A Second Measurement Problem ?

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Dedicated to Marie-Louise Nykamp

Abstract

Within quantum measurement there is the sharp difference in the dynamics between the case when the eigenstate of the prepared quantum system is different from any of those of the measuring device, and on the other and, when it is the same with one of those of the measuring devices. It is argued that here one may face a "second measurement problem".

"History is written with the feet ..."

Ex-Chairman Mao

1. Preliminaries

The vagaries of the scientific venture seem to be uncounted and endless. And in our times that seems to apply even more in the realms of quanta. As one of the many samples, here is a recent citation from a paper of a group of quantum physicists actively involved in state of the art research, [2] :

"In the beginning of modern quantum theory, the notion of entanglement was first noted by Einstein, et.al., [3], and by Schrödinger, [7]. While in those days quantum entanglement and its predicted physical consequences were - at least partially - considered as an un-physical property of the formalism - a 'paradox' - the modern perspective on this issue is very different. Now quantum entanglement is seen as an experimentally verified property of nature, that provides a resource for a vast variety of novel phenomena and concepts such as quantum computation, quantum cryptography, or quantum teleportation."

And yet, the fact is that, even at present, by far most of the 101 Quantum Mechanics courses do not mention entanglement ...

Let us now turn to the issue of the so called "measurement problem" which is the source of one of the main foundational controversies in quantum mechanics brought about by the Copenhagen Interpretation. The respective "jumps in quantum states" did from the very beginning shocked Schrödinger to the extent to declare, [1, p. 201] :

"If I have to go on with these damned quantum jumps, then I am sorry that I ever got involved."

As a kind of counter-shock, this time to the vast majority of quantum physicists, came the 1957 "many-worlds" interpretation of "jumps in quantum states" by Everett, an interpretation which simply disposed with the existence of any such alleged "jumps", yet until recently, it has been considered as rather outlandish.

Back, into the realms of the "one single world" interpretation, that which Schrödinger found so much repulsive, and that which nevertheless is - even if tacitly or implicitly - accepted by a majority of quantum physicists, especially those of the "working" type who focus on "calculations", rather than on foundational issues, we have to note that there are in fact no less than *to kind of jumps*, namely :

- a "presence of a jump" :

  when the prepared state of the quantum system is *not* an eigenstate of the observable, and then upon the respective measurement the state is supposed to "collapse" on one of the eigenstates of the observable, thus setting aside its evolution given by the Schrödinger equation,

- a "jump from the above 'presence of a jump', to the 'absence of any jump' " :

  when the prepared state of the quantum system *is* an eigenstate of the observable, and then upon the respective measurement the state is supposed not to "collapse" on one any other state, but simply to remain the given eigenstate of the observable.

Several amusing features of the above invite themselves to be noted :

1. It is commonly accepted that both the jump, and when the case is, the lack of jump in a process of measurement do not happen instantaneously, and instead, take some time which is required by the very process of interaction between the quantum system and the measuring device. Thus in fact, we are not facing a "jump" proper, but rather a dynamics on another and seemingly much faster time scale.

2. The Schrödinger equation seems completely to be set aside in the case of the above first alternative, that is, of the "presence of a jump".

3. It is less clear whether the Schrödinger equation is completely set aside in the above second alternative of the "absence of any jump".

4. Different measuring devices can be brought into the picture, and it can happen that they have, or on the contrary, do not have, one of their eigenstates the same with the prepared state of the quantum system. Similarly, no matter what measuring device is brought into the picture, it can happen that the prepared state of the quantum system is, or on the contrary, is not, one of the eigenstates of the measuring device. Thus the coincidence, or for that matter lack of it, between the prepared state of the quantum system and one of the eigenstates of the measuring device becomes operative only in the process of measurement. And then it leads to the two significnatly *different* dynamics,

namely, one with the "presence of a jump", and the other one with the "absence of any jump".

5. Thus there are no less than *three* very different possible dynamics available to a quantum system :

- the one given by the Schrödinger equation, when no measurement is performed,
- the one with the "presence of a jump" described above,
- the one with the "absence of any jump" described above.

6. As it happens, there seems to be no distinction of any consequence made between the last two dynamics, and instead, both of them are lumped together under the label of "measurement".

7. In conclusion, "quantum measurement" appears to be a sufficiently *invasive* process, in order to set completely aside the Schrödinger equation, and do so at least in the case of the "presence of a jump" described above.

8. Most amusingly, perhaps, the first and third dynamics described above are supposed to be perfectly deterministic, and thus, with no place at all for any probabilistic outcome. And the only probabilistic occurrence is supposed to happen with the second dynamics above.

2. A Second Measurement Problem ?

Let us consider more carefully the possible *difference* between the last two dynamics in pct. 5. above.

One way to see that difference is with respect to the *extent* of invasiveness of quantum measurement upon the quantum system.

And that way is quite open in view of the related controversy still ongoing in quantum foundations. In this regard, let us recall the following.

1. Heisenberg himself, when arguing his uncertainty principle, made use of his "microscope", [1,4,5,8], in which a photon is shot at an electron in order to determine the position and momentum of the latter. The semi-classical argument ensuing makes it clear that, due to the invasive nature of the resulting interaction between the photon and electron, it is not possible to determine precisely both the position and momentum of the electron.

2. Such an inevitable effect of the measuring device on the quantum system, [8, p. 25], argued by Heisenberg, is not supposed to be limited to his "microscope", but it is often claimed to be generic to quantum measurements as such, as commented upon within the perspective of a wider and rather detached analysis in [4, p. 148], for instance.

3. A sharply contrary view is also known to be pursued. In [5], among other places, the very uncertainty principle is argued in some detail to be but an "ill-defined notion".

Thus we are still in the presence of widely divergent views regarding the possible generic invasiveness of measurements upon quantum systems.

And then, as far as such a foundational controversy is not yet settled, the possible *difference* between the last two dynamics at pct. 5. above can be seen as leading to the :

Second Measurement Problem :

> How is it that the invasive nature of quantum measurement which is manifest in the second case at pct. 5. above, is completely set aside when the eigenstate of the quantum system is the same with one of the eignestates of the measuring device ?

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