On the wages of Copenhagen's non classical sins

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ABSTRACT. The following is a carefully-documented proposition to discontinue currently still standard references to the conceptual images of the Copenhagen interpretation, because they are at variance with the reality presently confronting the world of physics. The Aharonov-Bohm and Ampère-Gauss integrals of quantum interferometry fame now gain an independent fundamental image in light of their potential to assume period integral status. The ensuing two-tier aspect of quantum theory then grants a conceptual perspective that permits dispensing with some of the nonclassical wages of sin of standard one-tier presentations. The suggested changes interfere little with standard mathematical procedures of operation, but they do affect decisions as to when to use Schroedinger-Dirac tools pertaining to randomized ensembles versus period integral tools for single systems.

KEY-WORDS. Copenhagen, period integrals, non-classical, pre-metric.

1 Factural Summary of Suggested Changes

Standard presentations of quantum mechanics hold a Schroedinger-Dirac process to be applicable to single systems as well as ensembles thereof. This dichotomy of duty is warping the interpretations of what is going on.

First of all the Schroedinger-Dirac process has a built-in plurality connotation that prevents it from being regarded as primary law(s) of physics. The conclusion argued in the following sections is that the Schroedinger-Dirac (SD)procedures are derived and that derivation indicates SD applies to randomized ensembles of identical systems.

Having said that SD is derived, begs the question: derived from what? The conceptual input was generated by pre-1926 rules of experimental quantization ranging from Planck to Bohr, Sommerfeld and de Broglie. Yet, until now the rules seemed too diverse to deserve primary status, which was a major reason why SD became elevated to the level of primary law.

A conglomerate of mathematical and physical-experimental reasons have since been pointing at a reorganization of these rules in terms of three period integrals emerging as quantum counters of flux *h/e*, charge *e* and action *h*. These integrals are invariant under arbitrary Diffeo(4) changes of spacetime reference. Moreover, they have been shown independent of the metric, which extends known macro applicability to the physical micro domain. These quanta counters are compatible with the general theory of relativity.

This new assessment of the pre-1925 quantization rules suggests the following changes in procedure:

The period integral quanta counters are pre-statistical and only apply to single systems or ordered ensembles thereof behaving as a single system.
The SD process only applies to ensembles of identical single systems. The states of the single systems in the ensemble obey a randomness.
The Ψ function of the SD process serves as a collective for the ***classical*** *statistical descriptions of randomness in the ensemble.*

Descriptions of these desirable changes in Copenhagen views have been around for about a decade. Yet, they have not created a strong disposition to rid our thinking of quantum fundamentals from unnecessary nonclassical complications. The following sections are a mixed bag of current examples strengthening this cause either in matters of theory or experiment.

2 Symptoms of Conflict

When the Dirac equations based on a synthesis of quantum principles and the special theory of relativity yielded spectacular results about the nature of the electron, expectations were high that an imposition of premises of the general theory would promise more triumphs. Leading physicists and mathematicians had a go at it, yet the results were mind numbing complexity and no predictive physical substance. The conclusion of these endeavors, which took place in the Thirties, sort of epitomizes the conflict situation between quanta and relativity. The abundance of quantum situations demanding a theoretical assessment versus a scarcity of practical checks of the general theory of relativity have shifted frontiers of theorizing from relativity to quantum phenomena.

The mathematical hurdle of transcribing the Dirac equations for the general domain was rooted in the mathematical nature of spinors as mathematical entities, confined to a two-dimensional overgroup of the Lorentz group. While spinors accounted for the success of the Dirac equations, an extension of this description to general spacetime references leads to *anholonomic* relations between the arbitrary frames of relativity and the inertial Lorentz frames demanded by spinors. The ensuing complexity of operating with these nonintegrable frames simply defied attempts at extracting physically significant frame-independent observable invariant features.

Mindful that imposing demands of the general theory on spinor language of the Dirac equations led to inextricable mathematics convinced the establishment not to pursue that avenue further. While orientability studies are not restricted to linear Lorentzian frames, whereas spinors are, one might expect a shift of interest to the global mathematics of orientability and its associated physics. In fact, because processes with built-in anholonomity are less than desirable, physics may at some time be forced to abandon spinors altogether. The appendix discusses how the need for more local-global connections underlines the here favored *two-tier* view of quantum theory.

3 Diagnosis

Incompatibilities between relativity and quantum mechanics have been due to QM's fading distinctions between single system and ensemble situations. They have in part been brought about by the at the time near-blinding impact of the new Schroedinger formalism of 1926. The amazing mystique of the new quantum revolution was such that it successfully lured the physics establishment in accepting almost unanimously this equation as holding a potentially exact key to all questions pertaining to atomic physics. Of course, this expectation was contingent on being clever enough to extract valid answers from this magical equation and its many body extension.

The early acceptance of Copenhagen views led to neglecting, if not a prematurely discarding of the more ad hoc pre-1925 quantum recipes. They were taken as asymptotic to solutions of the Schroedinger and Dirac equations. While the asymptotics was an unmistakable mathematical fact, it was not due to one exact and one approximate description of the same situation.

Instead, the mathematical proximity was due to two asymptotically related physically distinct situations. They relate to experimentally observed responses from what are dilute ensembles of identical single systems versus the much more rarely observed responses from veritable single systems or ensembles acting as such.

4 Current Support for the Diagnosis

Apart from the self-explanatory options already present in the just given assessment, we proceed here with a more detailed justification. A logical starting point is to inquire how the Schroedinger equation was obtained.

Schroedinger obtained his equation by submitting the Hamilton-Jacobi (H-J) equation to a variational process, which really means submitting the solution manifold of the H-J equation to variational changes. Since a point of the H-J solution manifold represents a conceivable system, the Schroedinger variational process averages and optimizes the collective of systems in an ensemble. The latter is the solution manifold of the H-J equation. There are now two options of interpretation.

I: *The Copenhagen choice of 1927-1933 was a Gibbs-like ensemble. It sees the solution manifold as representing conceivable manifestations of one and the same system.*
II: *The other choice is one of taking the H-J solution manifold as representing an actual physical ensemble of identical single systems.*

Option II was perhaps first suggested by Slater, which resulted in a fall-out between him and Bohr, then taken up again by Karl Popper in 1934. While Popper was criticized for his argumentation, Einstein in a footnote agreed with Popper's conclusion that the Ψ function should be seen as describing a **real physical ensemble**, not a Gibbs-type ensemble.

The Copenhagen people supporting option I had trouble finding a universe of discourse for the statistics implied by the Ψ function. Forging ahead with their view of the new discoveries, they made the ominous decision that the statistics had to be nonclassical in nature. It meant the statistics' universe of discourse either could not be found or it did not exist.

By the time when Option II emerged in 1934, option I had already convinced the physics establishment about an unavoidability of all kind of non-classical things. The people of option II did not make a stand and settled for having a non-classical statistics also pertaining to their real ensemble.

It may well remain one of the great mysteries in science communication that in 1912 Planck [1] had already anticipated the existence of a perfectly classical ensemble statistics pertaining to the mutual phase of an ensemble of harmonic oscillators. He considered their mutual phase as a source of ensemble randomness and then proceeded to show how the existence of a zero-point energy is necessary to keep the ensemble in a state of phase disorder. Here was a perfectly classical counter example disproving the flight into non-classical statistics. *Planck's book today is still available.*

A comparison of Planck's 1912 introduction of zero-point energy with Schroedinger's recipe-flavored derivation of a universal wave equation reveals some interesting similarities. Both optimize ensembles. Planck is specific and has a discrete ensemble of harmonic oscilators, whereas Schroedinger an unspecified ensemble the specifics of which is hidden in the Hamiltonian H. After specifying H for the harmonic oscillator Schroedinger ends up with the same hv/2 as Planck. It is up to readers familiar with these matters to conclude whether the study of these similarities have been exhaustively investigated in the literature or cast aside.

Schroedinger is known to have been aware of this Planck result as being identical to what he had obtained from his wave equation. His intention to investigate later may well have come to a halt in his difficult exchanges with the Copenhagen School. Schroedinger, refined mathematician physicist, and Bohr, wizard of ideas, while so very close to a resolving step, suffered a tragical breakdown in communication.

It seems in less than one generation, a complete disconnect occurred between the leading authorities at the frontiers of physics. It made an impression as if the later generation found itself so carried away by the magic of Schroedinger's gift from heaven that those earlier thoughts by Planck were ignored or put aside. The new divine tools with which physics had been entrusted made anything else appear as tinkering. Yet Planck's so-called tinkering of 1912 was a discrete special case of Schroedinger's own recipe. It had the potential of turning the recipe into a legitimate derivation,

During the Thirties, option II was adopted by a significant minority in the East and West. Jammer [2] has given a most scholarly account of these matters. Yet as far as the statistics was concerned, Copenhagen prevailed with its statistics that had no universe of discourse.

Today it is hardly known there ever was an ensemble interpretation for Schroedinger's equation, not even mentioning a classical alternatives for its statistics. In the Feynman Lectures [3] one can find another perfectly classical calculation pertaining to an ensemble of quantum rotators of random orientation. It yields the quantum number $[n(n+1)]^{1/2}$, which first became known through Schroedinger's equation and Heisenberg's matrix equivalent. This spatial addition of angular momentum elements strengthens the earlier Planck position pertaining to the zero-point average of harmonic oscillators.

Yet, not a word by the Feynman authors that their result could amount to another counter example verifying the classical nature of the Ψ function statistics. This classical calculation occurs in volume II as well as volume III; somebody must have thought it to be significant. It seems a tongue in cheek attempt at provoking response, the challenge is here humbly accepted!

5 Consequences of the Diagnostics

Reconsidering the ensemble views of the Thirties, there is now enough evidence to reestablish contact with the possibility of the ensemble obeying a classical statistics. Since the Copenhagen view had regarded all quantum phenomena as affected by its non-classical statistics at any time and everywhere, an ever present universal uncertainty and zero-point energy became part of the non-classical bargain. There was nothing beyond this nonclassical presence, which means it was disorder without an order reference.

Anything and everything was presumed to be everywhere and at all times affected by the Copenhagen creations of absolute uncertainty and its associated zero-point energy. After Planck's quantum had rescued physics from the infinities of the ultraviolet catastrophe, Copenhageners promptly reintroduced vacuum infinities by assigning a zero-point energy to every vacuum oscillator.

Since Copenhagen's single system proposition has not been found compelling, while counter examples obviate the need for a non-classical statistics, the premises underlying option I of Copenhagen can no longer be supported. It violates a sound pursuit of science to let this matter rest as is.

The classical nature of Ψ not only invites us, but obligates us to reconsider system order in an ensemble as well uncertainty and zero-point energy. Since the so-called ad hoc pre-1925 quantum recipes did not have these uncomfortable implication, they are not to be discarded as mere approximations, because some of them might have independent exact meaning for ordered ensembles or single systems. These possibilities have indeed been pioneered by R M Kiehn [4] in 1977 by establishing contact with de Rham's [5] period (residue) integration in assessing field topology.

A closer examination leads to the following pre-statistical law statements. They were recently reviewed in this journal as part of an electromagnetic quantum superstructure [11]:

1: The Aharonov-Bohm (AB) integral can assume the status of a period (residue) integral that is an exact counter of linked flux quanta, iff the integration loops reside where flux is zero.
Similarly:
2: The Ampère-Gauss (AG) integral is a period integral that can assume the status of an exact counter of enclosed quanta of net electric charge, iff the cyclic integration surface resides where charge is zero.

These two familiar integrals already had a wide realm of applicability in quantum interferometry. Let it be known, these integrals are invariant under general space-time transformations, thus meeting premises of the general theory of relativity. As early as in 1924, Cartan [6] showed these integrals to be independent of space-time metric specifications; in retrospect a most essential feature, because counting better be independent of centimeters or inches. Metric-independence permits a micro extrapolation if macro applicability is well established.

The inescapable conclusion of these considerations is that the AB and GA laws can assume the status of primary quantization laws fully compatible with extended relativity premises. It means Schroedinger and Dirac equations don't have a primary law status and are to be regarded as secondary derived laws pertaining to ensembles. The latter circumstance does not make them natural candidates to be submitted to relativity's premises of general covariance. Without invoking lots of higher mathematics it should be clear though that quanta counting should not be affected by choice of spacetime frame or metric. To those objecting to overloading physics with mathematics, please keep in mind that skimping mathematical form to convey a counting process can create unforeseen liabilities.

6 Conclusion

The changes here proposed don't really affect the traditional mathematical process of quantum mechanics, as borne out by the fact that these discussions did not require writing down any mathematical expression to speak of. A more extensive coverage with mathematical detail of the here presented arguments has been given in [7].

As frequently happens, more detailed treatments may lack the specificity of brief accounts, whereas too much detail numbs the mind. The two reviews [8,9] that have appeared of ref.[7], while friendly in tone, have remained evasive about crucial criteria that make Copenhagen's interpretation questionable and unfit for further use. Such guarded responses are natural when it concerns a rejection of a three quarter century long tradition.

As mentioned, experiments on single systems or ordered ensembles are still quite rare. The plateau states of the Quantum Hall effect currently present the best evidence of grave difficulties encountered when ordered ensembles are treated by Schroedinger methods. A comparison of the eigenvalue- versus the period (residue) integral procedure, as applied to the Q. Hall effect, is discussed in ref. 10; readers be judge what comes out best,

So, Copenhagen's interpretation is not compatible with the two counter examples pertaining to phase and orientation. The same holds for the non-classical paradigms following in its wake. They need to be replaced by a real physical ensemble obeying a classical statistics pertaining to the elements in the ensemble.

The ensuing absence of tools for what to do about pre-statistical single system is well taken care of by a proven extended validity of the AB and GA integrals as exact quanta counters.

Since the Gibbs' type ensemble option with its vacuum infinities needs replacement by a real ensemble, Ψ now serves as a collective, say a David Bohm-like hiding place, for unidentified classical realizations of ensemble distributions. However, the latter are now knowable in a classical sense.

7 Appendix

The crucial aspect of Dirac's linear decomposition of the quadratic energy momentum modulus of relativity is the (re)injection into the linear parts of a sensitivity for parity P and time reversal T. The quadratic modulus insensitive to P and T sign changes had a quantum transcription that had given the wrong fine structure. Dirac's equation reproduced Sommerfeld's earlier fine structure, which was spectroscopically confirmed. All this showed fine structure as a P and T contingency, which was not so apparent from Sommerfeld's 1917 approach.

Since Dirac's hypercomplex linear decomposition spawned the spinors instrumental in his approach, spinors become part of a P and T contingency. In fact Haefliger [12] showed that manifold orientability properties hold a key to the 1→2 spinorization technique of mapping. It raises questions what physical entities described by spinors can be equally well or better described by an orientation changing enhanced process of spacetime description.

More than hundred years of identification of polar and axial vectors in vector analysis has not exactly sensitized physics to systemic incorporation of spacetime orientation features. Since anholonomity prevents spinors to go well with the general spacetime Diffeo(4) changes of relativity, note that changes of orientation are still a natural part of Diffeo(4).

Mindful of Paul Ehrenfest's remark "who ordered the spinors?" physics may wonder whether past neglect of orientation resulted in getting trapped in spinors. Even so, Dirac's reminder of thus reinjecting P and T remains a most imaginative and ingenious move for opening up new avenues.

Since Diffeo(4) governs the metric-free invariance of the period integrals here identified as primary quantizers of single systems, whereas Schroedinger and Dirac equations defied effective Diffeo(4) renditions, only a two-tier approach can reveal how primary quantization reconciles with relativity.

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