Laws and relativistic space-time

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Why fields?

Isaac Newton:

It is inconceivable that inanimate Matter should, without the Mediation of something else, which is not material, operate upon, and affect other matter without mutual Contact. [...] That Gravity should be innate, inherent and essential to Matter, so that one body may act upon another at a distance thro' a Vacuum, without the Mediation of any thing else, by and through which their Action and 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 a competent Faculty of thinking can ever fall into it.

Action-at-a-distance: forces/influences acting

instantaneously

unmediated

E. Schrödinger:

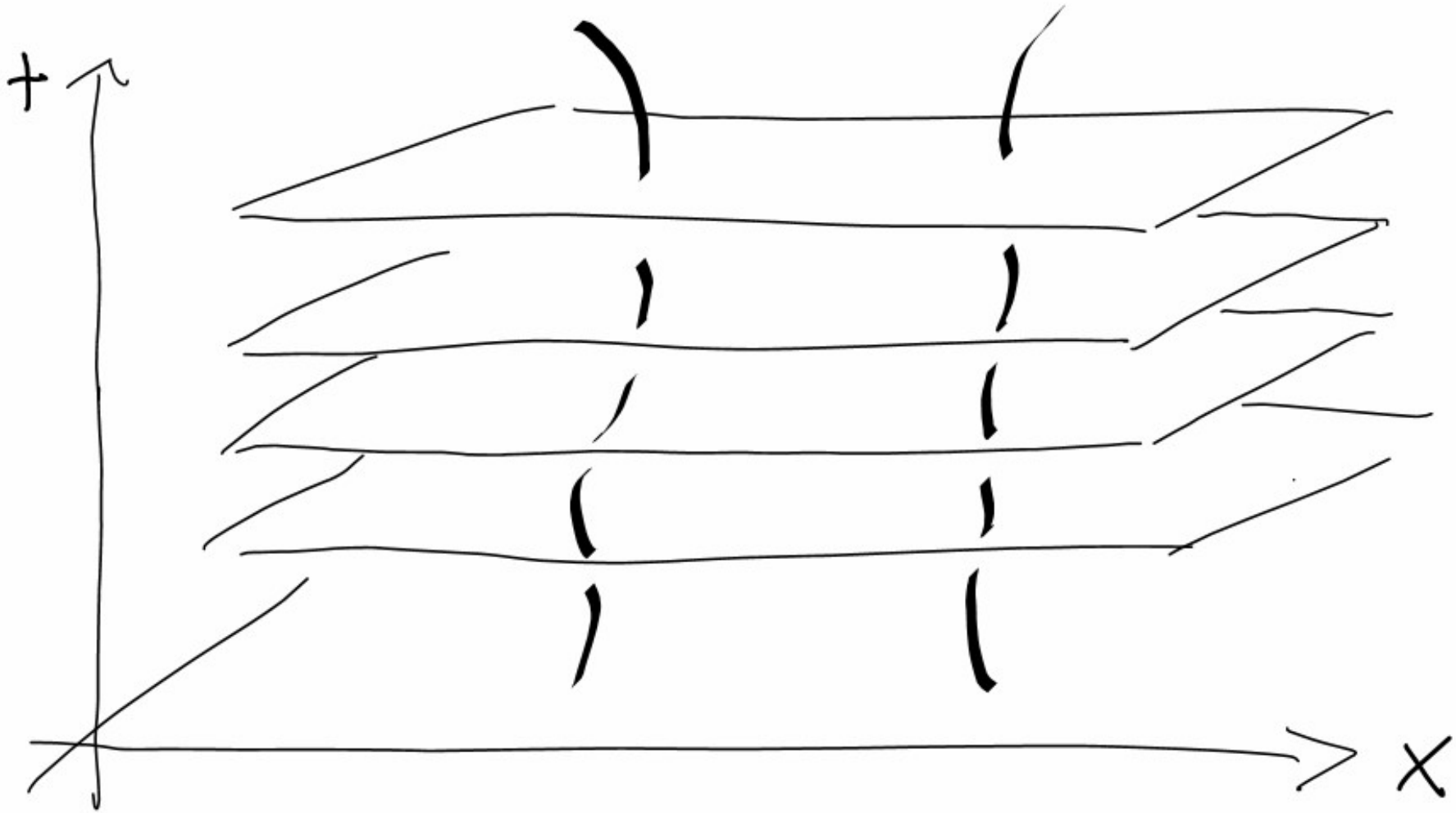
As Mach rightfully observes, some residues of animism are attached to the abstract idea, that we designate by the conceptual pair of cause and effect. [...] In physics, the force has established itself as the "cause of motion". This understanding is clearly derived from the act of will of muscle innervation and the feeling of pressure that accompanies this act whenever a limb of our body sets a solid body into motion or brakes its motion.

Schrödinger 2/3

We may insist, at least, that we have removed from the physical notion of force the attribute of intention that is so inseparably linked to its psychophysiological example; it remains dubious whether we succeeded, as long as we are setting the cause-effect-relation in its place, the causa efficiens for the causa finalis. It still causes the result, even though unconsciously, without intention. It is someone or something. For a nobody or nothing cannot cause at all.

Schrödinger 3/3

Thus Kirchhoff argued that the force in mechanics must be understood solely as the product of mass and acceleration. In this way, the Newtonian law of motion, claiming this equality, becomes neither tautological, nor trivial. To the contrary, freed from the slag, its true content just comes to light more clearly: the bodies determine each other's acceleration – not the velocities or anything else.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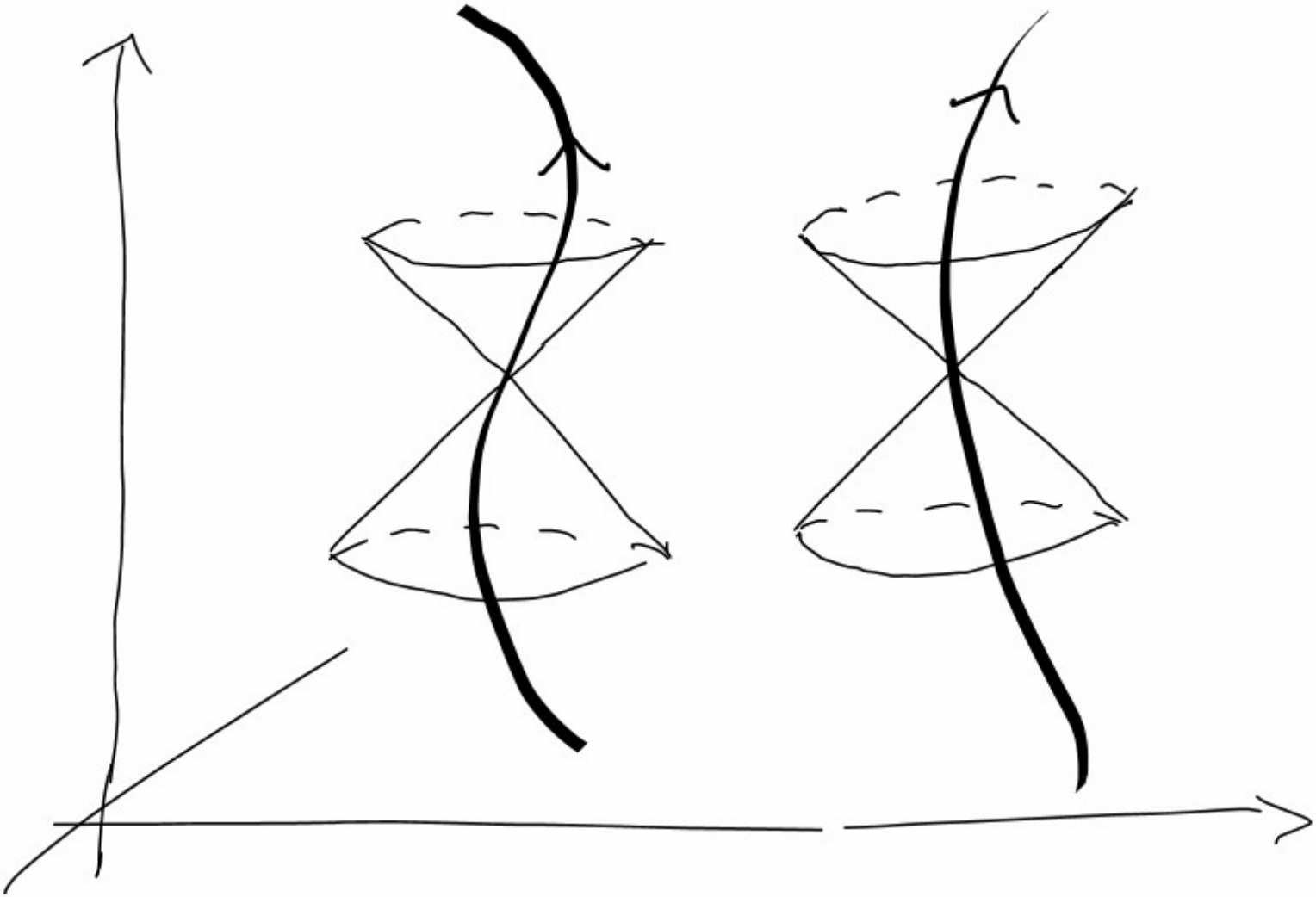
Electromagnetic fields do not live in Newtonian space-time.



Compare:

$$\Delta V = \delta(x) \qquad \text{(Galilei invariant)}$$

$$\Box A^{\mu} = \delta(z) \qquad \text{(Lorentz invariant)}$$

Initial Value Problem:

LAW + INITIAL CONDITIONS = HISTORY

The true role of fields:

Enlarge the physical state-space to turn relativistic interactions into an initial value problem

But: the field-concept doesn't work.

$$m_i \ddot{z}_i^{\mu} = e_i \, F_j^{\mu\nu}(z_i) \, \dot{z}_{i,\nu} \tag{1}$$

$$F^{\mu\nu} = \partial^{\mu} A^{\nu} - \partial^{\nu} A^{\mu} \tag{2}$$

$$\Box A^{\mu} = -4\pi j^{\mu} \tag{3}$$

$$j^{\mu}(x) = \sum_{i=1}^{N} j_i^{\mu} = \sum_{i=1}^{N} e_i \int \delta^4(x - z_i(\tau_i)) \dot{z}_i^{\mu}(\tau_i)\, \mathrm{d}\tau_i \qquad (4)$$

Solution: Liénard-Wiechert fields:

$$A^{\mu}_{i,\pm}(x) = e_i \frac{\dot{z}^{\mu}_i(\tau^{\pm}_i)}{\big(x^{\nu} - z^{\nu}_i(\tau^{\pm}_i)\big)\dot{z}_{i,\nu}(\tau^{\pm}_i)}, \tag{5}$$

where $\tau^{+}_i(x)$ and $\tau^{-}_i(x)$ are the solutions of

$$\big(x - z_i(\tau)\big)^2 = 0. \tag{6}$$

self-interaction catastrophe

UV-divergence

The dualism of fields and particles doesn't work.

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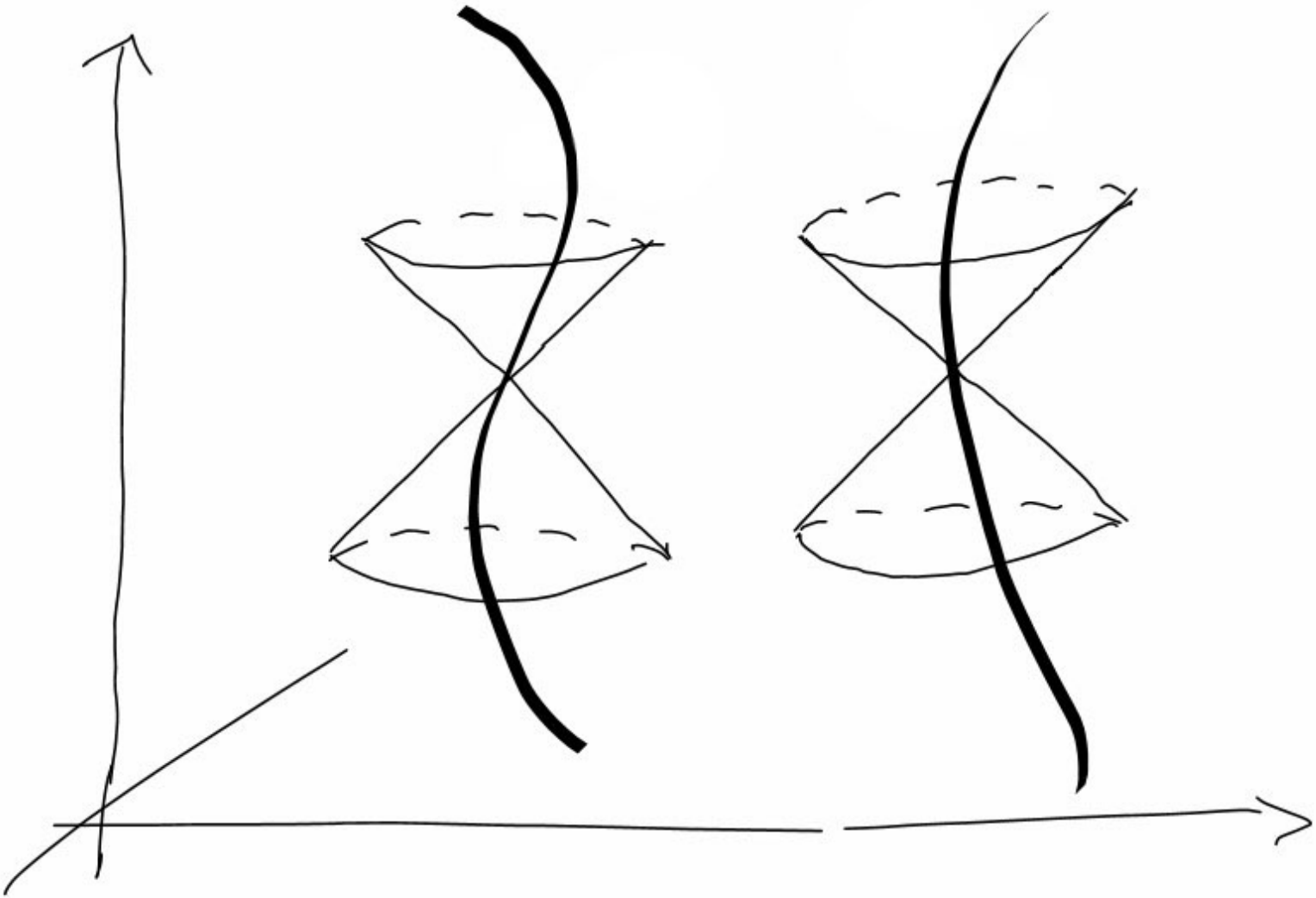
We have to take relativistic space-time (more) seriously.



Eternalism $\leftrightarrow$ Presentism

Perdurance $\leftrightarrow$ Endurance

What are physical *laws* in a world without *change*?