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Nobel Prize in Physics 1969

Murray Gell-Mann

The Nobel Prize in Physics 1969 was awarded to Murray Gell-Mann *"for his contributions and discoveries concerning the classification of elementary particles and their interactions"*.

RESEARCH INFORMATION:

Elementary particle physics which is now so vigorous was still in its infancy when Murray Gell-Mann in 1953 published the first of the papers which have been honoured with this years Nobel Prize in physics.

The physicists were, however, already then aquainted with a rather large number of particles which apparently were indivisible and therefore elementary building stones of all matter. The elementary particle known for the longest time was the electron.

New particles were added when the atomic nuclei were explored. It was found that the atomic nuclei consist of positively charged protons and electrically neutral neutrons. These particles are held together in the atomic nuclei by enormously strong forces called nuclear forces which do not distinguish between protons and neutrons. This symmetry of the nuclear forces was expressed by saying that the nuclear forces are charge-independent. A proton and a neutron have further very nearly the same mass. They form a doublet of particles and have been given the common name of nucleons.

An increase already expected and desired occurred in the family of elementary particles at the end of the 1940's, when new particles called pi-mesons were discovered. They were named mesons because they have a mass between the electron and the nucleon masses. The pi-mesons had been predicted by the Japanese physicist Yukawa. They form a triplet of particules having nearly the same mass but different charges which are + 1, 0 and -1 in units of the proton charge. Their interaction with the nucleons is strong and charge-independent. Their most important task is to be an intermediary agent for the strong interactions between the nucleons.

A very remarkable discovery which marked a new area in particle physics was made by the British physicists Rochester and Butler about the same time. They found new unstable particles which did not fit in with the theoretical ideas developed so far. Some of the new particles are heavier than the nucleons and were grouped together with them under the common name of baryons. The others were lighter than the nucleons but heavier than the electrons and were called K-mesons. The new particles were copiously produced when high-energy pi-mesons collide with nucleons and were therefore assumed to interact strongly with other particles. But they had such a long lifetime that some law must exist which prevent the strong forces to act when they disintegrate into other particles. Gell-Mann discovered this law after some preliminary results had been found by Pais.

It had been assumed earlier that the new baryons from doublets like the nucleons and that the K-mesons form triplets like the pi-mesons. Gell-Mann made the fundamental new assumption that the new baryons instead form a singlet, a triplet and a doublet, the latter being different from the nucleon doublet, and that the new mesons form two kinds of doublets, one consisting of the antiparticles of the other. Gell-Mann assumed further that the principle of charge-independence was generally valid for strong interactions. He could thereby explain the mysterious properties of the new particles. He introduced a new fundamental characteristic of a multiplet called its hypercharge. This is defined as twice the mean value of the charges in the multiplet. Gell-Mann's proposed the new rule: Elementary particles can be transformed in others by the strong and the electromagnetic interactions only if the total hypercharge is conserved. This rule reminds of the law of conservation of the electric charge. It should be remarked that Gell-Mann initially used instead of the hypercharge a closely related number called the strangeness.

This discovery by Gell-Mann was admirable considering in particular the very meagre experimental material available to him. In the predicted baryon multiplets there occurred empty places. Gell-Mann could on this ground predict two new baryons. One of them was soon discovered but the other not until six years later.

This classification of the elementary particles and their interaction discovered by Gell-Mann has turned out to applicable to all strongly interacting particles found later and these are practically all particles discovered after 1953. His discovery is therefore fundamental in elementary particle physics.

It should be added that two Japanese physicists, Nakano and Nishijima, published a similar classification some months later than Gell-Mann.

Many theoretical physicists tried during the following years to find new symmetries which should give relations between the particle multiplets. Initiated by Sakata a series of papers were published in particular by Japanese physicists. They indicated that a certain kind of symmetry could be of interest. Gell-Mann showed in a new fundamentally important paper of 1961 that this symmetry which had since long been studied in pure mathematics could be used for the classification of all strongly interacting particles. Assuming the validity of the new symmetry which includes the symmetry corresponding to charge-independence, Gell-Mann found that his earlier multiplets could be brought together into larger groups called supermultiplets each containing all baryons or all mesons which have the same spin and the same parity, i. e. have the same measure for their rotation around their axes and are transformed in the same way by reflections. Gell-Mann called this classification "The Eightfold Way". The nucleons were found to belong to a supermultiplet of eight particles *i.e.* an octet. For the mesons an octet was proposed were the pi- and *K*-mesons filled seven places. Because one place was empty a new meson was predicted. Its existence had been suspected already by some of the Japanese physicists

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mentioned above. It was soon discovered which meant that Gell-Mann's theory was strongly supported. Still more famous is Gell-Mann's prediction in 1962 of a new baryon called omega minus.

A similar classification was proposed by Y. Néeman somewhat later than Gell-Mann. Gell-Mann has also found that "The Eightfold Way" can be described very simply by assuming that all particles which interact strongly with each other are composed of only three kinds of particles which he called quarks and of the corresponding antiparticles. The quarks are peculiar in particular because their charges are fractions of the proton charge which according to all experience up to now is the indivisible elementary charge. It has not yet been possible to find individual quarks although they have been eagerly looked for. Gell-Mann's idea is none the less of great heuristic value.

And interesting application of "The Eightfold Way" is the so-called current algebra which was founded by Gell-Mann. It has e.g. made evident that there are important connections between the different kinds of elementary particle interactions.

Gell-Mann has given many fundamental contributions to the theory of ele mentary particles besides those which have been mentioned here. He has during more than a decade been considered as the leading scientist in this field.

Professor Gell-Mann. You have given fundamental contributions to our knowledge of mesons and baryons and their interactions. You have developed new algebraic methods which have led to a far-reaching classification of these particles according to their symmetry properties. The methods introduced by you are among the most powerful tools for further research in particle physics.

On behalf of the Royal Swedish Academy of Science, I congratulate you on your successful work and ask you to receive your Nobel Prize from the hands of His Majesty the King.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/physics/laureates/1969/press.html