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Is the World Local or Nonlocal? – Towards an Emergent Quantum Mechanics 80 Years after EPR

80 years after Einstein, Podolsky, and Rosen (1935), workers in quantum foundations are still debating whether science must give up entirely the idea of an ‘objective reality’. What is ‘locality’? What is ‘nonlocality’? What is ‘the world’? What does it mean for an object ‘to exist’ in the first place? The question concerning ‘ontology’ has turned out to be a hard one to answer when it comes to reality’s smallest dimensions – the quantum. Significantly, despite defending opposite ends of the metaphysical spectrum – indeterminism versus determinism – Bohr and Einstein were in complete agreement, however, on the impossibility of “action-at-a-distance”, i.e., of the ‘objective’ or ‘intrinsic’ nonlocality of nature!
Could the inherently nonlocal structure of quantum theory (e.g., non-separability, relationality, or holism) imply that the empirical reality it accounts for is intrinsically nonlocal as well? It is well-known that orthodox, operationalist quantum mechanics vigorously denies fundamental interconnectedness: the orthodox position (e.g., Copenhagen) holds that only exclusively local phenomena could have existence in any physical sense; central tenets of orthodox quantum mechanics would otherwise be violated, i.e., intrinsic randomness and the non-signalling constraint.
By contrast, non-orthodox, realistic quantum mechanics as exemplified by de Broglie-Bohm theory, has long postulated the (ontic) existence of instantaneous, nonlocal influences (Bohm, 1952ab). Crucially, in realistic quantum mechanics the observed ‘quantum randomness’ need not be viewed as evidence for the rule in nature of ‘objective chance’ but as evidence only for the ‘in-principle unpredictability’ of individual quantum events. This is the case even when these events are governed by deterministic relations. In the realistic quantum mechanics of Bohm, individual quantum events, we propose, represent strictly ‘emergent events’. The chief characteristic of emergence, self-organization, or complexity, theory is its account of the appearance of novel, unpredictable outcomes based upon entirely deterministic relations. Put simply, the concept of emergence represents a concept of “determinism without pre-determinism”: an ‘indefinite ontic structure’ (IOS) becomes a ‘definite ontic structure’ (DOS) as a result of new boundary conditions.
Therefore, the development of an “emergent quantum mechanics” (EmQM), as envisioned here, calls for research into the microscopic processes manifesting IOS-DOS transitions, a form of “quantum reality without pre-determination” ensuring free will of the observer/agent in science.
Does Bell’s theorem (Bell, 1964) imply necessarily the impossibility of instantaneous nonlocal

influences, i.e., of those influences which Bohr and Einstein denied so vehemently? To the contrary, it is well-established that Bell himself, like Bohm, was a realist about quantum mechanics, and that he maintained a strong interest in Bohm's theory even long after publishing his seminal proof. Since Bell and Bohm were unified on the concept of "reality without pre-determination", even at the level of the quantum, both can be considered foundational pioneers of the EmQM project. Finally, it is highly likely that – assuming nonlocality – the possibility of an EmQM will depend on breakthroughs in our understanding of space-time itself as an emergent phenomenon. Fact is, an increasing number of physicists are convinced that space is an emergent, not fundamental, concept, as exemplified in new approaches such as 'emergent gravity'. "Emergence" may stand central in unification efforts.

References

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[1,2] This work is funded in part by the Fetzer Franklin Fund of the John E. Fetzer Memorial Trust.

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