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Can Decoherence make quantum theories unfalsifiable? Understanding the quantum-to-classical transition without it

Decoherence plays a relevant role in many foundational problems: the quantum measurement, the emergence of the classical world, the origin of irreversibility, etc. However, the proper definition and understanding of what decoherence means is still a vigorous on-going field of research and controversies.
In principle, decoherence is just a consequence of the quantum entanglement between an open system and its environment. However, due to the many-body computational burden associated with treating a large number of particles, many times decoherence is not explicitly computed, but postulated instead as a new “magical” source of physical phenomena (like an additional fundamental law) that can explain by itself the appearance of irreversibility and non-linearity, why the entropy grows, why quantum systems become classical, etc. Within this last point of view, any disagreement between predictions and experiments can always be attributed to the lack of a “proper” modelling of the decoherent phenomena, not to a failure of the theory itself. This last understanding of decoherence makes quantum theories unfalsifiable (true by construction) and universal (valid for any system by definition). Thus, any predicted deviations from present quantum theories, for example (a limited spatial range of non-locality [1]) become undetectable. Examples on how decoherence can be included as a fundamental law in quantum transport for mesoscopic systems satisfying thermodynamics requirements will be critically discussed [2].
In this conference, I will show, without invoking decoherence in any sense, how a closed quantum system becomes classical when a very large number of particles are involved [3]. Using Bohmian mechanics, the conditions for the classicality are obtained only for the centre of mass of a macroscopic closed system, not for other degrees of freedom, at each individual experiment, not for an ensemble of experiments. It is shown that the conditions to ensure that the centre of mass follows a Newtonian trajectory are naturally satisfied by most macroscopic systems, when the number of particles is large enough [3]. This last result shows clear evidences for the ontological goal of providing quantum-classical inter-theory unification and a deeper understanding of what decoherence means, allowing a better definition of an intermediate domain of physics, where the behaviour is neither purely quantum nor classical.

[1] T. Norsen, D. Marian, X. Oriols “Can the wave function in configuration space be replaced by single-particle wave functions in physical space?” Synthese, 1-27, (2014).
[2] X. Oriols, Z. Zhen, E. Colomés and D. Marian “Dissipative quantum transport using one-particle time-dependent (conditional) wave functions” International Workshop on Computational

Electronics (IWCE), USA, (2015).
[3] D.Tena, A. Benseny and X. Oriols “Natural classical limit for the center of mass of a many-particle quantum system” Submitted (2015).

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