Louis de Broglie Looking Back on His Discovery of Electron Waves

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A **heavily edited** (focus on clarity) summary of mehranshargh's translation on YouTube post:
Louis De Broglie, interviewed by Pierre Grivet (1967) (Jan 2, 2023)
https://youtu.be/5MDJC029tfc

Dr. Louis de Broglie, 1929 Nobel Prize Laureate and Perpetual Secretary of the Académie des Sciences, works in the Institut de France on the left bank of the Seine, which is not far from the Latin quarter. In this 1967 interview, Professor Pierre Grivet asks him a few questions.

PG: Professor de Broglie, you received the Nobel Prize in Physics in 1929 for discovering electron waves, which now are named after you. Could you please explain the significance of these waves, how they changed our conception of mechanics, and how they created a new science of wave mechanics?

Yes, it was in 1929 that I received the Nobel Prize in physics for discovering the wave nature of electrons.

My discovery of electron waves resulted from a very long reflection that began in 1905 when I was only 13. That was when Professor Einstein discovered that light contains not only waves — which had been well-known for a long time — but also *particles*. This insight allowed Einstein to explain the formerly unexplainable photoelectric effect. Einstein's insight on photons and his 1905 theory of relativity fascinated me, and I thought about these ideas for years. Through my contemplations, I eventually concluded that a wave should accompany every concrete particle, including electrons, as with the photon.

Electrons as waves created a profound change in particle mechanics. Until then, everyone thought that all one needed was a well-known set of laws to calculate the trajectory of particles. However, with wave mechanics, everyone realized that the trajectory of a *wave* instead determines the particle path. The implication was that wave-like behavior had to appear even with particles like electrons.

For example, for a wave containing many associated electrons, the electrons can, in some circumstances, spread out in a way that corresponds to well-known diffraction phenomena of light. Studies done in 1923-1924 verified the existence of such electron diffraction phenomena and, by 1927, provided experimental confirmation of my ideas.

PG: Could you please tell us if your World War I work on radio waves at the Eiffel Tower contributed to the development of your ideas?

My interest in photons and special relativity began long before my 1913 military conscription, though admittedly, my ideas were still elementary since I was very young. I wrote my first notes on wave mechanics in 1923, then focused entirely on the topic in my 1924 Ph.D. thesis. I think my progress might have been more efficient if the severe circumstances of the war had not changed my life for several years.

I was indeed mobilized at the Eiffel Tower for five years during World War, where I dedicated myself to radio waves. While this delayed my primary work, I worked extensively on electromagnetic waves and electrons during those five years, and that did help in developing my later ideas. I became familiar with such ideas because the radio, which was still embryonic, developed quickly after the invention of three-electrode vacuum tubes that enhanced the reception and emission of electromagnetic waves. I learned a lot about practical things and thought much about waves and electrons, which helped prepare me for my work in the 1920s.

PG: Is that true that you are what we call today a "pure theoretician" and that you made all your discoveries using only a pen and a sheet of paper? Or was the fact that your older brother was an experimental physicist and the head of a prestigious research laboratory a significant contributing factor in the evolution of your ideas?

It is true that I am, in a way, a pure theoretician since I never did experimental work and always worked on the theoretical questions at my table with a pen.

However, it is also true that I had contact with experimental groups during my youth. These included not only at the Eiffel Tower, as I mentioned earlier, but also working on X-rays in my brother's laboratory. Working with my brother taught me many things, and I also did some theoretical work on the experimental results we obtained in his lab.

So, I gathered knowledge during that period that later proved highly useful in developing my theoretical work.

PG: Your discovery was so revolutionary that it was not immediately accepted. Is it true that you based it on the theory of relativity and that Einstein was the first to acknowledge its extreme importance? I understand, for example, that he immediately asked one of his students, Mr. Elsasser, to study your idea. Could you please tell us how the theory of relativity plays in your conception of physics?

Well, yes, that question is straightforward to answer.

The theory of relativity heavily inspired my work on wave mechanics. I regret that, nowadays, the physics community has largely forgotten the importance of relativistic considerations in my development of wave mechanics.

The fact that my theory is relativistic is likely what grabbed Dr. Einstein's attention in the first place. When I first submitted my Ph.D. thesis to Dr. Paul Langevin, he was reluctant to accept such a radically new theory, so he forwarded it to Dr. Einstein and asked for his advice. Einstein responded by saying my ideas were extremely interesting, and he later published a note mentioning my works in the Berlin Academy of Science proceeding. I think that this is what made people, in particular Dr. Schrödinger, aware of my works. Dr. Schrödinger and others then continued my work in the same direction.

I don't know whether Dr. Einstein commissioned Dr. Elsasser to study my ideas. However, Mr. Elsasser published works on the same topic at roughly the same time. From that, I think Dr. Einstein likely directed Dr. Elsasser to work on this.

Thus I think it's safe to say that the theory of relativity plays a significant role — much more extensive than most people usually think — in the basic ideas of wave mechanics. To understand wave mechanics well, one must come back to relativistic considerations.

PG: Your mechanics was developed mainly during the 30s when the uncertainty principle first appeared. This principle had significant philosophical consequences by giving philosophers arguments against determinism. Do you think that these philosophical developments are interesting, either for philosophy itself or for science?

Well, it is true that around 1927-1930, there was an evolution in our interpretation of wave mechanics that led many physicists to think that we mostly had to give up physical determinism. Heisenberg first formulated his uncertainty principle around this time, in which phenomena exist that we can never fully describe. Philosophers naturally discussed this idea and, perhaps imprudently, also generalized it.

However, I think we have gone too far in that direction. The uncertainty principle only says we don't know and can never precisely know certain things. That is not the same as saying they are undetermined, which is a much bigger statement.

My thoughts now are that it would be advantageous to go back to a much more precise picture. That's because science is all about uncovering previously unknown causality links between diverse phenomena, so looking for new causality links is always an extremely productive science strategy. On the other hand, assuming absolute determinism of all phenomena may go too far in the other direction. I am careful and don't want to give the impression that I am advocating absolute determinism. However, I think bringing back a focus on finding new causality links could be very useful for science.

PG: Dr. Einstein said that the probabilistic interpretation of your mechanics never reached its ultimate development. For example, while discussing the uncertainty principle, he said, "I don't believe in this little god that plays with dice." Could you please give us your opinion on this philosophical issue?

Yes, certainly.

It's important to recall that during the development of the uncertainty interpretation of wave mechanics and quantum mechanics, two of the principal founders of quantum theory, Einstein and Schrödinger, thought that any purely probabilistic interpretation could not be exact. That led Einstein to say God was not playing dice as phenomena unfolded. Einstein and Schrödinger made exact objections, ones that were not purely philosophical. Their objections were about precise cases in the accepted theories.

I've thought a lot about this over the years. I think Einstein's and Schrödinger's objections remain strong, and we need to find a less profoundly probabilistic theory. This new theory will introduce probabilities — a bit like the ones that used to be in the kinetic theory of gases, if you will — but not to the extent that forces us to believe there is *no* causality.

PG: You've written many books. Some are on theory for specialists, some for a broader audience, and two for radar and electron microscopy applications. What do you see as the connection between teaching and research?

When you teach, you learn how to present ideas precisely. That helps research, so I've always thought of teaching and research as strongly linked. I've also always felt that it's more helpful to students and researchers to capture and further share what I'm teaching in the form of books. You can tell that I considered teaching very important from all of my lectures and books on various topics.

Consequently, yes, I have indeed written many books. As you noted, they include two on applied physics and general readership books, though I've seldom lectured on those. As a professor at the Faculté des Sciences de Paris, my lectures over the past 34 years focused almost exclusively on my scientific books, though I have also given many lectures on my book about electromagnetic waveguide theory.

There is, however, a bit of a drawback in teaching: Composing clear lectures forces you to be a bit more dogmatic. After all, one cannot stand in front of students and say, "Well, I think that it is this way… but it may be the opposite." The impact of such ambiguous methods on students might be less than excellent, but that same striving for clarity also makes you dogmatic. It can trick our mind a bit since you can get into a habit of affirming certain things about which, to be honest, you are personally unsure.

Nonetheless, I think teaching and research are valuable and complementary activities. When the same person does both, it contributes clarity to research questions.

PG: Your students say your current focus is on understanding light more profoundly. Could you explain why you remain interested in something as simple in behavior and easily accessible as light while others focus on strange new particles from large colliders?

I used to follow the many exciting problems emerging from work in elementary particles carefully and with much interest. It's true that, for now, I'm neglecting that a bit and have gone back to studying the theory of light and particles connected with light.

The reason is that I don't think that light is completely understood yet, even using current formalisms. These formalisms are, after all, based on my wave mechanics model, which in turn is based on Einstein's insight that light contains waves and particles at the same time. We still need a better understanding of how those particles and waves are associated. For that kind of research, light is as good a model — and one far more accessible — than the particles coming out of exotic accelerators.

In short, I think there is still much to do in the theory of light. Recent discoveries of new phenomena have occurred, most notably in the functioning of lasers. Another interesting example that addressed the relationship of waves and particles in light is the Hanbury Brown and Twiss phenomenon that compares quantum fluctuations of light at different points in space. Careful assessment of such issues can likely improve our understanding of light and the nature of the association of waves and particles throughout physics.