Title: From timeless physical theory to timelessness

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Abstract: Peter Evans
The extent to which Julian Barbour's Machian formulation of general relativity and his interpretation of canonical quantum gravity can be called timeless is addressed. We differentiate two types of timelessness in Barbour's work (1994a, 1994b and 1999) and attempt to refine Barbour's metaphysical claim by providing an account of the essential features of time through considerations of the representation of time in physical theory. We argue that Barbour's claim of timelessness is dubious with respect to his Machian formulation of general relativity but warranted with respect to his interpretation of canonical quantum gravity. We conclude by discussing some of the implications of Barbour's view.

From Timeless Physical Theory to Timelessness

P. W. Evans
Joint work with S. Baron and K. Miller

Centre for Time
University of Sydney

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The aim

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- Barbour claims that we live in a timeless reality

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- Two separate claims:

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- Two separate claims:
  - Machian formulation of general relativity is timeless

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  - Machian formulation of general relativity is timeless
  - interpretation of canonical quantum gravity is timeless

Overview

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- Barbour's theory:

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  - time in Jacobian mechanics

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  - Machian dynamics

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  - Machian dynamics
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- Two senses of timelessness:

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- Barbour's theory:
  - time in Jacobian mechanics
  - Machian dynamics
  - canonical quantum gravity
- Two senses of timelessness:
  - Rovelli's attributes of time

State space geometry

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- Hamiltonian geometry: (Γ, ω)

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State space geometry

- Hamiltonian geometry: (Γ, ω)

$$\Gamma := T^*Q$$

$$\omega := \mathrm{d}\theta \qquad\qquad \theta : T(\Gamma) \to \mathbb{R}$$

State space geometry

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- Lagrangian geometry: Q

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  kinetic energy, $T = \frac{1}{2} a_{ik} \mathrm{d}q_i \mathrm{d}q_k$

State space geometry

- Lagrangian geometry: Q

  kinetic energy, $T = \frac{1}{2} a_{ik} \mathrm{d}q_i \mathrm{d}q_k$

  $$\mathrm{d}s^2 = 2T\mathrm{d}t^2 = a_{ik}\mathrm{d}q_i\mathrm{d}q_k$$

Reduction

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$$A = \int_{\tau_b}^{\tau_a} \mathcal{L}\left(q_i, \frac{q_i'}{t'}\right) t' \mathrm{d}\tau$$

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$$\delta A_r = \delta \int_{\tau_b}^{\tau_a} \sqrt{2(E-V)}\mathrm{d}s = 0$$

Machian dynamics

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  - $Q \longrightarrow Q_0$

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- Machian dynamics:
  - Jacobian theory on Q_0

Machian dynamics

- Relative configuration space:
  - $Q \longrightarrow Q_0$
- Machian dynamics:
  - Jacobian theory on Q_0
  - require frame independent definition of ds

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$$\mathrm{d}s_0 = \sqrt{a_{ik}\left[\frac{\mathrm{d}q_i}{\mathrm{d}\lambda} - \varepsilon_\alpha(\lambda)O_\alpha q_i\right] \cdot \left[\frac{\mathrm{d}q_k}{\mathrm{d}\lambda} - \varepsilon_\alpha(\lambda)O_\alpha q_k\right]}\,\mathrm{d}\lambda$$

Machian geometrodynamics

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- Extend best matching from configurations to Riemannian 3-geometries

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  - geometry $\rightarrow$ *dynamical supermetric*
    - form an action integral and construct a Jacobian principle
    - four dimensional trajectories from sequences of 3-geometries
- Barbour claims that general relativity is a relativistic Machian theory of mechanics

Timeless general relativity

Timeless general relativity

- Theory is construed as a Jacobian geodesic principle on configuration space

Timeless general relativity

- Theory is construed as a Jacobian geodesic principle on configuration space
- Time is not present in any 3-geometry but reconstructed via a Machian algorithm

Canonical quantum gravity

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- Applying Dirac's constrained canonical quantisation procedure to Machian geometrodynamics yields the Wheeler-DeWitt equation:

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  - a constraint equation of the form $\hat{H}\Psi = 0$
  - Ψ is a complex-valued function of 3-geometries

Quantum probability distribution

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Quantum probability distribution

- Barbour suggests that we interpret the Wheeler-DeWitt equation as a static wavefunction on superspace:
  - gives the likelihood of actualising a configuration
  - no time-dependency

Barbour's interpretation

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- External picture

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- Internal picture

Barbour's interpretation

- External picture
  - possibility $\rightarrow$ actuality
- Internal picture
  - experience encoded in brain configuration

What about time?

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- Time capsule:

What about time?

- Time capsule:

  a static configuration of part or all the universe containing structures which suggest they are mutually consistent records of processes that took place in a past in accordance with certain laws.

What about time?

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- Timelessness:

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- Timelessness:

  Time is not a framework in which the configurations of the world evolve. Time exists only so far as concrete configurations express it in their structure.

Rovelli's attributes of time

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  - increase in universality $\rightarrow$ decrease in attributes

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Machian timelessness

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- Time recovery algorithm:

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Machian timelessness

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  - relative configurations define dynamical supermetric
  - dynamical supermetric determines geodesics
  - geodesics connect 3-geometries into spacetime
- Explicit emergence of linear and metric 'time'

QPD timelessness

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QPD timelessness

- Time is not recovered in Barbour's quantum gravity:
  - three dimensional configurations
  - static quantum probability distribution (QPD)
  - the *appearance* of time arises from time capsules
- No relation whatsoever between 3-geometries

Timeless physical theory

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- Timeless Machian geometrodynamics:

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  - reason to be suspect

Timeless physical theory

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- Timeless canonical quantum gravity:

Timeless physical theory

- Timeless Machian geometrodynamics:
  - reason to be suspect
- Timeless canonical quantum gravity:
  - much firmer ground