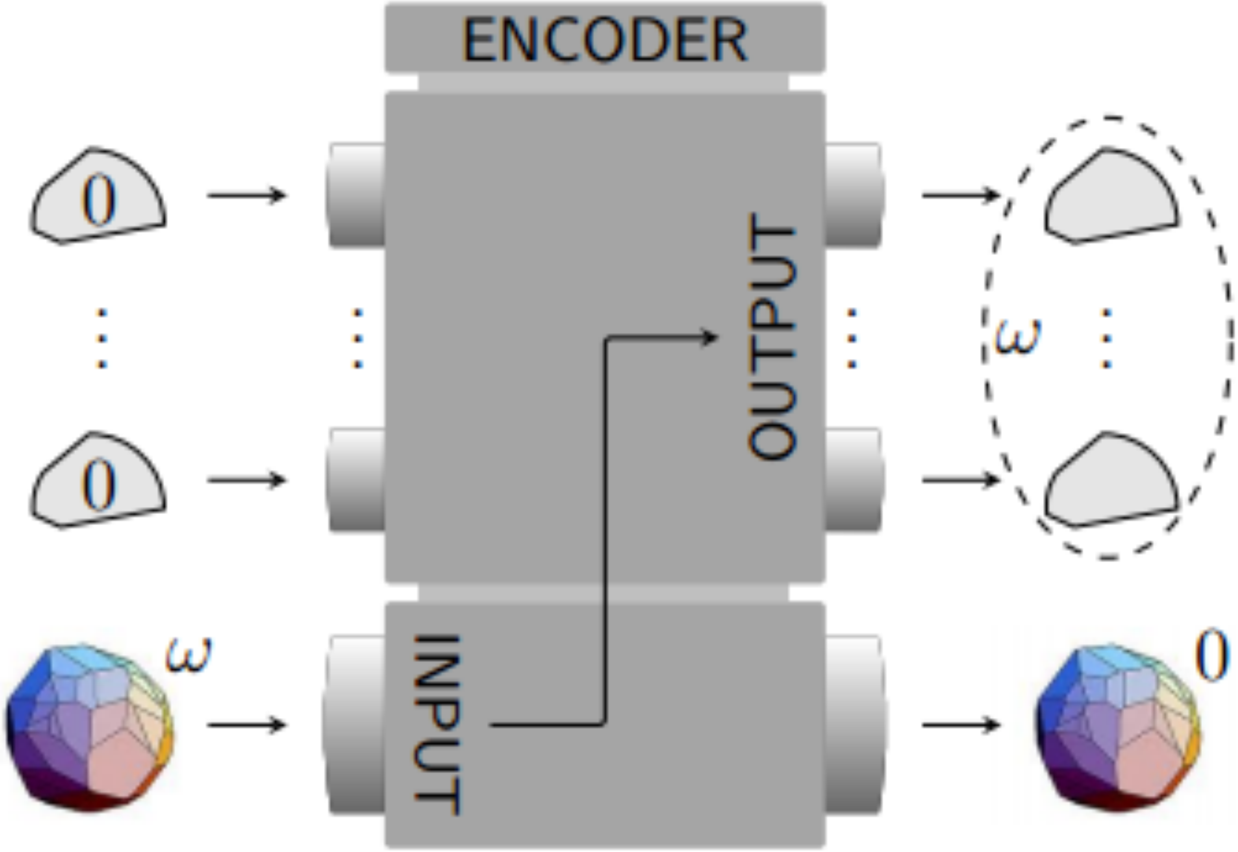

How Quantum Mechanics Derives from a Revolutionary New Theory of Information

Information and computation form the bedrock of the reality, say physicists who have used this idea to derive quantum mechanics

The Physics arXiv Blog in The Physics arXiv Blog

One of the great puzzles of quantum mechanics is that nobody quite understands what it means for reality to be quantum in nature. Indeed, many physicists entirely disagree over the correct interpretation. The result is a frustratingly woolly insight into the nature of the Universe.

That’s quite unlike other fundamental theories. General relativity, for example, produces remarkable insights into the nature of spacetime. And Noether’s theorem—that every symmetry in the universe produces a conservation law—is one of the most satisfying and beautiful in science. Quantum mechanics, by contrast, is the poor relation.

The problem is that quantum mechanics has to be derived from abstract mathematical ideas that have little or no meaning in the real world. One common derivation, for example, uses the entirely abstract ideas of Hilbert spaces and the operators that act on them. So it’s hardly surprising that the theory is hard to interpret.

Today, that changes thanks to the work of Lluís Masanes at the University of Bristol in the UK and a few buddies who for the first time derive quantum mechanics from ideas that have a clear basis in reality. Their derivation is based on the revolutionary idea that information and computation form the bedrock of reality.

In the new work, Masanes and co put forward four postulates about the Universe. If we accept these, they say, quantum mechanics naturally follows. What’s more, their formulation solves an important question about reality—why the universe relies on quantum mechanics and not one of the numerous similar theories that physicists have recently discovered.

So what are these four postulates? Let’s go through them one by one.

1. The existence of an information unit.
This is the big new idea. It states that information exists, it comes in fundamental units and only in one type so there cannot be different types of information. Masanes and co call this fundamental unit a ‘general bit’ or gbit and say that any aspect of the Universe can be encoded given a sufficient number of them.

This idea has significant implications. If there is only one type of information, then everything in the universe must be possible with it. Or as Masanes and co put it: “Any physical process can be simulated with a suitably programmed general purpose simulator.”

Another way to think about this is that reality is substrate-independent. It’s always possible to reproduce one aspect of the universe perfectly using some other part.

2. No simultaneous encoding
This states that if a gbit is used to perfectly encode one classical bit, it cannot simultaneously encode any more information.

3. Continuous reversibility
This is the idea that a pure state can always be made to evolve into another pure state in a continuous, reversible way.

4. Tomographic locality
When a state is made of many components, it can be completely characterised by measured correlations between the individual component

parts.

And that’s it. Masane and co go on to show that combining the mathematical formulations of these ideas leads directly to quantum mechanics. Indeed, they show that the *only* theory that obeys them all is quantum mechanics.

That’s significant because by relaxing some of these ideas, other types of physics emerge. For example, relaxing the condition of continuity in the second postulate leads to the classical probability theory that governs the macroscopic world.

That’s interesting work with profound implications. It gives physicists a set of physically realistic and acceptable ideas on which the theory is based. Chief among these is the idea that information and computation somehow form the bedrock of reality, an idea that has been knocking around in physics for some time now without anybody nailing it.

The problem with information as a fundamental unit is that physicists have never been sure how to think about information. That’s partly because we are surrounded by seemingly different types of information. There are the 0s and 1s of digital code, information in the form of entropy or as the opposite of randomness, genetic information and even the stuff we use for thought and communication.

The question is how are these different types of information related? Masane and co solve the conundrum by saying they are identical. There aren’t any different types of information, only gbits.

In some ways this is equivalent to the position that physicists found themselves in 200 years ago when thinking about energy. They knew energy was important but were overwhelmed with the different forms it could take—chemical energy, heat energy, gravitational potential, kinetic energy and so on.

It was the realisation that all these were different manifestations of the same fundamental thing that solved this problem. That led to the law of conservation of energy and to profound new insights into the universe.

Interestingly, Masanes and co do not tackle the thorny issue of whether information is conserved (or the symmetry that might lead to this conservation law).

That's clearly something for another day. Any budding theoretical physicists with some time on their hands might find this an enlightening avenue to pursue.

Ref:arxiv.org/abs/1208.0493: Existence Of An Information Unit As A Postulate Of Quantum Theory

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