Intrinsic Time Quantum Gravity & The Unique Initial State of the Universe

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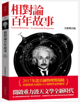
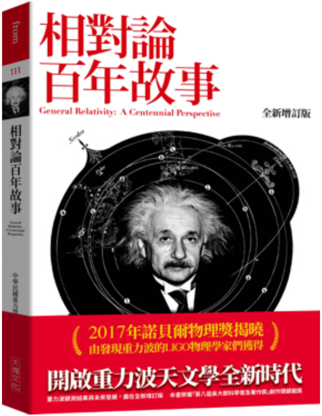
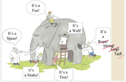
GR: A Centennial Perspective:





The purposes of this talk:



What is the Most Important Observation about our Universe?

Universe's expansion should be taken fundamentally

- What are the majors fallacies of conventional inflation models ?

Outlines of this talk:

1. Conceptual and technical technical difficulties of GR in FWR Cosmology
   - Weyl tensor drops out from GR
2. Inflation doesn't solve the initial value problem of the Universe
   - Common features of inflationary models
3. Intrinsic Time Quantum Gravity(ITQG)
   - Singularity is necessary at the Big Bang to have Time
4. The initial state of the Universe is determined by the Cotton-York Tensor
5. ITQG ground state driven inflation without Inflaton & Experimental tests

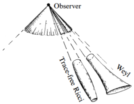
Universe Expansion should be noted fundamentally

1. The expansion of the Universe should be treated as fundamental as:
   - Newton's discovery of equivalence between falling apple and Moon's falling; therefore law of Gravitation
   - Einstein's discovery of equivalence between acceleration and gravitation; therefore GR
2. Universe's expansion means Time is special and therefore no space-time symmetry
3. Taking Universe's expansion seriously at fundamental level allows both a self-consistent formulation of QG and the existence of semi-classical limit

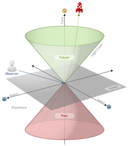
Major fallacies of GR & Inflationary models

1. Complete geometrical data of space-time needs the full 20-components Riemann Tensor;

   $R^{\mu}_{\ \nu\alpha\beta}$ = Ricci(trace, source for gravity) + Weyl(traceless, dynamical d.o.f of gravity)



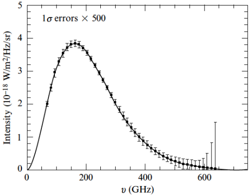
2. Eqt. that det'd the Conformal Invariant Structure(Causal) (Weyl tensor) is missing from GR



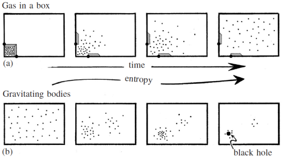
3. Matter can't tell spacetime how to curve; i.e. even in vacuum, spacetime form black holes
4. LIGO discovery of GW1050914 confirms that GW carries NON-ZERO local energy density
5. Homogennity & isotropy conflicts the basic feature of gravitation, i.e. attractive
6. Wrong to describe inflation, a particular property of space-time by scalar matter fields
7. Predictions of inflationary models can be changed by varying the shape of the inflationary energy density curve or the initial conditions; basically means no prediction

Difference between Matter & Gravitation Entropy

1. Observation of 3K thermal(equilibrium) radiation⇒U. can't evolve after recombination!?



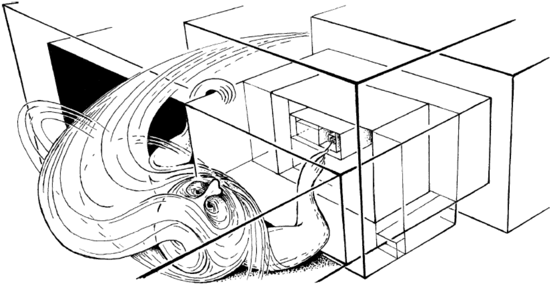
2. As matter homogenises, entropy increases but gravitation entropy increases when clumps



3. Gravity's d.o.fs are not in the thermal equilibrium(means very special) near Big Bang

The Initial state of the Universe is the Biggest puzzle

1. Entropy of solar mass BH is $\sim 10^{21}$, there about 10^{80} baryon in the Universe
2. Pro. of U. begin in such a low entropy state, $10^{-10^{123}}$; Cosmological const. is $\sim 10^{-120}$
3. Homogenous & isotropic(zero entropy) state in gravitation is very rare and special



Inflation is irrelevant in solving the initial state puzzle

1. The uniformity in the universe we now observed should be the result of inflation acting on its early evolution is basically misconceived
2. Homogenous and isotropic condition is still a MUST for inflation to happen; i.e. the basic Friedmann eqt. must be kept intacted!
3. Computer simulations requires homogenous within 3 Hubble lengths and vacuum dominated condition to have inflation to happen
4. There must be a great uniformity in the matter distribution at that time, for otherwise inflation cannot be introduced; A puzzle!?
5. Inflation only pushed the puzzle to an earlier epoch but didn't solve the uniformity puzzle
6. Inflation, a property of space-time structure evolution; shouldn't be driven by matter fields
7. Need to kill gravity entropy(not been thermalised) but keep its d.o.f. in the initial state

Conventional wisdoms about Physics of Inflation

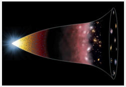
1. Starobinsky-like model captures the conformal structure through extra $\frac{R^2}{6M^2}$
2. Going to Einstein frame through $q_{\mu\nu} \to e^{\phi}\tilde{g}_{\mu\nu}$; and obtain a characteristic potential with a large Mass scale dictated by M, i.e.
$$V = \tilde{R} + (\partial_\mu \phi)^2 - \frac{3}{2}M^2(1 - e^{\frac{\sqrt{2}}{3}\phi})$$
3. The appearance of this large Mass scale($M \gtrsim 10^{13} GeV$); drives exponential spatial expansion(inflation) in the Friedmann equation
4. Basically, all inflation models with scalar field inflaton MAKE use of this large mass scale
5. The problem is still requiring homogeneity to simplify the Einstein eqt. to Friedmann eqt.
6. All these models only push the initial condition to an earlier time; none of them explains: why the homogenous and isotropy initial condition can be achieved at the Big Bang

Diffeomorphism & Yang-Mills gauge structures

Table 1. Comparison of the two different gauge structures

	Diffeomorphism Gauge Structures	Yang-Mills Gauge Structures
Basic Variables	Spatial metric tensor q_{ij}	Gauge connection A_{ia}
Symmetry Generators	$H_i(\mathbf{x}) = -2q_{ik}\nabla_j\pi^{jk}(\mathbf{x})(=0)$	$G^a(\mathbf{x}) = \nabla_i\pi^{ia}(\mathbf{x})(=0)$
Gauge transformation	$[q_{ij}(\mathbf{x}), H_k[N^k]] = \mathcal{L}_{\vec{N}}q_{ij}(\mathbf{x})$; $H_i[N^i] = \int N^i H_i d^3\mathbf{x}$	$[A_{ia}(\mathbf{x}), G^b[\eta_b]] = -\nabla_i\eta_a(\mathbf{x})G^b[\eta_b]$; $G^b[\eta_b] = \int \eta_b G^b d^3\mathbf{x}$
Commutation Relations	$[H_i(\mathbf{x}), H_j(\mathbf{y})] = H_j(\mathbf{x})\partial_i\delta(\mathbf{x}-\mathbf{y}) + H_i(\mathbf{y})\partial_j\delta(\mathbf{x}-\mathbf{y})$	$[G^a(\mathbf{x}), G^b(\mathbf{y})] = if^{ab}{}_c G^c(\mathbf{x})\delta(\mathbf{x}-\mathbf{y})$
Potentials	$V \sim [\frac{\delta exp(CS)}{\delta q_{ij}}]^2$	$V \sim [\frac{\delta exp(CS)}{\delta A_{ia}}]^2$
Locality & Dimension	Not product of identical group(i.e. $SL(3R)$) at each spatial point of base manifold i.e. not of principle fibre structure	Infinite tensor product group $\prod_x G$; G=finite dimensional Lie group =usually referred to as the 'gauge group'

Initial Time Quantum Gravity



1. Decompose $(q_{ij}, \tilde{\pi}^{ij})$ irreducibly into conjugate pairs: $(\bar{q}_{ij}, \bar{\pi}^{ij})$, $(\ln q^{\frac{1}{3}}, \pi)$; identifying $\ln q(x)$ as intrinsic time, $\pi = q_{ij}\tilde{\pi}^{ij}$ the energy function

2. ADM Hamiltonian constraint($\beta^2 = \frac{1}{6}$ for GR) delivers dynamical; not gauge evolution
   - $H(x) = -qR + \bar{q}_{ik}\bar{q}_{jl}\bar{\pi}^{ij}\bar{\pi}^{kl} - \beta^2\pi^2 = 0$; doesn't generate Temporal gauge symmetries, otherwise, Universe becomes block diagonal & not consistent with QM
   - Dynamical eqt & local Hamiltonian density are derived from:

$$-\pi = \frac{\bar{H}(x)}{\beta} = \frac{1}{\beta}\sqrt{\bar{q}_{ik}\bar{q}_{jl}\bar{\pi}^{ij}\bar{\pi}^{kl} - qR} \rightarrow \frac{1}{\beta}\sqrt{\bar{q}_{ik}\bar{q}_{jl}\bar{\pi}^{ij}\bar{\pi}^{kl} + V}$$

   - Allow modifications of gravitation potential away from Einstein's theory
   - Classically, $H = K.E. + V$; Relativistically, $H = \sqrt{momenta^2 + V}$
   - The square root Hamiltonian correctly captures the dispersion relation $v = \frac{p}{E}$ & particle-wave duality with upper limit in speed; readily for carrying out quantization

Singularity is necessary at the Big Bang to have Time

1. What is diverging at the Big Bang is $\ln q = T \to -\infty$, which is exactly what we need to represent the beginning of Time in the Universe
2. Although R diverges(however, is suppressed by the Time factor) but $\bar{q}_{ij}$ is non-zero by construction and the Cotton-York(C.Y.) tensor(density) is regular at the Big Bang
3. This necessary temporal singularity is usually misinterpreted as a curvature singularity
4. Gravitation d.o.fs are well defined and described by the C.Y. tensor at the Big Bang
5. The local Hamiltonian density stays semi-positive definite during the Big Bang
6. Big Bang singularity is necessary to allow the Universe to begin

Conformal flatness initial state & Penrose Conjecture

1. $\bar{H} = \sqrt{(extrinsic\ curvature)^2 + (C.Y.\ tensor)^2 + q\mathcal{K}} = \sqrt{\bar{\pi}^i_j \bar{\pi}^j_i + (C.Y.\ tensor)^2 + q\mathcal{K}}$
2. $\bar{H}$ attains classical minimum iff $\bar{\pi}^i_j$ & C.Y. vanishes identically, precisely the criterion for conformal flatness(S^3) in 3d
3. Vanishing of the extrinsic curvature components & spatial conformal flatness at $T \to -\infty$ together with $\nabla_i \bar{\pi}^{ij} = 0$, realizes a FRW Big Bang compatible with 4d Weyl tensor = 0
4. 'Our extraordinarily special Big Bang' with low entropy emerges naturally from the ground state of $\bar{H} = 0$ in the C.Y. tensor dominance era & rules out the possibilities of primordial black hole
5. 2nd Law thermodynamic 'arrow of time'&'gravitational arrow of intrinsic time'(increasing vol.)point in same direction
6. Nontrivial realisation of Poincare conjecture; ∞ nos. 3d simply connected diff. structures all conformally equiv. to S^3

The initial Quantum State

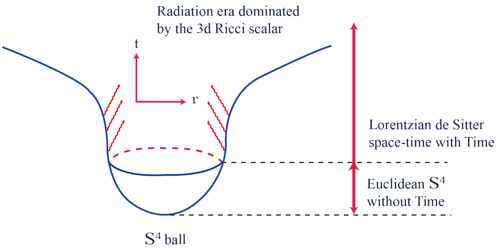
1. C.Y. dominating era(right after Big Bang), $\bar{H} = \sqrt{\hat{\bar{\pi}}^{\dagger i}_{j}\hat{\bar{\pi}}^{j}_{i} + g^2\hbar^2\tilde{C}^{i}_{j}\tilde{C}^{j}_{i} + q\mathcal{K}}$; $[\hat{\bar{\pi}}^{j}_{i}, \tilde{C}^{j}_{i}] = 0$
2. $\hat{\bar{\pi}}^{i}_{j} \rightarrow \hat{Q}^{i}_{j} = e^{gW_T}\hat{\bar{\pi}}^{i}_{j}e^{-gW_T} = \frac{\hbar}{i}E^{i}_{j(mn)}[\frac{\delta}{\delta\bar{q}_{ij}} - g\frac{\delta W_T}{\delta\bar{q}_{mn}}] = \bar{\pi}^{i}_{j} + ig\hbar\tilde{C}^{i}_{j}; W_T = W_{CS} + W_{EH}$
   $= \frac{g}{4}\int\tilde{\epsilon}^{ijk}(\Gamma^{l}_{im}\partial_j\Gamma^{m}_{kl} + \frac{2}{3}\Gamma^{l}_{im}\Gamma^{m}_{jn}\Gamma^{n}_{kl})\,d^3x - \alpha\int\sqrt{q}Rd^3x; Q^{i}_{j}, Q^{\dagger i}_{i}$ are unitarily inequivalent SL(3R) reps.
3. $\tilde{C}^{i}_{j} = \frac{\delta W_{CS}}{\delta q_{ij}}$; is the C.Y. tensor(density); analogous to the magnetic field in the Yang-Mills Hamiltonian density,
   $\frac{q_{ij}}{2}(E^{ia}E^{j}_{a} + B^{ia}B^{j}_{a}) = \frac{q_{ij}}{2}\hat{Q}^{\dagger ia}\hat{Q}^{ja}$; $\hat{Q}^{ja} = e^{W_{CS}}E^{ia}e^{-W_{CS}} = E^{ia} + iB^{ia}$ & $B^{ia} = \frac{\delta W_{CS}}{\delta A_{ia}}$
4. Hamiltonian density becomes $\bar{H} = \sqrt{\hat{Q}^{\dagger i}_{j}\hat{Q}^{j}_{i} + q\mathcal{K}}$ with $\hat{Q}^{i}_{j}e^{\pm gW_T}|0\rangle = 0$; $\hat{Q}^{\dagger i}_{j}$ and $\hat{Q}^{j}_{i}$ are not symmetrical;
   the generalised coherent state generated is given by $e^{\int\frac{1}{\sqrt{q}}\hat{C}\cdot\hat{Q}^{\dagger}}|0>$
5. Classical conformally flat(C.Y.=0) is an extremum of W, and thus precisely a saddle point for the quantum ground state wavefunctional $\Psi_0[\bar{q}_{ij}] = Ne^{g(W-W_o)}\langle\bar{q}_{ij}|0\rangle$
6. Imaginary momentric means $\Psi_0[\bar{q}_{ij}]$ is a quantum tunnelling solution, however, for compact manifolds, i.e.S^3;
   $<\Psi_0|\hat{\bar{\pi}}^{\dagger i}_{j}|\Psi_0> = 0$, $<\Psi_0|\tilde{C}^{i}_{j}|\Psi_0> = 0$ (metric can still fluctuate; steepest descent)
   $\Rightarrow\Psi_0[\bar{q}_{ij}]$ is barely classically allowed; therefore the initial state indeed satisfies the Weyl hypothesis
7. Important feature: Q Time=Semi-classical Time=Classical Time; Asymptotic free quantum state is also a semi-classical state $\Rightarrow$ classical world is always possible
8. Intrinsic time framework allows continuation of β across zero from real to imaginary values(Lorentzian to Euclidean)

Inflation by ground state property without Inflaton

1. $< \hat{\tilde{\pi}}^i_j >= 0$, force metric fluctuations buried inside $< \tilde{C}^i_j >= 0 \Rightarrow < \pi > \propto < \bar{H} >= 0(\text{allow}\beta \to 0)$

   $\Rightarrow$ zero extrinsic curvature, the junction condition needed for Euclidean to Lorentzian continuation of the metric

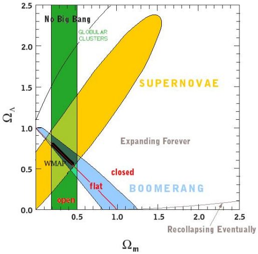
2. Exponential growth in spatial volume as time changes is a result forced by geometries of the initial state at the throat of the de Sitter junction after the Big Bang. No need for scalar field inflaton!



The equator of S^4 is S^3. The de Sitter manifold joins to this S^3 ball tangentially because of the vanishing extrinsic curvature. Therefore the spatial exponential expansion is due to the geometric junction conditions.

Observational Tests of the New Model

1. Zero extrinsic curvature & C.Y. tensor exclude the possibility of $k = 0$, spatially flat $\mathcal{R}^3$ & $k = -1$, spatially open $\mathcal{H}^3$
2. This will be confirmed by the future high precision mass density measurements



3. The de Sitter expansion period is controlled by $T_f - T_i = \frac{2}{3} ln \frac{V_f}{V_i}$; $a_f = a_i e^N$ with

   $N = \frac{1}{2}(T_f - T_i) \sim 50 - 60$ e-folding before the Ricci scalar terms begin to dominate
4. Neither scalar field inflaton nor large v.e.v. is needed to drive the Universe into the de Sitter expansion period, instead, the self-determined geometries fix all the details of the Universe's evolution/expansion at the beginning of the Big Bang

Predictions of primordial scale invariant tensor modes

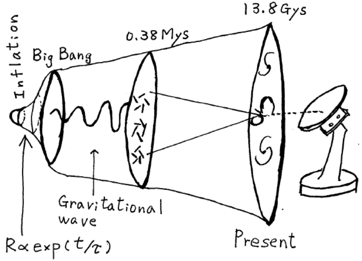
1. C.Y.=0 is the classical extremum of W, & thus precisely a saddle point for the quantum ground state wavefunction;

   $\Psi_0[\bar{q}_{ij}] = Ne^{g(W-W_o)}\langle\bar{q}_{ij}|0\rangle$

2. The Quantum ground state therefore contains primordial fluctuations(CS is a topology inv. entity under infinitesimal variation of metric); expansion of W about the saddle point $\frac{\delta W}{\delta \bar{q}_{ij}} = \tilde{C}^{ij} = 0 \Rightarrow$ primordial tensor mode fluctuations

   $$W_{\bar{q}_{ij}} - W_o = W_{\tilde{C}^i_j=0} + \frac{1}{2}\int d^3x \int d^3y \delta\bar{q}_{ij}(x) H^{ijkl}(x,y)|_{\tilde{C}^m_n=0}\delta\bar{q}_{kl}(y) + \ldots - W_o$$

3. Predicts $\sim 1/k^3$ scale invariance tensor mode fluctuations; can be measured by the BICHEP experiments



Quantum Hamiltonian

1. $\bar{H} = \sqrt{Q^{\dagger i}_j Q^j_i + q\mathcal{K}} = \sqrt{\bar{\pi}^{\dagger j}_i \bar{\pi}^i_j + \hbar^2(g\tilde{C}^i_j - \alpha\sqrt{q}\bar{R}^i_j)(g\tilde{C}^j_i - \alpha\sqrt{q}\bar{R}^j_i) - i\alpha\hbar\sqrt{q}[\bar{\pi}^i_j, \bar{R}^j_i] + q\mathcal{K}}$;

   $\tilde{C}^i_j = \bar{E}^i_{j(mn)}\frac{\delta W_{CS}}{\delta \bar{q}_{mn}}$, $W_{CS} = \frac{g}{4}\int \tilde{\epsilon}^{ijk}(\Gamma^l_{im}\partial_j\Gamma^m_{kl} + \frac{2}{3}\Gamma^l_{im}\Gamma^m_{jn}\Gamma^n_{kl})\, d^3x$ & $[\bar{\pi}^i_j, \tilde{C}^j_i] = 0$

2. $Q^{\dagger i}_j$ & Q^i_j related to $\bar{\pi}^i_j$ by $e^{\mp W_T}$, are non-Hermitian, generate 2 unitarily inequivalent rep. of the non-compact group $SL(3,R)$ at each x; $\bar{\pi}^i_j = \frac{1}{2}(Q^{\dagger i}_j + Q^i_j)$ generates a unitary rep. of $\prod_x SU(3)_x$. In fact, the commutator term in $\bar{H}$ can be identified as $-i\alpha\hbar\sqrt{q}[\bar{\pi}^i_j, \bar{R}^j_i] = [Q^{\dagger}{}^i_j, Q^j_i]$

3. The commutator at coincident spatial position in functional Schrodinger representation is,

$$[Q^{\dagger}{}^i_j(x), Q^j_i(x)] = -\alpha\hbar^2\sqrt{q}\bar{E}^i_{jkl}(x)\frac{\delta\bar{R}^j_i(x)}{\delta\bar{q}_{kl}(x)} = -\alpha\hbar^2\sqrt{q(x)}\int d^3y\,\delta(x-y)E^i_{jkl}(x)\frac{\delta R^j_i(y)}{\delta q_{kl}(x)}$$

4. Variation of the Ricci tensor;

$$\begin{aligned}\delta R_{mn} &= -\frac{1}{2}(\nabla^2 + R)\delta q_{mn} + \frac{3}{2}(R^s_n\delta q_{sm} + R^s_m\delta q_{sn}) + \frac{1}{2}(\nabla_m\nabla^s\delta q_{sn} + \nabla_n\nabla^s\delta q_{sm}) \\ &\quad -(R_{mn} - \frac{1}{2}q_{mn}R + \frac{1}{2}\nabla_m\nabla_n)\delta\ln q\end{aligned}$$

Emergence of Einstein's Theory I

1. Through integration by parts, the point split commutator term becomes

$$[{Q^\dagger}^i_j(x), Q^j_i(y)] = -\frac{5}{6}\alpha\hbar^2\sqrt{q(x)}(-\nabla^2_x + R)\delta(x-y). \qquad (1)$$

2. Heat kernel, $K(\epsilon; x, y)$ with $\lim_{\epsilon\to 0} K(\epsilon; x, y) = \delta(x-y)$, regulates the coincident limit in (1) for generic metrics;

$$\nabla^2 K(\epsilon; x, y) = \frac{\partial K(\epsilon; x, y)}{\partial \epsilon};$$

Seeley-DeWitt coefficients a_n, $2\sigma(x,y)$ square of the geodesic length, & Δ_V the Van Vleck determinant,

$$K(\epsilon; x, y) = (4\pi\epsilon)^{-\frac{3}{2}}\Delta_V^{\frac{1}{2}}(x,y)e^{-\frac{\sigma(x,y)}{2}\epsilon}\sqrt{q(y)}\sum_{n=0}^{\infty} a_n(x,y;\nabla^2)\epsilon^n,$$

wherein ϵ is of dimension L^2. In the coincidence $x = y$ limit, the coefficients for closed manifolds are

$$a_0 = 1; \quad a_1 = \frac{R}{6}; \quad a_2 = \frac{1}{180}(R^{ijkl}R_{ijkl} - R^{ij}R_{ij}) + \frac{1}{30}\nabla^2 R + \frac{R^2}{72}$$

3. Coincidence limit of $\lim_{\epsilon\to 0} K(\epsilon; x, y) = \delta(x-y)$ regulates $\delta(0)$, and $\lim_{\epsilon\to 0}\frac{\partial K(\epsilon;x,x)}{\partial\epsilon}$ for $-\nabla^2\delta(0)$,

Emergence of Einstein's Theory II

1. $[Q^{\dagger i}{}_j(x), Q^j_i(x)] = \lim_{\epsilon\to 0} -\frac{5\alpha\hbar^2 q}{6(4\pi\epsilon)^{\frac{3}{2}}}\left[\frac{3}{2\epsilon} + \frac{13R}{12} + (a_1 R - \frac{a_2}{2})\epsilon + \text{terms with } \epsilon^{n\geq 2}\right]$;
2. This yields the full fledge local Hamiltonian density

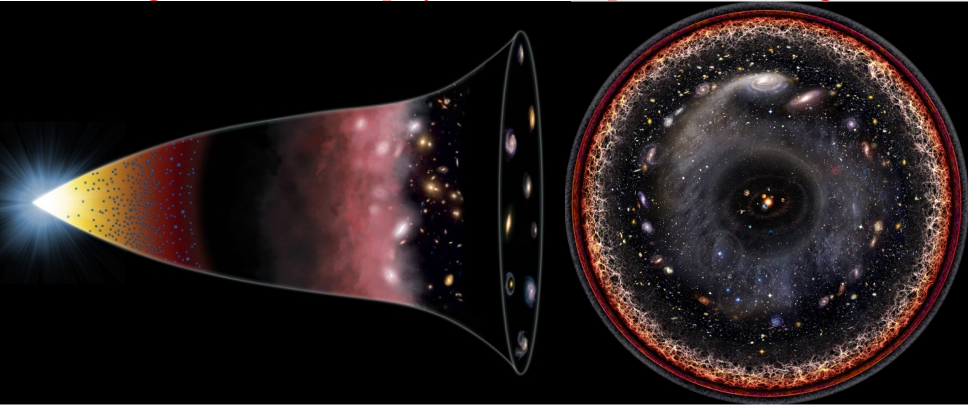
$$\bar{H} = \lim_{\epsilon\to 0}\sqrt{\begin{array}{l}\bar{\pi}^{\dagger j}_i \bar{\pi}^i_j + \hbar^2(g\tilde{C}^i_j - \alpha\sqrt{q}\bar{R}^i_j)(g\tilde{C}^j_i - \alpha\sqrt{q}\bar{R}^j_i) + \\ q(\mathcal{K} - \frac{5\alpha\hbar^2}{32\pi^{\frac{3}{2}}\epsilon^{\frac{5}{2}}}) - \frac{5\alpha\hbar^2 q}{6(4\pi\epsilon)^{\frac{3}{2}}}(\frac{13}{12}R + (a_1 R - \frac{a_2}{2})\epsilon);\end{array}}$$

   3 fundamental coupling constants $g, \mathcal{K}$ and α. Upon regulator removal, $\epsilon \to 0$, divergences are countered by $\mathcal{K}$ and α
3. Renormalized values are identified phenomenologically, with $\frac{1}{(2\kappa)^2} = \frac{5\alpha\hbar^2}{6(4\pi\epsilon)^{\frac{3}{2}}}(\frac{13}{12})$ to yield the correct Newtonian limit, and read off the effective cosmological constant $\Lambda_{\text{eff}.}$ from $\frac{2\Lambda_{\text{eff}}}{(2\kappa)^2} = (\mathcal{K} - \frac{5\alpha\hbar^2}{32\pi^{\frac{3}{2}}\epsilon^{\frac{5}{2}}}) = (\mathcal{K} - \frac{2^4 3^2}{13\kappa^2\epsilon})$
4. $\alpha = \frac{72(4\pi\epsilon)^{\frac{3}{2}}}{65\hbar^2(2\kappa)^2}$, and finiteness of κ implies $\alpha \to 0$ as $\epsilon \to 0$. The theory actually produces all the Seeley-DeWitt coefficients, but these higher curvature terms with positive powers of ϵ all disappear upon regulator removal
5. Finally $\bar{H} = \sqrt{Q^{\dagger i}_j Q^j_i + q\mathcal{K}} = \sqrt{\bar{\pi}^{\dagger j}_i \bar{\pi}^i_j + \hbar^2 g^2 \tilde{C}^i_j \tilde{C}^j_i - \frac{q}{(2\kappa)^2}(R - 2\Lambda_{\text{eff}})}$

Four Pillars of whys, that make the Universe as it is

1. Causality: Foundation of orders $\rightarrow$ allows our mother nature being accessible to human minds
   - Gravity forces $\{,\}_{P.B.}$ to be replaced by $[,]\rightarrow$ Causality regained dynamically
   - Realised by a single Ψ(therefore can globally be agreed) in Quantum Mechanics
2. Unitary: Information preserving, none will be left behind $\rightarrow$ Universe to evolve as a whole inside the Ψ
3. Computability: Dimensionless Schrödinger eqt. ($\hbar$ & κ being conversion factors) unifies everything into a single GI Ψ
   - $\{,\}_{P.B.}$ replaced by $[,]$ $\rightarrow$ evolution guaranteed; Universe needs no reboot
   - Gauged$\rightarrow$To get rid of the ∞ d.o.fs in the field operator for 'Time'$\rightarrow$ integrability
   - Completeness $\rightarrow$ 1^{st} order S-eqt. guarantees consistency with trillions of H-J eqt.
   - Integrability & Complexity $\rightarrow$ only ONE Time & flows in the direction of entropy$\uparrow$
4. Renormalizability: Allow structureless point-like Quantum Fields to make Geometrodynamics possible
   - Each point between the Small/Large Universe can be identified
   - Geometrodynamics allows the Universe to expand without leaving out anything

Meaning of Time - A physicist's response to Bergson



Time and Causality is to evoke existence: Things come into beings and facts become true all the time & therefore flows in the same direction as entropy↑

Meaning requests causality & the reality of time, therefore must be QM