"1. Casimir's legacy: the quantum vacuum rules the universe!

When Hendrik Casimir published his celebrated paper in 1948, the Casimir effect was little more than a curiosity. To be sure, the effect has subsequently been measured experimentally, but because the Casimir force is so small, it joined the Lamb shift and the anomalous magnetic moment of the electron as an elegant and crucial verification of quantum vacuum effects, but with little practical or natural significance. Today, however, physicists and cosmologists agree that the quantum vacuum holds the key to the universe. It seems very likely that the cosmos, at least as we know it, was born in a quantum event, and that the large-scale structure of the universe was fashioned by quantum vacuum processes during the first 10^{-32} sec. It also seems likely that the ultimate fate of the universe will be determined by quantum vacuum energy—now dubbed 'dark energy'.

The importance of Casimir's foundational paper is that it showed how geometrical or topological constraints can affect the quantum vacuum. The significance of this for cosmology was first recognized twenty years later by Sakharov (1967, 1968), who proposed a theory of 'induced gravity' in which the modes of a quantum field in its vacuum state are changed, not from the presence of reflecting boundaries, but by spacetime curvature. The resulting shift in vacuum energy was then interpreted by Sakharov as gravitation." Paul Davies "Quantum Vacuum Friction"

http://aca.mq.edu.au/PaulDavies/publications/papers.htm

Sarfatti Commentary 1
The problem with Sakharov's idea was which came first, the zero point modes or the curvature? -- obviously the former. Indeed, I suggest what the curved tetrad Cartan 1-forms are for each point-like Einstein "local coincidence" x that is not a bare manifold point. Einstein made this distinction in his 1917 "Hole Paradox." It corresponds to the redundant non-dynamical gauge freedom of the connection potentials. We need to quotient group delete the nondynamical pseudo-degrees of freedom by using non-overlapping equivalence classes or gauge group "orbits" of the bare manifold points in non-Abelian Yang-Mills internal symmetries SU(2) & SU(3), which when quantized with Feynman path integrals, involves the Faddeev-Popov method. Thus, Einstein's "local coincidence" x is an entire "orbit" containing an infinity of bare manifold points. The Faddeev-Popov method includes ghost spin zero scalars that violate the spin-statistics connection here obeying the Pauli exclusion principle. The spin-statistics connection (spin 0, 1, 2 bosons, spin 1/3, 3/2 fermions in 3+1 spacetime) is needed if you want causal influences inside the light cone and stable quantum vacuums. These causality-violating "ghosts" do not appear in the radiative on-mass shell far field of the S-Matrix, but they do appear in the coherent virtual near induction fields that are usually not measured in experiments.

$$A(x)^a = M(x)^{aa}$$
$$M(x)^{ab} = d\Theta(x)^a \wedge \Phi(x)^b - \Theta(x)^a \wedge d\Phi(x)^b$$
$$a,b = 0,1,2,3$$

With two Lorentz 4-vector 0-forms from the independent 8 Goldstone phases $\Theta(x)^a$ & $\Phi(x)^b$ of the 9 real Higgs scalar fields $\Psi(x)_{i=1,2,3,\ldots 9}$ with $O(9)$ internal symmetry.

$$\Theta(x) \equiv \sqrt{\Theta^a\Theta_a} = \sqrt{\Theta_0\Theta_0 - \Theta_1\Theta_1 - \Theta_2\Theta_2 - \Theta_3\Theta_3}$$
$$\Phi(x) \equiv \sqrt{\Phi^a\Phi_a} = \sqrt{\Phi_0\Phi_0 - \Phi_1\Phi_1 - \Phi_2\Phi_2 - \Phi_3\Phi_3}$$

The complete Einstein-Cartan tetrad 1-forms are

$$e(x)^a \equiv e^a_\mu dx^\mu = I^a + \alpha(x)A(x)^a$$
$$\alpha(x) = \frac{\hbar G}{c^3}\Lambda(x)_{zpf}$$

Where I^a are the 4 globally flat special relativity tetrad 1-forms that you get in the limits

$$\hbar \to 0$$
$$G \to 0$$
$$\Lambda(x)_{zpf} \to 0$$

If in addition you let $c \to \infty$, then we get Galilean relativity. Note that $\Lambda(x)_{zpf}$ is a locally variable scalar field when the torsion field 2-form (defined below) $T^a \neq 0$ from additional terms in the Bianchi identities.

Einstein's fundamental local frame invariant is

$$ds(x)^2 = g(x)_{\mu\nu}dx^\mu dx^\nu = e(x)^a e(x)_a = e_0e_0 - e_1e_1 - e_2e_2 - e_3e_3$$
$$= I^aI_a + \alpha\left(I^aA(x)_a + A(x)^a I_a\right) + \alpha^2 A(x)^a A(x)_a$$

Note that for an unaccelerated geodesic inertial observer in globally flat Minkowski spacetime without any gravity and torsion fields

$$I^a_\mu \to \delta^a_\mu \equiv \begin{matrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}$$

In contrast, for an accelerated off-geodesic, non–inertial observer feeling a non-gravity force in Minkowski spacetime, the effective tetrad field components $I^a_\mu \to I^a_\mu(x)$ relative to that accelerated observer is a general curvilinear matrix such that the 4th rank GCT Riemann curvature tensor is zero everywhere-when. Note that the total tetrad 1-form e^a is a local GCT scalar invariant and a Lorentz group 4-vector, but the pieces we break it up into need not be separately GCT invariants. They undergo mutually canceling gauge transformations in a GCT, which is itself merely a locally gauged T4 translation group transformation with a different small displacement at each local coincidence x. How do we calculate the curvature tensor? For that we need the 6 spin connection 1-forms $S^{ab} = -S^{ba} = S^{ab}{}_\mu dx^\mu$ seen by Lorentz group spinors as well as tensors.

$$S^{ab} = M^{[a,b]} \equiv \frac{1}{2}\left(M^{ab} - M^{ba}\right)$$

Problem: Is there any physical meaning to the off-diagonal symmetric combination?

$$\Sigma^{ab} \equiv M^{\{a,b\}} = \frac{1}{2}\left(M^{ab} + M^{ba}\right)$$

We then have the covariant exterior derivative where the torsion gap dislocation defect field 2-form is

$$T^a \equiv T^a{}_{\mu\nu} dx^\mu \wedge dx^\nu = De^a = de^a + S^a_c \wedge e^c$$

The curvature disclination defect field 2-form is

$$R^{ab} = R^{ab}{}_{\mu\nu} dx^\mu \wedge dx^\nu = dS^{ab} + S^a_c \wedge S^{cb}$$

The Einstein-Hilbert pure gravity field “exotic” (i.e. $\Lambda_{zpf} \neq 0$) vacuum action density is the 0-form local frame invariant under both 4-parameter GCTs and 6-parameter Lorentz group is

$$\frac{\delta A_G}{\delta V^4} = \varepsilon_{abcd}\left(R^{ab} \wedge e^c \wedge e^d + \Lambda_{zpf} e^a \wedge e^b \wedge e^c \wedge e^d\right)$$

This is the essential structure of Einstein-Cartan theory that reduces to Einstein’s 1915 GR when the torsion 2-form vanishes, i.e. $T^a \to 0$. Note there are terms linear, quadratic, cubic and quartic in the spin 1 tetrad A^a fields. If we re-quantize then it's a "supersolid" where

$$A^a \to \langle 0|A^a|0\rangle + \hat{A}^a$$

where $|0\rangle$ is the physical vacuum of all fields and $\hat{A}^a$ is the tetrad quantum destruction operator. The ODLRO c-number vacuum expectation value $\langle 0|A^a|0\rangle$ is the condensate reservoir for virtual zero point and real tetrad quanta at finite temperature. Entangled pairs of tetrad quanta have spin 2, spin 1 and spin 0 as well as orbital quantum numbers.