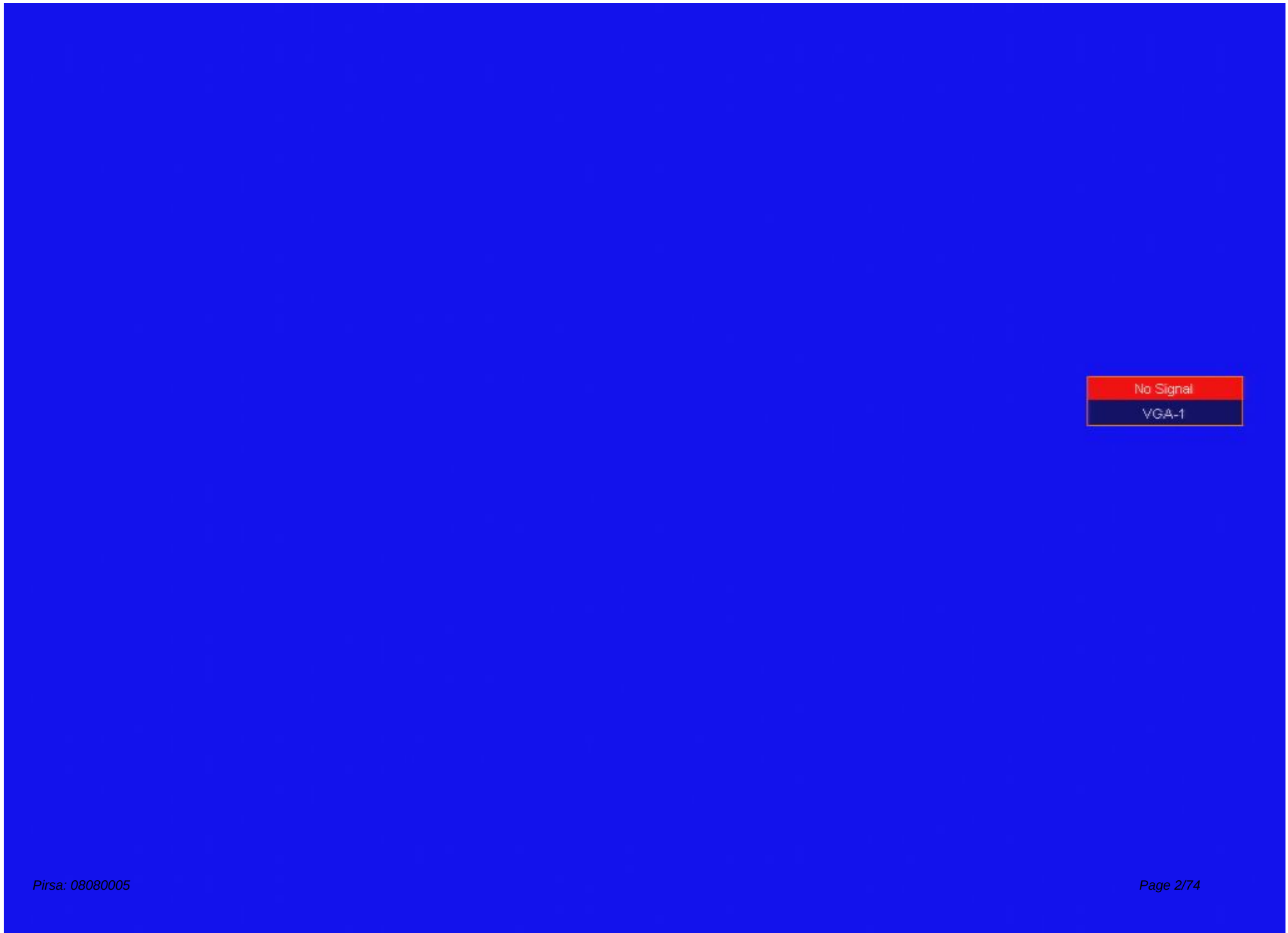
Title: Quantum Gravity: The quest to quantise Einstein's theory of General Relativity

Date: Aug 01, 2008 09:00 AM

URL: http://pirsa.org/08080005

Abstract: In the first part of the talk, a brief introduction to general relativity and quantum theory is given. Their independent successes are discussed, as well as the desire and difficulty in merging them, to obtain a unique language to describe the universe. Then I focus on Loop quantum gravity, a particular approach towards this objective, in which a discrete microscopic structure of spacetime is envisaged.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Quantum Gravity

The quest to quantise Einstein's theory of General Relativity

Simone Speziale

Perimeter Institute, 1-08-2008

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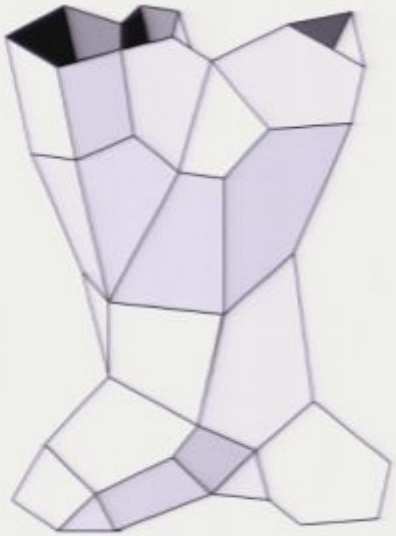

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Perimeter Institute, 1-08-2008

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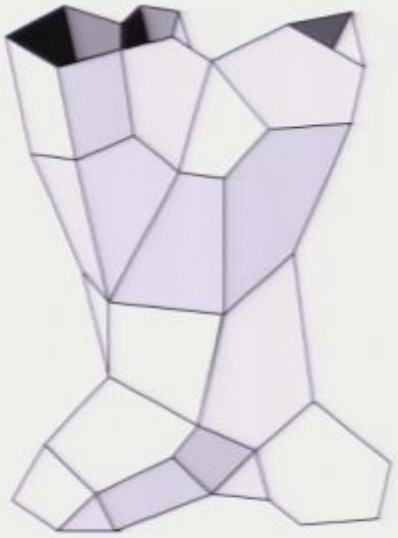

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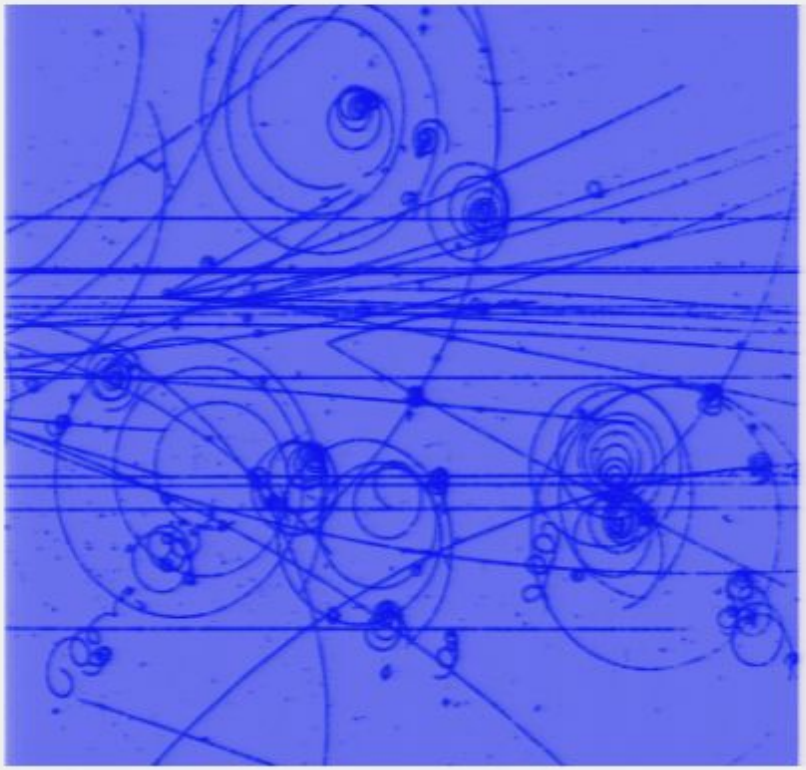
Perimeter Institute, 1-08-2008

Physics of the 20th century: the incomplete revolution

General Relativity



Quantum Theory

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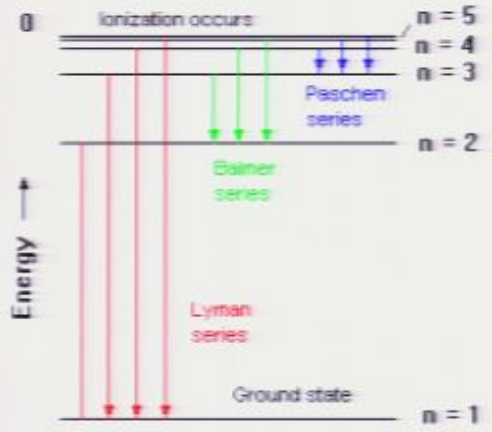

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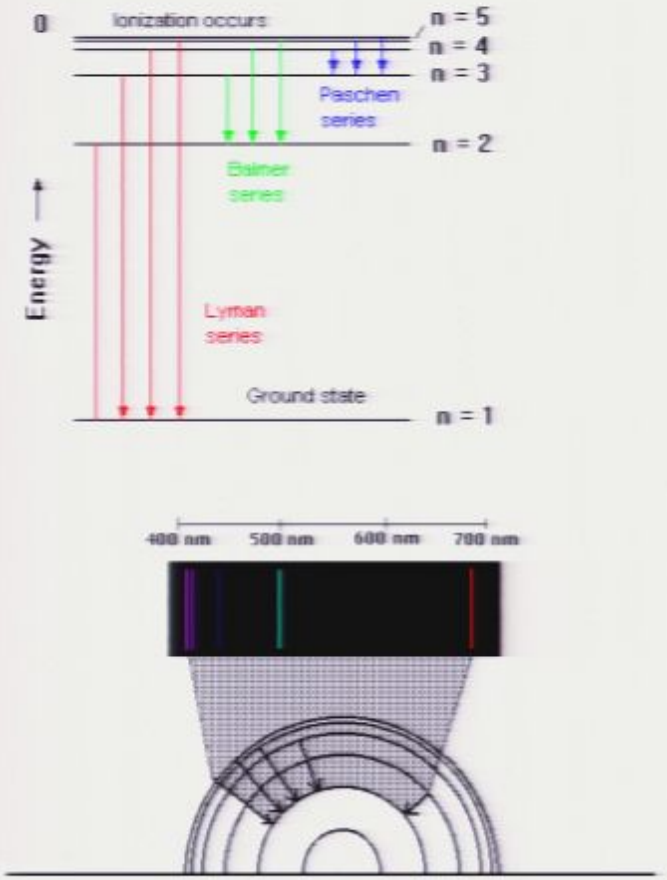


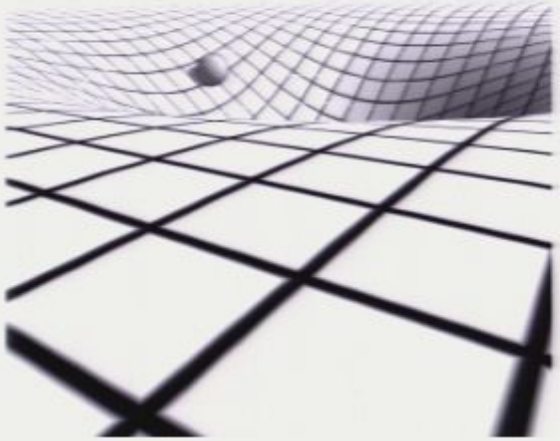
General relativity

Quantum theory

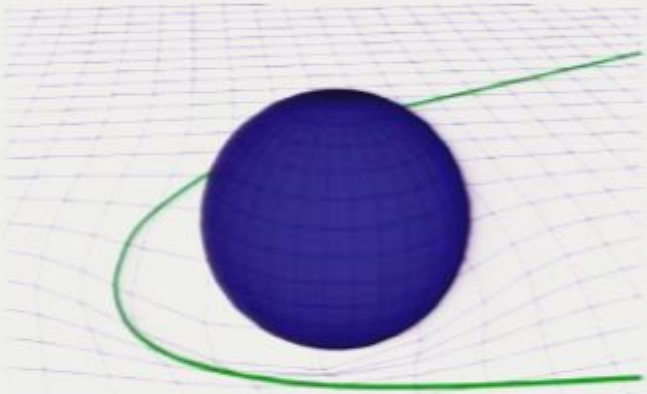
General Relativity

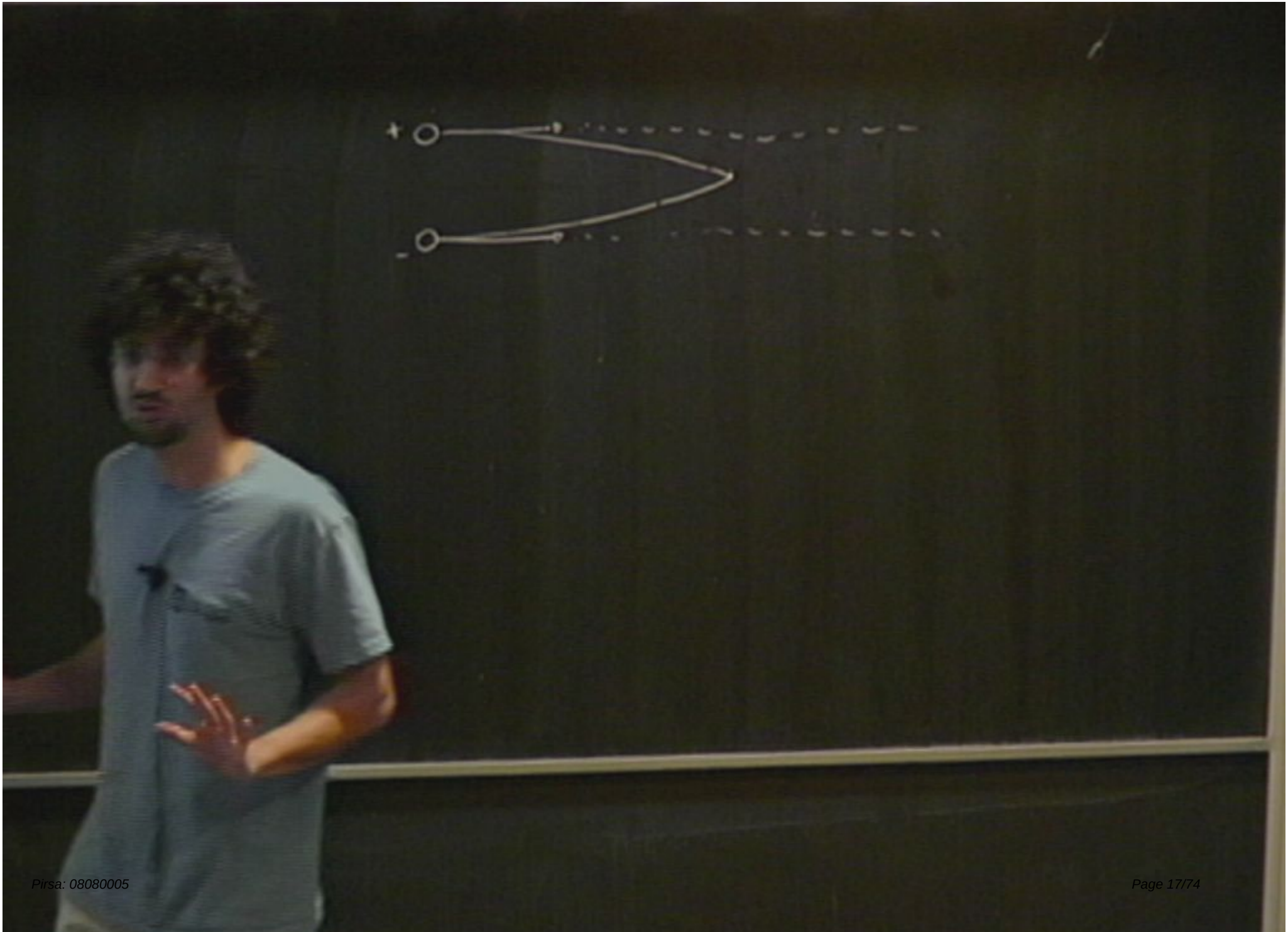
Equivalence principle: The laws of nature are the same for all observers, inertial or not

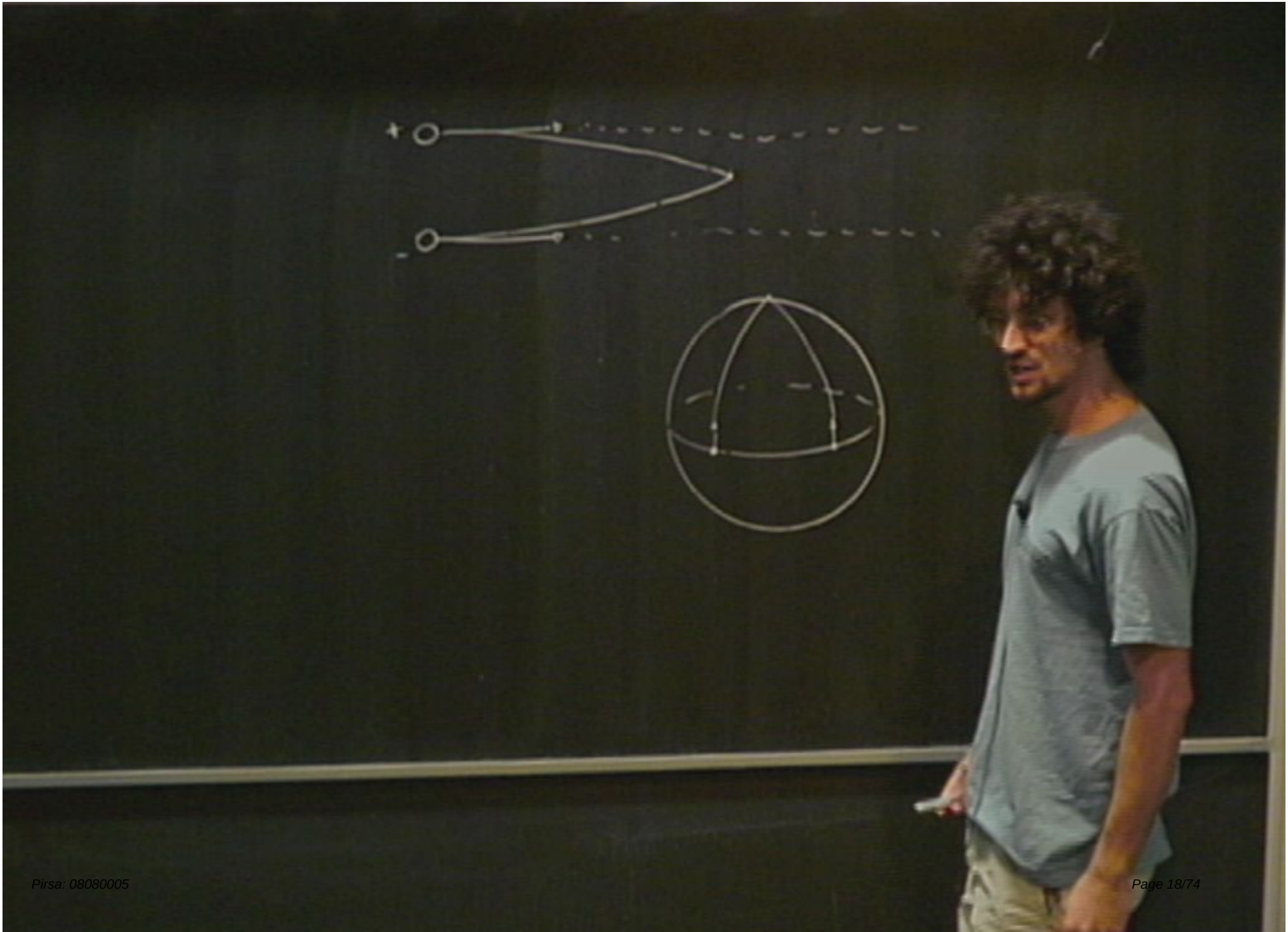
The force of gravity is the manifestation of the curvature of spacetime



Matter moves along geodesics







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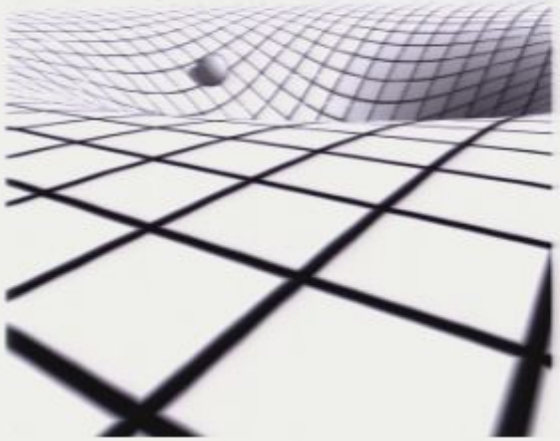

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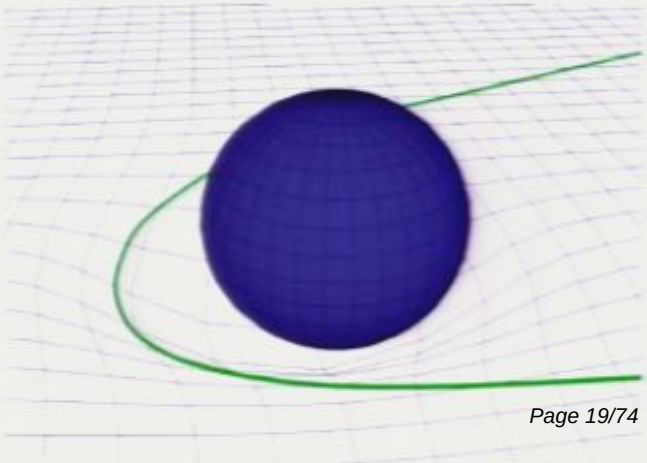
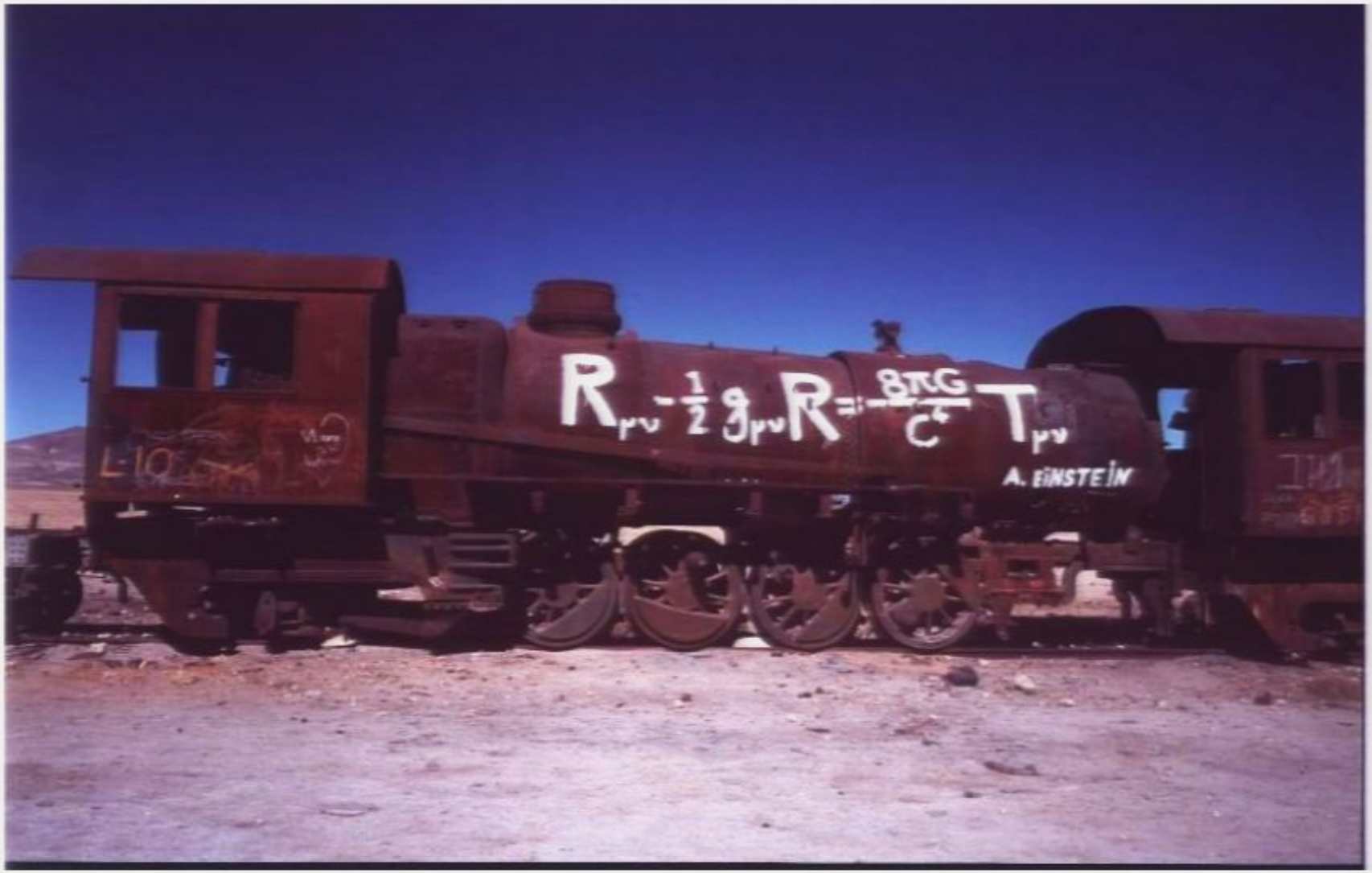


Einstein's equations



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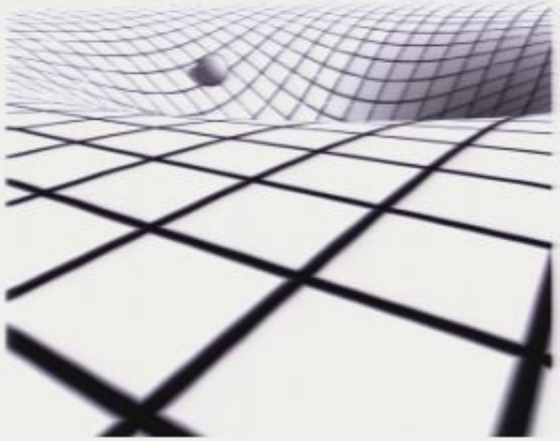

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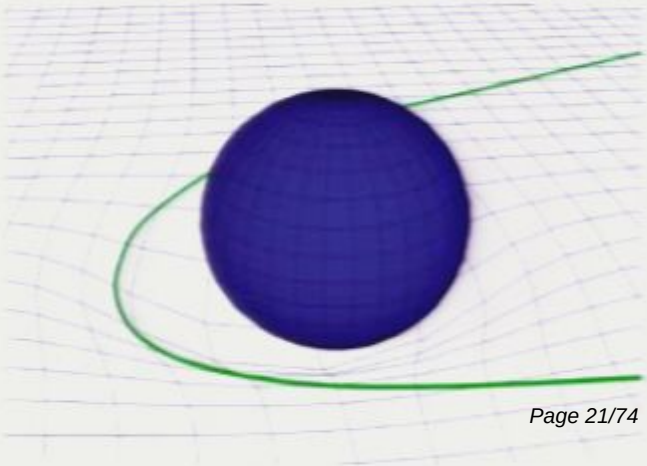

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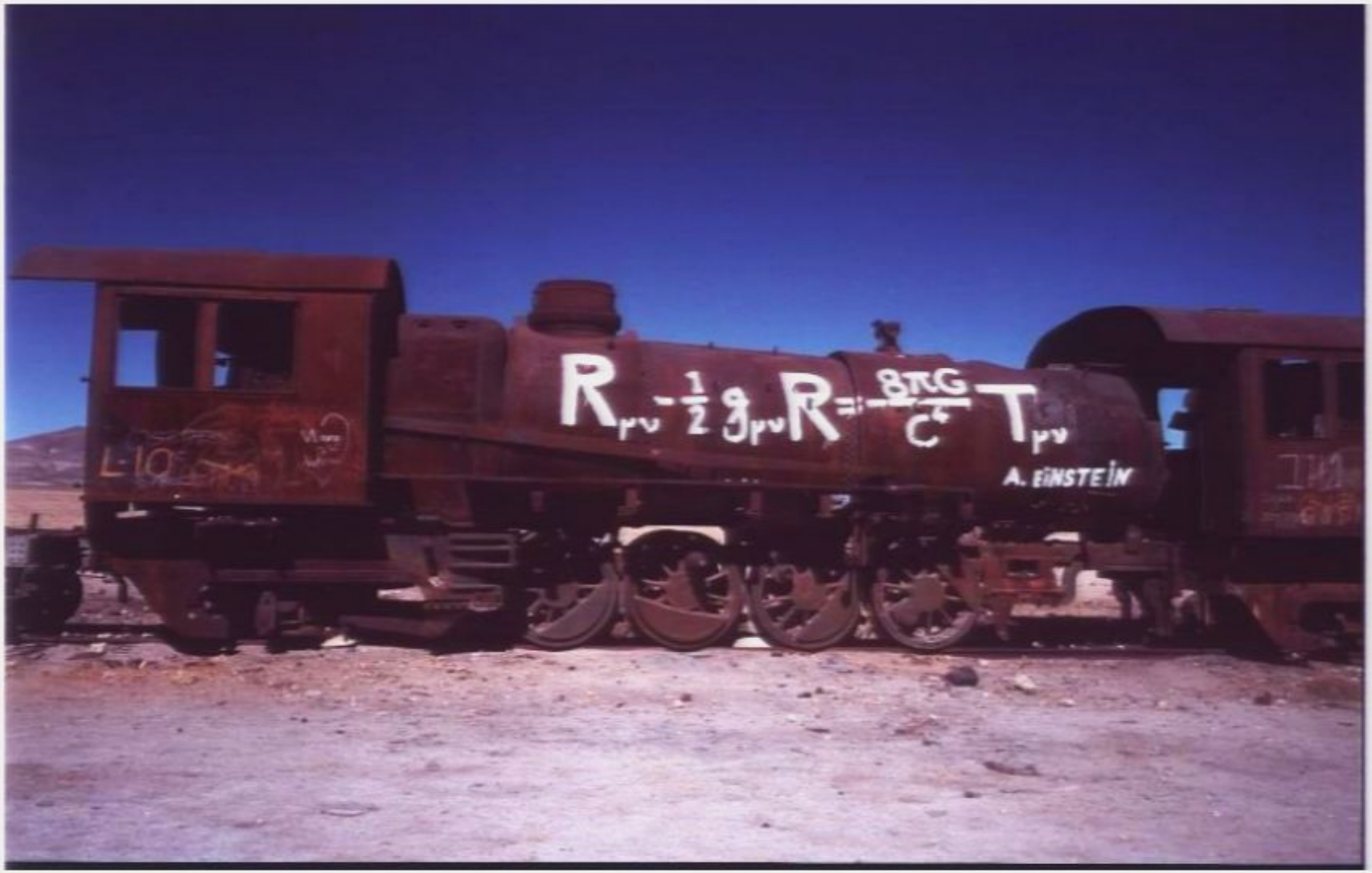

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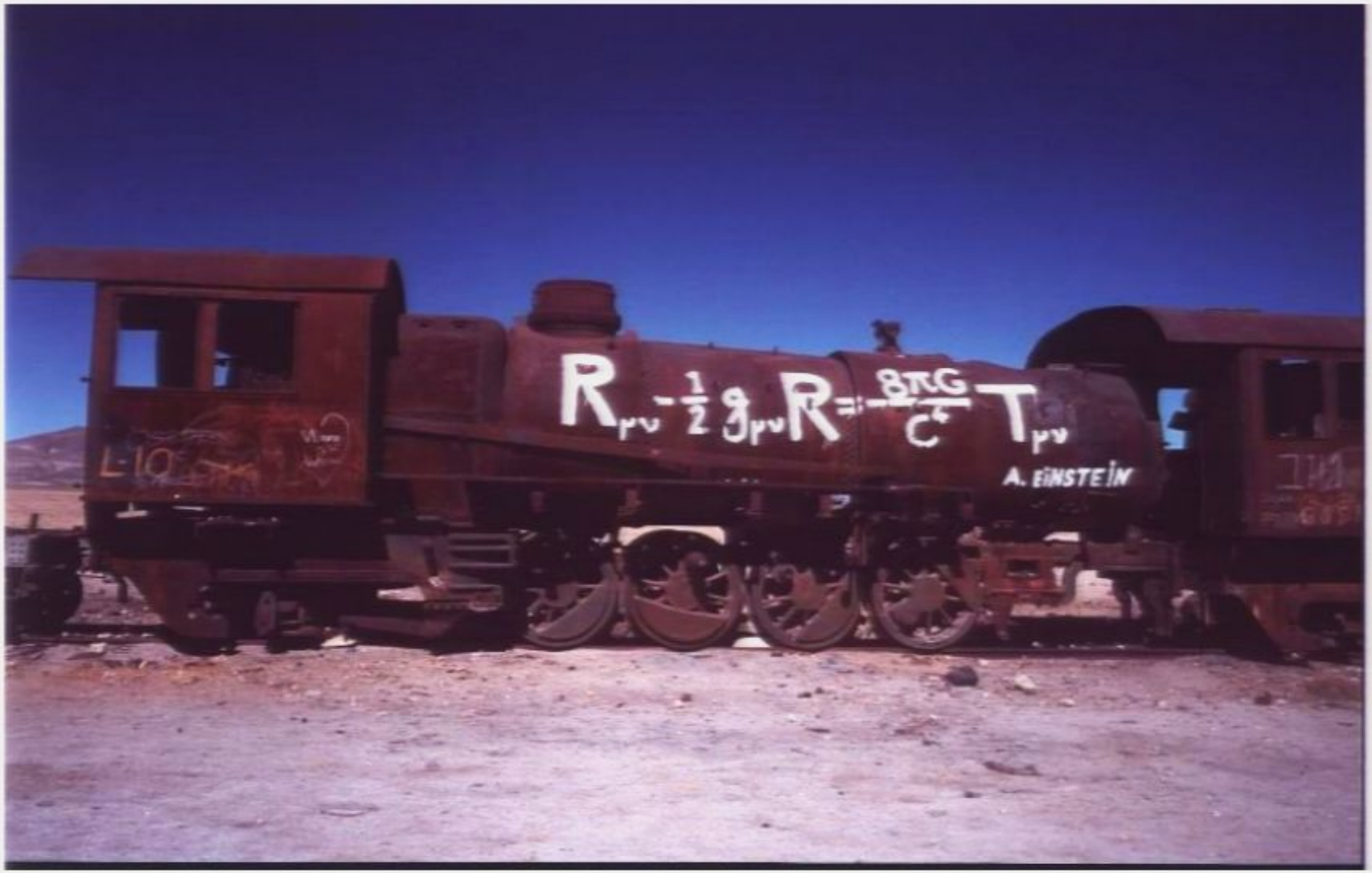

General Relativity: the black hole

(Laplace 1795!!)

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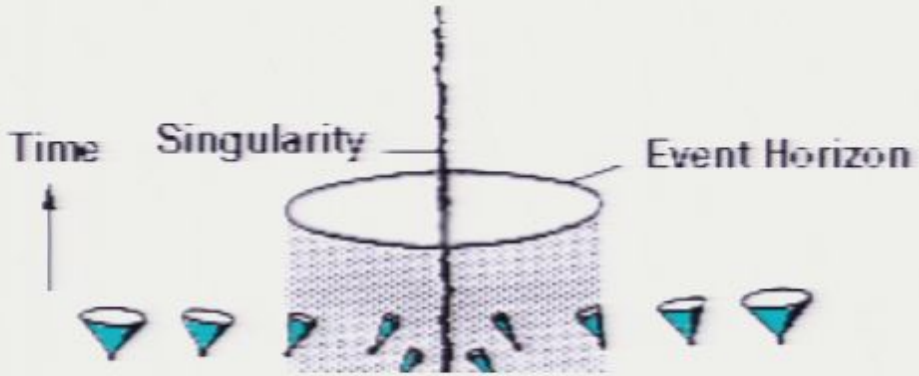

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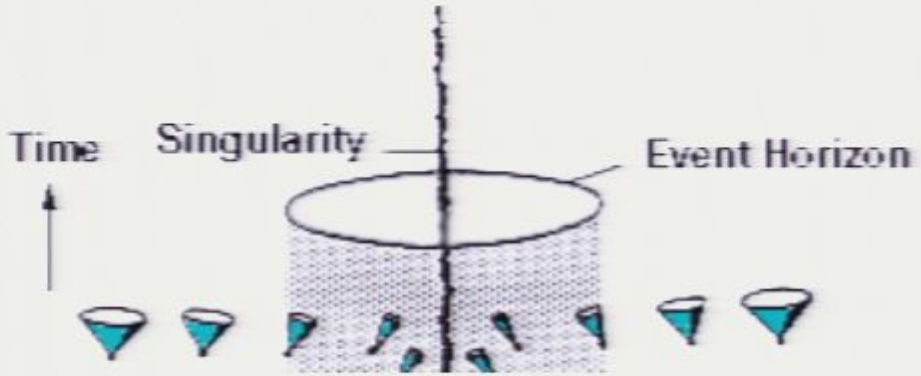

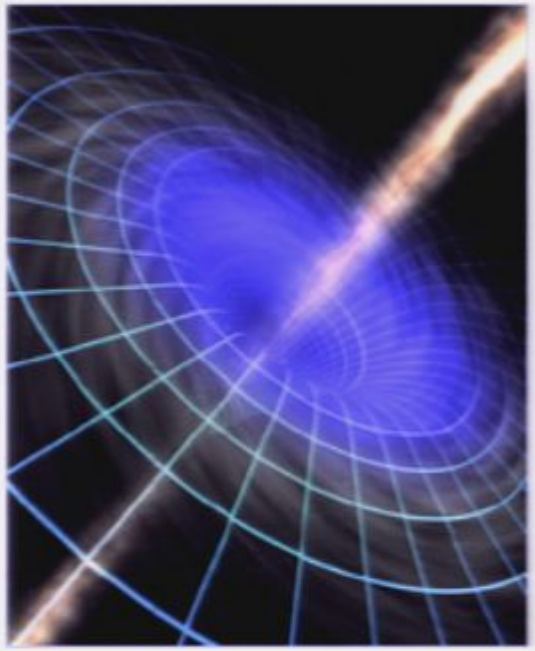

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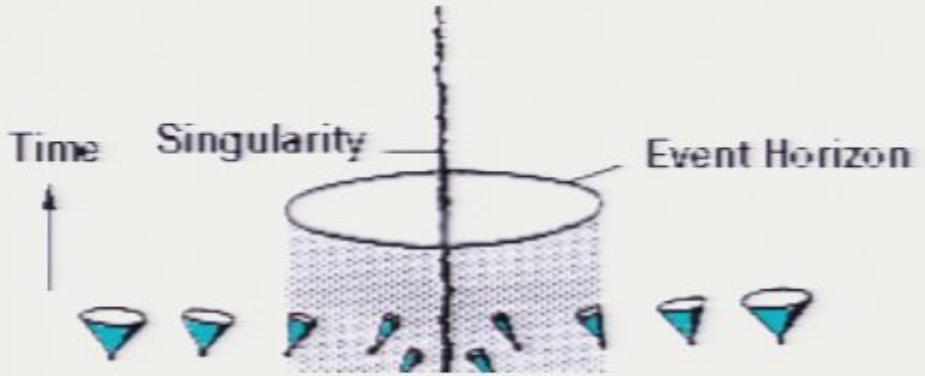
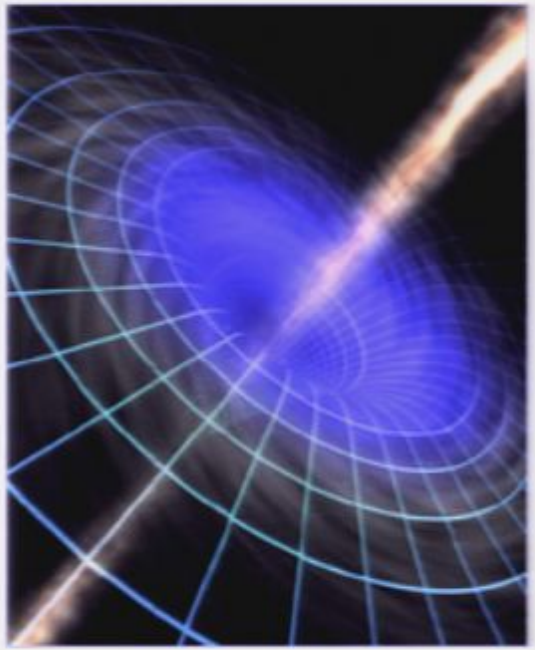


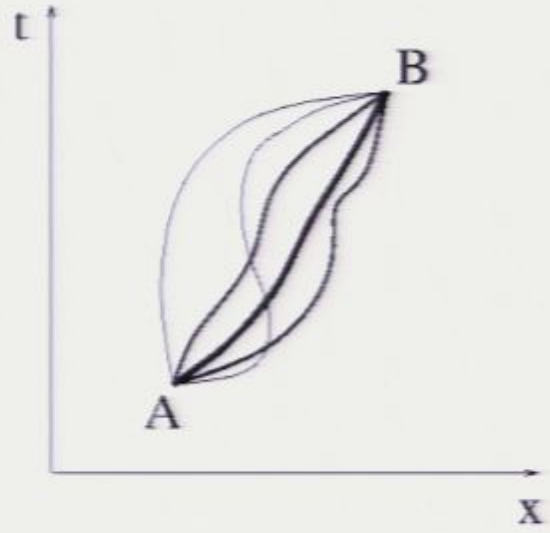


Quantum Theory

Heisenberg uncertainty principle: exact position and momentum of a particle can not be known simultaneously

$$\Delta x \, \Delta p \geq \frac{\hbar}{2}$$

fuzzy trajectories



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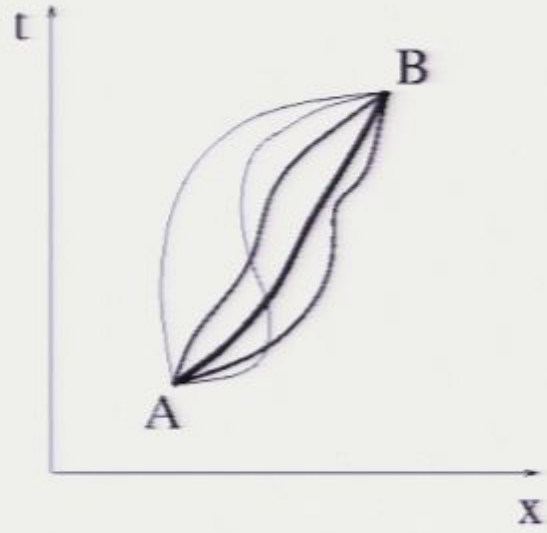

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Quanta of space

What are the quanta of gravity

"grains of space"

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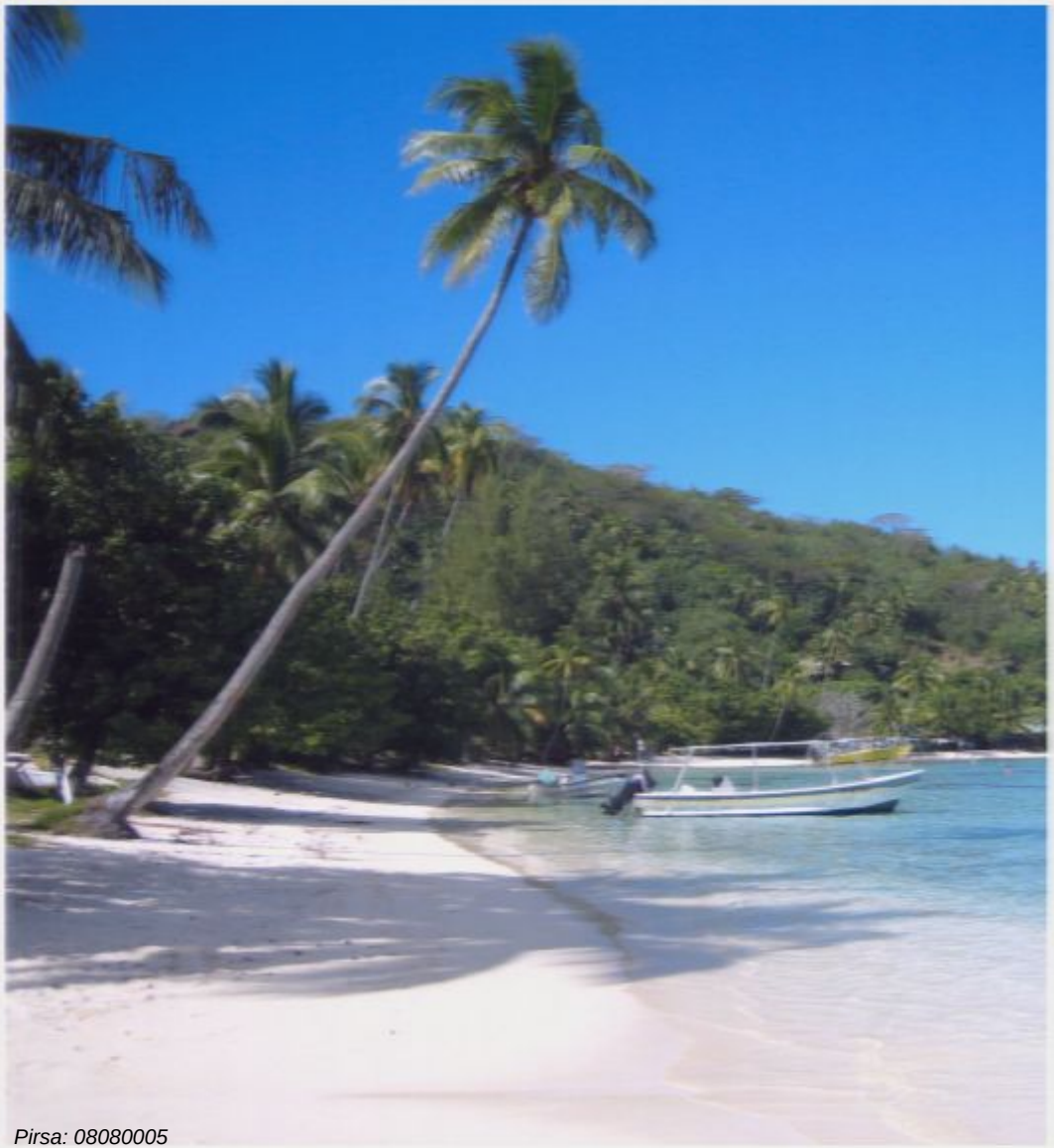

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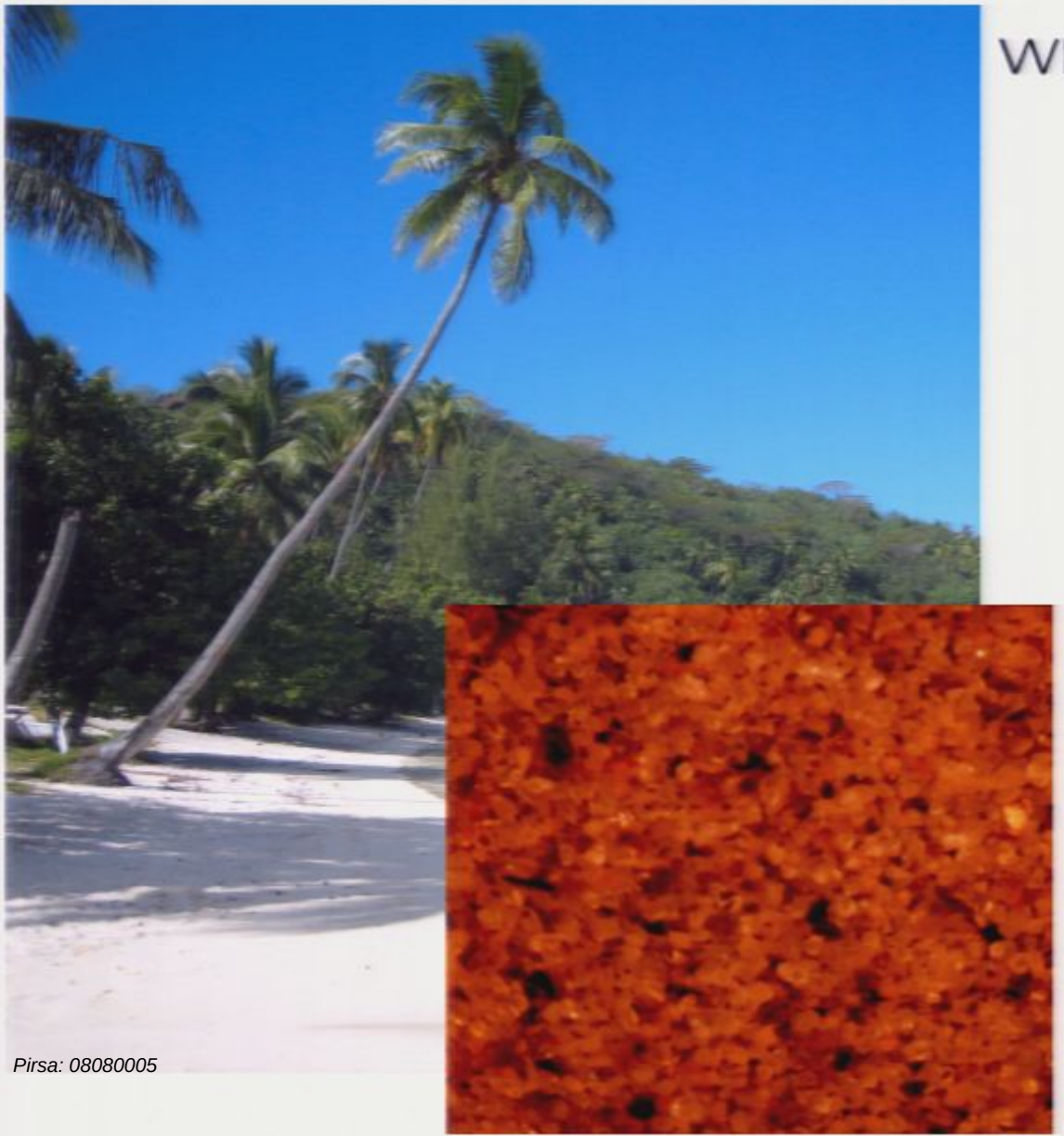

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...but there are also other ideas around! especially in the absenc

of experiments, one should try to be as open–minded as possible

A (brief) look at the Dark Side:

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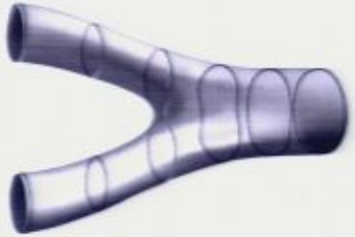

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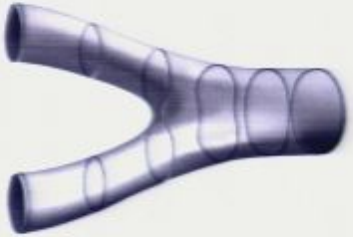

String theory

Very tempting: it follows a path which has been elegant and successfull until 1974

Very powerful: gives a unified picture of matter and interactions

To be consistent, it requires a paraphernalia of new objects:

- extra dimensions — Unseen: they must be very small (or we are confined not to see them)
- SUSY particles — Unseen: they must be very heavy

table predictions

the question of quantum spacetime

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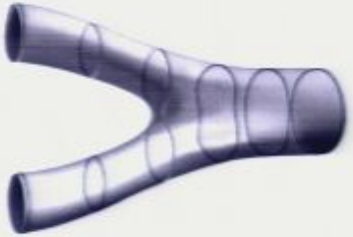

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In spite of all efforts, no testable predictions

It does not address directly the question of quantum spacetime

Loop Quantum Gravity

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Abhay Ashtekar

Loop Quantum Gravity

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Carlo Rovelli

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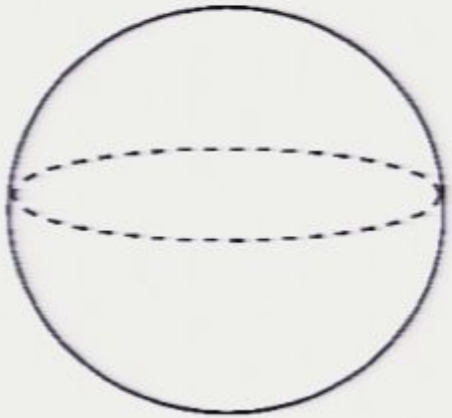
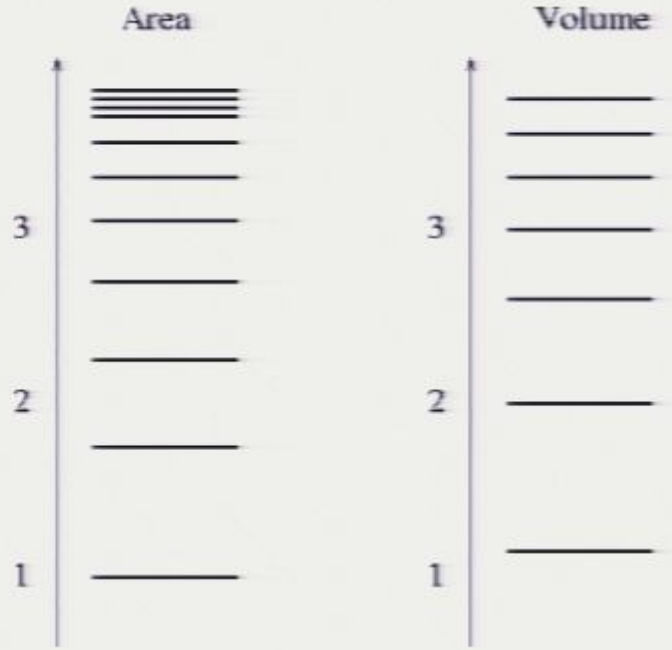
Lee Smolin

Loop Quantum Gravity

A candidate theory to a quantum description of spacetime.

It describes quanta of spacetime and their dynamics





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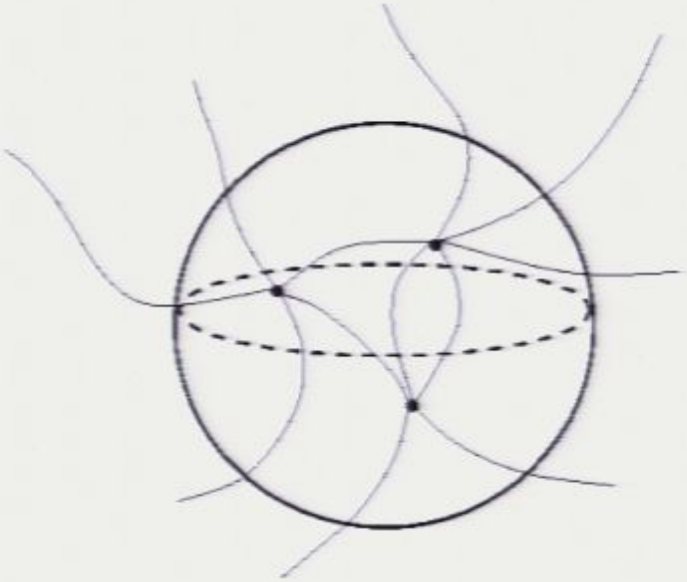

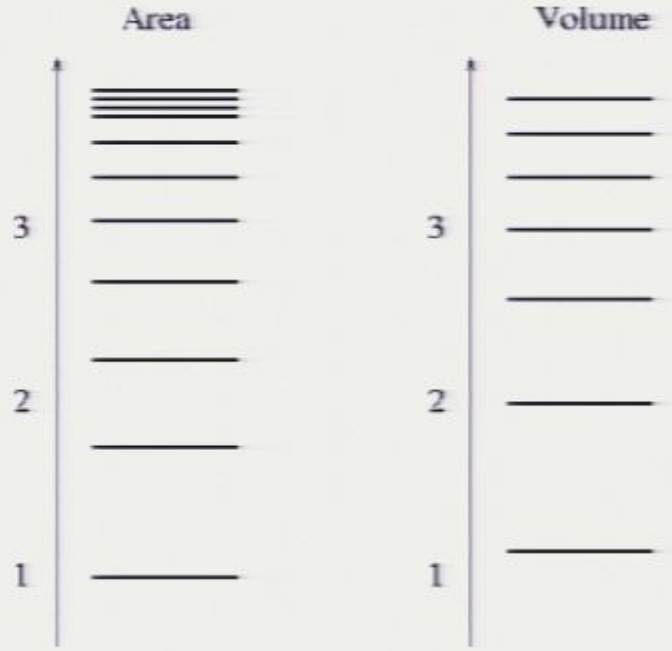

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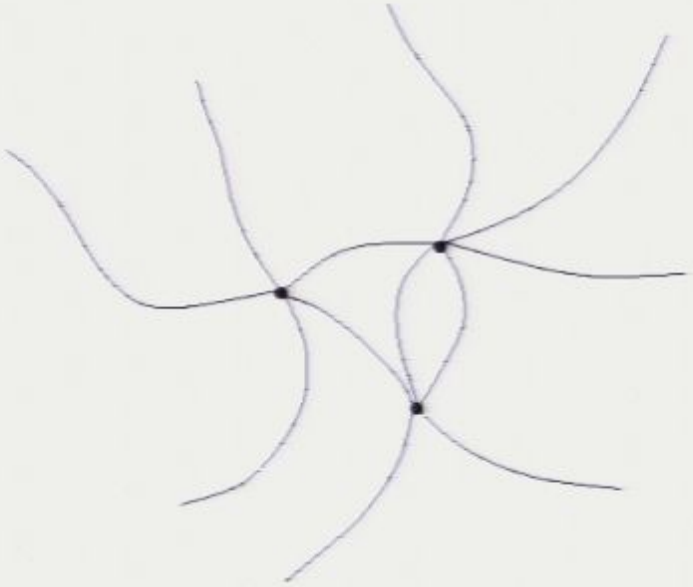
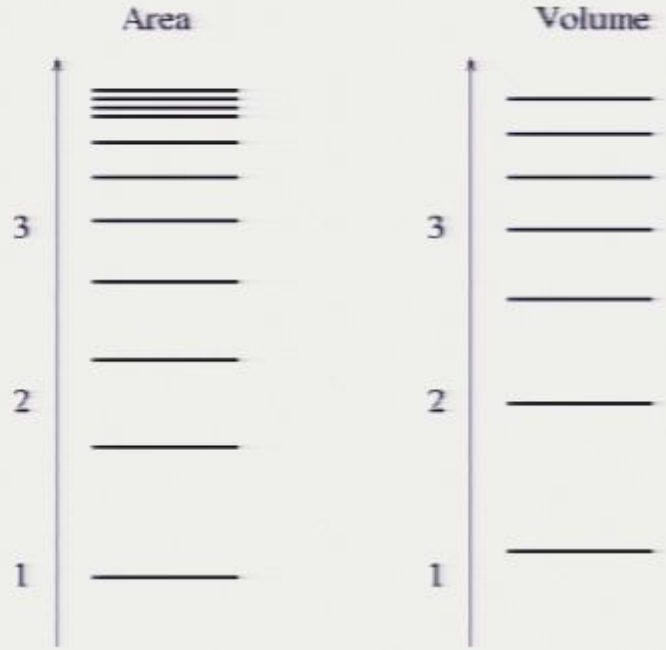
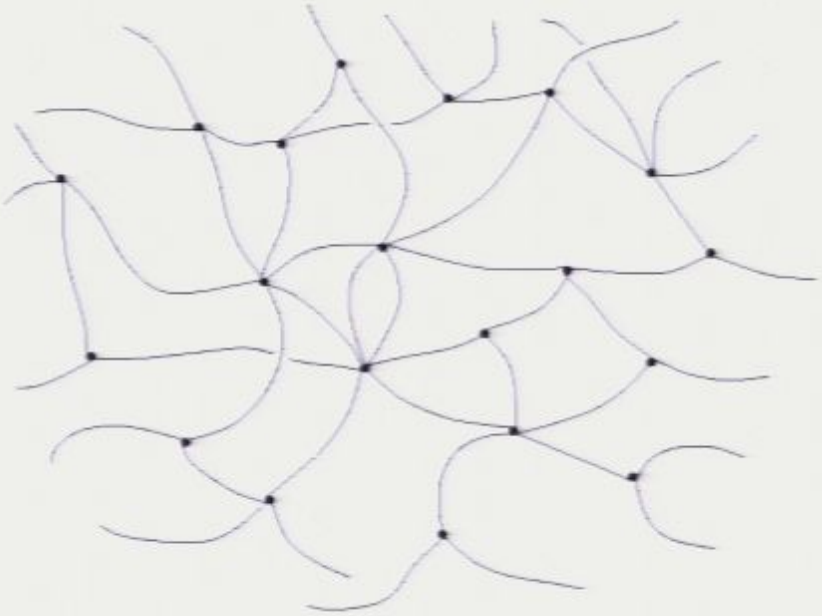




Spin Networks

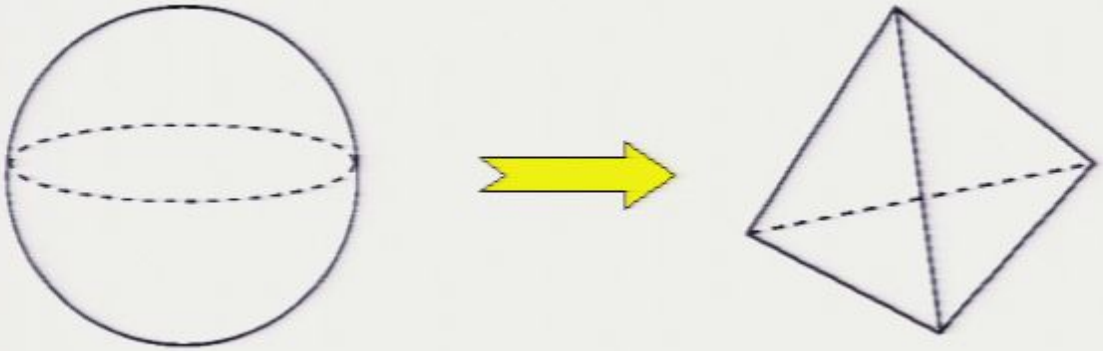


A graph: a set of nodes linked to each other

Each graph is defined solely by the way the nodes are linked together there is no background structure over which the graph lives

Particularly suitable to implement the idea of relationalism of physics pushed by General Relativity

Quantum Geometry

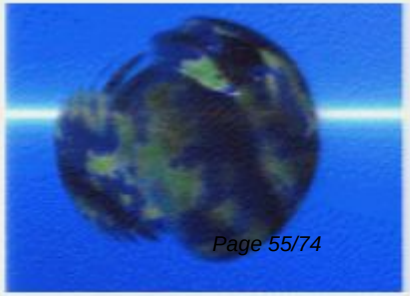


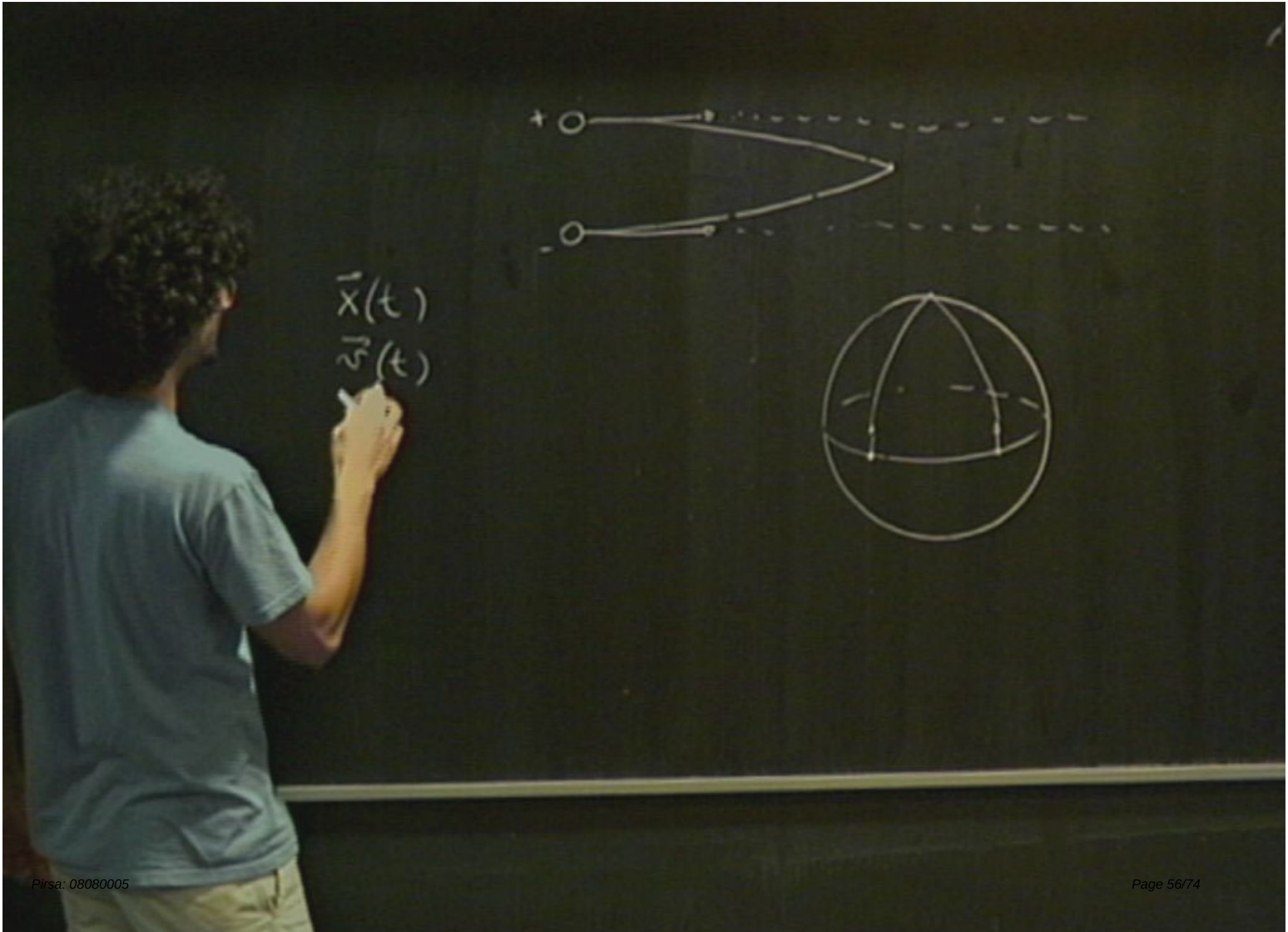
A tetrahedron as the basic atom of spacetime

6 classical observables

5 compatible quantum observables

Fuzzy geometry

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$\vec{x}(t)$
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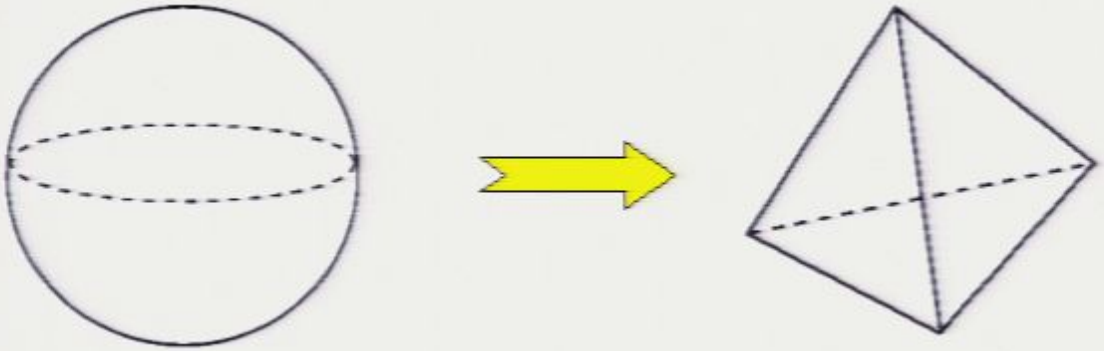
Quantum Geometry



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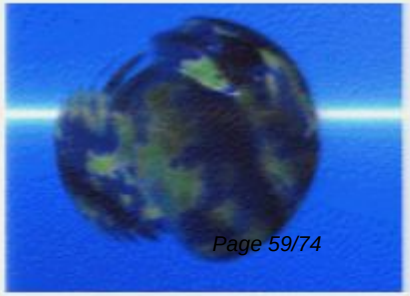


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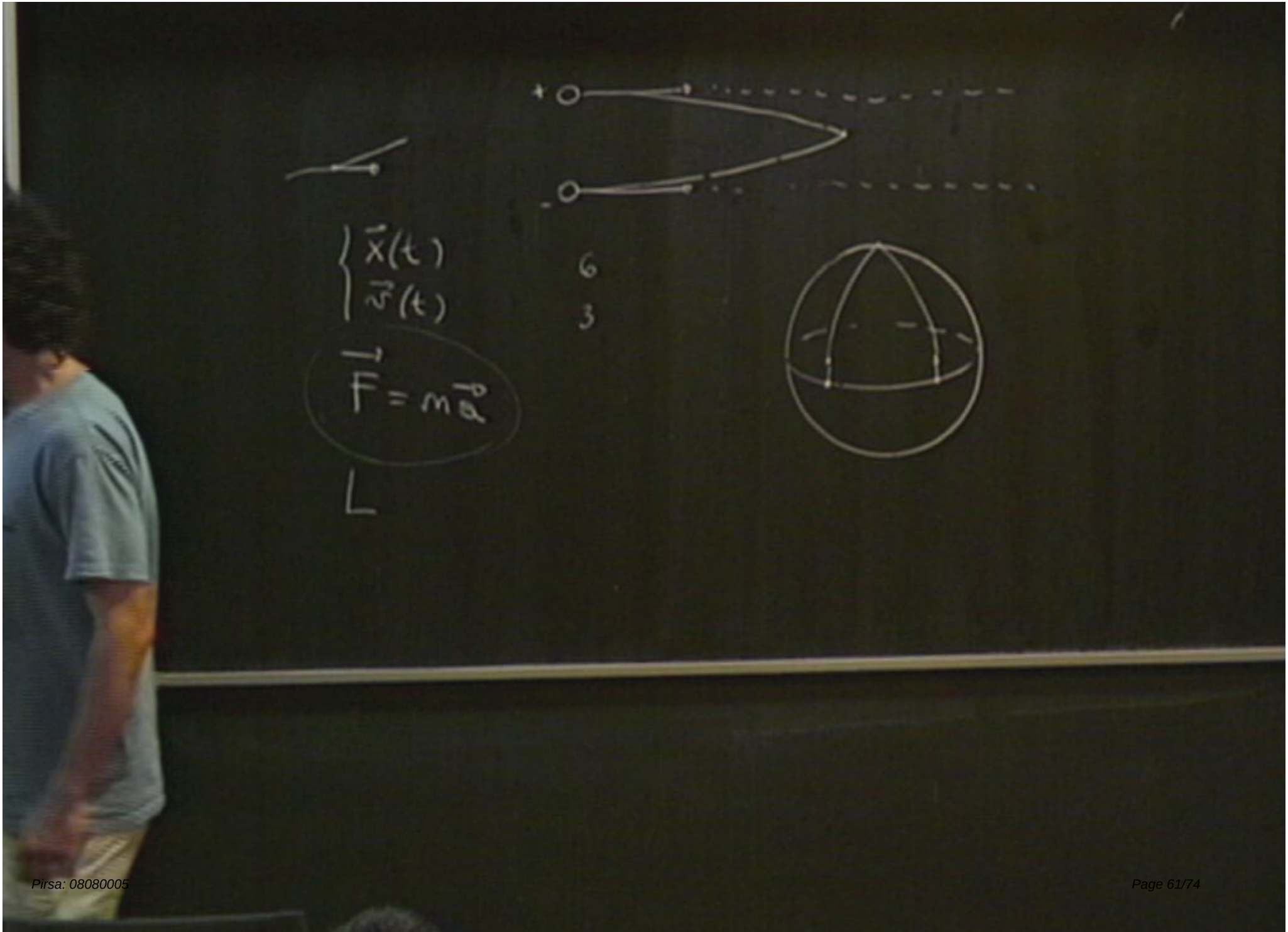
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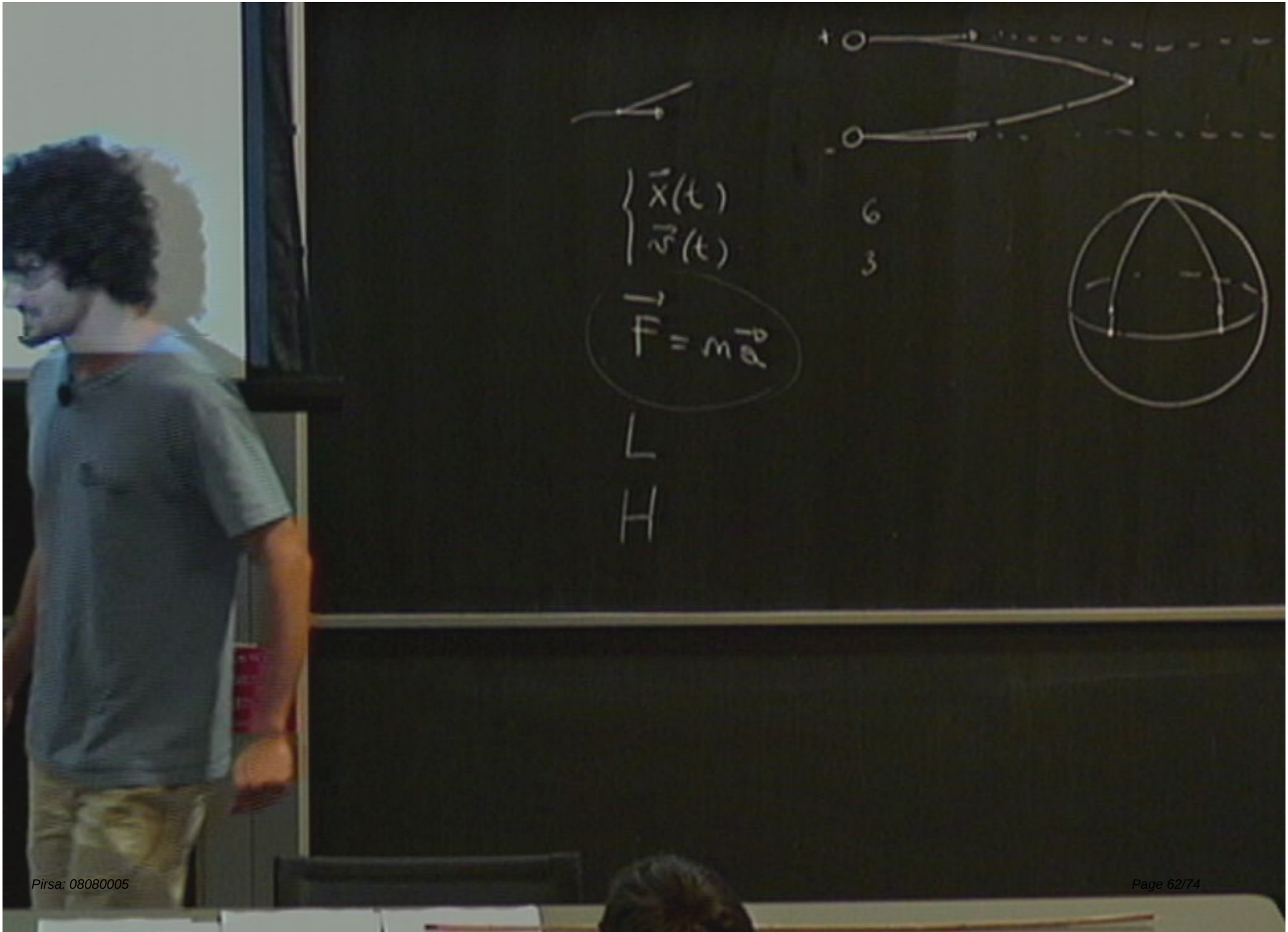
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LQG dynamics: spinfoams

The Hamiltonian operator
acts on the nodes
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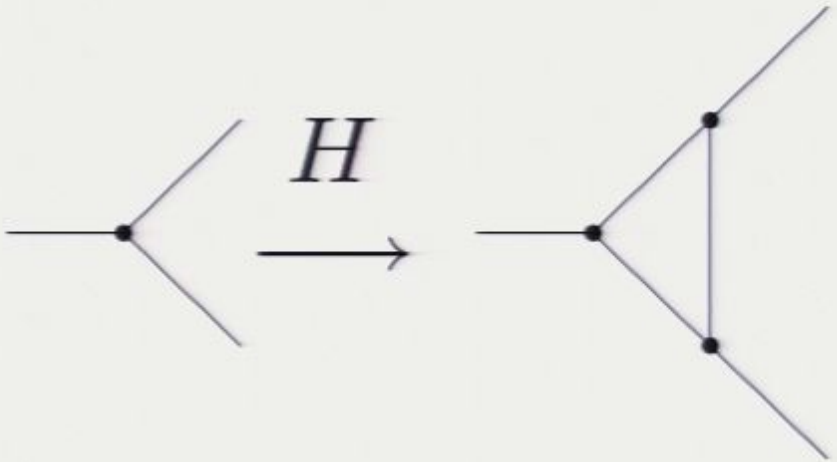

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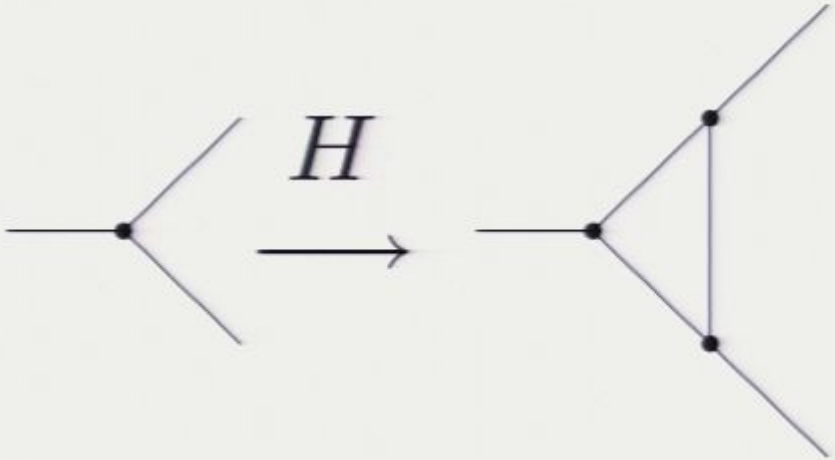

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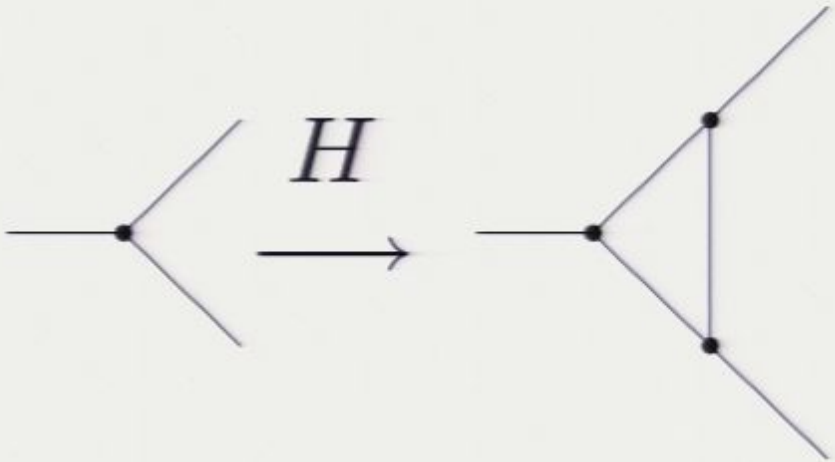

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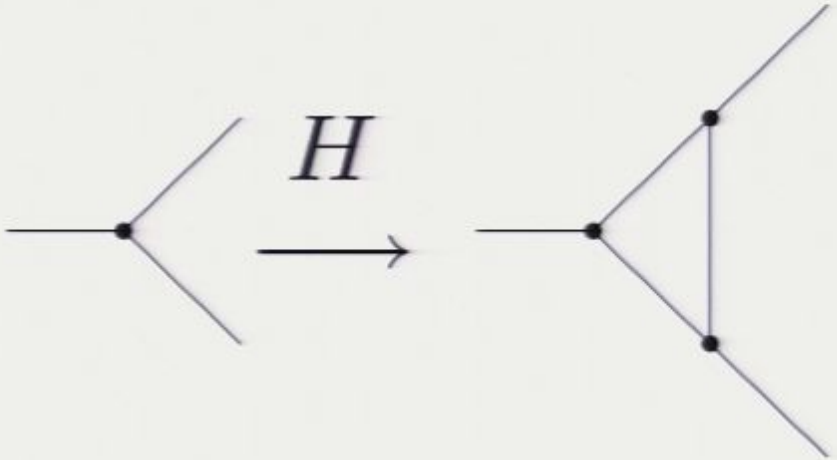
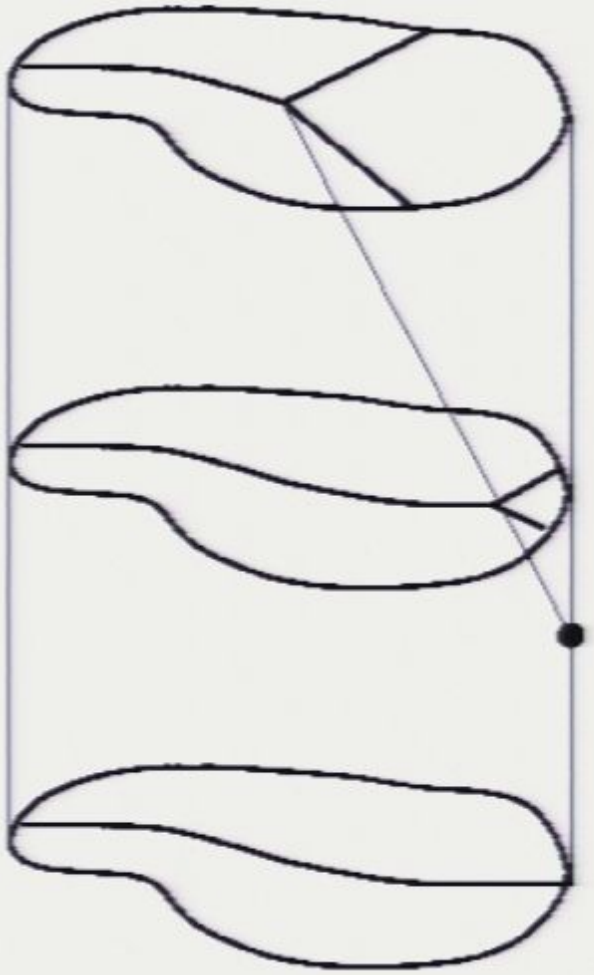
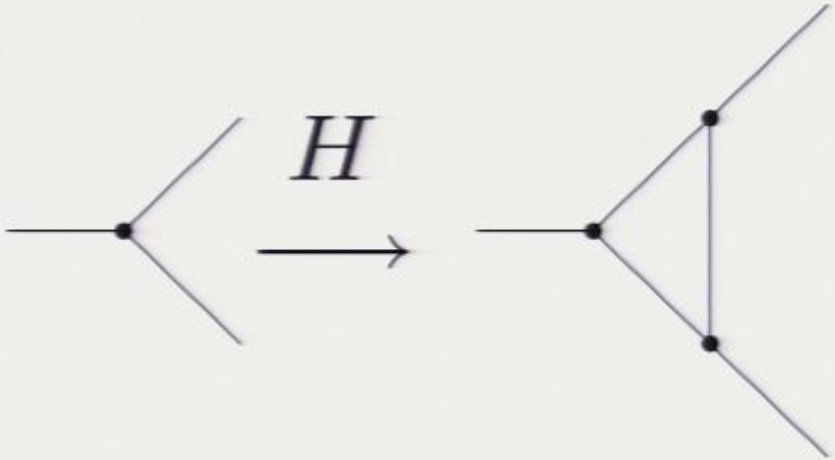
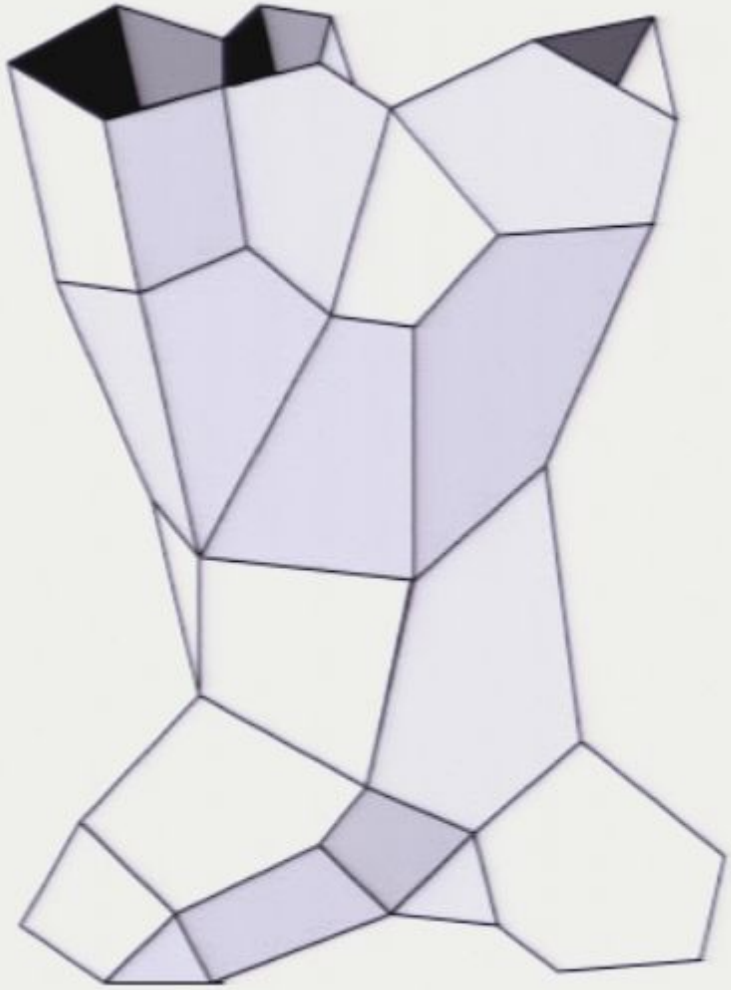




LQG dynamics: spinfoams

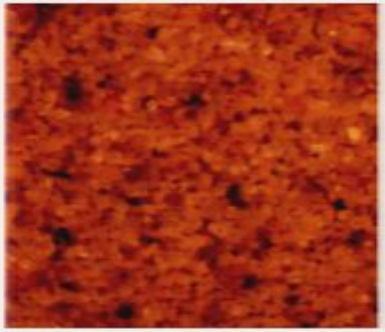
The Hamiltonian operator
acts on the nodes
of the spin network:





Physics of LQG

Discreteness of spacetime

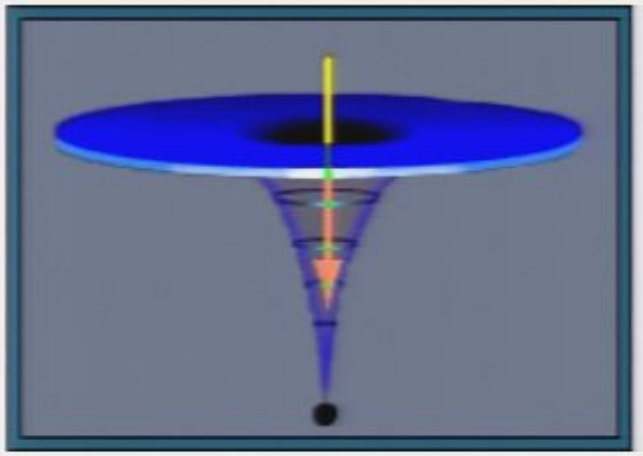


Risolution of singularities

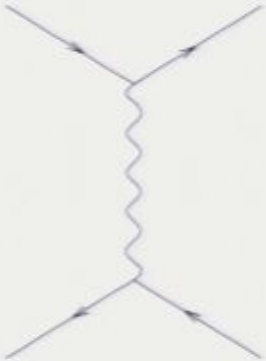
New description of the propagation of matter

Resolution of singularities

Spacetime singularities



Particle interaction singularities



Phenomenology

Deformations of the Lorentz symmetry

$$E^2 = m^2 + \vec{p}^2 \qquad +$$

Phenomenology

Deformations of the Lorentz symmetry

$$E^2 = m^2 + \vec{p}^2 \qquad + \alpha \ell_{\mathrm{P}} E^3 + \beta \ell_{\mathrm{P}}^2 E^4 + \dots$$

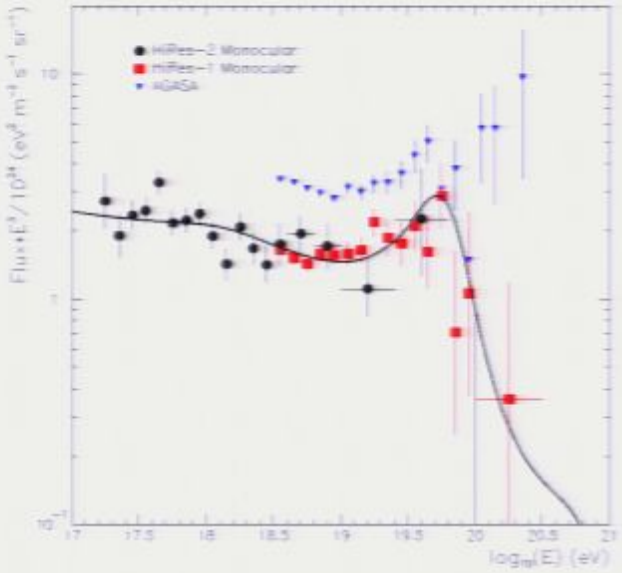
Phenomenology

Deformations of the Lorentz symmetry

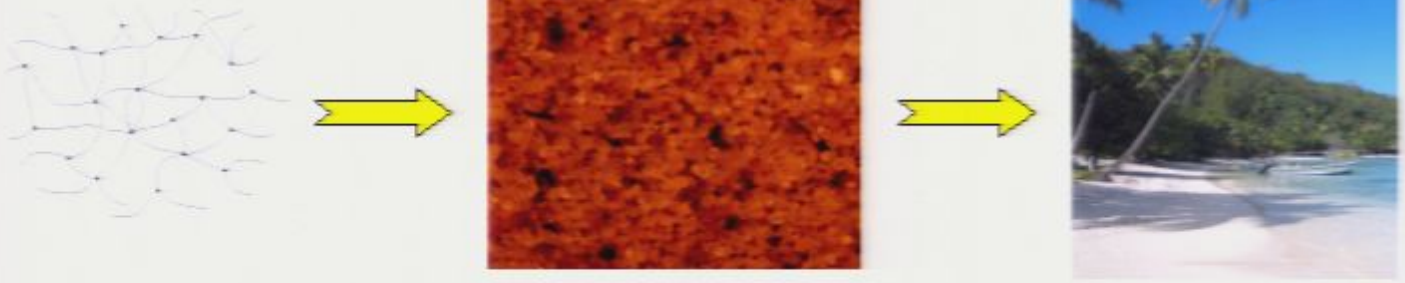
$$E^2 = m^2 + \vec{p}^2 \qquad +\alpha \ell_P E^3 + \beta \ell_P^2 E^4 + \dots$$

Example: GZK threshold

$$p + \gamma_{CMB} \mapsto \begin{cases} p + e^+ + e^- \\ p + \pi_0 \end{cases}$$



Discrete structure of spacetime?



We don't know if this picture is correct until we have experimental confirmation of predictions of the theory

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The path is right in front of us!

[Nessun titolo]

Disegno Forme

Struttura Struttura predefinita