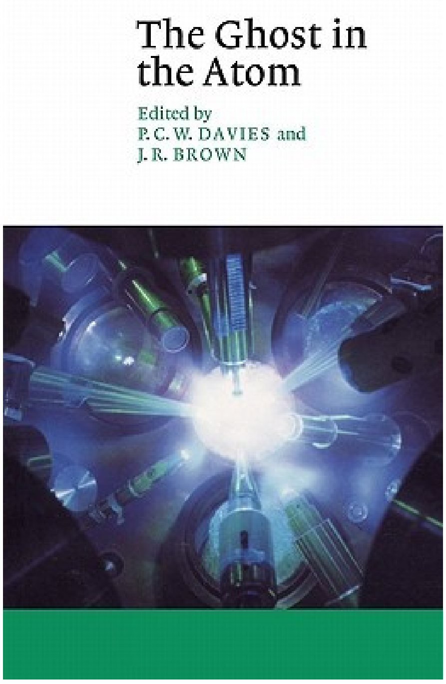

The Ghost in the Atom: A Discussion of the Mysteries of Quantum Physics

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Nine distinguished physicists consider the conceptual foundations of quantum physics, its paradoxes, and its profound implications for the theory of nature. The text is based on a BBC radio documentary and includes interviews with several scientists who have played a prominent role in the debate over these issues.

The Ghost in the Atom: A Discussion of the Mysteries of Quantum Physics Details

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Download and Read Free Online The Ghost in the Atom: A Discussion of the Mysteries of Quantum Physics Paul Davies (Editor) , Julian R. Brown (Editor)

From Reader Review The Ghost in the Atom: A Discussion of the Mysteries of Quantum Physics for online ebook

Taom says

Najbardziej podoba mi si? teoria ?wiatów równoleg?ych. Realizuje si? taki, który odpowiada naszej ?wiadomo?ci :))

Lee Richardson says

Quantum mechanics is not simple. I actually read this book two times, and still don't have a solid grasp of the details underpinning the Aspect experiment, much less the mathematics, why it works so well, and what it all means. But that's not the point of this book. The main point (to me) is showing a broad audience the controversies surrounding interpretation of quantum mechanics.

Since quantum mechanics is one of the most successful scientific theories ever, in terms of predicting results of experiments, and the discipline of physics is interested in understanding precisely how the world works, it is natural to want to interpret the physical meaning underlying quantum mechanics. But the interpretation is not simple, and even mis-aligns with classic physicists.

This book has two parts:
1. Explain quantum mechanics as simply as possible (Chapter 1),
2. Interviews with leading physicists who advocate certain interpretations (Chapters 2-9)

The main interpretations are Copenhagen, Many Universes, Ensemble, Quantum Field Theory, and Quantum Potential. Naturally, all physicists interviewed believe their position is correct.

The Copenhagen interpretation seemed the most prominent, and is a little eery. From what I gather, it is inextricably linked with the Heisenberg Uncertainty principle, which states we can't measure both the position and velocity of an electron simultaneously. The eeriness comes from the implication that things don't exist until they are observed, which interesting relates to the old saying: "If a tree falls in a forest and no one is there, does it make a sound"? Supporters of objective reality "out-there" (Einstein) believe that of course the tree makes a sounds, but some (e.g. Eugene Wigner) may claim that no sound is made unless a conscious observer hears it.

As a statistician, it is interesting to see physicists interpreting probabilities, especially when their careers are at stake, and they're discussing one of the most fundamental problems in science. Statisticians can glean subtle but interesting insights here. For example, David Deustch was asked "why do we need an interpretation", and he gave the very interesting two part answer:
1. The whole point of physics is explaining reality
2. If we just say they're algorithms, who cares, then we may halt scientific progress.

I wonder if these relate to statistics, whose famous motto can be summarized as "All models are wrong, but some are useful". Clearly, statisticians don't care as much about their models matching objective reality, and are more than happy to use them for pragmatic purposes.

Caution This book is relatively old, so I should look into more recent takes on Quantum Mechanics to see if anything has been resolved since.

Aina says

Great coverage of the measurement problem, Copenhagen interpretation and other alternative views. The book is a bunch of conversations with leading physicists of 1980s.

Rama says

The real (unreal) world of quantum theory; views of eight active researchers

Anyone who is interested to understand reality (universe, consciousness and life), and laws of physics applicable to them must be interested in learning about the laws quantum mechanics. A number of books are available, and this one stands out as a book for good introduction. The authors' interview eight physicists who are actively engaged in research and the profoundness of the universe and the concept of quantum reality begins to unravel as you progress through the book. The book is written for common readers but you must appreciate basic quantum physics experiments, whose results are discussed throughout the book. There are nine chapters, and the first chapter introduces the basics of quantum theory.

Matter at the most fundamental level has both particle and wave nature (wave-particle duality), because some experiments illustrates the particle properties, and other experiments shows the wave properties. In addition, the Heisenberg Uncertainty principle postulates that the position and momentum of a fundamental particle are not determinable at the same time. This is not due to experimental limitations but inherent characteristic of matter, an intrinsic fuzziness of the subatomic world. Therefore it follows, in experiments measuring the path of fundamental particles; the famous two - slit electron experiment of Thomas Young; identical experiments yield different results. It is a common experience in the real world that the laws of cause and effect dictates common sense, for example, a planet in its orbit uses a well defined path and its position can be predicted at any give time, but in quantum world, this is uncertain and we can only discern the point of departure and point of arrival of an electron in an experiment but nothing about the actual path.

There are five major interpretations of quantum theory, they are; a. Copenhagen interpretation; b. Hugh Everett's many universes interpretation; c. Wigner's interpretation; d. Hidden variables interpretation and quantum potential; and e. Ensemble (statistical) interpretation. Copenhagen interpretation is considered as the official view. According to this, reality of classical world is ambiguous and non-specifiable. It gives subatomic particles an abstract mathematical status but does not provide reality in full common sense of the word. In classical thought the universe is independent of an observer; it exist no matter we observe that or not. This is objective reality that squares off with common sense perception. This is precisely the concept that Bohr challenged in his interpretation that objective reality doesn't exist per se until measurements are performed. In general, a quantum state may contain an infinite number of superimposed quantum states. The act of observation and measurement will result in one quantum state and others disappear instantaneously. Many universes interpretation of Hugh Everett proposes that superposition of wave function result in splitting the universe into multiple units each corresponding to one particular wave function or one state. The observer also splits into the same number of units and each universe will have a copy of the observer.

According to Wigner's interpretation, the quantum phenomenon does not happen until reality sets into the consciousness of the observer, but John Wheeler states that realty may have occurred but not put to use until this information is communicated.
Ensemble (statistical) interpretation which implies that any quantum mechanical measurement made is made on an ensemble of identically prepared systems. Hence the results of experiment take the form of a probability distribution of particular values for the measurement. This interpretation looks at the statistics and do not care about individual event. Hidden variables interpretation postulates that a particle like an electron has a potential called quantum potential (QP) which is a new property. Its effect does not depend on its magnitude but only on its form (particle or wave nature) so that it may have big effects over long distances. This wave (QP) also carries experimental arrangement with it and also the states of all other particles in the system. This interpretation also suggests that a particle has both position and a definitive momentum, and QP modifies classical behavior of particles to quantum behavior.

The negative feature of the book is that the authors do not discuss the results of experiments they describe (see pages 11, 16, 19, and 40)

Mitch Allen says

This interview transcript from the Ghost in the Atom BBC radio show has some interesting nuggets from the likes of John Bell, David Bohm, Basil Hiley and other physicists. The first part of the book is a light summary of quantum mechanics leading into the interviews. Not the best introduction to the topic, but provides color to some interpretations of quantum theory.

Tony duncan says

this totally changed my understanding of Quantum mechanics. I do not know enough to make judgments about the various different theories, but each was such an interesting and provocative explanation of reality, that it really made me think.
I hope there is a subsequent volume that looks at how the "string" crumbles so to speak.

Linda Hamonou says

Even if this book is designed for no-physicists. I'm not sure how easy it is to follow.
It is composed of interviews of various physicists: theoretical physicists, experimental physicists in different field related to quantum mechanics who answer questions about the interpretation of quantum theory.
The first side is to say that the mind of the observed has an impact on the world around and that the observer is outside of the system. An idea that for me doesn't seem to hold with quantum cosmology when extended to the entire universe and therefor placing the mind of the observer outside of the universe.
On the other side there is the many universes theory allowing an infinite number of parallel universes. In this case having a infinite number of universe seem to be a problem as most believe those other universe can't be reached, which other believe they are reached through interference patterns at an atomic level.
It was a fun read and totally redefines what you consider as "reality".

Eric Layton says

This little book is a gem. I read it in one sitting. To read the opinions of the actual physicist about their own take on quantum mechanics and relativity was quite interesting.

Andrew says

Fascinating but somewhat above the level of the general reader like me. The final chapter with David Hiley I found to be a little more understandable than those before. A lot of the time the book enters into philosophical debate about the true nature of reality which often became a struggle to follow. However, I would still recommend it to anyone who seeks to enhance their knowledge as I do.

Peddiraju Bhargava says

A fantastic book with different points of view from some of the eminent physicists of the 20th century. The Copenhagen interpretation, many worlds interpretation, Schrodinger's kittens and the discussion about God Doesn't Play Dice - all very interesting and thought provoking. Thanks to SVNIT for providing this gem of a book.

Mills College Library says

530.12 D2571 1986

Ege Özmeral says

1) In two slit experiment, particles make an interference pattern, which means they act like waves. This also means that each particle goes through both slits. However, if you close one of the slits or put detectors on slits, particles don't make an interference pattern, which means they act like waves, and each particle goes one slit or another NOT BOTH. Then, how they "know" if there is a detector or one of slits are closed? One of answering this question is that particles don't have well-defined paths. They go through every possible ways.

2) An experiment was pointed out by John Wheeler is Delayed Choice Experiment, which shows that we can determine the path of particles AFTER each particle has already traversed. It seems like observation can affect past of the particles. This experiment was implemented:
http://images.iop.org/objects/phw/new...
In this image, mirrors divides each particle. If we put half-silvered mirror(which means it only reflects not propagate) on BS2, we can know which way particle has taken and we won't see interference pattern. However, if we don't put a half-silvered mirror, we can't know which way particle has taken and therefore we

will see interference pattern on both detectors.

Copenhagen Interpretation

According to Bohr, it is meaningless to ask "what is electron" when we don't observe it. Either we can leave electrons alone and observe an interference pattern, or we can take a peek particles' trajectories and wash out the pattern. Two situations are not contradictory but complementary such as momentum-position complementary. Therefore, Copenhagen Interpretation says it is meaningless to say electron exists on its own(not as a result of an observation).

If an atom is excited at t1, then quantum mechanics can calculate the probability of that it will no longer be excited at t2. All we know the observations of its energy at t1 and t2. We don't need to assume anything between t1 and t2. For example, energy is not an abstract thing but conserved mathematical analogy that observations of mechanical process. What Bohr suggests things like electron, photon, atom... is the same. This traditional interpretation creates a paradox in it because it gives very importance to observer. Geiger counter, which is an apparatus used to observe, is also made of quantum objects. Troubles arise when we ask where the dividing line comes between quantum(microscopic) and classic(macroscopic) world. Particles don't posses well-defined properties. However, they do after we make a measurement and we can choose which measurements to make, either position or momentum. If you put a particle in a state of given position, and then decide to measure the momentum, you get a particular value, although the value can't be predicted. The rules of quantum mechanics say, a quantum system can evolve in time in two quite distinct ways. When observation is made, waves that were used to interfere with each other have disappeared but one of them. We cannot undo it and restore the original complex wave pattern, which means mathematically "non-unitary". We can considered both apparatus and quantum object as an isolated system. Yet, this also leads into the paradox because we need another apparatus to determine the quantum state the former apparatus and so on. Von Neumann(and Eugene Wigner) concluded that consciousness can be an end to this vicious circle. However, this seems also paradoxical. For example, if we replace a person with the cat in Schrödinger's thought experiment and if the person is in a superposition state(dead and alive) when we open the box(let's say the person is alive) we can ask the person how he felt before we opened the box. Maybe because the person is a conscious, he collapse the wave function. Some say even the cat can be count as an conscious observer. "Drawing line" problem is now between conscious and unconscious.

Many-Universes Interpretation

When we consider the quantum cosmology unless mind is involved, we must think an external apparatus beyond our universe. Hugh Everett proposed a radical interpretation which, it is claimed, requires less assumption than the traditional interpretation. According to Everett, transition occurs because the universe slips into copies where each quantum states are real in each copies. Therefore, the number of copies depends on the number of quantum states. Furthermore, these universes are the same completely except the quantum state. For example, in Schrödinger's thought experiment in one of the universes cat would be alive whereas cat would be dead in the other. A proponent of this interpretation, Bryce DeWitt expressed it as: Every quantum transition taking place in every star, in every galaxy, in every remote corner of the universe is splitting our local world on Earth into myriads of copies of itself. Here is schizophrenia with vengeance. There two major criticism against it. One is that the interpretation has lots of excess metaphysical baggage while we observe only one universe. In defense, proponents say, the interpretation emerges formal rules of quantum mechanics, without making any epistemological hypothesis despite other interpretations. The other is that it is unstable. If our consciousness is confined to one universe at a time, how could we confirm or refute the others? David Deutsch say it can be tested by very intelligent computers in future. Some say this interpretation may also explain why the universe we living looks arranged precisely so that living creatures arise.

The statistical Interpretation

This interpretation abandons what actually goes on in an individual quantum object. Quantum mechanics seems working good statistically, however there is no case to answer as regards the measurement problems. Therefore, there is no way to know what actually happens when a particular measurement takes place.

Uncertainty, Non-locality and Bell's Theorem
Suppose a single stationary particles explodes into two particles. Uncertainty Principle forbids us from knowing position and momentum of either particle definitely at the same time. We choose one or the other to be well defined. However, because of conservation of momentum, we can measure the momentum of a particle to deduce the that of other one and also by symmetry one of particle must move a distance equal to that of the other one(also if particles are photons, their polarization must be the same).
If faster than light communication is false, quantum mechanics must be incomplete. Bell introduced some inequalities to test this idea. To illustrate, the number of black people can't be greater the number of men plus the number of women. If quantum mechanics is true, Bell inequalities must be exceeded(they were in Aspect's experiment). Entanglement is incompatible with objective reality or locality. By objective reality, we mean the reality of the external world that is independent of our observations. By locality, we mean not instantaneous but separable effect. If one wants to accept entanglement, one should leave locality or objective reality.

John Bell: The Aspect experiment did not prove indeterminism of quantum world, it only proved action at a distance. It must certainly be explored that the hypothesis which says mind has an essential role in physics but it certainly has paradoxes in it. Pre-Einstein position of Lorentz and Poincare, Larmor and Fitzgerald is perfectly coherent and consistent with relativity theory. Thus, we should get back the idea of aether because if all Lorentz frames are equivalent, things can go back in time. Quantum theory is a temporary expedient. It's enough reason to dislike the many-universes interpretation that we only observe one universe. The de Broglie-Bohm theory was developed for non-relativistic quantum mechanics. If you try to extend it to the relativistic context, you will have difficulties.

John Wheeler: The complementarity description of Bohr was the only possible objective(rational) description. The many-universes interpretation seemed to represent the logical follow-up formalism of quantum theory. However, there's too much metaphysical baggage carried along with it. It also takes quantum theory as the currency and leaves the observation as a mere secondary phenomenon, the primary concept must be make meaning out of observation. Maybe philosophy is too important to be left to the philosophers. Consciousness has a crucial role. It seems we can influence on which path a photon will take. As Bohr said, we have no right to talk about what photon is doing until we observe it and also the pas has no meaning or existence until it exist as a record, this can be view as we, conscious observers, are responsible for reality. The gravitational lens effect provides us to see what delayed-choice experiment do in cosmological level.

Rudolf Peierls: There is only one interpretation and one way to understand quantum mechanics - Copenhagen Interpretation. Therefore, when you refer to Copenhagen Interpretation, what you really mean is quantum mechanics. Table(a macroscopic object) is not real until we observe it. We can't replace observer with inanimate device. Suppose you have an apparatus that tells you whether a radioactive atom decayed or not by the position of a pointer. To determine the position of the pointer, you need to shine light on it. Bu you only know the possibility of light being reflected. It goes until you become conscious of that experiment has one result. If you put an unconscious observer such as camera, wave packet won't collapse. Universe wasn't unreal(undecided) before us because we have the information of 13 billion years ago. There is no sensible view of hidden variables theory that doesn't conflict with Aspect Experiment. If we don't communicate with other universes, why invent them?

David Deutsch: The Many-Universes Interpretation is that there are parallel universes which include all existing at the same time and normally not communication with each other. However, they have some influence on each other in microscopic level, that's the reason why we postulate them. It is the simplest interpretation of quantum theory because it involves the fewest assumptions in it. That human consciousness has direct effect on the nature is more unacceptable than the parallel universes. The exact number of universes depends on physical theories which we don't know yet but it's safety to think it's very large, probably infinite. In his favorite way of looking, there is an infinite number of universes and this number does not change but content does. Before choice is made, all the universes are identical; when choice is made, they partition themselves into two groups. Everett proposed universe is branching itself, the reason was that if there was a collection of identical universes, he preferred to speak of it as being one universe. The problem of arrow of time is not also solved in this interpretation. The coming together of universes on a small scale can occur, interference experiment provides an indirect evidence of the fusion of two groups universe into one. The way that Everett interprets Double-Slit Experiment is to say there were two groups of universes that in one universe the photon passed through one slit, and in the other the photon passed through the other slit, but later appeared in the same position, which means that the universes were the same again. Physical reality is the set of all universes evolving together, you cannot move one without moving the others. So parallel universes are connected as the universes of past and future. Copenhagen Interpretation fails in quantum cosmology. It's logically inconsistent to imagine observer outside of the universe. Another advantage of the interpretation is that it will work before we know what an observer is, contrary to the other interpretations.
Suppose an artificial observer(such as computer) which observes an interference phenomenon inside his mind. He tries to observe the effect of different internal states of his brain in different universes interacting with each other. These internal states are set up by a special organ which is essentially another quantum memory unit. The observer's mind differentiate itself into two universes. At the intermediate stage, he will write down "I'm here observing one of the two states". Moreover, he will write down the same thing in both universes because he won't tell which of the two states he observes and won't remember. If interference occurs it means Everett's interpretation is true; however, it does not it means conventional interpretation is true, which says all universes but only one will have disappeared.

John Taylor: the ensemble(statistical) interpretation says when we're observing a quantum system what we're actually doing is that we're making a measurement on an aggregate or ensemble of identically system. Hence, our results takes the form of a probability distribution of particular values for that measurement. We're not allowed to describe what is going on for an individual system. For example, in quantum entanglement we can't talk about the spin of an individual particle, we can only say some ensembles(nearby particles) has spin up/down while the other ensembles(far away particles) has opposite. There is a distinction between measuring and preparing. If you're preparing a state of an ensemble, then you know it will have properties identical with that preparation in the future. If you make a measurement, then you will have been able to gather what it was like before the measurement in the past. We can measure an individual electron, however, there will be an infinite range of possibilities. If we take an individual case in Schrödinger's experiment, it's meaningless to ask whether the cat is alive or dead. We can have wave function to describe the whole universe.

David Bohm: The Copenhagen interpretation only gives a formula describing the probability of what can be observed in a piece of apparatus. Yet the apparatus itself is made of atoms, therefore you should use another piece of apparatus to look at it. Every physicist believe that the external world exists. Descartes said that though is enfolded and matter is extended. However, both are enfolded and both unfold, therefore they are similar in their basic structure. Something can unfold either as a wave-like or a particle-like.It's very similar to the mathematics of the hologram. Think a tree grew from a seed. You can't say the tree was in the seed because its structure also depends on environment like matter does. Experiments and the questions we ask are determined by our way of thinking. In quantum theory we're now asking a certain kind of questions and we're getting a certain kind of answer. Faster that light signalling can make paradoxes such as being able to signal our own past. However, the present theories are not the last word and special relativity will be going to an approximation just as Newtonian mechanics. When we discovered new theories, we will get rid of all these paradoxes. Quantum mechanics does not explain anything but describe it. The quantum potential, which is carried as a wave, can affect particles even quiet far away from the slits, it's influence depends on the form not magnitude. For example, the quantum potential is different if second slit is open/close in double-slit experiment. It has never been introduced like tis new kind of wave(called "active information" by Bohm). We have no control over the influences that propagate faster than light therefore it doesn't violate the special relativity. This quantum potential field does not look like electromagnetic field because electromagnetic field is too simple. The Schrödinger's equations are sufficient to explain both the quantum potential and the many-body problem. Bohm doesn't accept physics is only about making models that explain observations. He doesn't accepet even Popper's idea, which say a theory can be regarded as scientific only if it's falsifiable.

Basil Hiley: "If anybody came to me and said 'I want to solve a certain physical problem, I would recommend that they go ahead with the conventional interpretation" he said, even though he was used to work with Bohm on non-local quantum potential. What we have to try and do is to build up a model which is intuitive and quantum mechanics seems completely counterintuitive. The model(quantum potential) was originated by de Broglie and subsequently developed by David Bohm. In this model, there is an actual particle that has both a definite momentum and a definite position and the wave function does not represent probability but a real field. The field can influence the behaviour of this or other particles, the motion can be derived by Schrödinger's equation. When an electron pass through slits, the result on the other side looks like as if two waves made an interference with each other. Contrary to orthodox theory, the wave is really an average of how a beam individual electron behave, and the intensity of the wave corresponds to the number of electrons arriving at that particular spot in a given time. Another contradiction with orthodox theory is that quantum potential enables you to calculate the set of individual trajectories that give rise the interference pattern. it seem quantum potential gives some information about environment to the particle. Therefore, one can regard the wave as a field of information more that a physical field. It's like direction of a ship's depending on what it receives information from environment by radar waves. Richard Feynman had already pre-empted (us) in saying that he thought of a point in space-time being like a computer with an input and output connecting neighbouring points. So the electron may act like a computer. The motive power that decides how particle act like, of course, comes from the quantum potential itself. The quantum potential does not violate special relativity because it offers an absolute in the background, the quantum aether. In quantum formalism state function for the cat at the end of experiment is a linear superposition of a cat alive and a cat dead. These two states exist together in some way. Hiley doesn't see why mind should be introduced into physics at this level, He's also not keen on the many-universes interpretation because we seem to be producing many universes of which only one is observed by us. Uncertainty that Heisenberg introduced is caused by the apparatus. The reason why there is Planck's constant in this uncertainty is that the constant is not relevant. It seems it is because if you put Planck's constant equal to zero, you will get classical mechanics from the quantum formalism. Moreover, the quantum potential contains Planck's constant, therefore if Planck's constant changed its value, the quantum potential would change its value.

Carlos says

A bit old-fashioned about quantum interpretation, it knows how to treat deep question in a easy way to explain it

Ed says

I dig this stuff.

Katie Muffett says

I constantly see this book of the BBC radio series cited in magazines and other texts, so I've got to make time for it someday.