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On some speculations about the state reductions of photons

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The spontaneous collapses of the wave functions of photons, within the framework of possible relativistic extensions of the theory of Ghirardi, Rimini, and Weber are discussed. It is shown that a recently published argument which claims that such collapses can account for the emergence of determinate outcomes of certain experiments involving fluorescent screens is inadequate, since it is based on an unreasonable speculation about the treatment of photons in the GRW theory.

We argued in a recent paper [1] that the theory of the collapse of the wave function due to Ghirardi, Rimini, and Weber (GRW) [2] fails to produce any determinate outcome of certain straightforwardly practicable sorts of Stern–Gerlach experiments involving fluorescent screens (or rather: we argued that that theory fails to produce any such outcomes at least until such time as the photons which those screens will emit, at the conclusion of such experiments, actually come into direct physical contact with the nervous systems of human observers). Recently Squires [3] contested that claim. In this note we shall show that Squires' critique misses its mark.

In the sort of experiment which we discussed, the wave function of an incoming spin-$\frac{1}{2}$ particle is split into two spatially separated components (a spin-up component and a spin-down component) by means of an inhomogeneous magnetic field. Those two components subsequently impinge on the neighborhoods of two different points on a fluorescent screen, and excite (we presumed) *macroscopic* numbers of fluorescent atoms in those two neighborhoods. Squires is in agreement with us that at this stage of things the GRW theory will not as yet have produced any determinate outcome of this experiment.

The next stage of the spin-measuring process involves the emission, by the excited atoms, of macroscopic numbers of photons. It is our discussion of this stage of the experiment with which Squires takes issue.

It happens to be the case that no extension of the GRW theory to relativistic systems has yet been explicitly written down; and so any discussion of the implications of the GRW theory about this stage of the measuring process will necessarily have to make use of a *speculation* about how a relativistic extension of that theory (if any such extension can eventually be cooked up) might turn out to work. What we supposed, was that some relativistic extension of GRW theory will eventually be cooked up, and that that theory will prove capable of accounting for (among other things) the fact that excited fluorescent atoms sometimes transfer some of their energies to the electromagnetic field by means of the *creation of photons*. And we supposed that that theory will entail that in case where the quantum state of the world happens to be an eigenstate of the photon-number, photons will be susceptible to the same sorts of collapses as nonrelativistic particles are susceptible to in the existing GRW theory. Moreover, although the experiment we described in our earlier paper involved, at a certain stage, the creation of photons, the apparatus we described there was carefully designed (in order to keep the necessary speculation to a minimum) so as to preclude the development of superpositions of states with different photon-numbers at any stage of the measurement [#1].

And what we were able to show, given all that, is that no determinate outcome of that spin measurement will emerge at this stage either. Squires agrees with us that, given these sorts of speculations, no determinate outcome of such an experiment will emerge since the distinguishability of different such outcomes in terms of the positions of the photons is too short-lived for GRW collapse to be likely to occur. However, he thinks that we ought to have proceeded very differently. What he suggests (if we understand him correctly) is that any contemporary investigation of the consequences of the GRW proposal which is conducted prior to the development of a fully satisfactory relativistic extension of that proposal ought to presume (even insofar as the treatment of *photons* is concerned) that the nature is completely *nonrelativistic*, and that (in particular) particles can neither be created nor destroyed!

And Squires points out (quite rightly) that if you presume *that*, then the argument we gave would not go through. The point is that if you presume that, then whatever photons any fluorescent atoms emit must have been *inside* of those atoms all along; and in that case, the measured spin will end up correlated to whether or not any given photon is inside or outside of its fluorescent parent-atom; and in *that* case, the GRW theory will indeed produce a determinate outcome of the measurement [#2].

But if Squires' suggestion were to be adopted, after all, then the whole business of cooking up arguments for *inadequacy* of the GRW theory (like the one we cooked up) would be entirely beside the point, because (under those circumstances) the GRW theory would need to be rejected out of hand, since (needless to say) the treatment of interacting photons as nonrelativistic particles is going to generate direct contradictions of a more or less innumerable collection of well known experimental facts. Note, that recent steps toward relativistic GRW theory [4] do not involve this approach.

What seems to be the right strategy to follow (and this is the one we followed in our earlier paper, and which we have already reiterated above) is to give the GRW theory the maximum benefit of the doubt, and to presume that some relativistic extension of that theory will ultimately prove possible, and to make the best and the most generous guess we can about how that might turn out to work.

It may be of interest to note, in this connection, that the developers of the GRW theory themselves agree with us in this matter [5,6]. What they suspect is that their theory will be able to produce a determinate outcome of the sort of spin measurement we have been discussing here once (and not before) the light emitted by the fluorescent screen comes into interaction with the nervous system of a human observer. One of us has argued elsewhere [7] that this is too late for such an outcome to emerge (for a different opinion, however, see ref. [6]), but those considerations are of course quite beside the point of the present note.

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[#1] A "naive" speculation, applicable to situations which are not restricted by this condition, is that photons occasionally undergo multiplication by the GRW Gaussian in each "branch" (of the universal wave function) in which they exist. This procedure also fails to lead to a determinate outcome of the experiment. However, we felt that considerations of superpositions of quantum states with different number of particles were clearly outside the framework of the GRW theory.

[#2] One might wonder, moreover, whether Squires' suggestion gives rise to *unwanted* GRW collapses. Consider this: The number of (uncreatable) photons which a fluorescent atom would have to carry around inside of itself would presumably (since such atoms have never yet been observed to run out of photons) be very large. And so (if those photons will all be subject to the standard nonrelativistic GRW collapses) atoms like that ought to behave more or less like macroscopic objects; and the interference, which quantum theory leads us to expect when various different superposed trajectories of atoms like that converge, ought not ever occur!

References

[1] D.Z. Albert and L. Vaidman, Phys. Lett. A 139 (1989) 1.
[2] G.C. Ghirardi, A. Rimini and T. Weber, Phys. Rev. D 34 (1986) 470.
[3] E. Squires, Phys. Lett. A 141 (1989) 95.
[4] G.C. Ghirardi, R. Grassi and P. Pearle, Found. Phys. 20 (1990) 1271.
[5] G.C. Ghirardi and A. Rimini, private communications.
[6] F. Aicardi, A. Borsellino, G.C. Ghirardi and R. Grassi, Found. Phys. Lett. 4 (1991) 109.
[7] D.Z. Albert, in: Sixty-two years of uncertainty, ed. A.I. Miller (Plenum, New York, 1990) p. 153.