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Nobel Prize Winners in Physics: Claude Cohen-Tannoudji

Claude Cohen-Tannoudji is a physicist who currently lives in Paris, France and still conducts his research at École Normale Supérieure in Paris. He is best known for his work in quantum optics. This is an area of physics that deals with the relationship between quantum mechanics and how light interacts with other matter. His work is significant because it allowed more detailed study of the structure of atoms. His conclusions helped bridge the worlds of traditional and quantum physics. In 1997 he and two other researchers won the Novel Prize in physics for their work.

Claude Cohen-Tannoudji was born on April 1st, 1933 in Constantine, Algeria, which was then controlled by France. He grew up having a modest Jewish life, and had a good education. The Americans arrived in Algeria in 1942, which protected them from the Nazis and their persecutions, so Cohen-Tannoudji was very lucky in that respect.

In 1953, he left high school in Algiers, Algeria to go to Paris, France, where he was accepted into Ecole Normale Supérieure, one of the most prestigious schools in Europe. Founded during the time of the French Revolution, the school has helped produce many of France's greatest scientists, writers and politicians. Among the graduates of Ecole Normale

Supérieure are twelve Nobel Prize laureates (including Cohen-Tannoudji), ten Fields Medalists, one Gauss Prize winner, and two winners of the John Bates Clark Medal (for economics).

While at Ecole Normale Supérieure Claude Cohen Tannoudji had the opportunity to hear the lectures of Henri Cartan and Laurent Schwartz in mathematics and Alfred Kastler in physics, three of the greatest thinkers in their field. Originally, Cohen-Tannoudji was more interested in mathematics, but because Alfred Kastler's lectures were so stimulating, among a few reasons, he decided to change to physics in his studies. He ended up joining Kastler's diploma work group in 1955, which had very few students in it. The students involved were very passionate and enthusiastic about research, worked very hard, and had exciting discussions about the results of their experiments. According to his autobiography, Claude often looks back on these years as essential for how he would become a researcher, both with his peers and the exceptional personalities and knowledge of Alfred Kastler.

After Cohen-Tannoudji finished his studies, he still had to take the final exam before leaving École Normale Supérieure. The exam, called the "Agrégation," is a competitive exam that is used for teaching opportunities around France. After leaving the Ecole Normale and meeting his future wife around that time, he went back to do his military service because of the Algerian war. He was put in the scientific department, researching the upper atmosphere with rockets releasing sodium clouds at sunset, which made it possible for him to able to measure the wind velocity or temperature at different altitudes. In 1960, he went back to get his Ph.D. under the supervision of Albert Kastler and Jean Brossel. When he finished his Ph.D., he started teaching Quantum mechanics at the undergraduate level at the University of Paris. And so began the long road toward the Nobel Prize.

His lecture notes during this time became the foundation for the textbook *Mécanique quantique,* which he wrote with two of his colleagues. Much of this work at the time focused on atom-photon interactions, which would later help form a partial basis for the model of the *dressed atom.* "Dressed" is a term for using lasers to mix together different energy states within atoms. This was an essential technique for his research.

In 1973, Cohen-Tannoudji became a professor at the Collège de France, and his career started to take off. Later in the 1979s he came up with another theory that specifically had to do with lasers. It said that when an atom is surrounded by photons, it is constantly absorbing and re-emitting them. For this, he won the Young Medal and Prize for this research in the field of optics.

In the 1980's, Cohen-Tannoudji began to have theories specifically about the light of a laser and the effect of it on the motion of an atom, and he joined a laboratory with Alain Aspect, Christopher Salomon, and Jean Dalibard. He and his colleagues performed many experiments related to this, which involved the cooling and "trapping" of atoms.

This research led to a better way to isolate and study individual atoms. This is sometimes called "polarization gradient cooling." It means using light to force atoms into other energy states. This helps to reduce the movement of the atoms and make them easier to study.

Claude's first major discovery in this regard was in 1985, when he began to see that a moving atom slows down when it is in a standing light wave. This later became known as Sisyphus cooling, because an atom's motion is determined by the temperature of the material. Several years later, Cohen-Tannoudji had an unexpected breakthrough. While he was studying an atom trapped in a standing light wave, he found that it was dependent on optical pumping, which is when an atom emits light energy in pulses. This variation of Sisyphus cooling ended up bringing the temperature to 0.18 millionths of a degree above absolute zero. And at that temperature the atom moved a fraction of the speed as it would under normal conditions.

It was by this time that Claude started getting a lot of attention for his work, not to mention numerous medals and awards. He received the Julius Lilenfeld Prize from the American physics society in 1992, the Charles Hard Townes medal from the Optical Society of American in 1993, and the Harvey Prize in 1996. He also won the Médaille d'Or of the National Center for Scientific Research in 1996 for his research in atoms and cooling methods, which is the highest possible honor a person can receive for scientific research in France.

Claude Cohen-Tannoudji finally won the 1997 Nobel Prize for Physics, along with Steven Chu and William Daniel Phillips because of his research in the development of methods to cool and trap atoms with laser light. The press release by the Nobel Foundation in Stockholm, Sweden, summed up the practical significance of his research:

"The new methods of investigation that the Nobel Laureates have developed have contributed greatly to increasing our knowledge of the interplay between radiation and matter. ... The methods may lead to the design of more precise atomic clocks for use in, e.g., space navigation and accurate determination of position. A start has also been made on the design of atomic interferometers with which, e.g., very precise measurements of gravitational forces can be made, and atomic lasers, which may be used in the future to manufacture very small electronic components."

Since 1997 he has continued to teach and do research. In 2010 he published the textbook *Advances in Atomic Physics: An Overview*, with David Guery-Odelin. But he will forever be remembered for his contributions to Quantum physics and optics, along with his research on cooling and trapping atoms.

Sources

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