1 Physics' Major Boo-Boo of the 20th Century?

1.1 (U of H seminar by E J Post, October 2, 2007)

The following is a critique of the Copenhagen single syetem interpretation of quantum mechanics, which can be advantageously replaced by an ensemble view obeying a perfectly classical statistics!

In 1905 Einstein had his miraculous year and two decades later Schroedinger sort of experienced his own miraculous year. The idea of this discussion aims at taking a perspective on both.

Einstein's explanation of the photo-electric effect removed any doubt that Planck's quantum of action was a most fundamental en-tity of nature, his assessment of Brownian motion established a new key between micro- and macro world, and his paper on the electrodynamics of moving matter initiated a first reluctant criti-cism of Newton's Euclidean world and its absolute time.

It is not given to many people to open up so many horizons of new insights, yet in a similar wave of creativity Schrödinger in 1925 and 1926 enriched the world of physics with two remarkable new insights pertaining to the universe in the large and in the small. In 1925 he took up a study of what Einstein had referred to as Mach's principle. In 1926 he came up with his quantum wave equation that would dominate the rest of the century.

Mach gave the distant masses of the universe a crucial role in the inertia manifestation we experience. While gravity forces of distant masses, as experienced locally, may cancel out when we find ourselves at rest, Mach suggested they come into action as in-ertia manifestations when we are set in sudden motion. In other words, if gravity is a local manifestation of Newtonian attraction then inertia is a global counterpart thereof.[1]

While forces of the distant masses may cancel, their potentials would be adding up to a very large quantity that has the physical dimension of a velocity squared. In the light of relativity's mass-energy theorem E=mc2, the question arose whether Mach's poten-tial of the distant masses of the universe might be related to c2. Us-ing at that time available astronomical data, Schrödinger [1] made a valiant attempt indicating the two might be of a same order of magnitude. Taking the Mach potential to be c2/2 has later been shown [2] to reproduce results similar to that of the Schwarzschild solution of the Einstein field equations that led to the major effects of the general theory that now seem supported by observation.

In the Twenties up and coming global insights in Riemannian structures had barely

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[1] Let it be said, as in Newton's laws of motion, the so-called Christoffel symbols of Ein-stein's geodetic line hypothesis of the general theory all testify to the additivity of gravity and inertia forces. Together they combine in frame-independent tensorial statements.

reached a level of awareness in mathematics and much less so in physics. Schrödinger may have had a physical inkling of being at the threshold of important local-global developments first requiring some preceding more abstract mathemati-cal assessment. Conceivably frustrated by inhibitions preventing at that time unwarranted leaps in the macro-domain, Schrödinger switched to the micro-domain when in 1926 he published his spectacular series of papers on wave mechanics [3].

Schrödinger's equation has now been the single most frequently used tool in the realm of quantum physics for almost a century. The overall interpretive picture that emerged around this equation was and has been far from clear, yet the equation has the amazing potential of producing data that make physical sense independent of that picture. Hermann Weil, a mathematician who had injected group symmetry procedures in the Schrödinger's process, used to refer to the equation as a veritable *favor of fortune.*

All this meant, there never had been an accepted derivation of the equation from first principles. Schrödinger had used a variational principle operating on the Hamilton-Jacobi equation. *His equation was accepted, not his derivation!* The latter was replaced by an empiric substitution $p \rightarrow ih\partial/\partial q$ in which p was taken as representing a momentum in Hamilton-Jacobi mechanics.

Yet this admittedly unusual recipe is still today an accepted ho-cus pocus in quantum instruction. As such it has become a de facto identification of Schrödinger's equation as some first principle item sort of replacing earlier quantizations of the pre-1926 era.

This nutshell rendition of Schrödinger's process has been used in a manner that has been largely independent of whatever inter-pretative ideas one may favor. For the record, let it be mentioned that Schrödinger himself held on to an interpretive single system view, later revised and much elaborated by the Copenhagen circle. Except for an ensemble intermezzo initiated by Popper [4] in the Thirties, the single system view has been dominating the physical scene. Max Jammer [5] has given an even-handed historical ac-count of these interpretive matters.

Finally it should be mentioned that doubts about a conceivable primordial position of the Schrödinger equation came already into question in the Twenties during a presentation by Schrödinger in Munich. Heisenberg who was in the audience asked the speaker whether his equation could do anything for Einstein's explanation of the photoelectric effect. The speaker took some time to consider the point. In the end the two grand masters of the new quantum mechanics concurred that Schrödinger's equation could do nothing to improve or even replace Einstein's assessment of the photoelec-tric effect.

Yet a measure of unlimited confidence in Schrödinger's favor of fortune swept the physics world in a belief that in due time those pesty exceptions would be resolved and found to be just temporary obstacles without fundamental implications. Yet eighty years of subsequent experiences with the new quantum mechanics has known some uncertainty whether this confidence is justified or not. This discussion is meant to home in on what, in retrospect, may now seem physics' perhaps greatest and most persistent interpre-tive misstep of the last century.

A near-unbelievable error of conception sneaked into the physi-cal picture that developed around the meaning of the dependent variable Ψ of the Schrödinger equation. Without much of a justification or discussion it had been assumed that the Ψ described a single quantum system. When it was later established that Ψ had unmistakable statistical connotations, the single system assumption prevented the statistics from having, what statisticians like to call, a universe of discourse. So in the absence of a universe of dis-course and its parameters it was decided to create a new *primordial type of statistics* that was said to be nonclassical in nature.

The new **nonclassical statistics** had to be of an ever-present non-adjustable nature, because the absence of a universe of discourse had bereaved it from the parameters to do so.

Somehow this very inventive gospel of nonclassical statistics and its ensuing string of nonclassical conceptions caught the imagination of the world of physics. Nonclassical became the unit of conceptual exchange in the world of quanta. Even when Popper, followed by Kemble and many others in Europe and Russia, called for an ensemble interpretation during the mid-Thirties, *nonclassical lingo remained the principal medium of conceptual exchange.*

Prior to assuming unknown nonclassical modifications of statistics, it is necessary to make sure that classical alternatives have been really exhausted. It may come as a complete surprise to the vast majority of the physics community that an ensemble interpre-tation of the Schrödinger equation can be combined with a classical statistical identification of a Ψ distribution. The latter is found as describing phase and orientation correlations between members of the ensemble. *Examples of such calculations have even been re-produced in modern textbooks without making the connection that those examples contradict the very need to call on these nonclassical escapes.* Planck initially presented some of these calculations in a still available text on radiation theory [6]. His book saw the light of day in 1912 before the birth of Schrödinger's equation. Questions that need to be asked as to why the modern textbook in-dustry does not acknowledge these matters are not within the pur-view of this assessment.

Now that the enigma of nonclassical has been removed from the new quantum mechanics of the Twenties, let it suffice that this change in interpretational environment hardly affects Schrödinger's process; it does, however, restrict its applicability to randomized ensembles, thus excluding isolated photoelectric emission events.

In the light of the cited conceptual changes, it will be clear that the Schrödinger procedure can no longer be seen as a primordial quantization, instead it needs to be considered as a process that is derivable from first principles. In this changed interpretive atmos-phere Schrödinger's own recipe for obtaining his equation should now be reconsidered as a candidate to be promoted to the level of an honest to goodness derivation.

All of this is a valid reminder to reexamine the earlier quantiza-tion recipes, which Copenhageners had prematurely placed in a category of reduced relevance; i.e., **to be avoided by all those who want exact results.** A mental repositioning with respect to the first principles of quantization can be helped by pointing out that *Faraday's electrolytic experiments of 1836 first established a quantized nature of electric charge e.* Avogadro's number then made it possi-ble to obtain a first estimate of its magnitude. These findings permit us *to envision Gauss' law of electrostatics as a counter of net charge, say trapped, inside a closed surface of integration.*

The better pat of a century later Planck postulated the existence of a quantum of action h. Five years later Einstein's explanation of the photoelectric experiments identified that same quantum h.

Finally in 1961 experimentation [7] led to the discovery of a new quantum of flux that had the magnitude h/2e. Similarly as net charge quanta e can be counted by a closed surface integral, the quanta h/2e can be counted by a one-dimensional closed loop integral of the vector potential A. It is in the same category as the Gauss integral; in mathematics they are known as period or residue integrals. They may be viewed as de Rham's [8] generalizations in the real domain of Cauchy's familiar applications of residue inte-grals in the realm of complex functions.

In macroscopic quantum physics a *path integral version* of this loop integral of A is now known as the Aharonov-Bohm integral. It counts flux quanta h/e instead of h/2e. This apparent discrepancy led in the Sixties to what may still be an unresolved dispute between Onsager [9] and Feynman [10]. From a period integral angle the path integral may be regarded as a physically forced combina-tion of a spatial loop and a time loop each contributing h/2e. While this accounts for the double Aharonov-Bohm quantum h/e; keep in mind that in the case of cyclotron orbits immersed in magnetic fields, results are contingent on orbiting objects havimg a field free interior.

Finally a word is in order about Robert M Kiehn who used to walk the hallways of U of H showing off his mighty physique in a T-shirt given to him by one of his students. On the back it said: Super Prof. As an ardent student of the Cartan school of mathematics Robert constructed a three-dimensional period integral that has **action** residues by taking as integrand the exterior product of the integrands of Aharonov-Bohm and Gauss. For a single charge it reduces to the familiar Bohr-Sommerfeld condition. These perspectives are instrumental in revealing a topological angle in which quantum physics reflects basic discreteness aspects of the universe.

Kiehn [11] so revised the discards of the past into a basic set of topological probes. The pre-statistical nature of these probes created a near-irresolvable conflict situation with Copenhagen's doctrine that had assigned Schrödinger's process a realm of responsi-bilities it could not possibly meet. Yet, notwithstanding its inherent inadequacies the voice of Copenhagen kept prevailing.

Kiehn's trio of 1-, 2- and 3-dimesional period integrals stands out as a complete physical recognition of a space-time topological description that is perfectly compatible with requirements of the general theory of relativity. De Rham [8] developed the mathematics during the Thirties for n-dimensional manifolds.

Isolated applications of the Aharonov-Bohm integral have testified to a relevance and exactness of the process in ordered macro situations. Photoelectric emission, Davisson-Germer, Aharonov-Bohm interferometry, Josephson and quantum Hall effects are now all in a realm calling for *non-statistical assessments*, i.e., excluding Schrödinger fare. *They now yield the most precise data of h and e while obviating any so-called quantum-relativity conflicts.*

If Copenhagen doctrine can still work in forbidden territory, it is the asymptotic closeness of statistical and pre-statistical results that saves the day. A Schrödinger approach for the quantum Hall effect can give some relevant data but no encompassing picture. The rea-son is that it entails a disturbing dichotomy between integer and fractional effects. The pre-statistical approach [12], by contrast, yields a straightforward unified treatment that does not call on additional *nonclassical* propositions to fit observation.

The honest desire to make headway in modern physics has led to situations in which measures of discrepancy are natural and need to be tolerated. Yet needed reasonable coexistence of different doc-trines at times change into unreasonable denominational battles in which victory prevails over truth. Copenhagen followers defend their stance a *tous et travers* with more religious than logic fervor. The celebrated doctrine was given a benefit of doubt long enough that it is now time to be lifted out of its own realm of uncertainty.

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