Title: About Semi-Classical Quantum Gravity

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Abstract:

Some Issues in Semiclassical LQG

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October, 2004

Work by many + collaboration with:
A. Ashtekar, B. Bolen, L. Bombelli, O. Winkler.

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What is the Holy Grail?

Semiclassical LQG

- Solutions to constraints that for physical observables behave classical.

- Recover space time notion g_{ab} and with it
  - notion of time
  - causality

- Make QFT on a Quantum Geometry finite

- Give us enlightment about
  - non-renormalizability of gravity
  - non-trivial fixed point
  - ⋮

- Your own favorite goal

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The Landscape

Enough Solutions

$g^\circ_{ab} \longrightarrow \Psi_{g^\circ}(A)$

Kinematical vs. Dynamical

Vacuum (+ linearizations)

$\mathcal{H}_{kin}$ vs $(G_{VI})^*$

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The Landscape

Enough
Solutions

Kinematical
vs.
Dynamical

$g^\circ_{ab} \longrightarrow \Psi_{g^\circ}(A)$

$\mathcal{H}_{\text{grav}}$ vs. $((\nabla\nabla)^n$

Vacuum
(+ linearizations)

Kinematical vs. Dynamical (Lichtner, Bombelli, AC)

Basic Question:

Can we avoid the hassle of actually solving constraints?

can we define Kinematical semi-classical states that do the job?

Since we can not answer in a definite form unless we solve constraints ....

- go to models and try to build an intuition.

- Keep fingers crossed ...

(Belen, Bombelli, ec)

Bianchi models

$$q_{ij} = e^{2\beta^0}\, \mathrm{diag}\left(e^{2(\beta^+ + \sqrt{3}\beta^-)},\ e^{2(\beta^+ - \sqrt{3}\beta^-)},\ e^{-4\beta^+}\right)$$

$$H(\beta_i, P_i) = \frac{1}{2}\left(-P_0^2 + P_+^2 + P_-^2\right)$$

$$|\langle \hat{O}_\alpha\rangle_\psi - O_\alpha(\bar{q},\bar{p})| < \epsilon_\alpha \qquad (\Delta \hat{O}_\alpha)_\psi < \delta_\alpha$$

$$|\langle \hat{H}\rangle_\psi| < \epsilon \qquad (\Delta \hat{H}_2)_\psi < \delta_2$$

$\hat{P}_2$	ϵ_p	δ_p
$\hat{V}_2$	ϵ_v	δ_v

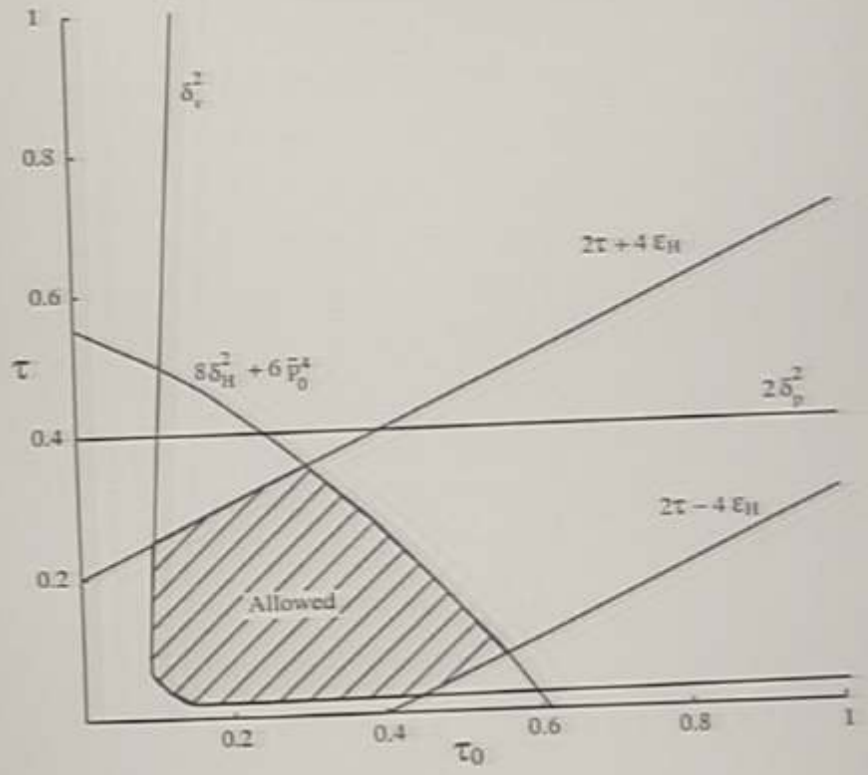
Dirac observables

Kinematical $\quad \psi_{kin} = \prod N_i \exp\left[-\frac{(P_i - \bar{P}_i)^2}{2\sigma_i} - i(P_i - \bar{P}_i)\bar{\beta}_i\right]$

Dynamical

$$\psi_{Dyn} = N^{-1}\int d\lambda\, e^{-i\lambda\hat{H}}\, \psi_{kin}.$$

Allowed values for Kinematical States



Other models

- Linear Constraints ✓
- Quadratic Constraints

$$H_1 = p_1^2 + q_1^2 + p_2^2 + q_2^2 = cte \qquad so(3)$$

$$H_2 = p_1^2 + q_1^2 - p_2^2 + q_2^2 = cte. \qquad so(2,1)$$

Kinematical coherent states do approximate physical ones in certain regime.

- Maxwell and 2+1 Gravity

We need to explore these examples and more to gain intuition.

The Landscape

Enough
Solutions

Kinematical
vs.
Dynamical

$g^{\circ}_{ab} \longrightarrow \Psi_{g^{\circ}}(A)$

$\mathcal{H}_{kin}$ vs $(G_N l)^n$

Vacuum
(+ linearizations)

• $\mathcal{H}_{kin} \simeq (Cyl)^*$

What is the proper home for semiclassical states?

$\mathcal{H}_{kin}$: T.O.H.-kernel states $\begin{cases} (A_0, \pi_0) & \text{phase space point} \\ \Gamma & \text{graph (+ surfaces)} \end{cases}$

$(Cyl)^*$: Fock states $\rightarrow$ Coherent states $\begin{cases} \text{heat Kernels} \\ \text{Fock motivated} \\ ? \end{cases}$

$(Cyl)^* \ni \psi_o \xrightarrow{\Gamma}$ Its shadow on Γ

$\psi_\Gamma(A) \in \mathcal{H}_{kin}$

For both, how do we choose the graph?

Use statistical geometry!

• $\mathcal{H}_{kin}$ vs. $(Cyl)^*$

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Traditional Viewpoint

Give $q^{\circ}_{ab} \longmapsto (A^{\circ}_a, E^{\circ}_a)$ classical spacetime

Find a state $\Psi_S(A_a)$ that approximates q°_{ab}

How? Use observables O and impose conditions on $(\Delta O)_\psi$

Complementary Viewpoint

Imagine that the "true" nature at Planck scale is discrete. No space-time notion. Assume that a quantum state Ψ_Γ describes this geometry at Γ graph/complex.

How do we recover a space-time notion at large scales?

How do we estimate uncertainties in reconstruction?

Use statistical geometry ideas! (Bombelli)

Traditional Viewpoint

Give $q^{\circ}_{ab} \hookrightarrow (A^{\circ}, E^{\circ})$ classical spacetime

Find a state $\Psi_g(A_k)$ that approximates q°_{ab}

How? Use observables O and impose conditions on $(\Delta O)_k$

Complementary Viewpoint

Imagine that the "true" nature at Planck scale is discrete. No space-time notion. Assume that a quantum state Ψ_Γ describes this geometry at Γ graph/complex.

How do we recover a space-time notion at large scales?

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Use statistical geometry ideas! (Bombelli)

The Vacuum

A lot of work has been devoted to the issue of finding the right vacuum state.

- Fock motivated vaccum.
  - ⊙ take U(1) and translate the ordinary vacuum state $|0\rangle$ to the polymer description. It does not fit in $\mathcal{H}_K$ (Cyl^*).
  - ⊙ Use Heat-Kernel thniques (generalized by Thiemann) and build it
  - ⊙ Hope that it also works in gravity
  - ⊙ what "Laplacian" should we use?

- Other techniques in $\mathcal{H}_K$ (Conrady)

- De-Sitter and the Kodama State

  The Kodama state "solves" the constraints for a cosmological constant Λ.

  It approximates de-Sitter space.

Outlook

- what are semi-classical states?
- How much can we say without dynamics?
- How do we in practice find them and compute?
- How far are we from true phenomenology?
- Who is going to come with the bright idea we need?

⋮

Thanks!

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