

The Metaphysics of Quantum Gravity

Antonio Vassallo

Instytut Filozofii, Uniwersytet Warszawski
Section de Philosophie, Université de Lausanne



Summary

- General Relativity
- Metaphysics of GR
- Weak Essentialism
- Canonical Quantum Gravity

General Relativity

$$R_{ij} - \frac{1}{2}g_{ij}R = \frac{8\pi G}{c^4}T_{ij}$$

«Space acts on matter, telling it how to move. In turn, matter reacts back on space, telling it how to curve.»

C.W. Misner, K.S. Thorne, J.A. Wheeler – *Gravitation*. Freeman & Co., 1973 (p.5).

General Relativity

DEFINITION 1

A *cosmological model* $\langle M, \mathbf{g}, \mathbf{T} \rangle$ of GR is a solution of Einstein's field equations where \mathbf{T} represents the global distribution of matter in the universe.

DEFINITION 2

A *possible world* according to GR is a cosmological model of GR.

General Relativity

Gauge theorem for GR

If $\langle M, \mathbf{g}, \mathbf{T} \rangle$ is a model of GR and f is a diffeomorphism from M onto M , then the carried along triple $\langle M, f^*\mathbf{g}, f^*\mathbf{T} \rangle$ is also a model of the theory.

J. Earman, J. Norton – What Price Spacetime Substantivalism? The Hole Story. *Brit. J. Phil. Sci.* 38 (1987), p. 520

Metaphysics of GR

Two metaphysical views:

- *Geometrical realism*: the geometrical objects constituting a model of the theory represent real physical entities.
- *Moderate realism*: only the gauge invariant quantities ("observables") constructed out of geometrical objects in a model represent real physical entities.

Metaphysics of GR

- Against geometrical realism: proliferation of entities "transparent" to physics (hole-type problem).
- Against moderate realism: a straight commitment to observables dismisses as unreal intuitive features of "everyday reality" (e.g., the problem of time).

Weak Essentialism

- The objects constituting a model of the theory represent real physical entities, i.e. physical objects and properties.
- Fundamental physical objects carry *essentially* certain *determinable* physical properties.
- These objects lack intrinsic identity.

Weak Essentialism

Example: spacetime.

- Spacetime points enter directly any model of GR.
- They carry essentially the property "has a metric".
- These objects have no "primitive thisness".

Weak Essentialism

- Weak Essentialism commits to a more parsimonious ontology than "standard" geometrical realism.
- Supplies a metaphysical account of gauge invariance.
- Accounts for the existence of non-gauge invariant quantities.

Canonical Quantum Gravity

Few elements of Quantum Mechanics.

- The state of a quantum mechanical system is described by a *wave function* Ψ .
- The space of all possible states for a quantum mechanical system is a *Hilbert space* \mathbb{H} .
- The dynamics of the system is governed by the Schrödinger equation:

$$i\hbar \frac{\partial}{\partial t} \Psi = \hat{H} \Psi$$

Canonical Quantum Gravity

- The dynamics on the Hilbert space of gravitational states is given by the *Wheeler-DeWitt* equation:

$$\hat{H}\Psi = 0$$

- The dynamics is "stationary".
- Gauge invariant quantities do not depend on time: *there is no real change*.
- Gauge invariant quantities are non-local: *our local existence is ruled out*.

Canonical Quantum Gravity

- Weak Essentialism is a clear example of a metaphysics of local non-gauge invariant objects and properties which underlies a physics of non-local gauge invariant observables.
- As such, WE is compatible with those interpretations of the Wheeler-DeWitt equation that seek to recover classical phenomena from the quantum regime.