The emergence of gravity as a retro-causal post-inflation macro-quantum-coherent holographic vacuum Higgs-Goldstone field

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Abstract.
We present a model for the origin of gravity, dark energy and dark matter: Dark energy and dark matter are residual pre-inflation false vacuum random zero point energy ($w=-1$) of large-scale negative, and short-scale positive pressure, respectively, corresponding to the "zero point" (incoherent) component of a superfluid (supersolid) ground state. Gravity, in contrast, arises from the 2nd order topological defects in the post-inflation virtual "condensate" (coherent) component. We predict, as a consequence, that the LHC will never detect exotic real on-mass-shell particles that can explain dark matter $\Omega_{\rm DM} \approx 0.23$. We also point out that the future holographic dark energy de Sitter horizon is a total absorber (in the sense of retro-causal Wheeler-Feynman action-at-a-distance electrodynamics) because it is an infinite redshift surface for static detectors. Therefore, the advanced Hawking-Unruh thermal radiation from the future de Sitter horizon is a candidate for the negative pressure dark vacuum energy.

1. Gravity from topological singularities in the quantum vacuum

We consider the possibility that the Einstein-Cartan 1-forms consistent with 1915 General Relativity (GR) are local macro-quantum emergent *supersolid* [1] c-number fields. We mean this in the same sense that v (the locally irrotational superflow 3D Galilean relativity group velocity 1-form in superfluid ^{4}He) is emergent, with quantized circulation. The single-valuedness of the associated S^1 macroquantum coherent Higgs-Goldstone order parameter $\Psi = |\Psi|e^{i\Theta}$ emerges from an effective spontaneous broken [2] non-electromagnetic $U(1) = O(2)$ ground state gauge symmetry[1].

$$v = \frac{1}{2\pi}\frac{h}{m}\mathrm{d}\Theta \tag{1}$$

$$\oint v = \frac{1}{2\pi}\frac{h}{m}\oint d\Theta = n\frac{h}{m} \tag{2}$$

$$n = \pm 1, \pm 2, ... \tag{3}$$

[1] This corresponds to Hagen Kleinert's multi-valued singular phase transformations (discussed elsewhere in these proceedings).

In analogy to the above, we use a phenomenological model for the moment of inflation with eight macroquantum coherent relative phase 0-forms Θ^I and Φ^I that form two Lorentz group 4-vectors with magnitudes Θ and Φ, respectively. These magnitudes, in turn, are the phases of a S^2 vacuum order parameter manifold. This S^2 fiber bundle over real spacetime supports stable point monopole topological defects (simultaneous nodes of the three corresponding Higgs fields) [3].

These GeoMetroDynamic (GMD) point monopoles are the lattice points in spacelike slices of Hagen Kleinert's "world crystal lattice" [4]. They correspond to a non-trivial 2^{nd} homotopy group of emergent effective post-inflation field $O(3)$ mappings of surrounding non-bounding 2-cycles $\mathrm{S}^2{}_{3D}$ in 3D physical space to the vacuum manifold S^2.

The inhomogeneities in all eight phases Θ^I and Φ^J form the emergent GMD tetrad field A^I. For details, see equations 14-20, below.

In the world hologram conjecture [5][6], with total hologram screen area A, the mean separation ΔL of the lattice points is for our pocket universe $\mathrm{c/H_0} = \sqrt{N}L_P = 10^{29}$ cm on the cosmic landscape of the megaverse, given by[7]:

$$\Delta L = \left(\mathrm{L}_P{}^2\sqrt{A}\right)^{1/3} = \left(\mathrm{L}_P{}^2\frac{c}{\mathrm{H}_0}\right)^{1/3} \approx 10^{-13}\mathrm{cm} \tag{4}$$

$$N = \frac{A}{4\mathrm{L}_P{}^2} = \frac{1}{4\Lambda\mathrm{L}_P{}^2} = \frac{A^{(3/2)}}{(\Delta L)^3} = \frac{V}{(\Delta L)^3} \tag{5}$$

$$A = \partial V \tag{6}$$

where ∂ is the quasi-boundary operator because the surrounding future light cone surface is a non-bounding de Rham 2-cycle. This 2-cycle encloses N GMD point monopole defects in the three effective real $O(3)$ Higgs field macroquantum coherent Penrose-Onsager off-diagonal-long-range-order post-inflation vacuum parameters[8].

Wrapping once around $\mathrm{S}^2{}_{3D}$ through solid angle 4π wraps an integer N times round the vacuum manifold S^2. This is analogous to the global quantized circulation vortices in superfluid ^{4}He that are the stable topological defects in the first homotopy group for an $O(2)$ mapping with only a single relative Goldstone phase Θ and two real Higgs scalars Ψ_1, Ψ_2 (instead of the three Ψ_1, Ψ_2,Ψ_3 with two relative Goldstone phases Θ, Φ over 3D spacelike slices of physical spacetime in our toy model).

This wrapping integer N is the explanation for the Bekenstein bit quantized areas of null black hole event horizons and observer-dependent cosmological (e.g. dark energy future de Sitter) horizons[2] of area A that obey Hawking's entropy and temperature formulas

$$S = \mathrm{k}_B A/4\mathrm{L}_P{}^2 = \mathrm{Nk}_B \tag{7}$$

$$T = \frac{\partial E}{\partial S} = \frac{\mathrm{hc}}{\mathrm{k}_B\sqrt{A}} = \frac{\mathrm{hc}\sqrt{\Lambda}}{\mathrm{k}_B} = \frac{\mathrm{hc}}{\mathrm{k}_B\mathrm{L}_P\sqrt{N}} \tag{8}$$

$$\oiint 2d\Theta \wedge d\Phi = 4\pi N = A/4\mathrm{L}_P{}^2 = 10^{124} \text{ Bekenstein BITs,} \tag{9}$$

where the double integral around the vacuum manifold is induced by a single wrap around the future asymptotic de Sitter horizon. The de Sitter horizon is a surrounding (but non-bounding [9]) closed 2-cycle at lightlike conformal infinity. It is also a stretched thermal horizon for comoving observers in the accelerating Hubble flow [5].

[2] In this paper we use the term "de Sitter horizon" informally. A more precise description would be "future cosmological event horizon".

The remaining six Goldstone phase angles form the Calabi-Yau space of string theory - the same field Gennady Shipov calls the "oriented point" [10]. Einstein's 1915 curvature field is simply the local gauge field from the 4-parameter translation universal spacetime symmetry group $T(4)$ for all matter fields (i.e., strong equivalence principle) with the constraint of zero torsion.

Locally gauging the 10-parameter Poincare group $P(10)$ of Einstein's 1905 special relativity gives the Einstein-Cartan theory of (*dislocation* defect) torsion[4] in addition to (*disclination* defect) curvature [3] of the symmetric Levi-Civita connection. Indeed, this local gauge field model can be reinterpreted in terms of the eight multi-valued Goldstone phases of the coherent post-inflation vacuum field. The Calabi-Yau space seems to be simply the torsion field in disguise.

2. Dark energy from the future

The future de Sitter event horizon world hologram is "our past light cone at the end of time"[11]. It can be pictured as a pixelated spherical shell of area $NL_P{}^2$ infinitely far from our detectors (in proper time) on their *future* light cone, with thickness L_P and duration L_P/c. This shell, or "screen", has 4D volume $NL_P{}^4$ with dark energy density hc/(4DVolume Hologram Screen). This screen projects the voxels of our accelerating expanding 3D space hologram image back from the future - indeed, back to the moment of inflation 13.7 billion years ago in what Igor Novikov calls a "globally self-consistent" strange loop in time.

To summarize: The area of an observer's future de Sitter horizon holographically determines the dark energy density seen by that observer.

For a static local-non-inertial-frame (LNIF) observer (with covariant acceleration $g = c^2/\sqrt{N}L_P = cH_0 \approx 10^{-9}$ m/sec^2 relative to the $\Lambda = 0$, $k = 0$ spatially flat post-inflation background Friedman metric) the Hawking-Unruh temperature of the future de Sitter horizon is proportional to his acceleration. This is in similar to a static outside observer adiabatically approaching the horizon of a black hole – being "slowly lowered down on a cable" – who measures a temperature which approaches the Planck temperature $hc/L_P k_B$ as he approaches the horizon.

Of course, the locally coincident geodesic observer relative to the Friedman metric sees no heat radiation - only $w = -1$ positive dark zero point energy density vibrations of equal but opposite negative pressure per large space dimension, as required by the Einstein Equivalence Principle (EEP).

In contrast the NASA WMAP isotropic black body radiation in the comoving Friedman frame is coming along our past light cone from the surface of last contact 380,000 years after the post-inflation reheating of the Big Bang, and its energy density weakens $a(t)^{-4}$ as space expands because it has $w = +1/3$ ratio of pressure to energy density[4].

[3] There are two classes of defects: The monopole defects which form the "atoms" of the supersolid world crystal lattice, and the disclinations and dislocations in this lattice, which account for, respectively, the curvature and torsion of spacetime.

[4] There is a lack of consensus and clarity in the literature on who sees what. The Unruh effect in globally flat Minkowski spacetime is: A covariantly proper accelerating local detector (not on a timelike geodesic, which by definition has zero covariant proper 4-acceleration) sees thermal equilibrium blackbody radiation whose temperature is proportional to its covariant 4-acceleration magnitude. In contrast, a momentarily coincident non-accelerating detector sees only zero point vacuum fluctuations instead of the thermal radiation. That is, some of the vacuum fluctuation energy is converted into thermal radiation in the rest frame of the intrinsically accelerating detector.

Static detectors outside the event horizon of an ideal Schwarzschild black hole are covariantly properly accelerating in order to "stand still" at a fixed Schwarzschild radial coordinate r. This is in accord with the actual Pound-Rebka Harvard Tower experiment showing the gravity redshift using the nuclear Mossbauer effect. Furthermore, the comoving detectors in the Robertson-Walker representation at constant χ are analogous to the previous case at constant r [11]:

$$ds^2 = -c^2dt^2 + R(t)^2[d\chi^2 + S_k^2(\chi)d\psi^2],$$

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We propose that the dark energy zero point vacuum fluctuations measured by non-rotating covariantly unaccelerated Local Inertial Frame (LIF) detectors (on timelike geodesics relative to the physical spacetime multi-valued connection local gauge field $\Gamma^{\mu}{}_{\nu\lambda}$ that forms curved and torsioned spacetime) appear as advanced Wheeler-Feynman quasi-thermal blackbody "Unruh radiation". It comes back from the future de Sitter horizon "perfect absorber" with temperature that has order of magnitude

$$T = \frac{\mathrm{hg}}{\mathrm{ck}_B} \to \frac{\mathrm{hc}}{\mathrm{k}_B \mathrm{L}_P \sqrt{N}} \approx \frac{\mathrm{hc}}{\mathrm{k}_B \mathrm{L}_P 10^{62}} \tag{10}$$

for covariantly accelerated Local Non-Inertial Frame (LNIF) detectors off timelike geodesics.

For example, a static observer outside the event horizon of a non-rotating black hole must covariantly accelerate away from the black hole radially with

$$g = -\frac{GM}{r^2}\frac{1}{\sqrt{1-\frac{2GM}{c^2 r}}} \sim T \tag{11}$$

in order to stay at fixed r in the curved spacetime outside the black hole. They need to fire their rocket engines in order to remain static. These static LNIF observers see the event horizon as a "stretched membrane" with Unruh temperature T. Coincident LIF observers do not see this at all. This is an example of what Leonard Susskind calls "horizon complementarity" [5], in analogy with Niels Bohr's quantum complementarity of wave-particle duality from the non-commutativity of the Lie algebra of observable operators on qubit Hilbert space fibers over classical field configuration space.

The comoving observers that see an approximately isotropic WMAP Cosmic Microwave Background (CMB) in our accelerating expanding universe are analogous to the static LNIF observers in the Schwarzschild model where now there is a universal acceleration $g \approx 10^{-9}$ m/sec^2, which is the same order of magnitude of the anomalous Sun-centered radial accelerations of the two NASA Pioneer space probes beyond the orbit of Jupiter. This is a curious coincidence that possibly has deeper significance, although it is surprising to find Hubble's parameter H_0 appearing on such a short scale local metric field. In contrast LIF detectors see this advanced quasi-thermal Unruh Wheeler-Feynman radiation as zero point vacuum fluctuation energy density

$$\rho_{\mathrm{DE}} = \text{string tension} \times \text{vacuum curvature} = \frac{\text{string tension}}{\text{area of future cosmic horizon}} \tag{12}$$

$$= \frac{\mathrm{hc}}{\mathrm{NL}_P{}^4} = \frac{\mathrm{hc}}{(10^{-2}\mathrm{cm})^4} = 0.73 \times 10^{-29} \mathrm{grams/cc}.$$

It is as if there is an effective high frequency cutoff at $c/10^{-2}$cm $= 3 \times 10^{12}$ Hz for the $w = -1$ zero point dark energy virtual photon vibrations with critical wavelength equal to the geometric mean of the future de Sitter horizon scale and the Planck scale. The world hologram model posits that the number N of interior 3D voxels N of size ΔL *equals* the number of 2D pixels of size L_P on the world hologram future de Sitter horizon.

However, e.g., Davies & Davis [12] write "the response of a particle detector travelling along a geodesic in a de Sitter invariant vacuum state; the detector behaves as if immersed in a bath of thermal radiation" Of course,"geodesic" depends on choice of the local GCT frame invariant gravity tetrad field. Thus, the detector on a geodesic in the de Sitter gravity tetrad field is actually properly accelerating with respect to the geodesic in the zero cosmological constant Robertson-Walker gravity tetrad field. This is the point of view we take in this paper and it agrees operationally with how the dark energy data is actually interpreted.

3. Calabi-Yau from torsion. Brane theory from the 1970s

The four tetrad 1-form fields e^I are the General Coordinate Invariant (GCI) gravitational fields in Einstein's 1915 GR. They form a single 4-vector under the 6-parameter homogeneous Lorentz group $SO(1,3)$. The non-trivial curvilinear 4D General Coordinate Transformations (GCT) connect covariantly accelerating coincident LNIFs with g-forces on its rest detectors. A non-gravity force is required to create a translational covariant acceleration. Conservation of angular momentum maintains a rotating LNIF in the absence of friction in deep space once the external torque is removed. The Lorentz group transformations connect coincident covariantly non-accelerating LIFs with vanishing g-forces. The tetrad field components $e^{\mu}{}_I$ and their inverses $e^I{}_\mu$ connect locally coincident LIFs with LNIFs. The LNIF curvilinear metric field is $g_{\mu\nu}$. The coincident LIF Center Of Mass (COM) metric η_{IJ} is that of Minkowski space-time of Einstein's 1905 SR. The Strong Equivalence Principle (SEP) implies for the absolute differential local frame invariant ds

$$ds^2 = g_{\mu\nu}(\text{LNIF})dx^{\mu}dx^{\nu} = \eta_{IJ}(\text{LIF})e^I e^J \tag{13}$$

The multi-valued Goldstone phase transformations in our toy model form a 4x4 M-Matrix of non-closed 1-forms where the non-trivial parts of the four curvature-only tetrad 1-forms A^I and the six non-trivial torsion field spin connection 1-forms $\varpi^{IJ} = -\varpi^{JI}$ are the diagonals and antisymmetrized off-diagonal M-Matrix elements.

$$M^{IJ} = d\Theta^I \wedge \Phi^J - \Theta^I \wedge d\Phi^J \tag{14}$$

$$dM^{IJ} = -2d\Theta^I \wedge d\Phi^J \tag{15}$$

$$d^2 = 0 \tag{16}$$

$$A^I = diag(M^{IJ}) \tag{17}$$

$$e^I = I^I + A^I = e^I{}_\mu e^\mu{}_{\text{LNIF}} = e^\mu{}_I e^I{}_{\text{LIF}} \tag{18}$$

$$I^\mu{}_I = \delta^\mu{}_I \tag{19}$$

$$\varpi^{IJ} = M^{[I,J]} \tag{20}$$

The Einstein 1915 zero torsion field i.e. $\varpi^{IJ} = 0$, curvature field 2-form is

$$R^{IJ} = D\omega^{IJ} = d\omega^{IJ} + \omega^I{}_K \wedge \omega^{KJ} \tag{21}$$

Where the torsion field 2-form in Einstein-Cartan theory beyond 1915 GR would be

$$\varpi^I = De^I = \varpi^I{}_K \wedge e^K \tag{22}$$

The 1915 GR Einstein-Hilbert pure gravity field action density is the 0-form

$$L_G = \epsilon_{IJKL} R^{IJ} \wedge e^K \wedge e^L \tag{23}$$

$$S_G = \int L_G d^4x. \tag{24}$$

$$\frac{\delta S_G}{\delta e^I} = 0 \tag{25}$$

is the pre-Feynman action principle. It is the critical point pure gravity vacuum classical field equation in the absence of matter field sources, that in the usual tensor notation is

$$R_{\mu\nu} = 0. \tag{26}$$

Adding the on-mass-shell matter fields of real quanta plus their off-mass-shell virtual quanta, which contribute to the cosmological scalar $\Lambda_{\rm zpf}$ field, replaces the above classical vacuum curvature field equation. The vanishing functional derivative of the *total* action S with respect to the 4 GCT invariant tetrad 1-forms[5] i.e:

$$\frac{\delta S}{\delta e^I} = 0 \tag{27}$$

$$S = \mathrm{S}_G + \mathrm{S}_M + \mathrm{S}_{\rm zpf} \tag{28}$$

$$\mathrm{R}_{\mu\nu} - \left(\frac{1}{2}R + \Lambda_{\rm zpf}\right) \mathrm{g}_{\mu\nu} = -\frac{8\pi G}{\mathrm{c}^4}\mathrm{T}_{\mu\nu} \tag{29}$$

We can no longer assume the zero torsion field limit ($\varpi^{\rm IJ} = 0$) of the Bianchi identity of 1915 GR. And so we dream that the final theory will use a more general connection than that of Levi-Civita. This more general connection is induced by locally gauging a more general spacetime symmetry group (e.g. the Poincare[13], de Sitter or perhaps the conformal group) instead of gauging $T(4)$ as is usually done in GR.

We use ";" and "|" to denote covariant differentiation with respect to the LC connection and the more general connection, respectively, and so rewrite the divergence of the Einstein equation as:

$$\mathrm{G}_{\mu\nu}{}^{|\nu} + \frac{\partial \Lambda_{\rm zpf}}{\partial \mathrm{x}^\nu} g^\nu_\mu + \frac{8\pi G}{\mathrm{c}^4}\mathrm{T}_{\mu\nu}{}^{|\nu} = 0 \tag{30}$$

This more general divergence (flow) equation with its additional stress-energy currents suggests new channels inter-connecting the incoherent random vacuum zero point fluctuations to the smooth coherent (generalized) curvature field. However, it must be supplemented by a similar torsion field equation that comes from the vanishing functional derivative of the total action S with respect to the 6 dynamically independent spin connection ϖ^{IJ} 1-forms. The ϖ^{IJ} form the compensating gauge field induced from localizing the 6-parameter homogeneous Lorentz group $SO(1,3)$ that also acts equally on all matter field actions, i.e.,

$$\frac{\delta S}{\delta \varpi^{\rm IJ}} = 0 \tag{31}$$

The extra-dimensional brane M-Theory, when mature, should predict a renormalization group flow to larger gravity coupling strength in the short-distance limit. This, when combined with the world hologram conjecture, suggests Abdus Salam's 1973 bi-metric f-gravity [14] formula

$$G = \mathrm{G}_{\rm Newton}(1 + \alpha e^{-r/\Delta L}) \tag{32}$$

$$\alpha \gg 1$$

has been rediscovered by brane theorists [15] looking at the Calabi-Yau (torsion) field.

4. Conclusions

In this model there is no quantum gravity in the usual sense of starting with a classical field and quantizing it. Rather, we go the opposite way in the spirit, though not the letter, of Sakharov's 1967 proposal [16]. What hitherto was called the classical gravity field is seen to be really an emergent effective *macro-quantum coherent* c-number post-inflation vacuum field.

[5] The tetrad 1-forms are the compensating gauge fields from localizing the global space-time universal translation symmetry group acting equally on all matter field actions.

We claim the residual random negative-zero-point-pressure advanced virtual bosons *back-from-the-future* manifest as the anti-gravitating universally repulsive dark energy. This is because the future de Sitter horizon for a co-moving observer in our universe is a Wheeler-Feynman perfect absorber – an infinite red shift surface – just like a black hole event horizon is for a static LNIF observer.

In contrast, we claim the universally attracting dark matter comes from residual positive-zero-point-pressure virtual fermion-antifermion pairs. In this picture, looking for real on-mass-shell dark matter particles in the LHC or in underground WIMP detectors is like looking for the motion of the Earth through the mechanical aether of Galilean relativity using Michelson and Morley's Victorian interferometer.

This model pocket universe, relative to our Earth-bound detectors, is created nonlocally and self-consistently by what Igor Novikov and Kip Thorne call "a loop in time" [17]. Advanced Hawking radiation is emitted from the future cosmic ("de Sitter") horizon at all times and is blue-shifted as it travels into the past. However, only the advanced radiation emitted at time $t_{trigger} \approx 4$ Gyr arrives back at $t = 0$, where it ignites the big bang (see figure 1.1 in [11]).

Advanced information (Hawking radiation) flows from the infinite future proper time "Omega" S^2 horizon of the observer's world line (shown in the lower "conformal time" (τ) diagram in [11] Fig 1.1) down the null cosmic event horizon to its intersection with the null particle horizon (at $t_{trigger} \approx$ 4Gyr, $\tau \approx$ 32Gyr). It flows back along the particle horizon, winding up at the initial "Alpha" moment of inflation completing what John Cramer calls a "transaction"[18].

Furthermore, looking at Fig 5.1 of [11] we see that the future cosmic de Sitter horizon area $A_c \sim N(t)$, where t is the proper cosmic Robertson-Walker time (corresponding to spacelike hypersurfaces of maximal CMB isotropy), rises from "zero" (1 Bit) to de Sitter asymptote $N(t \rightarrow \inf) \approx 10^{124}$ Bits rather quickly. The advanced dark energy thermal Hawking radiation reaching us now backward-through-time along our future light cone is very close to the asymptotic value.

The final entropy of our (retro)-causal[18][19] universe is $Nk_B \approx 10^{124}$ Bekenstein bits, as mandated by the area of the future de Sitter horizon, whereas the initial entropy of the universe is exactly $k_B = 1$ bit, as mandated by the (Planck) area of the initial singularity.

This shows very clearly why the cosmological arrow of time is aligned with the thermodynamic arrow of time, solving Roger Penrose's main objection [20] to inflationary cosmology: why the early universe has relatively low entropy. We need both retrocausality and the world hologram principle to properly understand the Arrow of Time of the Second Law of Thermodynamics.

5. Background related reading

The works of John Wheeler and Richard Feynman [21], Fred Hoyle and Jayant Narlikar [22], James Woodward [23], Michael Ibison [24], Robert Becker [25] and John Cramer [18] on advanced electromagnetic waves, radiation reaction and vacuum fluctuations, Leonard Susskind [5] and Jack Ng's work on the world hologram [7], Gennady Shipov on torsion fields [10], and finally Hagen Kleinert's work on singular multi-valued phase transformations as local gauge transformations [4] are essential background reading. We have also found Chapter 2 of Rovelli's lectures on quantum gravity [26] very clear regarding the use of Cartan forms in gravity theory.

During the preparation of this paper we be became aware of a publication entitled: "Is dark energy from cosmic Hawking radiation?"[27] that relates $w = -1$ dark energy to observer-dependent Hawking radiation. However, those authors do not clearly specify which horizon they are referring to. They omit the (key) notion of retro-causality. We claim retrocausality is necessarily implied when the correct cosmic horizon - the *future lightlike* de Sitter horizon – is specified. Tamara Davis's thesis [11] (especially her figures 1.1 and 5.1) clarifies much of the rampant confusion over this subtle issue.

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