

*EPFL Master course*

*Philosophical perspectives on  
science and its history*

**Philosophy of space and time: the  
contemporary debate**

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# From Newton to Einstein

**1687 Newton: universal laws of mechanics and gravitation**

**but: gravitation as action at a distance**

**1860 Maxwell: field theory of electromagnetism: local propagation of effects, maximal velocity of propagation**

**1887 Experiment of Michelson and Morley: speed of light constant**

**1905 Einstein: theory of special relativity**

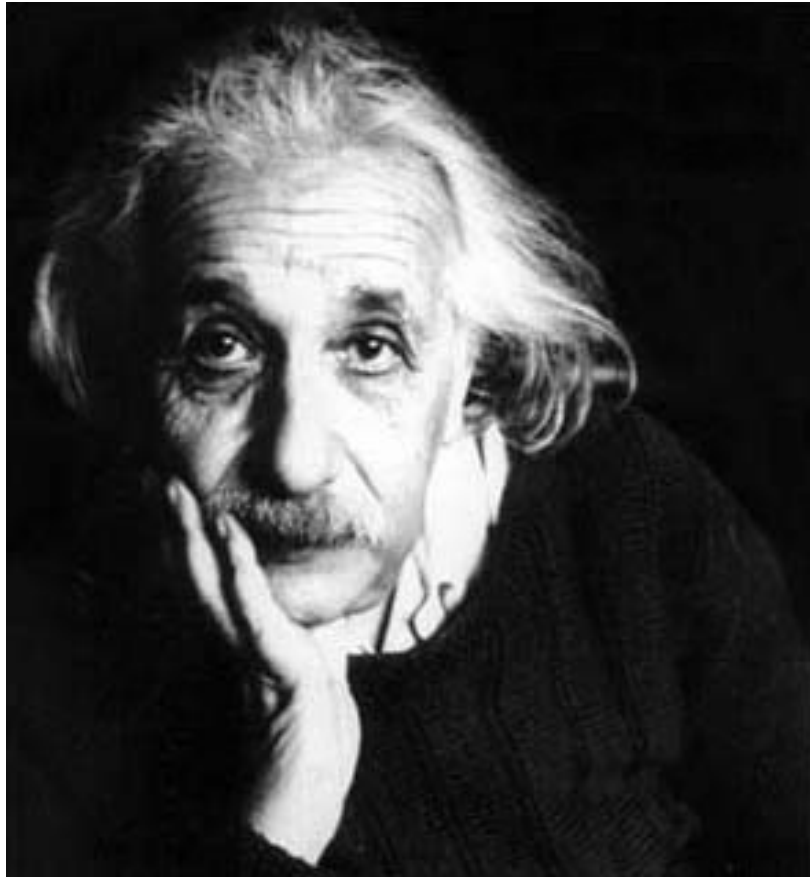
**1916 Einstein: theory of general relativity**

# Newton to Bentley 25 Feb. 1692

**“That gravity should be innate inherent & essential to matter so that one body may act upon another at a distance through a vacuum without the mediation of anything else by & through which their action or force may be conveyed from one to another is to me so great an absurdity that I believe no man who has in philosophical matters any competent faculty of thinking can ever fall into it.”**

# Albert Einstein (1879-1955)

## Special relativity (1905)



1. All inertial referential systems are equivalent.
  2. Light always propagates with a constant velocity in all referential systems.
- space and time united in spacetime

# General relativity (1916)

- adds a theory of gravitation
- gravitational field identical with the metrical field that encodes the geometry of spacetime
  - spacetime curved
  - gravitation local interaction between the metrical field and the fields of non-gravitational energy-matter
  - spacetime no background structure, dynamical entity

# General relativity (1916)

- **no clear distinction between spacetime and matter:**  
does the metrical field belong to spacetime or to matter?
- **spacetime:**  
without this field, no light cones and no distinction between timelike, spacelike and lightlike intervals between events.
- **matter:**  
the metrical field includes energy, namely the gravitational energy; **gravitation: material interaction**

# Spacetime as a substance

- 1) *manifold substantivalism*: spacetime without the metrical field is a substance that exists on its own. **The points of spacetime are substances without the metrical properties, their identity does not depend on the metrical properties.**
- 2) *metrical substantivalism*: it is spacetime with the metrical field (= the geometrical structure) that defines absolute spacetime. **The metrical properties are essential properties of spacetime points, their identity depends on them.**

# The field argument

- Fields are defined on spacetime.
- The field properties exist at spacetime points.  
→ substances in the form of spacetime points as that what instantiates the field properties
- compatible with both versions of substantivalism

# The argument from the vacuum solutions

- vacuum solutions of the Einstein field equations: **the metrical field can exist without non-gravitational energy-matter.**
- spacetime with the metrical field as a substance

# The hole argument

- **transformation that does not change the relations among the physical properties, but produces a difference on the level of the bare spacetime points at which the physical properties occur**
- **Indiscernible**
  - **indeterminism: different possibilities which spacetime points bear given physical properties, but no physical difference**
  - **hits only manifold substantivalism; decisive argument against manifold substantivalism**

# Relationalism



- only metrical relations among material entities
- **only fields, metrical field is a field like the other ones**
- metrical properties as causal properties like the other material properties (gravitational effects)

# The point at issue

- What is the relationship between the metrical properties and the properties defining non-gravitational energy-matter?
- **metrical substantivalism:** two distinct types of entities. Why?
- **relationalism:** only material properties of material entities. But how can one explain the special status of the metrical-gravitational properties (universal, defining spacetime)?

# Matter reduced to spacetime

- **general relativity: reduction of the theory of gravitation to a geometrical description of spacetime**

- reduction of electromagnetism

- reduction of particle physics

- **geometrostatics:**

- build physics on the basis of recognizing only spacetime and its geometrical properties

# John A. Wheeler (1912-2008)



**“Is spacetime only an arena within which fields and particles move about as “physical” and “foreign” entities?**

**Or is the four-dimensional continuum all there is?**

# John A. Wheeler (1912-2008)

Is curved empty geometry a kind of magic building material out of which everything in the physical world is made: (1) **slow curvature in one region of space describes a gravitational field;** (2) **a rippled geometry with a different type of curvature somewhere else describes an electromagnetic field;** (3) **a knotted-up region of high curvature describes a concentration of charge and mass-energy that moves like a particle?** Are fields and particles foreign entities immersed *in* geometry, or are they *nothing but* geometry?"

# Geometrodynamics

- failed for physical reasons  
(notably quantum physics)
- abandoned by Wheeler in 1973

# The situation today

- 1) *the hole argument*: no points of spacetime without metrical properties
- 2) *the field argument*: One cannot eliminate spacetime points.
  - There are spacetime points characterized by metrical properties. The properties of non-gravitational energy-matter exist as well at these points.

# The situation today

- **classical physics, special relativity:** What is the relationship between space-time and matter?
- **general relativity:** What is the relationship between the metrical field and the fields of non-gravitational energy-matter?