HEISENBERG, THE SALIERI OF PHYSICS

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A NEW PERSPECTIVE BY K. STRANG

The Rivals

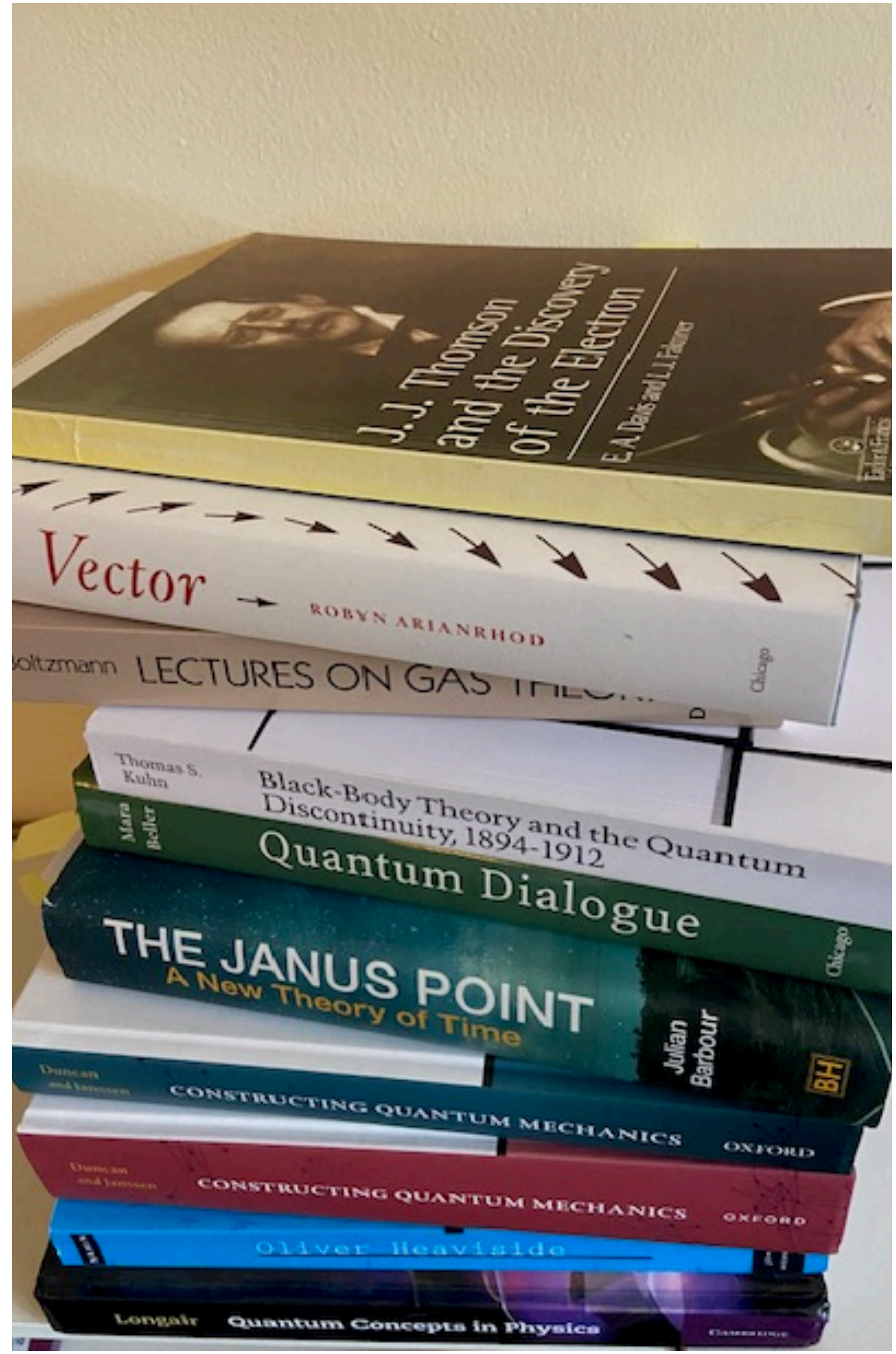
The professional rivalry between Heisenberg (1901-1976) and Schrödinger (1887-1961) is well documented and the fact that Schrödinger's wave equation was preferred to Heisenberg's matrix mechanics, must have rankled him and he set about sabotaging Schrödinger's work in much the same way as Salieri attempted to sabotage Mozart.

The two physicists were attempting to give a theoretical description of the motion of the electron in Bohr's model of the hydrogen atom. The 'solar-system' model of a nucleus made up of one positively charged proton and one negatively charged electron orbiting the nucleus. This schematic model helped develop the periodic table and has been essential to an understanding of chemistry and biology but I believe falls short in describing the physical reality. A. N. Whitehead warned against mistaking the map for the territory as for example thinking the London underground map, the utility of which cannot be questioned, actually describes the network of tunnels beneath London's streets.

Bohr's faulty reasoning can be found in a 1911 paper in which he states that electromagnetic waves cannot be included in the description of the atom because:

'This is presumably due to the circumstance that the electromagnetic theory is not in accordance with the real conditions and can only give correct results when applied to a large number of electrons (as are present in ordinary bodies) or to determine the average motion of a single electron over comparatively long periods of time (such as in the calculation of the motion of cathode rays) ***but cannot be used to examine the motion of a single electron within short intervals of time.*****"** (Bohr 1911,p378 our emphasis) [*Constructing Quantum Mechanics* Vol 1, p 147]

This conclusion is only true if one thinks of the electron as a discrete particle moving from *a* to *b* in its orbit around the nucleus. However if one thinks of the electron as a pulsing standing wave then the theory of electromagnetism is relevant. In describing the atom, Heisenberg followed a particle approach and Schrödinger a wave approach. It should be noted in passing that the corpuscular theory of matter had been discredited centuries earlier by Leibniz (1646–1716). Whatever the benefits of using systems of particles for calculations and models, does not make the ontological claim more persuasive. As discussed below, Bohr's atomic model encounters many logical difficulties.



Interpretation of Schrödinger's Wave equation

There was a tug of war between the competing theories of Heisenberg's matrix mechanics and Schrödinger's wave equation to explain the evolution of quantum systems and effects. Max Jammer in *The Philosophy of Quantum Mechanics: The Interpretations of QM in Historical Perspective* writes of Heisenberg's theory:

' . . . [it] defied any pictorial representation; it was an algebraic approach which, proceeding from the observed discreteness of spectral lines, emphasised the element of discontinuity, in spite of its renunciation of classical description in space and time it was ultimately a theory whose basic conception was the corpuscle.'

and of Schrödinger's approach:

' . . . based on the familiar apparatus of differential equations, akin to the classical mechanics of fluids and suggestive of an easily visualisable representation: it was an analytical approach which, proceeding from a generalisation of the laws of motion, stressed the element of continuity, and as its name indicates, it was a theory whose basic concept was the wave.' [M. Jammer,1974, Wiley, New York]

So the schism which developed over blackbody radiation and the existence of 'quanta' deepened and the main protagonists were not very polite about each other's work:

'The more I ponder about the physical part of Schrödinger's theory, the more disgusting it seems to me.' [Heisenberg in a letter to Pauli, Quantum Concepts in Physics by Malcolm Longair published by Cambridge University Press, 2013, p292]

Schrödinger responded in kind:

'I was discouraged, if not repelled by what appeared to me a rather difficult method of transcendental algebra, defying any visualisation.' [ibid p 293]

The main thrust of Heisenberg's criticism was that Schrödinger's wave equation, although powerful 'throws overboard everything which is 'quantum theoretical' namely the photo-electric effect . . .' [ibid, p345]

The upshot was a strange compromise whereby the wave equation was accepted but reinterpreted by Max Born (1882-1979) not as a description of reality involving wave phenomena but as a probabilistic mathematical tool to preserve the notion of a particle as a discrete entity and to locate the probability of its whereabouts. Heisenberg was fully on board with this interpretation. It is really this mathematical and epistemological schism which manifests itself in all the ensuing experiments as evidence of a real particle-wave duality and the heralding of a new age of physics where the universe is not deterministic but random, probablistic and contains weird effects.

Schrödinger never accepted this interpretation and believed his wave equation described a real physical process:

'I am no friend of probability theory, I have hated it from the first moment when our dear friend Max Born gave it birth. For it could be seen how easy and simple it made everything, in principle, everything ironed and the true problems concealed. Everybody must jump on the bandwagon [Ausweg]. And actually not a year passed before it became an official credo, and it still is.' [Letter to Albert Einstein (13 June 1946), as quoted by Walter Moore in *Schrödinger: Life and Thought* CUP 1989]

Mara Beller points out how the Copenhagen cabal did everything they could to discredit Schrödinger:

'After Einstein, Schrödinger was the most prominent and the most adamant opponent of the Copenhagen Interpretation of quantum physics. As in Einstein's case, the Copenhagen orthodoxy trivialised Schrödinger's objections and understated his prominent insights. Goittingen-Copenhagen physicists presented Schrödinger as a reactionary, hopelessly trapped in the deterministic, naively realistic modes of thought of classical physics . . .' [*Against the Stream - Schrödinger's Interpretation of Quantum Mechanics, Dublin Seminars and other Unpublished Essays* Ox Bow Press 1995]

The Bohr v Schrödinger Model of the Atom

Bohr's model of the atom as a mini solar system with a nucleus orbited by electrons lent itself to a discrete particle view, despite the fact that it was riddled with logical flaws. The first was the three-body problem encountered centuries earlier when trying to apply Newton's inverse square law to more than two celestial objects.

‘ In treating atomic systems with more than one electron, Bohr immediately faced the enormous difficulties involved in the treatment of systems of three or more bodies . . . Effectively, analytic solutions to the equations of motion in such cases were restricted to a very limited class of special configurations of enhanced symmetry, which in many cases are not even mechanically stable (i.e., small arbitrary displacements from the initial motion would lead to ever-increasing deviations.’

[*Constructing Quantum Mechanics* Vol 1 Anthony Duncan and Michael Janssen, OUP, p187]

Secondly, as electrons have negative charges they would repulse each other if more than one, and also collapse into the positively charge nucleus. Notwithstanding this, the structure proved invaluable to chemistry, biology and technology.

Schrödinger’s model of the atom was based on a system of standing waves which could change frequencies and energies when absorbing or emitting radiation. He believed his wave function described something physically real. I believe it is unfortunate that the wave equation was hi-jacked by Heisenberg and others.

The Uncertainty Principle

Heisenberg was not finished and continued to confound and confuse by introducing his Uncertainty Principle (c1927).

It states that we cannot know the position and momentum (velocity times mass) of a sub-atomic particle at the same time, and by solving the wave equation we can only arrive at a measure of probability as to its whereabouts. Until measurements are made there are a superposition of possible states, which collapse on measurement to one actual state.

So, Heisenberg doubled down on the discrete and discontinuous nature of quantum systems even though Bohr and others pointed out the logical mis-steps in two of his arguments: (i) in relation to the gamma ray thought experiment in his Uncertainty paper and (ii) in relation to the particle theory. Mara Beller gives an account of both of these:

(i) **‘There are other reasons for regarding Heisenberg’s paper as a direct attack on Schrödinger’s competitive efforts. Only under such an assumption do some puzzling features of Heisenberg’s paper . . . become intelligible . . . In his description of the λ ray thought experiment, Heisenberg had committed a trivial error, which both Bohr and Dirac . . . brought to his attention (Heisenberg to Pauli, 16 May 1927, PC). Heisenberg had treated both photons and electrons as point particles and argued that at the time of their collision a photon transfers to an electron a discrete and uncontrollable amount of momentum (Compton recoil).The more precisely the position of the electron is determined, the greater the uncertainty of the discontinuous change in the electron’s momentum (Heisenberg 1927b, 64). Yet Compton recoil does not lead to indeterminacy but rather to exactly calculable momentum changes. For the conservation laws for energy and momentum, and knowing the energy and momentum of the colliding photon, one can calculate the momentum change of the electron exactly. There is no way to transcend the classical deterministic framework once it is assumed that photons and electrons are point particles obeying conservation laws . . .’** [*Quantum Dialogue: The Making of a Revolution,* The University of Chicago Press, p71-72]

In a note to this analysis, Beller states:

‘In his initial mistaken analysis of a λ-ray microscope, Heisenberg treated both photons and electrons as point particles without taking into account their wave attributes. This analysis is equivalent to the scattering of light quanta by intra-atomic electrons in the Compton effect . . . and it leads not to indeterminacy but to exactly calculable changes. Heisenberg’s misleading analysis is sometimes repeated in popular expositions of the uncertainty principle.’

(ii) ‘In Heisenberg’s fluctuation paper (1927b), the formulas are correct, but Heisenberg’s logic is faulty. If we designate by D, discontinuous jumps, M, the matrix version of quantum mechanics, and F, the fluctuation formulas, then Heisenberg’s incorrect reasoning runs as follows:

D ——>F and M ——>F; therefore M —> D.' [ibid p77]

This is the equivalent of arguing that (i) an apple is a fruit; (ii) an orange is a fruit, therefore an orange is an apple. Heisenberg used this to 'disprove' Schrödinger's continuous wave theory based on frequencies and resonance.

Heisenberg was also given to making unjustified claims of his own prowess as a physicist, comparing himself favourably with Einstein. The article *Uncertainty from Heisenberg to Today, by* Reinhard F. Werner and Terry Farrelly, [Quantum Information Group, Leibniz Universitat Hannover April 15, 2019] covers the Uncertainty Principle in some detail and with much criticism; and notes in passing:

'Upon closer inspection, many of Heisenberg's arguments are not conclusive. This was probably known to him, but it did not keep him from making bold proclamations.'

Is any further proof needed as to Heisenberg's analysis being mistaken and driven by professional jealousy?