Impossibility of Detecting Coherence

A logical possibility to be considered in regards to the resolution of the measurement problem is that there exists some physical limitation that prevents meeting the requirements of a Category 1 theory. For example, consider the previous mass threshold and charge threshold theories which indicate that double-slit interference is lost once the mass (or charge) becomes large enough that which-way information can be discerned from external measurements of the gravitational (or charge) field. If it were additionally found (this is not known as of yet) that it is impossible to discern the unitarily predicted entangled state from the measurement case of product states, then such theories would be rendered a Category 2 theory.

Note that one might argue that it is impossible to detect coherence because it requires reversibility of a macroscopic object. However, we have taken pains to develop the Chapter 3 UMDT in a manner that does not require the original interaction between photon and particle to be reversed. Hence claims that reversibility is required in order to conduct a UMDT appear to be falsified by the Chapter 3 UMDT.

In a paper by Hartle and Gell-Mann, they add an additional requirement of decoherence to the consistent history theory. However, we have already seen that decoherence is simply an orthogonalization methodology that by itself, is not sufficient to resolve the measurement problem. They state in [294]:

> *When the past is permanent, we may still lose the ability to retrodict the probabilities of alternatives in the past through the impermanence or inaccuracy of present records but not from the failure of those past alternatives to decohere in the face of the projections that describe information we acquire as we advance into the future. Yet we know that such continued decoherence of the past is not guaranteed in general by quantum mechanics. Adjoining future alternatives to a set of histories is a fine graining of that set and in general a fine graining of a decoherent set of histories may no longer decohere. Verifying the continued decoherence of all the past alternatives as we fine-grain our set of histories to deal with the future would in general require significant computation. We would have to check that the branches corresponding to every alternative past that might have happened continue to be orthogonal in the presence of their newly adjoined sets of projections. Yet we adjoin sets of projections onto ranges of quasiclassical operators without making this calculation, secure in the faith that previous alternatives will continue to decohere despite this fine graining. It is this assumption of continued decoherence of the past that permits the focus for future predictions on the one branch corresponding to our particular history and the discarding of all others. In other words, we pointed out above, it is the permanence of the past that permits the "reduction of the state vector."*

That is, the authors make an assumption of continued decoherence, in order to focus future predictions. However, such an assumption may or may not prove to be a sufficient condition for measurement and this issue is at the heart of a proper resolution of the measurement problem. For example, consider a spin particle that enters a Stern-Gerlach apparatus and splits into two paths. Suppose an experiment is performed in which the particle is allowed to split through a Stern-Gerlach apparatus and continues to propagate in a superposition. In such a case, there is continued decoherence of the past. If one concludes that continued decoherence of the past is sufficient for measurement, one is in for a surprise. It is possible within quantum mechanics to perform a different experiment and reverse the splitting and recombine the two paths in a manner that maintains coherence. Therefore, in terms of the Chapter 3 development, there is no measurement that has occurred due to the initial splitting.

One option is to demand or simply assume that it is impossible for reasons of thermodynamics or otherwise to physically reverse decoherence at some level. Omnès, who has written substantially regarding the measurement problem [295], has more recently examined the possibility of necessary randomness in the environment in tandem with decoherence theory [296]. Omnès considers the use of predecoherence of waves that randomly effect the growth of other waves that carry entanglement. The resultant of the wave interactions is allowed to generate random fluctuations in a manner that is consistent with the Born probability rules. However, Omnès admits that the randomness that would be required in the environment is still unexplained.

In cases such as in mass threshold theory, it does appear that first-order decoherence will be lost forever once a particle of substantial mass passes through the two slits in Figure 4.3. In cases other than mass or charge threshold theories, for which the underlying physics is in principle unitarily reversible, no physical rationale has been rigorously established as to why there should be measurement.

Although it a logical possibility, there is no experimental evidence to date nor theoretical rationale for expecting that unitary evolution *below* force thresholds (gravitational, etc.) should not be reversible. At its very core, the channels of reversibility are present in unitary evolution below threshold which can in principle be accessed to reverse any given operation. It would seem that a much more intelligent approach would be not to look toward unitary reversible processes in order to find irreversible processes, but rather into the existence of physical process that are indeed irreversible. These two rather different approaches will be further discussed in Chapter 6.