Einstein's Ghost Field

Einstein believed that the state of *N* particles should be specified via a product of states associated with each of the *N* particles and that the evolution of these particles should be specified by a product state operator. This is discussed further by Howard [3, p. 60]. A product state operator has the property of operating independently on each particle that composes the initial state. Each component or particle of a product state will add an amount toward any observable quantity that is independent of the other particles. Quantum states can be further categorized as *separable* or *entangled*. A product state is an example of a separable state.

There are several reasons why Einstein believed that particle time and space evolution should be governed by such a product state evolution operator and the initial states be product states. The primary reasons appear to be: 1) the Boltzmann entropy formula is only fully additive for multiple particles when the particles are independent [3, p. 74], 2) an entangled state composed of a Particle *A* that is separated from a Particle *B* has the property that Particle *B* does not have a physical well-defined state that is independent of a measurement on Particle *A* [3, p. 91], and 3) Einstein believed non-separable theories were non-causal [3, p. 84].

Interestingly it appears that Einstein also had more than one reason to believe the contrary: the derivation of Planck's radiation law required an assumption that particles were not mutually independent [3, p. 78] and the Bose-Einstein statistics that were later derived in 1925 also showed statistical dependence between particles that Einstein believed pointed to a "physically mysterious interaction." [3, p. 68] The entangled states might appear to be just another example of such non-independence, so one might wonder why Einstein did not accept such states. The reason may be that the lack of independence in the derivation of Planck's radiation law and Bose-Einstein statistics perhaps could still be hoped to eventually be explained by reasons other than the breakdown of the reality of local states that is seen rather poignantly in the theory of entangled states. It does appear that Einstein had an in-depth knowledge of the most significant issues regarding quantum mechanics and what was to become ultimately, the measurement problem.

In 1925 Einstein presented a lecture in which he considered that individual particles were accompanied by a ghost field that guides the particles [4, p. 222]. In Einstein's ghost field, the evolution of the particles is governed by a classical tensor product evolution. However, the problem for Einstein was that such a tensor product evolution could violate energy conservation when one particular term was considered for any single outcome.

Note that at least in this model, one is seemingly left to either accept action-at-a-distance through the existence of entangled states, or to reject energy conservation on every outcome in favor of energy conservation on-average [4, p. 226]. It does not appear that Einstein was comfortable with either of these alternatives and the ghost field was never published and faded into obscurity. The reasoning for rejection of Einstein's model has since been reconsidered in more depth by Holland [5] in regards to realistic trajectory theories.