The Illusory Appeal of Decoherence in the Everettian Picture: Affirming the Consequent

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ABSTRACT. The idea that decoherence in a unitary-only quantum theory suffices to explain emergence of classical phenomena has been shown in the peer-reviewed literature to be seriously flawed due to circularity. However, claims continue to be made that this approach, also known as “Quantum Darwinism,” is the correct way to understand classical emergence. This Letter reviews the basic problem and points out an additional logical problem with the argument. It is concluded that the “Quantum Darwinism” program fails.

1. Introduction.

The idea that unitary-only dynamics can lead naturally to preferred observables, such that decoherence suffices to explain emergence of classical phenomena (e.g., Zurek 2003) has been shown in the peer-reviewed literature to be problematic. However, claims continue to be made that this approach, also known as ’Quantum Darwinism,’ is the correct way to understand classical emergence.

The problem of basis ambiguity in the unitary-only theory is laid out particularly clearly by Bub, Clifton and Monton (1996), and the difficulty highlighted by them is not resolved through decoherence arguments alone. This is because decoherence is relational rather than absolute (Dugić and Jeknić-Dugić 2012; Zanardi et al 2004). In order to get off the ground with a particular structure, “Quantum Darwinism”-type arguments depend on assuming special initial conditions of separable, localizable degrees of freedom, along with suitable interaction Hamiltonians, which amount to “seeds” of classicality from the outset.

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Under these circumstances, the purported explanation of classical emergence becomes circular (Kastner, 2014a, 2015). But circularity is not the only problem with the decoherence-based attempt to explain the emergence of classicality. In what follows we examine the logical structure of the argument and find a further, serious flaw: affirming the consequent.

2. The logical flaws of “Quantum Darwinism”

The structure of the Quantum Darwinism argument is as follows:

If 1. the quantum dynamics is unitary-only, and
if 2. the universe has initially separable, localizable degrees of freedom such as distinguishable atoms, and
if 3. those degrees of freedom interact by Hamiltonians that do not re-entangle them, then
4. classicality emerges.

For decoherence to account for the emergence of classicality under the assumption of unitary-only (U-O) evolution (approximately and only in a “FAPP” sense, see below), all three premises must hold. However, classicality is implicitly contained in 2 and 3 through the partitioning of the universal degrees of freedom into separable, localized substructures interacting via Hamiltonians that do not re-entangle them, so (given U-O) one has to put in classicality to get classicality out. Premises 2 and 3 are special initial conditions on the early universe that may not hold—certainly they are not the most general case for an initially quantum universe. Yet it seems common for researchers assuming U-O to assert that 2 and 3 also must hold without question. This actually amounts to the fallacy of affirming the consequent, as follows: one observes that we have an apparently
classical world (affirm 4), and then one asserts that 1, 2 and 3 therefore must hold.

The insistence on 2 appears, for example, in Wallace’s invocation of “additional structure on the Hilbert Space” as ostensibly part of the basic formalism (Wallace 2012, p. 14-15). Such additional structure—preferred sets of basis vectors and/or a particular decomposition of the Hilbert space—is imposed when quantum theory is applied to specific situations in the laboratory. However, what we observe in the laboratory is the already-emergent classical world, in which classical physics describes our macroscopic measuring instruments and quantum physics is applied only to prepared quantum systems that are not already entangled with other (environmental) degrees of freedom.

If the task is to explain how we got to this empirical situation from an initially quantum-only universe, then clearly we cannot assume what we are trying to explain; i.e., that the universe began with quasi-localized quantum systems distinguishable from each other and their environment, as it appears to us today. Yet Wallace includes this auxiliary condition imposing structural separability under a section entitled “The Bare Formalism” (by which he means U-O), despite noting that we assign the relevant Hilbert space structures “in practice” to empirical laboratory situations. The inclusion of this sort of auxiliary condition in the “bare formalism” cannot be legitimate, since such imposed structures are part of the application of the theory to a particular empirical situation. They thus constitute contingent information, and are therefore not aspects of the “bare formalism,” any more than, for example, field boundary conditions are part of the bare theory of electromagnetism. These separability conditions are auxiliary hypotheses to which we cannot help ourselves, especially since the most general state of an early quantum universe is not one that comes with preferred basis vectors and/or distinguishable degrees of freedom. Thus, the addi-
tion of this condition amounts to asserting (2), and becomes (at best) circular reasoning, or (at worst) outright affirming of the consequent, illicitly propping up the claim that quasi-classical world “branches” naturally appear in an Everettian (unitary-only) picture.

Now, to be charitable: perhaps unitary-only theorists are tacitly assuming that (1) is not subject to question; i.e. they take it as a “given.” If one presumes the truth of (1) in this way, then (2) and (3) seem required in order to arrive at our current apparently classical world. If (1) were really known to be true, the logical structure of the argument would be: 2 and 3 iff 4. So, rather than reject the argument based on its circularity, such researchers seem to assume that the consequent is evidence for the truth of premises 2 and 3 (i.e., 2 and 3 together are seen as the only way that we could have arrived at the classical macro-phenomena we now experience). The possibility that the dynamics may not be wholly unitary—the falsity of the unitary-only premise (1)—does not seem to be considered. However, the need to use a circular argument in order to preserve the claims of Quantum Darwinism should prudently be taken as an indication that the U-O assumption (1) may well be false, and that non-unitary collapse is worth exploring for a non-circular account of how classically well-defined structures arise in a world described fundamentally by quantum theory.

3. Conclusion.

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2Such an account is proposed in Kastner (2012) and (2014b). In that account (‘possibilist transactional interpretation’ or PTI), decoherence can of course occur under circumstances discussed in Zurek (2003), as a deductive consequence of quantum theory under certain specified conditions; but decoherence alone is neither necessary nor sufficient as an explanation for everyday classical phenomena such as the observed determinacy of macroscopic objects. Decoherence is not necessary because classical emergence can arise through a specific collapse process in PTI, and decoherence is not sufficient because it does not solve the measurement problem (cf. Bub 1997, p. 231).
Everettian unitary-only quantum theory seems to have become so “mainstream” that in many quarters it now appears to be considered the “standard” theory, replacing the theory consisting of Schrödinger unitary evolution plus von Neumann non-unitary measurement transition. Yet the only way to arrive at the world of classical phenomena we experience in the unitary-only theory is to assume classicality at the outset—and even this is only approximate and “FAPP,” since it fails to solve the measurement problem, as noted in Bub 1997, Section 8.2. The “decoherence” process as invoked in service of “Quantum Darwinism” is at best circular and at worst amounts to the logical fallacy of affirming the consequent. The alleged utility of decoherence is greatly overstated and illusory. It is time to consider the possibility that Everett might have been wrong.
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