Many-Worlds Quantum Mechanics and the Measurement Problem

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Workshop *The Physics of What Happens and the Measurement Problem*
INFN Frascati, May 24-26, 2017

Introduction

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How come?

What does MWI say?

What does it say, specifically, about the measurement problem?

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A (the?) major problem in (understanding) QT consists in accounting for this Janus-faced aspect of the theory

Measurement Problem

Notice that the measurement problem has ***two*** components:

i) How come we only observe determinate outcomes?

ii) What qualifies as a measurement event?

Problem i) has to do with our experience
Problem ii) has to do with classical/quantum divide and the putatively special nature of certain interactions

This will be relevant in a moment…

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- Biting the bullet
- Spontaneous collapse, no distinction between ‘normal’ evolution and measurement
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- Modal interpretations, distinction between *dynamical* state and *value* state

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But let us focus on one in particular: that based on the many-worlds idea (MWI)

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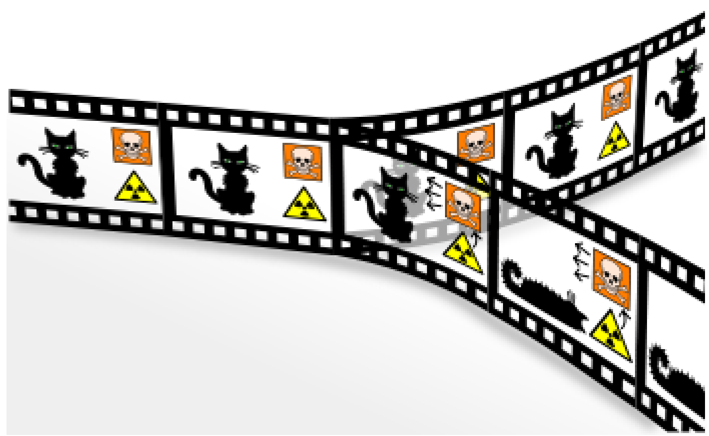

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However, there are issues:

1) Probabilities
2) Preferred basis
3) Violates Ockham's razor
4) Metaphysical addition

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5) The proposal does ***not*** *solve the measurement problem!*

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A bit more carefully, just *what branching is* is unclear

Proposed solution II. Everett's QT

The 'obvious' reaction is to say that branches are not caused by measurements, but are in some sense 'already in the wavefunction'

As a matter of fact, the original proposal (Hugh Everett III's PhD Thesis, 1957) *did not* postulate a proliferation of worlds

(It was rather Bryce DeWitt in the 1970s)

It is rather a '*pure wave mechanics*' or '*relative-state formulation*' of QT that aims to show that the theory is empirically adequate even *without* the collapse postulate

The key idea is the following:

- It is true that, without collapse, an interaction between an observer J and a system S in superposition results in a system S+J which is in a superposition

$$|\text{“ready”}\rangle_J\,|\text{x-spin up}\rangle_S \rightarrow |\text{“spin up”}\rangle_J\,|\text{x-spin up}\rangle_S$$

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$$|\text{“ready”}\rangle_J \, (a|\text{x-spin up}\rangle_S + b|\text{x-spin down}\rangle_S)$$

$$\Downarrow$$

$$a|\text{“spin up”}\rangle_J \, |\text{x-spin up}\rangle_S + b|\text{“spin down”}\rangle_J \, |\text{x-spin down}\rangle_S$$

- However, this means that there is no determinate *absolute* state

- Relaxing the Eigenstate-Eigenvalue link, one can nevertheless say that the observer is in a determinate *relative* state, corresponding to one of the relevant 'wave-parts'

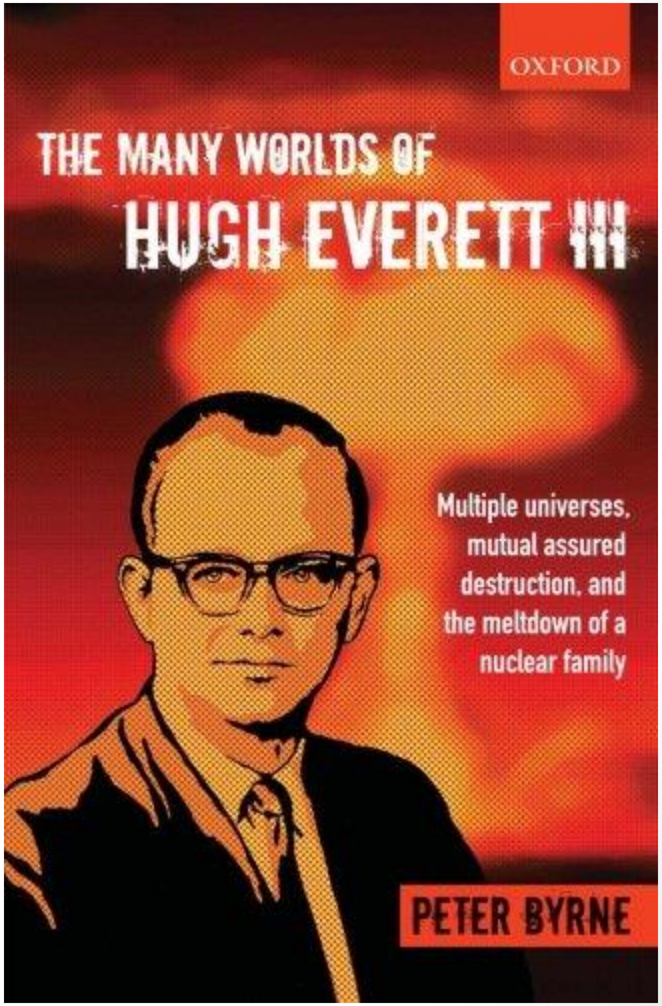
$$a|\text{“spin up”}\rangle_J\,|\text{x-spin up}\rangle_S + b|\text{“spin down”}\rangle_J\,|\text{x-spin down}\rangle_S$$

Allegedly, this «is in full accord with our experience (at least insofar as ordinary quantum mechanics is) […] just because it *is* possible to show that no observer would be aware of any 'branching'»

In particular, the alternative 'wave-parts' are mutually orthogonal and for all practical purposes independent of each other

(Cfr. the theory of *decoherence*)

Crucially, Everett's proposal has no splitting, nor does it attribute a peculiar role to measurement events



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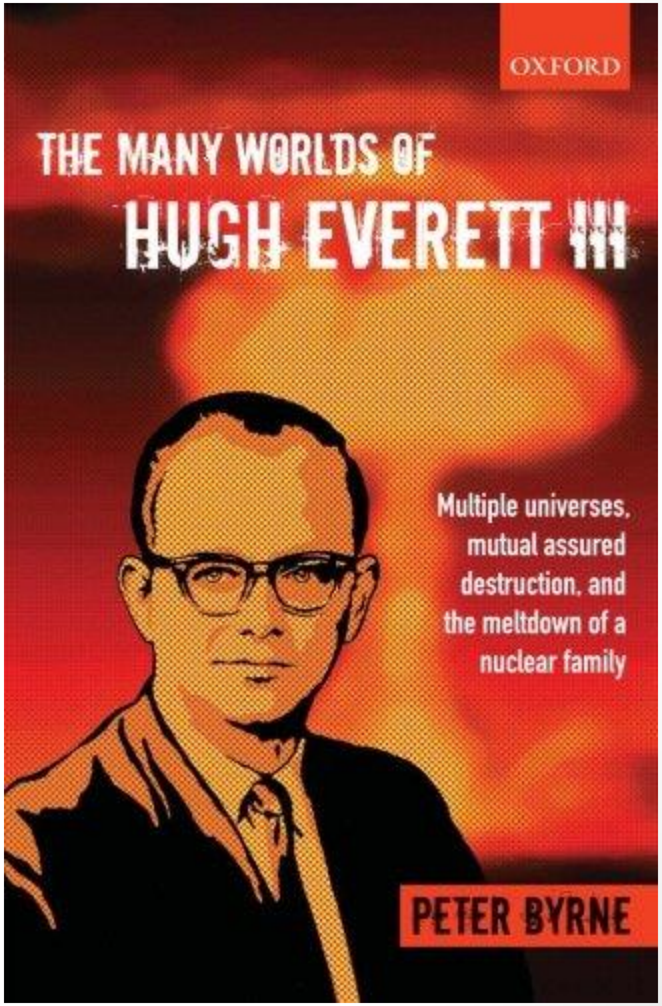
- 'We' cannot (ordinarily) notice that there are alternative outcomes/records (every 'recording state' is isolated)

- Yet, it is the 'same' subject *qua* physical system that experiences/can experience multiple alternative results



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5: the 'multiplication' of reality occurs as soon as there is interaction, hence superposition – measurement is irrelevant

3-4: Physical reality remains entirely within the wave-function of *one* world (ours)

2: *Any* admissible decomposition of the state of the composite system into relative states is acceptable (yet, position seems privileged as a matter of fact; exact role of decoherence?)

1: Typicality (Everett)? QT+decision theory (Oxford group)?

Proposed solution III. Relational QT

An interesting connection emerges with another approach, which may be regarded as belonging to the group of views that 'multiply reality' in some sense

The sort of *relational quantum mechanics* proposed most forcefully by Carlo Rovelli

Also Lee Smolin, Louis Crane, David Mermin,…

According to it, quantum mechanics is not a theory about the way physical systems *are* in the *absolute* sense, but rather about the way in which they *are relative to* other systems

Connection to relativity theory

(Claimed relevance with respect to non-locality/EPR)

There are not even branches, but information concerning the way one system is connected to another

Thus, truly one has *correlations* rather than *intrinsic properties*

Quick comparison:

Approach	QT conveys information relative to	Number of 'realities'	Significance of the universal wave-function	Basic ontology
Relative-state QT	States in branches	High (several states for each system)	Maximal	States
Relational QT	Systems	Low (really just several 'perspectives')	None	Events

Summing up

Many-worlds quantum mechanics is really a family of different views, exchanging ontological 'plausibility' for explanatory power

In spite of the name, it goes back to a theory which doesn't have (at least not explicitly) worlds, nor branches

Everett's relative state QT/MWI QT/Relational QT

Philosophical and physical issues abound, both at the level of explanation (probability, preferred basis, decoherence,…) and at the level of methodology

What do you think (especially about MWI and the measurement problem)?

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