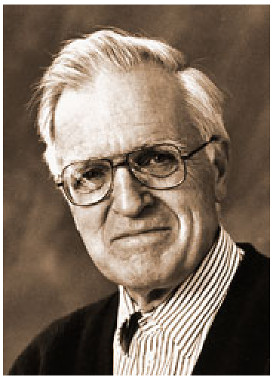
Pontificia Accademia delle Scienze

Aage Bohr



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Disciplina Fisica

Titolo Professore di Fisica, Università di Copenhagen

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Commemoration – Aage Bohr was born in Copenhagen a few months before his father won the Nobel Prize. His father was Niels Bohr, one of the giants of physics in the early 20th century, who was able to untangle the confusing mysteries of quantum mechanics. Aage Bohr's childhood was one in which a pantheon of great physicists were friends visiting the family home. The remarkable generation of scientists who came to join his father in his work became uncles for him. These uncles were Henrik Kramers from the Netherlands, Oskar Klein from Sweden, Yoshio Nishina from Japan, Werner Karl Heisenberg from Germany and Wolfgang Pauli from Austria. These are all giants of physics, so Aage Bohr is an example of what science means and what political violence means. In fact, three years after he was born, Hitler ordered the deportation of Danish Jews to concentration camps but the Bohrs, along with most of the other Danish Jews, were able to escape to Sweden. I would like to recall that, despite these great tragedies and political problems, Aage Bohr was able to follow his father's track, contributing to clarify a very important problem in nuclear physics. He was able, together with Ben Roy Mottelson, to explain why the nuclei were not perfectly spherical. I remind you that the volume of the nucleus is 1 millionth of a billion, 10-15 smaller than the atom, and when Bohr was young the general feeling about nuclear physics was that the nuclei were perfectly symmetric, perfect spheres, platonically perfect spheres, and here comes the contribution of Aage Bohr with Mottelson, because some experiments were showing that this was probably not true. How can it happen that such a small volume, I repeat, one millionth of a billion times smaller than the atom, cannot be perfectly symmetrical and spherical? Aage Bohr and Mottelson explained that the rotational motion of protons and neutrons inside this extremely small sphere could distort the shape of the nucleus. This had very important developments in nuclear fusion, which generates ten million times more energy than the standard transformation of mass into energy via electromagnetic forces. What Aage Bohr was able to do was, in fact, the last and most important step in the field of nuclear physics. Before, nuclear physics was shown not to be a fundamental force of nature but a result of the fundamental force of nature, which now we call quantum chromodynamics. It is remarkable that this field of physics, which was unknown in the 1930s, gave rise to an incredible series of unexpected events, the last one being, as I said, understood and explained by Aage Bohr. The first incredible event was the discovery that the particle proposed by Yukawa to be the nuclear glue was not a nuclear glue, it was a particle that had nothing to do with the nuclear forces and which we now call the muon, which is a lepton, not a meson. The decay of the particle considered to be the nuclear glue, namely the pion, was shown to violate two fundamental invariance laws, parity and charge conjugation, and when the first example of real nuclear glue was discovered, namely the pion – this was in 1947 – everybody believed this was the last step in nuclear physics. However, it was later shown that this so-called elementary particle would result of two quarks, a quark and an antiquark, glued by the fundamental force, which is quantum chromodynamics. In this impressive series of unexpected events, it was the privilege of Aage Bohr to demonstrate his reasons why the last one should be there. So the scientific credit of Aage Bohr will remain in the history of physics as the last step in understanding nuclear physics before a new era started, the one which is now called the physics of quantum chromodynamics, from which nuclear physics derives, but no one knows how to make this apparently elementary passage, namely from quantum chromodynamics to nuclear physics and here comes the latest interest of Aage Bohr. He was very interested to know how the passage takes place, and this reminds me of the first transition from the vacuum to inert matter, a topic which was of great interest to Aage Bohr, namely, does the transition take the simplest elementary case to be or does this transition involve less elementary passages? The simplest way out is not followed by nature in the transition from vacuum to inert matter. Bohr's interests were not limited to these fundamental problems of physics. He was a member of a scientific committee called Science for Peace, which played an important role during the half century of east-west confrontation. He was also interested in scientific culture, the way in which our understanding of physics comes in, in the sense of involving a great number of people. We should not forget that we live in a world where, as he used to repeat, our culture is as if science had never been discovered. He was very active in promoting the value of Galileo Galilei, who is the father of first-level science. In giving our gratitude to his remarkable work in physics and modern culture we should not forget that we live in a world were it is our responsibility to let people know the great values of science. It is the most civilized of all possible battles, because it does not produce tragedies but improves our culture. In this battle Aage Bohr was a great leader.

Antonino Zichichi

Most important awards, prizes and academies

Selected awards: Dannie Heineman prize (1960); Pope Pius XI medal (1963); Atoms for Peace Award (1969); H.C. Ørsted medal (1970); Nobel prize in Physics (1975); Ole Rømer medal (1976). *Academies*: Danish, Norwegian, Croatian, Polish, and Swedish Academies of Sciences; Royal Physiographic Society, Lund; American Academy of Arts and Sciences; National Academy of Sciences, USA; Deutsche Academie der Naturforscher Leopoldina; American Philosophical Society; Finska Vetenskaps-Societeten; Kungl Vetenskaps-Societeten, Uppsala; Pontificia Academia Scientiarum.

Summary of scientific research

The main part of his research work was concerned with the structure of atomic nuclei. A recurrent theme was the interplay between collective nuclear motion and the motion of the individual particles (neutrons and protons) of which the nucleus is composed. His work in that area began in 1949 and soon afterwards he was joined by Ben R. Mottelson in a close cooperation that continued over the years. Among the topics that occupied them were: 1) The occurrence of rotational spectra as a striking consequence of nuclear deformation. The role of symmetry in the description of rotational spectra; 2) The role of correlations between pairs of nucleons that lead to a superfluid phase of nuclear matter; 3) The analysis of the spectrum of quantal channels for the fissioning nucleus passing over the saddle point; 4) The great variety of collective modes, involving the spatial density of nucleons and the spin, isospin, and pairing variables; 5) The development of a unified description of nuclear dynamics based on the coupling between particle and vibrational variables; 6) The effect of angular momentum on nuclear properties and the study of nuclear states with very high spin. In his final years his research activity was focussed on the basis for quantum mechanics, in a joint effort with Ole Ulfbeck. The project centered on the origin of indeterminacy and the related nature of the fortuitous basic events (clicks in counters), which the probabilistic theory deals with. By a sharpened distinction between what happens on the spacetime scene (experiences) and what concerns the symbolic formalism, quantum mechanics is seen as having a fully abstract foundation, based on the representation of spacetime symmetry. The notion of a particle, as an intermediary between source and detector is, thereby, eliminated, as a remnant from classical physics, and the basic events are seen to come by themselves, without a cause (genuine fortuitousness). Finally, in a joint project with Ben R. Mottelson and Ole Ulfbeck, it was found that genuine fortuitousness, as described above, provided the principle behind quantum mechanics. From this principle, which asserts that the basic event, a click in a counter, comes without any cause, the formalism of quantum mechanics emerges, no longer dealing with things (atoms, particles or fields) to be measured, but as the theory of distributions of uncaused clicks that form patterns laid down by spacetime symmetry. The subject, thereby, revealed itself with unexpected simplicity and beauty. The departure from usual quantum mechanics was strikingly borne out by the absence of Planck's constant from the theory. The elimination of indeterminate particles as cause for the clicks, which the principle of genuine fortuitousness implies, was analogous to the elimination of the ether implied by the principle of relativity.

Main publications

Bohr, A., 'The Coupling of Nuclear Surface Oscillations to the Motion of Individual Nucleons', *Dan. Mat. Fys. Medd*., 26 (14), (1952); Bohr, A., 'Collective and Individual-Particle Aspects of Nuclear Structure' (with Mottelson, B.), *Dan. Mat. Fys. Medd*., 27 (16), (1953); Bohr, A., 'On the Theory of Nuclear Fission', *Proceedings Intern. Conference on Peaceful Uses of Atomic Energy* (Geneva, 1955), Vol. 2, pp. 151, UN (New York, 1956); Bohr, A., 'Study of Nuclear Structure by Electromagnetic Excitation with Accelerated Ions' (with Huus, T., Mottelson, B. and Winther, A.), *Rev. Mod. Phys*., 28, 432 (1956); Bohr, A., 'Possible Analogy between the Excitation Spectra of Nuclei and those of the Superconducting Metallic State' (with Mottelson, B. and Pines, D.), *Phys. Rev*., 110, p. 936 (1958); Bohr, A., 'Quantization and Stability of Currents in Superconductors' (with

Mottelson, B.), *Phys. Rev*., 125, p. 495 (1962); Bohr, A., Elementary Modes of Nuclear Excitations and their Coupling. *Comptes Rendus du CIPN* (Paris, 1964), Centre National de la Recherche Scientifique, pp. 437; Bohr, A., 'Pair Correlations and Double Transfer Reactions', *Nuclear Structure*, IAEA (Vienna, 1968), p. 179; Bohr, A., 'Perspectives in the Study of Nuclei with High Angular Momentum' (with Mottelson, B.), suppl. *Journal Phys. Soc. of Japan*, 44, p. 157 (1978); Bohr, A., Nuclear Structure, Vol. I: *Single-Particle Motion*, 1969; Vol. II: *Nuclear Deformations*, 1975, (with Mottelson, B.), W.A. Benjamin Inc., New York; Bohr, A., 'Primary Manifestation of Symmetry. Origin of Quantal Indeterminacy' (with Ulfbeck, O.), *Rev. Mod. Phys*., 67, p. 1 (1995); Bohr, A., 'Genuine Fortuitousness. Where Did That Click Come From?' (with Ulfbeck, O.), *Foundations for Physics*, 31, p. 757 (2001); Bohr, A., 'The Principle Underlying Quantum Mechanics' (with Mottelson, B. and Ulfbeck, O.), *Foundations for Physics*, 34, pp. 405-17 (2004).