From :

The Monastery and the Microscope

Conversations with the Dalai Lama on Mind, Mindfulness, and the Nature of Reality

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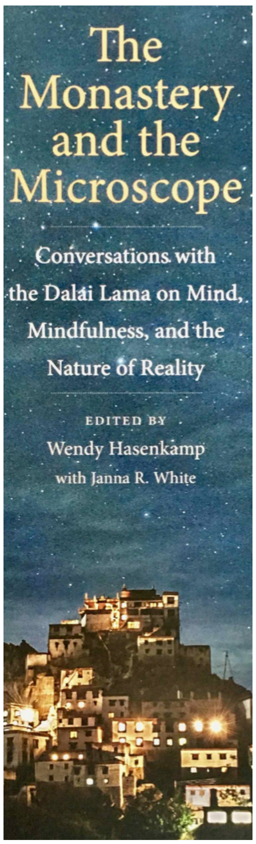

Chapter 2: Why the Moon Follows Me: Observation and Relationality in Quantum Phenomena (Michel Bitbol, PhD)

Michel addresses some of the paradoxes that arise in quantum physics, and their philosophical implications for our view of reality. He examines some of the foundations of scientific theory within physics, exploring what science can (and cannot) tell us about the world. After outlining some classic observations, he offers alternatives to traditional interpretations of quantum theories, including foregoing the desire to have a representation of the world at all, and explains what we might gain from such a view.

Michel Bitbol: Your Holiness, it's a joy and an honor to be here and speak to you about the philosophy of quantum mechanics. It's also a challenge, because I am aware you know a lot about it!

Dalai Lama: Usually I describe myself as a hopeless student of quantum physics. I seriously listened to the explanations of the late David Bohm on a few occasions, and later from several others. While I listened, it seemed that I understood something, but after it was finished, nothing was left. (*laughter*) So what John said about understanding or not understanding quantum physics was quite true.

John Durant: All of us have challenges here!

Michel Bitbol: I hope I will not make things worse…

Replacing Properties with Relations

Michel Bitbol: Our challenge will be to dig in to the philosophy of quantum mechanics in order to understand something very important about the difference between classical and quantum physics.

Classical physics supposes that bodies have an intrinsic existence and some intrinsic properties such as mass. But in quantum physics, this idea that bodies have intrinsic existence, and that properties are intrinsically ascribed to the bodies' particles, becomes a challenge. Even though certain physicists are still very eager to hold on to classical concepts, they encounter so many difficulties that sometimes they have to renounce these ideas. Here I will develop a critique of the idea of the intrinsic existence and properties of bodies.

To illustrate this idea, I want to take a very simple example to show how we can improve our understanding by renouncing the idea of intrinsic properties. The example comes from my own early life. When I was a child, six or eight years old, I was riding a bicycle on the road at night, and on my right I saw the moon and also a line of trees. As I rode, a strange phenomenon occurred—I saw that the moon was following me, and whenever I stopped I saw that the moon stopped with me. I was surprised. I thought, what's so special about me that the moon is following me? And what's so special about the moon that it knows what I'm doing? I was thinking about the intrinsic properties of the moon, and of me, to try to explain this strange phenomenon.

When I was a little bit older, around twelve years old, I began to understand that it was not about me or the moon individually, but about the *relation* between me, the moon, and the trees. The moon was very far away from me. Therefore, the angle under which I saw it changed very little when I was moving, giving the impression that it was always with me. By contrast, the trees were very close to me, so I had the impression that they were moving backwards. The whole explanation was clear to me as soon as I shifted my thinking from intrinsic properties to relations.

Let me give you another example, this one not about my childhood but about astronomy. Ptolemy, the Greco-Egyptian astronomer, said that the sun and all the other planets rotate around Earth. Now, in this framework, how can you understand the apparent motion of planets in the starry sky? You see here (figure 2.1, top) the motion of Mars in the sky over the course of a year, going forward toward the left, and then going backward toward the right, and then going forward again toward the left.

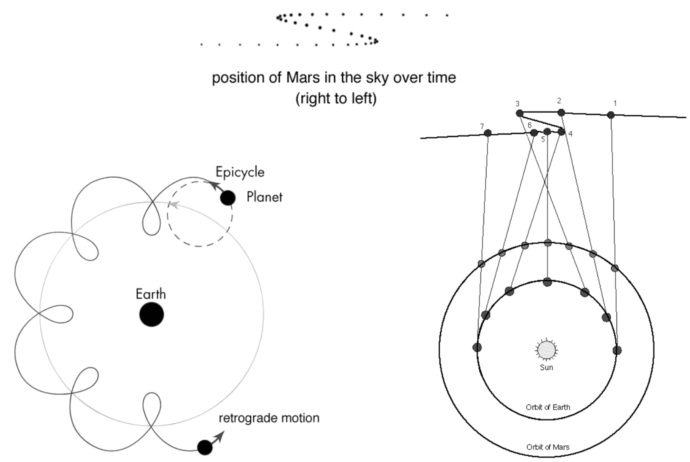

Figure 2.1: Relative vs. intrinsic properties. The top image shows an example of the retrograde motion of Mars, as seen from Earth, in 2005 (composite of 35 images taken approximately once a week). To explain this apparent "retrograde" motion, Ptolemy proposed a complicated orbit for Mars consisting of a set of epicycles (bottom left). This model (incorrectly) assumed that Earth was fixed and not moving, and the pattern of motion was an intrinsic property of Mars. Copernicus later proposed that both Earth and Mars were orbiting the sun, which took into account the relative perspective we have from Earth (bottom right).

Now to explain this strange phenomenon, Ptolemy ascribed to Mars an intrinsic motion that was made of two cycles. Mars, according to him, was first rotating around the earth by one cycle and then on that big cycle there was what he called an *epicycle*, namely, a little cycle that was rotating while Mars was rotating around Earth. Therefore, as you see in the picture (figure 2.1, bottom left), there were some loops that, when they were seen in the starry sky, gave the appearance of this strange motion forward and backward and forward again.

But when Ptolemy studied this problem a little bit further, he discovered that in order to account for the details of the apparent motion of Mars in the starry sky, he had to add not one epicycle but a series of epicycles that had no end. This was a problem, because quantifying the series was very artificial. No one knew whether or why it should have been 10 epicycles or 20 or 200. So this explanation didn't totally make sense.

Then came Copernicus in the 16th century. He said, let's suppose that *both* Earth and Mars rotate around the sun; and let's also suppose that Earth is rotating faster than Mars on its smaller orbit and that Mars is going slower on its larger orbit (figure 2.1, bottom right). That explains why Mars *looks like* it is going backward relative to us. It's not because intrinsically it is going backward, but because the *relation* between Earth and Mars is such that we are seeing it that way.

This was a very important move. Science made a momentous step forward as soon as it was understood that certain explanations have to be given in terms of relations rather than in terms of absolute properties.

Relationality and Schrödinger's Cat

Michel Bitbol: Quantum mechanics is best understood as a generalization of this idea. In classical mechanics, two properties are taken to be relative to the situation of the observer: velocity and position. Most other properties are absolute. In quantum mechanics, any property whatsoever is relative to an act of observation. Spatial components of the spin (or angular momentum), the intensity of an electromagnetic field, the qualities of strangeness and charm, energy, the number of particles, velocity, position—all these properties are relative to an act of observation. Even those properties that are provisionally treated as "absolute", such as mass and electric charge, can be understood as the outcome of a process of "superselection" exerted on relative properties. We then say that, in quantum mechanics, properties are replaced with "observables", namely, *relational characteristics*.

Coming back to the wonderful saying of Richard Feynman that John quoted: "Nobody understands quantum mechanics." Since it was Feynman saying that, and he was one of the best physicists in the world, it should in principle be taken seriously. But maybe he was wrong.

Maybe Bohr was right. Bohr said it's true that all these quantum concepts seem very awkward, but in order to transform them into something less strange, we have to change our very concept of understanding. Bohr's idea was that we have to change our idea of understanding the world into an idea of understanding our *relation* with the world.

This is exactly what Bohr meant when he said, "We are both onlookers and actors in the great drama of existence." We cannot subtract ourselves. We cannot describe the world as it is independent of us; we have to understand that we are actors and participants in the drama of the world. Werner Heisenberg also said that. He claimed that quantum theory provides us not with an image of nature, but with an image of our relations with nature. As soon as you have understood that, many things in quantum mechanics become clear that were unclear before.

Of course you can complain that this is a regression. You can say, classical physics promised me a full picture of the world, and now with quantum mechanics I only get a picture of my relation with the world and our collective relation with the world. I want more. I want to go back to the good old days of classical physics. Many physicists share this view. Even Einstein held this view, I must say. He wanted to find a better theory that fit with the classical ideal.

Yet if we accept Bohr and Heisenberg's point of view and fully exploit it, we can clear up many so-called paradoxes of quantum mechanics. This is what I want to do now: show you that if each quantum feature is understood in terms of a relation between us as observers, and the micro-environment, then many apparent paradoxes become much less paradoxical.

Our first example is Schrödinger's cat experiment (figure 2.2). In this experiment you have a box, and inside the box is a cat. Also in this box you have a radioactive atom that has a 50% probability of disintegrating in the next hour. With the strange formalism of quantum mechanics, we say that during that hour there arises a superposition: the atom is in a superposition between being disintegrated and not being disintegrated. Just as Arthur was explaining, both states seem to exist at the same time. The atom is represented as both disintegrated and non-disintegrated during that hour.

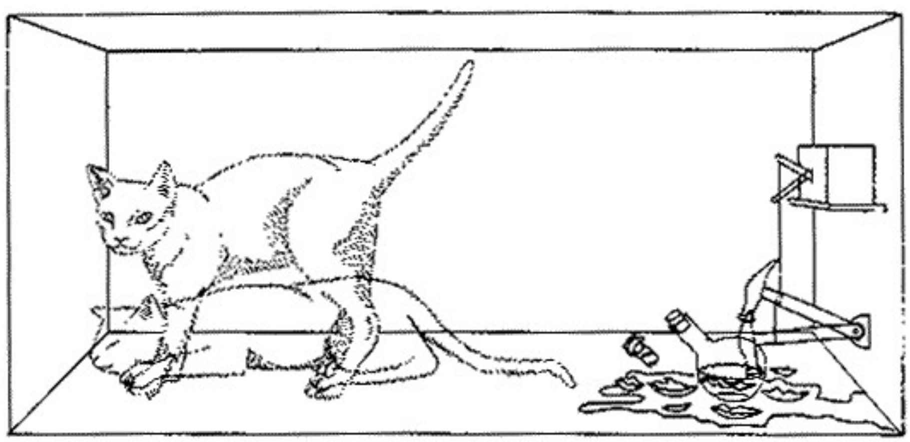

Figure 2.2: Schrödinger's cat: Is there a paradox?

If the radioactive atom disintegrates, there is a counter that detects the disintegration and suddenly clicks and sends a signal to a computer. The computer controls a hammer, and if the detector has clicked, the hammer falls on the bottle and cracks the bottle. The bottle contains poison, and if the bottle is cracked then the poison is released and the cat dies.

At this point a problem arises, the famous problem of Schrödinger's cat. I said that the radioactive material was in the superposition of being half disintegrated and half non-disintegrated. Taking into account this chain of events, the cat must be half dead and half alive, because if the radioactive material disintegrates the cat is dead, and if it doesn't disintegrate the cat remains alive. Thus, according to quantum mechanics, the cat should be in a superposition state—half dead and half alive!

But this is absurd, because when you open the box and look inside, you see either a dead cat or a living one. What you could accept for the radioactive material you could hardly accept for a cat. How could you acknowledge that the cat is half alive and half dead? This is Schrödinger's cat paradox.

John Durant: Maybe we should add that there is no cruelty involved here—this is a thought experiment. (*laughter*)

Michel Bitbol: Yes. Fortunately, it's a thought experiment. In his real life, Schrödinger had cats and loved them.

Now we have a terrible paradox—or do we? On the one hand, we predict that after Schrödinger's preparation, the system "atom + cat" is in a state of superposition—namely, the state of the cat is half alive and half dead. On the other hand, when one opens the box, one finds that the cat is either in the state "alive" or in the state "dead." So there seems to be a contradiction: either the cat's state is half alive *and* half dead, or it's either one *or* the other.

Is there really a contradiction? I claim that without the word "state," (taken as an intrinsic characterization of physical systems) the two sentences would have no contradiction. If you understood these sentences as an expression of the information we have about the state of the cat, or of the cognitive *relation* between us and the cat, then there would be no contradiction. In one case, the information we have about the cat is incomplete because we acquired it only before the experiment. In the other case, the information we have about the cat is complete because we have opened the box and we have seen what is in it after the experiment.

We must then accept that the so-called quantum state expresses nothing about the cat, but it expresses the state of information about the relation between us and the cat. There is no contradiction between the two former statements; it is rather that our relation with the cat has changed when we have opened the box and seen the result.

The only difficult point in this case is that, as Arthur said, this is not a matter of mere ignorance. There is no one watching with a bird's-eye view who could say in reality the cat was dead or in reality the cat was alive before we opened the box. There is no possibility for such an objective, final view outside of the stance of the observer-participant.

So what we have is relations between us and things, and no absolute properties waiting for us to be "discovered." As soon as you have understood that, you can also understand that the two seemingly contradictory sentences of the cat paradox actually express two different types of relationships: one of relative indeterminacy, and one of relative determination. There is no such thing as absolute indeterminacy or absolute determination.

Dalai Lama: Our sun is five billion years old, so at that time there was no observer.

Michel Bitbol: Yes, absolutely right. But, Your Holiness, who is saying that the sun is five billion years old? Science says that *now,* on the basis of the work of *present* observers.

Dalai Lama: In that case we have no criteria of distinguishing between what constitutes true knowledge versus mis-knowing.

Michel Bitbol: This is a very good objection. But what is truth?

Dalai Lama: In that case there's no need for education, no need to do this kind of research.

Michel Bitbol: Actually, to do this kind of research we need to be very educated observers; observers who are educated to look for mutual agreement on the basis of sound criteria. When I say there is a glass here on the table and Jinpa says yes, there is a glass, and Christof says yes, there is a glass, and so on, then we feel entitled to say there is definitely a glass. This is intersubjective agreement.

It doesn't mean, however, that the glass has some intrinsic existence; we just need to agree between educated observers about the *relation* between us and something, that it *looks like* a glass. If we all agree about this relation, then we have intersubjective truth, intersubjective knowledge. Physics is an amazingly efficient tool for producing effects that everybody can observe and that everybody can agree upon.

But for this, we don't need any absolute standpoint. We don't need what in Western philosophy we call the "God's-eye" point of view.

Dalai Lama: Your line of thinking seems to be very much in tune with the Buddhist approach to all of these questions. For example, the very definition of what constitutes existence is something that is cognized by knowledge.

However, we do need to understand that that doesn't mean that if a person is looking at a particular glass and then he turns his eyes away the glass no longer exists. So we also need to find a way of avoiding that kind of consequence.

Michel Bitbol: Yes, of course. Classical objects behave in such a continuous and predictable way that nothing prevents us from assuming that when we go out of the room, the glass is still there. But for micro-objects—electrons, photons, and so on—that's not the case.

Dalai Lama: That's right.

Michel Bitbol: Micro-objects do not behave in such a way that we can assume that nothing changes when we are not observing them. Something very different occurs when we do not observe—for example, the effects of superposition occur. When we do observe, superposition collapses. Not, to repeat, because we alter the properties of objects when we observe them, but because these so-called properties are in fact "observables", whose values co-arise with the act of observation.

The Appearance of Phenomena

Michel Bitbol: Now let me move on to wave-particle duality, which was discovered by Einstein. Arthur was discussing wave-particle duality when he mentioned that light acts like a wave and also like a particle. When Einstein made this discovery, he was extremely puzzled because it seems impossible and yet it's real! We have two very contradictory processes, yet they are co-existing: a wave, which is extended in space, and a particle, which is a point or a dot.

The concept of wave-particle duality can be demonstrated with a famous experiment known as the "double slit" experiment, outlined in figure 2.3. This experiment involves shooting electrons at a solid wall in which there are two openings (slits). Beyond the wall is a detector screen that will indicate the locations where the electrons make impact.

Before the experiment begins, one could make predictions about the pattern on the screen. On the one hand, if the electrons are solid particles, they will pass through one of the two openings and strike the detector screen one at a time, in two distinct regions (figure 2.3a). On the other hand, if electrons are waves, they will pass through both openings simultaneously. In this case, they will interfere with themselves, giving rise to what's known as an interference *or* diffraction *pattern.*

When the actual experiment is performed, however, the results are surprising, and paradoxical. With two openings, the electrons determine a pattern on the detector screen that is both *particle-like and wave-like (figure 2.3c). That is, they strike the target one at a time in specific locations, as particles would, but they also create an* *interference pattern, as waves would. This interference pattern can only occur if the electrons are passing through both openings at once.*

Thus, physicists conclude that—as strange as it may seem—electrons act as both waves and particles (figure 2.3d). This is referred to as wave-particle duality. *Michel in fact argues against this stance, suggesting instead that electrons are neither waves nor particles, but that wave-like and particle-like patterns arise from a relation between them and certain experimental devices.*

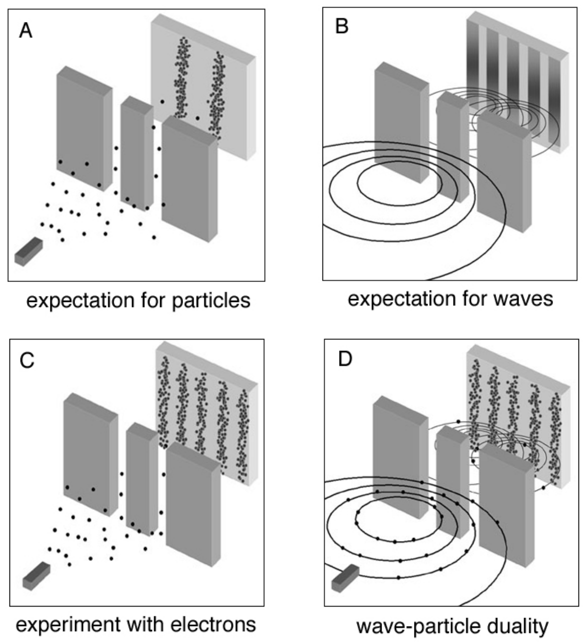

Figure 2.3: Examining the double-slit experiment. See text for description. (images from Backlight Power, Inc. http://www.blacklightpower.com/theory-2/theory/double-slit/)

So is it true that micro-objects are *intrinsically* waves and particles? Quantum mechanics is best understood if we assume that this is not the case. In fact, I would claim they are *neither* waves nor particles.

For instance, when we see an interference or diffraction pattern, we assume there is a wave, because usually waves make this type of pattern (e.g., fig 2.3b). A wave generates diffraction and interference, but is it true, conversely, that the presence of any pattern of diffraction and interference means that there is a wave? According to logic, that's false! If A entails B, that doesn't mean that B necessarily entails A. If waves entail diffraction and interference, that doesn't mean that diffraction and interference necessarily entail the (intrinsic) existence of waves.[1] Diffraction and interference would prove the existence of waves if there were no alternative explanation for the existence of diffraction and interference, but that's not the case. There are physicists who have found alternative explanations that show how you can get interference or diffraction patterns without waves.

The same holds for particles. We see tracks in bubble chambers, these boxes filled with an unstable liquid that boils and generates myriads of little bubbles when some object endowed with electric charge penetrates in it. Is this a proof that there are permanently localized little bodies called "particles" which have an intrinsic trajectory manifesting in a track? Not at all. For there are alternative explanations that show how you can get tracks without permanent little bodies having intrinsic trajectories.

That means that none of this is proof of there being either waves or particles. Thus we are left with no idea of what is out there in the micro-world. Are there particles or waves or neither? We don't know.

So then we have to go back and ask, well, what do we know? We know only one thing: there are *phenomena.* There are spots on screens, there are clicks in counters—*phenomena.*

Then, from this presence of phenomena, we can exert reason. Sixty years ago, two French physicists named Jean-Louis Destouches and Paulette Destouches-Février developed a theorem that said that when phenomena are understood *relative* to their measurement contexts, one predicts the wave-like distributions of these phenomena. In other words, if you accept that these phenomena can only be relational, namely, they result from the relation between the measurement apparatus and the micro-world, then you automatically yield the consequence that the phenomena are wave-like distributions, that they give rise to the *appearance* of waves. But it is *appearance only*; that's the point...

This is the same idea that was formulated by Bohr, that waves and particles do not intrinsically exist and that there are no intrinsic properties of micro-objects, only appearances relative to measurement apparatuses. Certain apparatuses will bring out predominantly wave-like effects and other apparatuses will bring out predominantly particle-like effects.

Dalai Lama: What would rule out the possibility that individual photons are particles, and yet they display a wave pattern as a result of aggregation from sending them through the equipment?

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[1] See also Michel's discussion of correlation and causation in chapter 7.

Michel Bitbol: "Aggregation" meaning many photons?

Dalai Lama: Yes, many photons together. Actually it's a continuation of that one photon, which is changing moment to moment. The position changes, so the very nature of the photon is actually changing. So couldn't one say that at a very discrete point in time it may behave like a particle, but if you take into account the continuum, it could behave like a wave? How would you rule that out?

Michel Bitbol: Yes, it's a possibility. But actually the interference effect can be observed even from one photon completely isolated from everything. So it's not a collective effect.

Dalai Lama: But what about this idea of a single photon in its temporal continuum?

Michel Bitbol: A single photon changing sometimes into a particle, sometimes into a wave?

Dalai Lama: It is moving. So in a particular slice of time, it may be a particle, but a wave means there is movement. The particle itself is changing; therefore, it is moving.

Michel Bitbol: There is one model that seems to fit your description somehow. It is called the guiding wave theory, and was formulated by de Broglie and by Bohm. Bohm supposes that there is a particle that is guided by a field that has a wave-like property, and with that he can explain a lot of things that are quite similar to quantum mechanics. So this is a model that fits some aspects of what you are saying and that works.

That's a very important point, because when you propose an idea, you have to test it against all the facts that are predicted by quantum theory. The only theory that roughly agrees with what you say that has been tested against quantum theory is Bohm's guiding wave theory. But it is limited to "classical" quantum mechanics, namely non-relativistic quantum mechanics. As soon as you go to more complicated effects such as quantum chromodynamics, it no longer works. Because of this, the guiding wave theory tends to be abandoned, or at least restricted to a non-exhaustive set of situations.

This is also why I think it is more coherent to assume, as I did, that there are no intrinsic properties or intrinsic nature at all to be found in the micro-world. That idea works with the whole spectrum of present-day knowledge, from ordinary quantum mechanics to quantum chromodynamics.

The Mode of Existence of a Rainbow

Michel Bitbol: Arthur has beautifully illustrated the idea that quantum particles are indistinguishable. This is a strange idea. How is it possible that two solid bodies can penetrate one another, more or less disappear into one another, and suddenly reappear again as if they had temporarily lost their identity? It sounds strange to ascribe such properties to solid bodies.

Maybe there are no solid bodies. Schrödinger had exactly this idea. He said that particles, in the old naïve sense, do not exist. Modern physicists such as Joos, a specialist in the theory of "decoherence," claim exactly the same thing. This is one way to explain this strange behavior of indistinguishability.

But maybe they do not exist only in the absolute sense. They must have some mode of existence, because we can see them. There are counters that can measure them. So they must exist in some sense.

Now what mode of existence do they have, if they do not have absolute existence? Two professors of mine, Jean Marc Lévy-Leblond and Bernard d'Espagnat, both came to the same conclusion independently. They said, "Particles have the mode of existence of a rainbow"—not of something solid, but of a rainbow.

What is the mode of existence of a rainbow? It's a relational mode of existence. In order to produce a rainbow you need three things: you need the sun, you need drops of water, and you need an observer. If there is no observer, there is no rainbow. There are photons everywhere, but there is not this wonderful arc of color if there is no observer or camera located somewhere. To get a rainbow, you definitely need the relation between three things. In the same way, particles only arise as relational phenomena, as byproducts of the relation between a field of potentialities and a detector.

The example of a rainbow is used commonly in Buddhist literature to demonstrate the concepts of interdependence and emptiness. For instance, the quote below from Visions of the Great Perfection, *a commentary from Tibetan master Dudjom Lingpa, explores how a rainbow seems to us to exist separately in the sky. In reality, a rainbow has no inherent existence; it emerges from—and is dependent on—causes and conditions, as Michel describes.*

> *"When a rainbow appears, even though it is not other than the vast expanse of empty sky, the rainbow and the sky appear separately, even though the rainbow does not exist apart from the sky. Such appearances are dependently related events*

> *emerging from the confluence of causes and conditions. Regarding the cause, the limpid, clear sky, having the potential to manifest any kind of appearance, serves as the cause. Regarding the contributing conditions, the confluence of the appearance of the sun, darkening clouds, and the moisture of rain serve as the contributing conditions. When these two are conjoined, the dependently related appearance of a rainbow emerges, even though it doesn't exist."*[2]

Discussion: The Phenomenon of Cold

Michel Bitbol: I can show you a wonderful experimental illustration of this concept of relational existence. It is called the case of Rindler particles. In this case, there is an opaque box from which you have pumped out all the air, all the particles, until it is empty. You put a counter in it and verify that it is empty of everything. It's empty of air, it's empty of photons, it's empty of everything. It's in the dark; there is nothing.

Dalai Lama: You can take out the photons completely?

Michel Bitbol: You can do that by cooling down everything. You remove energy, and when there is no energy there are no photons.

Dalai Lama: But even the cool temperature has some material property.

Michel Bitbol: Yes, but when you have a box without air that is completely opaque to light and is at -273°C, which is absolute zero…

Dalai Lama: But still, cold itself is a phenomena. There must be some substance.

Michel Bitbol: It is a phenomenon in a negative sense only.

Dalai Lama: But it is a phenomena, the coolness. It has certain attributes.

John Durant: Cold is not something in itself; it is simply the absence of heat. So at this temperature of -273°C, there is no heat. That's as cold as it can get. It doesn't mean there's some active thing there called coldness. There is just a complete absence of heat.

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[2] B. Alan Wallace, trans., *Düdjom Lingpa's Visions of the Great Perfection*, vol. 2 (Boston: Wisdom Publications, 2015).

Dalai Lama: So would you say that space is also the same kind of phenomenon, an absence of obstructive property?

Michel Bitbol: In some ways you could say that, yes. Let's suppose that indeed you have cooled everything down. There is nothing, no air, no photon, and the detector in the box confirms that. There is no click. This is a phenomenon—the absence of a click.

Dalai Lama: Let's forget about this experimental box. Even in the universe, in outer space, there are sites where there is extreme cold, so that's a real phenomenon.

Michel Bitbol: Absolutely true.

Dalai Lama: So if one can say that the coldness of space is a phenomenon, why can't we say that the coldness in that particular box is a phenomenon? What is the difference? Is there a categorical difference between the coldness that's out there and the one in the box?

Michel Bitbol: Let's accept that. There is cold in the universe; far away from the earth, far away from the sun, there is cold. How does it become a phenomenon? It becomes a phenomenon when, for instance, you can measure the velocity of a certain molecule. Even if there is only one molecule in a cubic meter, you can take this molecule, measure its velocity, and see that it is moving incredibly slowly. This means that there is cold. This is a phenomenon.

If there is no molecule, it's more difficult. You have another criterion, however. The other criterion is the absence of photons, or photons with such a long wavelength and so little energy that it is almost like no photon at all. So here it is a phenomenon also. There is very low energy, almost no light, a detector that detects nothing, and you say this means that it's very cold. So the absence of velocity of a molecule and the absence of energy of a photon means that it is a phenomenon of cold. But this is a phenomenon because the detector doesn't detect anything.

Dalai Lama: Nothing at all. No space, nothing. No source of heat.

Arthur Zajonc: No source of heat.

Dalai Lama: So there must be cold.

Arthur Zajonc: But it's cold as an experience. You're trying to get to the phenomenon of cold.

Dalai Lama: Before the Big Bang there was no energy, so the absence of heat was there. There was nothingness, no source of heat, so cold must have been there. Then, in such a state, how did the Big Bang take place? From nothingness, the Big Bang? Impossible. There was some source or material or particle that created tremendous energy. So there must have been something.

Arthur Zajonc: That's called the quantum vacuum, Your Holiness.

Dalai Lama: There is cold, but something is there.

Michel Bitbol: This is what I want to say, actually. Let's go on with the box.

John Durant: Come on, what's with this box? (*laughter*)

Michel Bitbol: The box is easier than the universe. It's smaller. I can control it. The universe is too big for me.

So, you have an empty box cooled down so that the detector detects nothing.

Dalai Lama: But the detector detects a very specific thing, not everything.

Michel Bitbol: You can add many detectors, detectors specific to molecules, to photons, to everything, and none of them detects anything. This actually exists, it's an experiment, it's possible.

Now, let's suppose that we accelerate the detectors. We push them and suddenly *clack*, *clack*, *clack*—they click a lot. Suddenly they have detected something in what was believed to be the vacuum! That means that inside the box was not a perfect vacuum, or that the vacuum is not a perfect state of nothingness. That means, in fact, that this apparent vacuum was a *potentiality* of detection, *relative* to a certain state of the detector. So it's not true that there is nothing at all.

Dalai Lama: Good. Earlier you talked about how there is no such thing as absolute existence, but now you're beginning to talk about relative existence. Now this is good, more balanced, more relative.

Michel Bitbol: As Arthur said, it's called the *quantum vacuum*. But here again, one should not think in terms of something absolutely existing. One should think of the possibility of relating the quantum vacuum with something else, because if not, nothing happens. You have to have some relation. You have to have some dependent arising,[3] so to speak. If not, it doesn't work. The quantum vacuum is waiting for something, it's waiting for activation to give rise to "particles," in the same way that the air, once the sun and the drops of water are there, is waiting for an observer or a camera to give rise to a rainbow.

Quantum Indeterminism: Disturbing an Electron in Flight

Michel Bitbol: I know that in the past, you have often expressed puzzlement about quantum indeterminism—the idea that events have no cause.

Dalai Lama: The idea that there is no cause at all is a tough one. Maybe it is only that there are no causes that we can observe by means of our ordinary cognitive capacity.

Michel Bitbol: Absolutely true. I concur with you, actually, to a large extent. I will show you that we can accept your idea from the point of view of the best science we know today. Let me first explain how this idea that events have no causes came to be in modern physics. It came from a kind of thought experiment.

You have an electron that is sent through an electron gun, and then you suppose this electron follows a certain path, and you want to know its position (figure 2.4). In order to know the position of the electron you have to send a photon to it. When the photon bumps into the electron, you catch the photon in a microscope. Then you know the position of the photon, and by inference the position of the electron.

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[3] Dependent arising is a foundational concept in many branches of Buddhism, particularly the Madhyamaka school of Tibetan Buddhism; it says that all phenomena arise in dependence on other phenomena, and thus are empty of inherent existence. This is not seen as a nihilistic view but rather a way to make sense of the fact of there being phenomena in the world. Understanding this point is also the first step onto the path toward enlightenment: "Whoever sees dependent arising / Also sees suffering / And its arising / And its cessation as well as the path" (*Mulamadhyamakakarika* XXIV:40).

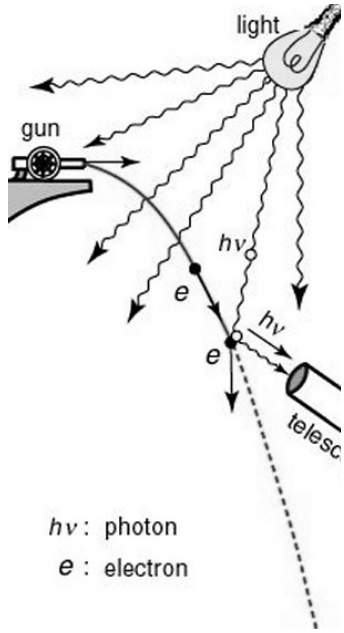

Figure 2.4: If an electron is fired through space, one supposes it will have a certain trajectory (red). However, in order to know this trajectory, you must interrupt the path of the electron with a photon (light), the position of which can then be measured.

Now when you do that, when you bump a photon into an electron, this disturbs the trajectory of the electron. Therefore, if you send out another photon later on, it will catch the electron somewhere completely unpredictable. The first photon has bumped into the electron and moved it somewhere. And the tricky problem is that this disturbance is uncontrollable. Nobody can know what disturbance was imposed. There is no way to reconstitute the trajectory, even by calculation, which we can do in classical mechanics.

This situation has two possible consequences.

One consequence is the absence of causality, or more precisely the inapplicability of the principle of causality. Werner Heisenberg came to the idea that causality was no longer applicable to quantum mechanics. Why? Because causality is the ability to deduce the position of a particle when you know the position of the same particle one instant before. The position of the particle one instant before is the cause of the position of the particle one instant after. But if you can't know the position of the particle one instant before because of this problem of disturbance, then you run into trouble.

Therefore, if we strictly follow Heisenberg's reasoning, it's not the case that there is no causality at all; rather, you can't apply the principle of causality due to a lack of knowledge of the initial state of the particle. This is what Heisenberg said—it's called the Heisenberg uncertainty principle. According to this principle, it's not true that you necessarily have to dismiss the idea that events have cause, but only the idea that you can apply the principle of causality in order to predict the effect.

The second consequence was stated by Bohr. When you're observing a photon with an electron, the photon is bumping into the electron. You are trying to imagine that the electron has an intrinsic trajectory, and that the photon has disturbed this trajectory. But Bohr pointed out we have no way to know that the electron has a trajectory in between the two observations. Maybe it has a trajectory, maybe it doesn't—the only things that we know are observable phenomena.

We catch photons in our microscope and say, this is where the electron was. What did it do in between the two observations? Nobody knows—and maybe it is just meaningless to ask the question! Maybe instead of saying that a photon has disturbed an electron, we should say that it's impossible to disentangle the object (an electron) from the act of observation (by means of a photon).

Therefore, Bohr claimed, the act of observation is an indivisible whole, a relationship that cannot be disassociated into two parts, the part of the intrinsic properties of the object and the part of the intrinsic properties of the measuring apparatus. Instead it is a single whole that is a *relation,* a dependent co-arising of a phenomenon from an interaction.

So, as you now see, there is a deep connection between the indeterminacy of quantum attributes and their relativity to experimental contexts. This is the crucial point to understand: *relativity is correlated with indeterminacy*.

Does this necessarily mean that there are no causes? No. It means that there are no absolute, intrinsic causes. As Grete Hermann, a German philosopher who was a friend of Werner Heisenberg, said, "In microphysics, causes are relative to the observation of this very event." So it's not true that there are no causes. There are no absolute causes, no intrinsically existing causes. But there are causes that are relative to the very act of observing the phenomenon, and therefore cannot be used to predict this phenomenon in advance, before the act of observation. Phenomena are not uncaused; they are caused by a whole set of factors that include the measurement apparatus that triggers them.

Dalai Lama: This is very much in tune with Buddhist Madhyamaka philosophy. As we search for an object of external reality we can observe a shared, intersubjective phenomenon, but if we try to look for the essence by virtue of which it exists, then you get into this problem. Existence at the ultimate level can only be understood in terms of these kinds of relations.

In Madhyamaka language we say that the existence of things can only be understood in relation to our conceptual imputation and designation. Beyond that, to speak of an independent existence has no meaning.

At the same time, as I mentioned, we also need to avoid the extreme consequence that if you are not looking then the thing does not exist, or if someone doesn't label it, then the thing does not exist.

Arthur Zajonc: Your Holiness, this is the point that we're anxious to make: that one of the dangers of physics is that people believe that there's a material universe that excludes all possible spiritual endeavor, that the work that you do here in Mundgod has no basis in reality or fact, and that physics or the sciences somehow make it impossible to have a philosophical position that would be consistent with spirituality.

But physics and the sciences, at least in Michel's belief and mine, are much more open. The realities that we're working with in the sciences are phenomena, and those phenomena are always in relationship to an observer, to someone who's cognizing or imputing certain conceptual designations. This is true even in the most detailed calculations and understandings of physics. And the way Michel and I understand them means that there's an openness, at least, to the pursuit of a spiritual philosophy. The danger that sometimes is perceived by those who do not know the intricacies of physics is that physics must lead to materialism, and materialism rejects spiritual traditions.

But the practice of science itself, and even physics, which is the most material science of all, does not lead to that conclusion. That's the reason that these very careful arguments are so important for Michel and myself and others. What one shows is that physics is a relational ontology, that what is real is real by virtue of a set of relationships, and that when one looks for absolutes they disappear.

That does not mean that there isn't a way in which, relatively speaking, we inhabit a world, we function in that world, we can do science in that world, we can have knowledge in that world, and so forth, but we have to be careful not to then project that which is true in that context into an absolute truth.

Dalai Lama: It's very true, the idea of this relational ontology. Your phrase "spiritual philosophy"—if you, for example, look at the Buddhist presentation of the four noble truths, the last two truths belong more to the spiritual domain.

But if you bring in the notion of the first two truths, the conventional truth and the ultimate truth, in the Buddhist presentation, then in some ways they're really secular. They are not spiritual in the sense of spiritual practice. They are really an investigation of reality. Buddhism is an understanding of reality. We apply our practice as a counter force to our distorted ignorance.

What Can Science Really Say about Reality?

Michel Bitbol: I'd now like to further discuss some of the philosophical consequences of what I've said so far. One of the consequences is quite strange and difficult to accept for some Western scientists. Typically when scientists have a physical theory, they want to develop a view of the world that goes with it. They aren't content with a theory that is efficient, that enables them to make predictions and to build technology. They want also to have a picture of the world, derived from their theory. Einstein was one of these daring scientists who dreamt of a grand view of the world based on a physical theory.

But the problem is that quantum physics has put some obstacles in the way. Presently there is no uncontroversial worldview that is compatible with quantum mechanics and that everybody accepts. Each of the proposed views of the world that fit with quantum mechanics contains paradoxes and difficulties. Thus my proposition is that maybe we have to accept that a physical theory provides us *no view of the world*.

Before I put forth this challenging proposition, I want to come back to basics: What is science actually? What is the purpose of science? One view is that science aims to give us a faithful picture of nature, that it works as a mirror of nature. This conception comes in two varieties. The first, which is called scientific realism, says that a scientific theory tends to be a faithful representation of reality as it is in itself. This is the ultimate dream of Western scientists: they want a picture of reality out there as it is in itself.

The second view is more modest. It says yes, scientific theory is a picture of the world, but not the hidden world. It is a picture of the manifest world, the world that is visible, the empirical world. Empiricists say that good scientific theory is just a faithful summary of observed phenomena, not more.

An opposite view is that science provides us with no picture of nature, but rather a projection of our minds. It's not that we are capturing nature in our nets; it's we who are superimposing our concepts and our views onto our image of nature. Kant is usually considered to be one of the proponents of this idea in Western philosophy, but he was certainly more nuanced than that.

Yet another possibility is what I would call here a middle way. A scientific theory, in this view, is neither a picture of nature nor just a superimposition of our own minds. Rather it is the byproduct of an interaction between us and nature. It's an expression of the interplay between us and nature (in a situation in which there is usually no way to disentangle this relation and access its two related terms separately).

Francisco Varela developed such a view under the name of *enaction*. This is the theme of his wonderful book *Embodied Mind*.[4] According to him, there is no way of building a foundation, of saying that we can ground our view of the world somewhere: we can ground it neither in nature nor in our mind. This he borrowed from Buddhist thought: the dependent arising of the knower and the known.

Science is interplay. Science can give us methods to behave adequately and efficiently in the world, to relate with the world in a very powerful way, but nothing more. In that case, scientific theory is only an instrument for us to reorient toward the world and to use what our relation with the world affords us in a mode that is helpful for us.

Physical Theories and Their Interpretation

Michel Bitbol: Now, another part of the basics: What is a physical theory? In other words, what is a scientific theory that bears on matter? In the history of Western thought there were at least four conceptions of what a physical theory is. The oldest one was the conception developed by Aristotle around 330 BCE. He said that a physical theory is a statement of the first causes of every phenomenon, meaning that you cannot go beyond them. It's quite unlike Buddhism, where you can always find another cause that causes the cause and so on and so on. According to Aristotle, there was a first cause, full stop, and physics should look for it. Physics is also meant, he said, to disclose the *essential* properties of things, the properties that are most intrinsic.

This conception was accepted throughout the Middle Ages, but eventually people started to see something unsatisfactory in it. For instance, when somebody wanted to explain the ability of opium to bring about sleep, he just said, "Opium has an essential property of being dormitive," as if the sleepiness it induced were somehow ready-made inside the substance.

Then, in the 1600s, people like the French philosopher René Descartes pointed out that this was completely artificial and that in order to get a clear understanding of nature you had to explain everything in terms of mechanical interaction, bodies

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[4] Francisco Varela, Evan Thompson, and Eleanor Rosch, *The Embodied Mind: Cognitive Science and Human Experience* (Cambridge: MIT Press, 1992).

moving and bumping into one another. The idea behind mechanicism is that you had to explain everything in terms of primary qualities—spatial qualities, extension, velocity. Even mysterious qualities like the ability of opium to bring sleep had to be explained in terms of the motion of particles in space.

Among many other things, Descartes wanted to explain *gravitation* by way of particles bumping into each other. He claimed that gravitation was due to the fact that there was a surrounding vortex of subtle matter whose pressure pushed bodies toward the ground.

Then came Isaac Newton. Newton went much further than Descartes in mathematically describing phenomena. His mathematical laws were amazingly efficient at predicting everything visible. You could predict all the motions of the planets for hundreds and even thousands of years, and your predictions would be perfectly exact. Yet Newton had no explanation of a mechanism of gravitation, only a mathematical law. There is a sort of regression in the ambition of physical theories here. Before (with Descartes) we had a tentative explanation of gravitation, and now with Newton we have no explanation. But we have a much better descriptive and predictive mathematical tool for astronomic and earthly phenomena.

More recently, in the 20th century, Bohr considered that a physical theory should not even be seen as a description of phenomena as they occur by themselves in nature. According to Bohr a physical theory (at least the *quantum* theory) is only a mathematical tool to predict the outcomes of experimental events in the laboratory, and to build technologies.

So, in the course of history, you see a progressive decrease in the scope of theories, but a progressive increase in their efficiency. This is very fascinating. The more efficient the theories are, the less they promise to make us understand the nooks and crannies of the world as it is!

Now I come to interpretation. It is often said that the interpretation of quantum mechanics is a problem, even though quantum mechanics works perfectly as a theory. What is the difference between a theory and its interpretation?

A physical theory is basically a mathematical framework used to describe or predict phenomena. It is made of mathematical laws that connect variables. What is a variable? It's the value of a (potential or actual) measurement. For instance, you can measure length, or you can measure velocity, and the value of the length or velocity you have measured is a variable.

As I said previously, a physical theory is made of mathematical laws that connect variables. Classical mechanics is of exactly this type. If you have measured that the position of this body is P_0 and the velocity is V_0 at the initial time T_0, then under certain circumstances you can calculate what the position and the velocity will be later on, at time T_x.

For example, imagine I throw a ball from the top of a tower. If I throw it at 2 meters per second of horizontal velocity, it falls quickly toward the earth because, due to gravity, it acquires a vertical velocity pointing downward. You can predict this fact with Newton's theory. If I throw the ball faster, with a higher horizontal velocity, it will go farther before it falls to the earth. But if I were to throw the ball fast enough, with a sufficient horizontal velocity (8 kilometers per second), it would go into orbit. Here again Newton's theory can predict that, and describe the trajectory of the ball around the earth. This is why the theory is so powerful and efficient.

Now, let's try to go beyond mere calculation. Is there a view of the world that fits this wonderful, descriptive mathematical tool that enables you to predict the value of velocity and position from another value of velocity and position?

In fact there are *several* views of the world that fit that theory, not only one. There is Newton's view, according to which the world is made up of mutually attracting material bodies with mass, velocity, and position. But there is also an alternative view that was formulated in the 19th century, that is completely different, and that says the world is not made of material bodies. It says the world is made only of *energy*, and sometimes there is a concentration of energy that gives rise to the *appearance* of a material body. This latter view was formulated by scientists such as Wilhelm Ostwald and Pierre Duhem in the 19th century.

These are two examples of conflicting views of the world that nevertheless both fit the mathematical skeleton of Newton's theory. Thus, there is a difference between a physical theory, which is just a set of mathematical laws, and its interpretation, which is a view of the world. There can be many views of the world that fit this one mathematical skeleton. As we have just seen, this was the case with classical physics. Each one of these views of the world fits perfectly well, but their *multiplicity* can be perceived as a problem. Why are there many rather than one? How can we decide which one of them corresponds to reality, since the best theory we have offers no criterion for this decision?

Quantum Theory and the Ψ Function

Michel Bitbol: Now, what is quantum theory? I claim that in fact quantum theory is simple and understandable. Maybe that means (according to Feynman) that I don't understand quantum mechanics, but no problem, I accept that! (*laughter*). Realizing that there is little to be understood in quantum mechanics can be part of understanding it…

Quantum theory is basically a mathematical scheme to predict measurement outcomes with certain probabilities. You have, for instance, in quantum theory a symbol that is very well known, the symbol Ψ (*psi*).

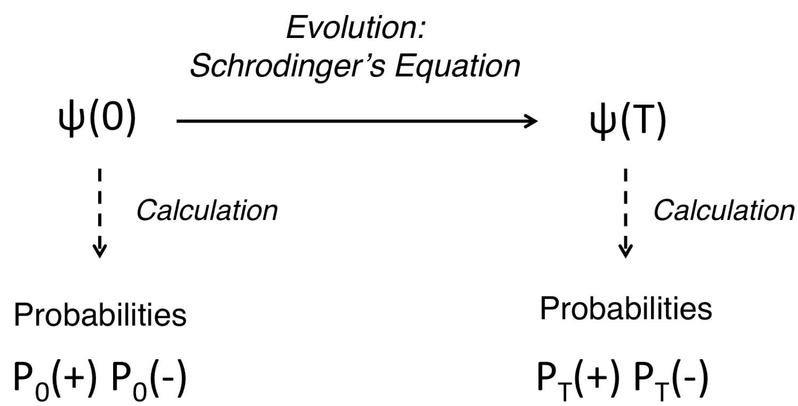

Figure 2.5: The psi function is used in quantum theory to calculate the probability of an event at time zero (0). Psi is a wave function, and the Schrödinger equation (not shown) determines how the wave function evolves over time. Using the Schrödinger equation, the probability of the event at a later time (T) can also be predicted.

This symbol Ψ is used for essentially one purpose: to calculate the probability of one event. Once you have the initial function Ψ, then this function Ψ enables you to calculate the probabilities of your measurements at time zero. But you also need an equation that gives you the same predictions not at time zero, but at a later time. This is called the Schrödinger equation (figure 2.5). The Schrödinger equation modifies the Ψ function and turns it into another function that enables you to calculate the probabilities of the measured phenomena at a later time (T). *That is all that is to be known of quantum mechanics.* Everything is in it. Only the mathematical details are missing.

Dalai Lama: Have you actually simplified it or made it more difficult? (*laughter*)

Michel Bitbol: I'm sorry…

Dalai Lama: It's OK.

Michel Bitbol: I made it as simple as I could, but of course it's quite difficult.

Thupten Jinpa: Essentially, quantum theory is simply this equation.

Michel Bitbol: Yes, exactly that. The Ψ function enables you to calculate probability, and the Schrödinger equation determines the evolution of the Ψ function, enabling you to calculate the probability not only at time zero, but also at a later time. That's it. There's nothing more to quantum theory (except for details).

Thupten Jinpa: So your claim is that quantum theory makes it possible to predict probability outcomes, not only at a specific time but also at a later time?

Michel Bitbol: That's the reason why it is predictive. It can enable us to predict the results of future measurements.

Thupten Jinpa: But only in probabilistic terms?

Michel Bitbol: Only probabilistic predictions, yes. This is what the mathematical skeleton of quantum mechanics does. Now you want a view of the world that fits with this skeleton and fleshes it out. You want to ask, what is this function Ψ? What is it, what does it represent? Is it a reality? Is it not a reality? Is it just a symbol that enables us to calculate probabilities? And probabilities of what? That's the question.

There are three types of standard answers, and three types of interpretations. One is that Ψ is all of reality. According to this interpretation, all of reality is made of a wave, which is described by Ψ. Schrodinger thought this way. He thought that there was nothing else other than the wave. Many modern-day scientists believe the same type of thing. This is called the view of the universal wave function.

Dalai Lama: In fact if you look at the cosmos from our vantage point, for example if you look at the Milky Way, there seems to be almost a wave pattern there.

Michel Bitbol: Yes, you are right, there are spiral density waves in galaxies. But this Ψ-wave of which we are speaking is not a visible wave; it is an inferred wave that enables us to calculate many things. Because it enables us to calculate so many things, Schrödinger believed it was in fact an adequate description of reality, and therefore that reality was wave-like, that it was made of a deep wave that was invisible but caused many effects.

The second interpretation is quite different. According to it the Ψ function is just a mathematical symbol, nothing more. It only allows us to calculate the probability of the presence of particles, and therefore only particles exist and Ψ is just a mathematical symbol. So either the wave is all of reality, or particles are all of reality and the wave is just a symbol.

However, as I alluded to earlier, there is also a third view, a mixed view, which was typical of De Broglie and Bohm. It says that in fact there are both things, both wave and particle, that the particle is in some way taken along or piloted by the wave, and that the wave is used by the particle to guide itself through the world.

So you have these three interpretations, these three views of the world. Either the world is made of a wave and particles are only appearances; or the world is made of particles and the wave is just a mathematical symbol; or there are two realities, both wave and particle. The problem is that each one of these three standard interpretations yields paradoxes of its own.

The Possibility of No-View

Michel Bitbol: But maybe there is a fourth possibility. This possibility is very challenging, but I offer it to you. It's that quantum theory says nothing of what the world is or is not. Instead it offers us a tool to orient ourselves, through probabilities, to the events and phenomena that we trigger and encounter in the world.

Of course this seems very counterintuitive. Quantum theory is an amazingly efficient theory. Many technological devices around us here are based on quantum mechanics, and they work so well! For instance, many components of our computers are based on quantum theory.[5] There are so many things that depend on quantum theory that are very powerful. So how is it possible that a theory that is not describing anything of the world as it is in itself is so powerful and efficient?

To answer this question I offer you a comparison. Let's consider insurance companies. Insurance companies must know how many accidents there will be during the year in order to ask people for the right amount of money to insure themselves against accidents.

How do they do that? Do they know what accidents you will have next year; do they know the detailed causes of

[5] See chapter 1 for more discussion on quantum computing.

accidents? Obviously they don't. But they have a powerful tool called statistics. This tool says nothing about the nature of the accidents, yet with it insurance companies are able to predict the number of accidents—approximately of course—that will occur during the next year.

It could be the case that quantum theory is this kind of theory, one that is very powerful on the statistical level and very weak on the descriptive or explanatory level.

Werner Heisenberg and Anton Zeilinger were very close to this position, and they even radicalized it. They considered that this so-called "weakness" of quantum mechanics is not contingent but necessary. According to Heisenberg, you cannot say by means of quantum mechanics what happens in the world independently of your intervention, of your experimentation, of your observation. You can only give the probability that something will happen in the laboratory when you observe it. Therefore, the verb "to happen," according to Heisenberg, is restricted to observation. In other words, without observation, it doesn't really mean anything to say that something "happened." Similarly, according to Anton Zeilinger, quantum mechanics is a theory of the limits of available experimental information. It's not a theory of what the information is about; it's just a theory of information itself.

I now wish to offer you a very daring interpretation: Maybe quantum theory has revealed to us that nature has no intrinsic features. Maybe that's the true revelation of quantum mechanics. Maybe quantum mechanics is not a revelation about the intrinsic nature of reality, but about the fact that reality has no intrinsic nature. This is a possibility.

But this no-view stance is a great challenge to Western physicists, who have tremendous difficulty accepting it. They rarely even consider this possibility. I could quote only a handful of physicists who agree wholeheartedly with it; most other physicists are very much against it. As Isabelle Stengers, a Belgian philosopher, pointed out, quantum theory is often accused of having "betrayed the ideal of science." The ideal of science was to reveal the nature of things, whereas here it looks like it is compelled to remain silent. Quantum mechanics cannot say anything except the probabilities of certain experimental events. René Thom, a French mathematician, was aggressively against this idea. He declared emphatically that quantum theory is "the scandal of our century."

Now my personal feeling is that we must ask the following question. Should we go on with the ideal of science, even though it brings so many paradoxes, or should we abandon the old ideal of science, provided this latter attitude gives us some clarity? Those are the two options. If the dream is suspended, we gain much intelligibility (at least a relational kind of intelligibility). But of course the dream was (and is still) so dear to so many scientists…

Actually, I think that the reason why quantum theory is so powerful is precisely because it's so "superficial," because it does not try to penetrate into the putative details of natural processes but rather sticks to probabilities of phenomena. It is then able to cover all sorts of events in all sorts of domains in physics and beyond. Some very recent work has shown that quantum theory can even be applied to human sciences such as linguistics and semantics.[6] The same theory applies to several fields that have no obvious similarity with one another. Why? What do microphysics and linguistics have in common? The common point is that in both cases, one tries to predict relational phenomena: either the value of a microphysical variable in some experimental context, or the meaning of a word in the context of a complete sentence.

We can draw a lesson from the deep connection between the universality and the superficiality of quantum mechanics. Perhaps it is not appropriate, not even in science, to go beyond what is manifest, beyond what is immediately given, beyond the freshness of the quality of presence. In science as in life, you should just appreciate "suchness,"[7] what is immediately given, and not try to go beyond it. You can describe what is given, but you should not try to imagine what is behind the presumed veil of appearances, not because it would be too difficult but because it would be in vain.

This proposal is entirely antithetical to the old dream of Western science, but it is quite familiar to Buddhism. Dǒgen, the famous Japanese Buddhist monk and philosopher, wrote, "This entire universe has nothing hidden behind phenomena." There is no veil, and thus there is no necessity to remove the veil to see behind it. We must only see the so-called veil, namely the display of phenomena, as it is presently.

What modern science does is exactly what Dǒgen described: In quantum physics, we unfold observable phenomena to their most exquisite details, and therefore we are able to describe and predict them in the most precise way. But we do not go further to ask what is the nature of reality beyond phenomena, because the very concept of "something beyond" is likely to be meaningless.

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[6] See, for example: Peter Bruza, Kirsty Kitto, Douglas Nelson, and Cathy McEvoy, "Is there something quantum-like about the human mental lexicon?," *Journal of Mathematical Psychology* 53 (2009): 362–377; Jerome Busemeyer and Peter Bruza, *Quantum Models of Cognition and Decision* (Cambridge: Cambridge University Press, 2012).

[7] Skt. *tathatā*; Tib. *de bzhin nyid*.

John Durant: Your Holiness, would you like to respond to this, whether you agree with Michel that there is some meaningful similarity here between his interpretation of quantum mechanics and the Buddhist philosophical tradition? This seems like a very big and bold claim.

Dalai Lama: An Indian nuclear physicist, Arvind Rajaraman, told me that quantum physics is a very new theory in the modern world, but that the essence of that concept can be found in Nāgārjuna's writings from 2,000 years ago.

There are four primary classical Buddhist schools of thought. Except for one of the branches of the Madhyamaka school, all the other Buddhist schools' views of the world, particularly of the physical and mental world, were driven by a quest for the ultimate, constitutive, elementary blocks that somehow have an intrinsic existence, an essence by virtue of which they exist.[8] But once you follow that line of inquiry, eventually you run into all sorts of problems.

According to Madhyamaka philosophy, if you don't investigate things, you can say that they exist in reality. If you begin to investigate what is the basis of that reality, you can't find it. Then there is nothingness.

The appearance of an object is due to many factors. If we investigate the object itself, we can't find it. The very nature of existence of something is due to other factors; it doesn't exist by itself. That's what it means, non-existence.

Michel Bitbol: Yes, exactly.

Dalai Lama: Then the question is, in what sense can we say they exist? What is the mode of their existence? That we can only understand in relational terms, or by mere designation.

Then another question could be raised: Does this mean that whatever the mind constructs exists? The answer is of course no. Not only should a convention be something that is affirmed by a consensus, but also the reference of that convention should not be something that can be contradicted by another valid convention.

The idea of research is very similar. One scientist determines something, then another and another, and when they all find similar results, only then is it accepted as true. This is Madhyamaka's second criterion, that a convention should not be violated or contradicted by another valid cognition.

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[8] See chapter 3 for more discussion of early Buddhist conceptions of the material constitution of the world.

Then there is a third criterion added to this, which is that something established as conventionally true (because it is apprehended by a valid cognition that apprehends the conventional) cannot be negated by another valid cognition that apprehends the ultimate nature of things.

Within the Buddhist world, while the other schools are seeking an ultimate mode of existence, from the Madhyamaka point of view there is no ultimate truth beyond the conventional reality. But that of course takes us deep into the Buddhist philosophical domain.

Of course in the details there are still lots of differences, but broadly I think Buddhist Madhyamaka philosophy and quantum physics can shake hands.

Arthur Zajonc: I think so.

Dalai Lama: Human intelligence is wonderful—such ability to think, to think, to think, to investigate. We can see in these talks and the great thoughts and ideas presented the fruits of human thinking.

But we must also remember that these are just human beings, nothing special. We should never lose sight of the fact that we are all human beings who have the same potential. Because sometimes that may seem like humility, but sometimes it could be just a cop out.

Arthur Zajonc: Your Holiness, you suggested that maybe in your retirement you would like to become a scientist, with Richie, perhaps, in his lab. But there's also the possibility of physics.

John Durant: We can start a bidding war.

Michel Bitbol: Your Holiness, you could also become a philosopher in my department!

Dalai Lama: Maybe I will accept this invitation on one condition. You spoke about how, as a function of special relativity, time can collapse and then particles can collapse and so on. Maybe you could decrease my age… (*laughter*)

Arthur Zajonc: I think Richie and I could both work on that. We'll come back next year.

John Durant: It is an interesting feature of science internationally, Your Holiness, that it is in principle open to everyone to do. Many people who become distinguished in science do not come from particular backgrounds; they do not have parents who were scientists for many generations. They got interested, perhaps, as children, as you indeed did, and just followed their dream.

I hope the people present here understand this, that there is an opportunity here for anyone who really wants to do this. Science is open.