

BOOKS

A Physicist Who Dreams with Open Eyes

Geons, Black Holes and Quantum Foam: A Life in Physics

John Archibald Wheeler
with Kenneth Ford
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Reviewed by Maurice Goldhaber

Autobiographies of scientists may appeal to a reader for a number of reasons: A reader may be interested in the scientists as people, or how their ideas were formed, or what they have achieved. On all counts, *Geons, Black Holes and Quantum Foam* by John Wheeler (Johnny to his friends), written with his former student Kenneth Ford, will not disappoint. The expert reader can only admire the skill with which many important concepts of physics are explained to the lay reader, (though some of the explanations seem to be written for that mythical person who has zero knowledge but infinite intelligence). Besides excellent thumbnail sketches of many physicists, there is also much illuminating history of physics.

The book starts like a detective story: Niels Bohr, accompanied by his son Eric and his coworker Léon Rosenfeld, arrives by ship in New York in January 1939. They are met at the dock by Wheeler and Enrico Fermi. Bohr brings with him a "secret": Otto Frisch and his famous aunt, Lise Meitner, have explained the discovery, made by Otto Hahn and Fritz Strassman (with whom Meitner had collaborated until she fled Germany), that barium, far removed in atomic number and mass from uranium, is among the products resulting when uranium absorbs neutrons. Frisch and Meitner called the process "fission."

The secret, which Bohr had promised to keep until its publication, leaked quickly, because Bohr had forgotten to tell Rosenfeld that it was a secret, and Wheeler unwittingly helped spread it by inviting Rosenfeld to address the Princeton Physics Journal Club. The news precipitated intensive studies, leading ultimately to the creation of the Manhattan Project and the atomic bomb; Wheeler

played an important role, starting with his collaboration with Bohr on a detailed model of fission, a paper that became a classic.

Wheeler introduces us lovingly to his extended family, to his remarkable wife of more than 60 years, Janette, whose wisdom he extolls, and to their three children.

Wheeler exhibited his gift for mathematics as a youngster, and he had an early and continuing interest in explosives. He started to study engineering at Johns Hopkins University at age 16, but he later switched to physics and obtained his PhD at Hopkins in 1933, at age 22.

After receiving his PhD, Wheeler's interests focused on nuclear physics. He spent a year with Gregory Breit at New York University and another with Bohr in Copenhagen. With Breit he learned "calculating"; with Bohr, "thinking." Bohr instilled in Wheeler an interest in deeper questions, which might be important "tomorrow." In Copenhagen Wheeler met Evan James Williams, of whom he writes that his "theory of high energy electron interactions provided what might be called a climate of opinion—an intellectual background for the discovery of a new particle," which ultimately led to the muon. (Historians of science might usefully pay more attention to changes in "climates of opinion," induced by either theory or experiment.)

After three years at the University of North Carolina, Wheeler moved to Princeton University. His stay there was interrupted by work on the Manhattan Project, during which he coined the word "moderator" for what Fermi had dubbed a "slower-downer." Wheeler played an important role in the design of the plutonium-producing reactors at Hanford in Washington State. When the reactivity of the first large reactor dropped after it had been running for a while, it was he who realized that it was due to poisoning: Neutrons were being absorbed by one of the fission products. He identified the poison as xenon-135.

Wheeler's modesty does not permit him to claim too much credit, and he appears to be a born diplomat. There is a striking example: More than a year before James Rainwater published a paper (for which he shared the Nobel Prize in Physics with Aage Bohr and Ben Mottelson), explaining the large quadruple moments of some nuclei

through their deformation by the orbit of a single nucleon, the same idea occurred to Wheeler. He speculates that, since he had discussed this idea with Niels Bohr, Niels might have mentioned it to his son Aage, who might have mentioned it to Rainwater, who was supervising Aage's postdoctoral work. Wheeler then adds, diplomatically, that the situation might have been reversed: Rainwater might have mentioned it to Aage, who might have mentioned it to Niels, who might have mentioned it to him! Alternatively, he suggests, the idea might have arisen independently, since such ideas were then in the air, to which I can attest. (It might be interesting, though difficult, for historians of science to study the (in)dependence of ideas in more detail!)

It is not until the second half of the book that one comes to the subject of its title, the field that Wheeler studied after his return to Princeton. During his work on reactor physics, he had kept his "Princeton physics" alive. Now, he felt the need to learn something new about what is most fundamental, and he finally found his calling in the study of general relativity and gravitation. He also started a cosmic-ray group, which was later taken over by George Reynolds. (The most notable contribution of that group was the discovery of muonic x rays by Wen-yü Chang.)

Wheeler started to speculate about extreme possibilities; for example, he tells us that he became obsessed with the possible existence of a "drop of liquid positronium," which he called a polyelectron, and which he hoped would somehow be stabilized. He dreamt of a world without fields, only particles, an idea he later developed with his most famous student, Richard Feynman. An indefatigable worker, Wheeler has guided the theses of more than 50 students, undergraduates as well as graduates, many of whom later had distinguished careers.

When President Truman made it a national priority to build the H-bomb, Wheeler felt obliged to accept the call for help, and in 1950 he joined the thermonuclear weapons project at Los Alamos. He remarks that his "old-fashioned patriotism was in short supply." He felt hurt that most of his colleagues disapproved of his decision, but after a while, the collegial spirit returned. Two of his students, John Toll and Ford, followed him to Los Alamos.

Wheeler relates an incident for

MAURICE GOLDHABER, of Brookhaven National Laboratory, Upton, New York, first met John Wheeler in 1934.

which he was reprimanded at the specific insistence of President Eisenhower. On a night train to Washington in January 1953, Wheeler took along a secret document, which mentioned the importance of lithium-6 for H-bombs. The document mysteriously disappeared, and he duly reported it. The news reached Eisenhower, who insisted on a personal reprimand. Ironically, as Wheeler remarks, lithium-6 had been used earlier in the first Soviet H-bomb. He felt he had been forgiven when President Johnson gave him the Fermi Award in 1968.

The theory of gravity, to which he and his students have made outstanding contributions, consumed Wheeler for the second half of his life; he reminds us that by now he has worked longer on gravity than Einstein did! In 1952, he started to study the singularity that may be left when a star collapses, and he popularized the term "black hole," which was suggested by an anonymous listener during one of Wheeler's lectures—an early information loss for black holes! Unlike some other phenomena he has been interested in, black holes are now accepted as real. The other two concepts of the title, and many other visions he has had, are still speculations: the geon, "a hypothetical entity, a gravitating body made entirely of electromagnetic fields," and quantum foam, "space time churned into a lather of distorted geometry."

At age 65, Wheeler accepted an offer from the University of Texas at Austin, where he stayed for ten years. There, he says, "I was not only tolerated as I pulled aside from the herd in theoretical physics to pursue my own byways. I was encouraged and supported."

Wheeler comes across as a man who dreams with open eyes; he feels he has earned the right to speculate, and his philosophical trend leads him to pronounce many dicta: for example, "The smooth flow of time is shattered when we look at short-enough intervals of time"; "There was no 'before' before the Big Bang, and there will be no 'after' after the Big Crunch" (recent observations do not favor a Big Crunch); "The laws of physics come into existence with the Big Bang as surely as space and time did." As an octogenarian, he asks himself every morning the "deep" questions: How come the quantum? How come the universe? How come the existence? He believes these questions will be answered by physics in the next century.

This is a splendid autobiography by an honest man who frankly tells us that his "naïveté" helped his scientific vision. Forever optimistic, he believes that nature has in the past made use of his visions, or may do so in the

future. One is tempted to paraphrase Shakespeare: There are more (or fewer) things in heaven and Earth, Johnny, than are dreamt of in your philosophy.

Quantum Mechanics

▶ Eugen Merzbacher
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edition. 656 pp. \$90.95 hc
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Back in the fifties, when I was learning quantum mechanics, there were only two "modern" textbooks to choose between: those by Leonard Schiff and David Bohm. Schiff's *Quantum Mechanics* (McGraw Hill, 1968, 1955, 1949) was a bread-and-butter book, presenting the ideas as succinctly as possible and reinforcing the results with lots of very good problems. It taught calculation, but there was no discussion of tricky fundamental concepts. It bolstered the prejudice of the day (which is, unfortunately, still prevalent) that physicists learn to use quantum mechanics and don't bother to ask what it means.

Bohm's *Quantum Theory* (Prentice Hall, 1951; Dover reprint), on the other hand, was full of words. The author was worried by the theory. He examined in detail what it meant to make a measurement. He cast the famous paradox of Einstein, Podolsky, and Rosen into a form that made it possible to analyze quantitatively the problems they raised, an analysis later taken on successfully by John Bell. A wonderful book, but short on calculational techniques. A student had to study both Bohm and Schiff to learn the subject. There was no intermediate approach.

Into this breach came the first edition of Eugen Merzbacher's *Quantum Mechanics* (Wiley, 1961), pedagogically a very good book. It introduced even the simple subjects with an eye toward what was ahead so that, when students saw more complicated material, they would have the feeling that it was merely an extension of what they had already seen.

The discussion was not formal, as in advanced texts, but was always geared to physical interpretation. Here one had a book in which providing a physical feeling for what was going on was foremost, and the mathematical techniques were important but subordinate. It did not go into the deep questions of interpretation, but its emphasis on the physics made up for this to some extent.

After about ten years came a second edition of Merzbacher (Wiley, 1970). By then there was more competition, but the newer books tended to give more formal treatments of the subject. I

found myself teaching from various new books as they came out, but generally returning to Merzbacher.

Now, after almost 30 years, comes a new edition of Merzbacher. Today there are many quite good quantum mechanics books, with different strengths and weaknesses. So the question is, Which one of them should I choose as a text? I don't think there is a single answer. The best I can do is to tell you what I consider to be some of the strengths and weaknesses of this new edition and let you decide for yourself. However, I recommend that, if you do not use Merzbacher's third edition, you should at least place it on reserve so your students can consult it.

Its strengths are those of the previous editions. The discussions are physically oriented, although there is now more emphasis on the mathematics. There is a trade-off in his discussion of measurements. He still does not analyze the mechanics of measurements, but he includes insightful discussions of the use of density matrices to describe measurements, and he relates the results of measurements to information theory and the entropy of the system. The discussion of WKB theory is very strong. He cures a previous problem by introducing perturbation theory and approximate methods earlier. He has a good discussion of gauge theories at this level and even introduces a gauge transformation when talking about the Born-Oppenheimer approximation. (However, although the index looks very detailed, you won't find in it anything related to "molecule," or to a number of other topics he discusses.) Merzbacher has retained a wonderful discussion of scattering, and now there is a reasonably strong discussion of aspects of quantum optics. Another new and good feature is the inclusion of lots of useful homework problems; in the previous editions, the problems were mostly used to complete proofs in the text.

Among the weaknesses is the haphazard discussion of atomic and nuclear physics. Most of the important topics are covered (the Stark effect and the like), but they are scattered throughout the book and are used to illustrate various principles, such as symmetry. The author doesn't pull them together into a coherent subject. He doesn't introduce the Pauli principle until late in the book, in a discussion of second quantization. This is unfortunate, and it leads to no mention whatsoever of the periodic table so far as I could tell. A number of more recent topics, such as Feynman path integrals or the Berry phase, are referred to in passing, or are discussed too briefly, while the Aharonov-Bohm effect and