Advanced Waves and Quantum Mechanics

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Abstract

Advanced waves are predicted by the negative solution of Klein-Gordon's equation. This equation is compatible with the major mysteries of quantum mechanics, making them compatible with special relativity. However advanced waves move backwards in time and require a new definition of causality. In this short paper the duality wave/particle, quantization and nonlocality are described as manifestation of advance waves and of the dual solution of the Klein-Gordon equation. These anomalous properties of quantum mechanics could be considered as evidence which supports the existence of advanced waves.

Introduction

The equation $E = mc^2$, commonly associated with the work of Albert Einstein, was first published in 1890 by Oliver Heaviside and then refined by Henri Poincaré in 1900 and Olinto De Pretto in 1903, and it then become famous with Einstein's special relativity where it was integrated with the momentum in the energy/momentum/mass equation:

$$E^2 = m^2c^4 + p^2c^2$$

Energy/momentum/mass equation

where the total energy (E) is the result of the sum of the momentum (p) and mass (m), multiplied by the speed of light (c). Being a second order equation, it is necessary to operate a square root which produces always two solutions, one positive and one negative. This simple property of square roots implies that the solution of energy is always dual: positive ($+E$) and negative ($-E$). According to Einstein's special relativity:

- the positive energy solution ($+E$) describes energy which diverges from causes located in the past and which propagates towards the future (retarded potentials);
- the negative energy solution ($-E$) describes energy which diverges from causes located in the future and which propagates backwards in time from the future towards the past (anticipated potentials).

Usually physicists tend to reject as "unphysical" any solution which contradicts classical causality, according to which causes always precede effects. Any solution which makes it possible to send a

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signal backwards in time is usually rejected. For this reason the negative energy solution was immediately considered impossible, a mathematical trick, because it implied the existence of causes located in the future which retroacted on the past. This absurd situation was automatically solved in inertial systems in which the momentum (p) is equal to zero. When the momentum equals to zero $c^2p^2=0$ the equation simplifies in the famous $E = mc^2$ which has only positive solutions (+E).

However when the Schrödinger (ψ) wave equation is turned into a relativistically invariant equation:

$$E\psi = \sqrt{p^2 + m^2}\psi$$

Klein-Gordon's relativistically invariant wave equation

both solutions of the equation need to be considered as a possibility, even a non physical negative energy has to be considered as a possibility. According to Klein-Gordon's equation:

- the positive solution ($+E\psi$) describes waves which diverge from causes located in the past and which propagate towards the future (retarded waves);
- the negative solution ($-E\psi$) describes waves which diverge from causes located in the future and which propagate backwards in time from the future towards the past (advanced waves).

Quantization, Planck's constant and unitary time

At the end of the 18th Century Lord Rayleigh and Sir James Jeans tried to extend the equipartition theorem of classical statistical mechanics in order to describe thermal radiations.

In classical statistical mechanics, the equipartition theorem is a general formula that relates the temperature of a system with its average energies. The idea is that energy is shared equally among its various forms.

When applied to waves, the equipartition theorem predicted that a body would emit radiations with infinite power, as it would all concentrate in the ultraviolet wavelength. This prediction was named the "ultraviolet catastrophe", but fortunately it was not observed in nature. This paradox was solved on 14 December 1900 when Max Planck presented a paper, at the German Physical Society, according to which energy is quantized. Planck assumed that energy does not grow or diminish in a continuous way, but according to multiples of a basic quantum, which Planck defined as the frequency of the body (v) and a basic constant which is now known to be equal to $6{,}6262 \cdot 10^{-34}$ joule·seconds and which is now named Planck's constant. Planck described thermal radiations as composed of packets (quantum), some small others larger according to the frequency of the body. Below the quantum level, thermal radiation disappeared, avoiding in this way the formation of infinite peaks of radiation and solving in this way the ultraviolet catastrophe paradox.

December 14 1900 is now remembered as the starting date of quantum mechanics. However Planck himself remained unconvinced about his discovery as he could not answer the question "*why a* *quantum?*"; this question has not been answered yet and remains one of the mysteries of quantum mechanics.

The dual solution of Klein-Gordon's equation suggests an explanation, based on the fact that in the universe two opposite forces would take place:

1. expansive forces associated with time moving forwards;
2. cohesive forces associated with time moving backwards.

In our expanding universe, expansive forces prevail and therefore time moves forward, whereas in systems where expansive and cohesive forces are balanced, such as the atoms, a sequence of expansive and cohesive phases should take place. During the expansive phase time would move forwards, whereas during the cohesive phase time would move backwards. According to this model of the atom based on a sequence of expansive and cohesive phases:

- atoms can emit energy only during the expansive phase and not during the cohesive phase, resulting in quantized emissions of energy;
- atoms can absorb energy only during the cohesive phase and not during the expansion phase, resulting in quantized absorption of energy and matter;
- each cycle of expansion and contraction would coincide with a fundamental unit under which it is not possible to go (Planck's constant);
- in the expanding phase time would move forwards, whereas in the cohesive phase time would move backwards. As a whole, time, at the subatomic level, would result to be unitary: past, present and future would coincide.

According to this model the quantization of energy can be considered an empirical evidence of the validity of the dual solution of Klein-Gordon's equation and of the model of the atom based on phases of expansion and contraction.

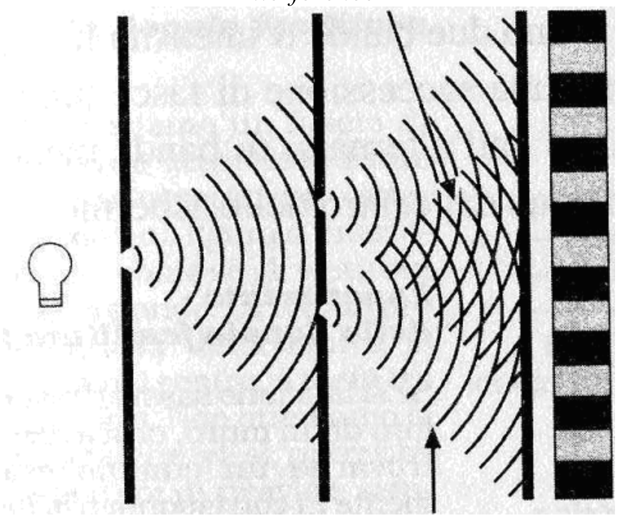
Wave/particle duality

On 24 November 1803 Thomas Young presented, at the Royal Society of London, the double slit experiment demonstrating that light is a wave:

"*The experiment I am about to relate (...) may be repeated with great ease, whenever the sun shines, and without any other apparatus than is at hand to everyone*".

Young's experiment was very simple in design: a narrow ray of sunlight shines through a pinhole in a cardboard, the light then goes through two pinholes in a second cardboard, and then ends on a white flat surface creating patterns of lines, light and dark. (Fig. 1) which Young explained as a consequence of the interference among light waves. White lines (constructive interference) are shown when light waves add up, whereas dark lines (destructive interference) are shown when they do not add up.

Interference



Diffraction waves

Fig. 1 – *Thomas Young's double slit experiment*

Young's experiment was generally accepted as the demonstration of the fact that light propagates as waves. If light were made of particles, the interference pattern would not have shown up, but only two well localized dots of light would have been observed in association with the pinholes in the cardboard. Instead, in the double slit experiment, the brightest line is located between the two pinholes, in what would have been expected to be a dark area (Fig. 2).

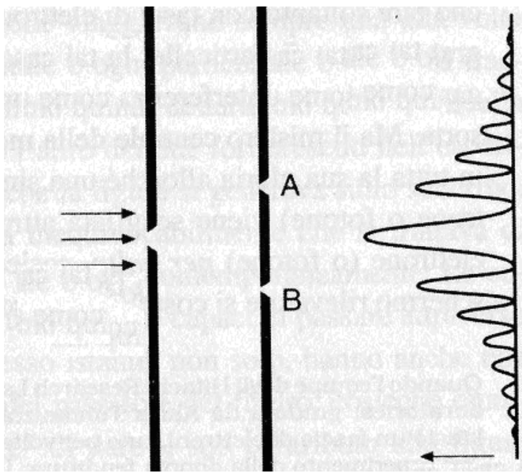


Fig. 2 – *Light patterns in Young's experiment*

Young's experiment has been considered the fundamental demonstration of the wave properties of light until Quantum Mechanics started to disclose the dual nature of matter: waves and particles at the same time.

Young's experiment can now be performed using single electrons. Electrons used in a double slit experiment produce an interference pattern and therefore behave as waves, but at their arrival they give place to a point of light, behaving as particles. Do electrons travel as waves and arrive as particles?

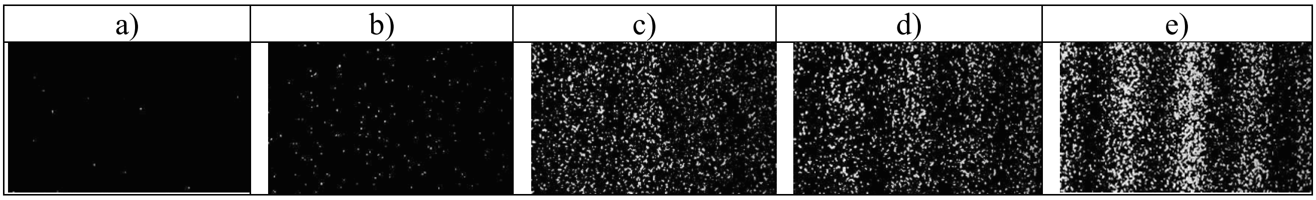


Fig. 3 – *Double slit experiment using electrons*
a) 10 electrons; b) 100 electrons; c) 3.000 electrons; d) 20.000; e) 70.000 electrons.

If electrons were particles we could conclude that they would go through one of the two slits, but the interference patterns shows that they behave as waves going through the two slits at the same time. Quantum entities seem to be capable of going through the two slits at the same time and know how to contribute to the interference pattern.

According to Richard Feynman: "*The double slit experiment is a phenomenon which is impossible, absolutely impossible, to explain in any classical way, and which has in it the heart of quantum mechanics. In reality, it contains the only mystery, the peculiarities of quantum mechanics.*" (Feynman 2001). Richard Feynman considered this experiment so important that he dedicated to it the first chapter of the third volume of his famous "*Lectures on Physics*".

In 1986 John Cramer of the Washington State University developed the Transactional Interpretation of quantum mechanics. This interpretation starts from the dual solution of Klein-Gordon's equation and arrives at the conclusion that the dual manifestation waves/particles is the consequence of the dual causality: past/future. Whereas a particle can be considered the manifestation of a cause which has been determined (and therefore arrives from the past), the wave can be considered as a cause which still has to be determined (and therefore comes from the future). Klein-Gordon's equation implies that emitters come from the past (diverging waves) whereas absorbers come from the future (converging waves) and describes physical reality as a continuous interaction between emitters and absorbers. Without one of these two forms of causality no transition of matter or energy would be possible. For example, if only classical causality would exist a battery could have only one polarity which emits electrons. On the contrary, two poles are needed, one which emits and one which absorbs. In the absence of this duality, if we only touch the emitting pole (-) or the absorbing pole (+) no electricity is released.

According to the Transactional Interpretation, this continuous interplay of causality and retrocausality (emitters/absorbers) takes the form of this dual manifestation of matter (wave/particle). The fact that matter always shows in this dual manifestation can be considered an evidence which supports the validity of Klein-Gordon's equation.

Nonlocality

The Copenhagen Interpretation of quantum mechanics, inspired by the works of Niels Bohr and Werner Heisenberg, explains the duality wave/particle stating that the particle propagates as a wave and when the wave is measured (observed) it collapses into a particle. This interpretation concludes that the act of observation creates reality, since it makes the wave collapse into a particle. According to this interpretation the collapse of the wave function (the collapse of the wave into a particle) happens in the same moment in all the points of the wave. This requires an instantaneous propagation of information which violates the limit of the speed of light which Einsten had discovered as the limit in the propagation of information and causality.

According to the Copenhagen Interpretation consciousness, through the exercise of observation, forces the wave function to collapse into a particle. This interpretation states that reality is a consequence of consciousness, and assumes that consciousness is an immanent property which precedes the formation of reality. The concept of panpsychism was explicitly used by Bohr and Heisenberg.

When Erwin Schrödinger discovered how his wave function had been reinterpreted into a probability function with mystical implications, he commented: *"I don't like it, and I am sorry I ever had anything to do with it"*. Einstein immediately refused the interpretation of Copenhagen stating that the use of the observer, of consciousness and probability proved the incompleteness of the interpretation. According to Einstein a scientific theory had to use causality: "*God does not play dice with the universe!*"

According to Einstein, causality is always local and information can only travel at speeds lower or equal to the speed of light, never faster. Starting from these assumptions Einstein refused the idea that information relative to the collapse of the wave function could travel faster than light and, in 1934, he formulated these considerations in the EPR paradox (named after the initials of Einstein-Podolsky-Rosen) which remained unanswered for more than 50 years.

In 1924 Pauli discovered that electrons have a spin, and that in a specific orbit only two electrons, with opposite spins, can find place (Pauli's exclusion principle). According to this principle any couple of electrons, which shared the same orbit, remain entangled showing opposite spins independently from their distance. The Copenhagen Interpretation predicts that when the measurement is performed on one photon it instantaneously determines the state of the second photon, whichever is the distance. This is what Einstein named "*a spooky action at a distance*".

EPR had been presented as a conceptual experiment, in order to demonstrate the absurdity of this interpretation, raising a logical contradiction. No one expected that the EPR experiment could be really performed.

In 1952 David Bohm suggested to replace electrons with photons in the EPR experiment, and in 1964 John Bell showed that the change introduced by Bohm opened the way to the possibility of a real experiment. At that times even Bell did not believe that the experiment could be performed, but 20 years later several groups had developed the precision of measurements required, and in 1982 Alain Aspect published the results of an experiment which showed that Einstein was wrong and that nonlocality was real.

Aspect's experiment measured the polarization of photons. It is possible to force an atom to produce two entangled photons, which go in opposite directions. Each photon, of an entangled pair, have opposite polarization.

Aspect measured the polarization of photons according to an angle which he could regulate. According to nonlocality, changing the angle with which the polarization of a photon is measured would instantaneously change the measurement effected on the second entangled photon. The experiment was conducted on series of entangled pairs of photons. Bell's theorem stated that if locality is true, the measurements of polarization performed on the photons moving through the first apparatus, which could be regulated changing the angle, should always be higher than the measurements performed on the second set of entangled photons (Bell's inequality theorem). Aspect obtained opposite results, violating Bell's theorem and showing that nonlocality is real. Einstein's good sense lost the competition against the unreasonableness of quantum mechanics. Aspect's experiment proved that in nature instantaneous correlations, where information propagates faster than the speed of light, are real and possible.

The dual solution of Klein-Gordon's wave equation offers an explanation of nonlocality which could reconcile Einstein with quantum mechanics, since it describes nonlocality in a totally causal way. Advanced waves move backwards in time and therefore move faster than light. For this reason they can create instantaneous links, correlations, between faraway points in space. The reconciliation between Einstein and quantum mechanics is therefore possible only if the negative solution of Klein-Gordon's equation and advanced waves are considered real. It is important to note that since advanced waves come from the future, they cannot carry information; information is necessarily associated with the past, with an event, a condition which has already been determined and therefore information can be carried only by waves which move forwards in time.

Conclusions

In this paper a concise description of how some of the fundamental mysteries of quantum mechanics can be explained by the advanced waves solution of Klein-Gordon's equation is provided. A totally different vision of quantum mechanics and of the subatomic world, compared to the Standard Model, is outlined. A vision which is totally compatible with the equations and data used in quantum mechanics.

John Cramer, of the Washington State University, developed in 1986 the Transactional Interpretation of quantum mechanics, which is based on the dual solution of Klein-Gordon's equation. This interpretation coincides with the model which was formulated by Luigi Fantappiè in 1942 and shows that once we extend the model to include advance waves, the results obtained by the experiments become totally compatible with the theory, and predictions of the model coincide exactly with the equations used in quantum mechanics.

The dual solution of Klein-Gordon's wave equation allows to solve the mysteries of quantum mechanics, and makes it compatible with special relativity. However this miracle is possible only if we accept that the negative solution is possible, that advanced waves are real and that at the subatomic level time is unitary: past, present and future coincide.

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