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Citation: AIP Conference Proceedings **1841**, 040003 (2017); doi: 10.1063/1.4982779
View online: http://dx.doi.org/10.1063/1.4982779
View Table of Contents: http://aip.scitation.org/toc/apc/1841/1
Published by the American Institute of Physics

# Progress in Post-Quantum Mechanics

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**Abstract.** Newton's mechanics in the 17th century increased the lethality of artillery. Thermodynamics in the 19th led to the steam-powered industrial revolution. Maxwell's unification of electricity, magnetism and light gave us electrical power, the telegraph, radio and television. The discovery of quantum mechanics in the 20th century by Planck, Bohr, Einstein, Schrodinger, Heisenberg led to the creation of the atomic and hydrogen bombs as well as computer chips, the world-wide-web and Silicon Valley's multi-billion dollar corporations. The lesson is that breakthroughs in fundamental physics, both theoretical and experimental, have always led to profound technological wealth-creating industries and will continue to do so. There is now a new revolution brewing in quantum mechanics that can be divided into three periods. The first quantum revolution was from 1900 to about 1975.The second quantum information/computer revolution was from about 1975 to 2015. (The early part of this story is told by Kaiser in his book, *How the Hippies Saved Physics*, how a small group of Berkeley/San Francisco physicists triggered that second revolution.) The third quantum revolution is how an extension of quantum mechanics may lead to the understanding of consciousness as a natural physical phenomenon that can emerge in many material substrates, not only in our carbon-based biochemistry. In particular, this new post-quantum mechanics may lead to naturally conscious artificial intelligence in nano-electronic machines, as well as perhaps extending human life spans to hundreds of years and more.

## INTRODUCTION

> Suppose there is even something vaguely teleological about the effects of consciousness, so that a future impression might affect a past action.
> Roger Penrose [1]

> It seems to me that biological systems are able in some way to utilize the opposite time-sense in which radiation propagates from future to past. Bizarre as this may appear, they must somehow be working backwards in time.
> Sir Fred Hoyle [2]

Classical physics from Newton to Maxwell emerged from the 17th to the end of the 19th centuries, dealing with the motion of matter under the influence of forces, mainly electromagnetism. Although Newton thought of gravity as a force, Einstein realized that gravity is not a real force in the same way that electromagnetism exerts forces on charged particles. Gravity is, in fact, the curvature of the four-dimensional spacetime continuum induced by large concentrations of matter. This is why astronauts on the space station are weightless; they move on "geodesic" paths free of real forces. This is the essence of Einstein's General Theory of Relativity.

Quantum mechanics is not only needed to understand the chemical bond using tiny electrons to make molecules out of atoms, and atomic nuclei out protons and neutrons, etc. We also need it to understand the stability and structure of solids, energy generation in stars, as well as the long-range coherent phase wave properties of superfluid helium and electrical superconductors at the lowest temperatures near absolute zero. The achievement of high-temperature superconductivity allowing electrical power to flow long distances without any heat dissipation would dramatically change the energy picture as would the development of nuclear fusion; unfortunately, neither goal has been achieved, despite many decades of effort. All of these applications were part of the first quantum revolution still unfinished.

The second quantum information/computation/crytpographic revolution described in Kaiser's book [3] is about what Einstein called "spooky telepathic action-at-a-distance" given the more neutral name of "entanglement" although some call it "quantum voodoo." Einstein was not comfortable with entanglement because it seemed to contradict

*Quantum Retrocausation III*
AIP Conf. Proc. 1841, 040003-1–040003-5; doi: 10.1063/1.4982779
Published by AIP Publishing. 978-0-7354-1511-9/$30.00

his classical physics theory of relativity which requires that no useful signals conveying meaningful messages can be transmitted faster than the speed of light in a good vacuum. However, we now know how to make observed quantum entanglement connecting widely separated particles consistent with Einstein's relativity. In fact, Einstein's mathematics is perfectly consistent with an extension of our notion of time, cause and effect. Our common sense is a psychological illusion in which time only seems in our consciousness to flow from past to present to future. This irreversible "arrow of time" (aka the Second Law of Thermodynamics) is seen in the tragic fact that we age and die, eggs do not unscramble themselves, etc. However, quantum entanglement, which is beginning to play the crucial role in practical command-control-communication technology, becoming increasingly important to Google, Apple, Microsoft, et al. in their artificial intelligence/big data business, is telling us that time also flows in reverse from future to present. In fact, all quantum entanglement phenomena in the present come from back-from-the-future "destiny" partial causes in addition to the familiar classical historical past partial causes of those same present effects. In other words what happens to the world now not only depends on our past history, but also on our future destiny.

Finally, we have the third or "post-quantum revolution" that explains not only how our own human consciousness emerges out of the two-way action-reaction between classical matter particle and fields with their respective back-from-the-future destiny and from-the-past history quantum information "thought" mental wave fields, but all possible forms of consciousness including conscious artificial intelligence machines from Intel, Microsoft, Apple, et al. at the billionth of a meter "nano-electronic" level. Our history mental field is the seat of our memories of things past. I suggest as a hypothesis or conjecture that our destiny mental field is the source of our intuition, of our creative ability to imagine, wonder and discover.

Antony Valentini has argued that the Born-Feynman probability rule (i.e, to take the modulus square of complex number path amplitudes ($\exp(iS/\hbar)$) and to add the amplitudes coherently before squaring when the outcomes cannot be distinguished, but to square first before adding when they can, is not a fundamental law of nature, but is an accident corresponding to what he calls sub-quantum equilibrium. What I am calling Post-Quantum Mechanics (PQM) corresponds to Valentini's sub-quantum non-equilibrium in which what he calls entanglement nonlocal signaling happens.

## SUBQUANTUM INFORMATION AND COMPUTATION

Antony Valentini:

> It is argued that immense physical resources - for nonlocal communication, espionage, and exponentially-fast computation - are hidden from us by quantum noise, and that this noise is not fundamental but merely a property of an equilibrium state in which the universe happens to be at the present time. It is suggested that 'non-quantum' or nonequilibrium matter might exist today in the form of relic particles from the early universe. We describe how such matter could be detected and put to practical use. Nonequilibrium matter could be used to send instantaneous signals, to violate the uncertainty principle, to distinguish non-orthogonal quantum states without disturbing them, to eavesdrop on quantum key distribution, and to outpace quantum computation (solving NP-complete problems in polynomial time).
> https://arxiv.org/abs/quant-ph/0203049 (2002).

Valentini wrote the above before Huw Price, Ken Wharton, Rod Sutherland convincingly explained, in my opinion, that spacelike nonlocality is not a good way to think of quantum entanglement. The alternative Costa de Beauregard zig-zag used implicitly at least by Yakir Aharonov and John Cramer in their respective interpretations of quantum theory, is preferable because it is consistent with the symmetries of Einstein's classical theories of relativity if we allow weak measurement future causes of present effects as well as the usual past causes of present effects of orthodox von-Neumann strong measurement interpretations. Indeed, the observed violation of Bell's inequality can be most simply and elegantly understood as the effects of future causes (strong measurements) of past effects (at the moment of emission of a pair). From this point of view it is obvious why the space-time separations between strong measurements of the localized parts of the entangled whole do not matter. Those separations can be spacelike, timelike or lightlike even in curved classical spacetime where one can try to connect them with corresponding geodesics. Huw Price has also pointed out that John Bell was confused on the difference between super-determinism and local retrocausality. This confusion caused him to erroneously think that local retro-causality conflicted with free will. All of this presupposes that we live in a block universe one physicist in particular thinks means there is no dynamics. This not the place to argue this, although, I mention it in passing, since it was discussed in this workshop. Suffice it to say, that the Lagrangian form of dynamics only makes sense in the block universe picture in which we take the global 4D spacetime view. The dynamical view is that of the Hamiltonian formulation (3D + 1). One beautiful result of Sutherland's fully

relativistic Lagrangian for Bohms pilot-wave particle theory is that because of the Costa de Beauregard zig-zag and the use of Yakir Aharonov's advanced destiny and retarded history waves in the weak measurements of the particle motions between strong measurements, we no longer need higher-dimensional configuration space in the description of many-particle entanglement. Indeed, Sutherland has applied this notion to the problem of quantum gravity.

The structure of Sutherland's Lagrangian, as shown in his talk, has classical particle parts independent of $h$ as well as quantum parts dependent on $h$, shows that Valentini need not use the word sub-quantum. The beables are not at some hidden level at all. They are at the classical physics level. Furthermore, Valentini thinks that non-equilibrium matter is only found around the time of the Big Bang. On the contrary, I propose that all living matter is non-equilibrium matter in the sense of locally-decodable key-less entanglement signaling that is strictly forbidden in the limit of orthodox quantum theory. Indeed, I propose that Sutherland's weak measurement action-reaction piece of his Lagrangian corresponds to what Valentini called sub-quantum non-equilibrium. Furthermore, when one reads Roger Penrose (e.g., Emperor's New Mind [1]; Shadows of the Mind [4]; and Fashion, Faith and Fantasy [5]), one sees mention of the possible importance of Herbert Frohlich's macro-quantum coherence in pumped open non-equilibrium dissipative structures. This leads me to further conjecture that any such open macro-quantum coherent pilot wave – but classically thermodynamically non-equilibrium – system will be post-quantum with Sutherland's action-reaction not equal to zero. Indeed, I conjecture that the PQM action-reaction term will be proportional to the amount of external pump stress-energy current densities above Frohlich's critical threshold. The mathematical model here is formally similar to that of a coherent laser beam above threshold rather than in the thermodynamic equilibrium of a conventional Bose-Einstein condensate. Now it turns out that Sutherland's PQM action-reaction is proportional to a factor, which when set equal to zero, in the limiting case PQM goes to QM, is exactly de Broglie's guidance equation that the particle world lines coincide with pilot wave fluid stream lines (gradients of the phase of the pilot waves). This explains why, in a beautiful way, we can dispense with the particles entirely in the orthodox quantum limit and pretend they are not there. Of course, doing that leads to bending over backwards with contortions like wave function collapse, problem of the classical limit, etc. – all non-problems in the Bohmian 1952 picture, not to be confused with his later less intuitive implicate/explicate order speculations. I have no need of that hypothesis here. Finally, it needs to be pointed out that the basic Sutherland Lagrangian theory is non-statistical God does not play dice (Einstein); it is nonlinear and non-unitary. The statistical linear unitary QM limit comes from doing several things:
(1) setting the wave action-particle reaction term to zero; and
(2) integrating over the future destiny causes of past effects with the ad hoc Born rule weighting factor
$| < destiny|history > |^2$.

As an example, the Aharonov weak measurements at $x$ are of the form for a local operator $J$:

$$< J(x) > w =< destiny|x > J < x|history > / < destiny|history > . \quad (1)$$

Therefore, the integral over all possible $< destiny|$ states with the above weighting factor in (2) is the orthodox strong von Neumann statistical expectation value:

$$< J(x) >=< history|x > J < x|history > . \quad (2)$$

And it appears as if time only flows one-way from past to future in accord with the Arrow of Time of the Second Law of Thermodynamics as in Henry Stapp's talk at this conference. (Sutherland only takes the real part of Aharonovs complex weak measurement. However, the imaginary part is also of experimental importance. All the anomalous motions of the particles that can punch outside the light cone and even turn around backwards in time only happen virtually.)

Finally, I would now like to comment on some recent developments having to do with the resurgence of interest in Geoffrey Chew's bootstrap, in ER = EPR which I first mentioned in 1975 in the book Space-Time and Beyond (E. P. Dutton version) and in the AdS/CFT interior bulk-horizon boundary duality in relation to PQM.

Chew's bootstrap was of a logical nature. It may be connected with Igor Novikov's temporal bootstrap of "globally self-consistent loops in time." Novikov was mainly thinking about time travel to the past through traversable wormholes in a classical way. Kip Thorne and students then did some calculations with quantum Feynman histories that seemed to agree with Novikov's idea. David Deutsch and Seth Lloyd considered slightly different models of quantum computation between a pair of entangled qubits, one going back in time through a CTC traversable wormhole. We also have ER = EPR connecting AdS ER wormholes in the interior bulk with EPR CFT correlations on the cosmological horizon boundary in Susskind's "The World is a Hologram" idea. In fact we have both past and future cosmological horizons, which take us to Yakir Aharonov's locally retrocausal "weak measurements" underlying von Neumann's strong measurements.

Huw Price of Trinity College Cambridge has clarified the meaning of entanglement and the violation Bell's locality inequality in terms of a more fundamental timelike locally real retrocausality of future causes of past effects as the only explanation of all kinds of entanglement that is consistent with Einstein's relativity. Price re-introduced the old idea of Costa de Beauregard's "zig-zag" implicit in both Yakir Aharonov's "destiny" and "history" quantum waves similar, though not identical, to John Cramer's "confirmation" and "offer" waves in the Transactional Interpretation.

Finally, in 2015 Australian physicist Rod Sutherland has taken these ideas in an action-principle Lagrangian mathematics of a fully relativistic Bohm pilot-wave/hidden variable particle model in which Aharonov's "weak measurements" are clearly represented a locally retrocausal "zig-zag" manner that allows us to dispense with higher dimensional configuration space. This is a considerable simplification conceptually and computationally.

Indeed, Sutherland has done some preliminary work on quantum gravity from this new point of view. Even more important Sutherland has taken some first steps toward a Post-Quantum-Mechanics PQM which is to QM as Einstein's GR is to his SR. In both cases the key is the action-reaction organizing principle (not to be confused with the more specific Newton's 3rd Law from translational symmetry of the dynamical action). In relativity, the action-reaction is between the space-time continuum and matter-energy. In PQM, which requires the Bohm 1952 picture, the action-reaction is between the pilot waves and matter-energy. In post-quantum gravity (PQMG) the action-reaction is between the space-time continuum classical geometrodynamic field and its pilot waves.

PQM is basically a non-statistical nonlinear theory in which messages encoded in an entanglement pattern can be locally decoded without a key. This corresponds to traversable ER bulk wormholes from signaling EPR entanglements on their horizon boundaries obeying Novikov's globally self-consistent loops in time. Thus we are back to Geoff Chew's "bootstrap," at least in spirit. The QM bootstrap posited a unitary S-Matrix. The PQM bootstrap is non-unitary corresponding perhaps to pumped open dissipative structures held far from thermodynamic equilibrium, but with macroscopic (ODLRO) long range quantum phase coherence (e.g. laser analogy). The QM limit of PQM involves setting the action-reaction to zero and ad hoc introduction of the Born rule for squaring amplitudes etc and then integrating the future away. This hides all retrocausal effects and yields the von Neumann collapse picture of strong measurements with linear unitary retarded time evolution of closed systems between the measurements.

In summary:

> Jack Sarfatti has been exploring a generalisation of David Bohm's ontological interpretation of quantum mechanics, extended so a particle is not just guided by the quantum potential, but, in turn, through backactivity, modifies the quantum potential field. Backactivity introduces nonlinearity into the evolution of the wave function, much like the bidirectional nonlinear interaction of spacetime and matter-energy in general relativity.
>
> The effects of backactivity are negligible in interactions at the atomic scale; divergences from the predictions of conventional quantum mechanics would be manifest only in systems where quantum coherence occurs at the mesoscopic and macroscopic scale. Sarfatti suggests that this post-quantum backactivity may be involved in various phenomena as follows:
>
> Life in general, and consciousness in particular, depends upon a backactivity-mediated feedback loop operating on macroscopic quantum structures in the cell
>
> Life, through homeostasis, maintains the far-from-equilibrium quantum machinery necessary for its own existence. Rocks aren't alive because they have no structures which prevent thermal decoherence of the wave function
>
> I don't know whether these suggestions are correct – nobody does at present, but there's nothing in any of them which seems inaccessible to experiment in the relatively near future.
>
> John Walker https://ricochet.com/archives/ )

## ACKNOWLEDGEMENTS

The author does not wish to acknowledge or thank anyone.

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