Thinking big

Fritz London's single-minded thinking led him to surpass even Einstein, as he believed correctly that quantum mechanics was right at all scales, including the macroscopic.

Philip W. Anderson

Fritz London began his career in physics as one of the originators of quantum theory during 1925–27. His training as a philosopher, before taking up physics, no doubt enhanced his contribution to the 'copenhagen interpretation' — the first general attempt to understand the world of atoms according to quantum mechanics. But London did much more than create the first theory of the chemical bond, and has not had the recognition he deserves.

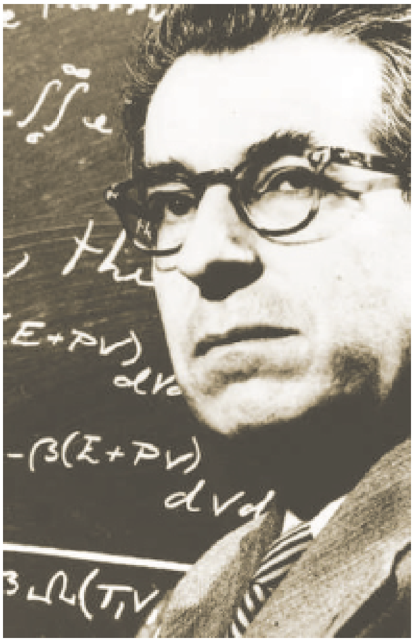
He was among the few pioneers who deliberately chose, once atoms and molecules were understood, not to focus his research on further subdividing the atom into its ultimate constituents, but on exploring how quantum theory could work, and be observed, on the macroscopic scale.

For a few years, London worked at trying to found chemistry on quantum theory, but in the end was overwhelmed by Linus Pauling's more heuristic approach; he never published his book on the subject. He then became intrigued by the twin phenomena of superfluidity and superconductivity, which, he was convinced, were macroscopic manifestations of quantum mechanics.

In 1935, London was the first to propose that superfluidity was Bose–Einstein condensation, and then in the late 1930s, with his brother Heinz, he developed the first heuristic theory of superconductivity. His pair of books on these subjects appeared around 1950 and admirably framed the questions that were soon to be answered — in the one case by Oliver Penrose, Lars Onsager and Richard Feynman, and in the other by John Bardeen, Leon Cooper and Robert Schrieffer. But London fell ill in 1950 and died in 1954, so he did not live to see the triumphs of his intuitions.

He had paid, however, for his unpopular choice of subject matter — quantum theory on the macroscopic scale — by having to settle for a job in the pre-war South. This meant being out of mainstream physics, and may have resulted in him being excluded from the Manhattan bomb project on which all his early associates worked.

In 1939, in an obscure paper called 'The observation problem in quantum mechanics,' London and Edmond Bauer took on the notorious Bohr–Einstein debates. This is the earliest paper I know of that expresses the most common-sense approach to the uncertainty principle and the philosophy of quantum measurement.



Lone thinker: Fritz London took an opposite tack from both Albert Einstein and Niels Bohr.

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In reading about these debates I have the sensation of being a small boy who spots not one, but two undressed emperors. Niels Bohr's 'complementarity principle' — that there are two incompatible but equally correct ways of looking at things — was merely a way of using his prestige to promulgate a dubious philosophical view that would keep physicists working with the wonderful apparatus of quantum theory. Albert Einstein comes off a little better because he at least saw that what Bohr had to say was philosophically nonsense. But Einstein's greatest mistake was that he assumed that Bohr was right — that there is no alternative to complementarity and therefore that quantum mechanics must be wrong. This was a far greater mistake, as we now know, than the cosmological constant.

At this point London took an opposite tack from either Bohr or Einstein. He found it difficult to believe Bohr's idea that there was a real 'complementarity' even though he had been an early contributor to that line of thinking. Instead he took the then radical step of assuming that quantum mechanics was not wrong, but right at all scales, including the macroscopic. This explains why London was intrigued by the realization that in the 'super' forms of matter, he was seeing quantum theory showing itself on the (relatively) everyday scale.

Taking London's point of view, one immediately begins to realize that the real problem of quantum measurement is not in understanding the simple electron that is being measured, but the large and complicated apparatus used to measure it. This apparatus has all kinds of properties that are not obvious consequences of quantum mechanics: rigid slits, for instance, and a photographic plate that darkens irreversibly where an electron hits it.

These properties are a real intellectual challenge to understand from first principles; the first thing one realizes is that time, for the measurer and the photographic plate, has a sign — earlier or later. This sign is not contained in the quantum theory and has to be the result of the organizing principles of quantum particles assembled into very large macroscopic objects. This and the fact that the apparatus has a definite position in space require that a quantum description of it can only be given in terms of a superposition of an unimaginably large number of different quantum states.

The electron interacting with it attaches (entangles) one part of its wave function to one batch of these states, the other part to a different batch. And these batches differ in so many ways that they can never be made to cohere again; they represent two entirely separate macroscopic histories of the apparatus. The message is that what is needed is an understanding of the macroscopic world in terms of quantum mechanics. This is the direction that London chose.

And that brings me to superfluid solids. Moses Chan and his student Eun-Seong Kim have recently shown that helium (and probably hydrogen), if solidified below a tenth of a degree Kelvin, flow through their own crystal lattice like a superfluid. (This has yet to be confirmed, but I believe it.) This means that a rigid object — the most primitive of our physical intuitions — is not a system in a simple, single quantum-mechanical ground state, but only arises as a consequence of thermal fluctuations.

Thus, Albert Einstein's clocks and rigid measuring rods, which play such a key role in the theory of relativity, must be not primitive but derived in a very complex way from the underlying quantum laws of microscopic physics. At which point I could immodestly take the opportunity to announce that after all, "more is different!" ■

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