigm of the day.

There have been many (far too many, I think) biographies of Einstein, some written for physicists (like Subtle is the Lord by Abraham Pais (1982) and many for the general reader but there are only two for Dirac: one by the physics historian Helge Kragh, written for specialists and the one by Graham Farmelo written for the general reader, but certainly attractive for scientists in general as well as physicists. For example, if the physicist wants to know the mathematical derivations as well as occasional comments made by Dirac about his particular scientific thinking and philosophical orientation, she can refer to Kragh’s book (1990) for explanation.

While Einstein provides a sustained discussion of his scientific thinking Dirac provides only intermittent and brief comments and one has to read between the lines to guess at his meaning.
When reading Farmelo’s book one soon realizes that the inscrutable, extremely private Dirac who almost never made public statements, actually lived a very interesting, highly adventurous life in the difficult pre-war and also post war era. His childhood and early adult life in Bristol and later at the Cavendish are described in detail. The difficulties he had with his authoritarian father, the relationship with his mother and two siblings, one of whom committed suicide, take up a good deal of the first part of the book. The rationale for such a detailed description is probably that these early years shaped his personality, especially the severe ruling of his father and the event of his older brother’s suicide. Dirac studied engineering in Bristol but later received a scholarship to read mathematics at Cambridge.

His genius for the emerging quantum mechanics was soon discovered when his doctoral thesis on the new quantum mechanics (supervised by Ralph Fowler), the first doctoral thesis on the topic, was published. Dirac then published his famous quantum mechanical solution of the behavior of electron and postulated the existence of antiparticles. He wrote the definitive text on quantum mechanics, still used today. All this before he was 30 years old. At the age of 33 he accepted the Lucasian professorship at Cambridge. He travelled a lot between 1925 and 1938: to Germany, America, Japan, Russia, the Crimea; he even took the Trans-Siberian railroad from Vladivostok to Moscow.

Dirac corresponded with most of the leading physicists, especially Heisenberg, Born, Schrödinger Oppenheimer and Einstein. He was especially impressed with the Schrödinger’s wave equation; later remarked that when Schrödinger first got the idea for this equation he immediately applied it to the hydrogen atom but his result did not agree with experiment. The reason for the disagreement was that the spin of the electron was not known at that time. However, after he incorporated the theory of special relativity he obtained the correct equation. Dirac then makes the following famous statement that sums up his own modus operandi:

It is more important to have beauty in one’s equations than to have them fit experiment… It seems that if one is working from the point of view of getting beauty in one’s equations, and if one has really a sound insight, one is on a sure line of progress. If there is not complete agreement between the results of one’s work and experiment, one should not allow oneself to be too discouraged, because the discrepancy may well be due to minor features that are not properly taken into account and that will get cleared up with further developments of the theory. (p. 47).

He had two very close friends, the Russian experimental physicist Peter Kapitza (Nobel Prize 1978) whom he met as a young man when Kapitza was working under Rutherford at the Cavendish, and in his old age in Tallahassee, Florida, the biologist Kurt Hofer. Kapitza was a very talkative, ebullient and very outspoken, just the opposite of the shy retiring Dirac. Late in life, in Tallahassee, Dirac for the first time became very talkative about his early life, especially describing in detail the mistreatment by his father. Hofer listened carefully but was very embarrassed. He did not know how to respond to a Dirac who for the first time talked for hours.

To sum up his early achievements in physics: he found the equation that describes the behaviour of the electron, proton and neutron, derived Schrödinger’s equation independently, anticipated Heisenberg’s uncertainty principle and wrote the most referred-to textbook on quantum mechanics. He used Einstein’s equation to argue that there is a positively charged particle and in his Nobel lecture he suggested that every elementary particle should have an antiparticle.

His approach was very personal, logical, and devoid of any history. According to Farmelo one reason why his approach was so puzzling was that he was an unusual hybrid: part theoretical physicist, part pure mathematician, and part engineer. He had the physicist’s
passion to know the underlying laws of nature, the mathematician’s love of abstraction, and the engineer’s insistence that theories give useful results. One is reminded of Einstein’s difficulties with the new mathematics he required for his general theory of relativity and Schrödinger’s outcry: “I wish I knew more mathematics!”. In the late 1930s he took a brief sojourn into cosmology. In 1937 he published a very short article (actually a letter written to the editor of the British journal *Nature*) on what he called “The large number hypothesis” an idea that speculates why some of the ratios of size scales in the universe are related to that of force scales. The ratios constitute very large, dimensionless numbers. He argued that the apparent equivalence of these ratios could imply a cosmology with these unusual features would mean that the strength of gravity, as represented by the gravitational constant, is inversely proportional to the age of the universe and that the mass of the universe is proportional to the square of the universe’s age. Apparently, when Bohr read this he said to his student George Gamow: “Look what happens to people when they get married.”

After the war Dirac worked on quantum electrodynamics and in 1946, at a conference “The Future of Nuclear Science” his lecture apparently had nothing new to say. The 28 year old Richard Feynman summed up what Dirac just said but concluded by cracking a few jokes and saying that Dirac “was on the wrong track”. Dirac was silent but Bohr urged Feynman to take the proceedings more seriously.

To get a good idea about Dirac’s thinking in his middle years, Farmelo suggests that one should read the only article that Dirac ever wrote for the layperson: “The Evolution of the Physicist’s Picture of Nature”, published in *Scientific American*, May Dirac (1963). It is possible to download this excellent article directly from Google.

In this article he describes two kinds of difficulties in quantum mechanics. The first kind is based on the question “How can one form a consistent picture behind the rules of the present quantum theory”? The other is connected to the fact that the present laws of quantum mechanics are sometimes inadequate to give any results. He thought that quantum mechanics had been so successful that the class one difficulty is important only to the philosopher and not the physicist. The class two difficulty leads to infinities that, although physicists have been able to handle by the so-called method of renormalization, he considers mathematically unsound and somehow a fluke, very much like the success of the Bohr model was a fluke and did not survive. Moreover, he argued that of the fundamental constants, c, h, and e, h will be derivable quantity in terms of the other two. Therefore the ideas we now have based on Heisenberg’s uncertainty relationship, will be different.

Finally, he reintroduces a new version of the ether and an idea of electrons not as point charges but as strings. His anticipation of the “new” mathematics (namely string theory) that could be productive using his style of scientific thinking, is illustrated in the following quote, taken from his 1963 *Scientific American* paper:

…”It may well be that the next advance in physics will come about along these lines: people first discovering the equations and then needing a few years of development in order to find the physical ideas behind the equations. My own belief is that this is a more likely line of progress than trying to guess at physical pictures (p. 53). One wonders how Dirac would react today to the global efforts of string theorists to understand nature. Would he admire their tenacity to continue working in this sustained top-down effort to be able to make empirically testable predictions? I will give the last word to Eugene Wigner, the brother-in-law of Dirac, taken from his celebrated paper, “The Unreasonable Effectiveness of Mathematics in the Natural Sciences”:
...it is important to point out that the mathematical formulation of the physicist’s often crude experience leads in an uncanny number of cases to an amazingly accurate description of a large class of phenomena (p. 8)

1 Implications for Physics Education

When you ask students in their first year of physics in secondary school what physics is, many of them will answer that “physics is mathematics”. Not surprising, students get the idea that physics consists of formulas to be memorized and then used to solve problems in the textbook. Textbooks in turn imply that the contemplative Newton sat under the tree and when an apple fell on his head he said “Aha, F = mg.” The conceptual evolution and the model building in response to empirical evidence that preceded the equations of mechanics are seldom given.

Galileo believed that nature is written in the language of mathematics. What he understood by the term was geometry and Euclidean ratios. Newton also believed that. What he meant by mathematics was Euclidean geometry and calculus (fluxions) and a little algebra. Dirac’s approach to understand the physics of the small was to find beautiful differential equations imbedded in modern geometry that yielded the result that could be empirically tested.

The new generation of theoretical physicists like Feynman, Gell-Mann, and Weinberg, however, drew inspiration from experimental observations that became much more productive than the top-down approach of Dirac that took inspiration from beautiful mathematics. Apparently, Dirac privately admitted this but refused to change his top-down approach to doing physics.

I have so far resisted to mention any of the many well known anecdotes (apocryphal or otherwise) featuring Dirac’s eccentricities but I cannot resist to conclude with the following story Farmelo tells us. When the head of the physics department at Florida State University in Tallahassee defended his invitation of the aging Dirac as a distinguished professor to be on the staff he said: “That would be like having the English department refusing a seat for William Shakespeare”.

References