EPR and the Bell Inequality

In the classical world, our intuition tells us that the physical properties of objects (i.e. – position of a football) exist independent of observation. Contrary to that, the postulates of quantum mechanics says that physical properties of objects appear only as a consequence of measurement/observation; thus, an unobserved object (essentially, in the quantum world, particles), do not possess physical properties independent of observation. Along with the given postulates of quantum mechanics, we can only ascribe to each physical property of an object probabilities for each possible measurement outcome/observation.

Nonetheless, we must introduce Albert Einstein, Nathan Rosen, and Boris Podolsky. The three introduced the famous *EPR paradox*, which was an attempt to show that quantum mechanics is incomplete. EPR paradox attempted to prove that physical properties of interacting particles, essentially, their positions and momentum, can be measured more accurately than the Heisenberg's uncertainty principle allowed if they interacted in a certain way.

30 years later, a new experimental test was performed that experimentally invalidated the EPR paradox. The experimental invalidation was due to a mathematical formulation defined as *Bell's inequality*. Bell's inequality can be described with a thought experiment, requiring just our intuition, followed by a quantum mechanical analysis, which will be inconsistent with the former analysis. The former analysis follows the thinking of Einstein, Rosen, and Podolsky, while the latter analysis disqualifies their thinking.

The formulation of Bell's inequality was followed by many experiments which showed that Nature appeared to obey the latter analysis. Review detail of Bell's inequality here.

In conclusion, one or more of the assumptions that went into the former analysis of Bell's inequality were incorrect, which is still a place of debate among Physicists today. Essentially, two overarching assumptions were made in the former analysis of Bell's inequality.

1. *Realism*: Physical properties have definite values independent of observation.
2. *Locality*: Measurement on one particle does not influence measurement on another particle.

The two combined are defined as *local realism*. Nevertheless, today, Bell's inequality, alongside many experimental evidence, show that either or both assumptions are incorrect for our world view. Coincidentally, further progression of our understanding of quantum mechanics requires that we drop either or both assumptions.