John Bell Across Space and Time

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Abstract

This is a review of the book **Quantum [Un]speakables: From Bell to Quantum Information**. Reinhold A. Bertlmann and Anton Zeilinger (editors). xxii + 483 pp. Springer-Verlag, 2002. $89.95.

Ten years after his death, one of the sharpest minds in quantum physics was celebrated in a memorial conference.

John Stewart Bell (1928-1990) was one of the leading physicists of the 20th century, a deep and serious thinker. He worked at CERN in Geneva on the physics of particle accelerators, made a number of impressive contributions to quantum field theory, and became famous for the discovery of a phenomenon he called nonlocality. However, the most remarkable thing about him was perhaps that he was a realist.

Realism is the philosophical view that the world out there actually exists, as opposed to the view that it is a mere hallucination. We are all born realists, but some of us change our minds as adults. Now it may seem to you that for physics to make any sense, a physicist would have to be, or at least pretend to be, a realist; after all, it would seem that physics is about finding out how the world out there works.

But, as a matter of fact, in the 1920s Niels Bohr, the leading quantum physicist of his time, began to advocate the idea that realism is childish and unscientific; he proposed instead what is now called the "Copenhagen interpretation" of quantum physics, a rather incoherent philosophical doctrine, which (according to Richard Feynman) "nobody really understands." Part of this doctrine is the view that macroscopic objects, such as chairs and planets, do exist out there, but electrons and the other microscopic particles do not. Correspondingly, Copenhagen quantum theory refuses to provide any consistent story about what happens to microscopic objects, and instead prefers to make contradictory statements about them. According to the Copenhagen view, the world is divided into two realms, macro and micro, "classical" and "quantum," logical and contradictory—or, as Bell put it in one of his essays, into "speakable" and "unspeakable."

Although it is not clear where the border between the two realms should be, and how this duality could possibly be compatible with the fact that chairs consist of electrons and other particles, Bohr's view became the orthodoxy. That is, it became not merely the majority view among physicists, but rather the dogma. Ever since, being a realist has been rather dangerous for a quantum physicist, because it has been widely regarded as a sign of being too stupid to understand orthodox quantum theory—which, as we've mentioned, nobody really understands.

Along with Albert Einstein, Erwin Schrödinger, Louis de Broglie and David Bohm, Bell was one of the few people who felt compelled by his conscience to reject Bohr's philosophy. Bell emphasized that the empirical facts of quantum physics do not at all force us to renounce realism: There is a realist theory that accounts for all of these facts in a most elegant way—Bohmian mechanics (also known as de Broglie–Bohm theory). It describes a world in which electrons, quarks and the like are point particles that move in a manner dictated by the wave function. It should be taught to students, Bell insisted, as a legitimate alternative to the orthodoxy. And in 1986, GianCarlo Ghirardi, Alberto Rimini, and Tullio Weber succeeded in developing a second kind of realist theory, encouraged by Bell and known as *spontaneous localization*. But overcoming prejudice and changing convictions takes more than one generation.

Quantum [Un]speakables is the proceedings volume of a conference held at the University of Vienna in November 2000 to commemorate the 10th anniversary of Bell's death. The 30 articles written for this volume by 35 authors deal foremost with nonlocality and, of course, the meaning of quantum theory. The contributions focus very much on personal recollections and mostly presuppose that the reader is familiar with the relevant physics and mathematics. The recollections make this book a valuable source both on John Bell the man and on the history of quantum physics between 1950 and 1990. Among other things, several authors complain about the dogmatic aversion among physicists in the 1960s to even take note of Bell's nonlocality theorem.

Quantum [Un]speakables also reflects the prevailing situation in the year 2000 in that it collects personal, diverging views about the meaning of quantum physics from a cross-section of physicist. The cross-section is biased, though, because researchers working on Bohmian mechanics, of which Bell was the leading proponent during the decades before his death, were simply not invited to the conference, and the realists are in the minority among the authors. Thus we recommend that readers be very cautious in regard to the conclusions drawn in this book about the foundations of quantum physics.

This warning concerns in particular the conclusions drawn from Bell's nonlocality theorem. Let us tell the story briefly here. Bohmian mechanics involves superluminal action-at-a-distance and thus violates the "locality principle" of relativity theory. This was considered, by the Copenhagen camp, an indication that Bohmian mechanics was on the wrong track. In 1964, Bell proved that any serious version of quantum theory (regardless of whether or not it is based on microscopic realism) must violate locality. This means that if nature is governed by the predictions of quantum theory, the "locality principle" is simply wrong, and our world is nonlocal. It also means that the nonlocality of Bohmian mechanics is not a sign of its being on the wrong track, but quite the contrary.

The Copenhagen view, in comparison, is indeed less local: It is nonlocal in cases that Bohmian mechanics can explain in a purely local way. (For example, for a particle in a quantum state that is a superposition of being in London and being in Tokyo, according to Copenhagenism there is no matter of fact about whether the particle actually is in London or in Tokyo prior to the first attempt at detection—which presupposes a temporal ordering.) But it is also contradictory, vague and confusing enough for its adherents to claim it is completely local, and thus that nonlocality is a consequence of an attachment to *realism*. Therefore, so the argument goes, it was Bell who finally proved realism wrong! Bell, of course, emphatically rejected this incorrect interpretation of his nonlocality theorem.

The crucial experiments violating Bell's inequality and thus, according to Bell's theoretical analysis, demonstrating nonlocality have been performed many times since 1980, and have also lead to significant improvements in experimental techniques. Some of these techniques have now become valuable for quantum cryptography and the first steps towards the construction of a quantum computer. These two fields are usually summarized under the key word "quantum information," and great hopes are expressed, also in *Quantum [Un]speakables*, that quantum information will provide new insights into the nature of the quantum world.

But we see no reason for such hopes. Quantum information theory is a straightforward application of the rules laid down in, for example, John von Neumann's classic 1932 book on the mathematical foundations of quantum mechanics. Any interpretation of quantum mechanics, to the extent that it succeeds in explaining these rules, also explains quantum computers and the like. And to the idea that quantum theory may after all be merely about information and nothing else, Bell responded with a crucial question: "Information? Whose information? Information about what?"

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