19. Collapse interpretations.

Introduction.

When we look at the world around us, it certainly appears to be *the* physical world, upon which we all agree. But in the mathematics of quantum mechanics, the current, highly successful mathematical paradigm of physics, there is **no unique physical world**; instead there are many simultaneously existing versions of physical reality (Ch. 6). A second peculiar feature of quantum mechanics is that if an experiment is repeated many times, each version will be perceived with a **probability** equal to the coefficient squared ($|a(i)|^2$, Ch. 8), even though the basic theory is deterministic, not probabilistic .

One way to explain these peculiarities is to suppose that the state vector, with its several possible versions of reality, collapses down to just one version, with the collapse to state *i* having probability. $|a(i)|^2$. There are two problems with this proposal. The first is that there is no evidence for collapse. (It is possible to explain the perception of only one version and probability by other means, so these two observations, by themselves, do not imply collapse.) And the second is that the linear, unitary equations of motion of basic quantum mechanics do not imply collapse to just one version; they imply each version continues to exist forever. These two problems do not rule out collapse, however, so it must be considered as a possible interpretation of quantum mechanics. (And in fact the majority of physicists would probably say that collapse is the most likely interpretation.) So we will consider here possible forms for a theory of collapse, and the rather severe difficulties one runs into in attempting to construct such an interpretation.

General forms for collapse models.

There are two general forms for collapse. The first is to suppose that it occurs upon perception of the wave function (by a human being). But it is shown in A19.1 that this proposal is logically inconsistent, so it is ruled out. The other general form is that of a mathematical 'theory' of collapse. Suppose we consider the half-silvered mirror experiment with state vector

$$a(1)|H\rangle + \mathrm{a}(2)|\mathrm{V}\rangle \quad (1)$$

after the mirror. Then because the usual unitary, linear processes of basic quantum mechanics leave a(1) and a(2) unchanged (A8.1, Ch. 18, A18.1) so there can be no collapse, there is presumed to be an additional non-linear process that causes the coefficients to change with time. For large t, this process leads either to $a(1,t), a(2,t) \to 1{,}0$, in which case the horizontal detector is perceived as detecting the photon, or to $a(1,t), a(2,t) \to 0{,}1$, with the vertical detector detecting the photon. The mathematical form of collapse is what will be examined here and in more detail in A19.2.

[**Note on non-mathematical schemes.** It has occasionally been proposed that there is no mathematical theory of collapse; it just happens, presumably instantaneously. But the fact that collapse can be experimentally shown to *not* happen when only a small number of particles is involved (see A19.3) would seem to imply that collapse must be governed by a mathematical model (which involves the number of particles participating in the collapse).]

[**Note on collapse theories and particles.** In a collapse theory, there is the implicit assumption that physical existence consists of the state vector alone (or else one wouldn't need collapse to explain why we perceive only one version of reality). This assumption itself depends on another assumption—that the state vector, by itself, without particles, is sufficient to account for all observations. So if one adheres to strict logic, one should show that the mathematical properties of the state vectors alone can account for the photoelectric effect, the Compton effect, and all other particle-like phenomena, before embarking upon the search for a mathematical collapse scheme. That is, strictly speaking, the reasoning of Part II is a prerequisite for collapse schemes.]

The GRWP mathematical model.

In a mathematical model, there are equations that govern the collapse. Because it is the most highly developed (actually, I am aware of no other serious mathematical attempts), we will consider only the mathematically elegant GRWP model of Pearle [1], [2], which builds on the work of Ghirardi, Rimini, and Weber [3]. A thumbnail sketch of the theory (see A19.2 for more details) is that space is divided up into small volumes and a random potential, w_n (analogous to an electrical potential) gives potential energy to all the particles (particle-like wave functions) in volume n. The potentials in the different cubes are almost independent. But there is one condition that **coordinates their random fluctuations**. When the random potentials are chosen in accord with the rules of the Pearle scheme, then just one state, say i, will be picked out—it's norm becomes very large compared to the others for 'long' times—with probability $|a(i)|^2$.

Problems with the model.

Mathematically, there is nothing obviously wrong with the model. But it has several questionable physics-related features which make it unlikely, in my opinion, that it is a 'correct' description of collapse.

(0) No evidence. There is no experimental evidence for collapse by the GRWP or any other mechanism (A19.3).

(1).Origin of the random potential. We do not know what the physical source of the random potential is (Pearle's 'legitimization' problem [2]). (See A19.4 for a conjectured tie-in with gravity). The w's that occur in the energy must correspond to some entirely new type of field because they make the equations nonlinear (Ch. 18 and A19.2) and all current fields obey (as far as we know) linear quantum mechanical equations of motion.

(2) Use of particle number. Because differences in the positions of particles are the most obvious distinguishing feature of the different versions of reality, Pearle chose particle number, the number of particles in each small cube, as the quantity which triggered collapse. But it is unlikely that particle number differences between versions of reality can lead to collapse in *all* situations (A19.2).

One might add that making the coupling depend on the mass instead of particle number (A19.2, A19.3) is reminiscent of the epicycles of 17th century astronomy; when the data contradict the model, you propose a more complicated model.

(3) Nonlinearity. The condition on the random fluctuations makes this proposed model non-linear (as any collapse theory must be; see A18.1). This is a huge departure from conventional, highly successful, quantum mechanics, where linearity is the most basic principle.

(4) Coordination of random processes within a version. The size of the volume elements is assumed to be about 10^{-15} cm^3 (a larger volume might make the effect detectable). So if we have a typical detector volume of, say, 1 cubic millimeter, then there will be 10^{12} volume elements, and hence 10^{12} different randomly chosen potentials, w_n. But the GRWP model says the random fluctuations of these 10^{12} potentials are instantaneously (at least in the original model) **coordinated**. It is most unlikely that there is a physical process which could precisely coordinate all the random fluctuations in these macroscopically separated volume elements.

(5) Coordination of random walks across different versions of reality. Further, the coordination is not just between potentials in different volumes. It also goes **across versions** of reality. In fact, no such cross-version mechanism is possible in current linear quantum mechanics because different versions are in different, non-communicating 'universes' (Ch. 10). And we have no idea in physics of how random processes in different versions of reality might be coordinated.

(6) Consistency with the |a(i)|^2 law. The very specific forms of the equations of motion and the coordination of the fluctuations were chosen by Pearle so that the end result matched the $|a(i)|^2$ probability law. There was no physical model or reasoning (apart from achieving the desired end result) which governed those choices. The net result is that one is deriving the $|a(i)|^2$ probability law from other probabilistic laws whose origin is unknown and whose form is simply conjectured. That seems quite unsatisfactory.

[More generally, in *any* proposed mathematical collapse model, one must explain why the model should just happen to yield the only form—the $|a(i)|^2$ law—for probability that is consistent with linear, unitary quantum mechanics. (See Ch. 8)]

Summary

In spite of somewhat in tensive efforts, no experimental evidence has been found for collapse. Further, the primary proposed theory, GRWP, has a number of questionable characteristics. So there is no reason to be optimistic that collapse will yield the correct interpretation of quantum mechanics.

Evaluation.

The majority of physicists would consider collapse to be the primary candidate for an interpretation and many of them are under the impression that collapse is actually a done deal. But that is not correct; there is no evidence for it. And the premises of the primary proposed theory, the GRWP model, are, at this point, impossible to justify.

References.

[1] Philip Pearle, *How stands collapse I*, arXiv, quant-ph/0611211v1 (2006).

[2] Philip Pearle, *How stands collapse, II*, arXiv, quant-ph/0611212v3 (2007).

[3] G. C. Ghirardi, A. Rimini and T. Weber, *Unified dynamics for microscopic and macroscopic systems*, Phys. Rev. D**34**, 470 (1986).