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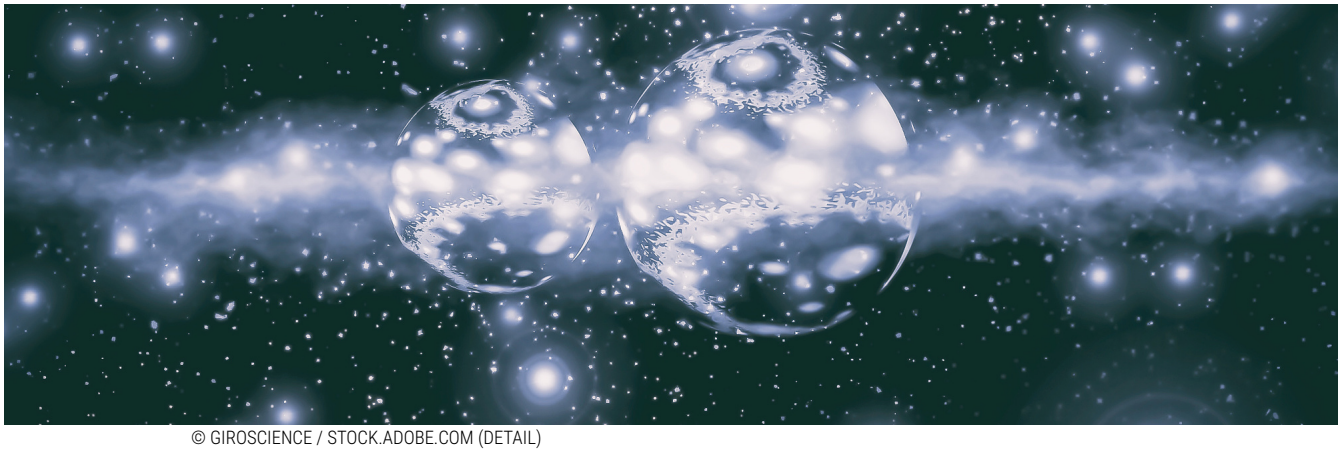
UNIVERSE

God's last loophole

Quantum physics is based on coincidence, as physicists are actually sure. But a residual doubt remains. A new experiment is supposed to get rid of him.

by Robert Gast



What is guiding the universe? Since the beginning of the 20th century, physicists believe they know the answer: The world is based on chance. He determines whether atomic nuclei fall from one moment to the next. Whether electrons bounce left or right. Or whether suddenly a radiant flash appears from nowhere, directing the microcosm at an important point in an unexpected direction.

That is what the formulas of quantum physics say, developed by physicists like Niels Bohr, Werner Heisenberg and Erwin Schrödinger almost a century ago. But is that the whole truth? Is there really nobody who decides before each quantum move which path nature chooses? Albert Einstein had big problems with this idea. "God does not roll the dice!" He is supposed to have said.

God is actually throwing dice

At the moment it looks as if the century genius was wrong - God dices, and always. Experiments have long since proven not only the randomness of quantum physics, but also revealed other peculiarities. Thus, quantum objects are always in a superposition of several states, similar to a football lying in front of and behind the goal line at the same time. It is only in a measurement that nature decides on the basis of probabilities exactly where an object is (or what properties it has).

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John Bell at CERN | |
The physicist John Stewart Bell (1928-1990) used his theorem to examine the central contradictions of classical physics inherent in quantum physics.
In this recording from 1982, he is standing in a seminar room of CERN on a blackboard. |

It is particularly bizarre when physicists describe several interacting particles, such as photons, the quantum particles of light. Their states are then also superimposed, and curiously, this remains so when the light particles move away from each other. The consequence is hard to imagine: when measuring a quant, the state of its partner is also defined; physicists speak of "entanglement".

Hope for hidden variables

Especially crazy: entangled particles even react to the measurement of their partner, even if this is actually too far away to transmit the signal at the speed of light (the cosmic speed limit). From the point of view of most people, something very strange is going on in the microcosm.

Albert Einstein - he was really not a fan of quantum theory - mocked this prediction of his colleagues as "ghostly long-range effect." He suspected that there is a deeper, deterministic level of reality that determines how a measurement ends. That would remove chance from the world view of physics.

Together with Boris Podolsky and Nathan Rosen Einstein 1935 invented a famous thought experiment on this question. The Irishman John Stewart Bell developed the idea further and in 1964 designed an experiment to put quantum physics to the test in the laboratory.

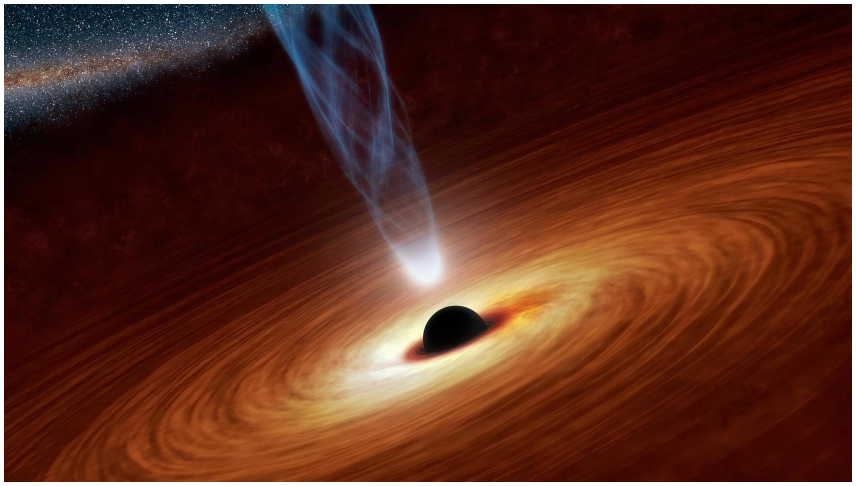
Bell's thought: If quantum physics is really purely random, the degree to which the states of entangled particles correlate should always exceed a certain threshold. In the meantime, many of these Bell tests have been carried out. The result was always clear. In fact, quantum theory is what Einstein feared: coincidental and a crystal clear violation of "local realism," that is, the assumption that objects must be causally linked when they interact.

But no coincidence?

But until today there are gaps. One of them, the so-called "freedom-of-choice" loophole, is particularly hard to cram and has been attracting a lot of attention for several years. The core issue is the question of whether physicists could only fool the random character into quantum measurements. That is quite

conceivable so far.

Physicists use only quantum objects from Earth for their Bell tests. For example, they interleave two photons and test their polarizations with the aid of two optical modulators, which pass only light particles of a certain vibration direction. Which is that, determine random number generators. Many measurements give us an idea of how strongly the states of entangled particle pairs correlate, and how clearly they violate local realism.



Quasar | |
A quasar - artistically depicted here - arises when a supermassive black hole with its enormous gravity gradually consumes the rotating disk of gas and dust that surrounds it.
The radiation of the giants is still visible in billions of light years away. |

But what if nature linked the photons and the two random number generators on a hidden level of reality? In that case, something might come out of the measurement that looks random, but in truth represents a causality that goes back to the value of Einstein's "hidden variables."

Hundred years old photons

A year ago, physicists made a spectacular measurement that reduced this loophole . In it they used light particles, which came from distant stars, as the basis of their random generators. The photons were hundreds of years before their use in the random generator and came from different corners of the universe. Thus physicists could rule out that they had influenced other part of the experiment during the past 600 years .

But that was only the beginning of the fight against the "freedom-of-choice" loophole. In the long term physicists still want to carry out ambitious experiments. An important milestone in this direction is now presented by a team led by David Kaiser of the Massachusetts Institute of Technology: the researchers have developed the random generator from the 2017 experiment of their colleagues. This could close the loophole even further than before, say the researchers in the journal "Physical Review A" .

The random generator of Kaiser and colleagues not only uses the light of stars from the Milky Way, but also that of twelve quasars. Behind them lie the cores of active galaxies, which repeatedly fire large amounts of radiation into space - and which are billions of light years away from each other and from us.

Some of the extremely far-traveled photons could be equipped in the future, the random generators in Bell tests, the researchers write. If such bored tests once again confirm quantum physics, critics would have to argue that particles have settled over a distance of billions of light years. This would significantly reduce the space for a cosmic quantum conspiracy.

The ultimate loophole

It is quite possible that such a measurement will succeed in the foreseeable future. But at least one loophole would remain unaffected: What if at the Big Bang something manipulated all the particles in the universe far-sighted? And in such a way that it looks at today's measurements as if they happened

by chance? Albert Einstein would probably like such "hyper-determinism". The only question is why a presumed creator should resort to such a treachery in order to lead mankind by the nose.

Robert guest

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