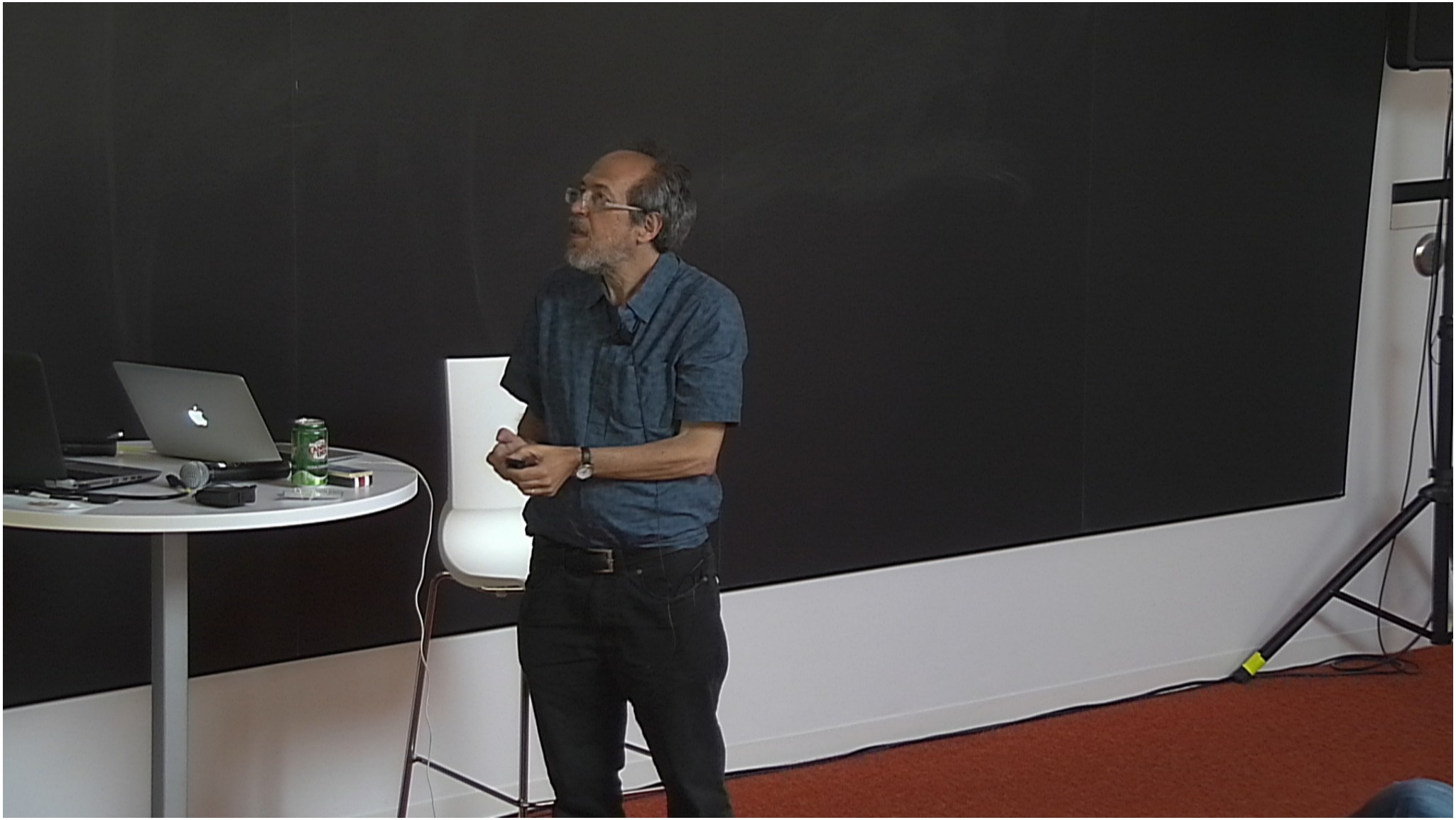
Title: Fundamental Time

Date: Jun 29, 2016 02:30 PM

URL: http://pirsa.org/16060116

Abstract:



The Singular (unique) Universe and the reality of time:

A brief sketch of a key argument

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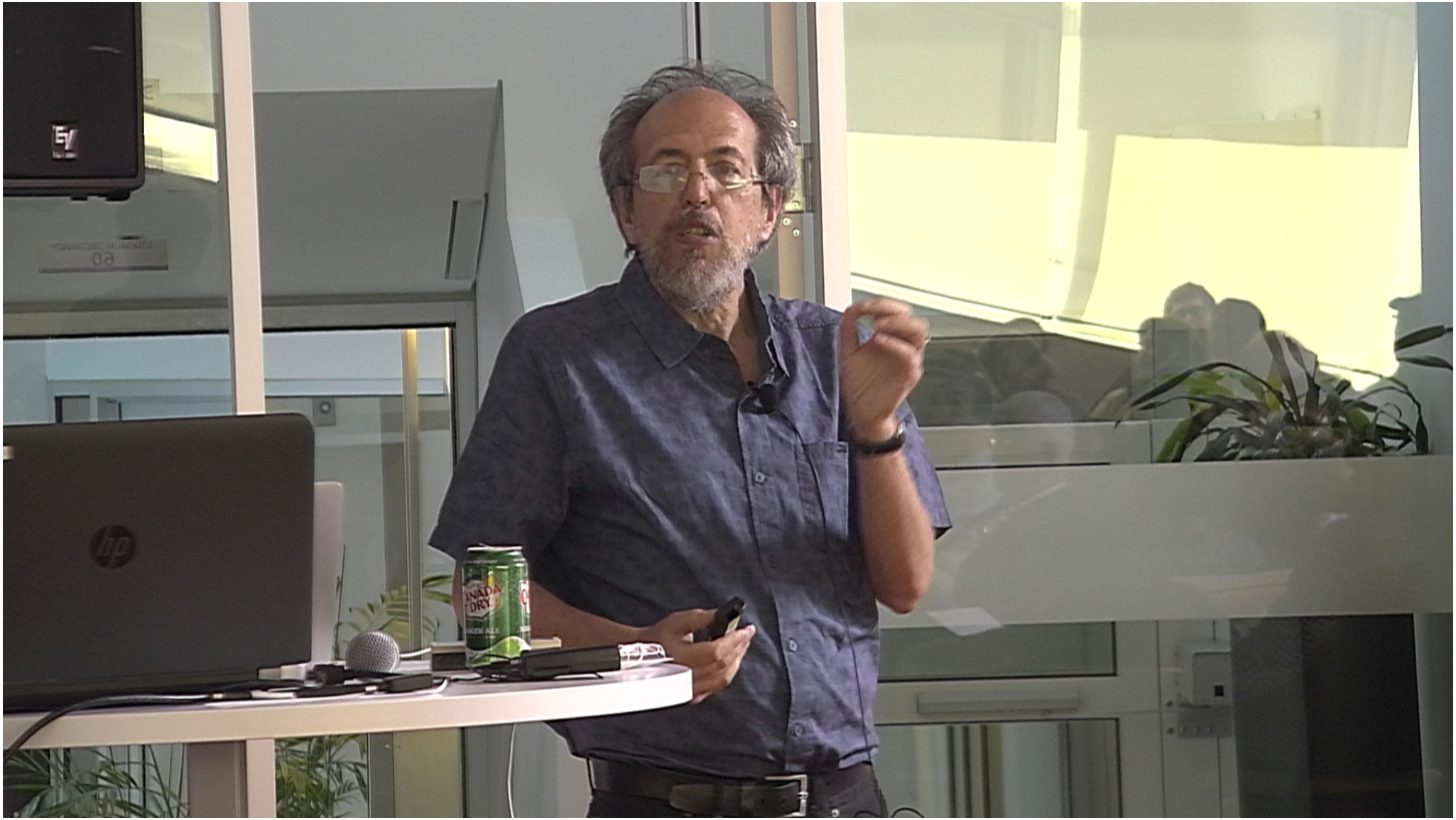
Perimeter Institute
June 2016
Work with Roberto Mangabeira Unger,
also Marina Cortes, Henrique Gomes, Andrew Liddle,

The full argument is in our book of the same title.


CANADA DRY

We seek a cosmological theory which must:

1. Apply to a single, causally closed system, which has no copies and is not a member of any ensemble (the universe as a whole is unique).

2. Allows no, and needs no, external clocks, reference frames, measuring systems or external observers. "There is nothing outside the universe."

3. Can explain how the laws of physics were selected.

4. Can explain how any initial conditions needed for those laws were selected, without need of a past hypothesis or a recourse to atypicality.

5. Reduces to the known (quantum) laws for subsystems. Hence, resolve the measurement problem.

All current theories are only functional (can be related to experiments) when considered as theories of subsystems of the universe.

1. Apply to a large set of possible cases, which can be distinguished by externally imposed preparations. These allow a clean separation of the roles of laws and initial conditions. You vary the initial conditions to test hypotheses as to the laws.

2. Thus are formulated in terms of fixed, timeless, state spaces on which fixed timeless evolution laws act. (The Newtonian paradigm.)

3. These states can be distinguished by the values of observables, which correspond to externally imposed preparations, transformations and measurements. (ie the bare Hilbert space is not enough.)

4. The laws and initial conditions are not explained because the paradigm allows the free specification of laws and initial conditions. This reflects the freedom of the experimentalist to choose the preparation.

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The (first) cosmological fallacy: *Apply to the universe as a whole a methodology which only can have a correspondence with observations when applied to subsystems of the universe. Example: The Newtonian paradigm.*

ie you can't just scale up Newtonian mechanics or QM to the universe, because its states and observables require external reference systems to make them operationally meaningful. Similarly as there is only a single case,and we have no choice of preparation, you can't make sense of the separation of laws and initial conditions.

Hence, the cosmological theory seek cannot be formulated in the Newtonian paradigm. We require a new methodology.

What can we deduce about it?

Much goes wrong when we try to put the whole universe in the Newtonian paradigm.

-The operational context for the infinite set of initial conditions breaks down.

-One cannot distinguish hypotheses about laws from hypotheses about initial conditions.

-The notion of a general law doesn't win anything applied to a unique case.

-There are big questions one cannot answer:

Why these laws?

Why these initial conditions?

The cosmological dilemma:

-All applications of the standard physics to subsystems of the universe are approximate-because interactions with the outside are neglected.

-But when you expand the subsystem to the universe as a whole you loose explanatory power, for the reasons just indicated.

HENCE: All exact theories are incomplete descriptions of the physics based on truncations

The consequences for time

In the Newtonian paradigm, time is inessential, or weak.

1. Any property P(x(t)) at a time t can be mapped to another property P' (x(0)) at the initial time, t=0.

2. As there is a complete mathematical model of evolution, causal evolution is equivalent to (timeless) logical implication.

3. The state space is timeless so there is no possibility for novelty, by which is meant properties or states not entailed by the past

In a cosmological theory, time may be strong, in the senses that:

- Time, in the sense of relational change, and causation, may be prior to law.
- The state space may change in time, and in ways not entailed by the past.
- The laws may change, also in ways not entailed by the past.
- There can be no perfect mathematical mirror of nature, as that would be a copy of the universe, and that contradicts our postulate that the universe is unique. Hence the effects of causal evolution are not identical to any logical implications.
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Not necessarily, if the meta-law is not in the Newtonian paradigm.

EXAMPLES of non-Newtonian dynamics:

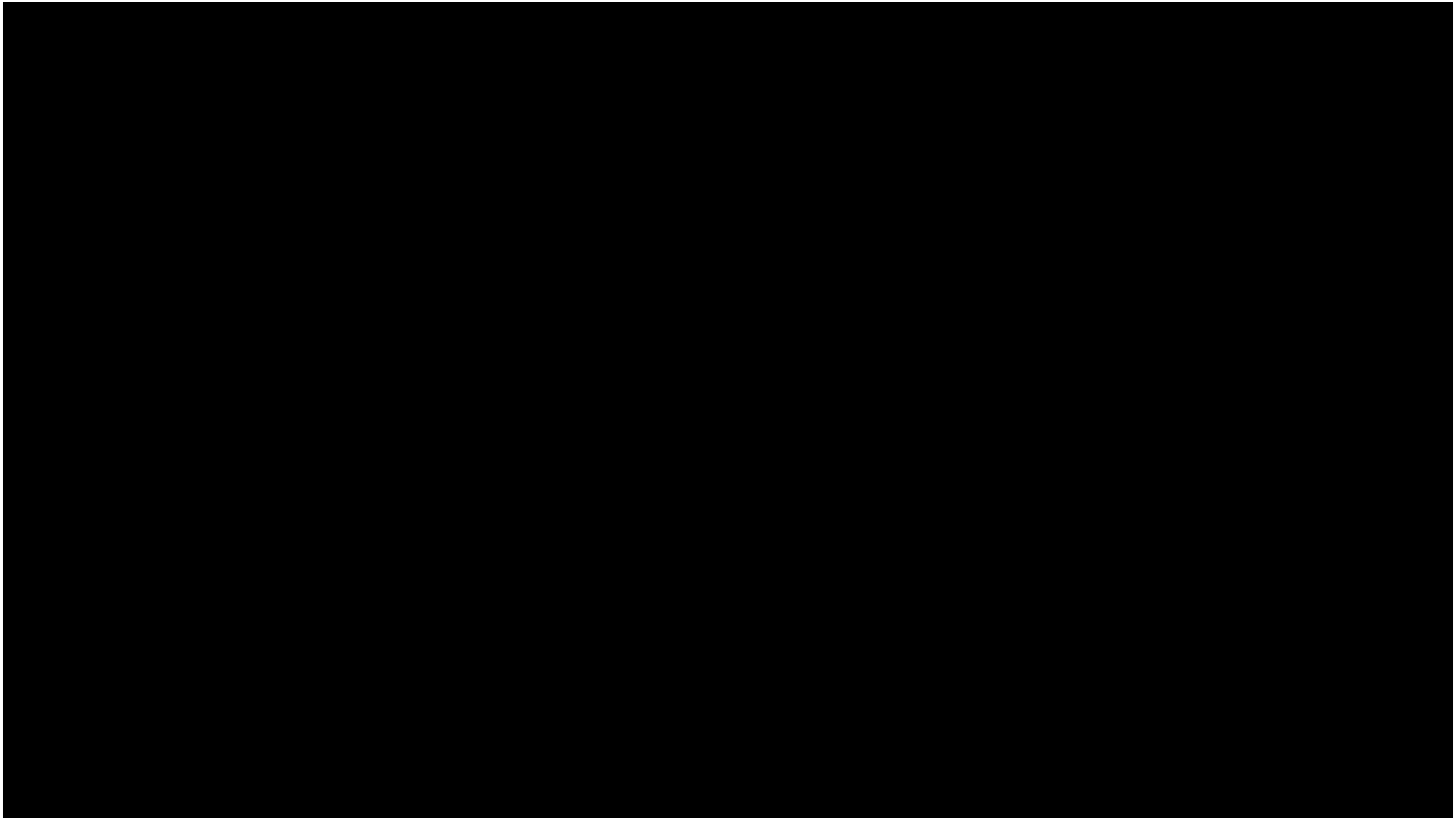
Cosmological natural selection.

Principle of precedence.

Energetic causal sets (Cortes)

Anti-deterministic evolution.

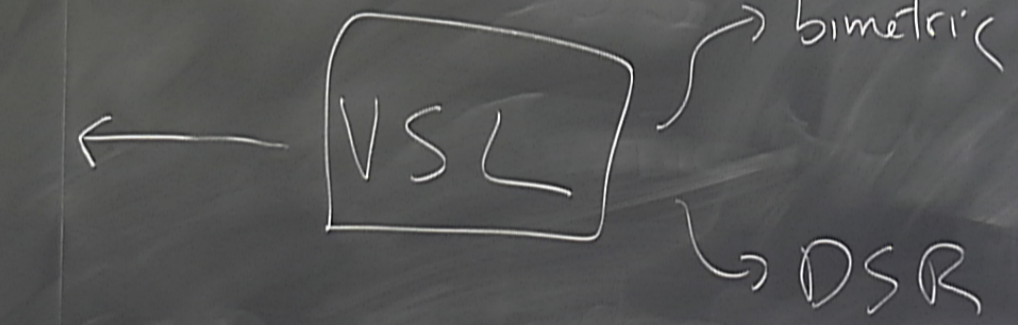
Hence, there exist non-Newtonian theories that address the needs for a cosmological theory. The study of such theories and their empirical consequences is a live research program.

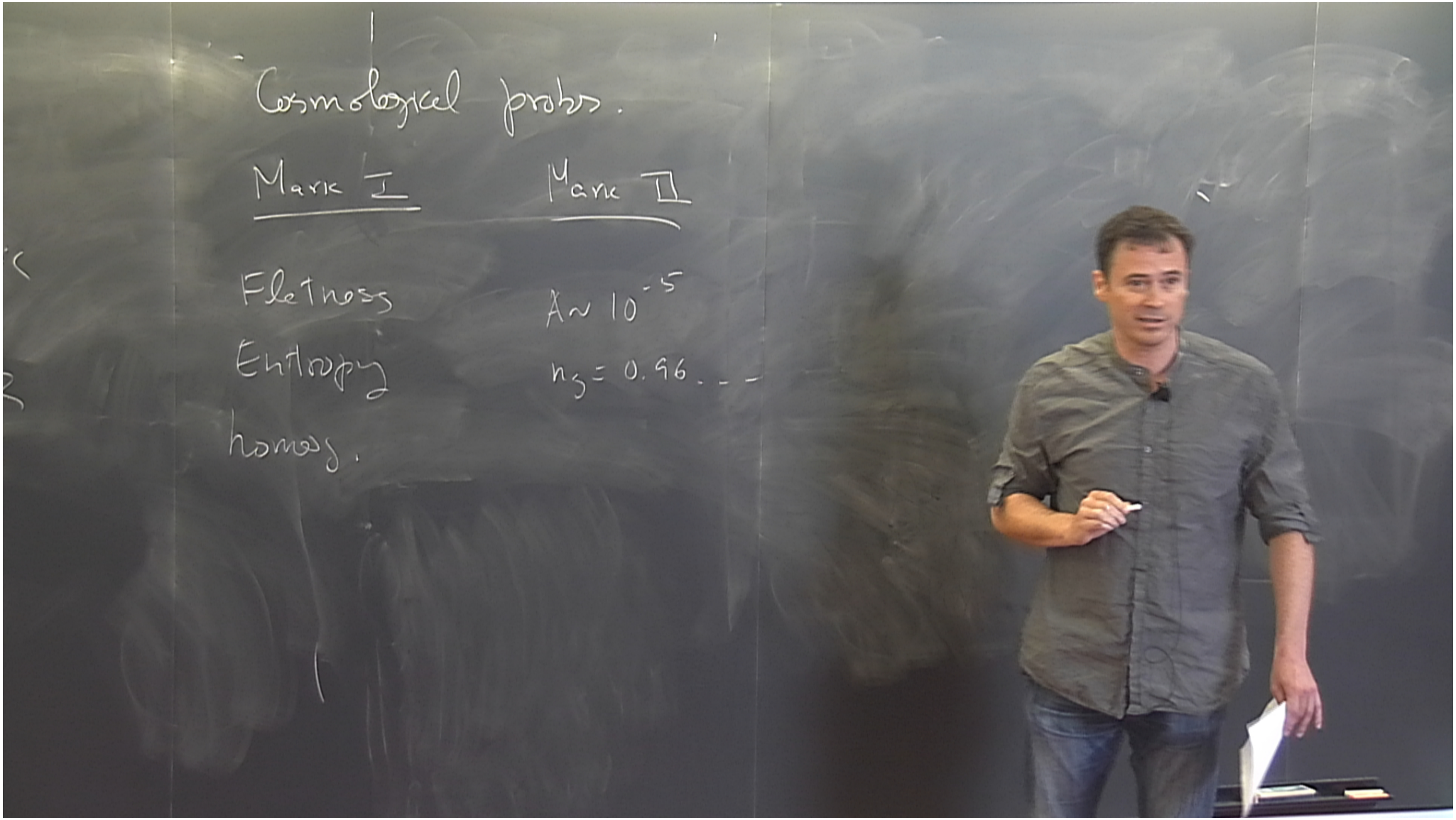


Hard breaking

- local Lorentz
- Diff. inv.
- Time translation

ihv



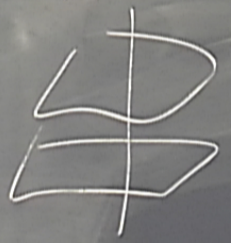

Cosmological probes.
Mark I
Mark II
Flatness
Entropy
homog.
$A \sim 10^{-5}$
$n_s = 0.96...$

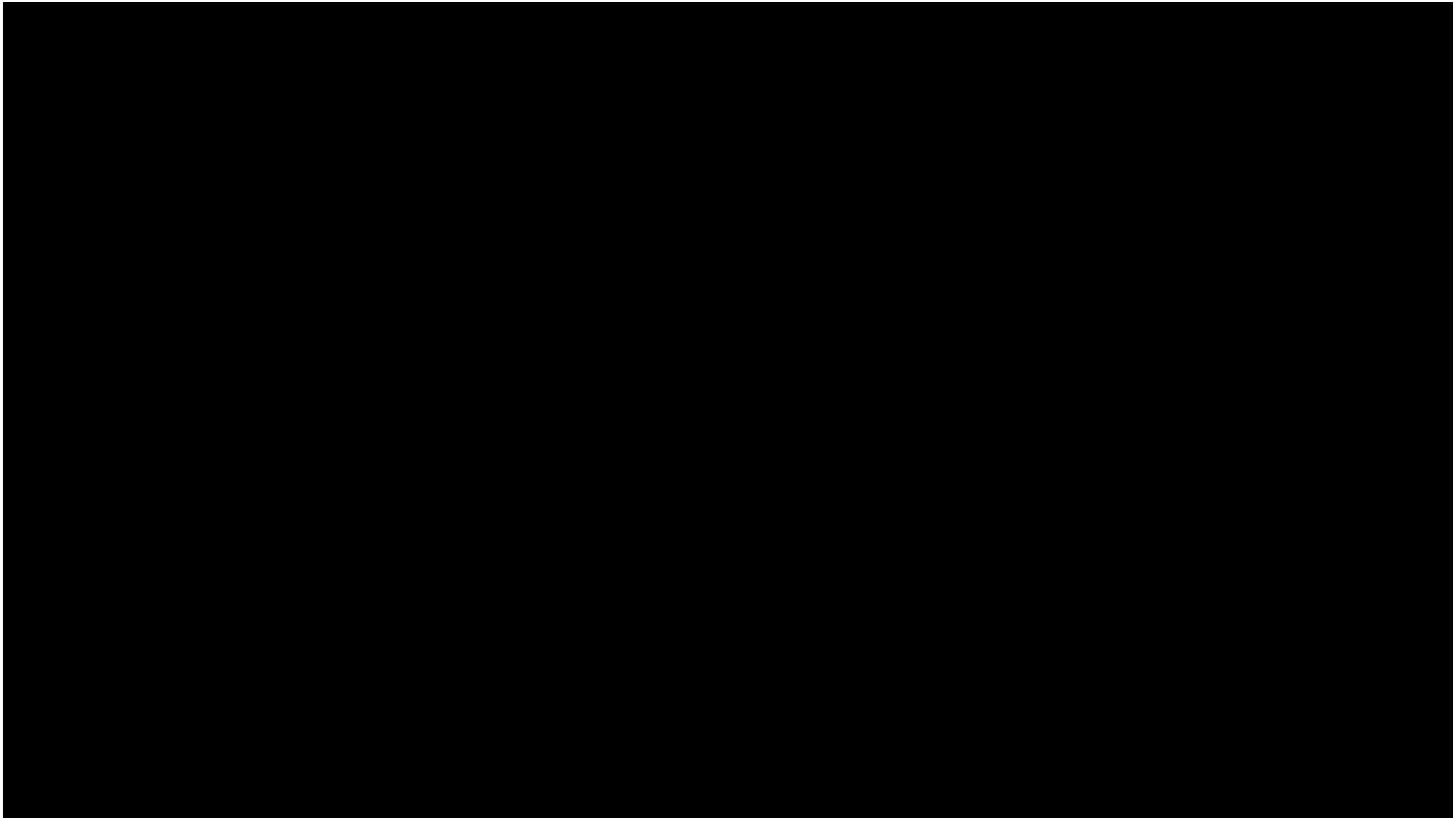
(1) There is a preferred frame - cosmic frame

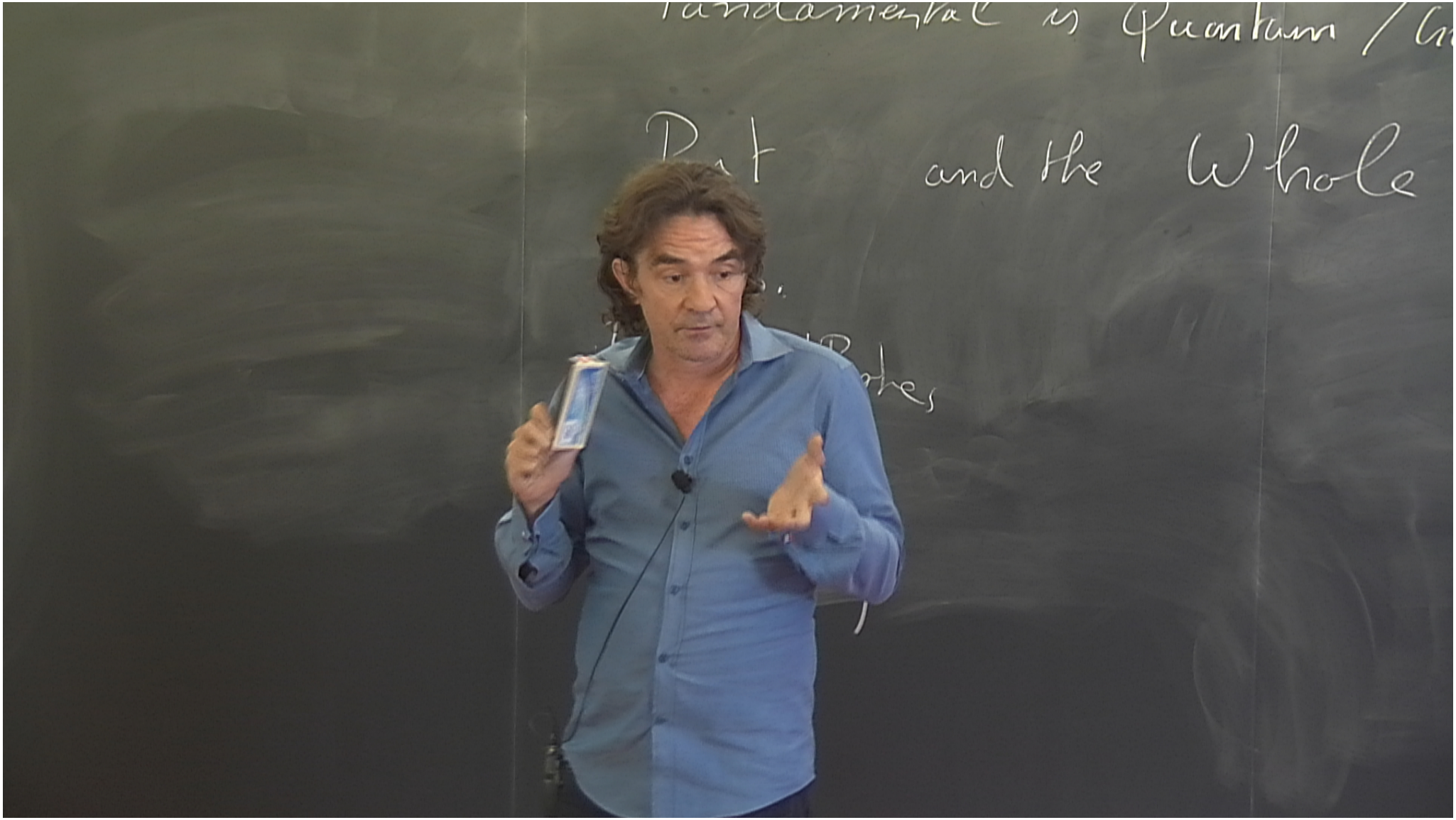
(2) Perverse that it does not partake in the laws.

(3) Explicit time variability

4 = 3 + 1






and the Whole

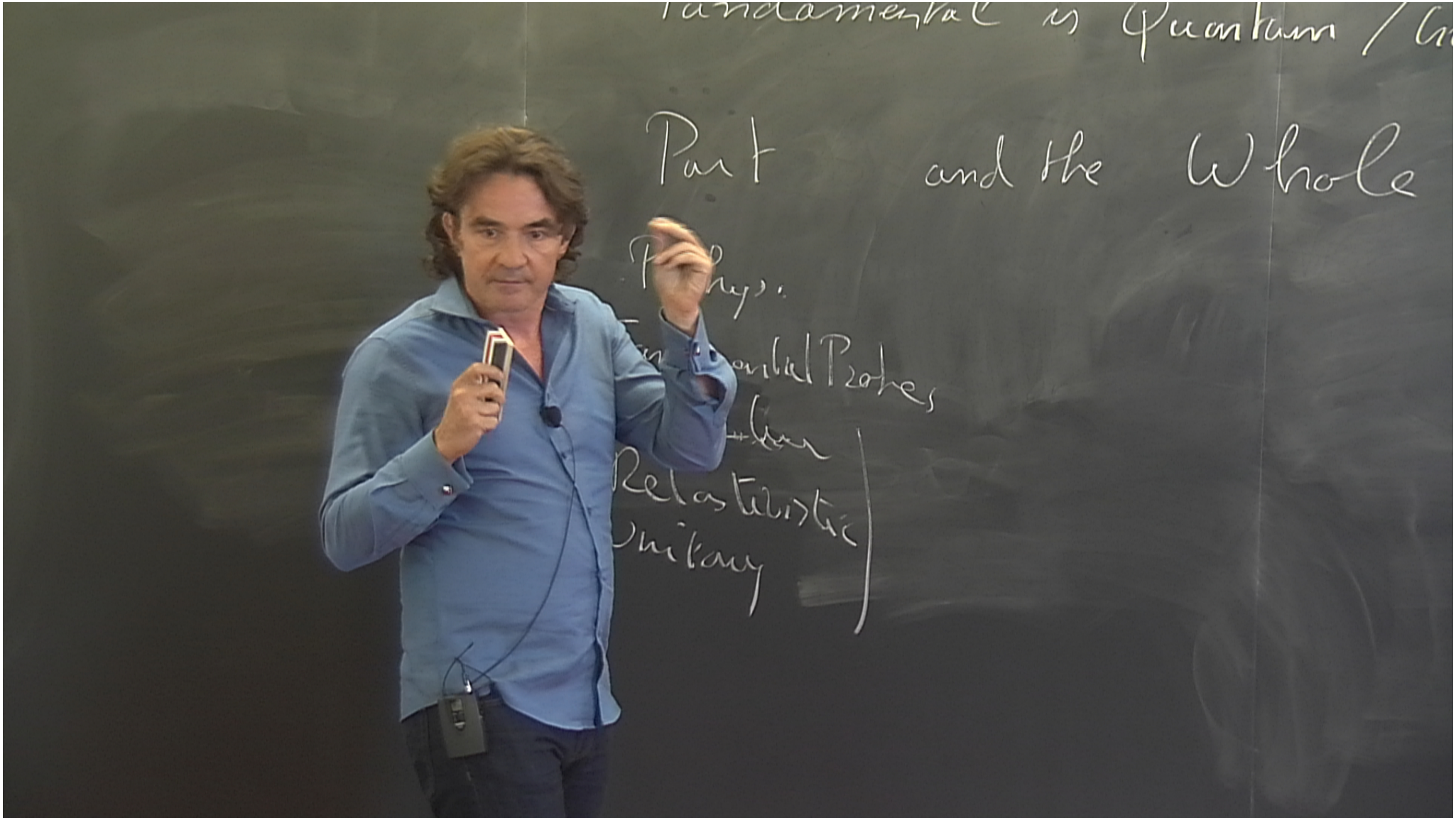
Fundamental is Quantum / Gravitational

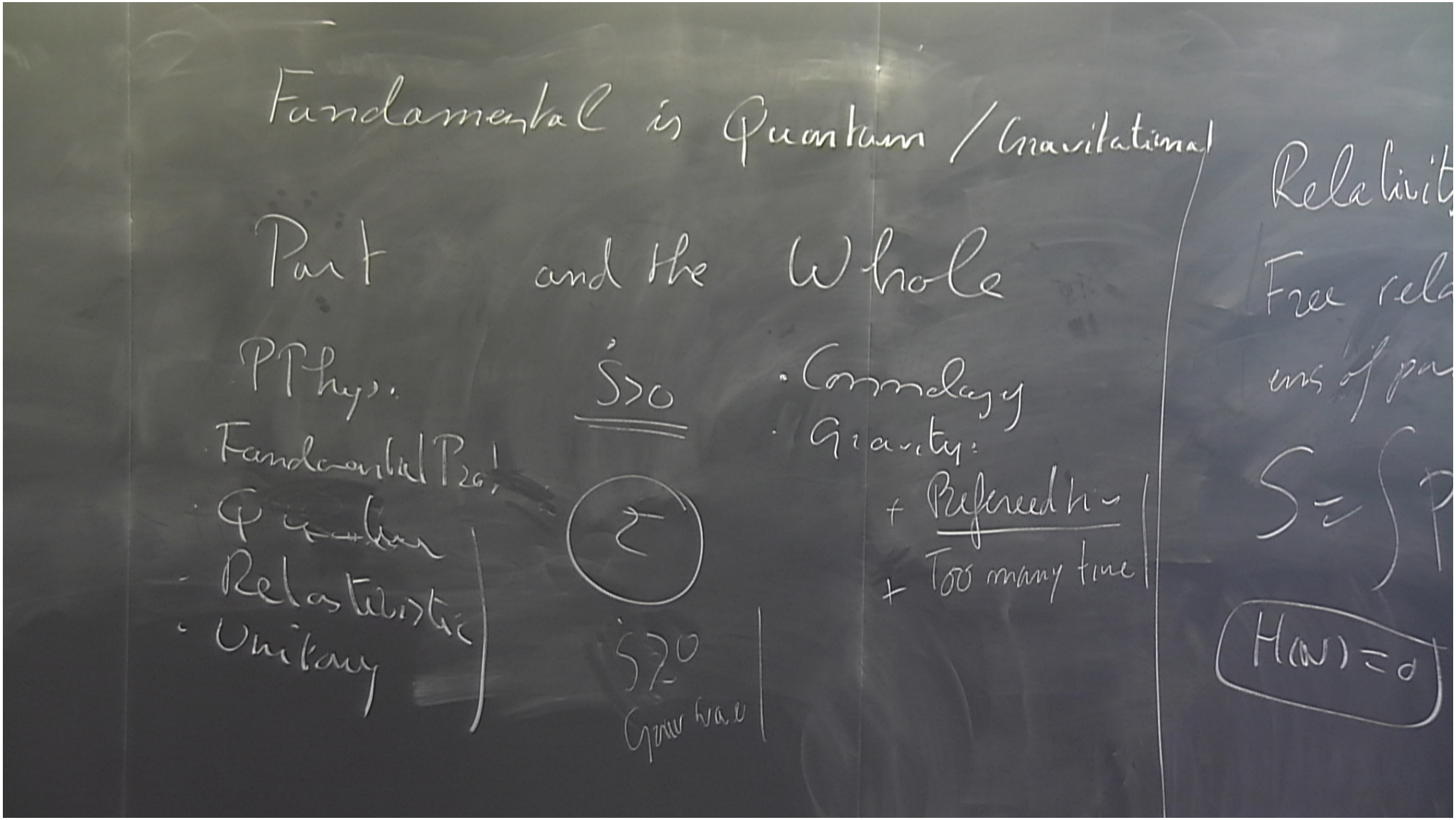
Part and the Whole

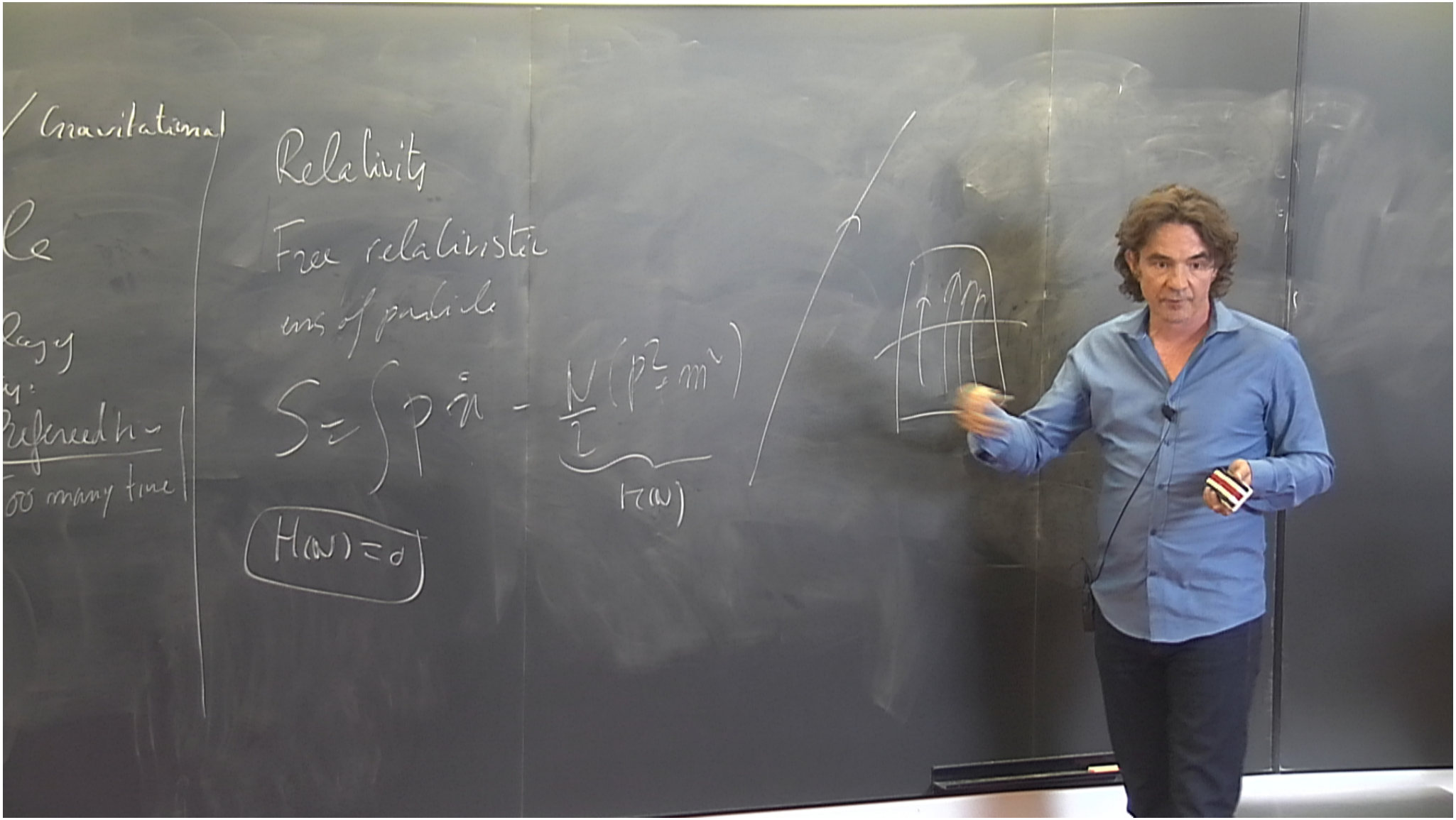
PThys.

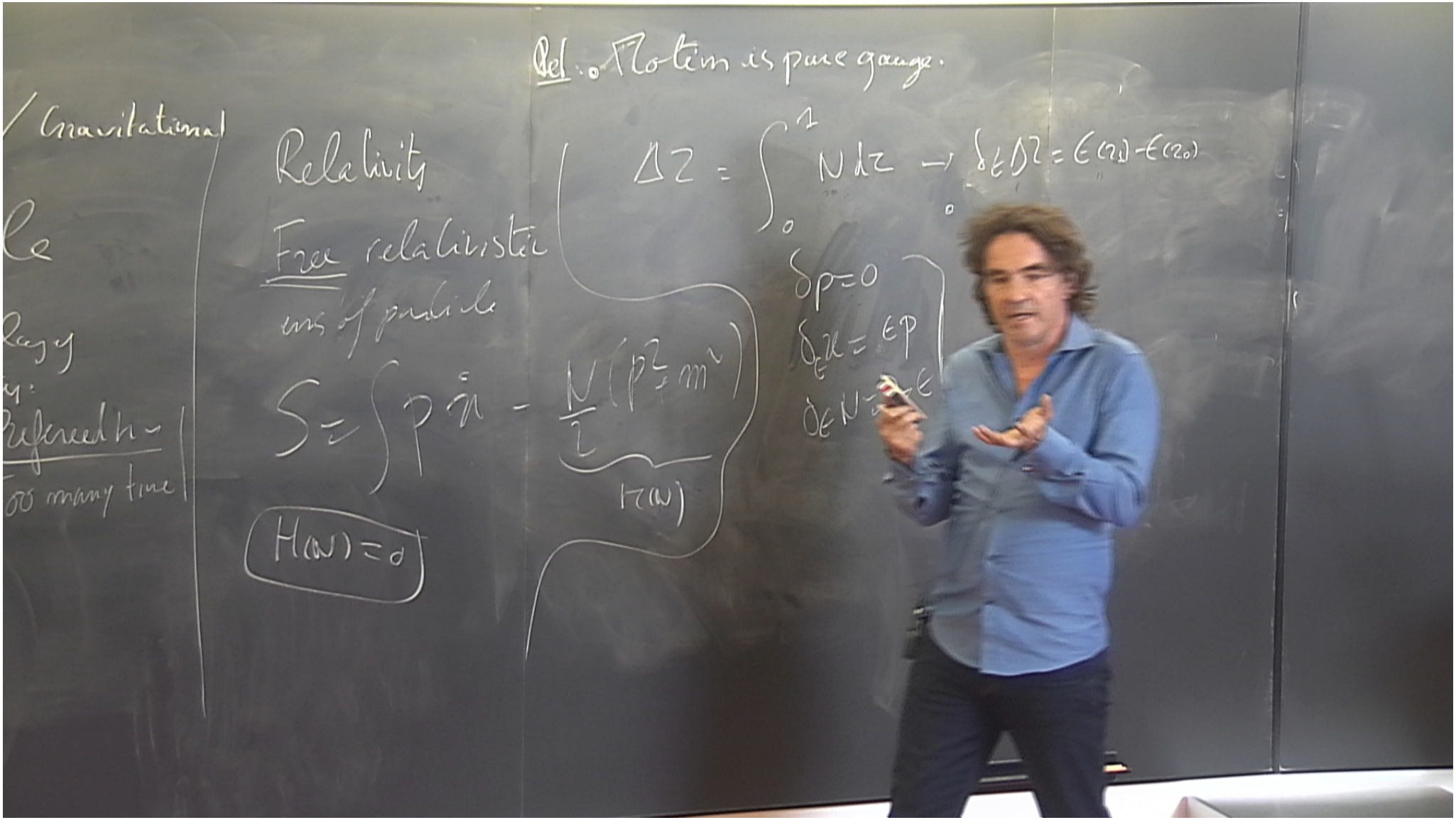
Fundamental Probes

- Quantum
- Relativistic
- Unitary


Part and the Whole
Relativistic
Unitary


Fundamental is Quantum / Gravitational
Part and the Whole
PThys:
Fundamental Pzs:
Quantum
Relativistic
Unitary
S>0
Σ
S≥0
Gauge
Cosmology
Gravity:
+ Renormalizn
+ Too many time
Relativity
Free rela
ons of pa
S=∫P
H(N)=0


Gravitational
Relativity
Free relativistic
$S = \int p\dot{x} - \frac{N}{2}(p^2 - m^2)$
$H(N)$
$H(N) = 0$


Rel. : Motion is pure gauge.
Gravitational
Relativity
Free relativistic
ms of particle
$\Delta z = \int_0^1 N dz \rightarrow \delta_\epsilon \Delta z = \epsilon(z_1) - \epsilon(z_0)$
$\delta p = 0$
$\delta_\epsilon x = \epsilon p$
$S = \int p \dot{x} - \frac{N}{2}(p^2 + m^2)$
$H(N)$
$H(N) = 0$

Def. Motion is pure gauge.

Relativity

Free relativistic

ons of particle

$$\Delta z = \int_0^1 N \, dz \rightarrow \delta_\epsilon \Delta z = \epsilon(z_1) - \epsilon(z_0)$$

- Change = interaction

$$S = \int p \dot{x} - \frac{N}{2}(p^2 - m^2)$$

$$\delta p = 0$$

$$\delta_\epsilon x = \epsilon p$$

$$\partial_\epsilon N = \partial_z \epsilon$$

$$H(N) = 0$$

$$S_P = \sum_e S_e + \sum_\sigma S_\sigma$$

$$S_\sigma = \left(\sum_{e \supset v} p_{e\sigma} \right) (x_{e\sigma} - z_v)$$

X