Buddhism and Quantum Physics
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'The most beautiful thing we can experience is the mysterious. It is the source of all true art and all science. He to whom this emotion is a stranger, who can no longer pause to wonder and stand rapt in awe, is as good as dead; his eyes are closed.'

So, that's some words from Albert Einstein. I wanted to start with words from Einstein, who is I think a heroic figure; particularly because it is the hundredth anniversary this year of Einstein's discovery, or formulation, of Special Relativity, and of two other papers that he published in that year: one which proved conclusively for the first time that atoms really existed – that matter was made of atoms – and the third paper was on the nature of light, on what light was.

That was all in 1905. He was twenty-six at the time, and he had a day job as a patent officer. He had been rejected from university posts – he didn't have a doctorate – because he wasn't seen to be disciplined enough, or good enough. So he was working in this patent office and (presumably in the evenings) formulating these ideas, and he published these three papers which overturned the whole of physics. Relativity overturned our notions of space and time, and the papers on atoms and light, in a way, laid the foundation stones for quantum physics. [Einstein] is sometimes thought of as the grandfather of quantum physics; not so much the father, as the grandfather of quantum physics.

Interestingly, he hated it – quantum physics, that is. He was never reconciled to the grandchild that he had helped to spawn. He thought it was a bizarre, inelegant, fundamentally flawed theory that he spent the rest of his life trying to disprove... nsuccessfully.

Anyway, all that aside... his words speak to me, because they speak of the sense of wonder, and I think it is this sense of wonder that at least partly led me to want to study physics. Partly it was also that I knew it was a not very popular option and if I wanted to go to university I might get a place more easily! But it is also, in a way, part of what has led me to the Dharma – this sense of wonder, and a sense of wanting to get to the truth of things.

And at the time, as a young eighteen year old, I thought that physics *would* get to the truth of things. I was disappointed... in a way, fortunately.

Smritiratna prefaced this series [of talks] by talking about 'absorbing influences'. In a way, I feel a bit of a fraud to say that quantum physics is an absorbing influence. It's more like a tangential fad! – a fad that I have recently come back to over the last couple of years through doing these courses.

And I looked back at my physics notes in preparation for things, and found that I couldn't understand a word of what I had written – which is quite disconcerting when you find that it's your own handwriting, and you can't understand a word! So, most of what I am going to talk about is gleaned from popular layman's books on quantum physics that anybody can read.

So, that's me coming clean, as it were!

Mainly I am just going to talk about the physics. I'm not going to talk too much about the Dharma. I am going to leave you to make the Dharmic parallels yourself – partly because there isn't time, and partly because I don't think I need to spell things out too much and join the dots for you. So, you can make the Dharmic links yourself.

What I'm going to do is say a few words to set quantum physics into context. Then I'm going to actually have a look at it, and say, 'What does it have to say about the nature of Reality?' Then I've got some reflections of my own, or gleaned from various sources – and then I'll conclude.

Introducing quantum physics; the physics of the very small; atoms as mostly empty

So, what is quantum physics? (This is the 'contextual' bit).

Well, it's the physics of the very small. Physics, of course, concerns itself with matter – that is what it is primarily concerned with, the science of matter – and quantum physics is the physics of the very *small* bits of matter; the smallest bits of matter there are, that we can imagine. It is primarily about atoms, and the bits that make up atoms. And atoms make up everything else.

So I thought – well – *how* small? I would like to give you some illustrations of *how* small is the very small. So I'm going to use some analogies:

If you take a granule of sugar – brown sugar – the light stuff, not the thick muscovado or whatever, but the light demerara sugar... a grain is probably about a millimetre across, isn't it; a millimetre-ish. That little millimetre square, or cube, of sugar contains in the order of a *thousand billion billion* atoms. A thousand billion billion (and a billion is a thousand million – or at least that's how I'm using it).

So, a thousand billion billion. That's 1... if you wanted to write it out, it would be '1' followed by twenty-one zeros – yeah?... which is... which is a lot, isn't it?... [LAUGHTER] ...It's a lot. And that is in a grain of sugar, give or take probably a few... I don't know... billion? [LAUGHTER]

Another way that I came across of thinking about it was if you had a millimetre of 'stuff'

– I don’t know – sugar, or anything else... and you wanted to count how many atoms you would have to lay end to end to just form a millimetre line of atoms, it would be equivalent (roughly) to laying pieces of paper on the ground, from the ground up to the height of the Empire State Building. It would take as many sheets of paper to cover the height of the Empire State Building, as there are lines of atoms in a millimetre.

So... that’s huge, isn’t it. That’s huge. And another fact which might help (or might not!) – might help at least to bamboozle you – is that the little bits of atoms weigh roughly *a billionth of a billionth of a billionth* of a gram – yeah? So, one gram of ‘stuff’ would have to contain a *billion billion billion* of these things.

So I thought, well, what does a ‘billion billion billion’ look like? I mean it’s hard to know what a billion billion billion *is*... and I came across this thing which said if you took sugar cubes... (sugar seems to feature largely in my life!) ...if you took sugar cubes that are about a centimetre cubed, and you laid them out end to end, how far would a billion billion billion sugar cubes stretch?

And they would stretch to the distance of a *billion light years* – which is about a tenth of the distance to the furthest known thing in the universe. So it’s about a tenth of the distance of the observable universe – yeah? That’s how many a billion billion is!

So you could say that the quantum world is to a sugar cube as a sugar cube is to the entire observable universe. It is that much smaller, to a sugar cube. So perhaps it is not surprising that the physics of atoms is *weird* – very, very weird. I think it is extraordinary, in a way, that human endeavour has been audacious enough to want to even *try* and probe into that level of smallness.

But even more astounding is that within an atom mostly there’s nothing. One way of thinking about an atom is that most of the stuff in there – most of the matter – is condensed into a tiny, tiny, tiny bit at the centre, and that the rest of the ‘stuff’ is just whizzing around it, flying around it *in empty space.*

So, an ‘electron’ is a bit of an atom that is flying around this stuff at the centre – this nucleus. If you blew an atom up to the size of St. Peter’s Dome in Rome, which is the largest dome, I’m told, in the world, then the stuff at the centre – the nucleus – would be the size of a fly buzzing around that dome – yeah? The rest would be sort of empty space.

So what we think of as ‘solid stuff’ is largely empty – empty space. There is nothing there. We have this *illusion* of solidity.

The relevance of quantum physics

So then I would say it’s worth asking, ‘All this physics of the very, very small, does that have any relevance to our lives, to our ordinary experience, at all?’

And I just want to say why it does – in three ways.

Firstly quantum physics is the most *successful* scientific theory of matter that has ever been developed. It is successful in its explanatory power – in how much it seems to be able to explain of the material world – and also in its predictive power, so it can predict how things *should* work. And much of modern technology, for good or ill, we owe to quantum physics.

So, without quantum physics you wouldn't have a laser – you wouldn't have lasers at all. So you wouldn't have bar codes being read in the supermarket, without quantum physics. Without quantum physics you wouldn't have computer chips. You wouldn't have mobile phones. You wouldn't have, actually, most of the technology that we seem to rely on in the 21st century which depends on computers – none of that would be there without quantum physics. You wouldn't have nuclear power, of course, but nor would you have molecular biology. You wouldn't have genetic engineering. Much of modern molecular biology is based on quantum physics.

Quantum physics also explains how metals conduct electricity. For a long time before quantum physics, people knew that metals *did* conduct electricity but nobody quite had a theory of how or why. It has taken quantum physics to explain how electricity is conducted through metals. It has taken quantum physics to explain why the sun shines, and why it stays shining year in, year out, when it could have just... you know.. fizzled out.

So – yes – it's successful, and it has impacted our lives whether we know it or not. That is why it's relevant.

Secondly, it is relevant because it is dealing with the smallest stuff, and smallest implies *fundamental* – most fundamental. So it is dealing with the most fundamental reality of matter that there is. And that is important, I think, for its own sake.

And I think thirdly it is important because of what it says about Reality, and the world view that it implies about Reality. And that is what I really want to concentrate on in this talk.

Classical physics; the universe as a giant machine

But I need to set a bit more context. I need to say a little bit about what happened *before* quantum physics.

Quantum physics started around 1900, and all the physics that went before it is called classical physics. Pre-quantum physics is all classical physics. And classical physics also had theories of matter. Sir Isaac Newton had developed his laws of motion and matter, etc., and they worked – by and large, they worked.

In fact they worked so well that physicists thought that they had come to the *end* of physics. They thought that they'd done it all.

I can't remember his name, but I think it was a man called Michaelson who famously said that all there was left to do in physics was to fill in the sixth decimal place – to find a little bit more accuracy – and I think he said it in 1890-something... so he lived to regret it! [LAUGHTER] – he lived to be very embarrassed by his statement.

But, yes, [classical physics] was successful. So there were theories about matter, and there were also theories about light – Maxwell had invented theories about light – and again, it seemed to work very well.

So matter was 'stuff'. People thought of it as 'stuff'. They didn't realise that it was actually largely vacuous. They thought of it as solid 'stuff' and they thought that atoms were probably rather like solid billiard balls, or ball-bearings – but small ones. And light was thought of as a 'wave' – so, there was either material 'stuff' or there were 'waves'.

So light was a sort of wave. So I was thinking of this last night: I was thinking, 'well – let's have a bit of audience participation,' and I was thinking, 'Jnanavaca, you *hate* audience participation in talks and things!' ...and then I thought, 'well, *I* don't have to do it!'

So... hands up who doesn't know what a 'Mexican wave' is? ... Several of you – my goodness – that's a huge number of you!

Ok... so, a Mexican wave is... I'll sort of have to demonstrate without falling off the platform... what will happen is that each person on my right, from Paramabandhu, in each row, will do something like this [RAISES HANDS] – 'Woooah!' ...You don't have to make the sound... [LAUGHTER] ...you just have to raise your hands – yeah? And Smritiratna, who's sitting next to Paramabandhu – as soon as Paramabandhu's hands start to come down, Smritiratna's will go up – yeah? And so on along the row until we've done the whole row. So we should have a 'wave' passing through from the right hand side of the room to the left hand side of the room, of *this* – [RAISES HANDS] – yeah? So you just have to get into the... sit down but try not to hit the person in front of you... [LAUGHTER] ... because that's not very good.

So I'll give us a sort of count... One, Two, Three... Go...

[AUDIENCE DOES A MEXICAN WAVE!]

...Great. That's it! So we're going to do it again... When we reach my left, the last person on my left, I want it to come *back*... [AUDIENCE GROANS]... and then back *again*... [LOUDER GROANS]... so we're going to do *three* waves back and forth – ok? So one two three go!

[AUDIENCE DOES THREE MEXICAN WAVES!]

...Ok, very good. Round of applause! [APPLAUSE/LAUGHTER/GROANS]

...So – that looked lovely! It's a shame you couldn't see it... [LAUGHTER] ...I'm not really sure that it helps explain waves... but if I'd said that at the start you wouldn't have done it!

...I guess what you have just demonstrated with your hands, in a way, is what happens to ripples in water. So the actual bits of water – the particles of water – are just going up and down, but a ripple spreads across the surface of the water just as *something* – a continuity of energy – spread across the room and then back again. Do you see what I mean? That is what a wave is. It's a ripple, just like a ripple of water – and this was a ripple of people waving their hands.

So, just bear that in mind. I'll come back to it!

Back to classical physics... It was very, very successful. One of the things about classical physics was that the world view that it implied was that the universe was like a giant machine – a clockwork machine – that, once you set it going (and perhaps it was the great hand of God, certainly according to Newton, that set it going), it just sort of *ran* – yeah? It just ran. The planets orbited the Sun; apples fell to the Earth, etc. Everything just happened according to clockwork. There was no room for free will. There was no room for choice. Everything was pre-determined once it was set going. This doesn't seem to have bothered physicists very much, because it worked.

And what's more, our bodies were seen to be like complex machines (and to some degree, perhaps, they are). That was the kind of world view: we are complex machines. Our brains were seen as complex machines. And in fact some scientists still believe that – that actually we have just got some sort of equivalent of a super-computer in our heads and that is what keeps us going. So it was a mechanistic model of the universe; a mechanistic model of 'everything'.

This world view is I think still largely prevalent. If you think about scientific materialism, it is the view that everything can be reduced to matter, that all things in this phenomenal world can ultimately be reduced to bits of matter – atoms – yeah? Maybe people don't consciously hold that view, but I think the implications of that view are still current. It is a nihilistic world view. It is the world view that says, 'Well, you might as well just have as much pleasure in this life as you can. You might as well just go shopping, because matter is all there is, and we're all lumps of matter moving around.' There is no place for ethics, there is no place for values, in this world view.

And it is sometimes said that part of the environmental crisis that Kamalashila was talking about a couple of days ago – part of our environmental crisis that is facing us... in a way our cultural crisis – arises, partly at least, from such a world view, of scientific materialism.

A physicist called Ilya Prigogine said (I don't know when he said it) that:

'We are suffering the consequences of the separation of science and philosophy which followed upon the triumph of Western physics in the eighteenth century.'

And I think that still applies.

Interestingly, Einstein (just to come back to him) was a deeply spiritual man, and he said that *'science without religion is lame.'* But then, he also said that *'religion without science is blind.'*

Young's 'double slit' experiment; the 'delayed choice' Wheeler experiment

...Ok, so that has set something of the context of the pre-quantum physics world: classical physics.

So now I want to come onto the quantum world – quantum physics – and I am going to try and do that by talking about one experiment that physicists can do in the lab. It is an experiment that a man called Richard Feynman has described as the only mystery in quantum physics. In a way it is at the heart of all the paradoxes that quantum physics brings up; so if you can grasp this experiment – and it is very, very simple – if you can grasp it, you've understood quantum physics; you've understood what all the fuss is about.

So we're going to have a go at grasping the profoundest mystery of quantum physics... on four flipchart papers that I drew up earlier. ...[LAUGHTER]

There's a number of steps to go through. First of all I want you to imagine that you've got a pile of rocks that you are throwing at a wall in front of you. The rocks are all perhaps the size of your hand, roughly the same size. The wall in front of you has a hole in it that is just a bit bigger than the size of the rocks – yeah? And you are just throwing the rocks at the wall; in the general direction of the wall.

What will happen, I hope you can see, is that most of the rocks will hit the wall and just fall to the ground, and some of the rocks will pass through the hole in the wall and land the other side of the wall. And if you keep doing this long enough you will end up with a pile of rocks the other side of the wall. They have all sort of landed roughly in the same place. If you were throwing them at the same speed, with the same amount of power, they would probably land in roughly the same place and form a heap the other side of the wall.

So far, so straightforward? [AUDIENCE MEMBER: 'There's only one hole in the wall?'] ... Yeah, there's just one hole in the wall... ...I'll ask for questions later... [LAUGHTER] ... actually, I *won't*.... [LAUGHTER] ... But Vimalabandhu is right! – actually, now imagine it with *two* holes in the wall, side by side: there's a hole here, a hole there – yeah?

So again you throw this bunch of rocks at the wall. And I hope you can see that what you'll end up with is most of the rocks, again, hitting the wall; some of them passing through this hole; some of them passing through that hole; and you'll end up with *two* piles of rocks the other side of the wall – yeah? Straightforward.

Ok... But *waves*. Remember our waves. Waves don't behave like rocks, because they're not made of 'stuff'. If you imagine waves on water – ripples on water – and you can imagine them passing through some sort of barrier with two holes in, they wouldn't behave like the rocks.

So I've got a little diagram to say how they *would* behave... [DISPLAYS DIAGRAM]... So... this is nothing to do with quantum physics *just* yet... [POINTS TO DIAGRAM WITH BREADSTICK]... and I've got my breadstick, which isn't either... [HYSTERICAL LAUGHTER] ...I hope you can see this at the back!

What you've got here is something that is causing some ripples in some water, and I've drawn these ripples as curved lines. Actually they would be concentric circles spreading out in all directions, but I've just drawn part of the ripple. So there are some ripples, and then I've got a barrier here – a screen, or a barrier – and the barrier has got two holes in it: one there, called 'A', and that one is hole 'B'.

What happens when the ripples hit the barrier is that they pass through these holes – they pass through hole 'A' and they pass through hole 'B' – and it is almost as though hole 'A' is a new source of new ripples. You get a whole series of ripples that seem to come from hole 'A' and a whole series of ripples that seem to come from hole 'B'.

And ripples pass through each other as, in a way, waves... hopefully you can see how waves pass through each other. And as they pass through each other they overlap, don't they? So you get this overlapping pattern of ripples. And you can see this in water – you can see it in your bath, can't you?... [LAUGHTER] ...So you get this overlapping pattern of ripples.

Thomas Young, in the nineteenth century, did this experiment with light – not using water, but light. And he showed that you got overlapping patterns of light waves, and that is how he proved, or showed, that light behaves as a wave. So this experiment is named after him: it is called 'Young's double slit experiment'. There are two slits, and Thomas Young was the man who did it: so, 'Young's double slit experiment'.

When you do it with light, if you shine the light onto a projection screen, what happens is that this pattern of overlapping waves gives you a particular pattern on the projection screen. It gives you a pattern which is bands of light interspersed with bands of darkness. So you get a band of light, a band of darkness, or a strip of light; strip of darkness; strip of light; strip of darkness.

And I've tried to illustrate that here in the way that it is normally done in physics textbooks, by showing this curvy line... and the broader that curve, the brighter that strip of light. So, this is a band of light, this is a band of darkness; band of light; band of darkness; band of light; band of darkness. And the light gets fainter as each band goes out from the centre. Ok? So that is how waves would behave, if they went through two slits.

So far, so straightforward (hopefully).

Now, instead of rocks through a wall, we are going to throw electrons – yeah? – these tiny little things that are almost unimaginably small. We are going to throw *them* through the wall.

So first of all we've just got one hole, and we've got something that fires electrons just like you were throwing rocks (and I won't go into that) – and you've got a hole in this barrier – hole 'A' – and this thing is going to fire electrons.

What happens is that most of them hit the barrier just like the rocks did. Some of them go through... and I've shown one of them going through... [POINTS TO DIAGRAM] ... and it has just gone '...ch-ch-ch-ch-ch...' all the way until it lands on the screen where you can detect it – like a television screen. And what you get is a pile of electrons around that area – that's fair enough isn't it? – like the pile of rocks.

So far, so easy? Ok. So, now we're going to do.... sorry?... [INAUDIBLE QUESTION...] ... They don't bounce off. They bounce off that screen, if you like, or... but it's the ones that *pass through* that we're interested in. And you get a pile of them.

So, that's the electrons through *one* slit. Now we're going to introduce *another* hole – so it will be like the 'two hole' thing. And what you would expect, now that I've got hole 'A' and hole 'B', is you would expect some of the electrons to go through the top hole, some of them to go through the bottom hole, and to end up with *two* piles – yeah? – just like the two piles of rocks.

But you don't get that. That's what you would expect... but you don't get that. So I've marked that with a question mark – because that's wrong.

And now we are coming to the mystery of quantum physics. This is the heart of the mystery of quantum physics – or we're getting there.

What you get, instead, is *lots* of piles of electrons – lots of them, but in *strips*, just like the light waves were in strips.

So you get a sort of strip of electrons there, then nothing... a strip of electrons there, then nothing... then another strip, and then nothing... so it's almost like: imagine you've thrown these rocks through this wall and somehow they've arranged themselves on the other side in lots of different piles. Real, tidy little piles, with nothing in between.

And what's more, the biggest pile – that one – is *directly behind an obstructed bit*. So it is almost like the rocks have gone through the hole and gone *round*, and landed in a place where they couldn't land – yeah? – landed in a place where they *shouldn't* land.

So this seems to imply that in this experiment at least, the electrons have gone through these two slits just like water waves, or light waves. They have gone through and behaved like waves. But to do that, each electron needs to have gone through *both slits*... which for a bit of matter is a bit surprising... yeah? ...[LAUGHTER] ...A bit of matter shouldn't do that. I mean – also – how does it *know*? If it was about to go through the top hole, how does it know that now this wall has got *two* holes, and it mustn't just go through the top hole, it must somehow go through *both*? It seems to know that, and behave differently.

So what's happening?

But it's even stranger than that...

What people said was, 'Ok, what we'll do is we'll set up clever little detectors that will tell us: Did it go through the top hole? Did it go through the bottom hole? Did it go through both?' ...You can do that. You can put little particle detectors in the way that will detect which hole it went through.

And what happens is that as soon as you try and detect which hole it goes through, they stop behaving like waves, and you *do* get two tidy piles of electrons. ...[LAUGHTER] ...As soon as you try and *notice*, they behave themselves as proper 'stuff', and either they go through this one or they go through that one, but they won't go through both, and they'll just create two nice tidy little piles... as soon as you look. If you *don't* look, then they seem to want to go through both holes, and happily do that.

Some clever man called Wheeler thought, 'We'll wait! We'll wait until the electrons have gone through this little barrier *before* deciding whether to measure them or not! So we're not going to tell them.' ... [LAUGHTER] ... 'We're not going to tell them in advance whether we'll measure which hole they went through; we'll wait.'

So this takes an *enormously* sophisticated bit of apparatus, and it's called the 'Delayed Choice Wheeler Experiment', because you are going to delay making that choice until you *know* that these electrons are well and truly through these holes.

Ok: so you wait. And then, if you decide to suddenly, quickly put a detector in the way and ask, 'Which hole did you go through?' – well – you find that they behave as particles and you get two heaps. And it either goes through one, or the other.

If you decide *not* to ask, then you get this... [PUTS UP DIAGRAM OF ELECTRONS BEHAVING LIKE WAVES, IN STRIPS]. ...And that is *after* they've passed through the holes. It's almost like either they know in advance. But that seems a bit daft, because the experimenter – *you* – didn't know in advance...yeah? Either they know in advance, or they sort of... I don't know... go back in time? – and decide whether they should behave as a wave or as a particle depending on what you've now put in their way.

So, that's what electrons do. And of course it's not just electrons, it's *all* these little bits of particle. And actually light, as well, does this.

So what you've got there is a very mysterious situation.

And quantum physics explains it mathematically. Mathematically, it all holds water (as it were) – the equations predict this. But nobody knows what the equations mean! ...[LAUGHTER] ...So you are left with this theory that works – mathematically it is foolproof – but nobody knows what it means. So it completely defies common sense. But then, Einstein said that *'common sense is nothing more than a deposit of prejudices laid down in the mind before you reach the age of eighteen.'*

The Copenhagen Interpretation; looking at a rainbow; Einstein & Schroedinger's discomfort with quantum physics; the Schroedinger experiment

Ok. What I want to now do is just talk a little bit about how physicists have tried to make sense of this, and what that means for the nature of Reality.

There is no one standard interpretation that everybody buys into, but there is one that is pretty standard that *most* people buy into. At least when I was studying physics this was the norm; this was what undergraduates were taught. I am told that in the last ten years it has sort of lost a bit of favour, but it is still pretty much the one that everybody believes.

It is called the Copenhagen Interpretation, and its main exponent was a man called Niels Bohr. Bohr seems to have been one of the few physicists, along with Einstein, who was capable of thinking outside of the box of mathematical equations, and asking philosophical questions about what this meant about the nature of matter.

What Bohr said was that there is no underlying real electron passing through the holes at all. There never was any electron really passing through the holes at all. There is no underlying real objective thing out there called an electron. Instead, what there is is *potential* electrons; *probable* electrons; *likely* electrons. And the whole world of electrons just exists as this ghostly world of potentialities, probabilities and likelihoods. And what happens is that when you look for an electron – when you actually try and measure it, and look – well, one of those likelihoods, potentialities and probabilities becomes *actual*. So, the electron manifests *because you look at it*. Before you looked at it, you couldn't say it was there. It was only *probably* there; it was only *potentially* there.

So what he said was happening is that when you *don't* look, the electron has got a probability of going through the top hole and a probability of going through the bottom hole, and both of those probabilities are equally probable, and they both interfere with each other. And it is those probabilities that cause the 'wave' pattern.

When it hits the screen, suddenly you've *measured* it, and the electron becomes real – the particle actually becomes real. Here, in this experiment where we tried to look – well – as soon as we looked, it became real.

So he is saying that Reality only manifests when you look at it. Material objects – material reality – only manifests when you look at it. When you're not looking, it is not really there. It is there in potential – it has got a likelihood of being there – but it's got a likelihood not to be there as well -it has got a likelihood to be somewhere else... or not at all... yeah?

So then you have to ask, 'Well – why? What is it about *looking* that creates reality?' And a standard answer is that it is consciousness; that something to do with *observing* creates reality, and observing is something to do with consciousness. Or at least that is one standard answer. Most physicists don't bother probing that far; they'll just get on with turning the handles of the equations, and it works – the maths works.

But certainly this interpretation, which has been held as the standard interpretation for well nigh one hundred years – it's eighty years, probably – says that there is no objective reality out there. That is what the standard interpretation of physics is. So you extrapolate from this experiment, and you say there's no objective reality out there.

An analogy that I came across, which I thought was useful although not completely accurate, is looking at a rainbow. When you see a rainbow, actually what you're seeing is something that's created by the mind. There is no actual rainbow out there. It is light refracted through water droplets in the air, and it causes this sort of sense of illusion of a rainbow. And when you look at a rainbow and when I look at a rainbow, even if we are looking at the so-called same rainbow, actually it is not the same – we're seeing different refracted images, and it's our mind that creates this illusion of a shape – do you see what I mean?

Einstein hated this idea. Einstein hated the fact that quantum physics said that there was no objective reality. He couldn't reconcile himself to that. The other thing he hated was this notion that all that there is is potentials and probabilities – there is a 50% chance that the electron is here, a 50% chance that it's there, etc. He famously said, *'God does not play dice with the Universe!'* And Bohr famously retorted, *'Stop telling God what to do!'*

Another physicist – a famous genius really – Schroedinger, who you may have heard of, was responsible for one of the mathematical formulations of all of this, that worked. He was appalled by this notion as well, that there was no objective reality out there, that there were just potentials – and he tried to dream up an experiment which showed how absurd such an argument was.

Actually, I just wanted to mention that Schroedinger was a genius *and* a womaniser... a famous womaniser. It is said that while Heisenberg (another genius) used to gain his inspiration through walking in the mountains, and Paul Dirac used to gain his inspiration through a very quiet monastic setting at Cambridge University, Schroedinger got his inspiration from – well – less refined means! ...I always find that sort of optimistic, in a way! ...[LAUGHTER]

So Schroedinger dreamt up this experiment of putting a cat in a box. (It's a thought experiment – nobody has actually done this experiment!).

You put a cat in a box; you seal the box, so there is *no looking*; and inside the box you set up a little experiment with electrons, a bit like this [INDICATES DIAGRAM]. And you cleverly set it up so that if the electron goes through the top hole, it bumps into some clever, macabre device that releases poison gas – cyanide – and kills the cat. If it goes through the bottom hole it bumps into a more benign device that releases some cat food. Ok? So it has got a 50% chance of going through the top hole and a 50% chance of going through the bottom hole. And the Copenhagen Interpretation says that until you *look*, both of those probabilities sort of exist. Neither one is actual, but both are equivalently there.

And so therefore according to the Copenhagen Interpretation the cat has to exist in a sort of both alive-and-dead state at once, and until you look, it's not allowed to either live or die. It exists in this super-position, in this 'Doctor Who' state of being both alive and dead at once. And [Schroedinger] said:

'How absurd to imagine in this dark box a cat that is both alive and dead at the same time!'

Until you look – you open the box – and of course, you find it is either completely dead *or* completely alive.

So [Schroedinger] invented this thought experiment as a way of showing that the Copenhagen Interpretation was nonsense; was completely flawed. But around eighty years have passed, and nobody has been able to come to the bottom of Schroedinger's Cat paradox. It has entered into the text-books as a real paradox, as something of a mystery. It has not been enough to show that the Copenhagen Interpretation doesn't work. The Copenhagen Interpretation stands – still – as the most popular accepted interpretation.

So that is Schroedinger's Cat. I will come back to some other interpretations very very briefly – but not yet.

Interconnectedness and empty space

I just want to look a little bit more at this Copenhagen Interpretation. It says that not only does reality not exist until you look at it, but somehow consciousness seems to be involved in *making* reality – somehow the subject has to be there for the object to manifest – that you can't have one without the other.

Not only is it saying that, it is also saying that you can't actually chop Reality up into bits at all; that the whole notion of separate bits of Reality – like an electron, like an observer, like a slit – is fundamentally flawed. The electron is *not* an isolated entity. The whole set-up, including our observation, has to be treated as a whole.

Heisenberg said:

'The world thus appears as a complicated tissue of events in which connections of different kinds alternate, or overlap, or combine, and thereby determine the texture of the whole.'

So there is this sense of the whole of Reality being a web of flowing conditions determining the texture of the whole, and that it doesn't make sense to analyse anything out as separate from anything else.

There is further evidence for this interconnectedness. There are other experiments that can be done which show that when you've got two particles that were created from the same cause, even if you separate them in space as far away from each other as you like – they could be at different sides of the room, or different sides of the universe – they behave as one particle. When you touch one, the other one moves. It knows that you have touched its 'brother' or 'sister' particle. It sort of knows, and it moves – it is affected.

Well, that's just with *two* particles. But then if you think back to what physics says about the birth of the universe – *all* particles coming from a sort of Big Bang at the birth of the universe – well, the implication is that every particle in the universe is connected to every other particle in the universe. And suddenly this beautiful image of 'Indra's Net' seems to be more than just a poetic image.

So the notion of 'separateness' becomes an illusion.

David Bohm, another physicist and philosopher, has this to say:

'One is led to a new notion of unbroken wholeness which denies the classical idea of analysability of the world into separately and independently existing parts. The inseparable quantum interconnectedness of the whole universe is the fundamental reality, and the relatively independently behaving parts are merely the particular and contingent forms within the whole.'

So he is saying that every time we break Reality up into parts, that is not the truth. We have simplified – falsified – to some extent.

Let me read you some words by Lama Govinda:

'The Buddhist does not believe in an independent, separately existing world, into whose dynamic forces he could insert himself. The external world and the inner world are for him only two sides of the same fabric in which the threads of all forces and of all events, of all forms of consciousness and of their objects, are woven into an inseparable net of endless, mutually conditioned relations.'

– Very, very similar to what Heisenberg has to say.

Ok... one more startling fact:

Quantum physics has things to say about empty space. It has something to say about what we normally consider to be a vacuum. In deep space, in outer space, there is just ‘vacuum’ in a lot of places. It is ‘empty’.

Well, quantum physics, together with Einstein’s Theory of Relativity, says that empty space isn’t empty at all. Relativity says that actually what we consider to be matter is just another form of energy, and quantum physics says that in a vacuum, out of nothing, all the time you’ve got little bits of matter arising and then disappearing very, very quickly, before you can look at them – before you can sort of say anything – they’ve gone! ...[LAUGHTER]

So the ‘vacuum’ – empty space – is actually a bubbling sea of form that comes and goes almost instantaneously; the form disappearing into the vacuum, into the empty space, almost as soon as it arises – but nothing is still. Nothing is ever static, even what we think of as empty space.

So that is the Copenhagen Interpretation, which is the standard interpretation. It is my favourite interpretation... but probably would be, as a Buddhist! There are other interpretations, as I say – some of them gaining in popularity – but I don’t think they will stand the test of time (and I’m biased, I guess)!

The ‘many worlds interpretation’; hidden variable theories and others

So, the first interpretation – I’m just going to talk about these very, very briefly – the first interpretation that is gaining popularity is called the ‘Many Worlds Interpretation’. That says that there *is* an objective reality; in fact, there is more than one objective reality; in fact, every time an electron has to decide which hole to go through – or make any decision whatsoever – the whole universe splits into two, and in one universe it goes through the top hole and in the other universe it goes through the bottom hole. You split into two; I split into two; we fall into different universes; and in the different universes, one never knows the other one.

But because there are a massive amount of particles even in a grain of sugar, doing all sorts of weird things all the time, pretty much there are an infinite number of universes all the time, splitting into an infinite number of other universes all the time – yeah? So it is ‘many, many worlds.’

Well, the appeal of that for physicists is that it says there *is* an objective reality! [LAUGHTER] And, yes, a lot of physicists hold to that – the ‘many worlds’ theories.

There are also theories called ‘hidden variable’ theories, which say that something *else* is going on at a deeper level of Reality than we can ever know. David Bohm, who I quoted earlier, is an exponent of one of these, and he has a lovely analogy or image. He says:

'Imagine a dancer on a stage, with two spotlights on the dancer. Imagine the shadows that that causes, as the dancer dances. So you will have two shadows as the dancer dances...'

And then he says, *'Imagine that you couldn't see the dancer, but you could only see the shadows...'* – yeah? – so you would suddenly see these two shadows as somehow being interconnected. You would see them moving in synchronicity, together, and you would think that there was something amazing going on because these two separate things were behaving as one. But that's because you couldn't see the uniting principle of the dancer.

So he is saying that underlying the fabric of our universe there is a deeper Reality which connects everything together, but we can't see that, so we think of things as separate.

So that's another interpretation. A third interpretation that I only read about recently, that seems to have gained popularity in the nineties, is that you *do* have particles travelling backwards in time, fixing things after the event. Behaving themselves, but only by travelling backwards in time.

Philosophically, things going backwards in time... well, if you've seen Doctor Who... it causes all sorts of problems. So... [LAUGHTER]

But interestingly, all of those other interpretations imply *interconnectedness*. They all imply that everything is interwoven, that separateness is illusory. All of them. There is not a single interpretation of quantum physics that seems to be able to get away from the notion of interconnectedness.

Some dangers of scientific materialism

So those are the interpretations. That is quantum physics. If you have understood or followed that, you've understood it all, in a way.

So what? – I just want to ask, 'So what?' And I just want to point out some dangers – at least dangers that I was thinking of.

I was thinking, 'Well, there's a danger of trying to make too many quick analogies between the Dharma and the scientific theory. What if that scientific theory turns out to be wrong, in another fifty years or so?' And of course that could prove to be the case. So that is a danger.

Another danger is of sort of 'mystery-mongering' – that quantum physics is weird, the Dharma is weird, so therefore they must be the same! ...[LAUGHTER]

I saw a film (I don't know if you saw this film) – 'What The (BLEEP) Do We Know?' – and it was about quantum physics and the nature of Reality. And it was good... but it did go in for this 'mystery-mongering' a bit. Various scientists were interviewed who seemed on the whole to say sensible things, and then there was this person interviewed who turned out later to be a mystic Eastern philosopher or meditation teacher or something, and she was very heavily made-up and the camera would zoom in to her face, whereas everybody else was given a bit more space. It would zoom into her face, and she would say some things like... well, I can't remember, actually... they were all banal! ...[she would say] things like, 'Is it Love?', and then she'd go dewy-eyed! And that is all she would say – and there would be tears in her eyes – and then we would go to something else! [LAUGHTER]

Unfortunately, such things give quantum physics a bad name, I think... let alone the Dharma!

There is a third danger, I think, which is a sort of 'reductionism'. In fact I am just going to point out three types of reductionism.

The first one is the danger that I have already talked about, of scientific materialism. I think that, at least, quantum physics starts to undermine simple scientific materialism. If you think that it is 'common sense' that we are just made of 'matter' – well then think again, because 'matter' is completely un-common-sensical. So common sense doesn't get you many marks.

Perhaps as Buddhists we don't fall so crudely into scientific materialism, but I think we can hold subtle versions of it. Just to refer to Ratnaguna's talk last night – perhaps a form of scientific materialism that *we* can fall into is, in a way, not having enough faith in the karma and dharma *niyamas*; basing all our faith on these material forms, this body.

We often say in the FWBO that you don't have to make up your mind about rebirth, for example – you know – you can remain agnostic or whatever you like about rebirth. But I think it is worth thinking about that if we don't believe that there is more to consciousness than the body, if we don't believe that there's anything after the body dies... what does that say? Isn't that a form of materialism, and nihilism?

Anyway quantum physics seems to undermine that at a simple level, but there is a danger that everything could be reduced to quantum physics, still. What I mean by this is that some people have tried to explain consciousness as quantum physical processes going on in the brain – and that's attractive, because there *must* be some quantum physical processes in the brain – but it seems to do away with consciousness still as a material phenomenon. Do you see what I mean?

Ken Wilbur, who I have been reading recently, has some good things to say on this. He is basically saying that you cannot reduce the subjective and the objective into each other. The objective world cannot be reduced into the subjective, and the subjective cannot be reduced into the objective.

Einstein kind of knew that, actually. He was one of the few physicists that seems to have known that. I think it is implied in this that he wrote – he says:

'...No, this trick won't work. How on earth are you ever going to explain in terms of chemistry and physics so important a biological concept as 'first love'?...'

Basically what he is saying is that you can't reduce human experience – actually, any experience – to quantum physics, or to matter, at all; that there is more going on.

And then there is another form of reductionism which is that just because everything is interconnected, sometimes people portray this interconnected net as a sort of *soup* where everything has sort of equal value – you know – so a particle has an equal value to a human being, because they are somehow interconnected... and to a tree... to a cow.. to whatever.

Ken Wilbur is very clear about this: that if you are going to talk about interconnected networks you have also got to introduce the principle of hierarchy: a hierarchy of values, a hierarchy of complexity, a hierarchy of consciousness. Without that, everything gets reduced to the same level. And he is very critical of some ecological thinkers who talk very much in terms of interconnectedness but because they lack an explicit hierarchy of values they can't say why a human being is more valuable than a bacterium. [Wilbur] has a very worked-out way of marrying this tension between a hierarchical view and a network kind of view, and he warns against losing this notion of hierarchy in our modern culture.

So I think there is probably much to explore in that... though I haven't got time to do that.

Just one more quote from Einstein... Well, it's not the last one actually, but one more anyway – I like it! He says:

'Two things are infinite: the universe, and human stupidity... and I'm not sure about the universe.'

That's Einstein!

Conclusion

So, what *can* we be sure of?

Well, the first thing – and this is sort of by way of conclusion – the first thing that we can be sure of is that *things are not what they seem*. Even if quantum physics proves to be incorrect, and is superseded by a more impressive theory, we are never going to, I think, be able to return to a simple, 'common sense' view of matter – of Reality. Relativity (which I have not been able to go into) says that space and time are not what they seem – so not only is 'matter' not what it seems, 'space' and 'time' are *nothing like* what we take them to be. The past, the present and the future – this notion of time as flowing through an absolute space – is not how physics sees things.

I just want to read another bit of Einstein: he was writing a letter of condolence to the widow of a friend that had died. It is a lovely thing to write – he says:

'...Now he has departed from this strange world, a little ahead of me. That means nothing. People like us, who believe in physics, know that the distinction between the past, the present and the future is only a stubbornly persistent illusion...'

So... things are not what they seem.

Secondly, if the Copenhagen Interpretation *is* correct, then we can't talk of an objectively existing reality separate from our consciousness; separate from the subject. It is almost as if physics, starting from the assumption of objectivity, comes to the very limits of the subject-object duality and starts to come unstuck. Because its assumptions are that there is an objective world, it comes unstuck.

And thirdly, even if the Copenhagen Interpretation is proven to be wrong – even if there IS an objective reality – it seems to be now indisputable that everything is connected to everything else – the interconnectedness of that objective reality is a fact – and that we are woven into that.

So I find all of that very fascinating. Hopefully some of you, at least, have found that interesting. But I think I want to conclude by saying – well – of course, it's very limited. Even if it is all true, quantum physics doesn't really say anything about how we live our lives. It doesn't say anything about ethics; it doesn't say anything about values, even though it might hint at such things.

However, it *can* influence our world view, and I think that that is an important thing to try and take on board. It *can* influence our perspective. I think, for me, it can help me stay in touch with a sense of wonder, and a sense of wonder, for me, is very connected with the sense of *sradhha* – of reverence. It is when I think I know it all that the sense of *sradhha* seems to go.

I want to finish now with some words again from Einstein, who seems to, I think, have been a man of spiritual insight. Certainly his writings seem to me to imply that. Genuine depth.

These words that I am going to read, they are my favourite thing that I have read of Einstein. They echo, for me, words in the Manjugosha Stuti Sadhana – perhaps you will see why – but they definitely seem to me to be words of wisdom, and I just want to conclude with them:

'A human being is part of a whole, called by us 'Universe' – a part limited in time and space. He experiences himself, his thoughts and feelings, as something separated from the rest – a kind of optical delusion of his consciousness. This delusion is a kind of prison for us, restricting us to our personal desires and to the affection for a few persons nearest to us. Our task must be to free ourselves from this prison by widening our circle of compassion to embrace all living creatures and the whole of Nature in all its beauty.

Nobody is able to achieve this completely, but striving for such an achievement is in itself a part of the liberation, and a foundation for inner security.'