Wheeler's "It From Bit" and Sakharov's "Metric Elasticity"

Emergence of Spacetime and Matter from Superconducting Quantum Foam

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Abstract

The cosmological constant mystery[2] is solved in terms of Sakharov's implicit notion of the virtual off mass shell superconducting quantum vacuum origin of inertia and spacetime curvature. Both are simply from phase modulation of the Goldstone condensate. This condensate is a coherent quieting, or derandomizing, of zero point fluctuations from spontaneous broken symmetry giving a more stable vacuum. Dark matter, 90% of the universe's mass is simply a configuration of Type I string defects in the superconducting vacuum. The anomalous acceleration of the expansion of the universe, "quintessence" is from Type II string defects. "Quintessene and "dark matter" are two sides of this same coin having a unified simple explanation. Fredkin's "missing workload" for the universe as a computer is related to string theory's conjecture of strong short range Salam gravity with compactified dimensions ~ 10^{-17} cm.

"this the invisible police officer of the Fates, who has the constant surveillance of me, and secretly dogs me, and influences me in some unaccountable way."[3]

The phrase "It from bit" is John Archibald Wheeler's.[4] Wheeler works from Bohr's idealism point of view that quantum reality consists only of waves without particles that are "hidden variables" in Bohm's sense of realism. I take some liberties with Wheeler's phrase. I posit that quantum waves are intrinsically "thought like" and that particle-hidden variables are intrinsically "rocklike" in the sense of Henry Stapp.[5] "It" is then the

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[1] San Francisco, North Beach

[2] http://www.calphysics.org/articles/wesson.pdf

[3] "Moby Dick" (1851), Chapter One "Loomings" by Herman Melville. Objective evidence of precognitive remote viewing of terror full September 11, 2001, better, or, rather, worse, than the Nostradamus disinformation spread like cosmic inflation on the Internet. 150 years in advance, we find Melville writing, completely out of context, "Grand Contested Election for the Presidency of the United States." Alluding to Bush-Gore election of 2000? Followed soon by "BLOODY BATTLE IN AFFGHANISTAN." (CAPS in Melville's MS). I posted this at http://stardrive.org/ on Sept. 30, 2001. New York Times of Oct. 18, 2001 "With Ishmael in the Island City" by A. O. Scott, p. E5 notices the synchronicity as well. "Spooky telepathic action at a distance"? (Einstein's phrase), Yes. Violation of "subquantal heat death", i.e. nonequilibrium of Bohm's hidden variables (Tony Valentini), giving post-quantum "signal nonlocality" override of uncontrollable local quantum randomness? Yes. Global Consciousness Project of PEAR Lab at Princeton, brain data of Libet, Radin, Bierman relevant? Yes. Roger Penrose's "teleology" of human consciousness? Yes. Recall allegations of "The Bible Code". It's not only the Bible quite obviously.

[4] "Time Today" and "Physics in Knots" in "The Physical Origins of Time Asymmetry" (Cambridge, 1994) "'It From Bit,' the theme that every particle, every field of force, even the spacetime continuum itself, derives its function, its meaning and its very existence directly or indirectly from apparatus-elicited answers to yes or no questions."p.17 Wheeler uses Bohr's "Smoky Dragon" rather than Bohm's realism, no matter here. Can do it either way.

[5] "Matter, Mind and Quantum Mechanics"

"rocklike" material quality of the world. "Bit" is the "thought like" mental quality of the world in the sense of Bohm and Hiley's "active information"[6] of "pilot" "qubits".[7]

Start with a quantum foam of the zero point fluctuations (ZPF) of the electro-weak-strong gauge fields fibered over the global inertial frame GIF of special relativity.[8] Enter the Goldstone mode spontaneous symmetry breaking of this unified U(1)xSU(2)xSU(3) gauge force field[9] and its lepto-quark sources.[10] The Goldstone field $\phi(x)$ is a coherent phase field of a local broken order parameter $\psi(x)$ of the quantum vacuum. Real superconductors are made from real electron-electron pairs of charge 2e. The virtual superconductor that is part of the quantum vacuum structure would then be made of virtual electron-electron pairs off the mass shell in a positive background of virtual positrons giving electrically neutral plasma. I cannot be too precise about this of course. Indeed, one might imagine this level to be dominated by a mirror or "dual" world of virtual magnetic monopole charges g obeying Dirac's string quantization with homotopic winding number n.

$$ge \approx n\hbar c \tag{1.1}$$

In which magnetic fields are replaced by electric fields, electric super currents by magnetic super currents and the quantized flux of a vacuum vortex would be e instead of g. [11] In general

$$\psi(x) = |\psi(x)| e^{i\phi(x)/\Phi_o} = |\psi(x)| e^{i\theta} \tag{1.2}$$

where Φ_o is either the usual quantized magnetic flux in an electrically superconducting quantum vacuum, or, alternatively, is the quantized electric flux of lepto-quarks as Wheeler "geon" wormhole mouths using Abdus Salam's strong short range gravity G* >> G(Newton) over scales h/mc ~ G*m/c^2. The lepto-quarks look like point particles in electromagnetic deep inelastic scattering with virtual spacelike photon Heisenberg microscope probes because of the enormous elliptical space curvature at the wormhole mouth whose circumference C << h/mc.

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[6] "The Undivided Universe" (Routledge, 1993)

[7] "Minds, Machines, and the Multiverse: The Quest for the Quantum Computer", Julian Brown (Simon & Schuster , 2000)

[8] This corresponds to the perfect "world crystal lattice" of Hagen Kleinert (Free University of Berlin) in which 1-dim topological string defects of disclination and dislocation make curvature and torsion respectively. The size of a unit cell is the Planck length Lp that is variable because of the unseen hyperspace dimensions of the parallel classical material universes of Super Cosmos.

[9] Principal fiber bundle over globally flat spacetime base space for forces and associated bundle for sources.

[10] "The Quantum Theory of Fields", Vol. II, Steven Weinberg, 21.6 "Superconductivity" p. 332-351

[11] This would explain the anomalous experimental observations of vacuum electrical charge density reported by Bo Lehnert at Vigier 2000 at UC Berkeley Faculty Club.

I simply heuristically posit the following toy model U(1)[12] semi-phenomenological "Landau-Ginzburg" closed self-referential loop set of equations for the quantum *vacuum* local coherent order suppressing random zero point fluctuations[13]

$$g_{\mu\nu} D^{\mu} D^{\nu} |\psi| = -\frac{1}{\xi^2}|\psi| + L_p^* |\psi|^3 + |\psi| g_{\mu\nu} \left(D^{\mu}\theta - \frac{e}{\hbar c} A^{\mu} \right)\left(D^{\nu}\theta - \frac{e}{\hbar c} A^{\nu} \right) \qquad (1.3)$$

Eq. (1.3) is the effective generally relativistically covariant Landau-Ginzburg local field equation for the inhomogeneous virtual superfluid quantum vacuum coherent ordering derandomizing the zero point fluctuations for potentially useful work. [14] (1.3) is the "Schrodinger equation" for the giant wave function of the coherent virtual part of the quantum vacuum. Taking real and imaginary parts as in Bohm realism should give a generalized Hamilton-Jacobi equation and a current continuity equation for J_s^{μ}. One then posits a "pilot condition" for the motion of a volume element of virtual superfluid.

The model has 4 length scales.

- $L_p^*(x)$ is the variable "unit cell" Planck length of the 4-dim Kleinert "world crystal lattice".[15]
- $1/\sqrt{\Lambda^*(x)}$ is the variable microscopic cosmological field length scale ~ 10^{28} cm.[16]

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[12] This can be extended to the non-Abelian SU(2)xSU(3) Yang-Mills case.

[13] This is why the picture of deriving inertia m in F = ma, and gravity from purely random ZPF as suggested by Haisch, Rueda and Puthoff is entirely wrong IMO. At best, the m computed by them from random electromagnetic ZPF Lorentz force drag is a small virtual "normal fluid" or random "noise" correction to the Goldstone lepto-quark rest mass m from the coherent virtual superfluid "signal".

[14] So called "tapping of zero point vacuum energy" as reported in the December 1979 "Memorandum for the Record" from the Central Intelligence Agency on my physics research at that time. Indeed, I had mentioned this potential application to San Francisco businessman, Alvin Duskin, in 1980. This caused him, he said to me recently at the San Francisco Bay Club, to get into the alternative energy business (flywheels from Ed Teller's Lawrence Livermore Lab). Duskin, today, runs the "Educate the Girls" Foundation at The Presidio with Lawry Chickering who ran the Reagan think-tank "Institute for Contemporary Studies" in the early 1980's when I consulted with Lawry on SDI and possible use of quantum nonlocality for untappable submarine ship to shore communications. This was many years before current explosion of R&D in "quantum cryptography" using EPR correlated pairs of quanta.

[15] This variation is from the hyperspace "anholonomic stress" on the world crystal from the unseen dimensions of superstring theory now extended to "membranes" as "M-theory". Searches for strong short-range gravity are now underway. Experiments so far show spontaneous gravity, i.e. not metrically engineered or "stimulated", is Newtonian with $L_p \approx 10^{-33} cm$ down to scale 0.2 millimeters. Abdus Salam introduced the idea of strong short-range "f-meson" gravity for hadrons in the early 1970's. I worked with him at ICTP (Trieste, Italy) in 1973 to show how Regge trajectories, the key data of modern string theory, were like extreme nonradiating Kerr-Newman rotating tiny black holes with G* >> G. This idea was forgotten for 25 years. See August 2000 Scientific American "The Universe's Unseen Dimensions" for a popular description.

[16] This idea was first noted for real rotating superconductors by Giovanni Modanese that seem to act like an anti-gravity shield. This excited interest in the NASA Breakthrough Propulsion Project as a possible explanation for flying saucers seen over restricted military air space for many years. NASA does not, of course, explicitly acknowledge this as their motivation for fear of ridicule. Modanese did not think of generalizing his idea to a virtual superfluid "off mass shell" for a complex quantum vacuum structure

- $\xi(x)$ is the variable "coherence length" of the superconducting quantum vacuum that sets the scale of variation of the modulus field $|\psi(x)|$ whose square is the local number density of the cohered quantum vacuum virtual superfluid effective off-mass shell Bose-Einstein condensate component.
- $\lambda(x)$ is the variable gauge field penetration depth of the "vorticity" field that is excluded from the bulk vacuum, i.e. "Meissner effect".

$$(\nabla\times\nabla\times A)^{\mu} = \left(\frac{1}{\lambda^2}\right)\left(D^{\mu}\phi - A^{\mu}\right) \tag{1.4}$$

Eq. (1.4) is essentially the covariant equation for the Meissner effect expelling 4-vorticity $(\nabla\times A)^{\mu}$. For an electrical superconductor the vorticity is essentially the quantized magnetic flux tubes nhc/e. The curl of the magnetic field appears in Maxwell's field equations as the Ampere law effect of a source electric current including the vacuum displacement current that led to the discovery of transverse electromagnetic waves of radar, radio, TV, light, x-rays, gamma rays etc. The dual vacuum of magnetic monopoles adds a magnetic current to Faraday's law of induction generating the curl of the electric field with electric flux quantized to ne, and possibly (n/3) e for quarks.

$$J_s^{\mu} \approx \left(\frac{1}{\lambda^2}\right)\left(D^{\mu}\phi - A^{\mu}\right) \tag{1.5}$$

J_s^{μ} in (1.5) is the 4-dim super current density whose conservation law would be

$$D_{\mu}J_s^{\mu} = 0 \tag{1.6}$$

The semi classical quantum corrected Einstein geometrodynamical local field equation[17] in the presence of real matter is then

$$G_{\mu\nu} + \Lambda^* g_{\mu\nu} = -\frac{L_p^{*2}}{\hbar c}T_{\mu\nu} \tag{1.7}$$

where the local cosmological field is[18]

$$\Lambda^*(x) = \frac{1}{L_p^{*2}(x)} - L_p^*(x)\left|\psi(x)\right|^2 \tag{1.8}$$

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quieting locally random zero point field fluctuations into a coherently phased order "interferogram" as I have done here. Modanese used a global Feynman path integral formulation and did not write down the intuitively appealing local geometrodynamical field equation with the quantum corrections as I do here.

[17] I use Peacock's not MTW's sign conventions +---metric signature convention.

[18] See equation (1.12) below for the derivation. Note the factor of the fine structure constant α.

As is well known, the random zero point fluctuations essentially make the contribution $1/L_p^{*2}$ to the cosmological constant.[19] A key mystery in physics today is

"why do the zero point energies necessarily associated with quantum fluctuations not curve spacetime?"[20]

$$\xi = \frac{\hbar}{\sqrt{2}mc} \tag{1.9}$$

ξ is the coherence length of the modular field $|\psi(x)|$.[21]

$$\frac{\lambda}{\xi} = \frac{1}{\sqrt{2\alpha L_p^{*3}|\psi|}} \tag{1.10}$$

$$L_p^*|\psi|^2 = \frac{1}{2\alpha L_p^{*2}}\left(\frac{\xi}{\lambda}\right)^2 \tag{1.11}$$

$$\Lambda^* = \frac{1}{L_p^{*2}} - L_p^*|\psi|^2 = \frac{1}{L_p^{*2}}\left(1 - \frac{1}{2\alpha}\left(\frac{\xi}{\lambda}\right)^2\right) \tag{1.12}$$

The key is the relative change of sign[22] of $\Lambda^*(x)$ in different regions of space.

The stress-energy tensor for a relativistic perfect fluid is

$$T_{\mu\nu} = \left(\rho c^2 + p\right)\frac{dX_\mu}{ds}\frac{dX_\nu}{ds} - pg_{\mu\nu} \tag{1.13}$$

Special relativistic Lorentz invariance in the LIF tangent space of the world bundle, and the local equivalence principle leasing to general covariance in the LIF to LNIF tetrad map at a fixed spacetime event P, demand that the ZPF vacuum stress energy tensor $T_{\mu\nu}(zpf)$ be the same for all inertial and non-inertial local observers. Therefore, apart from zero, the only choice that tensor calculus allows is that $T_{\mu\nu}(zpf)$ is an isotropic tensor proportional to the geometrodynamic field $g_{\mu\nu}$. This is the same structure as the cosmological constant term in Einstein's local field equation. Indeed, we must have

[19] Pp.25-6 "Cosmological Physics", John Peacock (Cambridge, 1999)
[20] "Fluctuation-Dissipation Theorem in Relativity and Cosmological Constant", E. Mottola, "Time Asymmetry" cited in footnote 2 above.
[21] i.e., distance over which the modular field significantly changes.
[22] The physical meaning of the sign depends on signature convention.

$$T_{\mu\nu}\left(zpf\right)=\frac{\Lambda^* c^4}{8\pi G^*}g_{\mu\nu}=\frac{\Lambda^*\hbar c}{8\pi L_p^{*2}}g_{\mu\nu}=\frac{\Lambda^*}{8\pi\hbar c\alpha'}g_{\mu\nu}=\frac{\Lambda^* T^*}{8\pi}g_{\mu\nu} \qquad (1.14)$$

L_p^* is the local, possibly hyperspace dilated, Planck scale. α' is the Regge slope of vibrating strings of length $\lambda_c = h/mc$. T^* is the string tension.

$$\begin{aligned} T \equiv T_\mu^\mu &= \left(\rho c^2 + p\right)\left(\frac{dx_\mu}{ds}\right)\left(\frac{dx^\mu}{ds}\right) - p g_\mu^\mu \\ &= \rho c^2 + p - 4p = \rho c^2 - 3p \end{aligned} \qquad (1.15)$$

(1.5) is the stress-energy scalar frame invariant. In the weak field Newtonian limit of Einstein's general theory of relativity

$$\lim_{\frac{L_p^2}{\lambda r}\to 0} G_{00} \to 2R_{00} \qquad (1.16)$$

$$\lim_{\frac{L_p^2}{\lambda r}\to 0} G_{00} \to 2R_{00} \approx -\frac{2}{c^2}\nabla^2 V \qquad (1.17)$$

$$R_{00} \approx -\frac{\nabla^2 V}{c^2} \qquad (1.18)$$

$$\lim_{\frac{L_p^2}{\lambda r}\to 0} g_{00} \to +1 \qquad (1.19)$$

where λ is the characteristic de Broglie quantum wavelength scale of the stress-energy source.

$$R_{\mu\nu} = -\frac{8\pi G}{c^4}\left(T_{\mu\nu} - \frac{1}{2}g_{\mu\nu}T\right) \qquad (1.20)$$

$$\begin{aligned} R_{00} &= -\frac{8\pi G}{c^4}\left(T_{00} - \frac{1}{2}g_{00}T\right) \\ &= -\frac{8\pi G}{c^4}\left(\rho c^2 - \frac{1}{2}g_{00}\left(\rho c^2 - 3p\right)\right) \\ &\approx -\frac{8\pi G}{c^4}\left(\rho c^2 - \frac{1}{2}\left(\rho c^2 - 3p\right)\right) \\ &= -\frac{4\pi G}{c^4}\left(\rho c^2 + 3p\right) = -\frac{\nabla^2 V}{c^2} \end{aligned} \tag{1.21}$$

$$\nabla^2 V = \frac{4\pi G}{c^2}\left(\rho c^2 + 3p\right) = 4\pi G\left(\rho + \frac{3p}{c^2}\right) \tag{1.22}$$

(1.12) is the Poisson equation for Newton's gravity potential energy per unit mass V .

Note, I am using Peacock's sign conventions not MTW's. That is the metric signature is +--- and Einstein's field equation has a – sign in front of the stress-energy source.

The Green's function solution of (1.12) is

$$V\left(x,y,x\right) \approx -\iiint dx'dy'dz' \frac{G\left(\rho\left(x',y'z'\right) - \frac{3p\left(x',y'z'\right)}{c^2}\right)}{\sqrt{\left(x-x'\right)^2 + \left(y-y'\right)^2 + \left(z-z'\right)^2}} \tag{1.23}$$

The gravity force per unit test mass m is then

$$\frac{d\vec{F}}{dm}\left(x,y,z\right) = -\vec{\nabla}V\left(x,y,z\right) = -\hat{e}_R \iiint dx'dy'dz' \frac{G\left(\rho\left(x',y'z'\right) - \frac{3p\left(x',y'z'\right)}{c^2}\right)}{\left(x-x'\right)^2 + \left(y-y'\right)^2 + \left(z-z'\right)^2} \tag{1.24}$$

where $\hat{e}_R$ is the unit vector pointing from source point (x',y'z') to test mass field point (x,y,z). Therefore, in these conventions the gravity force density is attractive pointing from field point back to source point with a positive RHS in Poisson's equation. This sign in Poisson's equation can change under different representation conventions. A negative source term in Poisson's equation is then antigravity repulsion. Now to the particular case of the zero point quantum vacuum fluctuation energy:

$$T_{00}\left(zpf\right) = \frac{\Lambda * c^4}{8\pi G *} g_{00} = \rho\left(zpf\right)c^2 \tag{1.25}$$

$$\rho\left(zpf\right)c^2 + p\left(zpf\right) = 0 \tag{1.26}$$

(1.15) is the equation of state of the quantum vacuum zero point energy demanded by local Lorentz symmetry and the local principle of equivalence. Furthermore, in general, in the Newtonian weak field limit of GR[23]

$$\nabla^2 V = 4\pi G\left(\rho + \frac{3p}{c^2}\right) \quad (1.27)$$

Where V is Newton's gravity potential energy per unit mass with dimensions velocity squared. Thus, in the special case of the quantum vacuum zero point energy,

$$\nabla^2 V(zpf) = 4\pi G^*\left(\rho(zpf) + \frac{3p(zpf)}{c^2}\right) = -8\pi G^*\rho(zpf) \quad (1.28)$$

The most useful form[24] of (1.18) is

$$\nabla^2 V(zpf) = -8\pi G^*\rho(zpf) = -\frac{8\pi G^* T_{00}(zpf)}{c^2} = -\Lambda^* c^2 g_{00} \to -\Lambda^* c^2 \quad (1.29)$$

Therefore, the random virtual[25] "normal fluid" component of the quantum vacuum "antigravitates". The coherent nonrandom virtual "superfluid" component "gravitates". The threshold of classical cosmology is when these two opposing quantum effects cancel out. We see in equation (1.8) that the key control parameter is the ratio ξ/λ of coherence to penetration depth.[26] Two cases,

- $\xi/\sqrt{2\alpha}\lambda > 1$ Type I string vortex defect of world crystal is inner cylinder core of almost normal unbroken symmetry inside of which the vorticity drops to zero. An outer annular cylinder in which $|\psi|$ rises to an asymptote. $\Lambda^* < 0$, therefore the Type I superconducting vacuum corresponds to gravitating "dark matter".
- $\xi/\sqrt{2\alpha}\lambda < 1$ Type II string vortex defect of world crystal is inner cylinder core of uniform vorticity flux inside of which $|\psi|$ rises to its asymptote. This "self-trapped filament" is $\Lambda^* > 0$ corresponding to antigravitational quintessence – the speeding up of the expansion of the universe rather than the slowing down.[27]

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[23] Eq. (185) p. 25, "Cosmological Physics", John Peacock, Cambridge (1999).

[24] Using Peacock's sign conventions that are not same as MTW's "Gravitation".

[25] Off-mass shell in the quantum field propagators of the bosons and fermions.

[26] I published papers in Physics Letters in 1967, while a professor at San Diego State, on "self-trapped laser filaments" in nonlinear optics. Ray Chiao (UC Berkeley) told Charles Townes, in my presence, that he read this paper of mine when he started experimental research on these filaments.

[27] This should also explain the "vacuum propeller" (John Walker's term) of alleged flying saucers.

The completely normal random ZPF Haisch-Rueda-Puthoff type vacuum is actually higher in *energy density* than the superfluid vacuum by the amount

$$\Delta = \frac{\hbar c}{L_p^*} |\psi|^2 \tag{1.30}$$

$$T_{\mu\nu}(x) = 0 \tag{1.31}$$

is the vanishing of the stress-energy density tensor of real matter on the mass shell for the classical vacuum.

$$\theta = \frac{\phi}{\Phi_o} \tag{1.32}$$

θ is the dimensionless scalar field "Bit" quantum coherent phase *from* which we derive the classical geometrodynamic field "It". [28] ϕ is the Goldstone phase field with the dimensions of the magnetic flux quantum Φ_o if the virtual superconducting quantum vacuum is the electrical type. [29]

$$\xi_\mu = \partial_\mu \left(L_p^2 \left(\theta - \frac{e}{\hbar c} \int dx^\nu A_\nu \right) \right) \tag{1.33}$$

Note the path integral of the Yang-Mills gauge connection.

$\xi_\mu(x)$ is the local distortion field of the Kleinert world crystal lattice.[30] It is the infinitesimal translation of Einstein's holonomic general coordinate transformations encapsulating the local strong equivalence principle.[31] Note that $\frac{e}{c}A_\mu$ is the electromagnetic field momentum.[32]

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[28] "Gravitation as the metric elasticity of space … in Sakharov's view." P. 1206, MTW "Gravitation" see Box 17.2 in MTW and Appendix A below for details.

[29] If the vacuum is made of virtual magnetic monopoles instead, then we use the electrical flux quantum e. We need also study replacing the ordinary partial derivative by a covariant spacetime derivative. This is a bootstrap self-organizing phase lock loop together with the Landau-Ginzburg equation.

[30] http://www.physik.fu-berlin.de/~kleinert/
http://www.physik.fu-berlin.de/~kleinert/kleiner_reb1/gifs/v1-1331s.html
http://www.physik.fu-berlin.de/~kleinert/kleiner_reb1/gifs/v1-1344s.html eq. (2.29) "local translations", i.e., distortions of the perfect world crystal, are infinitesimal holonomic Einstein general coordinate transformations.

[31] Einstein explains gravity by locally eliminating it in the timelike geodesic motion of the origin of coordinates of the free float weightless "LIF" for Local Inertial Frame. The tetrad map is between the LIF class and the LNIF (Local Non Inertial Frame whose origin of coordinate lines in a patch is on a timelike, but not geodesic, world line.)

[32] We can do the full Yang-Mills SU(2)xSU(3) including the weak and strong forces as well as the above U(1) for the electromagnetic force shown here explicitly for simplicity.

The Regge trajectory formula from hadronic resonances as string vibrations also, I conjecture, works for the electron, i.e.,

$$J(E) = J(0) + \frac{G^* m^2}{\hbar c} = J(0) + \alpha' E^2 \quad (1.34)$$

where

$$J\left(\sim \frac{1}{2} Mev\right) = \frac{1}{2} \quad (1.35)$$

is the spin of the electron as a Regge pole in the complex angular momentum plane of the scattering amplitude. α' the Regge slope is

$$\alpha' \approx \frac{2}{(1 Mev)^2} \quad (1.36)$$

$$J(0) = 0 \quad (1.37)$$

$$\Delta J = 2 \quad (1.38)$$

between Regge poles. Therefore, an exotic lepton of spin 5/2 mass ~ 1.18 Mev predicted. Similarly ones at spin 9/2, 13/2, 17/2… They need not be stable. Tightly bound atomic states with these exotic electrons corresponding to cold fusion and some forms of dark matter? So this half-baked idea is falsifiable.

$$\frac{G^* m^2}{\hbar c} = \frac{G^* m^2 c^4}{\hbar c^5} = \frac{G^* \hbar E^2}{\hbar^2 c^5} = \frac{L_p^{*2}}{(\hbar c)^2} E^2 \quad (1.39)$$

$$\alpha' = \frac{L_p^{*2}}{(\hbar c)^2} = \frac{1}{\hbar c T} \quad (1.40)$$

$$L_p^* \approx \frac{\hbar}{mc} = \frac{G^* m}{c^2} \quad (1.41)$$

$$T = \frac{\hbar c}{L_p^2} \quad (1.42)$$

T is the effective string tension. The length of the string is $\frac{\hbar}{mc}$ but the string looks like a point particle in electromagnetic scattering with a spacelike virtual photon probe because of enormous space curvature from the strong short range Salam G* field in which the effective size of the electron $\frac{C}{2\pi}$ is

$$\frac{C}{2\pi} = \sqrt{\left(1 - \frac{2L_p^{*2}}{\left(\frac{\hbar}{mc}\right)}\left(\frac{p}{\hbar}\right)\right)}\frac{\hbar}{mc} \tag{1.43}$$

where p is the spacelike 3-momentum transfer from the virtual photon Heisenberg microscope probe.[33] The electron looks like a mathematical point when

$$\frac{C}{2\pi} = \sqrt{\left(1 - \frac{2L_p^{*2}}{\left(\frac{\hbar}{mc}\right)}\left(\frac{p}{\hbar}\right)\right)}\frac{\hbar}{mc} = 0 \tag{1.44}$$

i.e.

$$p = \frac{\hbar^2}{2L_p^{*2}mc} \approx \frac{\hbar}{10^{-11}cm} \tag{1.45}$$

at the threshold for the creation of real electron-positron pairs out of the virtual zero point fluctuations of the Dirac spinor electron quantum field. That is, all the lepto-quarks look like point particles in quantum electrodynamic scattering processes as soon as the special relativistic region is reached. This explanatory picture is a major achievement of my theory. David Deutsch in “The Fabric of Reality” rightly laments the current Bohr-inspired attitude not to try to understand the world in detail, but to simply pragmatically calculate numerical predictions without a reality picture.

Finally, a brief review of how Kleinert’s world crystal formalism fits in, i.e. how the “It” of classical spacetime geometrodynamics emerges from the “Bit” of ψ:

$$g_{\mu\nu} = \eta_{\mu\nu} + \frac{1}{2}\left(\partial_\mu \xi_\nu + \partial_\nu \xi_\mu\right) \tag{1.46}$$

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[33] Note that (h/mc) is outside the *square root* length strong short range G* gravity contraction factor.

$g_{\mu\nu}$ is the curved spacetime metric rock like "It" field of Einstein's 1915 geometrodynamic field theory of gravitation. The second term on the RHS of (1.27) is the strain tensor of Kleinert's world crystal lattice.[34]

$$\eta_{\mu\nu} = \begin{matrix} -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix} \tag{1.47}$$

is the flat spacetime metric field of Einstein's 1905 special theory of relativity with the class of Global Inertial Frames (GIF) for a perfect uniform world crystal without any 1-dim topological defects of either curvature disclination or torsion dislocation

$$\Gamma^{\sigma}_{\mu\nu} = \frac{1}{2} g^{\sigma\upsilon} \left(\partial_{\mu} g_{\nu\upsilon} + \partial_{\nu} g_{\upsilon\mu} - \partial_{\upsilon} g_{\mu\nu} \right) \tag{1.48}$$

is the spacetime connection in the curved spacetime for parallel transport of rock like tensor objects ("It") along world lines.

$$D^{\nu}\psi = \partial^{\nu}\psi \tag{1.49}$$

The curved spacetime covariant derivative of a world scalar is same as the ordinary partial derivative.

$$D^{\mu}D^{\nu}\psi = D^{\mu}\partial^{\nu}\psi = \left(\partial^{\mu}\partial^{\nu} + \Gamma^{\mu\nu}_{\sigma}\partial^{\sigma}\right)\psi \tag{1.50}$$

Is the curved spacetime D'Alembertian wave propagator operator on the thought like world scalar field ψ ("Bit").

$$R^{\delta}_{\mu\nu\gamma} = \partial_{\nu}\Gamma^{\delta}_{\mu\gamma} - \partial_{\gamma}\Gamma^{\delta}_{\mu\nu} + \Gamma^{\sigma}_{\mu\gamma}\Gamma^{\delta}_{\sigma\nu} - \Gamma^{\sigma}_{\mu\nu}\Gamma^{\delta}_{\sigma\gamma} \tag{1.51}$$

Is the Riemann curvature tensor field of 4^{th} rank for the inhomogeneous "stretch-squeeze" tidal forces seen in the time like geodesic deviation of neighboring two freely floating "test particles".[35]

$$R_{\mu\nu} = R^{\gamma}_{\mu\nu\gamma} \tag{1.52}$$

[34] I published a paper in 1966-7 in Physics Letters A on ODLRO in "super crystals" e.g. He3.

[35] A "test particle", by definition, has no direct grip back on its rock like geometrodynamic pilot field from which it receives its marching orders. An alleged "flying saucer" cannot be a test particle, but must generate its own timelike geodesic by softening spacetime stiffness. That is, Lp* must be made larger in a boundary layer surrounding the ship. Similarly, ordinary rock like matter and rock like geometry has no direct grip back on its thought like pilot qubit field from which they receive their marching orders.

Is the Ricci tensor of second rank.

$$R = R^{\mu}_{\mu} \tag{1.53}$$

Is the curvature scalar of zero rank.

$$G_{\mu\nu} = R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} \tag{1.54}$$

Is the Einstein geometrodynamical tensor in eq. (1.7).

Appendix A
Sakharov's[36] "Metric Elasticity" as Kleinert's "World Crystal"

"as elasticity is to atomic physics, so – in Sakharov's view – gravitation is to elementary particle physics … The energy that it takes to curve space is nothing but perturbation in the vacuum energy of fields plus particles brought about by that curvature according to Sakharov" p. 1206 MTW

"The resistance of space to deformation is described by one elastic constant, the Newtonian constant of gravity." P. 426 MTW

Note that torsion should give a second constant. Curvature as disclination defects in world crystal, torsion as dislocation defects suggest two constants not one, same as in solid. Paul Wesson[37] also suggests this.

"the energy of deformation per unit volume of the elastic material of the form

$$e = A(Tr\mathbf{s})^2 + BTr(\mathbf{s}^2) \tag{1.55}$$

Here the strain tensor[38]

$$\mathbf{s} \to s_{\mu\nu} = \left(\frac{1}{2}\right)\left(\frac{\partial \xi_\mu}{\partial x^\nu} + \frac{\partial \xi_\nu}{\partial x^\mu}\right) \tag{1.56}$$

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[36] Sakharov, A. D., 1967 "Vacuum quantum fluctuations in curved space and the theory of gravitation," Sov Phys Doklady 12, 1040 (1968).

[37] Wesson suggests $G/pc \approx e^2/\hbar c \equiv \alpha \approx 1/137$. This means eq. (1.22) above. That is,
$J\hbar \sim pm^2 \sim (G^*/\alpha c)m^2 = \alpha' E^2 = E^2/cT$

[38] Same as eq. (1.29) above.

measures the strain produced in the elastic medium by motion of the typical point that was at location x^{μ} to the location $x^{\mu}(P)+\xi^{\mu}(P)$. The constants A and B are derived out of microscopic physics … Andre Sakharov (1967) … has proposed a similar microscopic foundation for gravitation or, as he calls it, the 'metric elasticity of space. He identifies the action term of Einstein's geometrodynamics"

$$S_G \approx \frac{\hbar}{L_p^2}\int {}^4R\sqrt{-g}\,d^4x \qquad (1.57)$$

"with the change in the action of quantum fluctuations of the vacuum" (Sakharov). In fact, this is vague and it is only in this paper that its real meaning is explicated.

Appendix B
Relation of Blackett and Regge Effects

Re: http://www.calphysics.org/articles/wesson.pdf

In string theory, the Regge relation is

$$J = \alpha' E^2 \approx \frac{G^* m^2}{2\alpha\hbar c} = \frac{1}{\hbar c T}E^2 \qquad (1.58)$$

Where the spin is dimensionless, α' is the Regge slope in dimensions of energy^{-2}, T is the string tension with dimensions of energy per unit length, G^* is the hyperspace dilated Newton constant of gravity. Define the dilaton field as

$$|\phi|^2 = \frac{G^*}{G} \qquad (1.59)$$

$$\frac{G^*}{c} = |\phi|^2\frac{G}{c} \qquad (1.60)$$

Try[39]

$$\frac{G^*(r)}{G} = |\phi(r)|^2 = 2^{\frac{1}{\alpha}\left(\frac{\xi}{\lambda}\right)^2 \tanh\left(\left(\frac{\xi}{r}\right)^n\right)} \qquad (1.61)$$

The parameter n is the number of extra hyperspace dimensions[40] so that the coherence length ξ may be the compactification scale. We see that

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[39] At this point, this is adhoc phenomenological modeling – pure intuition. I mean precognitive remote viewing of more rigorous things to come.

[40] "The Universe's Unseen Dimensions", August 2000, Scientific American

$$\lim_{\xi \to 0} |\phi(r)|^2 \to 1 \tag{1.62}$$

$$\lim_{r \to \infty} |\phi(r)|^2 \to 1 \tag{1.63}$$

$$\lim_{r \to 0} |\phi(r)|^2 \to 2^{\frac{1}{\alpha}\left(\frac{\xi}{\lambda}\right)^2} \approx 2^{137\left(\frac{\xi}{\lambda}\right)^2} \tag{1.64}$$

$$2^{137\left(\frac{\xi}{\lambda}\right)^2} \approx 10^{41.24\left(\frac{\xi}{\lambda}\right)^2} \tag{1.65}$$

$$\lim_{r \to 0} \frac{L_p^*(r)}{L_p} \to 10^{\frac{41.24}{2}\left(\frac{\xi}{\lambda}\right)^2} \approx 10^{20.6\left(\frac{\xi}{\lambda}\right)^2} \tag{1.66}$$

If $\xi/\lambda \approx 1$ note that

$$\lim_{r \to 0} \left(\frac{L_p^*(r)}{L_p} \right)^3 \to 10^{62\left(\frac{\xi}{\lambda}\right)^2} \tag{1.67}$$

Compare this to what you get if you think of the universe as a computer at the Newtonian quantum gravity Planck scale $L_p \approx 10^{-33} cm$, in contrast to Abdus Salam's 1970's idea of strong short range "f-gravity" at scale L_p^*

"Fredkin …. estimating the total amount of computation going on in the universe, producing, ironically, a figure that seems puzzling low. He calls this the problem of the missing workload. Essentially what he has done is to calculate how large a cellular automaton would need to be to simulate the entire universe in all its details. The answer, he argues, is that a cellular automaton that operated at the tiniest quantum scales known as the Planck length and Planck time would only need to be not much larger than a biggish star to faithfully simulate the entire macroscopic evolution of our universe from the Big Bang to the present in about four hours. The difference in spacetime volume between the universe and such a system is a factor of some 10^{63}. This figure is Fredkin's 'missing workload'… 'Either something else is going on in the universe that we don't know about,' he says, 'or God was incompetent on a scale that boggles the mind.'"[41]

[41] "Minds, Machines, and the Multiverse" pp. 76-77, Julian Brown (2000, Simon & Shuster)

$$N^* = \left(\frac{c}{HL_p^*} \right)^4 \qquad (1.68)$$

N^* is the number of Planck scale spacetime cells of the Kleinert world crystal for Hubble parameter H and effective average hyperspace dilated Planck scale L_p^*.[42] Let N be the number of cells for Newton's Planck scale ~ 10^{-33} cm. Fredkin says

$$\frac{N^*}{N} \approx 10^{64} \qquad (1.69)$$

Therefore,

$$\frac{L_p^*}{L_p} \approx 10^{16} \qquad (1.70)$$

$$L_p^* \approx 10^{-17} cm = 10^{-19} meters \approx 100 Gev \qquad (1.71)$$

This is consistent with modern string theory.[43] The random zero point energy density of the quantum vacuum of the actual unified field of sources and forces is also lower by a factor of ~ 10^{64}. What come out of this is that the ZPE density reservoir is only ~ $hc/(10^{-17})^4$ ergs per cc rather than $hc/(10^{-33})^4$ ergs per cc. Note that the dilated Planck time is now not ~ 10^{-44} sec, but ~10^{-27} sec. The lifetime of the universe is ~ 10^{17} sec. This means ~ 10^{44} computational steps. The idea here is that the universe is not a compressible algorithm. This is classical of course not quantum, so the idea is on shaky ground. Nevertheless, it is interesting to keep in mind. The universe creates itself by computing itself sort of like in Frank Tipler's Omega Point simulation in "The Physics of Immortality".

Next go to p. 9 eq. (7) of Wesson's paper. In my theory

$$\begin{gathered} \ell_g = \ell_p = L_p^* \\ \frac{G^* m}{c^2} = \frac{L_p^{*2}}{\lambda_C} \approx \frac{\hbar}{mc} \equiv \lambda_C \end{gathered} \qquad (1.72)$$

Next go to Wesson's eq. (6) on p. 7. In my theory this becomes

[42] We have averaged out the local inhomogeneities corresponding to the space distribution of real elementary particles.

[43] "The Universe's Unseen Dimensions", August 2000, Scientific American

$$\frac{8\pi L_p^{*2}\rho}{\hbar c} = -\frac{k}{R^2} - \frac{\dot{R}^2}{c^2R^2} - \frac{2\ddot{R}}{c^2R} + \frac{\left(1 - \frac{\xi^2}{2\alpha\lambda^2}\right)}{L_p^{*2}} \quad (1.73)$$

There will be a corresponding Landau-Ginzburg equation in this uniform isotropic coarse-grained metric with cosmological averages of the 2-fluid quantum vacuum coherence length ξ and gauge field penetration depth λ. The last term on RHS is the cosmological quintessence for the acceleration of expansion of the universe for the appropriate parameters. Local field versions will model elementary particles.

Wesson's empirical relation from astronomical data is

$$\alpha \equiv \frac{e^2}{\hbar c} \approx \frac{1}{137} \approx \frac{G}{2pc} \quad (1.74)$$

Therefore,

$$\alpha p \approx \frac{G}{2c} \quad (1.75)$$

$$\alpha p^* \equiv \frac{G^*}{2c} = |\phi|^2 \frac{G}{2c} \quad (1.76)$$

$$J\hbar = p^* m^2 = |\phi|^2 \frac{G}{2\alpha c} m^2 \quad (1.77)$$

The Blackett type relation is then

$$|\phi|^2 Gm^2 = e^2 \quad (1.78)$$

The above is not really consistent and should not be taken literally, but must be redone for Kerr-Newman metric extreme black hole in which

$$\left(\frac{G^* m}{c^2}\right)^2 = \left(\frac{J\hbar}{mc}\right)^2 + G^*\left(\frac{e}{c^2}\right)^2 \quad (1.79)$$

$$\left(\frac{G\hbar c|\phi|^2 m}{\hbar c^3}\right)^2 = \left(\frac{J\hbar}{mc}\right)^2 + \frac{\hbar c^3 G}{\hbar c^3}|\phi|^2\left(\frac{e}{c^2}\right)^2 \quad (1.80)$$

$$\left(\frac{L_p^2 c|\phi|^2 m}{\hbar}\right)^2 = \left(\frac{J\hbar}{mc}\right)^2 + \frac{\hbar c^3 G}{\hbar c^3}|\phi|^2\left(\frac{e}{c^2}\right)^2 \quad (1.81)$$

$$\left(\frac{L_p^2|\phi|^2}{\lambda_C}\right)^2 = (J\lambda_C)^2 + L_p^2\alpha|\phi|^2 \tag{1.82}$$

$$\left(\frac{L_p^2}{\lambda_C}\right)^2|\phi|^4 - L_p^2\alpha|\phi|^2 - (J\lambda_C)^2 = 0 \tag{1.83}$$

$$|\phi_\pm|^2 = \left(\frac{\lambda_C}{\sqrt{2}L_p^2}\right)^2\left(L_p^2\alpha \pm \sqrt{\left(L_p^2\alpha\right)^2 + 4\left(\frac{L_p^2}{\lambda_C}\right)^2(J\lambda_C)^2}\right) \tag{1.84}$$

$$|\phi_\pm|^2 = \left(\frac{\lambda_C}{\sqrt{2}L_p^2}\right)^2 L_p^2\alpha\left(1 \pm \sqrt{1 + \frac{4J^2}{\alpha^2}}\right) \tag{1.85}$$

$$|\phi_\pm|^2 = \left(\frac{\alpha}{2}\right)\left(\frac{\lambda_C}{L_p}\right)^2\left(1 \pm \sqrt{1 + \frac{4J^2}{\alpha^2}}\right) \tag{1.86}$$

Note that the negative root is anti-gravity. Let J get large

$$|\phi_\pm|^2 = \pm\left(\frac{\lambda_C}{L_p}\right)^2 J \tag{1.87}$$

$$J\hbar \sim \frac{G^*}{\alpha c}m^2 \tag{1.88}$$

$$J \sim \frac{e^2}{\hbar c\alpha} \sim 1 \tag{1.89}$$

The Hawking temperature of a Kerr-Newman rotating charged hairless black hole is

$$T = \frac{\kappa\hbar}{2\pi kc} \tag{1.90}$$

The surface gravity is

$$\kappa = \frac{4\pi}{A}\left[r_+c^2 - Gm\right] \tag{1.91}$$

$$r_+ = \frac{1}{c^2}\left[Gm + \sqrt{\left(G^2m^2 - \frac{J^2c^2}{m^2} - GQ^2\right)}\right] \qquad (1.92)$$

$$A = \frac{4\pi G}{c^4}\left[2Gm^2 - Q^2 + 2\sqrt{\left(G^2m^4 - J^2c^2 - Gm^2Q^2\right)}\right] \qquad (1.93)$$

Let[44]

$$G^2m^4 - J^2c^2 - Gm^2Q^2 = 0 \qquad (1.94)$$

In this extreme case

$$r_+ \to \frac{Gm}{c^2} \qquad (1.95)$$

$$A \to \frac{4\pi G}{c^4}\left[2Gm^2 - Q^2\right] \qquad (1.96)$$

Note that the maximal Blackett relation

$$Gm^2 - Q^2 \to 0 \qquad (1.97)$$

For an extreme black hole this implies

$$A \to \frac{4\pi G}{c^4}\left[2Gm^2 - Q^2\right] \to \frac{4\pi G^2m^2}{c^4} \qquad (1.98)$$

with

$$\kappa \to \frac{4\pi}{A}\left[Gm - Gm\right] \to 0 \qquad (1.99)$$

Hence, the Hawking temperature vanishes

$$T \to 0 \qquad (1.100)$$

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[44] This is a Pythagorean equation for a right triangle if you divide each term by c^4.

Can we have the Blackett effect at finite spin?

$$r_+ = \frac{1}{c^2}\left[Gm + i\frac{Jc}{m}\right] \tag{1.101}$$

No, at least not classically.

Next consider the Schwarzschild limit with zero spin $J \to 0$ and zero charge $Q \to 0$.

$$r_+ \to \frac{1}{c^2}\left[Gm + \sqrt{\left(G^2m^2\right)}\right] = \frac{2Gm}{c^2} \tag{1.102}$$

$$A \to \frac{4\pi G}{c^4}\left[2Gm^2 + 2\sqrt{\left(G^2m^4\right)}\right] = \frac{16\pi G^2m^2}{c^4} \tag{1.103}$$

$$\kappa \to \frac{4\pi}{\frac{16\pi G^2m^2}{c^4}}\left[2Gm - Gm\right] = \frac{c^4}{4Gm} = \frac{c^2}{4L_p^2}\left(\frac{\hbar}{mc}\right) \tag{1.104}$$

$$T \to \frac{\frac{c^2\hbar}{4L_p^2}\left(\frac{\hbar}{mc}\right)}{2\pi kc} = \frac{c^2\hbar^2}{8\pi mc^2L_p^2k} \tag{1.105}$$

is the Hawking blackbody radiation temperature.

Let's look at this more closely. We are modeling lepto-quarks as extended vacuum geometrodynamic "Bohm points" in Salam strong short range gravity with G* >> G in microscale. Therefore,

$$\begin{aligned} Q_n &= n\frac{e}{3} \\ n &= 0, \pm1, \pm2, \pm3, \ldots \end{aligned} \tag{1.106}$$

$$\begin{aligned} J_{n'} &= \frac{n'}{2} \\ n' &= 0, 1, 2, 3, 4, \ldots \end{aligned} \tag{1.107}$$

The only continuous variable is m.

$$\frac{GQ_n^{\ 2}}{G^2m^2} = \frac{e^2n^2}{9Gm^2} \equiv 1-\delta_n \tag{1.108}$$

δ_n is the Blackett deviation parameter. The maximal Blackett effect is when $\delta_n \to 0$.[45]

$$G^2m^2 - GQ_n^{\ 2} = GQ_n^{\ 2}\delta_n \tag{1.109}$$

$$\sqrt{G^2m^2 - GQ_n^{\ 2} - \frac{J_{n'}^{\ 2}c^2}{m^2}} = \sqrt{G^2m^2\delta_n - \frac{J_{n'}^{\ 2}c^2}{m^2}} = Gm\sqrt{\delta_n - \frac{J_{n'}^{\ 2}c^2}{G^2m^4}} \tag{1.110}$$

The Regge parameter is defined as

$$\eta_{n'} = \frac{J_{n'}c}{Gm^2} \tag{1.111}$$

$$\sqrt{G^2m^2 - GQ_n^{\ 2} - \frac{J_{n'}^{\ 2}c^2}{m^2}} = Gm\sqrt{\delta_n - \eta_{n'}^{\ 2}} \tag{1.112}$$

$$\delta_n - \eta_{n'}^{\ 2} \geq 0 \tag{1.113}$$

For an extreme nonradiating black hole at zero Hawking temperature

$$\delta_n - \eta_{n'}^{\ 2} = 0 \tag{1.114}$$

$$\delta_n = 1 - \frac{e^2n^2}{9Gm^2} \tag{1.115}$$

$$\eta_{n'}^{\ 2} = \left(\frac{n'\hbar c}{2Gm^2}\right)^2 \tag{1.116}$$

$$1 - \frac{e^2n^2}{9Gm^2} \geq \left(\frac{n'\hbar c}{2Gm^2}\right)^2 \tag{1.117}$$

An extreme black hole can only obey the maximal Blackett effect if it does not rotate. If it rotates it will be unstable. Stable particles of spin ½ therefore, do not obey the maximal Blackett effect. Indeed no stable particles with spin can obey the maximal Blackett effect. For the extreme black hole, we can get a mass spectrum.

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[45] It is understood that G* will replace G.

$$\begin{aligned}
&\left(\frac{n'\hbar c}{2Gm^2}\right)^2+\frac{e^2n^2}{9Gm^2}-1=0\\
&x=\frac{1}{m^2}\\
&a'=\left(\frac{n'\hbar c}{2G}\right)^2\\
&b'=\frac{e^2n^2}{9G}\\
&c'=-1\\
&x_{\pm}(n,n')=\frac{1}{2\left(\frac{n'\hbar c}{2G}\right)^2}\left[-\left(\frac{e^2n^2}{9G}\right)\pm\sqrt{\left(\frac{e^2n^2}{9G}\right)^2+4\left(\frac{n'\hbar c}{2G}\right)^2}\right]
\end{aligned}\tag{1.118}$$

For microphysics replace G by G*

$$m(n,n')^2=2\left(\frac{n'\hbar c}{2G*}\right)^2\frac{1}{\left[-\left(\frac{e^2n^2}{9G*}\right)\pm\sqrt{\left(\frac{e^2n^2}{9G*}\right)^2+4\left(\frac{n'\hbar c}{2G*}\right)^2}\right]}\tag{1.119}$$

Note the tachyon solutions.

$$m(n,n')=\sqrt{2}\left(\frac{n'\hbar c}{2G*}\right)\sqrt{\frac{1}{\left[-\left(\frac{e^2n^2}{9G*}\right)\pm\sqrt{\left(\frac{e^2n^2}{9G*}\right)^2+4\left(\frac{n'\hbar c}{2G*}\right)^2}\right]}}\tag{1.120}$$