On the Zitterbewegung

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Dedicated to Marie-Louise Nykamp

Abstract

An extension of the zitterbewegung phenomenon is suggested together with a solution to the measurement problem and the claimed incompleteness of quantum mechanics.

"History is written with the feet ..."

Chinese Ex-Chairman Mao,
of the Long March fame ...

Science is not done scientifically, since it is mostly done by non-scientists ...

Anonymous

Physics is too important to be left to physicists ...

Anonymous

Is the claim about the validity of the so called "physical intuition" but a present day version of medieval claims about the sacro-sant validity of theological revelations ?

Anonymous

1. A Traditional View Challenged

It is customary, following Schrödinger, to see the zitterbewegung phenomenon as related to the solution for the electron of the Dirac equation, [1]. In that paper, however, a wholesale reinterpretation of quantum mechanics is presented inn order to support the claim that the zitterbewegung is "a ubiquitous phenomenon with manifestations in every application of quantum mechanics, even in the non-relativistic domain".
In this paper, a considerably stronger claim is suggested, and it is simply based on obvious mathematical features not only of the Dirac, but also of the Schrödinger equation.

2. A Unique Feature of the Schrödinger and Dirac Equations

Each of the equations has terms which have extremely disproportionate coefficients. The effect is that solutions of both equations may contain terms with extremely high oscillations. The case of solutions of the Dirac equation has, as mentioned, been considered, starting with Schrödinger himself.

However, similar properties regarding oscillations can easily be found with the Schrödinger equation itself. In its general form, that equation is

$$(2.1) \qquad i\hbar\frac{\partial}{\partial t}\psi = \hat{H}\psi$$

where $\hbar$ is the reduced Planck constant. Consequently, formally, the solutions are

$$(2.2) \qquad \psi = \exp(-\frac{i}{\hbar} t \hat{H})$$

which in view of the extremely small size of $\hbar$ may lead to extremely high oscillations in ψ.
In view of the above, it may be more proper perhaps to talk about a kind of *generalized zitterbewegung effect* which relates to both Schrödinger and Dirac equations, namely, the likely presence of extremely high oscillations in the solutions of these equations.

3. Possible Foundational Consequences ?

The mere fact that such solutions with extremely high oscillations are associated with the Schrödinger and Dirac equations raises the following foundational question concerning the well known *measurement problem* in quantum mechanics :

- Is the typical randomness in the so called collapse of the wave function due to the fact that, on one hand, the extremely high oscillations in the wave function of the quantum entity under measurement, and on the other hand, the comparatively considerable time scales in the control of the moment of implementation of effective measurements make it highly unlikely to measure a quantum entity in the very same state of its wave function ?

In other words, our effective measurements can hardly ever catch two identically prepared quantum entities in an identical state of the wave function. This, of course, does not happen when the quantum entity is in a state which happens to be one of the eigenstates of the observable which is measured.

To the extent that one has a positive answer to the above question, the measurement problem obtains a solution, and so does the issue of randomness which led Einstein to claim the incompleteness of quantum mechanics, and the fact that the wave function only describes ensembles of identical quantum entities, and not individual ones.

References

[1] Hestenes D : The Zitterbewegung Interpretation of Quantum Mechanics. 1990, Found. Physics, Vol. 20, No. 10, pp. 1213-1232