Maria Goeppert Mayer

B Banerjee

B Banerjee, after his retirement from Tata Institute of Fundamental Research, has been teaching in the Physics Department, University of Mumbai. He is mainly interested in the application of nuclear physics to astrophysics and cosmology.

This is a brief biography of Maria Goeppert Mayer. We have tried to emphasise that even outstanding women like her had to suffer (and still suffer) great discrimination. In spite of the handicaps she achieved the highest scientific distinction.

Maria Goeppert–Mayer was born on June 28, 1906, in Kattowiz (then in Germany, now in Poland). She was the only child of her parents. Her father, Friederich Goeppert, was a paediatrician. In 1910 he was appointed a professor of Paediatrics in the famous University of Göttingen. The move to Göttingen turned out to be the major event that influenced her entire future. From her young days it was assumed that she will study in the university. It was not common for women to go for higher studies. Her father is said to have told her that she should not grow up to be a woman, meaning a housewife. She therefore decided " I wasn't going to be just a woman".

Maria got interested in mathematics early in her education and decided to enter the Göttingen University (Georgia Augusta University). To prepare for the entrance, she left the public elementary school and entered a private school for girls (Frauenstudium). Unfortunately the school closed because of financial problems before she had finished the full term of three years. Nevertheless she decided to take the university entrance examination and passed it. She was admitted as a mathematics student at the age of eighteen. The university was full of great mathematicians like David Hilbert, Hermann Weyl, Richard Courant, etc. Some of them were family friends of the Goepperts.

Keywords
Maria Goeppert Mayer, quantum emission, dynamic theory of crystal lattices, statistical mechanics, opacity project, magic numbers, elementary theory of nuclear shell structure.

The physics faculty at the university was equally strong. Max Born joined the university in 1921 followed by the experimental physicist James Franck. Born gathered around him many outstanding students and collaborators. The most distinguished was Heisenberg, one of the founders of quantum mechanics. Maria's interest shifted from mathematics to theoretical physics and she joined Born as a research student. Her extensive training in mathematics helped her in mastering the new physics of quantum mechanics quickly. Many years later, she commented on her shift to theoretical physics from mathematics – "Mathematics began to seem too much like puzzle solving. Physics is puzzle solving too, but of puzzles created by nature, not by the mind of man".

The so-called 'Anti-Nepotism Rules' did not allow more than one family member to work in the same faculty.

Maria completed her thesis in 1930. She tackled the problem of emission of two quanta in her thesis. Experimentally nothing was known about double photon phenomena at that time. Much later, with the invention of lasers and the development of non-linear optics, her work gained relevance.

Her father died during her PhD studies. Her mother took on student boarders so that the family could remain in their home. One of the boarders was Joseph Edward Mayer, an American student who had come to work with James Franck on a Rockefeller Foundation fellowship. Maria and Joseph became close and they married in 1930. She adopted the surname Goeppert–Mayer.

Joseph Mayer got a position in Johns Hopkins University in Baltimore and the couple moved to the USA. However Maria was not offered any job. The so-called 'Anti-Nepotism Rules' did not allow more than one family member to work in the same faculty. She became a 'volunteer associate'. In this position she could do research and she was allowed a small office. She became a US citizen in 1932.

The activity of the physics department was mainly in experimental physics. There was only one theoretical physicist, Karl Herzfeld. He was interested in chemical physics that was also Joseph Mayer's research area. Under their influence Maria Mayer got involved in this field and made many contributions. She had also the advantage of her knowledge of quantum mechanics which was starting to be applied to chemical physical problems. She wrote several papers in collaboration with her husband, Herzfeld and his students on chemical physics problems.

Maria Meyer's first paper in nuclear physics was on double beta-decay. She calculated the decay rate when a nucleus (A,Z) decays to a ($A,Z+2$) nucleus by emitting two electrons and two anti- neutrinos using the recently formulated theory of beta-decay by Fermi.

In the early thirties, Maria used to spend the summers in Göttingen to work with her teacher Max Born. They wrote the review article on 'Dynamische Gittertheorie der Kristalle' (Dynamic Theory of Crystal Lattices) for the famous encyclopaedia of physics, *Handbuch der Physik.* This collaboration ended when Born, being Jewish, lost his job when Hitler came to power in 1933. James Franck also had to emigrate for the same reason. As a coincidence he also joined the Johns Hopkins University and renewed his friendship with the Mayers. She began to take interest in nuclear physics which had become the 'frontier' subject. Remarkably, her first paper in nuclear physics was on double beta-decay. She calculated the decay rate when a nucleus (A,Z) decays to a ($A,Z+2$) nucleus by emitting two electrons and two anti- neutrinos using the recently formulated theory of beta-decay by Fermi. Since it is a very slow decay (lifetime ~10 years) it needed great improvements in detection techniques. The first measurement was made only in 1967. Her paper still retains its importance although it was published in 1935.

The Mayers left Johns Hopkins in 1939 as Joseph Mayer had been offered a position of an associate professor in Columbia University in New York. Maria Mayer again had no appointment. However she was happy that Fermi who had left Italy on the eve of the outbreak of the second world war, was on the faculty and she could work with him. On Fermi's suggestion she worked on the electronic structure of transuranic elements which had not yet been discovered. She came to the conclusion that these elements would form a new chemical rare-earth series. This turned out to be an accurate prediction. In 1940, the Maria and Joseph Mayer published a book *Statistical Mechanics.* For many years the book was popularly known as 'Mayer and Mayer'.

On Fermi's suggestion she worked on the electronic structure of transuranic elements which had not yet been discovered. She came to the conclusion that these elements would form a new chemical rare-earth series. This turned out to be an accurate prediction

Maria Mayer got her first job offer in the USA in 1941 – a half-time teaching position in Sarah Lawrence College, a liberal arts college for women (now co-educational) in New York. She taught in this college part-time, even when she had other jobs, throughout the war. In the meantime the project for building the atom bomb was gathering momentum and various groups of scientists were being drafted into the project for different tasks. The famous chemist Harold Urey set up a research group in Columbia University for separating uranium 235 (U-235) from natural uranium (U-235 constitutes only 0.7% of natural uranium). The rest is U-238 which cannot be split by slow neutrons and cannot be used in an atomic bomb). Urey offered her a half-time job on the project. This gave her an opportunity to use her knowledge of chemical physics. Urey's idea was to separate the isotopes by photochemical reaction. Her task was to study the thermodynamic properties of the uranium hexafluoride gas. Unfortunately the method of separation did not work. Other methods like thermal diffusion worked. Now ultracentrifuges are used to separate the isotopes.

In Columbia, Edward Teller, the father of the hydrogen bomb, formed a group to study the properties of matter and radiation at extremely high temperatures ('Opacity Project'). He invited Maria Mayer to work on the project.

In Columbia, Edward Teller, the father of the hydrogen bomb, formed a group to study the properties of matter and radiation at extremely high temperatures ('Opacity Project'). This was relevant to the development of the hydrogen bomb. He invited Maria Mayer to work on the project. In this connection she got to spend some time in Los Alamos (New Mexico) in the spring of 1945, where the atomic bomb was being made. (The first bomb test was carried out on July 16, 1945 in the deserts of New Mexico).

In February 1946, Joseph Mayer was appointed a professor in the Chemistry Department of the University of Chicago and also at the newly established Institute of Nuclear Studies (now called Enrico Fermi Institute) of the university. Maria became a 'voluntary' associate professor at the Institute. This was again an unpaid job. But she could participate in all the activities of the university including doing research, guiding students, lecturing etc. Teller and Fermi also moved to Chicago and Maria Mayer could continue to work with Teller on the 'Opacity Project'.

On December 2,1942, world's first nuclear reactor built under the unused football stands of Stagg Fields in the University of Chicago campus, went into successful operation.

On December 2,1942, world's first nuclear reactor built under the unused football stands of Stagg Fields in the University of Chicago campus, went into successful operation. The group of scientists that built the reactor under Fermi's leadership formed the 'Metallurgical Laboratory' or the Met Lab, in short. After the war, Met Lab was replaced by a new laboratory dedicated to the development of peaceful uses of nuclear energy in addition to basic research. The new laboratory called the Argonne National Laboratory was built in Lemont (Illinois) near Chicago. Maria Mayer was offered a regular appointment as a Senior Physicist (half time) in this new laboratory and she was happy to accept it. Since the main activity of the Laboratory was in nuclear physics she started learning the subject. This was the beginning of the most fruitful period of her life as a physicist. However, she did not give up her voluntary appointment at the University of Chicago and she continued to perform her duties there.

The nuclei of some elements that have neutron (N) or proton (Z) numbers 2, 8, 20, 28, 50, 82 and 126 are more stable. They are called 'magic numbers'.

The Institute of Nuclear Studies now boasted of a galaxy of physicists like Fermi, Teller, Wentzel, Libby and Urey. Teller persuaded Maria Mayer to work on his cosmological model of the origin of the chemical elements. This led her to analyse the data on the abundance elements. She noticed that the nuclei of some elements with specific number of neutrons or protons (or both) are more abundant than others. That is, they are more stable. She found out that a French physicist Walter Elsasser had noticed this already in 1933. But she now had more data and more nuclei to deal with. These nuclei have neutron (N) or proton (Z) numbers 2, 8, 20, 28, 50, 82 and 126. They are called 'magic numbers'.

Maria Meyer now looked for other evidence for the magic numbers – spins and magnetic moments and she was convinced these 'magic' nuclei were special. As we have stated above, the prevailing wisdom at that time was that nucleons behave collectively in a nucleus. But to explain the magic numbers one has to assume that *nucleons move independently* like the electrons in an atom. However, even if we assume that nucleons move in individual orbits specified by their orbital angular momenta, how to understand the magic numbers? Here came the crucial suggestion from Fermi. When she was discussing the problem with Fermi, he simply asked whether there was any indication of 'spin-orbit' coupling. She immediately understood that it was the solution of the problem of magic numbers.

When Maria Meyer was discussing the problem with Fermi, he simply asked whether there was any indication of 'spin-orbit' coupling. She immediately understood that it was the solution of the problem of magic numbers.

Maria Mayer established that although the nucleon-nucleon interactions are very strong , they exhibit individual particle motion and the common potential in which they move, has a strong spin-orbit coupling component. These two simple assumptions enabled her to explain a vast amount of data – binding energies, spin, magnetic moments, rates of beta-decay, etc. She published a series of papers on these topics.

Mayer and Jensen met for the first time in 1950, the two became good friends and collaborated in writing the book *Elementary Theory of Nuclear Shell Structure*. On winning the prize she commented "Winning the prize wasn't half as exciting as doing the work itself".

Maria Mayer was not alone in discovering the shell model of the nucleus. On the other side of the Atlantic, J Hans D Jensen, working with his colleagues O Haxel and H E Suess in Heidelberg (Germany) had come to an identical conclusion about the shell structure. Mayer and Jensen were not acquainted at that time. They met for the first time in 1950 when she visited Germany. The two became good friends and collaborated in writing the book *Elementary Theory of Nuclear Shell Structure*, published in 1955. In 1963, the Nobel Prize in Physics was awarded to them along with E P Wigner. She thus became only the second female Nobel Laureate in Physics after Marie Curie. (On winning the prize she commented "Winning the prize wasn't half as exciting as doing the work itself").

In 1960, for the first time she was personally offered a full professorship at the new campus of the University of California at San Diego. Joseph Mayer was also appointed a professor in the Chemistry Department. Unfortunately, soon after arriving in San Diego she suffered a stroke. Even with her declining health she kept up her teaching and research. Her last paper, a review of the shell model, written with Hans Jensen was published in 1966. She died in 1972 leaving behind her husband, a daughter, Marianne and a son, Peter.

Suggested Reading

[1] Joan Dash, *A Life of One's Own*, Harper and Row, New York, 1973.

[2] R G Sachs, *A Biographical Memoir*, National Academy of Sciences, Washington DC, 1979.

[3] S R Moeckly, *The Life and Work of Maria Goeppert-Mayer*, Augusta Chemistry, 381, 2000.

Address for Correspondence
B Banerjee
701, VIGYAN
Plot 23, Sector 17
Vashi
Navi Mumbai 400 705, India.