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Michael J Caola

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Quantum Mechanics (QM), probability, initial conditions of the wave function, and interpretation

Michael J. Caola
caolam@blueyonder.co.uk
6 Normanton Rd., Bristol, BS8 2TY, UK (/drpbx/ qm_init.tex)

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Abstract

We suggest that the experimentally-observed probabilistic nature of QM is associated with our (Nature's) inability to know the initial conditions $c_n(t = 0)$ of the wave function $\Psi(t) = \sum_n^\infty c_n(t)\psi_n(\mathbf{r}, t)$ describing the experiment.

Background

Two activities of physics are experiment and numerical calculation. A single QM calculation (on, say, an electronic computer) yields a single (numerical) result, *not* a set of several numerical results that might be a basis for a probabilistic interpretation.

So we consider that QM is in some sense deterministic: initial conditions $c_n(t = 0)$ of the wave function describing the experiment, starting at $t = 0$,

$$\Psi(t) = \sum_n^\infty c_n(t)\psi_n(\mathbf{r}, t) \quad (1)$$

always give the same result $\{c_n(t > 0)\}$.

Analysis

“The motion of particles follows probability laws, but probability itself propagates according to the laws of causality” (Born, 1926)

Nature tells us that however hard we try ($m = 1..M$ times) to exactly repeat an experimental result whose QM amplitudes are $\{c_n^m(t > 0)\}$, we cannot: that in general $\{c_n^m(t > 0) \neq c_n^{m' \neq m}(t > 0)\}$ is an irreducible feature of QM. So we have

- From pre-QM differential equations we have deterministic $c_n(t = 0) \rightarrow c_n(t > 0)$, i.e. if $c_n(t = 0)$ is given then (1) gives $c_n(t > 0)$
- In physical experiments Nature says that in M repeats ($m = 1..M$) of our best efforts to obtain the same result we in general have $c_n^m(t) \neq c_n^{m' \neq m}(t)$.

We reconcile these two bullets (if indeed they need reconciliation) by the following postulate:

We cannot know or control the experimental initial conditions $c_n(t = 0)$ of the wave function $\Psi(t) = \sum_n c_n(t) \psi_n(\mathbf{r}, t)$ describing the experiment: we call this lack of control ‘probability’. However, QM numerical calculations are deterministic, $c_n(t = 0) \rightarrow c_n(t > 0)$.

Discussion

“It is a truth universally acknowledged, that a single quantum system in possession of good initial values, must be in want of a life.”

We follow J. S. Bell, who rightly prefers ‘experiment’ to ‘measurement’.

If we provisionally accept the above postulate, then it would be useful to consider its relation to some present interpretational issues of QM : wave-function collapse, the measurement problem, hidden variables, non-locality, absolute irreproducibility, etc.