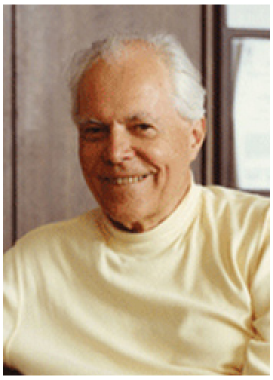
Rudolf Ludwig Mössbauer



Munich, Germany, 31 Jan. 1929 - Grünwald, Germany, 14 Sept. 2011

Nomination 10 April 1970

Field Physics

Title Professor Emeritus, Technical University of Munich, Nobel laureate in Physics, 1961

Commemoration – In October 1961 a sensational announcement mesmerized post-war Germany. Rudolf Mo#ßbauer, age 32, had won the Nobel Prize in physics for his discovery of the effect named after him. I remember this event vividly, since I had just enrolled at the University of Heidelberg as a new student of physics. Mo#ßbauer, a young German physicist recognized with the highest scientific honor, instantly became our inspiring hero, who symbolized the hopes and aspiration of a new generation of science students.

Rudolf Mo#ßbauer was born on 31 January 1929 in Munich, Germany. He was a talented piano player but decided to study physics at the Technical University of Munich (then called Technische Hochschule). He received his doctoral degree under Professor Heinz Maier-Leibniz in 1958. Since the Technical University was overcrowded with students, he carried out his experiments at the Max-Planck Institute for Experimental Medicine at Heidelberg. After graduating he continued this work for another two years as an assistant at the Technical University. During his experiments he observed for the first time what is now called the Mo#ßbauer effect.

In his research, Mo#ßbauer studied resonance fluorescence of nuclei. Resonance fluorescence is well known for atoms. Atoms emit light at spectral lines, which are determined by the surrounding bound electrons and are characteristic for each atomic species. Resonant radiation can be absorbed by atoms of the same species, but not by different atoms. It was expected that this method of resonance fluorescence would be much more selective for nuclei.The frequencies of gamma rays emitted by long living nuclei are determined much more precisely than the frequencies of light emitted by bound electrons and are usually much higher. A problem arises because each gamma ray photon transfers a small recoil momentum to the nucleus. This changes the gamma ray frequency by a tiny amount. Though very small, the change is large enough so that the radiation can no longer be absorbed by another nucleus.

Rudolf Mo#ßbauer tried to observe resonance fluorescence with Iridium-191 nuclei by heating both source and absorber. However, the effect was very small. When he cooled both samples, he expected the signal to disappear, because the line would become even narrower. However, he observed a stronger signal at lower temperature.The explanation comes from quantum physics. For a certain fraction of atoms, depending on temperature, the gamma recoil momentum is taken up by all the atoms in a crystal, not by an individual nucleus. The crystal acts like an immovable rock from which the gamma photon can jump away so that the frequency change due to recoil becomes negligible. The observation of nuclear resonance fluorescence enabled by this effect is known as Mo#ßbauer spectroscopy.This technique makes it possible to observe small changes in energy down to one billionth of an electron volt, compared to gamma ray energy of perhaps a hundred thousand electron volts.

This precision enables countless applications in physics and chemistry. To give a few examples:

– In chemical analysis one cannot only determine the atomic species of a

sample but also the kinds of chemical bonds.

– In biochemistry, this can be used to elucidate the structure and function

of iron containing enzymes.

– In technical chemistry, it has been possible to clarify the function of different catalysts.

– Among the most interesting applications in fundamental physics are precision tests of Albert Einstein's theories of special and general relativity. Already by 1959, Pound and Rebka Jr. had used the Mo#ßbauer effect to observe the red-shift of gamma photons in the gravitational field of the earth.

On the initiative of Richard Feynman, Rudolph Mo#ssbauer went to the California Institute of Technology in 1960. He was a Professor there from 1962 until he returned to the Technical University of Munich in 1964. Following the US model, he introduced non-hierarchical Department structures. Numerous new academic positions were created and new directions of research became possible.These measures contributed significantly to the reputation of physics in Munich.

In the late 1970s, Mo#ßbauer turned his attention to neutrino physics. Neutrinos are, for instance, produced in the nuclear reactions that generate the energy of the sun. It had been observed that much fewer neutrinos arrive on earth than expected from radiated energy. Some physicists speculated that the nuclear reactions powering the sun may have stopped and we are only witnessing some kind of afterglow.

A rather far-fetched explanation was the assumption that neutrinos are changing into some other elementary particle on their way from sun to earth. Mo#ßbauer tried to observe the transmutation of neutrinos from a nuclear reactor, without observing any effect. Although these experiments were belittled by quite a few colleagues, he was fundamentally correct. We know today that neutrino oscillations occur. However, the effect is so small that it was not feasible for Mo#ßbauer to observe it with the techniques available to him. Since then, the effect has been confirmed at large underground neutrino observatories. The experiments led to a Nobel Prize for Raymond Davis and Masatoshi Koshiba.The Journal *Nature* writes in its obituary: "(Mo#ßbauer) saw Science as a language connecting all of the people in the world." He started many international collaborations, and during the Cold War he was one of the first to organize Seminars with Soviet physicists, long before this became feasible for US colleagues.

Rudolf Mo#ßbauer was a charismatic and inspiring academic teacher. His legendary lectures may have motivated quite a few students to choose the Technical University of Munich for their studies of physics.

Despite his high reputation, Rudolf Mo#ßbauer always remained a friendly and modest individual. In this way, he continues to inspire many of us as a role model.

The Pontifical Academy of Sciences is proud to have counted Rudolf Mo#ßbauer among its members.

Theodor Hänsch

Most important awards, prizes and academies

Awards: Research Corporation Award, New York, USA (1961); Röntgen-Prize, University of Giessen, FRG (1961); Elliot Cresson Medal, Franklin Institute, USA (1961); Nobel Prize in Physics (1961); Guthrie Medal, Institute of Physics, London, UK (1974); Lomonossov Medal, Soviet Academy of Sciences, Moscow, USSR (1984); Einstein Medal, Einstein Society, Switzerland (1986). *Academies*: German Academy Leopoldina; Pontifical Academy of Sciences; Bavarian Academy of Sciences, FRG; Accademia Nazionale dei XL, Italy; National Academy of Sciences, USA; American Academy of Arts and Sciences; Academy of Sciences, USSR; Indian Academy of Sciences.

Summary of scientific research

Discovery of the phenomenon of recoilless nuclear resonance absorption of gamma radiation (Mössbauer effect) and its direct verification in a Doppler-shift experiment. Application of the method to numerous studies of nuclear hyperfine interactions in efforts to derive various nuclear and solid state properties such as values of nuclear moments and the behavior of magnetic fields and electric field gradients in solids under different physical or chemical conditions. Development of a new method for the structure analysis of macromolecules based on phase variation techniques. Measurements of the dynamical diffraction of gamma radiation under resonant conditions, in particular studies of the frequency and polarization dependence and the anomalous transmission features. Studies of the dynamical behavior of proteins and of their anomalous dependence on temperature. Analysis of the temporal aspects or recoilless resonance absorption of gamma radiation and of related phenomena. More recent research efforts were devoted to the problem of the restmass of the neutrinos. Extensive measurements of neutrino oscillations at nuclear power reactors have yielded no mixing and no mass values. Measurements with solar neutrinos (Gallex project in the Gran Sasso mountain range in Italy) gave oscillation parameters. The interpretation in terms of neutrino masses is still open. Efforts in Munich (Garching) have yielded cryogenic detectors with unsurpassed resolution in energy.

Main publications

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