The place of space

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Warning !

You enter a talk where a physicist will act as an historian (of phycics) to discuss philosophy (of physics).

Be careful . . . and indulgent.

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We are far and away not gonna be exhaustive.

Motivations

"*What then is time ? If no one asks me, I know ; if I want to explain it to a questioner, I do not know*"
St. Augustine

(From my point of view) The same idea can apply to space.

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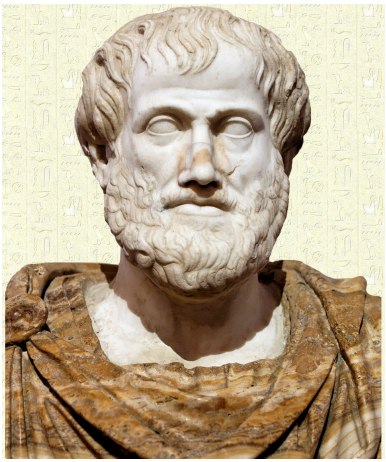
→ Space and time are fundamental/basic concepts in physics

→ But basic doesn't meen trivial

Plan

Aristotle (384AC – 322AC)



Space is absolute.

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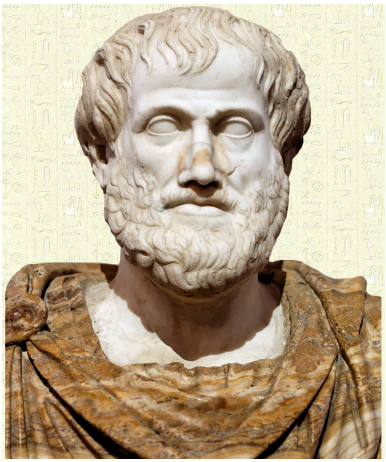

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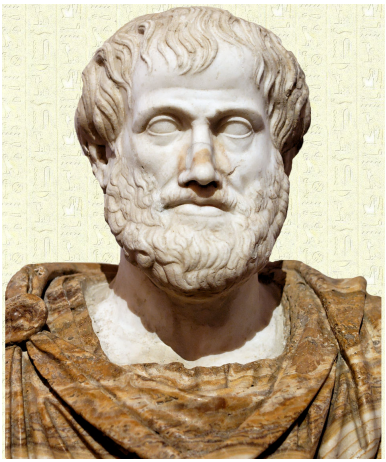

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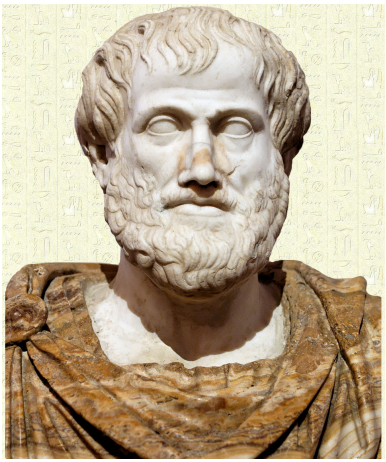

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Space ≈ Earth reference frame.

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Space is absolute
but has been created
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→ Space is a property of the universe

→ Doesn't make sense "outside the universe"

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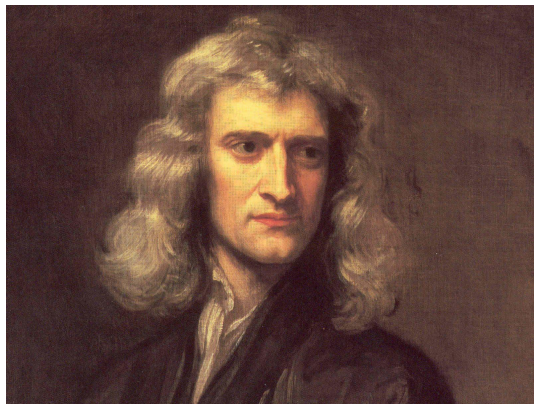
Space is relative.
(But it exist independently of any observation)

Isaac Newton (1643PC – 1727PC)



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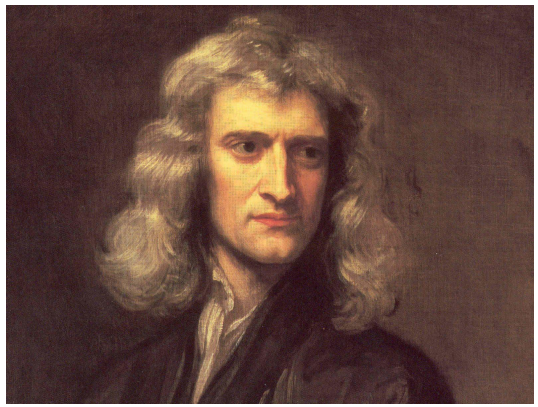

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Here, we need a dinstinction between Isaac Newton and Newtonian mechanics.

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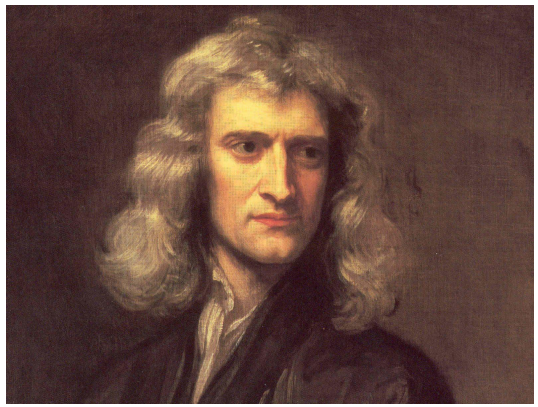

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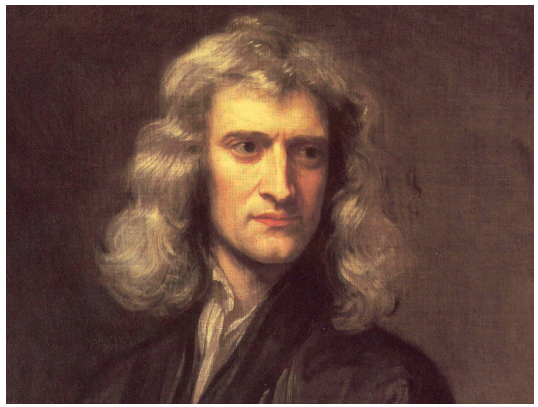

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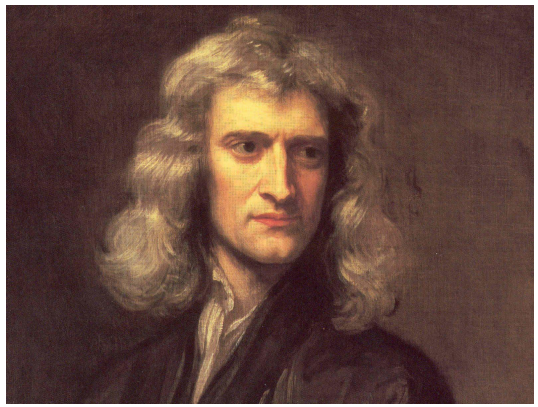

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$$\begin{array}{ccc} \text{Absolute space} & \neq & \text{Relative space} \\ \wr\wr & & \wr\wr \\ \text{"God's viewpoint"} & \neq & \text{"Human's viewpoint"} \end{array}$$

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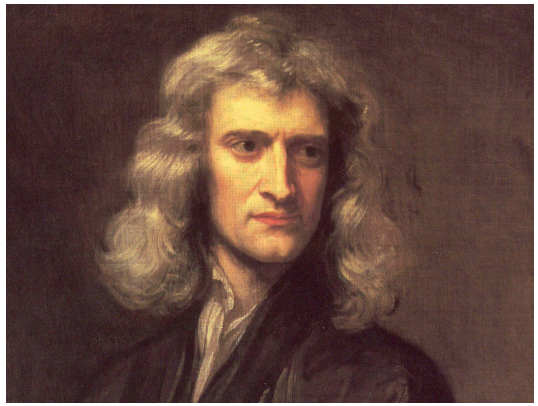

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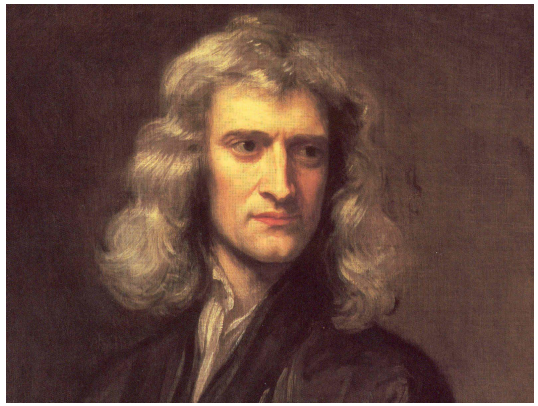

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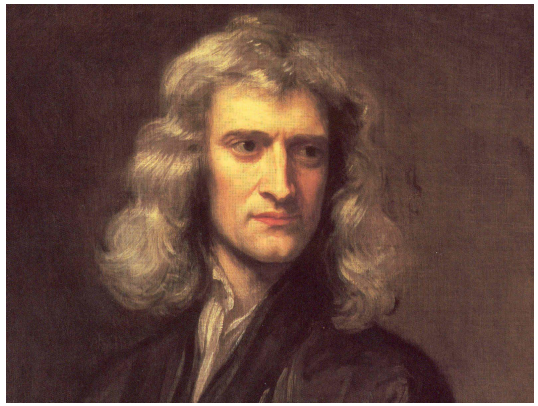

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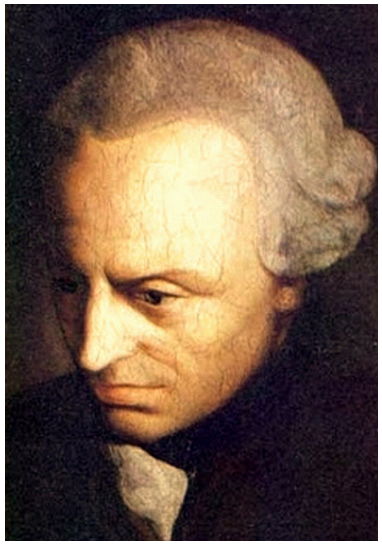
One cannot find [only] one "preferred reference frame for space".
But, the structure of Newtonian space(-time) is fixed and independent of any external cause.

$$\mathbf{N}^4 \approx \mathbb{R}_{\mathbf{t}} \times \mathbb{E}^3$$

Immanuel Kant (1724PC – 1804PC)



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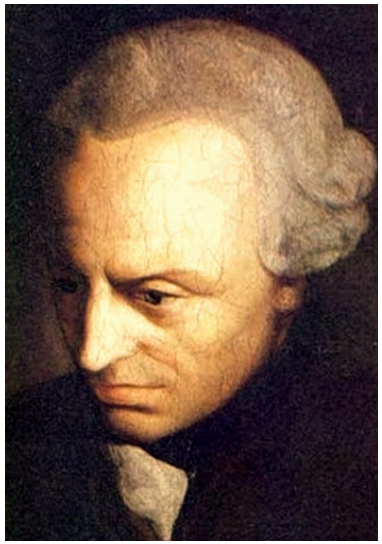

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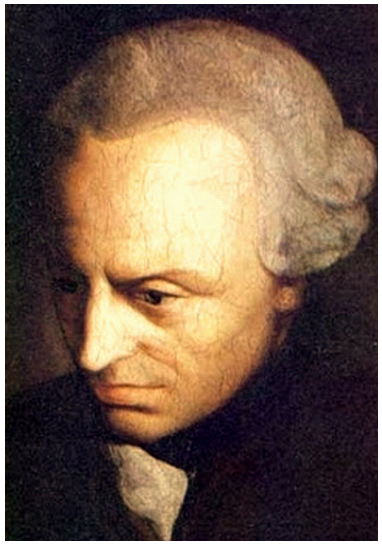

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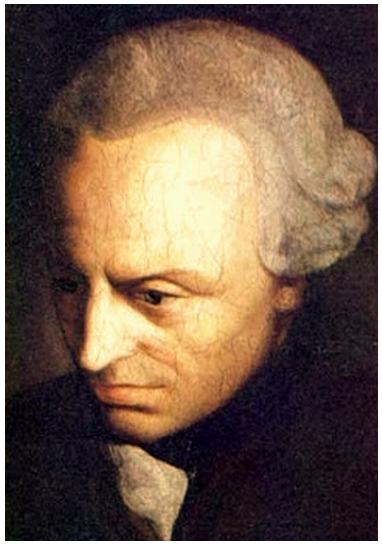

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Space is not real. It belongs to the subjective constitution of the mind.

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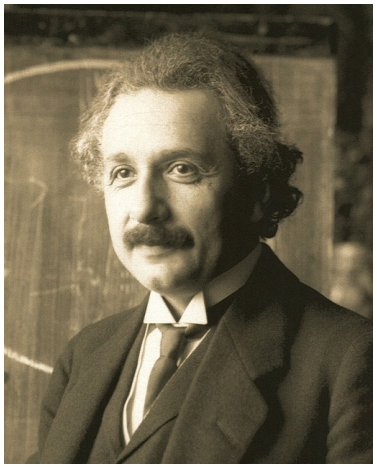
The notion of absolute space is unnecessary.

Albert Einstein (1879PC – 1955PC)



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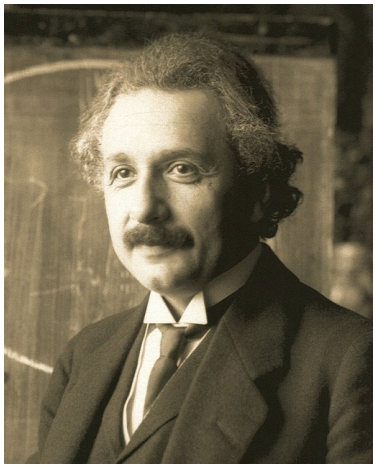

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Special Relativity (1905)

- → The speed of light in vacuum is absolute
- → Space and time have to merge into (Minkowski) spacetime : $(\mathcal{M}^4, \eta)$
- → Inertial frame are related via Lorentz Transformations Λ : $\Lambda^T \eta \Lambda = \eta$.

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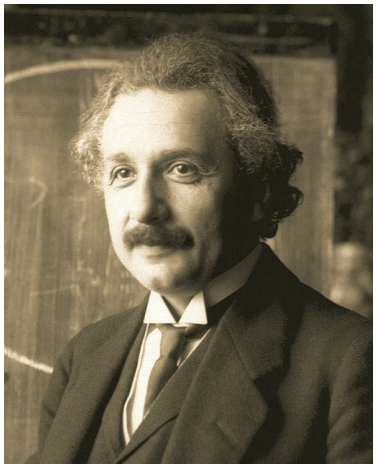

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There is no absolute space nor time.
Nevertheless, $(\mathcal{M}^4, \eta)$ remains independent of any external cause.

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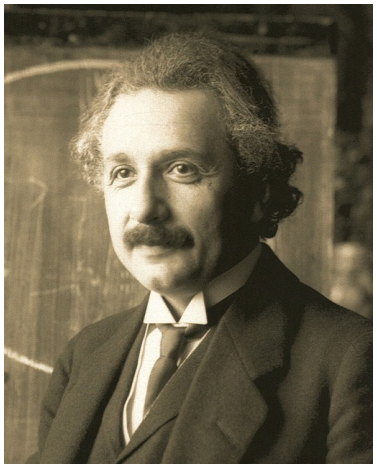

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- → Freely falling particles move along geodesics

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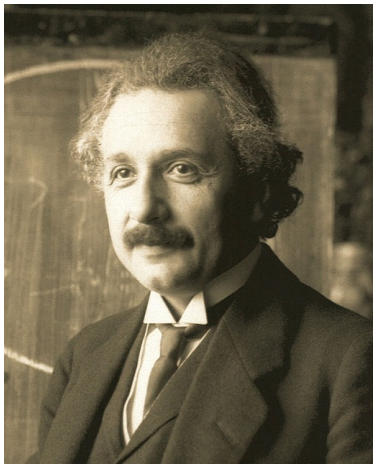

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For the first time, matter has an influence on the structure of spacetime.
$(\mathcal{M}^4, g)$ is not "independent on external causes".

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It doesn't make sense to think of space and time "outside" the universe.

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Thank you for your attention !