Excerpt: David Z. Albert & Rivka Galchen - Scientific American - Vol 22, Summer 2013

The other recent result, discovered by one of us (Albert), showed that combining quantum mechanics and special relativity requires that we give up another of our primordial convictions. We believe that everything there is to say about the world can in principle be put into the form of a narrative or story. Or, in more precise and technical terms: everything there is to say can be packed into an infinite set of propositions of the form "at tl this is the exact physical condition of the world," and so on. But the phenomenon of quantum-mechanical entanglement and the spacetime geometry of special relativity-taken together-imply that the physical history of the world is too rich for that.

That result, like most theoretical results in quantum mechanics, involves manipulating and analyzing a mathematical entiry called a wave function, a concept Erwin Schrodinger introduced eight decades ago to define quantum states. It is from wave functions that physicists infer the possibility (indeed the necessity) of entanglement, of particles having infinite positions, and so forth. And it is the wave function that lies at the heart of puzzles about the nonlocal effects of quantum mechanics.

But what is it, exactly? Investigators of the foundations of physics are now vigorously debating that question. Is the wave function a concrete physical object, or is it more like a law of motion or an internal property of particles or a relation among spatial points? Or is it merely our current information about the particles? Or what?

Quantum-mechanical wave functions cannot be represented mathematically in anything smaller than a mind-bogglingly high-dimensional space called a configuration space. If, as some argue, wave functions need to be thought of as concrete physical objects, then we need to take seriously the idea that the world's history plays itself out not in the three-dimensional space of our everyday experience or the four-dimensional spacetime of special relativity but rather this gigantic and unfamiliar configuration space, out of which the illusion of three-dimensionality somehow emerges. Our three-dimensional idea of locality would need to be understood as emergent as well. The non-locality of quantum physics might be our window into this deeper level of reality.

The status of special relativity, just more than a century after it was presented to the world, is suddenly a radically open and rapidly developing question. This situation has come about because physicists and philosophers have finally followed through on the loose ends of Einstein's long-neglected argument with quantum mechanics-an irony-laden further proof of Einsten's genius. He may turn out to have been wrong just where he was widely thought to be right and right just where he was widely thought to be wrong.