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Assessing the Montevideo interpretation of quantum mechanics

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ABSTRACT

This paper gives a philosophical assessment of the Montevideo interpretation of quantum theory, advocated by Gambini, Pullin and co-authors. This interpretation has the merit of linking its proposal about how to solve the measurement problem to the search for quantum gravity: namely by suggesting that quantum gravity makes for fundamental limitations on the accuracy of clocks, which imply a type of decoherence that 'collapses the wave-packet'.

I begin (Section 2) by sketching the topics of decoherence, and quantum clocks, on which the interpretation depends. Then I expound the interpretation, from a philosopher's perspective (Sections 3–5). Finally, in Section 6, I argue that the interpretation, at least as developed so far, is best seen as a form of the Everett interpretation: namely with an effective or approximate branching, that is induced by environmental decoherence of the familiar kind, and by the Montevideans' 'temporal decoherence'.

1. Introduction

This paper gives a philosophical assessment of a recent proposed interpretation of quantum theory, advocated by Gambini, Pullin and co-authors, and called by them 'the Montevideo interpretation'. (So I will dub these authors 'the Montevideans'.) Although the interpretation is bound to be controversial, it has the merit of linking its proposed solution to the measurement problem to the search for quantum gravity: in short, by suggesting that quantum gravity makes for fundamental limitations on the accuracy of clocks, which imply a specific temporal type of decoherence that 'collapses the wave-packet'. For it is surely a merit to link debate about quantum foundations to the search for new physics, even speculative new physics.

I therefore begin by sketching the standard topics on which the interpretation depends (Section 2). Then I expound the interpretation, from a philosopher's perspective (Sections 3–5).[1] Finally, in Section 6, I argue that the interpretation, at least as developed so far, is best seen as a form of the Everett interpretation: namely with an effective or approximate branching, that is induced by environmental decoherence of the familiar kind, and by the Montevideans' 'temporal decoherence'.

2. The landscape

I introduce the measurement problem and quantum clocks, in Sections 2.1 and 2.2 respectively. Then we will be ready for a prospectus about the Montevideo interpretation (Section 2.3).

2.1. *Collapse, Everett, decoherence—and gravity*

I will recall the relevant aspects of the measurement problem, by briefly sketching: the collapse of the wave-packet (Section 2.1.1), the Everett approach and decoherence (Section 2.1.2), and how the problem may be altered by considering gravity (Section 2.1.3). Later, I will return to these aspects in more detail: the first three in Sections 4.1 and 5.2, and the last in Section 5.1.

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[1] This interpretation has been developed in about a dozen papers over the last ten years. As I see matters, the main ones are Gambini, Garcia Pintos, & Pullin (2010, 2011b,a), Gambini, Porto, & Pullin (2006, 2007, 2008), and Gambini & Pullin (2007, 2009b,a). For the way in which considerations of quantum gravity, especially the 'problem of time' in quantized general relativity, have motivated the interpretation, cf. Gambini, Porto, Pullin, & Torterolo (2009) and Gambini & Pullin (2009a). But my summary will draw on just a few aspects of Gambini et al. (2007), and Gambini & Pullin (2009b,a); where I would recommend a philosopher to begin their reading. The papers are also available at a website: http://www.montevideointerpretation.org.

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2.1.1. *The collapse of the wave-packet*

Let us begin with the orthodox—or at least, traditional and minimalist—approach to securing that measurements have definite outcomes. ‘The collapse of the wave-packet’ refers to an irreducibly indeterministic change in the state of a quantum system, contravening the deterministic and continuous evolution prescribed by the Schrodinger equation. Anyone who advocates such a collapse, as a *bona fide* physical process that occurs to an isolated system, faces several questions. Three of the most pressing are as follows. Under exactly what conditions does the collapse occur? What determines the physical quantity (the basis) with respect to which it occurs? How does it mesh with relativity? Good questions, which went largely un-addressed by quantum theory's founding fathers: but which in recent decades have been addressed by a great deal of good work. Section 4.1 will mention one main line, the dynamical reduction programme of Ghirardi and others.

2.1.2. *Everett, decoherence and patterns*

The Everett or many-worlds interpretation proposes to reconcile quantum theory's deterministic evolution of the quantum state with the *apparent* collapse of the wave packet, i.e. with measurements having definite outcomes with various frequencies, by saying that measurement processes involve a splitting of the universe into branches. Obviously, this proposal has to face its own versions of the murky questions just mentioned: about the conditions under which a branching occurs, how we should understand branching, and how branching can mesh with relativity. Murky indeed. So it is hardly surprising that this interpretation has traditionally been regarded as vaguer and more controversial than others. Thus Bell (1986, 1987), in his masterly introduction to interpreting quantum theory, wrote that it ‘is surely the most bizarre of all [quantum theory's possible interpretations]’ and seems ‘an extravagant, and above all extravagantly vague, hypothesis. I could almost dismiss it as silly’ (pp. 192, 194).

But I submit since Bell wrote, Everettians have made major improvements to their interpretation. In my opinion, there have been two main improvements relevant to our purposes, which I will label ‘Decoherence’ and ‘Patterns’.[2]

2.1.2.1. Decoherence. Although the fundamental ideas of decoherence were established in the early years (and were clear to maestros such as Heisenberg, Mott and Bohm), detailed models were only developed from about 1980 (Schlosshauer, 2008 is an excellent recent survey).

Recall that ‘decoherence’ means, broadly speaking, the diffusion of quantum coherence from the system to its environment. This is the fast and ubiquitous process whereby, for appropriate physical quantities, the interference terms in probability distributions, that are characteristic of the difference between a superposition and a mixture, diffuse from the system to its environment. In a bit more detail: at the end of the decoherence process, the quantum probabilities for any quantity on the system are as if the system is in one or other of a definite set of states. In many models of how a system (such as a dust-particle) interacts with its environment (such as air molecules), this set consists of coherent states: states which are sharply peaked for both position and momentum, so that a system in any such state is presumably nearly definite in both position and momentum. (But the distributions have enough spread so as to obey the Uncertainty Principle's veto on simultaneous precise values for position and momentum.)

For our purposes, decoherence has two important features. The first is a kind of imprecision. That sounds like a defect; but I shall maintain—especially later, in Sections 4.1 and 6—that this imprecision is, for the Everettian, a merit. (Here I follow in the footsteps of some avowed Everettians, such as Saunders and Wallace.) So I will call this feature ‘flexibility’.

Thus we expect the classical physical description of the world to be vindicated by quantum theory—but only approximately. Only some subset of quantities should have definite values. And maybe that subset should only be specified contextually, even vaguely. And maybe the values should only be definite within some margins of error, even vague ones. Decoherence secures this sort of flexibility. For the selection of the quantity that is preferred in the sense of having definite values (relative to a branch) is made by a dynamical process—whose definition can be legitimately varied in several ways. Three examples: the definitions of the system–environment boundary, and of the time at which the interaction ends, and of what counts as a state being ‘sharply peaked’ for a quantity, can all be varied.

The second feature is that decoherence does not just by itself solve the measurement problem. More precisely, it does not imply that the system is in one of the set of states (typically coherent states). It implies only that the quantum probabilities are as if the system were in one. Furthermore, the theory implies that the system is in fact not in one of those states (on pain of contradicting the original hypothesis that the total system-plus-environment is in a superposition, not a mixture). This feature is well-known, and has been given various names, especially ‘the problem of outcomes’, ‘the problem of improper mixtures’ (following a jargon of d'Espagnat) and the ‘the problem of replacing ‘and’ by ‘or’ (following a jargon of Bell) (cf. my discussion of (Outcome) in Section 4.1).

To put this feature vividly, in terms of Schrodinger's cat: at the end of the decoherence process, the quantum state still describes two cats, one alive and one dead. It is just that the two cats are correlated with very different microscopic states of the surrounding air molecules. For example, an air molecule will bounce off a wagging upright tail, and a stationary downward one, in different directions! Since one's overall aim is to solve the measurement problem, this feature is usually considered a defect, not a merit, of decoherence. But we will now see how the Everettians' second main development may turn it into a merit.

2.1.2.2. Patterns. The second development is the application to the problems of quantum ontology, especially Schrodinger's cat, of the philosophical idea that the objects in ‘higher-level’ ontology, e.g. a cat, are *not* some kind of aggregate (e.g. a mereological fusion) of lower-level objects, but are dynamically stable patterns of them, of a special type—which type being spelt out by what we believe about objects of that kind. This idea is often associated with “functionalism” in the philosophy of mind (e.g. Dennett, 1991).

Some prominent Everettians, such as Saunders and Wallace, maintain that it snatches victory from the jaws of defeat: the defeat, just mentioned, that decoherence apparently does not by itself solve the measurement problem. The idea is that the final quantum state's describing two cats, one alive and one dead, is a matter of the state encoding two patterns—and the description is entirely right.

This becomes a bit clearer if we adopt a specific representation of the quantum state, for example position. Then, roughly speaking, the final state is a wave-function on the cat's classical configuration space, with two peaks: one peak over some classical configurations each corresponding to a live cat, e.g. with a wagging upright tail, the other peak over some classical configurations

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[2] I set aside a third improvement, viz. various arguments justifying, from an Everettian perspective, the orthodox (Born-rule) form of quantum probabilities. All three improvements have been developed in many papers over the last twenty years. Some of the latest work is in Saunders, Barrett, Kent, & Wallace (2010), and by Wallace (2012a,b). The first of these also contains penetrating critical assessments of all three improvements by non-Everettians.