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Retrocausality and Signal Nonlocality in Consciousness and Cosmology

Jack Sarfatti
ISEP.
Chestnut Street, San Francisco, CA 94133

ABSTRACT

I conjecture that the intrinsic conscious mental field is analogous to a hologram described by a low frequency effective field nonlinear dissipative (non-unitary) local macroquantum coherent c-number multi-component order parameter. This order parameter landscape in our brain obeys a Landau-Ginzburg type equation for a non-equilibrium dissipative structure with signal nonlocality violating microscopic orthodox quantum theory. Therefore, different parts of the brain can locally decode messages from other distant parts without having to wait for classical electrical and chemical signal keys to move slower than light. The coherent order parameter landscape is phase and amplitude locked into the distributed pattern of the electrical and chemical signals both for sensory input and motor output in a set of creative feedback-control loops. The imprinting action of the electrical and chemical signal patterns on the intrinsically mental landscape excites our inner conscious qualia and explains the "binding problem" of how the conscious mind has an undivided wholeness. The piloting reaction of those excitations in the mental landscape back on the electrical and chemical signal pattern is our volition in which thought is expressed in our motor behavior. The application of similar ideas to the cosmological dark energy and arrow of time problems is also discussed. Indeed, I suggest that the dark energy accelerating the universe is advanced Hawking-Unruh black body radiation from our future observer-dependent cosmological event horizon.

Keywords: retro-causality, signal nonlocality, conscious qualia, holography, arrow of time, horizons, dark energy, de Sitter space, Unruh effect, cosmological constant paradox, Wheeler-Feynman advanced radiation

"Science proceeds as if the past was the home of explanation; whereas the future and the future alone holds the key to the mysteries of the present. When that first cell divided, the meaning of that division was to be discovered in the future, not in the past; when some pre-human ancestor first uttered a human sound, the significance of that sound was to be interpreted by human language, not by apish grunts; when the first plant showed solicitude for its seed, the interest of that solicitude lay in the promise of maternal affection. Things must be judged in the light of the coming morning, not in the setting stars." (Sedgwick, 1916)

There is now ample independent reproducible evidence in many published papers (Bem, 2011), (Bierman, 2008; Libet, 1979; Radin, 2004) for back-from-the-future "presponse" in human consciousness (Stapp, 1996). Yakir Aharonov (Aharonov,1998) in his back-from-the-future version of quantum theory argues that unlike classical mechanics, in quantum mechanics the initial pre-selected and final post-selected conditions are truly independent. Indeed, the uncontrollable randomness of Heisenberg's microscope uncertainty gedankenexperiment only occurs because we integrate out the final condition in our intermediate observations. Aharonov shows with actual experiments using weak measurements that the statistical ensemble expectation values need two quantum state vectors instead of the usual one. For example, in addition to the retarded Dirac "bra" *history* propagating from the past preselected initial condition to the present intermediate measurement, we also need the advanced Dirac "ket"

$|destiny\rangle$ propagating back-from-the-future post-selected final condition to the present.

The present *weak measurement* expectation value in standard Dirac notation is different from the von-Neumann projection postulate for strong measurements, namely

$$\langle A\rangle_w \equiv \frac{\langle history|\hat{A}|destiny\rangle}{\langle history\,|\,destiny\rangle} \quad (1.1)$$

Aharonov and his students speculate that a final condition in our future retro-causally influences the past evolution of life on Earth. On the other hand, Michael Nauenberg wrote:

"The claim of Aharonov et al. that at various stages of the measurement process, ensembles can be separated into sub-ensembles which can be associated with quantum states, leads to contradictions with the principles of quantum mechanics, and gives rise to the paradoxes of 'impossible ensembles' discussed in their article. Their un-physical description of the measurement process, leads them to the false conclusion that 'quantum mechanics offers a place to specify both an initial and an independent final state", and to such outlandish statements like 'that quantum mechanics lets one impose . . . a putative final state of the universe'." (Nauenberg, 2011)

Aharonov's theory is still limited by what Abner Shimony calls "passion at a distance" aka signal locality. Signal locality precludes using nonlocal quantum entanglement as a stand-alone communication channel. This means that any attempt to encode and send a message from one part of an entangled system to another part will only show random noise at that second part. Decoding the nonlocally entangled stored message always requires an additional classical signal or "key" to break the code. Brian Josephson (Josephson, 1991) and myself (Sarfatti, 1998) independently suggested ways out of this Catch 22 involving generalizing quantum theory with "signal nonlocality" very much like the transition from special to general relativity where non-unitarity of the time evolution of the quantum state is analogous to non-vanishing curvature. Antony Valentini published detailed formal papers asserting that "sub-quantal non-equilibrium" of Bohm's "hidden variables" permits signal nonlocality with profound consequences for quantum cryptography (Valentini, 2002). In addition, the discovery of dark energy accelerating the expansion of our observable universe is evidence for the idea that we are retro-causal back-from-the-future hologram image computations from our future cosmological event horizon (Davis, 2003) whose increasing area-entropy from the moment of inflation almost trivially explains the irreversible arrow of time.

"Quantum correlations display a subtle nonlocality. On the one hand, as Bell showed, quantum correlations could not arise in any theory in which all variables obey relativistic causality. On the other hand, quantum correlations themselves obey relativistic causality—we cannot exploit quantum correlations to transmit signals at superluminal speeds (or at any speed). …. Nonlocality and causality seem prima facie incompatible. Einstein's causality contradicts Newton's action at a distance. Yet quantum correlations do not permit action at a distance, and Shimony has aptly called the nonlocality manifest in quantum correlations "passion at a distance."

(Popescu & Rohrlich,1996)

On the other hand, Antony Valentini wrote:

"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)." (Valentini, 2002)

I assume here as a fact that we have unconscious neurological responses before the external stimuli. This cannot be explained by orthodox quantum theory because this presponse is non-random violating the no-signaling with entanglement theorem based on unitary time evolution of the quantum wave function and the usual Born probability interpretation. The latter rule is that the squared modulus of the complex-valued quantum wave function is the probability density in configuration space for position measurements of many entangled particles. In Feynman's global path integral picture we coherently square the sum of the amplitudes for indistinguishable histories, but not for distinguishable histories.

Furthermore, I suggest that all living matter is "nonequilibrium" in Valentini's "sub-quantal" sense within Bohm's ontological interpretation of quantum theory. The latter pictures real electrons and other particles on definite spacetime trajectories influenced by the nonlocal context-dependent quantum potential as well as the classical local gauge electro-weak-strong forces. Therefore, we can apply ordinary non-equilibrium statistical mechanics because the "hidden variables" are not really "hidden" at all but correspond pretty much to our usual classical pictures contrary to Bohr's position in his debate with Einstein. All the quantum weirdness is in the quantum potential Q for fermions and its generalization to boson field theory. Orthodox quantum theory corresponding to "sub-quantal thermodynamic equilibrium" of the hidden variable particles corresponds to a "fragile" quantum potential Q. "Fragile" in this context was coined by Bohm and Hiley in their book "The Undivided Universe". It means that the hidden variables are test particles that are piloted by Q, but do not directly back-react on it. Such direct back-reaction would permit stabilizing feedback-control loops between the entangled particles and their shared Q. Pumping by an external flow of energy should establish sub-quantal non-equilibrium and long-range coherence analogous to a laser above threshold. The material hidden variables are then no longer passive test particles at the mercy of their intrinsically thoughtlike Q, but modify it whilst being moved by it. This change in the shape of the Q landscape is the origin of all conscious qualia. (Stapp, 1996) That's the model.

Mathematically, in the simplest case of two identical entangled point particles in the slow speed non-relativistic limit, the extended post-quantum theory has a post-quantum potential $\tilde{Q} \neq Q$ where

$$\begin{aligned}\tilde{Q} &= Q(x_1, X_1, x_2, X_2) \\ Q &\equiv Q(x_1, x_1)\end{aligned} \tag{1.2}$$

where x_i are variables of possible *virtual* coordinates of where and when the particles might be whilst, in contrast, X_i are the actual coordinates of the particles where and when they *really* are (Sarfatti, 2002).

Borrowing from Wheeler and Feynman's classical advanced potential electrodynamics that mutated to John Cramer's transactional interpretation (Cramer, 1986) and Aharonov's history and destiny double state vector theory, I replace the $\left|\psi(x_1 ... x_N)\right|$ in Bohm's quantum potential

$$Q \sim \frac{\left(\sum_{i=1}^{N} \nabla_i^2\right)|\psi|}{|\psi|} \tag{1.3}$$

by an entirely original Ansatz presented here for the first time to my knowledge:

$$\begin{aligned}|\psi| &\rightarrow \sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|\left(e^{\frac{i}{\hbar}\left(S_{history} - S_{destiny}\right)}\right)} \\ &= \sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\left(\cos\frac{\left(S_{history} - S_{destiny}\right)}{2\hbar} + i\sin\frac{\left(S_{history} - S_{destiny}\right)}{2\hbar}\right)\end{aligned} \tag{1.4}$$

$$\Theta \equiv \frac{S_{history} - S_{destiny}}{2\hbar} \tag{1.5}$$

$$\begin{aligned}&\nabla\left[\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\left(\cos\Theta+i\sin\Theta\right)\right]\\&=\left(\nabla\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\right)\left(\cos\Theta+i\sin\Theta\right)+\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\nabla\left(\cos\Theta+i\sin\Theta\right)\end{aligned} \tag{1.6}$$

Therefore

$$\tilde{Q}\sim\frac{\left\{\begin{array}{l}\left(\nabla^2\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\right)\cos\Theta+2\nabla\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\cdot\nabla\cos\Theta\\+\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\nabla^2\cos\Theta\\+i\left[\begin{array}{l}\left(\nabla^2\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\right)\sin\Theta+2\nabla\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\cdot\nabla\sin\Theta\\+\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\nabla^2\sin\Theta\end{array}\right]\end{array}\right\}\left(\cos\Theta-i\sin\Theta\right)}{\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}} \tag{1.7}$$

$$\operatorname{Re}\tilde{Q}\sim\frac{\left\{\begin{array}{l}\left(\nabla^2\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\right)+2\cos\Theta\nabla\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\cdot\nabla\cos\Theta\\+\cos\Theta\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\nabla^2\cos\Theta\\+\left[2\sin\Theta\nabla\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\cdot\nabla\sin\Theta+\sin\Theta\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\nabla^2\sin\Theta\right]\end{array}\right\}}{\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}} \tag{1.8}$$

$$\operatorname{Im}\tilde{Q}\sim\frac{\left\{\begin{array}{l}-\sin\Theta2\nabla\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\cdot\nabla\cos\Theta+\sin^2\Theta\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\nabla^2\cos\Theta\\+2\cos\Theta\nabla\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\cdot\nabla\sin\Theta+\cos\Theta\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}\nabla^2\sin\Theta\end{array}\right\}}{\sqrt{\left|\psi_{history}\right|\left|\psi_{destiny}\right|}} \tag{1.9}$$

The limiting case of orthodox unitary non-dissipative quantum mechanics is the very shaky ground

$$
\begin{aligned}
&\Theta \to 0 \\
&\nabla \cos\Theta \to 0 \\
&\nabla \sin\Theta \to 0 \\
&\nabla^2 \cos\Theta \to 0 \\
&\nabla^2 \sin\Theta \to 0
\end{aligned}
\tag{1.10}
$$

When we have spontaneous broken ground state symmetry in a complex system the local order parameter is a giant coherent "one particle" (BEC) field in ordinary space. I mean the ground state of quasi-particle excitations of the brain material probably at the level of the single electron dipoles inside the protein dimers of the microtubules in the now well-known model of Stuart Hameroff (Hameroff, 1987). Indeed, Max Tegmark's "warm brain" objection (Tegmark, 2000) against long-range coherence is under fire by recent work on, e.g., "modular entanglement" (ME) published in Physical Review Letters:

"*We will show that a most relevant feature of ME is its enhanced stability against thermal decoherence, even by several orders of magnitude, compared to the case of simple LDE … From the point of view of consciousness studies, this and other papers concerned with quantum features in proteins involved in photosynthesis look to sound the death knell for the recent orthodoxy that quantum features could not persist in biological tissues, thus leaving the road open for the possibility of quantum coherence and entanglement in the brain.*" (Guadli, 2011)

The "Catch 22" forbidding the use of nonlocal entanglement as a stand-alone communication channel depends on the linearity and unitary time evolution of the Schrodinger equation in the configuration space for many particles. We can also use the

Wigner phase space density, but there is no new physics there relevant to our quest for signal nonlocality. However, spontaneous symmetry breakdown of an invariance group G of the dynamical action means that the ground state for real particles (and the vacuum state for virtual particles) is described by the emergence of off-diagonal-long-range-order (ODLRO) in the quantum correlation functions that obey a Landau-Ginzburg equation. The formation of ordinary crystals, superconductors, and the Higgs mechanism in the standard model of quarks, leptons and gauge bosons correspond to G = T3, U1 and SU2 respectively. This mechanism gives macro-quantum long range phase coherence in an effective order parameter c-number theory whose dynamical equation is nonlinear, non-unitary and local in ordinary spacetime. Therefore, the necessary conditions for passion at a distance no longer obtain. This is what happens in all living matter in my opinion corresponding to Brian Josephson's idea of the biological utilization of nonlocality. Of course small vibrations in the macro-quantum coherent c-number will obey the usual quantum randomness with a linear unitary evolution in the configuration space of the vibrating quasi-particles and collective modes. The coherent order parameter is a source and sink for these incoherent quantum vibrations of its amplitudes and phases. The matter quantum information wave and its boson particle hidden variables essentially fuse together because a significant fraction of all the particles condense out of configuration space to occupy the same single-particle quantum state in ordinary space. P.W. Anderson (1972) calls this emergence of new order on longer scales with robust phase coherence "More is different." There is also another kind of protection against decoherence called global "topological order" (i.e., braid groups generalizing the permutation groups of quantum statistics) found in 2D thin films with string-like "anyons," e.g., electrons at the ends of magnetic flux vortex tubes (Wilczek, 1982). Anyons have fractional quantum numbers and fractional quantum statistics in-between the usual fermion and boson statistics that apply only in 3D systems. Indeed, the physics on the curved spacetime 2D +1 horizons $g_{00} = 0$ that holographically encode the interior 3D + 1 bulk gravity fields is probably anyonic. Future quantum computers immune from heat based on this idea are now actively studied and obviously this trick is probably used in our brains. However, I now go back to the local order model.

The emergent macroscopic non-relativistic local unentangled nonlinear nonunitary Landau-Ginzberg equation for the c-number ground state macroscopic coherent signal order parameter $\Psi(x)$ in ordinary 3D space replaces the nonlocal entangled linear unitary Schrodinger equation for the microscopic noise wave function $\psi(x_1, x_2, \ldots x_N)$ of N point particles in 3ND configuration space. One example of this is the superconductor Cooper pair condensate $q = 2e$

$$\begin{gathered}\frac{1}{2m}\left(-ih\vec{\nabla} - \frac{q}{c}\vec{A}\right)^2 \Psi + \alpha\Psi + \beta|\Psi|^2 \Psi = -h\gamma\frac{\partial\Psi}{\partial t} \\ \Psi \equiv |\Psi| e^{i\Theta}\end{gathered} \tag{1.11}$$

There is no “i” on the RHS of this dissipative time-dependent Landau-Ginzburg equation according to Berger. In general the coefficient multiplying the time derivative is complex with an imaginary wavelike unitary part and an real dissipative non-unitary part. The relative weights are highly model-dependent in a large variety of soft-condensed matter systems found in the literature on time-dependent Landau-Ginburg effective c-number condensate emergent field theories. That is one reason it is non-unitary. The Born probability distribution breaks down in the condensate as well. Jorge Berger wrote that (1.11) *" is not only nonlinear; it is also nonunitary."* He calculates both static and dynamical parts for the macro-quantum coherent Bohm quantum potential Q as follows.

$$\begin{aligned} Q_{static} &\equiv \frac{\hbar^2}{2m}\frac{\nabla^2|\Psi|}{|\Psi|} - \beta|\Psi|^2 \to \alpha + \frac{m}{2}\vec{v}^2 + \frac{\gamma h}{2|\Psi|^2}\frac{\partial|\Psi|^2}{\partial t} \\ Q_{dynamic} &\equiv \frac{\hbar}{|\Psi|^2}\left(\gamma\frac{\partial|\Psi|^2}{\partial t} - \frac{1}{\gamma}\vec{\nabla}\cdot\left(|\Psi|^2\vec{v}\right)\right) \end{aligned} \qquad (1.12)$$

Newton's macro-quantum coherent corrected 2^{nd} law for the convective "fluid" acceleration of the Bohm un-hidden variable is

$$\begin{aligned} \vec{a} &\equiv \left(\vec{v}\cdot\vec{\nabla}\right)\vec{v} + \frac{\partial\vec{v}}{\partial t} = -\frac{\vec{\nabla}}{m}\left(Q_{static} + Q_{dynamic}\right) + \frac{q}{m}\left(\vec{E} + \frac{\vec{v}}{c}\times\vec{B}\right) \\ \vec{v} &= \left(\frac{h}{m}\vec{\nabla}\Theta - \frac{q}{mc}\vec{A}\right) \end{aligned} \qquad (1.13)$$

"We have extended the de Broglie-Bohm theory, which was built for particles that obey the Schroedinger equation, to the case of electron pairs in a superconductor, which obey a more complex (nonlinear and nonunitary) equation. For the stationary regime this extension is completely natural; in the general case, in which the number of pairs is not conserved, additional postulates are required." (Berger, 2004)

Retrocausality was found in the physics of radiation reaction by Dirac in the 1930s and applied by Wheeler and Feynman (1945) for classical electrodynamics and to quantum theory The imposition of a perfect total future absorber for all light ensures that the world looks as if there is only past cause and future effect. Hoyle and Narlikar (1995) applied the Wheeler-Feynman idea even further to quantum theory as did Cramer (1986). Hoyle and Narlikar also applied it to cosmology. Of particular interest is their proof that the steady state cosmology obeys the perfect total future absorber final boundary condition. All of this was before the discovery of the gravitationally repulsive dark energy that is about 73% of all the stuff in our part of the multiverse that causes the expansion of 3D space to speed up rather than slow down. Our universe is evolving into a de Sitter solution described by a positive Einstein cosmological constant $\Lambda > 0$ in Einstein's field equation

$$G_{\mu\nu} + \Lambda g_{\mu\nu} + \frac{4\pi G}{c^4} T_{\mu\nu} = 0 \qquad (1.14)$$

The standard cosmological model uses a co-moving Hubble flow solution of the form

$$ds^2 = c^2 dt^2 - R(t)^2 \left[d\chi^2 + S_k^2(\chi) d\phi^2 \right] \qquad (1.15)$$

where t is the proper clock time of the force-free geodesic comoving observer at rest in the Hubble flow, i.e., zero peculiar velocity $R\dot{\chi} = 0$ corresponding to constant χ. We are located at $\chi = 0$. $D \equiv R\chi$ is the proper comoving distance of a galaxy from us on the 3D spacelike slice $dt = 0$. In general

$$\begin{aligned} \dot{D} &= R\dot{\chi} + \dot{R}\chi \\ R\dot{\chi} &\le c \end{aligned} \quad (1.16)$$

Only the peculiar velocity $R\dot{\chi}$ needs to be inside the local light cone to obey special relativity. (Davis, 2003) $\dot{R}$ is the speed of the Hubble flow, i.e. the deforming of the fabric of 3D space itself inside of which particles move relative to it. There is no such limitation on the recessional speed $\dot{R}\chi$ of the galaxy away from us. The cosmological redshift $z > 0$ for retarded light of positive energy along the future light cones is computed from

$$1 + z \equiv \frac{\lambda_{absorb}}{\lambda_{emit}} = \frac{R(t_{absorb})}{R(t_{emit})} \quad (1.17)$$

Now it turns out that the old Bondi-Hoyle-Gold steady state model has the same scale factor as does the accelerating de Sitter universe that is our future asymptote.

$$R(t) = R(0)e^{\sqrt{\Lambda}ct} \quad (1.18)$$

We then have to make a transformation to conformal time, which for our spatially flat $k = 0$ inflated universe on the large scale is

$$\begin{aligned} \tau &= \int_0^t \frac{du}{R(u)} \\ \rho &= r \\ g_{\mu\nu} &= \Omega^2 \bar{g}_{\mu\nu} \\ \Omega(\tau) &= \frac{1}{1-\sqrt{\Lambda}c\tau} \end{aligned} \tag{1.19}$$

Our original metric in the new coordinates for the de Sitter case is the overall conformal factor multiplying a globally flat Minkowski spacetime.

$$\begin{aligned} ds^2 &= \left(\frac{1}{1-\sqrt{\Lambda}c\tau}\right)^2 \left[d\tau^2 - d\rho^2 - \rho^2\left(d\theta^2 + \sin^2\theta d\phi^2\right)\right] \\ -\infty &< \tau \le \frac{1}{\sqrt{\Lambda}c} \\ \tau &= \frac{1}{\sqrt{\Lambda}c}\left(1 - e^{\sqrt{\Lambda}ct}\right) \end{aligned} \tag{1.20}$$

Showing our *future* event horizon in conformal time $\tau = \frac{1}{\sqrt{\Lambda}c} \Rightarrow \Omega \to \infty$. The condition for the event horizon in this conformally flat case is not the usual $g_{tt} = 0$ as it would be in the hovering static LNIF representation at fixed r of this same *observer-dependent metric*, i.e.

$$ds^2 = \left(1 - \Lambda r^2\right)c^2 dt'^2 - \frac{dr^2}{\left(1 - \Lambda r^2\right)} - r^2\left(d\theta^2 + \sin^2\theta d\phi^2\right) \tag{1.21}$$

Hoyle and Narlikar (1995) argued (their eq. 2.53) that the absorption integral diverges at the future event horizon ensuring complete absorption there that, in turn, implies complete cancellation of advanced signal effects giving effective past cause/future effect, but only in the large scale limit where the cosmological metric used is a good approximation.

$$I = -\int_0^{\sqrt{\Lambda}} k\,dr \sim \int_0^{\sqrt{\Lambda}} \frac{dr}{1-\sqrt{\Lambda r^2}} \to \infty \qquad (1.22)$$

we are at $r = 0$. They say that the redshift from the accelerating stretching of 3D space detected by a geodesic unaccelerating comoving observer/absorber using a conformal time clock is

$$\omega(r) = \omega(0)\left(1-\sqrt{\Lambda} r\right) \underset{r \to \frac{1}{\sqrt{\Lambda}}}{\to} 0 \qquad (1.23)$$

That is, retarded light from us is infinitely redshifted for an unaccelerated comoving detector crossing our event horizon when our retarded photon arrives. Their model, however, is not water tight and is shaky ground on which to assert that our future dark energy horizon is for sure the Wheeler-Feynman perfect absorber.

The situation is very different, indeed just the opposite, for an accelerating static observer at constant r in the metric of (1.21). His covariant acceleration, from firing rockets, is

$$g(r) = \frac{c^2\sqrt{\Lambda}}{\sqrt{1-\Lambda r^2}} \underset{r \to \frac{1}{\sqrt{\Lambda}}}{\to} \infty \tag{1.24}$$

The corresponding black body photon Unruh temperature is

$$T(r) = \frac{hg(r)}{k_B c} \tag{1.25}$$

I posit that virtual electron-positron pairs stuck to our horizon will see this Unruh temperature, which if high enough, would provide them with enough energy to be pulled out of the vacuum to make a real electron-positron plasma. That is one effect, but it appears that it is not strong enough to provide the real pair production threshold energy $2mc^2$. Indeed, if we consider a virtual electron-positron pair a distance $\varepsilon \ll \Lambda^{-1/2}$ from our future horizon, then the Unruh temperature is

$$T(\varepsilon) \sim \frac{h\Lambda^{1/4}}{c\varepsilon^{1/2}k_B} \tag{1.26}$$

This is a very interesting result because the Stefan-Boltzmann to Planck's 1900 law of black body radiation that launched quantum physics says that the energy density is proportional to the 4^{th} power of the absolute Kelvin temperature. We then get from (1.26)

$$\rho \sim \frac{h\Lambda}{c\varepsilon^2} \tag{1.27}$$

which is precisely the observed dark energy density when the thickness of the horizon ε is the Planck distance $L_P \sim 10^{-33} cm$. However, this black body Unruh radiation that matches the dark energy accelerating our universe must be advanced Wheeler-Feynman radiation from our future event horizon arriving at the Type 1a supernovae in our past light cone for reasons given below. It cannot be coming from our past particle horizon.

Fortunately, there is another effect, the retarded photon we send out is blue shifted relative to our clamped virtual electron positron pair who sees our retarded photon with an enormous energy that can create a real electron pair if

$$\omega(\varepsilon) = \frac{\omega(r=0)}{\sqrt{1-\Lambda\left(\frac{1}{\sqrt{\Lambda}}-\varepsilon\right)^2}} \sim \frac{\omega(r=0)}{\sqrt{2\sqrt{\Lambda}\varepsilon}} \geq \frac{2mc^2}{h} \tag{1.28}$$

The pair production cross-section would need to be calculated as well to see if this self-induced nonlinear pair production would be sufficient to ensure the total absorber condition sought by Wheeler and Feynman.

Einstein's general theory of relativity replaces Newton's mass source density ρ with $\rho(1+3w)$ in a 3+1 isotropic case. The ratio of pressure to energy density w is ~ 0 for ordinary slow moving matter and for cold dark matter viewed as real on-mass-shell particles whizzing through space with peculiar speed $v \ll c$. We have $w = +1/3$ for real transverse photons of zero rest mass. Indeed, this gives the famous factor of 2 in the gravitational lensing of light -- one of the classic tests of Einstein's 1916 theory. Lorentz invariance of Einstein's 1905 special theory of relativity combined with his principle of equivalence that special relativity is obeyed locally on scales small compared to the variable radii of spacetime curvature imply that $w = -1$ for all virtual off-mass-shell quanta. In addition, free quantum field theory's boson commutation rules for second-quantized creation and destruction operators give positive zero point vacuum fluctuation energy density with equal and opposite negative quantum vacuum pressure. The factor of 3 causes a net anti-gravity universally repulsive field. This is exactly what we see in the accelerating expansion of our observable universe sandwiched between our past particle and future event horizons. Similarly, the anti-commutation relations for fermions that give the Pauli exclusion principle give negative energy density for virtual lepton and quark particle-antiparticle pairs with equal and opposite positive quantum vacuum pressure. This causes a net gravity attractive field – essentially an anti-deSitter (Ads) local background metric. Remember, the equivalence principle demands all forms of energy both real outside the vacuum and virtual inside the vacuum must bend spacetime. The $w = -1$ virtual fermion-antifermion pairs will clump exactly like we see in the galactic dark matter halos that keep the stars in place and form the filaments seen on the larger scales. From a distance using gravity lensing these clumped virtual fermion pairs will mimic $w = 0$ cold dark matter. This is why I predict that all attempts to detect *real* dark matter particles in the LHC, in deep mines etc. will fail as a matter of fundamental principle. Looking for dark matter particles is like looking for the motion of the Earth through the Galilean group aether with a Michelson-Morley interferometer. So far, all attempts to detect WIMPs et-al have, and will I suspect, continue to fail.

The condition for a holographic universe is that the number N of 2D pixels (quanta of Planck area L_P^2) on the hologram screen quantum computer at an infinite redshift horizon $g_{00} = 0$ must equal the number of 3D "voxels" of scale δL (quanta of volume, the term "voxel" was coined by Lenny Susskind) enclosed by the horizon that is a *non-bounding* 2-cycle closed surrounding surface enclosing point topological defect zeros in the vacuum superconducting order parameter set – one for every pixel on the surrounding hologram screen.

Therefore,

$$\begin{aligned} N &\sim \frac{1}{\Lambda L_P^2} \sim \frac{1}{\Lambda^{3/2}\delta L^3} \\ \delta L &\sim \left(\frac{L_P^2}{\sqrt{\Lambda}}\right)^{1/2} \underset{\frac{1}{\sqrt{\Lambda}}\sim 10^{28}\,cm}{\sim} 10^{-13}\,cm \end{aligned} \tag{1.29}$$

Heisenberg's uncertainty principle must also be modified to include the formation of small black hole event horizons to

$$\Delta x \sim \frac{h}{\Delta p} + A\frac{\Delta p}{h} \tag{1.30}$$

where A is a quantum of area. However, it is not clear yet if A must be the Planck area, or something more like δL in (1.29). String theory models have strong short-range Yukawa gravity from extra space dimensions for example. Abdus Salam (1971) had the first such model back in the early 1970s that I worked on at his Trieste Institute suggesting that the universal Regge slope of the hadronic resonances were a strong finite range gravity effect in which the resonances were rotating Kerr-Newman type black holes. Today, I would instead try to use a microscopic $\Lambda < 0$ AdS interior inverse image as it were to George Chapline Jr's large-scale $\Lambda > 0$ dS interiors of "dark energy" gravastars in which the event horizon is replaced by a quantum critical surface (Chapline, 2004). George is trying to prevent gravity collapse to a singularity with the inversion of radial space with time with a repulsive dark energy interior. I am trying to do the opposite on the microscopic scale using $\Lambda < 0$ dark matter as the "Poincare stress" glue to prevent hollow shells of electric charge from exploding. This would provide extended Bohm hidden variable models of leptons and quarks with definite space-time world lines subject to the nonlocal form-dependent quantum potential Q including all the weird effects.

Our observable universe has both an observer-dependent past particle horizon that is the future light cone of the moment of inflation, and a future event horizon that is the past light cone of infinite proper time that is a finite Penrose conformal time (Tamara Davis, 2005). Assuming a timelike Killing vector field so that we have a comoving Hubble flow global cosmic time in which the black body thermal cosmic microwave background (CMB) radiation is maximally isotropic with NASA WMAP temperature fluctuations ~ 10^{-5}. We are surrounded by two spherical 2D shells corresponding to the two horizons on the constant CMB. Our past particle horizon shell recedes away from us, whilst we approach our future event horizon shell not reaching it in any finite proper clock time. Our past horizon is not at all de Sitter, but is radiation and matter dominated. Only our future event horizon asymptotically approaches the constant value $\Lambda \sim 10^{-56} cm^{-2}$ corresponding to the dark energy density

$$\rho_{DE} \sim \frac{hc\Lambda}{L_P^2} \tag{1.1}$$

that we observe in our past light cones from the anomalous z redshifts of Type 1a supernovae. How is this possible? Only if we have a Wheeler-Feynman advanced wave retrocausal effect in which our future horizon must act as a total absorber to ensure only net retarded radiation from past to future – at least on the large IR cosmological scale. The hologram screen cannot be our past particle horizon because its area is too small where our past light cone intercepts it. Therefore, the retarded dark energy density would be too large since it is proportional to the inverse area of the horizon. Thus, the hologram screen cosmic computer generating all material fields must be our future event horizon in my opinion. The increasing to saturation area of our approaching future 2D horizon is the total thermodynamic entropy of our observable universe *if* we are back-from-the-future 3D hologram images. The universe is stranger than we imagined, though not stranger than we can imagine. I am obviously more optimistic than Birkbeck College's J.D. Bernal who thought that the universe might be stranger than we can ever imagine.

Appendix

Emergent M-Matrix Gravity

The four elastic local inertial frame (LIF) gravity tetrad spin 1 Cartan 1-forms e^I are a first rank tensor under the 6-parameter Lorentz group SO1,3 (Sarfatti & Levit, 2009). Their non-trivial acceleration parts are the compensating gauge potential connections when the globally rigid 4-parameter translation group T4 is localized to the mutable T4(x) local group and the matter field dynamical actions are kept invariant. I use two Lorentz group first-rank tensor sets from eight Cartan 0-forms Θ^I & Φ^J and define the 4x4 M-Matrix of Cartan 1-forms as

$$\begin{aligned} &M^{IJ} = \Theta^I d\Phi^J - \Phi^J d\Theta^I \\ &d^2 = 0 \\ &I, J = 0,1,2,3 \\ &dM^{IJ} \sim 2d\Theta^I \wedge d\Phi^J \end{aligned} \tag{A1}$$

The first line in (A1) is the 4D elastic "world crystal lattice" (Kleinert, 2008) more complicated version of the irrotational superfluid flow Cartan 1-form of Helium 4 $v \sim (\hbar/m)d\Theta$ as the gradient of a single Goldstone phase Cartan 0-form corresponding to the rim of the Mexican Hat effective landscape potential for the ground state macro-quantum coherent simple complex-valued order parameter.

Define the compensating spin 1 gravity tetrad T4(x) potential connection A^I

$$\begin{aligned} A^I &\equiv diagM^{IJ} = M^{II} \\ e^I &= \mathrm{I}^I + A^I \end{aligned} \tag{A2}$$

Einstein's *equivalence principle* (EEP) connects locally coincident non-rotating timelike geodesic inertial frames (LIFs) with accelerating off-geodesic non-inertial frames (LNIFs), via the absolute local differential space-time interval frame invariant ds^2.

$$\begin{aligned} ds^2 &= \eta_{IJ(LIF)} e^I e^J = g_{\mu\nu(LNIF)} e^\mu e^\nu \\ e^I &= e^I_\mu e^\mu \\ \mathrm{I}^I_\mu &= \begin{matrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix} \\ \eta_{IJ(LIF)} &\equiv \begin{matrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{matrix} \end{aligned} \tag{A3}$$

The spacetime symmetry group T4(x) spin 1 gravity gauge potential Cartan 1-forms A^I are analogous to the internal SU2 & SU3 Yang-Mills gauge potential 1-forms. The LIF indices I, J, K are raised and lowered with the constant Minkowski metric η_{IJ} whilst the physically coincident LNIF indices μ, ν, σ are raised and lowered with the non-inertial curvilinear variable metric $g_{\mu\nu}(x)$. The eight Cartan 0-form super-potentials

Θ^I & Θ^J are post-inflation spontaneous broken vacuum symmetry Goldstone phases. They may be related to the SU3 QCD zero rest mass gluon colored condensate giving, perhaps, a profound unification of the internal symmetry strong force to spacetime gravity. However, this is simply a half-baked speculation at this stage. Note the "Yang-Mills" looking expression

$$ds^2 = \eta_{IJ}\left(\mathrm{I}^I\mathrm{I}^J + A^I\mathrm{I}^J + \mathrm{I}^I A^J + A^I A^J\right) \tag{A4}$$

This is not a weak-field perturbation theory. It works for strong gravity fields. I do *not* assume a non-dynamical Minkowski background with $A^I \ll \mathrm{I}^I$. This tetrad local gauge field formalism is background independent. The spin 2 character of gravity comes from the quadratic dependence of the Einstein metric tensor on the spin 1 tetrad local gauge potentials. Why there is no evidence for spin 0 and possibly repulsive spin 1 gravity in addition to spin 2 gravity needs to be explained since for angular momenta, group theory gives 1 + 1 = 0,1,2 spin irreducible representations. There would also be orbital angular momentum possible in entangled pairs of q-number spin 1 tetrad quanta $\hat{a}^I$ excited out of and into the c-number condensate vacuum expectation value A^I. Indeed, the vacuum condensate is a generally squeezed coherent Glauber state of uncertain large numbers of off-mass-shell virtual $\hat{a}^I$ quanta. There may be a "superconducting" Meissner-Anderson-Higgs-Kibble mechanism giving rest mass to the spin 0 and spin 1 gravity quanta only keeping the spin 2 quanta massless.

The torsion gap 2-form field is

$$T^{I} \equiv De^{I} = de^{I} + \omega^{I}_{J} \wedge e^{J} = dA^{I} + \omega^{I}_{J} \wedge \left(\mathrm{I}^{J} + A^{J}\right) \quad \text{(A5)}$$

$T^{I} \to 0$ in Einstein's 1916 GR. With this constraint the six antisymmetric spin-connection Cartan 1-forms $\omega^{IJ} = -\omega^{JI} = \omega^{IJ}_{\mu} e^{\mu}$ are dynamically redundant determined completely by T4(x)'s spin 1 gravity potentials A^{I} (Rovelli, 2004)

$$\omega[e]^{IJ}_{\mu} = 2\, e^{\nu[I} \partial_{[\mu} e_{\nu]}{}^{J]} + e_{\mu K} e^{\nu I} e^{\sigma J} \partial_{[\sigma} e_{\nu]}{}^{K}. \quad (2.89)$$

On the other hand, if we locally gauge the full 10-parameter Poincare group of Einstein's 1905 special relativity we get the Einstein-Cartan theory with a new additional dynamical torsion field spin-connection ϖ^{IJ} that must be added to Rovelli's eq. (2.89). I propose

$$\varpi^{IJ} \sim M^{[I,J]} \quad \text{(A6)}$$

The Einstein curvature 2-form (Ricci + Weyl) is for 1916 curvature-only GR is

$$R^{IJ} = D\omega^{IJ} = d\omega^{IJ} + \omega^{I}_{K} \wedge \omega^{KJ} \quad \text{(A7)}$$

The Einstein-Hilbert action density Cartan 0-form L is

$$L \sim \varepsilon_{IJKL} R^{IJ} \wedge e^{K} \wedge e^{L} \tag{A8}$$

The dynamical equations for matter fields Υ are usually given only for inertial frames. The equivalence principle's universal minimal coupling allows us to use accelerating non-inertial frames easily using the space-time covariant derivatives in addition to the internal U1xSU2xSU3 covariant derivatives.

$$D_{\mu}\Upsilon \equiv \left[e_{\mu}^{I} P_{I} + \left(\omega_{\mu}^{IJ} P_{IJ} + \varpi_{\mu}^{IJ} P_{IJ} \right) \right] \Upsilon \tag{A9}$$

Where the set $\{P_I, P_{IJ}\}$ are ten matrices representing the translations and space-time rotations of the Poincare group's Lie algebra appropriate to the number of components of the matter field Υ, e.g. a Dirac spinor. This prescription works equally well for translationally accelerating and rotating frames in Minkowski spacetime as well as curved spacetime. We can generalize to the fifteen parameter conformal group addition the dilation and the four constant proper acceleration Rindler horizon boosts with its thermal Unruh radiation. This introduces five new classes of gravity "local phases" in addition to the 16 tetrad components $A_{\mu}^{I}(x)$ and the 24 spin-connection components $\varpi_{\mu}^{IJ}(x)$. This would lead to new physics that might be relevant to present anomalies like the NASA Pioneer and flyby anomalies as well as to MOND attempts to explain dark matter. A new paper claims to solve the Pioneer anomaly as a mundane heating effect. The fact that the anomalous acceleration is ~ 1 nanometer/sec^2 of same order as the speed of light multiplied by the Hubble parameter appears to be merely a random coincidence and not a profound clue on the deep structure of the cosmos as many of us suspected. As Feynman said, a beautiful theory is murdered by an ugly fact.

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