Quantum Reality

A short fantasy

Mr Tomkins sells gloves. No ordinary gloves, mind. They are called 'Rainbow Gloves' because you can make them any colour you like. They come in a special box with a dial on the front. Before opening the box you dial up the colour you want, press a button and give the box a shake. Then, when you open the box, you have a pair of gloves the exact shade you wanted. Mr Tomkins' Rainbow Gloves are very popular and his factory and distribution centre on the equator is very busy sending pairs of gloves all over the world.

One day, his niece, Alice, who lives at the North Pole, was invited to a wedding so she sent an order to her uncle for a pair of gloves and when the package arrived she dialled her favourite colour – white – and opened the box. Imagine her disappointment then to find that, instead of a pair of gloves it contained just one left-handed white glove.

Later that day, she rang up her brother, Bob, (who lives at the South Pole) and mentioned the curious incident to him.

“That's strange”, he said, “I received a parcel from Uncle Tomkins too today. I haven't opened it yet but, yes, here it is; I will open it now.”

“Good heavens! Guess what it contains – one right-handed white glove! - The other one of the pair! I will send it on to you straight away.”

“That's great! Thanks.” said Alice. “But it is a bit odd all the same.”

“Why so? Obviously Uncle Tomkins got the addresses mixed up and sent one glove to you and the other to me. What's so odd about that?”

“No. That's not what is puzzling me. The thing is – why is your glove *white*?”

“Well it's the other one of a pair. It's got to be the same colour.”

“But I only dialled up the colour white when I received *my* glove. What colour did you dial up when you opened your box?”

“I don't know,” said Bob. “I suppose I must have just struck lucky and dialled up the same colour!”

“Yes, that must be it. Just a freak coincidence. Anyway – post it to me right away as the wedding is next week.”

A few weeks later, Alice had occasion to need a pair of black gloves for a funeral and sent an order to her uncle. The order was a few days late arriving but Alice dialled up the colour she needed (black) and opened the box. To her considerable dismay, not only did the box only contain one left-handed glove but that glove was not even black. It was a shocking pink colour!

Remembering what had happened before, she rang up her brother again and told him what had happened. Sure enough, he had received a box from Mr Tomkins and had opened it but he seemed rather reluctant to say what he had found.

“Well – what did you find in the box? Did it contain a right handed glove?”

“Well, yes it did.”

“And what colour is it?”

“You're not going to like this Alice.” he said.

“Go on...”

“Well, you see, when it arrived I didn't think it would matter what colour I dialled up so..”

“Oh no!”

“so, I, well, like, dialled up ...” his voice trailed off.

“Shocking pink!” screamed Alice. “How could you!”

“Well – I didn't know it was going to affect your glove too! How could I?”

“Yes I suppose so. Come to think of it, that is really bizarre. The action of dialling up a colour on one box seems to affect *both* gloves simultaneously.”

“ Wow! That's really cool!” said Bob. “Whenever I receive a glove, I can tell instantly what colour glove you have received! Perhaps we could use our uncle to send instantaneous messages to each other. Say you were sad one day and wanted to tell me; you could order a pair of gloves and when your glove arrived you could dial up black, and I would know instantly that you were sad that day.”

“Don't be silly, Bob!” Alice replied, “that's no way to send an instantaneous message. I would have to phone you up to tell you when to look in the box – and I might as well just tell you then.”

“I suppose so.” said Bob. “Even so, it's a bit spooky – at the instant you open your parcel you immediately know something about the contents of my parcel, even if I haven't opened it! That's really weird!” [1]

“That reminds me of something I read the other day about an experiment in which pairs of polarized photons were sent in opposite directions and some strange correlations were found which could not be explained on a common sense basis.” said Alice. “I didn't understand the details but from what I can gather, the experimenters concluded that the photons only decided which way they were polarized when they were actually detected.” [2]

“Well that's just stupid,” said Bob, “it would be like saying that the gloves didn't know whether they were black of white until you opened one of the packages.”

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1 In fact, Mr Tomkins Rainbow gloves as described *could* be used to send instantaneous messages because what Bob finds in his box only depends on what Alice found in hers and not what colour he dials up. In a scenario which corresponds more closely with what happens in the quantum world, when Alice dials up white, she would get *either* a white glove *or* a black one at random; and when Bob dials up shocking pink, he will get e*ither* a pink glove *or* lime green one (the complementary colour) at random. Only when Alice and Bob compare notes later will it become clear that, on those occasion when they both dialled up approximately the *same* colour (eg white) they *both* got the *same* colour glove (white or black). Unfortunately, these complications do not make for such a good story.

2 Alice is referring to an experiment carried out by Alain Aspect in 1982. which confirmed the predictions made by Einstein, Podolsky and Rosen in 1935 which seemed to suggest that Quantum theory was incompatible with local realism – that is, the idea that at all times, the state of a particle could be described completely in terms of local, real, potentially measurable variables.

“Don't jump down my throat, Bob, I am only saying what they said.”

“Well, they don't know what they are talking about, that's all.”

” I am not so sure. Tell you what – why don't we both attend a Physics Symposium which I have seen advertised in a magazine I take – Physics Universe. There are going to be lots of interesting people there, I am told, and it would be nice to see you again after all this time.”

So it was agreed. Alice and Bob would attend the symposium and in the plenary session at the end, they would describe their experience with the gloves and ask the question – how can the glove in Alice's box know what colour Bob has dialled up?

As a mark of respect, the chairman invited his honour Mr Justice Newton to give the first reply. Mr Newton was an elderly gentleman wearing a red gown and a long grey wig. He had a stern countenance and an air of gravity about him. “My dear children,” he said, gravely, “the case is quite simple. It is obvious that your uncle never mixes up the colours of his gloves and the reason why, when Bob receives a pink glove, Alice receives a corresponding pink glove too, is that both gloves were pink when they were put in the parcels, they were pink when they were sent through the post and they were pink when you opened the parcels. There can be no other explanation. Can we move on to the next question please?”

But at that instant there was a blinding flash of light and the sound of thunder. “No!!!” bellowed a deep voice, “The question is far from settled. Alice and Bob have raised a question of deep philosophical and practical interest and I demand to be heard.”

The speaker proved to be an aged wizard with a conical hat and a long beard holding a staff, the end of which glowed brightly and which had been the source of the flash and the sound of thunder.

“Er, well, yes, I suppose so.” said the chairman who was cowering under his desk. “If you must., Mr Dumble Bohr”

“You must understand” the wizard bellowed, “that the only observable realities are realities which are observed. If this were not the case then magic would be impossible. And without magic, there would be no mobile phones, no supermarket checkout lasers, no atomic bombs, no computers – the modern world would be quite impossible.” saying which, he banged his staff on the floor and another bang and a flash sent his audience scurrying for cover.

“All of these things have been brought about by my students at Copen Hogwarts and elsewhere because we passionately believe in the following fundamental principle: things are only real when you observe them. It is quite meaningless to ask the question 'What colour is this glove?' while it is in its parcel. The only thing you can say about it is that there is a certain probability of it being one colour and a certain probability of it being another. Period. My esteemed colleagues, Professor Schro Dinger and Professor Ein Stein have helped me work out the fine details of how to calculate the probabilities of any event being observed and how these probabilities change over time and I can't see why you are not satisfied with that. As soon as Bob opens his parcel, he makes a measurement on the system and at that instant the probability of the gloves being white or black collapses to zero and both gloves reveal themselves to be pink – and that's it. There is nothing else to say.” And with another thunderclap he sat down.[3]

Professor Dinger was the first to raise his tentative head. “Yes, Mr Bohr, I understand your position but with the greatest respect, I must point out that the mechanics we worked out together only works for very small objects like photons, electrons and simple atoms. As soon as you get anything more complicated, the maths becomes horrendously complicated and the we haven't a clue how to work out the probabilities” [4]

“Well that's just because you are so feeble-minded” roared Mr Dumble Bohr. “If you had a big enough brain – or a big enough computer – you could, in principle calculate the probabilities of all the atoms in a glove. But you needn't bother because I can tell you the answer you will get – 50% pink and 50% not-pink.'

“I am sorry, Mr. Bohr, but again, with the greatest of respect, I cannot agree. The glove in the box cannot be 50% pink and 50% not-pink no more than a cat can be 50% dead and 50% alive.” [5]

“Respect! Respect!” bellowed Mr Dumble Bohr, “I'll give you respect!” and gave Professor Dinger such a whack over the head with his staff that the poor man felt he was, if anything, more dead than alive. Alice jumped up and kissed the professor's sore head, at which he instantly became more alive than dead. Funny thing that...

Meanwhile, Professor Stein had got up from his seat and was saying something else: “Really, Mr Dunble Bohr, there is no need to act like that, and in any case, I have a more serious objection to your position than Professor Dinger's epistemological arguments. You say that at the instant Bob opens his parcel, the probability of his glove being black or some other colour falls from 50% to 0 and the probability of it being pink rises to 100%. Is that correct?

“Yes That's what I said didn't I?”

“And you also implied that at the very same instant, the probability of the glove in Alice's box being black also falls from 50% to 0% and the probability of it being pink instantly rises to 100%.”

“Of course – weren't you listening to anything I said?”

“And this happens, even if Alice has not yet opened her parcel”

“Yes, Yes. Get on with it!”

“And Alice and Bob can be light years apart?”

“What of it?”

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3 Niels Bohr, together with Werner Heisenberg and others, was responsible for what is known as the Copenhagen Interpretation of Quantum Mechanics, the position paraphrased by Wizard Dumble Bohr.

4 In 1926 Erwin Schrödinger explained the spectral lines produced by the hydrogen atom by proposing that the electron existed as a kind of 'matter wave' surrounding the nucleus. A couple of years later, Max Born interpreted the square of the amplitude of Schrödinger's wave at any particular place as the probability of finding the electron at that place. In this way, it became possible to interpret the interference patterns shown by individual photons or even electrons in an interferometer as due to the interference of Schrödinger's waves. It is worth pointing out that Schrödinger accepted this idea only very reluctantly.

5 The reference here is, of course, to Schrödinger's famous thought experiment with which he hoped to reduce Bohr's superposition theory to the status of an absurdity. To his surprise and consternation, many physicists under Bohr's spell were more than willing to accept the notion of a cat which is both alive and dead.

“Well, as you know, I have conclusively proved that no signal can possibly travel faster than light – so how can the glove in Bob's box tell the glove in Alice's box how to change its probabilities. Such spooky 'action at a distance' is impossible. Your thesis is untenable and I rest my case. What do you think, Mr Justice Newton?” he said, turning towards the latter.

“Well, er, I was always rather in favour of action at a...”

“Rubbish!” broke in Professor Dinger who had by now quite recovered “You are an old fuddy-duddy and don't know a thing about modern advances in physics.” turning on Mr Newton with a withering look. “Professor Ein Stein cannot be faulted on this. His theory has been experimentally proved dozens of times. What is more, even though some of his results are quite startling, the logic of his theory is impeccable and the axioms on which it is based, the fundamental principles of Special and General Relativity, are so simple a child can understand them.”

“Look here, Professor” said Dumble Bohr turning towards Prof. Dinger, “Far from disproving my thesis, Professor Stein has only confirmed my belief that it is pointless to ask questions about which you can know nothing. A great number of my students have devised all sorts of ingenious spells which prove conclusively that no theory based on the assumption that there is a real physical reality out there which is independent of the person observing it (an assumption we call local realism) is adequate to explain what actually happens. [6] More precisely, you have a choice: you either accept Prof. Stein's 'spooky action at a distance' or you abandon local realism. You can't have it both ways. In fact these spells are becoming so commonplace these days, I am thinking of putting one of them into my elementary transfiguration classes.”

“Let me get this right.” said Alice, who had been listening most attentively all this time. “I learned about a simple experiment which we did at school in which we shone a beam of light at two narrow slits placed very close together and a very surprising thing happened. Instead of seeing a splodge of light at the other end we saw a stripy pattern of light and dark. My teacher said that the dark areas were where the two light beams 'interfered' with each other and what is more, he proved this by covering up one of the slits and the dark areas became light again. I found that really weird. But the weirdest thing of all was when he told me that the experiment still worked, even when you only put one photon at a time into the apparatus, and that the same experiment had been done with electrons too, with exactly the same result.” [7]

“Now according to you, Professor Dinger, the photon and the electron are not particles at all but waves of probability which go through both slits and which collapse back into a particle again when it reaches the detecting apparatus. You, Mr Bohr, say that the question 'which slit does the photon go through?' is meaningless. You are content to use Professor Dinger's formula to get the right answer.”

“You're sure right there, babe.”

“Whereas you, Professor Ein Stein, don't know what to think. Is that it?”

“Yes, that just about sums up our positions.' said Prof Stein ' Don't you agree, Schro?”

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6 One of the more recent experiments carried out by P.K.Aravind in 2004 is described here.

7 Exactly who first carried out this experiment is discussed in an interesting article in the September 2002 issue of **Physics World** and an extended version may be read here. The most credit should probably be given to Akira Tonomura and his co-workers at Hitachi in 1989.

Professor Dinger nodded reluctantly.

"I've got it! I've got it! I've got it!" shrieked a young snotty-nosed teenager wearing horn-rimmed spectacles whom nobody had noticed until now and who jumped up, knocking over the tables and chairs in his excitement.

"You're all wrong! You're all wrong! You're all wrong!" he shouted.

"It's like this! Look!" and he grabbed two tables, placing them about a metre apart with a stool in the middle of the gap. "Professor Stein – you want the photon to go through either one slit, like this," whereupon he ran pell-mell through one of the gaps beside the stool "or like this," dashing through the other gap.

"Professor Dinger wants the photon to go through both gaps." saying which, a remarkable thing happened; as he ran towards the stool his body seemed to split into two and recombine on the other side!

"But Wizard Dumble Bohr wants me to just disappear" "and reappear over here!

"Well you're all wrong. What actually happens is that the whole universe splits into two parallel universes. In one universe the photon goes through this slit" pointing to one of the gaps beside the stool "while in the other universe the photon goes through the other slit."

"Don't talk rubbish, sonny" said Professor Dinger. "That's a stupid idea. And in any case, even if you were right, it wouldn't work because the stripy pattern would disappear in both universes. And which universe would **you** end up in? (Not mine, I hope!)" he said smirking at the others who smirked back.

"I can answer that!" cried the boy. !You see the two universes split apart only gradually and there is a brief time after the two photons have past through the slits for them to affect each other and produce the stripy pattern again; but when the photon hits the detector, the universes diverge permanently. And you, you are in both of them, sir! And me too! And everyone! And the sea and sky and..."

"Oh shut up!" snapped Dumble Bohr.

"Don't be too hard on him," said Professor Dinger, "after all he is only a boy and, you know, his idea might just be made to work. I wonder..."

"Oh but its too preposterous!" said Professor Ein Stein. "This multiplicity of worlds. The next photon that comes along, both worlds would have to split into two again making 4 parallel universes, then 8 then 16. After n photons have gone through the apparatus there will be 2^n universes. Come to think of it, every time any quantum event happens anywhere in the universe, the whole universe will be split into multiple copies of itself! Have you any idea how many particles there are in the universe – er – what's your name?"

"Everett, sir"

"Have you any idea how many particles there are in the universe, Everett?"

"Yes. sir, about 2^{80} I think."

"And how many quantum events happen to each particle every second, do you think?"

"Well, billions, of course"

“And how many seconds have there been since the Big Bang?”

“Everybody knows that, sir. 429 trillion seconds. That's in English trillions, sir. You know – a million million million – not those silly American trillions.”

“You mean 429 x 10^{18} seconds?”

“Yes, sir.”

“OK. So how many quantum events have occurred since the Big Bang?”

Everett whips out a pocket calculator and presses a few buttons and triumphantly presents the answer: “5.186291766 times ten to the power of 53, sir”

“Forget all those irrelevant digits; 10^{53} will do for now. Now I want you to tell me how many parallel universes there are right now.”

“Well, as you said, at each quantum event the universe splits into at least two so there must be at least 2 to the power of 10^{53} universes out there!”

“And have you any idea how big 2 to the power of 10^{53} actually is, my boy?”

“Not really – but its a lot smaller than infinity!”

At this reply Prof Dinger burst out laughing. “Well he's right there, Ein! You have got to admit, it really doesn't matter if the universe splits into two or into a quintillion zillion universes, the philosophical problem is no worse!”

“Pah!” replied Professor Stein.

“And you have to admit that, if his scheme can be made to work, every one of his universes conforms to local realism and there is no 'spooky action at a distance' either.”

“Yes – but he has just replaced one philosophical absurdity with another one. I don't see the point of that. But if you want to waste your time working out the details, go ahead. See if I care.” [8]

“I think we should ask for a ruling on this.” suggested Dumble Bohr and turning to Mr Newton said: “Your honour, you have heard the evidence so far – what is your opinion?”

Mr. Justice Newton stood up and grasping the lapels of his gown in both hands, he spoke.

“I have listened to all you have said and my supremely powerful intellect has decided that you are all partially right and partially wrong. My interpretation of quantum mechanics is based on a consistency criterion that then allows probabilities to be assigned to various alternative histories of a system such that the probabilities for each history obey the rules of classical probability while being consistent with the Schrödinger equation. In contrast to some interpretations of quantum mechanics, the framework does not include 'wavefunction collapse' as a relevant description of any physical process, and emphasizes that measurement theory is not a fundamental ingredient of quantum mechanics.” [9]

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8 In 1957 Hugh Everett proposed a theory, later popularised by Bryce deWitt and called the 'many worlds' interpretation of Quantum Mechanics. In it the wave function never actually collapses but in each of the many possible worlds, it appears to collapse in a different way.

9 This is an almost verbatim quote from the Wikipedia article on the 'Consistent Histories' interpretation of Quantum Theory. CH is a popular modern mathematical formulation of the standard Copenhagen interpretation which claims to solve all the paradoxes associated with QT but does not do so for the simple reason that its proponents cannot describe their ideas in simple English.

This produced a rather stunned silence amongst the assembled company during which Bob was clearly heard to whisper to his sister: “What the hell's he talking about?”

“I don't know.” she replied “but I have just had a funny idea of my own.”

“Well, let's hear it then” her brother encouraged her. “When these geniuses can't agree I don't see why your opinion should be any less worth hearing than theirs.”

So, plucking up all her courage, Alice said: “I've been thinking. Maybe..., Look, I don't like the idea that reality just ceases to exist for a while, and I like Everett's multiple realities even less, but, well, suppose - a physical phenomenon...” and her voice trailed away.

“Yes, my dear, what are you thinking?” said Professor Dinger whose own thoughts were turning towards a physical phenomenon of a rather different sort.

“Yes, well, suppose that when a physical phenomenon like radioactive decay occurs, reality is, sort of, like, *suspended* for a while.”

“You mean the phenomenon where an alpha particle can 'borrow' enough energy to get over a potential barrier and escape from the nucleus provided it returns the energy within a short enough time period?” [10]

“Yes. that's right, Professor Dinger. Maybe the same thing happens when the photon travels through the two slit apparatus. Reality is suspended for a while and when the photon hits the detector, reality snaps back into focus.”

“What you are suggesting is that the universe splits into two realities, but later on, only one of those realities becomes real reality.”

“Yes, and it explains the behaviour of the rainbow gloves too.” said Alice.

“How so?” said Bob.

“Well, when Uncle Tomkins puts the gloves into the boxes, their colour is simply not decided. We can express this by pretending that the world splits into multiple copies and in each world the two gloves have a different colour. In one world, both gloves are black, in another they ere pink etc.etc. Now when you dialled up pink on your box and looked inside, suddenly the suspended worlds vanished leaving just one real world in which both gloves were pink. There is no need for any 'spooky action at a distance' so your objection is met, Professor Stein, and provided you accept a temporary suspension of reality, we can still go on believing that there is basically only one world out there which we all live in.”

“Bravo!” said the two professors simultaneously.

“You know, Alice has got an idea there.” put in Dumble Bohr. “Her concept of suspended reality is almost the same as my idea that it is meaningless to ask questions about which slit the photon goes through.”

“You're wrong about that, Bohr” put in Professor Stein. “Alice's theory allows us to be quite specific about the answers to questions like 'What colour were the gloves before Bob opened his box?' or 'Which slit did the electron go through?' Once the suspended realities crystallise into one real reality we can categorically say that the gloves *always were* pink and that the photon definitely went though *this* slit.”

10 The idea that a quantum particle can 'borrow' energy for a short period of time and thus do things which it would be impossible for a classical particle to do is due to Walter Heisenberg.

“And her theory also needs many-worlds, doesn't it?” piped up a small voice from under the table.

“Yes – but they don't go on multiplying in such a ridiculous manner as yours.” said Bob.

“Mm – and I can see a possible link with my idea of probability wave functions too.” added Professor Dinger thoughtfully. “I remember that a young bongo-playing American student once showed that you could get exactly the same results as you get from my wave equation by pretending that the photons take every possible route through the apparatus; the probability of a particular outcome occurring is then simply the sum of all the probabilities of all the possible ways which could have produced that outcome. What Alice is really suggesting is that for a short while, this is what photons actually do – they really do try out all possible alternative histories!” [11]

“That's fascinating.” said Professor Stein. “I can see immediately that, mathematically speaking, the scheme will generate exactly the same results as the standard wave theory but I still have one problem which we haven't discussed at all yet.”

“What is that?” asked Alice.

“What do you think causes the realities to collapse into one real reality? Why should reality ever stop being suspended? What is it about the fact that the photon hits the detector that makes it hit here rather than there? Or to go right back to your original question, what is it about the action of opening the parcel from your uncle which crystallises the colour of the glove, making one possible reality real and not the other?”

“I had an answer to that once but I got shot down in pieces.” said Dumble Bohr morosely.

“What was that?”

“I said that things only became real when the effects reached a conscious mind but that raised all sorts of questions about whether cats were conscious or not which was not the issue at all.” [12]

“Well, has anyone got any better ideas?” prompted Alice.

“Yes, I think I might have.” said Professor Dinger. Suppose we set up some sort of quantum experiment which has two possible outcomes, both of which are equally likely. Lets suppose that the arrangement allows a photon either to hit detector A or detector B. According to my old theory, when the photon hits either of the detectors, the probability wave collapses and one or other of the detectors registers, basically at random. On Everett's theory, the wave function never collapses but the wave goes on propagating itself for ever and ever. Alice wants the wave function to collapse of its own accord and to crystallize one or other possibility. Now I did read the other day about a brilliant mathematician called Dr Pen Rose who is working on a similar idea involving a new theory of gravity[13] but I am told that he has run into all sorts of difficulties and that a quantum theory of gravity is still a long way off.

“I have also heard of a group of mathematicians who are working on the idea that for any

11 The bong-playing American is, of course, Richard Feynman.

12 Egene Wigner: 'The Problem of Measurement' 1963

13 Roger Penrose believes that the measurement problem will only be solved when we have developed a quantum theory of gravity – ie a theory which marries Quantum Theory and General Relativity. In essence his idea is that the wavefunction collapses automatically when the potential disturbance in spacetime reaches a certain threshold level.

individual particle, spontaneous wavefunction collapse happens at random with a probability of about 10^{-8} per second. Basically what this means is that a collection of 10^{23} particles ie a half dead/alive cat, would spontaneously collapse into one or the other in about 10^{-15} seconds.[14] I can't say I am very happy with this idea either and I am just wondering if a modification to my own wave equation might do the trick."

Professor Dinger remained silent for a while, thinking, and then said: "The wave equation for a single photon travelling through space is pretty simple and any student can predict its behaviour and say where a photon might go in any number of simple circumstances. But if that photon interacts with an electron, say, the wave equation which describes the behaviour of the scattered particles is much more complex and when several particles are involved, it defies analytical solution. In fact, the more particles get involved, the complexity of the situation increases exponentially. Now in the example I am suggesting, since the detectors are exactly the same, you might expect that the probability of detector A registering the photon will always be the same as the probability of detector B registering the photon. After all, the symmetry of the situation dictates that the alternative histories leading to the photon appearing at A and B will appear identical. Basically the reason for this is that my equation is linear and it doesn't matter how complex it gets, the whole is always just the sum of its parts.

"But suppose we introduce a tiny non-linear term into my equation. The possibility then arises that, as the system becomes more and more complex, instabilities may arise and the equation will become so sensitive to its initial conditions that eventually the symmetry will spontaneously break down and one probability will become greater than the other. At that point, the system will rapidly flip irrevocably into a situation where the probability of one outcome is 100% and that of the other is zero. Reality will have re-established itself spontaneously. In this way we can achieve our object without either arbitrary thresholds or random events. I think I shall call my new theory the "Chaotic Decoherence Theory" and write a paper on it titled "Alice in Suspended Reality – a solution to the measurement problem".

"Hooray!" cheered Bob and Alice simultaneously.

"Well, Schro, I think you might have to acknowledge your debt to this young lady here when you get your next Nobel Prize for solving the so-called 'measurement problem' for us" said his colleague Professor Stein, "but it sounds as if you have got some serious mathematical work to do, though. What do you think, Mr Newton?"

"Well I have to confess that things were a lot simpler when I was in my prime." said the aged judge. "But I have to take my hat off to you, Professor Dinger. You do seem to have outlined a solution to the problem which allows you, at least in hindsight, to say what might actually have happened and to avoid any reference to 'spooky action at a distance' and to dispense with our young enthusiast's Many Worlds as well, all at the price of a little bit of suspended reality while the alternative histories are totted up. All I can say is, I hope you can get it to work."

"Bah! Its a lot of rot! I tell you again, you don't need all this theorizing and philosophising about Many Worlds or Suspended Reality. All you need is Schro's brilliant

14 The first of these 'Objective collapse' theories was put forward in 1986 by Ghirardi, Rimini and Weber. A summary of the current state of these theories is given here.

equation and a calculator and you can do anything you want. I am working on a quantum computer at the moment and I am thinking of building a quantum tunnel that will get people from here to Alpha Centauri in the blink of an eye and...”

“Yeah! Yeah! Yeah! Stop bragging, Mr Mumble Bore.” said Bob irritably. 'We know you have worked some incredible magic in the past and it is likely that some of your ideas will come about in the future, but there will come a point when your ideas outstrip your tools and your magic will cease to work. What if you find that you can get your quantum computer to work with one or two quantum gates but it stops working when you build one with a hundred gates? What if you can get an atom to tunnel through a piece of paper but you find it is impossible to get a cat through a wall? Then you will have to come crawling to these humble geniuses here who have quietly been puzzling out what actually is going on for new ideas on how to proceed and how to work new magic. But until that time, just go home, shut up, and calculate.' [15]

And with that parting shot the symposium ended.

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15 The origin of Bob's parting shot it wittily discussed here.