

Superdeterminism

Superdeterminism is a concept in which everything is pre-determined and that free will is an illusion. In the case that Nature is superdetermined, an experimenter's choice of settings in performing the CHSH test cannot be done independently of the preparation of the two spin $\frac{1}{2}$ particles. Bell assumes in his derivation of his inequality that the settings of the CHSH test can be chosen independently of any hidden variables that might be used to predict the outcome of the experiment.

Superdeterminism is a natural consequence of Unitarianism. If one believes that everything obeys a universal wave function that evolves according to Schrödinger's equation, then in some sense everything is gear-like or mechanical.

Suppose that a gear (Gear 1) is thrown toward another spinning gear (Gear 2) such that the two gears can either mesh perfectly or can be misaligned and cause grinding. If it is found that the two gears always mesh perfectly and are never misaligned, then it must have been that when the gear was thrown that it was already time-synchronized with the second gear. Suppose that unitary evolution is found to have a similar property. Then the Unitarian might conclude that the question of hidden variables is irrelevant. Free will (in the sense of non-unitary physics) is an illusion to the Unitarian, and the preparation of the photons could be such that the results are already compatible with the selection of the angles in the CHSH test, for which the experimenter has no real say. Let us consider if unitary physics provides a back action when Gear 1 is not aligned with Gear 2. Consider a simple energy-conserving interaction Hamiltonian between two two-level systems. One can ask if the initial condition on the phase of one of the particles can in any manner change the time for the second two-level system to become excited. It turns out that the initial phase of the first particle is irrelevant and the time to become excited is independent of the initial phase. Hence in the sense of the two classical gears, there is no grinding to be expected in unitary theory. It does appear perfectly reasonable if one is an unwavering Unitarian to conclude that the gears of unitary evolution will *always* be found to be meshed: in the plus x direction and in the -x direction, in the +y direction and in the -y direction, in the +z direction and in the -z direction, and also forward in time +t and backward in time -t.

Remarkably, there is an important characterization in the mathematics of functions that appears to lend some support to the physical theory of superdeterminism [158]. A function is defined as an analytic function when it can be represented by a convergent power series. One might ask what should this have to do with physics? An analytic function has the property that one can determine the entire function from the function in any small interval. That is, if a wave function is analytic, then one can determine the wave function 100 miles away simply by analyzing it in any small interval. And many important wave functions that are eigenstates of the Hamiltonian that have been derived in quantum mechanics are analytic wave functions. For example, the theoretical solutions of the electron orbits that define the hydrogen atom are analytic, and these analytic functions have been so successfully verified in experiments that one might even consider the hypothesis that such electron orbits are truly analytic. These

properties of unitary evolution appear to leave open the possibility that superdeterminism is indeed relevant to certain issues in the foundations of physics. There have been a number of arguments that are counter to superdeterminism. Bell states [159, p. 101]

A respectable class of theories, including contemporary quantum theories as it is practiced, have 'free' 'external' variables in addition to those internal to and conditioned by the theory. These variables are typically external to and conditioned by the theory. These variables are typically external fields or sources. They are invoked to represent experimental conditions. They also provide a point of leverage for 'free willed experimenters', if reference to such hypothetical metaphysical entities is permitted. I am inclined to pay particular attention to theories of this kind.

Furthermore, [159, p. 103]

A theory may appear in which such conspiracies inevitably occur, and these conspiracies may then seem more digestible than the non-localities of other theories. When that theory is announced I will not refuse to listen, either on methodological or other grounds. But I will not myself try to make such a theory.

Bell is rather negative in terms of endorsing superdeterminism, although he does not close the door entirely on superdeterminism. Additionally, Zeilinger has criticized superdeterminism on the basis of the scientific process which allows one to vary parameters of an experiment [160, p. 266]:

*See the print edition of *The Quantum Measurement Problem* for quotation.*

It is interesting that the arguments by Bell and Zeilinger are not scientific proofs that conclusively show that superdeterminism is false; rather their arguments are based largely on the existence of free will to modify external fields or parameters as allowed in regards to the established scientific method. Still such arguments are heuristically compelling to many and very few have seriously considered superdeterministic theories.

A proposal based on superdeterminism has however been put forward recently by 't Hooft [161] [162]. Don't be surprised to see more superdeterministic theories put forward by devoted Unitarians.