Title: It Feels Like the Old Days: From Loop Quantum Gravity to Conformal Graphs

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It feels like the old days:
From Loop Quantum Gravity to Conformal Graphs

for Lee's Fest

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Quantum field theory

How can one deal with inifinitely many D.O.F.?

- We can quantize finite dimensional systems $\mathscr{Q} = (\mathfrak{A}, \mathbb{G}, U, \mathscr{H}, \pi)$
- Choose a set $\mathscr{S}$ of observables that separates points
- Construct a quantization for finite subsets $s \subset \mathscr{S}$, such that:
  1. **Projective limit**: One can systematically approach $\mathscr{S}$
  2. **Cylindrical consistency**: quantization of s must contain quantization of all subsystems of s.

Problem

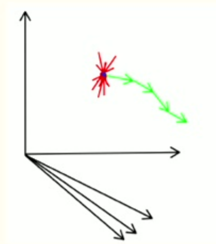
If $\mathbb{G}$ contains Poincaré group then and the theory is local:
$\Rightarrow$ Almost no non-trivial examples.

thws

Renormalization

Wilsonian renormalization

- Find a coarse graining procedure, such that the coarse grained **effective field theories** end up describing macroscopic systems
  - This is very difficult in a pre-metric regime!
- Calculate "best approximation" EFT in a piecemeal way by doing small coarse graining steps



(theory space)

Result

- A few (infinitessimal) perturbations of the Hamiltonian increase in strength
- Search for attractors finds solutions to (modified) consistency relations

thws

Application to LQG

Problem

$\mathbb{G}$ contains local time reparametrization as gauge symmetry
$\Rightarrow$ dynamics inextricably entangled with gauge problem
$\Rightarrow$ Must be implemented correctly to obtain theory space of GR

Wild fantasy (wishful thinking)

Could local Weyl transformations play role of gauge?

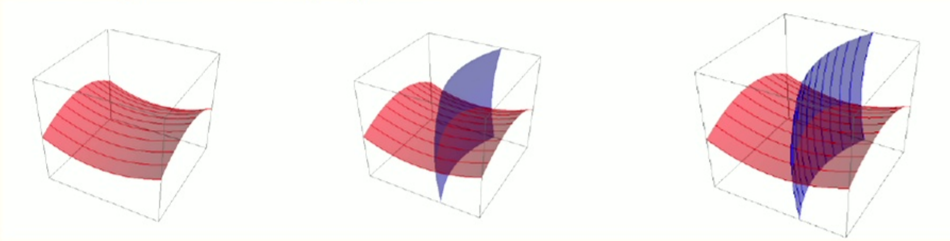
Relationalism

First encounter with Julian Barbour

- the universe is relational
  (all quantitative statements are ratios of properties of system and reference)
  $\Rightarrow$ Supremum of **objective** information is encoded relationally
- Somehow, this leads to a realization of my wild fantasy

With Sean Gryb and Henrique Gomes

1. In some circumstances, gauge symmetry and gauge fixing can be swapped while maintaining the same physics



2. Shape dynamics description of GR, possesses spatial Weyl symmetry

thws

Pure Shape Dynamics

This was not a technical accident

Any classical (or Bohmian) system allows this

- Choose securely relational quantities and calculate ratios of change

$$\frac{\dot{z}^a}{\dot{z}^b} = K^a_b(\vec{z})$$

  LHS scale and repearentrization invariant
  $\Rightarrow$ RHS can be expressed in scale and reparametrization inv. z^a

- iterate until system closes

$\Rightarrow$ This decouples an **empirically complete** and **autonomous** dynamical subsystem

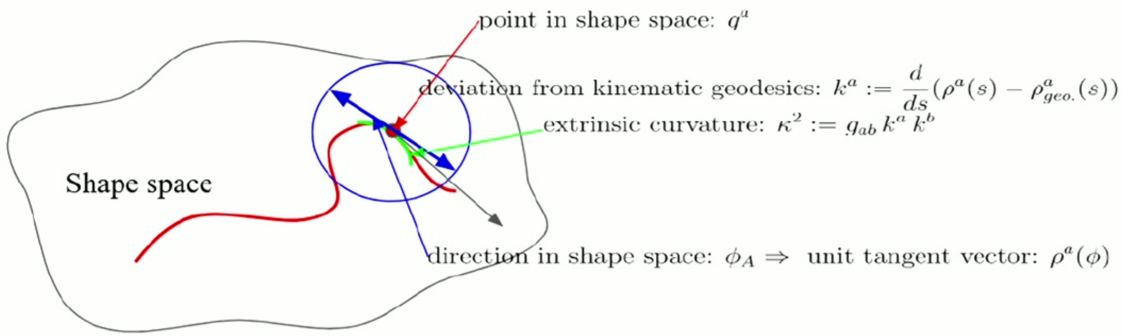
PSD postulate (application to configuration space)

The dynamics of the universe is the equation of state of the local differential geometry of an (unparametrized) curve in relational configuration space.

thws

Illustration of PSD

$$d\,q^a = u^a(q,\phi)$$
$$d\,\phi_A = \Phi_A(q,\phi,\kappa)$$
$$d\,\kappa = K(q,\phi,\kappa)$$

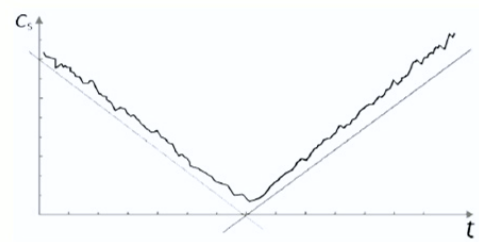


thws

Application to GR

Some results:

1. Classical GR can be described as an equation of state of the curve traced out in conformal superspace.
2. Attrtractors of dynamics ⇒ **gravitational arrow of time**. Gravitational AOT implies:
   (a) thermodynamic AOT (interaction of approx. auton. - subsystems)
   (b) quantum AOT (when applying to Bohmian SD)
3. Complexity (instance of Leibniz' variety) is the age of the universe
4. Decoupled dynamics evolves through big bang (EOM remain hyperbolic)



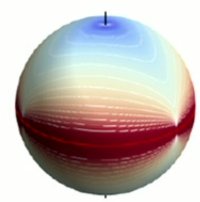
$$\alpha' = \frac{\sqrt{2}\cos^2\beta}{\psi\sqrt{\frac{\sin^2(2\beta)}{4\psi^2}+1}}, \quad \beta' = \frac{\sqrt{2}\cos^2\beta}{\sqrt{\frac{\sin^2(2\beta)}{4\psi^2}+1}},$$ (evol. of shape)

$$\psi' = \frac{1}{8\sqrt{2}\psi\sqrt{\frac{\sin^2(2\beta)}{4\psi^2}+1}}\Big[8\cos^2(\beta)\cot\beta\,(1+4\psi^2-\cos(2\beta)) + + s^2 e^{-\frac{2\pi\tan}{b}}(1+8\psi^2-\cos(4\beta))\times \times\left[C_2\left(\sin\alpha-\psi\frac{\cos\alpha}{2\sin 2\beta}\right)+C_1\left(\psi\frac{\sin\alpha}{2\sin 2\beta}+\cos\alpha\right)\right]\Big].$$ (evol. of direction)

$$b' = \frac{b\cot\beta}{6\sqrt{2}}\left[\frac{24}{\sqrt{\frac{\sin^2(2\beta)}{\psi^2}+4}} - bs(8e^{-\frac{2\pi\tan}{b}}C+3)\right].$$ (evol. of curvature)

$$s' = \frac{4Cs^2}{3\sqrt{2}} + \frac{s^3}{\psi\sqrt{\frac{2\sin^2(2\beta)}{\psi^2}+8}}\big[C_1(\sin\alpha\sin(2\beta)-2\psi\cos\alpha) - 2C_2(2\cos\alpha\sin(2\beta)+\psi\sin\alpha)\big]e^{-\frac{2\pi\tan}{b}}.$$ (evol. of scalar field)

shape space of Bianchi IX:



Why does it feel like the old days?

LQG observables

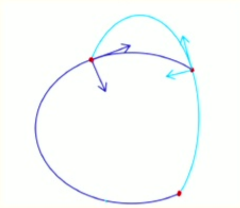
Cylindrical functions and Weyl-operators of fluxes:

$$O = \sum_{i \in \mathscr{I}} f_i(h_{e_1^i}(A), \ldots, h_{e_n^i}(A)) \cdot W_{S_1^i}(E) \ldots W_{S_k^i}(E)$$

- my first LQG paper was about a reason why embedding angles at vertices are unphysical

Conformal graphs

conformal graphs (edges have midpoints) and are embedded as conformal geodesics.



$\Rightarrow$ configuration variables are functions of frame rotations, like LQG wave functions:

$$f(R_i, \ldots, R_n)$$

Thank you, Lee!