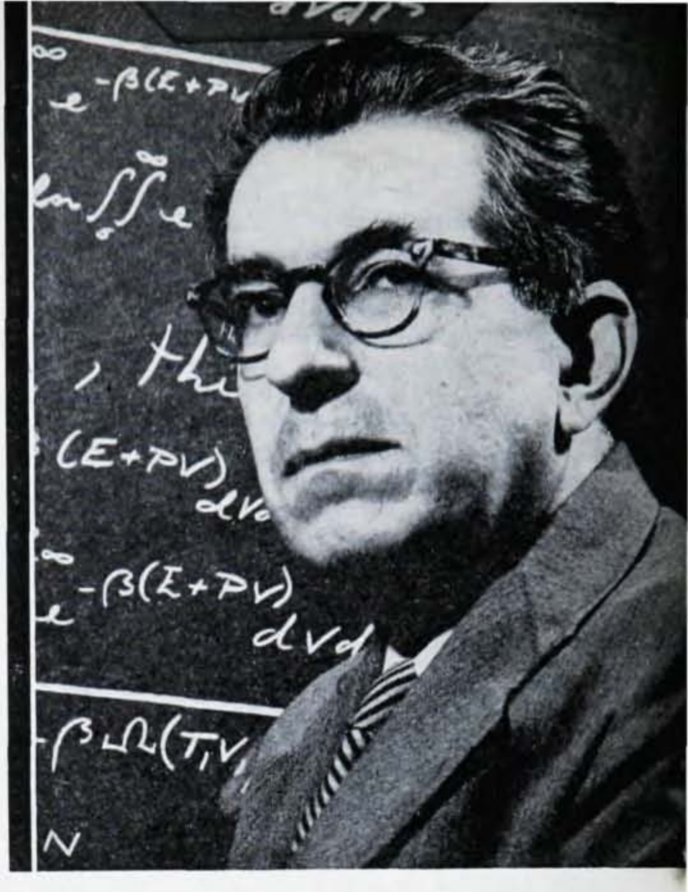
FRITZ LONDON

1900 – 1954

An appreciation of his work presented at the joint Duke University and University of North Carolina Physics Colloquium, April 24, 1954.

By L. W. Nordheim



Fritz London, born Breslau, 1900; PhD Munich, 1921; ScD Paris, 1937. Married Edith Caspary, 1929, two children. Rockefeller research fellow, Zürich, 1927; Rome 1931–32; lecturer, Berlin, 1928–33; I. C. I. research fellow, Oxford, 1933–36; maitre and directeur de recherche, Paris, 1936–39; professor of chemical physics, Duke University, 1939–; Lorentz Medal of the Netherlands Royal Academy of Science, 1953; awarded special James B. Duke distinguished professorship, Duke University, 1954.

AS a friend of very long standing, I should like to say a few words in memory of Fritz London, who so prematurely passed away on March 30, 1954.

I first became acquainted with London in 1923 in Goettingen, when I was working toward my degree. London, very characteristic for his personality, came there already as a PhD; however, not in physics, but in philosophy. He had earned this degree, at the age of twenty-one, by presenting an original thesis, conceived and written entirely by himself, to the faculty of the University of Munich, which accepted it. But London was not quite satisfied in this field. He sensed that developments more fundamental for our times were about to happen in physics, and he decided, therefore, to take up its study. So, first on his own, he went to Goettingen and from there to Munich, which at that time, under Born and Sommerfeld, possessed the most famous schools of theoretical physics in Germany. His work of this early period did not yet have the lasting impact of his later one, but it was good enough to secure him a Rockefeller Fellowship to work in Zürich with Schroedinger, who had just developed wave mechanics.

In Zürich, London and Heitler wrote their famous paper which gave the quantum mechanical explanation of the homopolar bond and marked the beginning of modern quantum chemistry. Naturally, his subsequent work was concerned with an elaboration of this theme and the beginning of the application of group theory to chemical problems. However, he soon became conscious of the fact that the theory of the chemical bond would either demand very elaborate mathematics, or great simplifications, which are difficult to justify rigorously. He became instead more interested in the dynamics of atomic and molecular interactions. The outgrowth was his fundamental studies in the late twenties and early thirties on the Van der Waals forces, on energy transfers in collisions, and on the mechanism of chemical reactions.

In those days of seemingly long ago, the number of physicists was still rather small. One knew each other, met each other occasionally and talked about ideas. I do not recall exactly when and where, but I remember distinctly that Fritz London started at that time to talk about macromolecules, about how long chains would know what was happening at a far end, and similar topics. Thus there started the growth of an idea, coming naturally after his studies on interactions at not too close distances, which was to be the leitmotif for all his later work. It is the conception of quantum mechanism of macroscopic scale, that is, of wave functions of macroscopic dimensions, influenced by the geometry of the sample, but nevertheless withdrawn from the disorder of thermal agitation in the same manner as is the electronic motion within atoms and molecules.

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In 1933, Meissner discovered that superconductors behaved also like perfect diamagnets. When London, together with his brother Heinz, studied this effect in 1934, they observed that it could not be explained simply by letting the resistivity go to zero, but that the macroscopic connection between fields and currents itself had to be changed. They developed a phenomenological theory in which Ohm's law, which relates the current with the electric field in ordinary conductors, is replaced by a new relation between the current and the magnetic field. This theory permits a complete phenomenological description of superconductivity in accordance with the principles of thermodynamics and classical electrodynamics, but it does not give in itself an explanation. London, however, was able to show that this description implies a kind of long-range order with respect to the momenta of the superconducting electrons. This is in sharp contrast to any picture of order with respect to spatial arrangement. In fact, order in momentum space demands extension of the wave functions over larger and larger dimensions so that the macroscopic connections of superconducting bodies become of primary importance. The task of a future microscopic theory of superconductivity is thus shifted entirely. One does not have to explain any more the absence of resistance, but the establishment of order in momentum space.

An interesting application of the idea of large dimensional molecular currents was given by London in his theory of the diamagnetic properties of aromatic compounds (1937). The resonating bond structure in the benzene rings permits the induction of currents around the rings, and thus a strong diamagnetic susceptibility for fields normal to the molecular plane but absent for field directions in the plane.

In the later half of the thirties, the very curious behaviour of liquid helium became gradually known. It undergoes at the "λ-point" at 2.2°K a kind of phase transition to a state called helium II with very peculiar properties, which can be best described as superfluidity. Now, liquid helium in itself should be one of the simplest substances, since it consists of inert atoms held together by the well-understood Van der Waals forces, and no obvious reason for any phase transition is apparent. It was London who pointed out that the helium atoms obey the Einstein-Bose statistics, and that Einstein himself had earlier predicted that a peculiar condensation phenomenon should happen in an Einstein-Bose gas. In this statistics there is a preference for many particles to go into the same state. So at very low temperatures, a finite fraction of the atoms, depending on temperature, will condense in the lowest possible state, that is, the state with momentum zero. This means that the de Broglie wave length for this fraction becomes infinite. Thus, again one encounters a quantum mechanism of macroscopic scale, and similarly as in superconductivity, the remarkable transport phenomena in helium II can be formally explained as due to the presence of this frozen-out fraction of atoms without energy and entropy.

London himself stressed the close relationship between the phenomena of superconductivity and superfluidity in his own beautifully written monographs[1] on these subjects, which he just managed to complete.

In discussions and also occasionally in his writings, London expressed a belief in an ultimately much wider applicability of the idea of macroscopic quantum states. It seemed to him that also the behaviour of macromolecules in biochemistry would demand quantum mechanisms involving the system as a whole, and he always had this idea in his mind.

The concept of the Einstein-Bose condensation as the explanation for helium II was not at once universally accepted. Since the rigorous mathematical description of a quantum liquid constitutes a problem of extreme complexity and rather outside the expectation of an early solution, London looked around for other support for his theory. During the last few years, another rare and peculiar substance has become available, the isotope He^3, of atomic weight three. He^3, in contrast to the normal He^4, contains an odd number of building stones, and thus obeys the Fermi-Dirac statistics, which deviates from the classical behaviour in the opposite way as the Einstein-Bose statistics. He^3 should, therefore, show no λ-point and no superfluidity. Neither has been found so far. Lately, London predicted further that liquid He^3 should show a different type of degeneracy, typical for a Fermi-Dirac substance, and it seems that this prediction is now well on the way to experimental verification.[2]

London's life work has the quality of a rare unit of outlook. Of course, we do not know what he would have further discovered, had he been permitted to live a full span of life, but what he did discover stands out, in spite of quite a diversity of topics, as a unit cut from the whole cloth, and a landmark in the evolution of scientific thought.

Fritz London was a man dedicated to his work and living with it and for it. In a way, he was the embodiment of the pure scholar, working by himself, and interested solely in the search for truth. In these days, when science is in some danger of becoming lost in bigness, he stuck to his ideals. He worked hard, shunned all distractions, and he was forever probing new ideas and perfecting his old ones. These qualities will always be required, if the wells of scientific progress are not to dry out. His were the highest standards of intellectual integrity, and he applied the same standards to all phases of life. However, he was by no means one-sided. He was a man of culture with wide interests in philosophical thought, the arts, and music. He was a loving father, happy in his life with his family. He will be remembered by his friends not only as an eminent scientist, but also as a personality of human warmth, with a keen sense of humor, and of great sincerity.

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[1] Fritz London, *Superfluids*, John Wiley and Sons, Vol. 1, *Macroscopic Theory of Superconductivity*, 1950; Vol. 2, *Macroscopic Theory of the Helium Superfluid*, in press.

[2] W. M. Fairbank, W. B. Ard, and G. K. Walters, Letter submitted to *The Physical Review*, "Fermi-Dirac Degeneracy in Liquid $Helium^3$ Below 1°."