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Einstein's Gravity and Dark Energy/Matter

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Abstract

Should Einstein's general relativity be quantized in the usual way even though it is not renormalizable the way the spin 1/2 lepto-quark – spin 1 gauge force boson local field theories are? Condensed matter theorists using P.W. Anderson's "More is different"[i] approach, consistent with Andrei Sakharov's idea of "metric elasticity"[ii] with gravity emergent out of quantum electrodynamic zero point vacuum fluctuations, is the approach I take in this paper. The QED vacuum in globally-flat Minkowski space-time is unstable due to exchange of virtual photons between virtual electrons and positron "holes" near the $-mc^2$ Fermi surface well inside the $2mc^2$ energy gap. This results in a non-perturbative emergence of both Einstein's gravity and a unified dark energy/dark matter w = -1 exotic vacuum zero point fluctuation field controlled by the local macro-quantum vacuum coherent field. The latter is a Bose-Einstein condensate of virtual off-mass-shell bound electron-positron pairs. The dark matter exotic vacuum phase with positive pressure does mimic w ~ 0 "cold dark matter" for distant observers even though its internal structure is w = -1. Old problems in elementary particles are also seen in a new light in terms of Ed Witten's reciprocal string tension parameter α'.[iii]

I. QED Vacuum Instability

Dirac's electron vacuum is a filled Fermi sphere of off-mass-shell negative energy electrons in which

$$E^2 \neq (pc)^2 + (mc^2)^2 \quad \text{(I.1)}$$

The non-perturbative BCS model of a superconductor works because the attraction caused by virtual phonon exchange between two on-mass-shell electrons overpowers the repulsion caused by virtual photon exchange. The resulting ground state phase transition of "More is different" spontaneous symmetry breaking is a collapse of the effective volume of phase space resulting in a relative lowering of the non-classical entropy that allows the emergence of a higher-level collective order seen in the local macro-quantum coherent order parameter

$$\Psi_s(x) \equiv \sqrt{\rho_s} e^{i\Theta} \quad \text{(I.2)}$$

with the Meissner effect exclusion of magnetic flux from the bulk, quantized vortex strings in the Type II ground state, Josephson tunneling across thin normal junctions etc. A similar instability happens in the QED vacuum, which is intrinsically unstable. The collapse of the QED "false vacuum" is, in the large-scale, the explanation of the scalar field of inflationary cosmology. That scalar field has hitherto been introduced ad-hoc with no fundamental micro-dynamical mechanism. The result is a charge neutral macro-quantum vacuum coherence local field

$$\Psi_{vac}(x) \equiv Higgs(x) e^{iGoldstone(x)} \quad (1.3)$$

The formula

$$\vec{v}(x) = \frac{\hbar}{m} \vec{\nabla} \arg \Psi \quad (1.4)$$

is well known in Bohm's micro-quantum pilot wave/hidden variable theory and in the macro-quantum theory of superfluid helium. Adding the gauge-covariant EM potential explains the Bohm-Aharonov and Josephson effects in their respective contexts. The idea of this formula also works for Andrei Sakharov's "metric elasticity" approach to Einstein's gravity as an emergent collective QED effect. Following Hagen Kleinert's classical reformulation of Einstein's gravity in terms of 4-dim elasticity tensor theory[iv], I define the "world crystal lattice" distortion field as

$$\xi^{\mu}(x) = \overline{L}_p^2 \frac{\partial}{\partial x^{\mu}} Goldstone(x) \quad (1.4)$$

I use $\overline{L}_p^2$ as the effective quantized Planck area, which can be much larger than 10^{-66} cm^2 in some of the new theories with large compactification scales for extra bosonic space dimensions. For example using the "world hologram" formula

$$\overline{L}_p^2 = L_p^{4/3} L^{2/3} = \hbar \overline{G} / c^3$$

For the effective Planck area at scale L, substitute $L = c/H_0$ to get an effective Planck scale of ~ 1 fermi in a kind of Mach Principle where the cosmological scale together with the Newtonian quantum gravity scale determines Ed Witten's string parameter α' for the universal slope of the hadronic resonance Regge trajectories. The problem here is that the Hubble parameter H_0 is time dependent in the FRW cosmology. This would mean that the Regge slope is increasing as the Universe expands, in other words, the string tension is decreasing starting out at the Planck value ~ 10^{19}Gev per 10^{-33}cm to its present value of ~ 1Gev per Fermi. However, this possibility would seem to be implausible, immediately falsifiable from existing astrophysical data on stellar evolution although I have not confirmed that. Therefore, I am only presenting this as a curious coincidence at the present time.

II. Einstein's Gravity as String Theory

Note that $c^4/8\pi G$ has the dimensions of string tension. Witten's α' is the reciprocal string tension. In fact one can write Einstein's 1915 local geometrodynamical field equation in a stringy way as

$$G_{\mu\nu} = \alpha' T_{\mu\nu} \quad \text{(II.1)}$$

My formula for the elastic 4D distortion field in terms of the Witten string parameter and the Goldstone phase of the macro-quantum vacuum coherence field is the "IT FROM BIT"[2] equation

$$\xi^{\mu}(x) = \hbar c \alpha' \frac{\partial}{\partial x^{\mu}} Goldstone(x) \quad \text{(II.2)}$$

This formula is intuitively satisfying because it says that curved spacetime is not possible when the string tension becomes infinite. Spacetime is then too stiff to bend with stress-energy density. Newton's gravity corresponds to both

$$\hbar \to 0 \;\&\; c \to \infty .$$

Einstein's curved spacetime metric tensor is then

$$g^{\mu\nu}(x) = \eta^{\mu\nu} + \frac{\partial \xi^{\mu}}{\partial x^{\nu}} + \frac{\partial \xi^{\nu}}{\partial x^{\mu}} \quad \text{(II.3)}$$

Where $\eta^{\mu\nu}$ is the constant Minkowski metric for globally flat spacetime. Note this is not a perturbation theory. The second 4D elastic strain tensor term on the RHS need not in any sense be small. Einstein's 1915 theory does not have torsion, but if one wanted to extend it, torsion would correspond to the anholonomic phase singularity field

$$\Omega^{\mu\nu}(x) = \frac{\partial \xi^{\mu}}{\partial x^{\nu}} - \frac{\partial \xi^{\nu}}{\partial x^{\mu}} \neq 0 \quad \text{(II.4)}$$

where the mixed second order partial derivatives of the Goldstone phase of the vacuum coherence field fail to commute. It is already known that the topological defects of the complex scalar vacuum coherence field with the O(2) local phase group in 4D spacetime must be strings like the vortex lines in a Type II superconductor where the coherence field vanishes in the core. In the present case there can be extra space dimensions, both boson c-number and supersymmetric Fermi matrix. The string Goldstone phase singularities then vibrate in the extra compactified dimensions. Hagen Kleinert has shown that these strings are of two types in 4D spacetime. Disclination string defects, in the long wave limit of the world crystal lattice with spacing L_p, correspond to Einstein's tidal force curvature tensor forces between two neighboring timelike geodesic observers. Dislocation string defects correspond to torsion fields.

The "two fluid model" of superfluid Helium then motivates the following Ansatz for the exotic vacuum field of residual random zero point vacuum fluctuations from *all* the dynamical quantum fields of spin 1/2 and spin 1

$$\Lambda_{zpf}(x) \equiv \left(\frac{1}{\hbar c \alpha'}\right)\left[(\hbar c \alpha')^{3/2} Higgs(x)^2 - 1\right] \quad \text{(II.5)}$$

Einstein's field equation, assuming zero torsion and metricity for now, is then

$$G_{\mu\nu}(x) + \Lambda_{zpf}(x) g_{\mu\nu}(x) = \alpha' T_{\mu\nu}(x) \quad \text{(II.6)}$$

However, in general we can no longer assume the result of the Bianchi identities. Therefore, local conservation of stress-energy density currents generalizes to

$$G_{\mu\nu}(x)^{;\nu} + \Lambda_{zpf}(x)^{,\nu} g_{\mu\nu}(x) = \alpha' T_{\mu\nu}(x)^{;\nu} \quad \text{(II.7)}$$

Where the Diff(4) covariant derivatives, marked by the semi-colon symbol in standard notation, are constructed from the usual timelike non-geodesic world line LNIF parallel-transport torsion-free metric connection fields $\Gamma^{\sigma}_{\mu\nu}(x)$ that are the usual combinations of first partial derivatives of the curved metric $g_{\mu\nu}(x)$, which, in turn, comes from modulating the Goldstone phase of the "More is different" vacuum coherence field.

III. Exotic Vacuum Physics

The weak curvature field slow motion limit of Einstein's field equation reduces to the quasi-Newtonian Poisson equation

$$\nabla^2 V_{stuff}(x) = G\rho(1 + 3w) \quad \text{(III.1)}$$

where the index for the equation of state for the source “stuff”, whether real (on-mass-shell) or virtual (off-mass-shell) is defined as the ratio of pressure to energy density

$$w = \frac{p}{\rho c^2} \quad \text{(III.2)}$$

w = 0 for cold matter, w = 1/3 for on mass shell real transverse far field radiation photons like the cosmic microwave background blackbody radiation that has adiabatically cooled down in the expansion of the 3D space of the Universe. Einstein’s classical principle of equivalence, that locally all physics obeys special relativity if we are not close to a spacetime singularity together with Heisenberg’s quantum uncertainty principle demand that w = -1 for all quantum field random incoherent zero point vacuum fluctuations. The Poisson equation for exotic vacuum is

$$\nabla^2 V_{vac}(x) = c^2 \Lambda_{zpf}(x) \quad \text{(III.3)}$$

Photons have positive zero point energy density with negative pressure that dominates the gravity indeed causing universally repelling “anti-gravity” that Herman Bondi called “negative matter” in the 1950s before this new physics was well understood. Electrons have negative zero point energy density with positive pressure. What matters is the net residual sum from all the quantum fields. $\Lambda_{zpf} > 0$ is anti-gravitating exotic vacuum “dark energy”. According to the Type 1a supernovae data the FRW parameter $\Omega_{dark-energy} \sim 0.7$. Similarly, $\Lambda_{zpf} < 0$ is gravitating exotic vacuum “dark matter” that simulates w = 0 “Cold Dark Matter” with $\Omega_{dark-matter} \sim 0.25$.

IV. Wheeler’s Geometrodynamics

We have seen that there is a close connection between Ed Witten’s fundamental string parameter and a possibly variable emergent gravity coupling[v]

$$\alpha' = \frac{8\pi\bar{G}}{c^4} = \frac{1}{string-tension} \quad \text{(IV.1)}$$

With a “World Hologram” dynamic scale-dependent Planck area that for spatially extended elementary particles must be

$$\overline{L}_p^2 = \frac{\hbar \overline{G}}{c^3} = \hbar c \alpha' = L_p^{4/3} \left(\frac{c}{H_o} \right)^{2/3} \sim 1 fermi^2 \quad \text{(IV.2)}$$

for the hadronic strings not the superstrings at 10-33 cm which may no longer exist due to the expansion of 3D space of the Universe if the Planck area is really expanding. This conjecture is easily tested and will probably prove false although it seems to be a direct consequence of the t'Hooft-Susskind idea that all the information in a 3D volume of space is coded in the 2D boundary with a bit per effective Planck area. There is no "hierarchy problem" in this scenario especially if the string duality principle

$$r' = \frac{\hbar c \alpha'}{r} \quad \text{(IV.3)}$$

is correct.

It is not clear if $\overline{L}_p^2$ is worth one c-bit or one qubit? The latter is much more interesting of course because then it says that the Universe is a quantum computer not a classical computer. On the other hand, if the effective Planck area is really increasing as the Universe expands, that suggests that the Universe will become more and more quantum gravitational on larger and larger scales in its future. We must remember, however, that one qubit is worth an infinity of Shannon c-bits.

The current cosmological epoch, which is 13.7 billion years since the inflationary decay of the globally flat incoherent micro-quantum vacuum to the coherent macro-quantum vacuum, has a rest mass scale for the lepto-quarks that is

$$m \sim \frac{e^2}{c^2 \overline{L}_p} = \frac{e^2}{c^2 \sqrt{\hbar c \alpha'}}$$

$$= \frac{e^2}{c^2} \sqrt{\Lambda_{zpf} (string - core)} \sim 1 Mev \quad \text{IV.4}$$

The hadronic rest mass scale of 1Gev is mostly kinetic energy of the trapped lepto-quarks and their virtual plasma according to the "Bag Model" of "QCD Lite"[3] Note that the rest mass goes to zero when the string tension goes to zero. This solves the 100-year old mystery of what prevents a spatially extended electron from exploding under the repulsion of its self-charge. What we have here is a strong short range exotic vacuum dark matter core with positive zero point pressure where the vacuum coherence field drops to zero just like in a Type II superconductor quantized magnetic flux vortex string. The strong short-scale gravity

$$\overline{G} = 10^{40} G(Newton) \quad \text{(IV-5)}$$

is the "glue" holding the charge together and compensating the centrifugal force from the "spin". Wheeler's "Geometrodynamics" of elementary particles as "Mass without mass" wormholes with quantized "Charge without charge" and "Spin without spin" now actually works. The lepto-quarks are open strings whose two ends form a topological handle or micro-geon "wormhole" stuck on the 3 dim "brane world". The higher dimensional branes are topological defects for a hyper-complex "Matrix" vacuum coherence field with O(N) symmetry. My simple toy model using O(2) symmetry is only meant as a low energy effective field approximation.

Deep inelastic electron-hadron scattering shows that the 3 real quarks inside a proton look like point particles less than 10-18 cm across. This is explained as the huge space-warp of the strong exotic vacuum "dark matter" core of enormous positive random zero point fluctuation pressure. As the momentum transfer p in the scattering increases the effective size s of the lepto-quark shrinks. In a crude micro-geon toy model neglecting charge and spin rotation of the string, the effective size of the lepto-quark is

$$s = \frac{\hbar}{mc} \sqrt{1 - \frac{2\overline{G}mp}{c^2 \hbar}} \quad \text{(IV-6)}$$

This new paradigm requires the Bohm pilot BIT wave with the IT "string" as the "hidden variable." Indeed, string theory makes no sense in the Copenhagen and Many-Worlds interpretations. The fly in the ointment in the present formulation is the "World Hologram" idea, which suggests that the e/m ratio changes as the Universe expands. This seems patently false. However there may be a way out of this conundrum. Of course if the Blackett Effect

$$e = \sqrt{\overline{G}}\, m \quad \text{(IV.7)}$$

is fundamental that may not be a problem? One must look, for example, at Martin Rees's "Six Numbers" very carefully and see if this hypothesis at the micro-scale is really falsified. I suspect it will be. If it is, it falsifies the "World Hologram" part of the present model not the model as a whole.

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[2] John Archibald Wheeler

[3] Frank Wilczek's term at APS March and April 2003.

[ii] A brief discussion is found at the end of Misner, Thorne & Wheeler's "Gravitation"

[iv] http://www.physik.fu-berlin.de/~kleinert/kleiner_reb1/gifs/v1-1331s.html

[v] Abdus Salam had such a "f-gravity" theory for hadrons in 1973.