A. Douglas Stone. *Einstein and the Quantum: The Quest of the Valiant Swabian.* 332 pp. Princeton University Press, 2013.

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This is, without a doubt, the most unusual biography of Einstein you will ever read. Whilst most Einstein biographies focus his development of special and general relativity, Stone's book is entirely focussed on his contributions to quantum theory. Furthermore, it is not about Einstein's later views and his famous debates with Bohr over the interpretation of quantum theory, which have received ample coverage elsewhere (see: Whitaker 1996, Lindley 2007, Kumar 2008), but rather about his contributions to the early development of the theory. Stone's thesis is that Einstein's contribution is vastly undervalued in most histories of the subject. He was so far ahead of the game that we might as well view quantum theory as entirely Einstein's baby until the likes of Bohr, Heisenberg and Schrödinger entered the scene.

At first sight, the idea that Einstein's contribution to quantum theory needs rehabilitation seems quite bizarre. Every undergraduate physicist learns of his explanations of the photoelectric effect and the specific heat of solids, and also that he played a role in discovering spontaneous emission, Bose-Einstein statistics, and Bose-Einstein condensation. This is already an impressive set of accomplisments, any one of which could serve as a basis for the entire career for an average physicist. However, the exact stories behind these discoveries and the multitude of other ways that Einstein contributed to quantum theory are not so well known. Stone's book aims to remedy this.

Stone makes a good case that only Einstein understood the significance of Planck's explanation of black-body radiation for a good decade or so after its discovery. Most physicists viewed it as a technical trick, and only Einstein argued from the very beginning that it required a radical reformulation of physics. Einstein returned to blackbody radiation multiple times, each time with more rigour, culminating in the derivation that we would today recognize as the correct approach.

Stone also makes compelling arguments that Einstein originated several other aspects of quantum theory, which are usually attributed to others. For example, I did not previously realize that Einstein was the first to introduce inherent probabilities into quantum theory via his theory of spontaneous emission. The originators of quantum atomic theory, such as Bohr and Sommerfeld, all thought that transitions between energy levels would be driven deterministically by classical electromagnetic fields. It was Einstein who introduced indeterministic jumps, and Stone successfully argues that this was the key inspiration for Born's statistical interpretation of the wavefunction.

Stone's discussion of Einstein's early thought experiments in quantum theory will be of special interest to those who work on the foundations of quantum theory. Whilst the EPR argument and his Solvay debates with Bohr are well-known, it is not common knowledge that Einstein was worrying about similar issues many years before the final form of quantum mechanics was pinned down. For example, in 1908, Einstein produced a thermodynamic argument aimed at showing that both wave and particle aspects of light must be real, and by 1916 he was already worring about the "spherical wave paradox", i.e. how can a sperical wave produce a pointlike detection event at a single place without nonlocal influences. The latter is essentially the same as a better known argument that Einstein gave at the 1927 Solvay conference, which eventually turned into the EPR argument.

There are a couple of places where I think Stone over-eggs the pudding in his arguments for Einstein's prescience. In Chapter 22, Stone describes Einstein's idea of understanding wave-particle duality in terms of “ghost fields”, which he discussed from 1918 onwards. The idea is that electromagnetic radiation is composed of particles, which are guided by ghost fields that obey classical electromagnetism. The particles are the things that we directly detect, whereas the ghost fields merely reveal their presence via a stochastic influence on the motion of the particles. Stone cites this as a direct precursor to Born's statistical interpretation of the wavefunction. However, to my mind it is much closer de Broglie-Bohm theory, the main difference being that Einstein intended the ghost fields to have a stochastic influence on the particles rather than a deterministic one. There is a big difference between saying that ghost fields are not directly detectable and saying that they are somehow insubstantive or less real than the particles, but Stone leaps effortlessly over this chasm. I doubt Einstein would have agreed.

Later on in the same chapter, Stone cites Einstein's work on Bohr-Sommerfeld quantization as a precursor to modern quantum chaos theory. The evidence for this is that Einstein pointed out that such a quantization procedure would not work for non-periodic orbits. To my mind, this is quite far from modern quantum chaos theory, which has to do with understanding how classical chaotic motion can emerge from quantum theory. In other words, we have no problem quantizing such systems, but rather with working out how they get dequantized. Einstein's issue seems more to do with the fact that the full theory of quantum mechanics had not been worked out yet, rather than being a precursor to modern quantum chaos.

It is worth mentioning that Stone's book is aimed at the lay reader, so it does not give any technical details. Those who study quantum theory professionally will want to supplement the book with some of Einstein's papers or a scientific biography like (Pais 1982). As a popular book, Stone's work suffers a bit from the “audience problem”, i.e. the topic is a bit too specialized to attract a wide lay audience and it does not include enough technical detail for the specialist. It is hard to imagine that many readers with no background in physics would want to read this rather than a general biography of Einstein, such as (Isaacson 2007). Similarly, (Lindley 2007) would be better for a first enounter with the history of quantum theory. However, the book does serve well for Einstein buffs who have already read those things, for physics undergraduates who want to know more history, and for professional historians, physicists and philosophers who want a gentle introduction to Einstein's role in the early development of quantum theory. Stone has a great narrative facility and a judicious eye for a good quote. In particular, the young Einstein's personality shines through the early chapters and I often found myself lauging at his wit and cheekyness. I would strongly recommend this book to anyone with an interest in the early history of quantum theory.

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