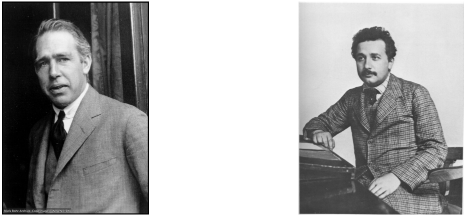
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Quantum information lost and found, and why the interpretation of quantum mechanics is important.

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why joining physical theories is important:

Isaac Newton: the stars and planets in the sky are discovered to be controlled by the same force laws as the material objects and fluids on earth; laws of gravitation

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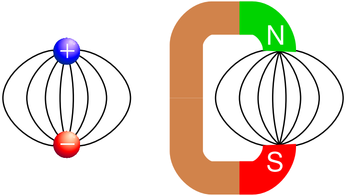
James C. Maxwell: elctricity and magnetism are two sides of one coin, the electromagnetic field,



and this force turns out to control *light* as well ...

why joining physical theories is important:

Einstein's theory of *Special Relativity* combines Maxwell's theory of electro-magnetism with theories of *matter*:

$$E \;=\; mc^2$$

why joining physical theories is important:

Modern science: the sub-atomic particles appear to combine quantum mechanics with Einstein's special relativity. Combining these two notions leads towards quantum field theory, QFT as a powerful paradigm: the Standard Model.

Gravity. works primarily on big and heavy things. This force manifests itself primarily when very many particles, coming together as stars and planets, reinforce each other, generating gigantic forces.

Putting Newton's laws in Einstein's Special theory of Relativity, yields General Relativity, or: space-time curvature.

putting these together. 1+1=2 again.
Getting the Standard Model complete had taken us almost 100 years, and turned out to be a gigantic success. But the Standard Model is not complete. We can see that elementary particles are sensitive to the gravitational force, but only when they act collectively.

What are the rules for individual particles, and how does QM act on space and time? Will this take us another 100 years? shouldn't we know by now how to unify such ideas into one? What's the problem?

black holes. Solving this difficulty is indeed hard. As Stephen Hawking said: you need to understand God's way. Hawking was interested in black holes. BHs are objects that are born when stars collapse under their own weight. That's just standard General Relativity. Known since late 1915: K. Schwarzschild. Hawking started to calculate how quantum particles behave near a black hole. He got a shock:

According to GR, particles can fall into a black hole, and will never be able to get out. But that was when you left out QM, and QFT. With quantum mechanics, particles do come out. But they are different particles! Black holes radiate, and the radiation consists of particles of all sorts.

A Black Hole handles these particles strictly equally. This was the first palpable implication found only by putting QM and GR together! Was Hawking about to understand God's way?

Here, we encountered a crucial problem. We know the equations, we know how to solve the equations, but we don't quite understand what they say. It looks as if all particles that emerge, came from their own little spot on the surface of a black hole (called 'horizon').

But what exactly happens out there? Ny moving around the way they do, the particles seem to transmit nessages from the particles that fell in. But how do we read those messages?

Our understanding of the laws of nature seems to be incomplete if we cannot answer such questions. Indeed, we have to answer first the question: what is the information in the quantum signals that particles seem to carry?

Quantum questions.

This question appears to be a philosophical one, and the way people go along trying to find answers, appears to be culture-dependent. Already shortly after the discovery of QM itself, people started asking questions as to what our quantum formulae are exactly telling us about these particles, how they move, and how they will behave wjen they collide to other particles.

Einstein, father of both Relativity theories, on the one hand, and Niels Bohr, Werner Heisenberg and more on the other hand, were disputing whether the information provided by their formulae would be complete. Einstein complained that something was missing, Bohr and others claimed that there couldn't be more. Who was right?

Free will. The answer seems to depend on what you can, or want to, say about free will. When you observe a particle, you have to decide what to look at and measure. Do you measure its position, or its velocity?

Or you can measure its spin, but you first have to decide which axis you choose. Once you made your decision, you cannot measure anything else, due to the particle's elusive behaviour.

Does the behavior of the particle depend on your 'free will' when you decided what to measure? Or was Einstein right, in saying that we must have overlooked something?

Bell Most scientists now side with Bohr and Heisenberg. Einstein was smart, but here he was wrong. Most scientists, but not all. I find myself fully on the side of Einstein. Not because he was so smart. He just happened to be right. What happened? John Bell reconsidered Einstein's argument, and designed a thought experiment.

A specially prepaired light source sends out two photons that are 'entangled'. Two observers named Alice (a) and Bob (b) make measurements of their choice, each on another photon. How is the photon polarised? How can this polarisation depend on the settings of their detectors? And hen we check how Alice and Bob's results are correlated.

In spite of the erratic behavior of the photons, the correlations Bob and Alice would find, were calculated to be too big for Einstein. Bohr and others must have been right. End of argument

But Bell made assumptions. Bob and Alice had 'free will' to choose their settings. Of course they had free will. Who would ever question. Were they predestined to decide about their setting? a and b were found to be correlated with the polarisation axis c of the photons.

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And what about gravity? Here, a similar dispute might emerge. Hawking computed the radiation emerging from black holes. But he used starting points not dissimilar from Bell. According to Hawking, black holes also show erratic behavior.

Particles that went inside cannot be measured. The information they carry simply gets lost. He did not see this as a missing ingredient of QM. I do.

If particles behave the way I suspect, they radiate differently from what Hawking claimed to have found. In my calculation, particles never go inside a black hole. The inside of a black hole is empty. This would imply that the black hole radiation will be much more intensive than what Hawking had found: the temperature of the radiation will be twice that of Hawking.

Unfortunately, Hawking radiation can only be detected for microscopic black holes, sufficiently close to us. Such black holes have never be detected, and it is unlikely that they will. Too bad for me. Unless scientists will manage to continue along this line of thought.

The questions raised, at first sight seem to be philosophical. And rereachers primarily turn to philosophical answers. Then they temd to think they understand ‘God’s way’.

But often I find myself at the other side. My God is much more mathematical, it seems, than others.

It will not be easy to find out who is right. But I believe most in the most rigid kind of logic.