Quantum Gravity in Relativistic Phase Space

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Why *Quantum* Gravity?

1. All the other fundamental interactions are quantized.
2. The Einstein Field Equation has matter in it.

**Spacetime Curvature = Matter**

3. Singularities of Black Holes and the Big Bang
   (Compare to UV divergence of Rayleigh-Jeans)
Why *Quantum* Gravity?

Dark Matter and Dark Energy

- **Unexplained gravitational phenomena**
  - Dark Energy
  - Dark Matter

![Pie chart and 3D visualization showing proportions of dark energy, dark matter, intergalactic gas, and stars.](image)
Quantization Necessities
What is needed for the quantization process?

Canonical Quantization, à la Dirac

\[ \{x, p\} = 1 \rightarrow [\hat{x}, \hat{p}] = i\hbar \]

1. Multiply by \( i\hbar \).
2. Phase space dynamical variables become operators.
3. Change the Poisson Bracket to a commutator.
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So what is needed?

- Phase Space
- Canonically Conjugate Fields
- Relativistic geometry
Quantization Necessities

Usually taken care of with *Hamiltonian Dynamics*

- $H = H(x, p)$
- Poisson Brackets $\{A, B\}$
- *Canonically Conjugate* if $\{A, B\} = 1$
- All over in QM $\mapsto \hat{H}\psi = i\hbar \frac{\partial}{\partial t} \psi$ (Schrödinger Eqn)
- Generalizes to relativistic fields.
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But it is not geometric
Biconformal Space
→ Relativistic Phase Space

**Gravitational Gauge Theory** is born from an attempt to understand gravity from a particle physics perspective and use the symmetries of spacetime measurements to construct theories of gravity.
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Biconformal Space: A space, formed from the symmetries of the light cone, that contains General Relativity and is special because:

- **Derive** the structures that make it a relativistic phase space.
  - Symplectic form $\rightarrow$ Poisson Bracket
  - Time is an emergent property!
- Allows direct characterization of canonically conjugate variables.
Biconformal Space

Current Calculation

- Combine general relativity result of Wehner and Wheeler with time result of Spencer and Wheeler.
- Solve the structure equations that we obtain.
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We have general relativity set in a broader framework.
Biconformal Space
Curved Phase Space

Curved Momentum space
- Principle of Relative Locality
- 2+1 Quantum Gravity (regularization)
Thank You