

Title: Special Topics in Physics - Lecture 8B

Date: Mar 05, 2008 08:00 PM

URL: <http://pirsa.org/08030023>

Abstract: The Problem of Time in Quantum Gravity and Cosmology

5. The case is the same with respect to time. Supposing any one should ask, why God did not create every thing a year sooner; and the same person should infer from thence, that God has done something, concerning which 'tis not possible there should be a reason, why he did it so, and not otherwise: the answer is, that his inference would be right, if time was any thing distinct from things existing in time. For it would be impossible there should be any reason, why things should be applied to such particular instants, rather than to others, their succession continuing the same. But then the same argument proves, that instants, consider'd without the things, are nothing at all; and that they consist only in the successive order of things; which order remaining the same, one of the two states, viz. that of a supposed anticipation would not at all differ, nor could be discerned from, the other which now is.

Leibniz's 3rd Paper, Alexander 1956, 25-7)

## *What do physicists mean by relationalism?*

- The world is made of a large number of entities or events

### *How do they get their properties?*

- In an absolute scenario, there is an external and static entity, such as Newton's absolute space, and properties of elementary particles are defined individually in terms of their relations to the absolute entity.
- Hence, a particle in Newton's absolute space has the same properties whether it is one of many or the only thing in the universe.
- The absolute entities make up *the background*.

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The most basic statement of relationalism is:

***R1     There is no background***

2) When forces

$$a^a = \frac{F^a}{m}$$

X  $a^a$  dimensional  
I(t)  
↑ pulse

2) When forces

$$a^a = \frac{F^a}{m}$$

$$a = a$$

$x_I(t)$  ← dimension  
↑ particle

$$d_{IJ} = |x_I - x_J|^2$$

$X_I(t)$  ← dimension  
↑ photo

$P_I$

$$d_{IJ} = |X_I - X_J|^2$$

$P_{IJ}$      $P_{IJ} \pi \dots$

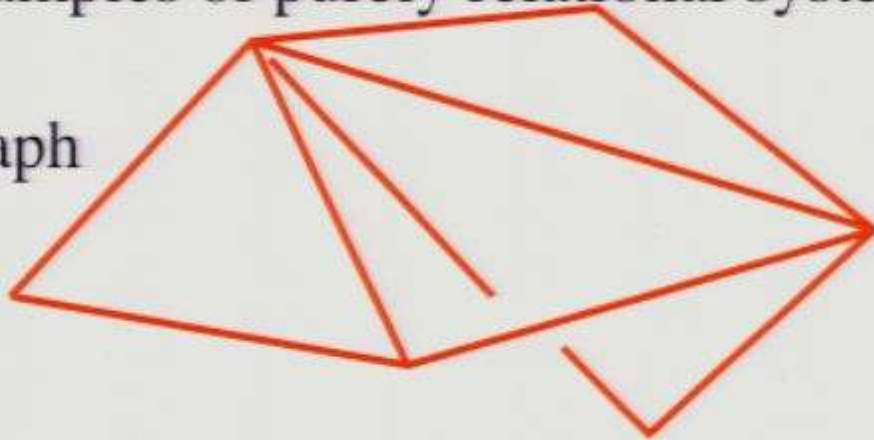
*How then do we understand the properties of elementary particles?*

The relational view posits that

***R2*** *The fundamental properties of the elementary entities consist entirely in relationships between those elementary entities.*

Examples of purely relational systems:

Graph



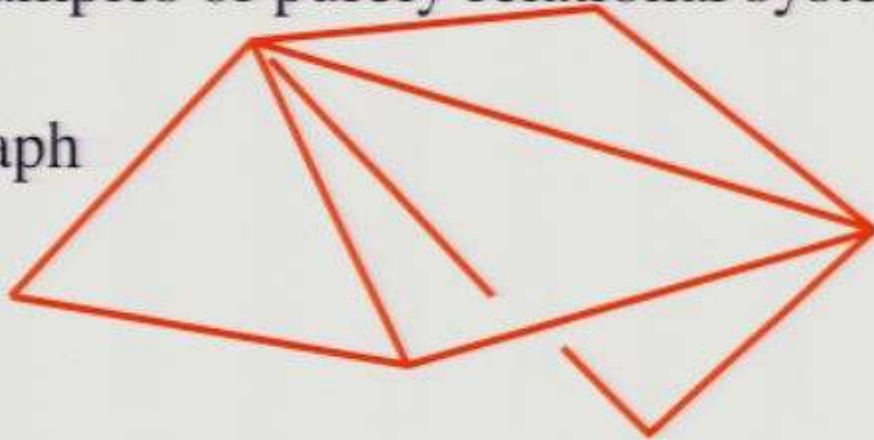
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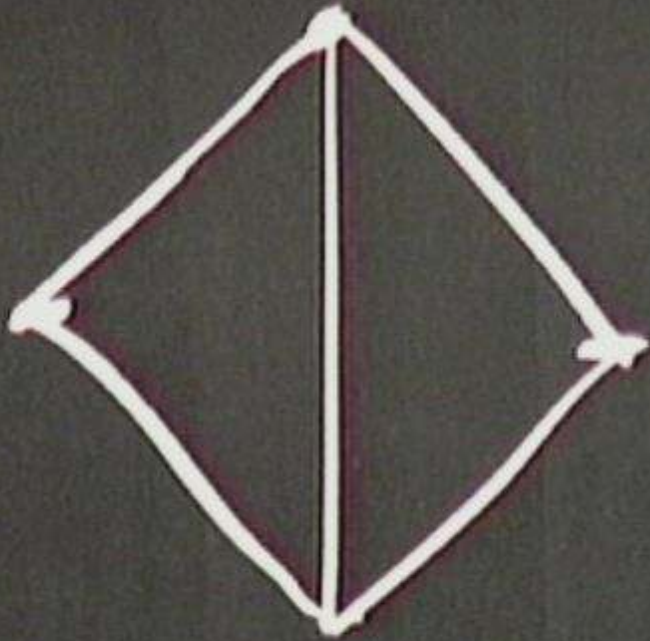


Adj Matrix

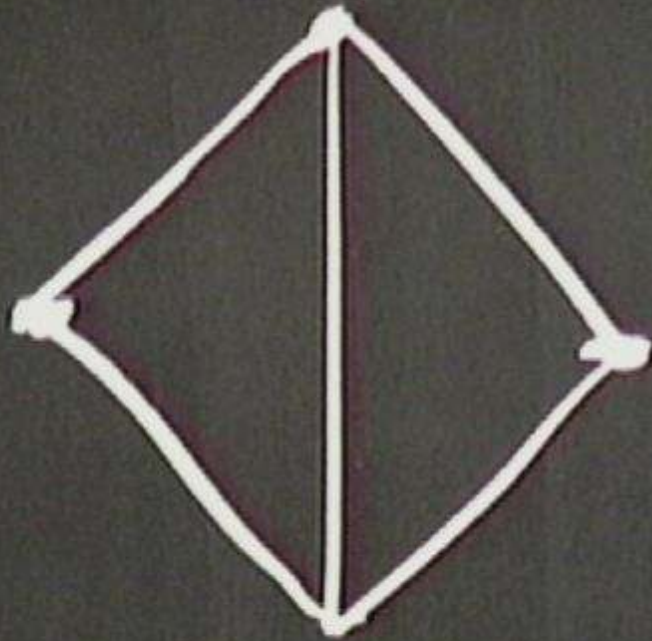
$$M_{ij} = \begin{cases} 1 & \text{if } i \text{ is com } j \\ 0 & \text{if not} \end{cases}$$

$M_{ij} / \text{Permut}(N)$

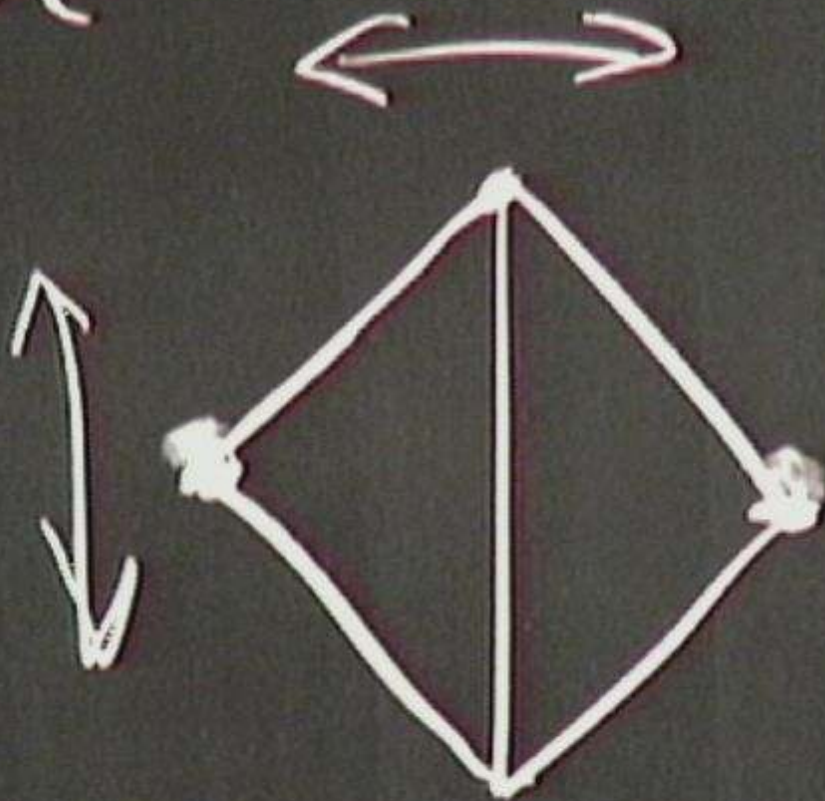
$i$  is com  $j$   
not



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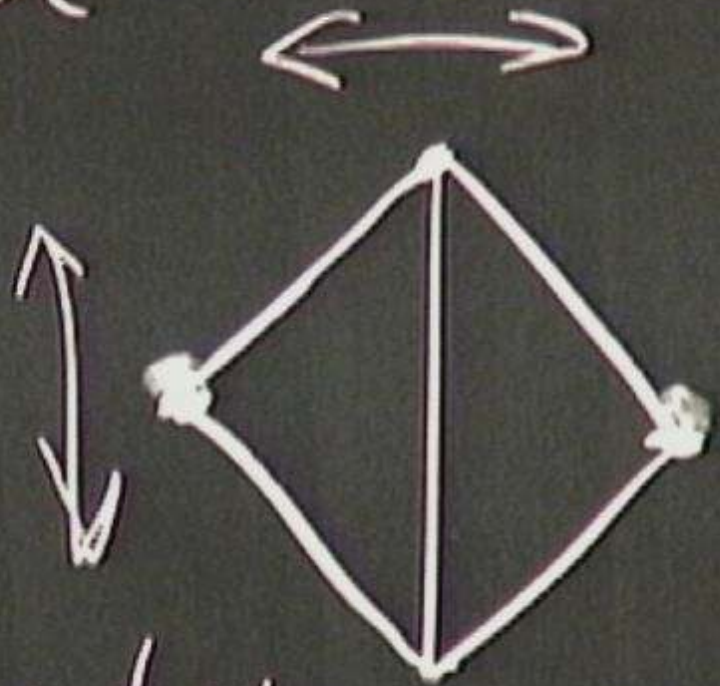
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Matrix

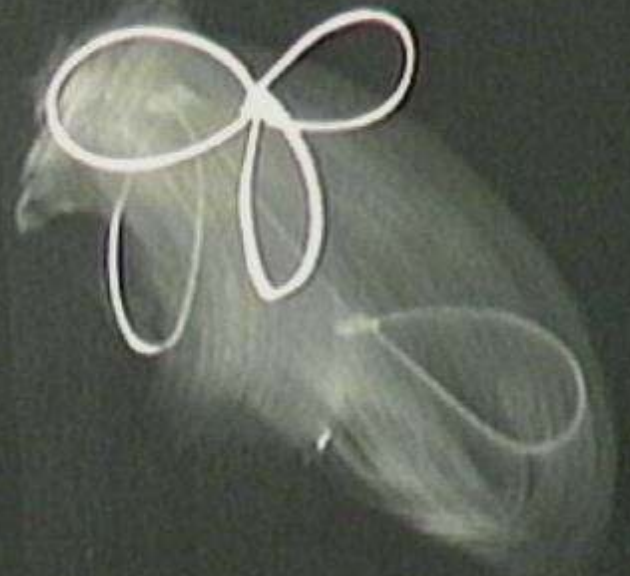
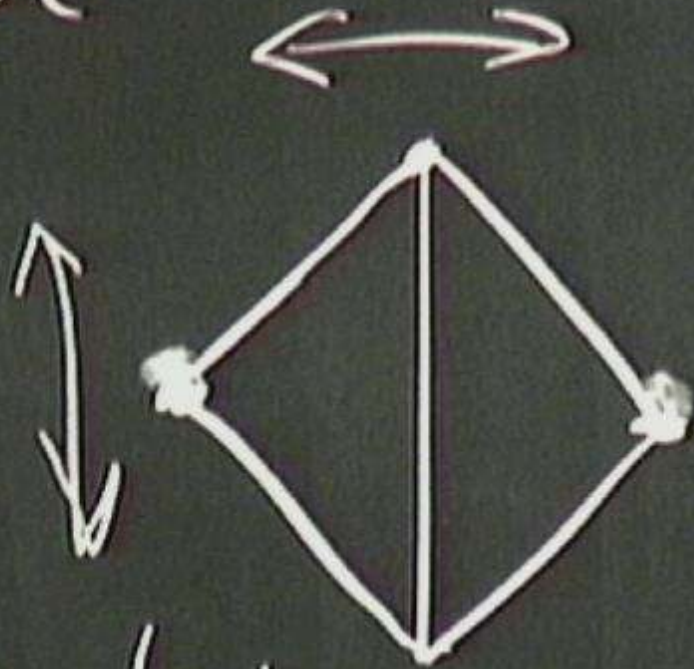
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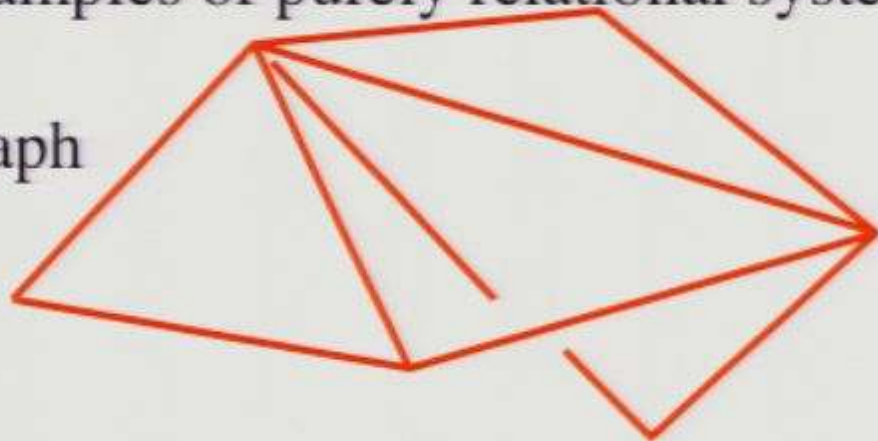
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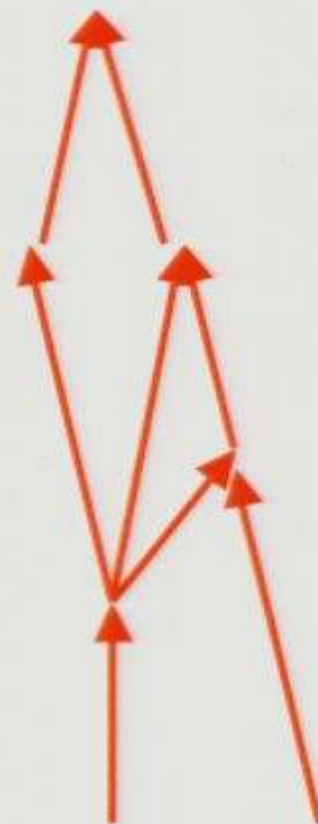
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Partially ordered set



Permut (N)

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$B < A$

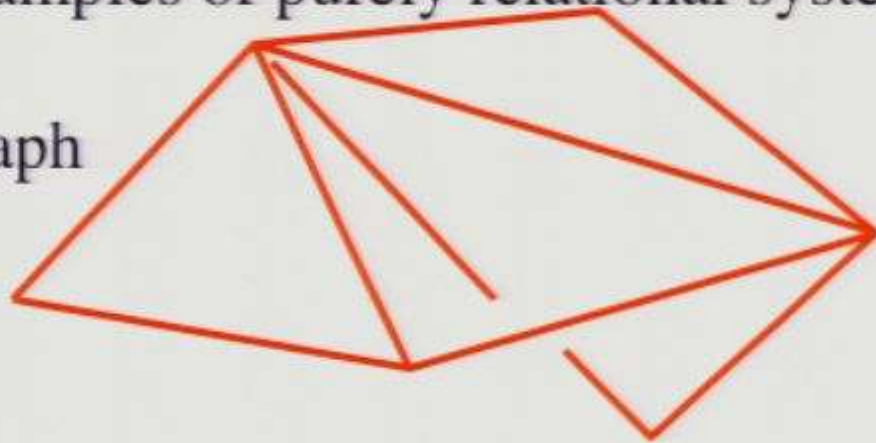
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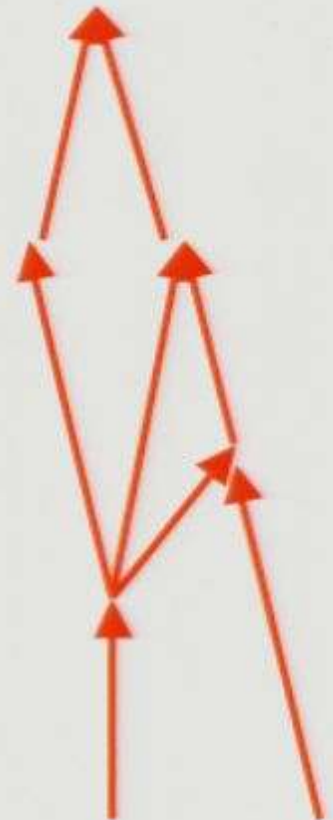
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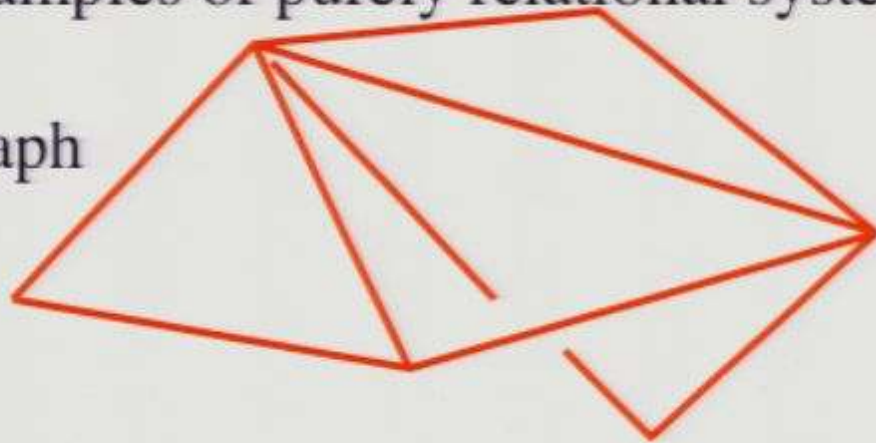
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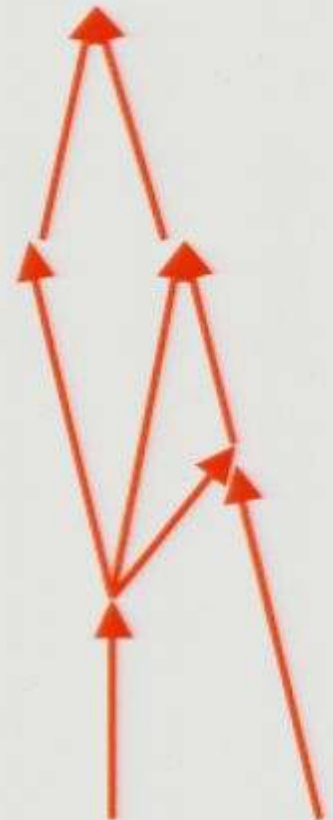
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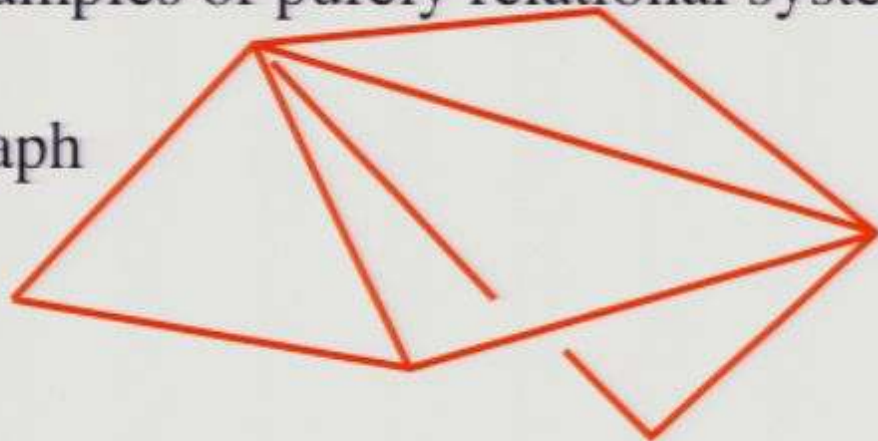
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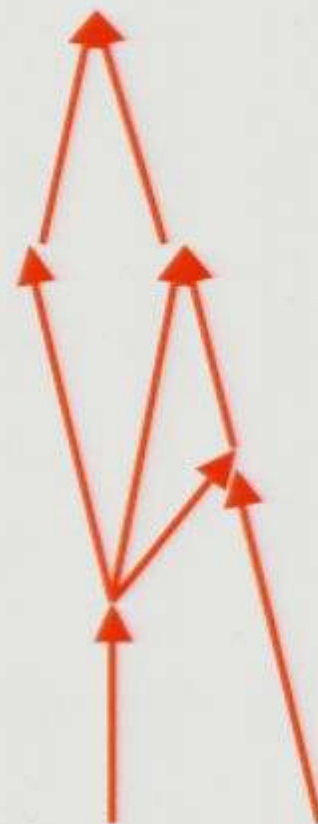
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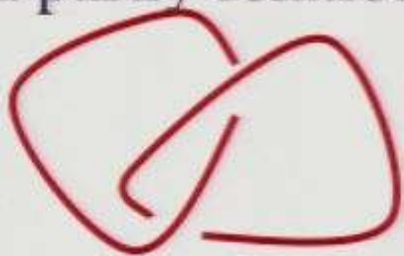
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Example of a partly relational system: knots and links



## **What is time in a relational theory?**

*R3 The relationships are not fixed, but evolve according to law. Time is nothing but changes in the relationships, and consists of nothing but their ordering.*

Relationalism is also a research strategy:

*Relational strategy:*

*Seek to make progress by identifying the background structures in our theories and removing them, replacing them with relations between physical entities which evolve subject to dynamical law.*

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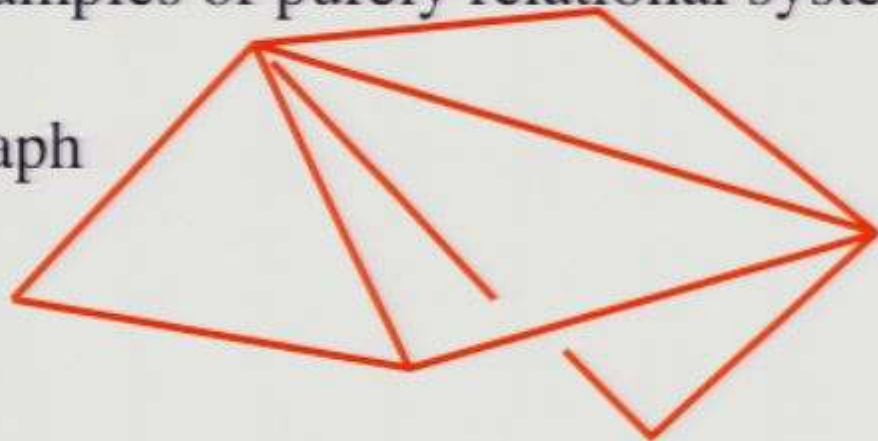
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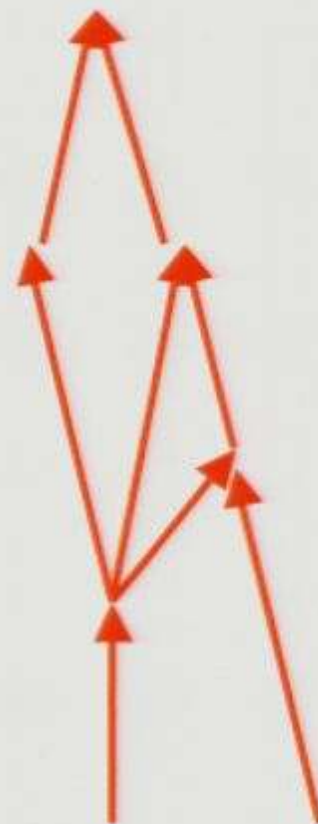
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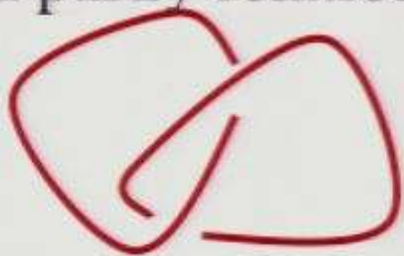
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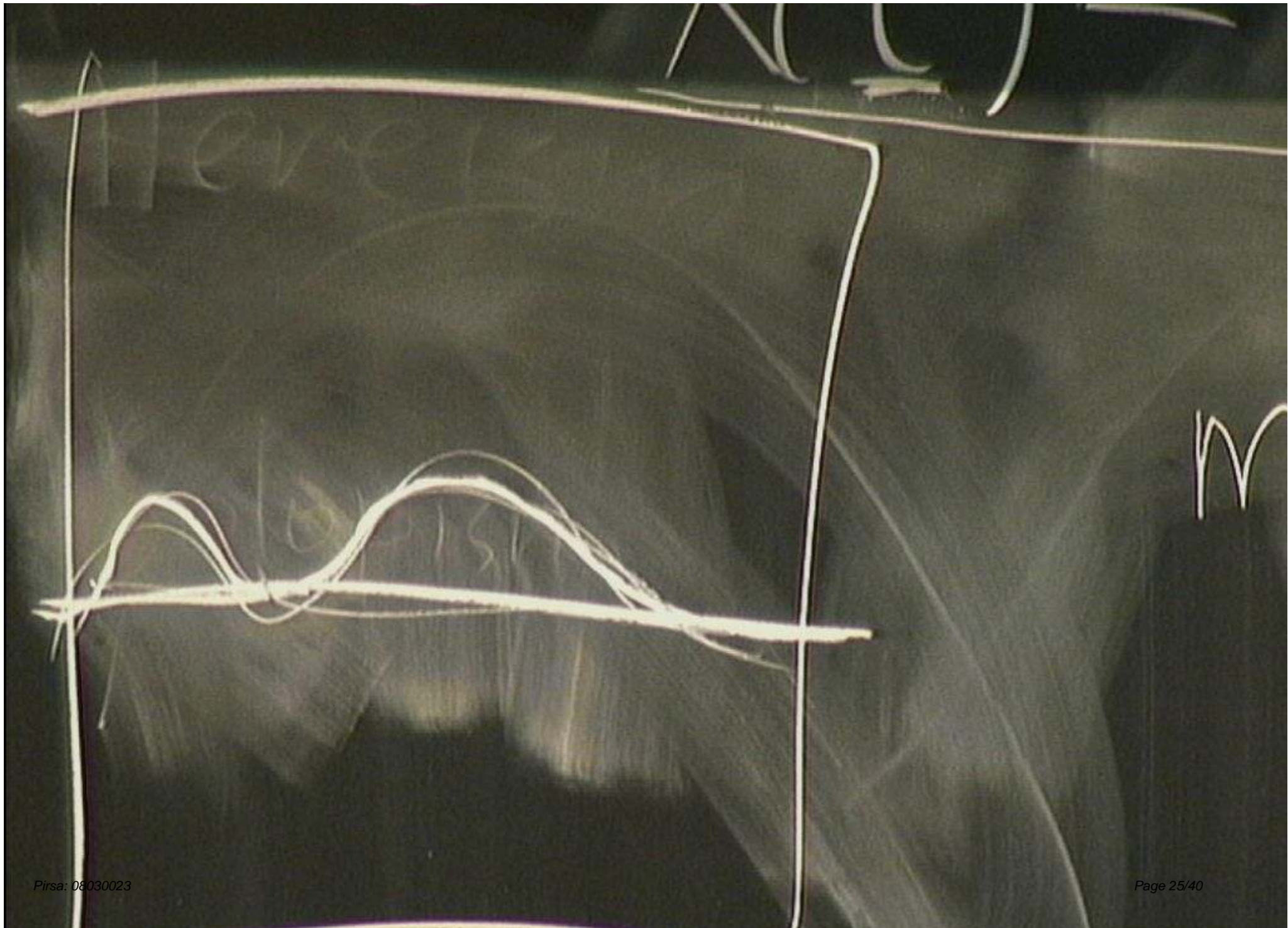
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## General relativity is a partly relational theory:

### Layers of structure:

Dimension  
Topology  
Differential structure  
Metric and fields

}  $M$

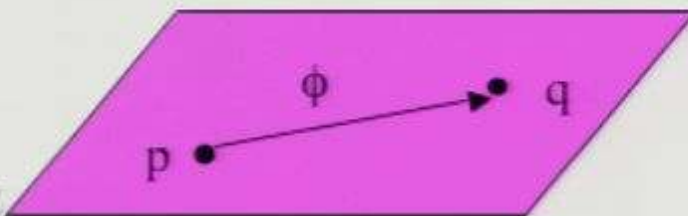
$g_{ab}, f$

In GR:  $M$  is fixed.

$g_{ab}$  and  $f$  describe relational information.

**KEY POINT:** A physical spacetime is **NOT** modeled by a manifold, metric, and fields, but by an equivalence class of manifolds and metrics, which are equivalent under any diffeomorphism !!

A diffeomorphism is a smooth map from  $M$  to itself that takes differential functions to differential functions.



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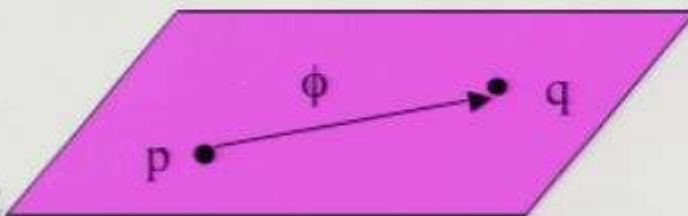
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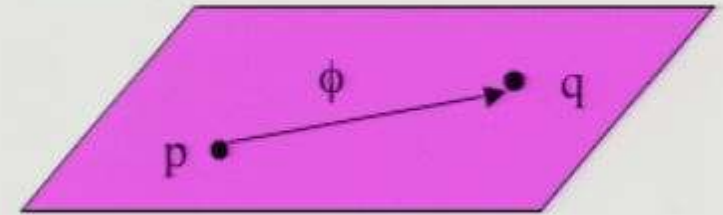
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What information is coded inside an equivalence class?

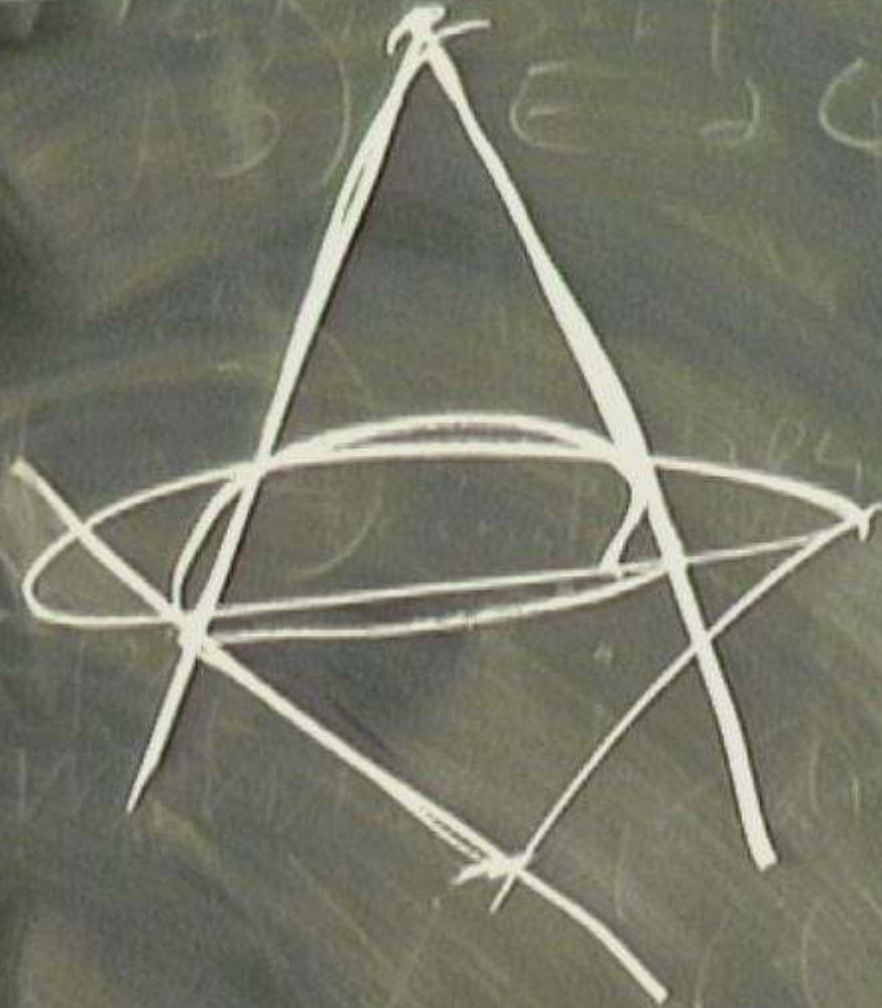


- **Not** fields at points. because physical points are only identified by what happens there.
- **The causal structure.** i.e. which events are causally related to which?
- **The measure.** i.e. what is the volume of each set defined by the causal structure?

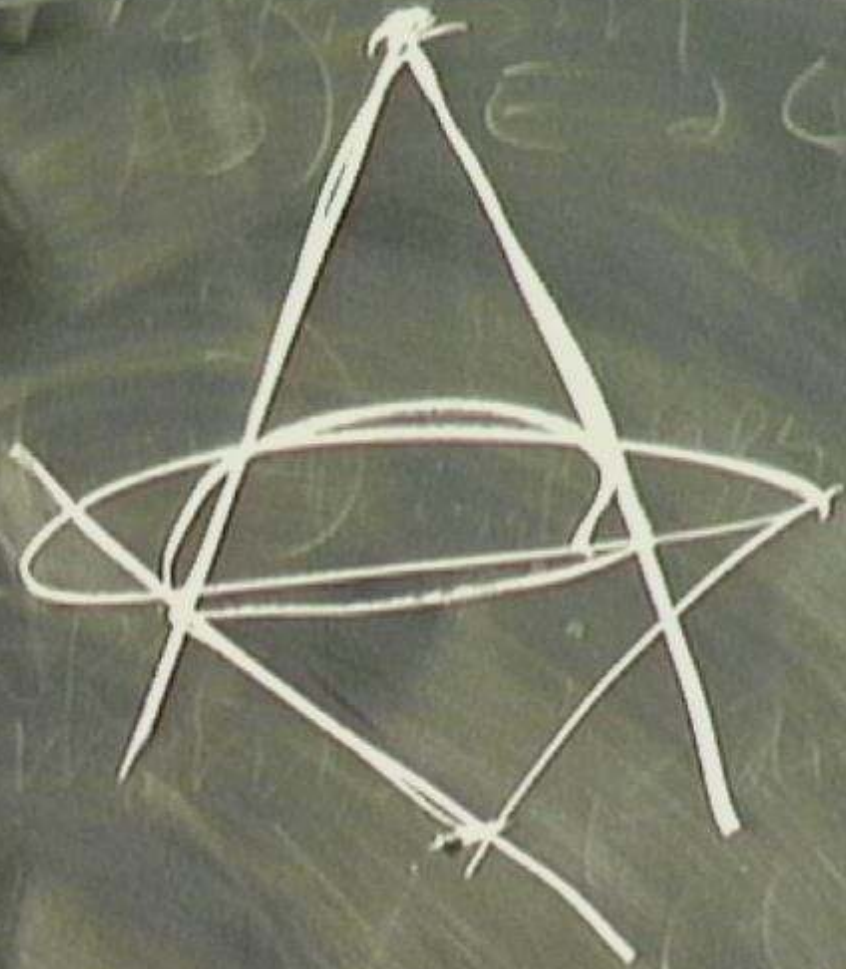
It can be shown that the information in a spacetime  $\{M, g_{ab}, f\}$  is completely characterized by the causal structure and the measure.

Hence, once the dimension, topology and diff structure are fixed, the physical content of GR is about the causal relations among physical events.

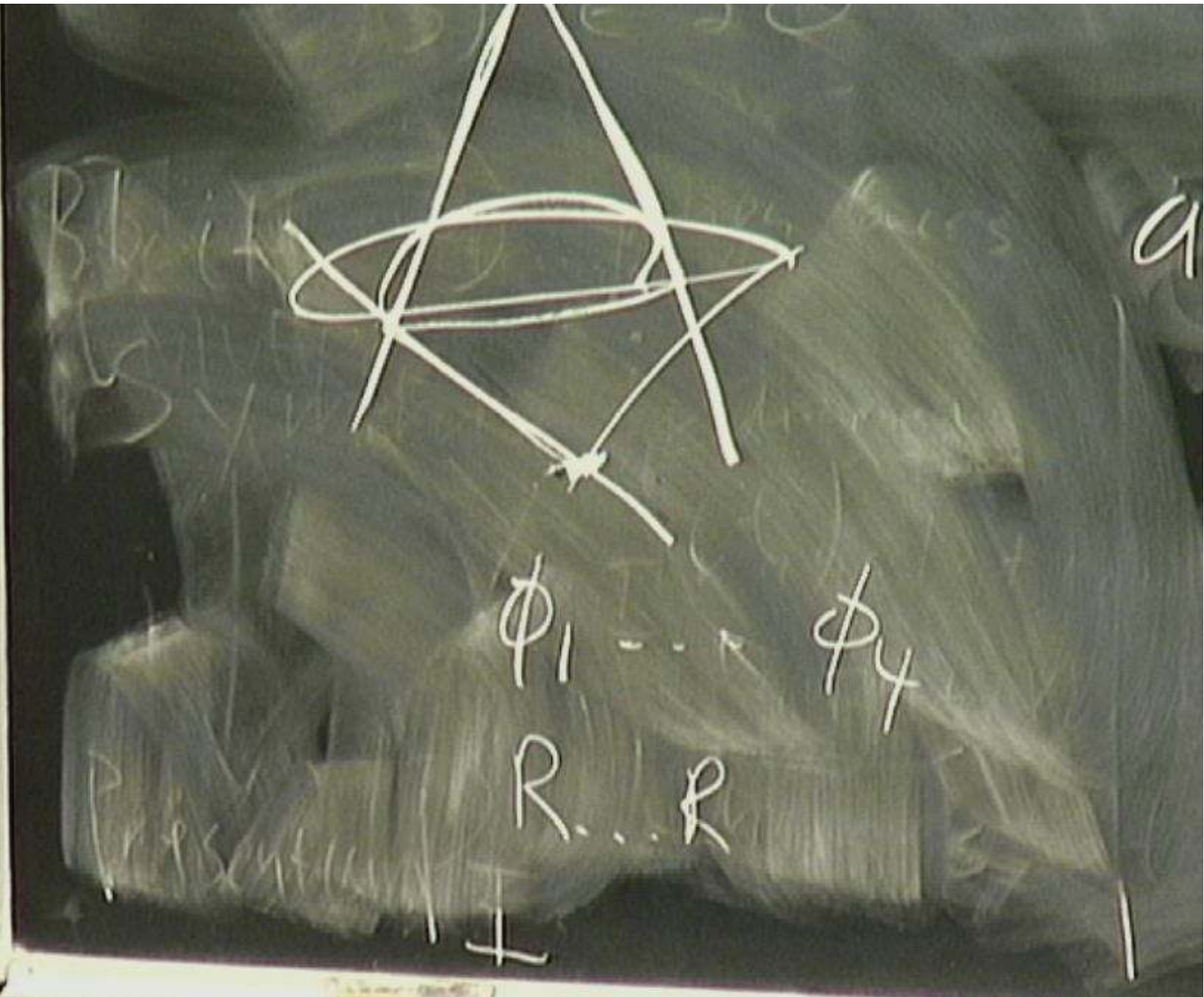
No forces  $\Rightarrow$



$a^a =$



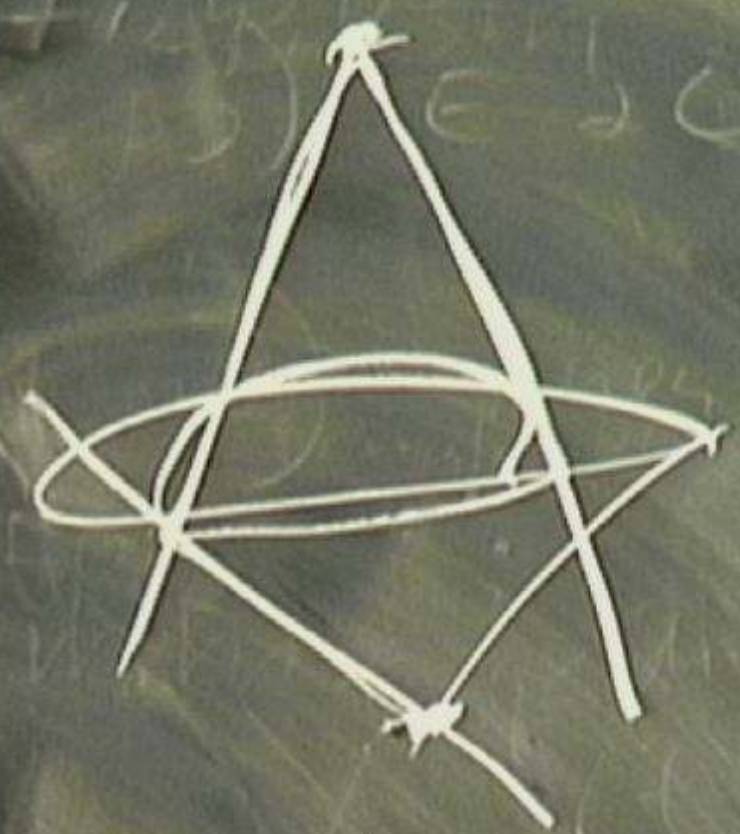
$\phi_1 \rightarrow \phi_4$



Relativity  $\in \mathbb{C}$

No. 10000  $\rightarrow$

Black  
S



$a^a =$

$\phi_1 \dots \phi_4$

$R \dots R$

Present





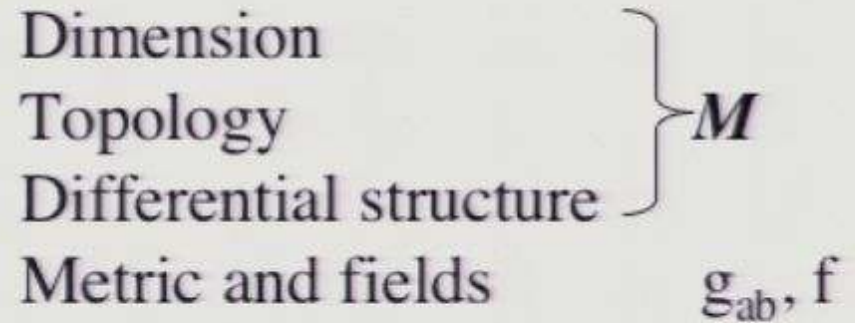
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