

Title: General Covariance and Causal Sets

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Series: Quantum Gravity

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Abstract: If General Relativity emerges from quantum gravity, then general covariance, the gauge invariance of GR, will emerge with it. We can ask, within any approach to the problem of quantum gravity, what is the “precursor” principle or precept that will give rise to “ or manifest itself as “ general covariance in the large scale semi-classical approximation?

Given how important the understanding of general covariance (or lack of it!) was in the development of GR we might expect that thinking about this question will be similarly important in the development of quantum gravity.

I will explain how general covariance is seen from the perspective of the causal set approach to quantum gravity and describe recent progress in creating a framework for causal set dynamics that is completely covariant and does not refer to any gauge degrees of freedom at all.

FD, Nazireen Imambaccus, Amelia Owens, Rafael Sorkin & Stav Zalel

PLAN

Causal Set = Discrete Spacetime

1. General Covariance = "label invariance"
2. Path integral QM = generalised stochastic process

BLOCK \swarrow GROWING BLOCK

3. Classical Sequential Growth (CSG) refers to labels (Rideout & Sorkin)

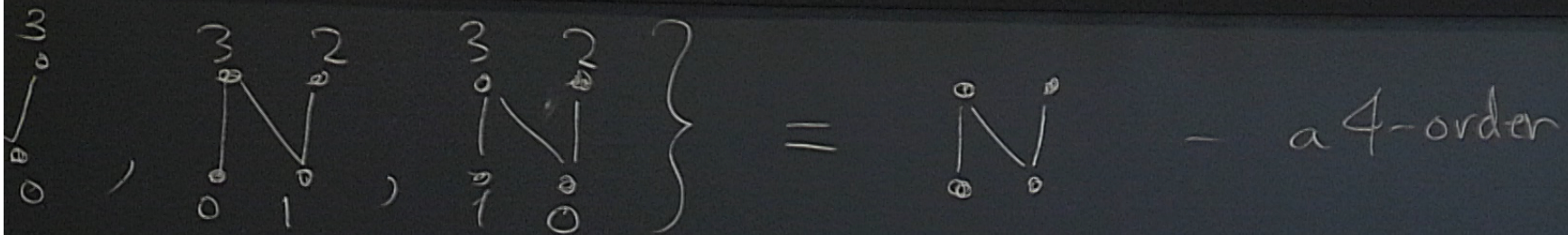
4. Covtree: a framework for label-free growth \leftarrow

5. Physical conditions: causality....?
Quantum growth....?

$$1. \left\{ \begin{array}{c} 2 \quad 3 \\ \circ \quad \circ \\ | \quad | \\ \circ \quad \circ \end{array} \quad , \quad \begin{array}{c} 2 \quad 3 \\ | \quad | \\ \circ \quad \circ \end{array} \quad , \quad \begin{array}{c} 3 \quad 2 \\ \circ \quad \circ \\ | \quad | \\ \circ \quad \circ \end{array} \quad , \quad \begin{array}{c} 3 \quad 2 \\ | \quad | \\ \circ \quad \circ \end{array} \right\} = \begin{array}{c} \circ \quad \circ \\ | \quad | \\ \circ \quad \circ \end{array}$$

~~$$\begin{array}{c} 1 \quad 2 \\ \circ \quad \circ \\ | \quad | \\ 3 \quad 0 \end{array}$$~~

← no labels like this.

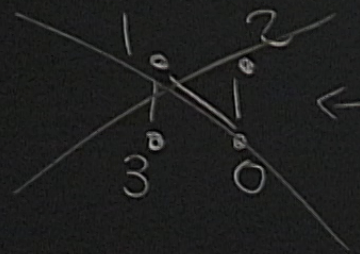


looks like this.

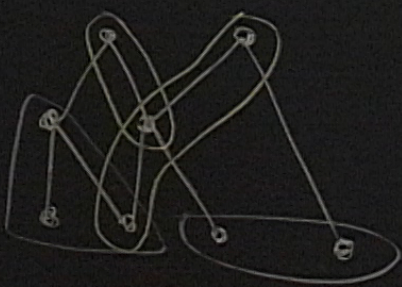
GC = "label invariance"

- ① physical statements do not refer to labels
- ② what else?

(0 1 , 1 0 , 0 1 , 1 0)



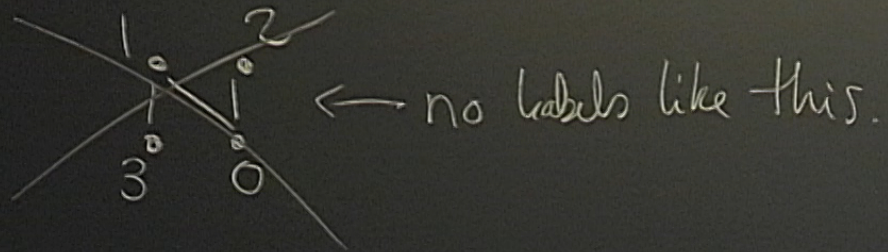
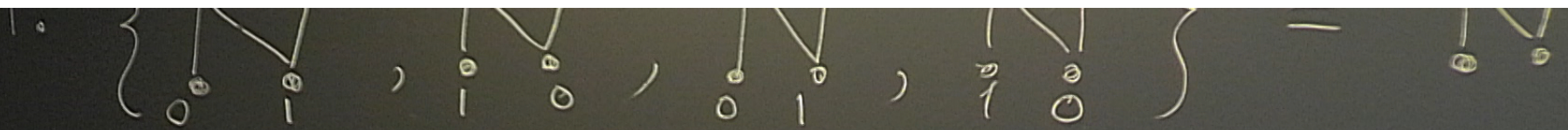
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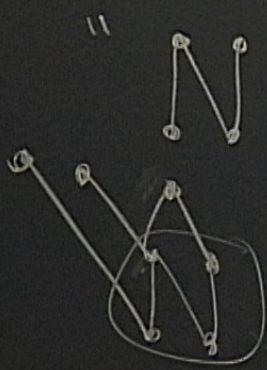
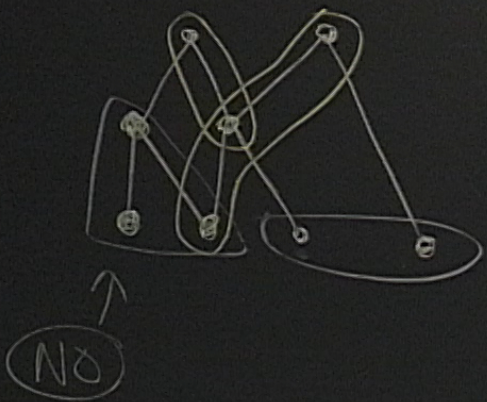
"N is a stem of the caused universe"

GC = "label invariance"

- ① physical statements done
- ② what else?



GC = "label invariance"
 ① physical statements
 ② what else?

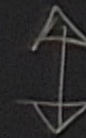


"N is a stem of the causal ^{set} universe"

e :
{
[B] Transitions from one state to
another state with transition probs

2. \boxed{A} Measure space:

$\{\Omega, \mathcal{O}, \mu\}$



Surya, Rideout, Cunningham.

pace :
 $\mu \{$

gham

[B] Transitions from one state to another state with transition probs

↓
Rideout & Sarkin's : Sequential Growth models ;

Sequence of transitions from n -element causal set to an $n+1$ -element causal set.

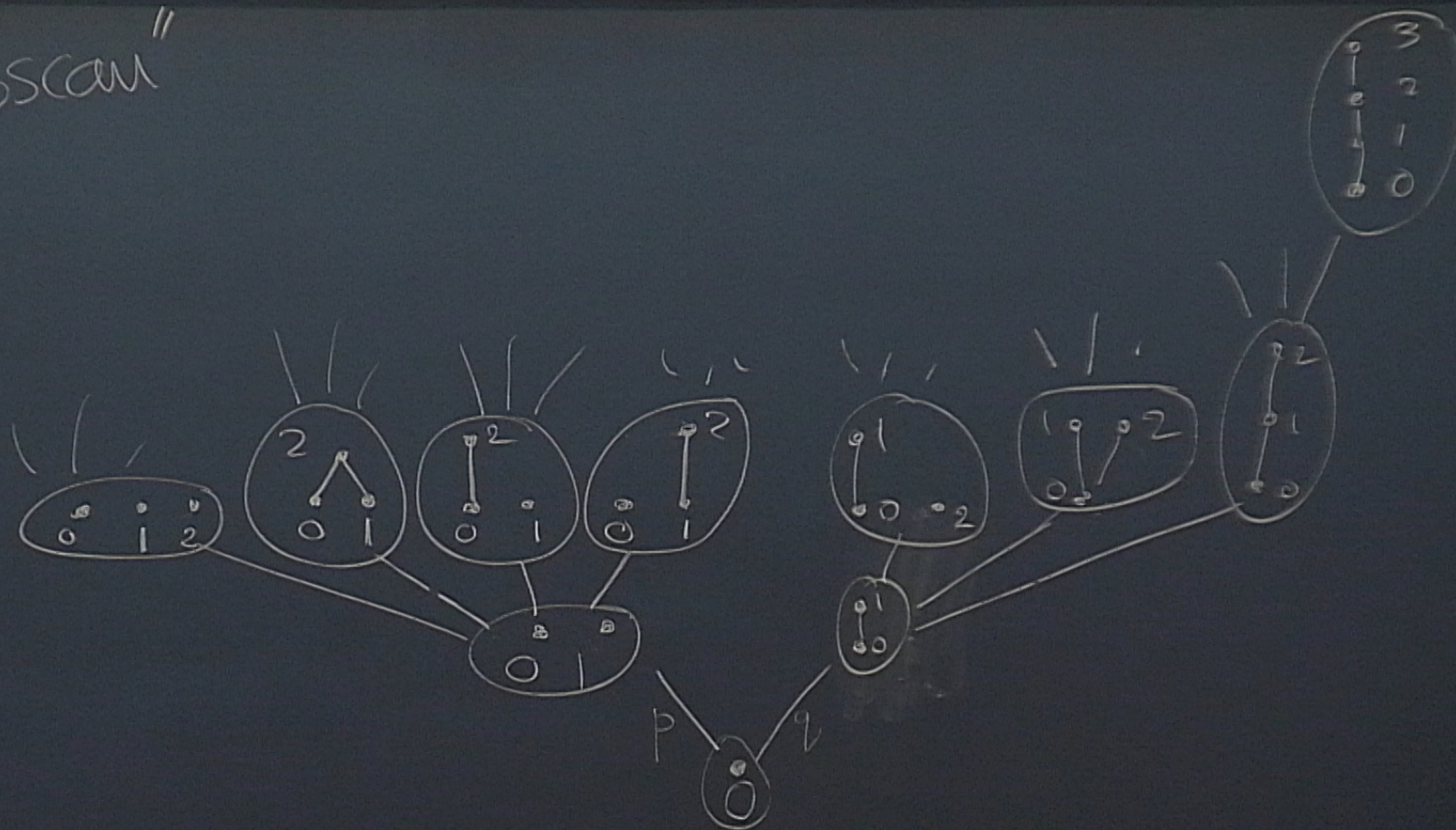
3. "poscan"

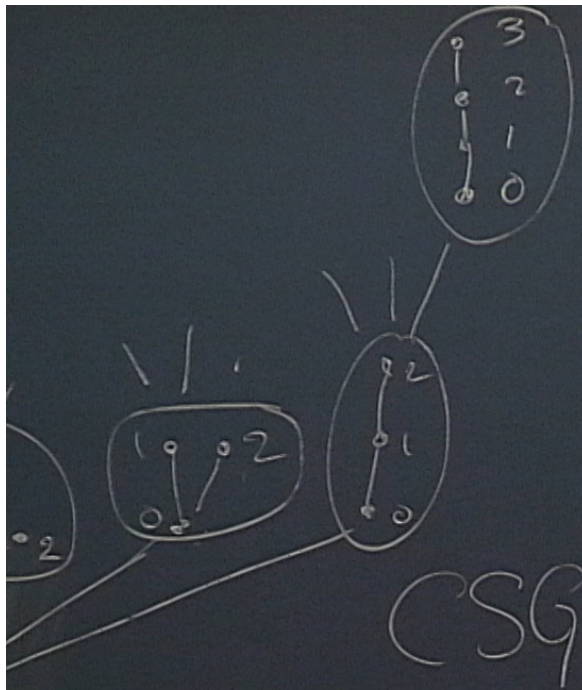
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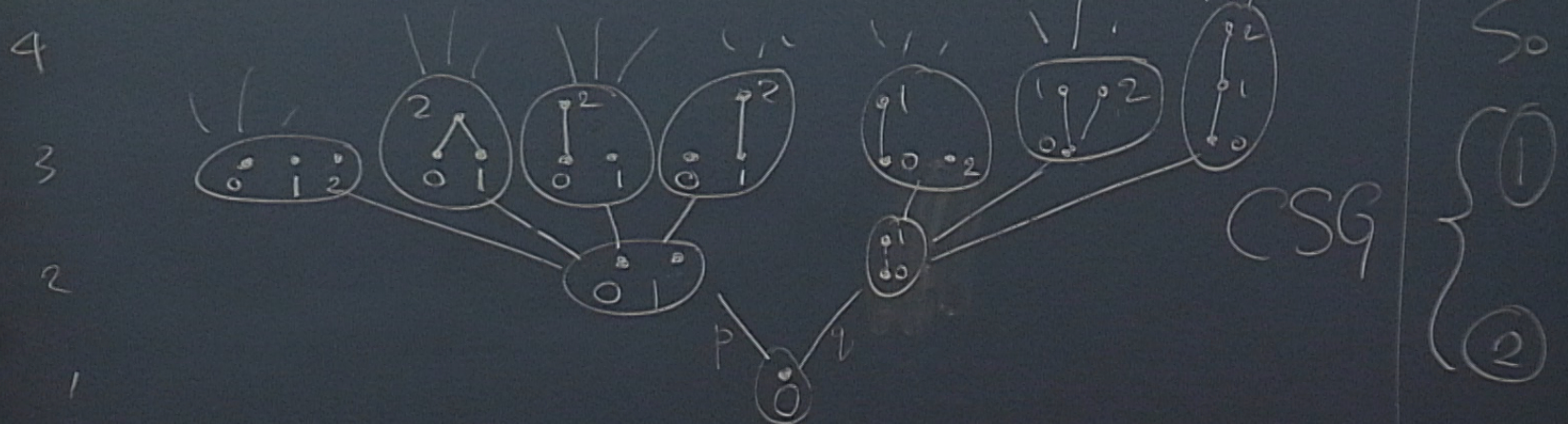


RW's up poscan : too many to be interesting

So RS imposed

- ① DGC - prob of arriving at a node doesn't depend on labels.
- ② Bell Causality.

3. "poscan"



All this gives us a measure space:

$$\{\tilde{\Omega}, \tilde{\mathcal{O}}, \mu\}$$

A measurable set $E \in \tilde{\mathcal{L}}$ is

covariant if $\{ \gamma \in E$

\Rightarrow all other labellings of $\gamma \in E$

$\text{stem}(N) = \{ \gamma \in \tilde{\mathcal{L}} \mid N \text{ is a stem of } \gamma \}$
is covariant

E
 new labellings of $x \in E$ } events : $\mathcal{O} \subset \tilde{\mathcal{O}}$
 N is a stem of x }
THEOREM FAPP
 $\mathcal{O} = \mathcal{O}_S$
 for any CSG model

CONTREE

