

Quantum Randomness in Nature

Full randomness from arbitrarily deterministic events in Nature Communications.

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Do random events exist in nature? This question has attracted and keeps attracting the interest of many different communities, ranging from philosophers to physicists and mathematicians. Classical physics is deterministic and does not contain any form of randomness. Quantum physics, however, does contain some form of randomness as it is only able to make predictions in probabilistic terms. Yet, the fact that a theory is only able to make probabilistic predictions does not necessarily imply that nature is random, but may simply be a limitation of the predictability power of the theory.

In 1964, Bell proved a theorem where he implied that quantum theory cannot be completed, suggesting the existence of an intrinsic form of randomness in the quantum world. Unfortunately Bell's theorem assumes in its derivation the existence of an initial source of perfect randomness, which introduces circularity in the argument: random processes are

shown to exist by assuming an initial random source!

The necessity of some form of randomness to run a Bell test implies that the strongest proof of randomness one can hope for using quantum physics is the following: does any amount of randomness, however small, suffice to run a Bell test that certifies perfect randomness? In other words, can randomness be amplified in the quantum regime?

A study carried out by the research group led by ICREA Professor at ICFO, Antonio Acin, recently published in Nature Communications, provides a solution to this question and indicates that randomness is indeed unavoidable in our description of nature: given an arbitrarily small amount of initial randomness, they show how non-local quantum correlations certify the existence of fully random processes in nature.

Beyond the clear implications this achievement has from a fundamental perspective, the obtained results are also relevant for quantum information processing. In fact the study provides the first quantum protocol for full randomness amplification. In randomness amplification, the goal is to extract perfect random bits from a source of arbitrarily imperfect randomness. In a seminal work, Santha and Vazirani proved that randomness amplification is impossible when relying only on classical systems. In this study, the results obtained by Acin?s group prove that full randomness amplification becomes possible when using quantum resources.