A Potential Mechanism for Emergent Observer-Based Space-Time

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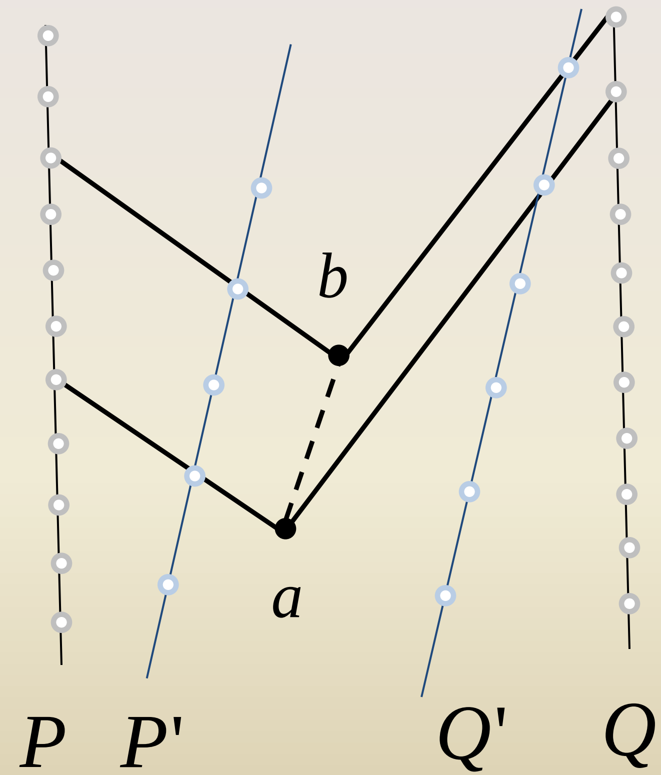


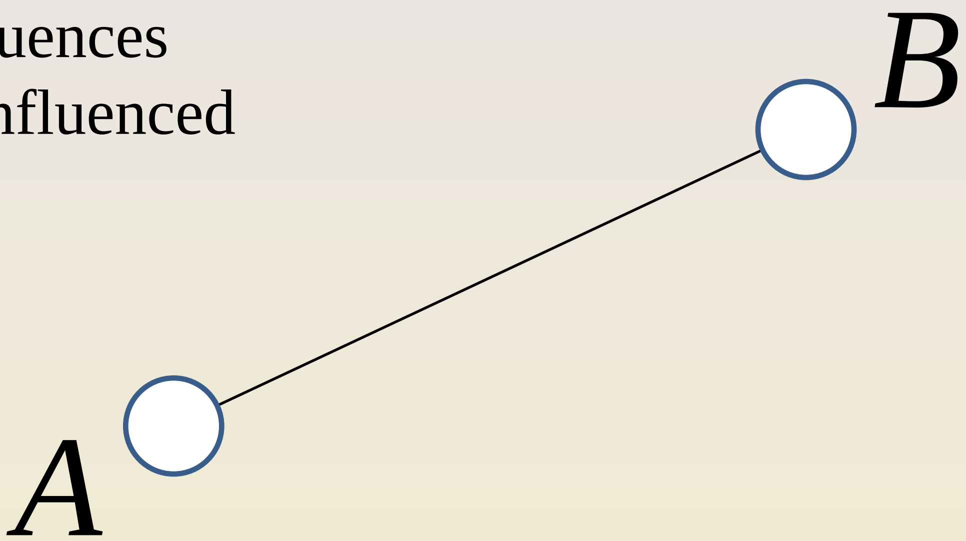
Consider the most basic properties of interactions and see what physics we get

Interactions and Events

An interaction defines two events and orders them

Event A: A influences
Event B: B is influenced

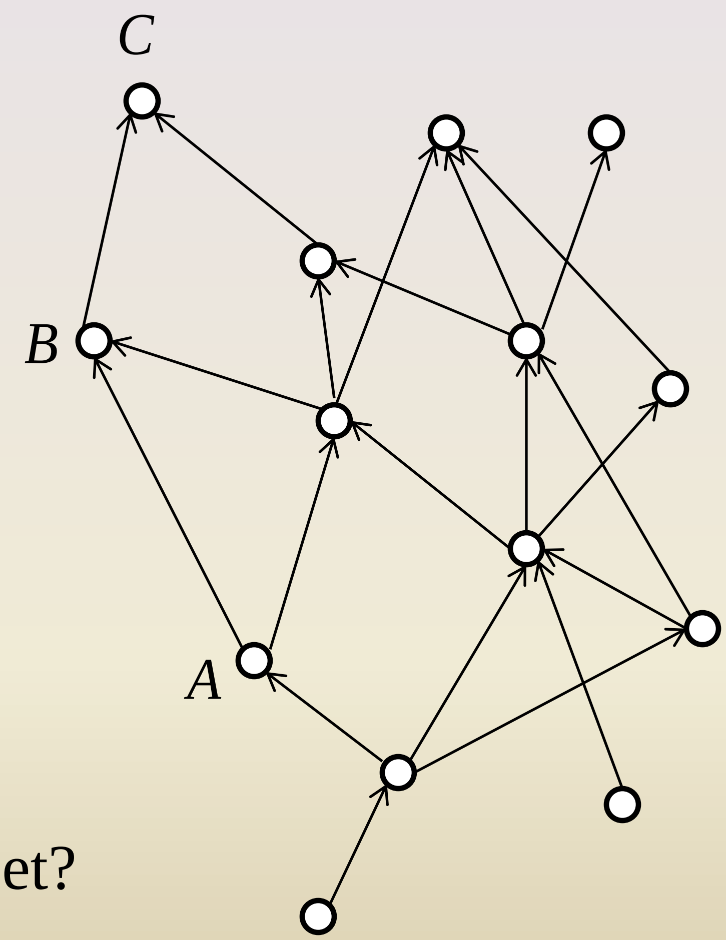
$$A \rightarrow B$$



The direction of the ordering relation is arbitrary.

Partially-Ordered Set of Events

A **Set of Events**
along with a
Binary Ordering Relation
results in a
Partially-Ordered Set of Events

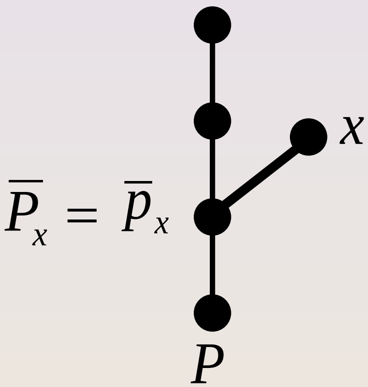


What constraints exist for consistent quantification of this partially-ordered set?

Chains are Easily Quantified

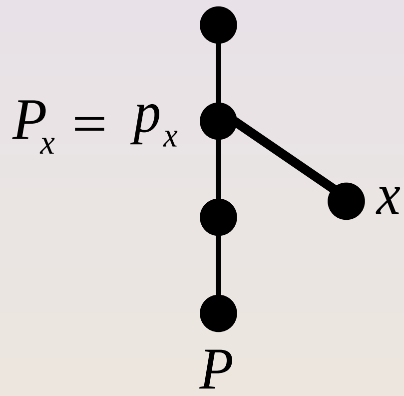
Other Elements can be Quantified by Relating them to a Chain

Projection Operator



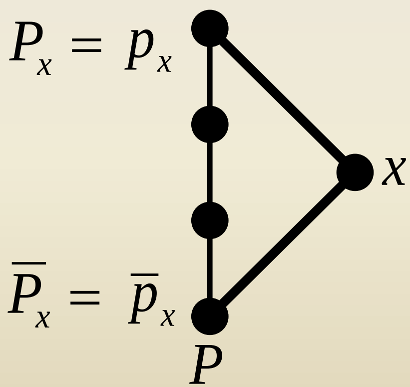
$p_i \leq x$ for all $p_i \leq \overline{p}_x$

$p_i \,||\, x$ for all $p_i > \overline{p}_x$



$p_i \geq x$ for all $p_i \geq p_x$

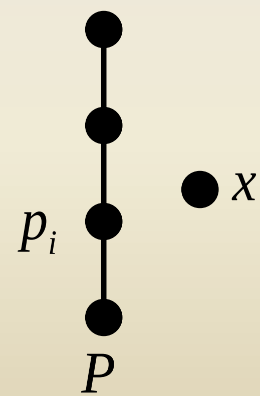
$p_i \,||\, x$ for all $p_i < p_x$



$p_i \leq x$ for all $p_i \leq \overline{p}_x$

$p_i \,||\, x$ for all $\overline{p}_x < p_i < p_x$

$p_i \geq x$ for all $p_i \geq p_x$

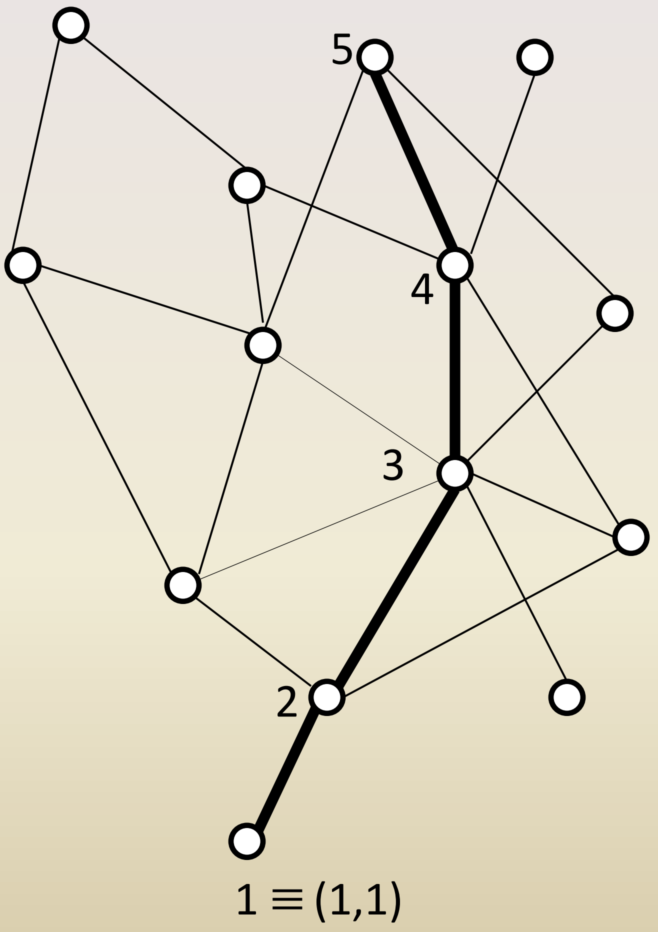


$p_i \,||\, x$ for all p_i

Quantification of a Distinguished Chain

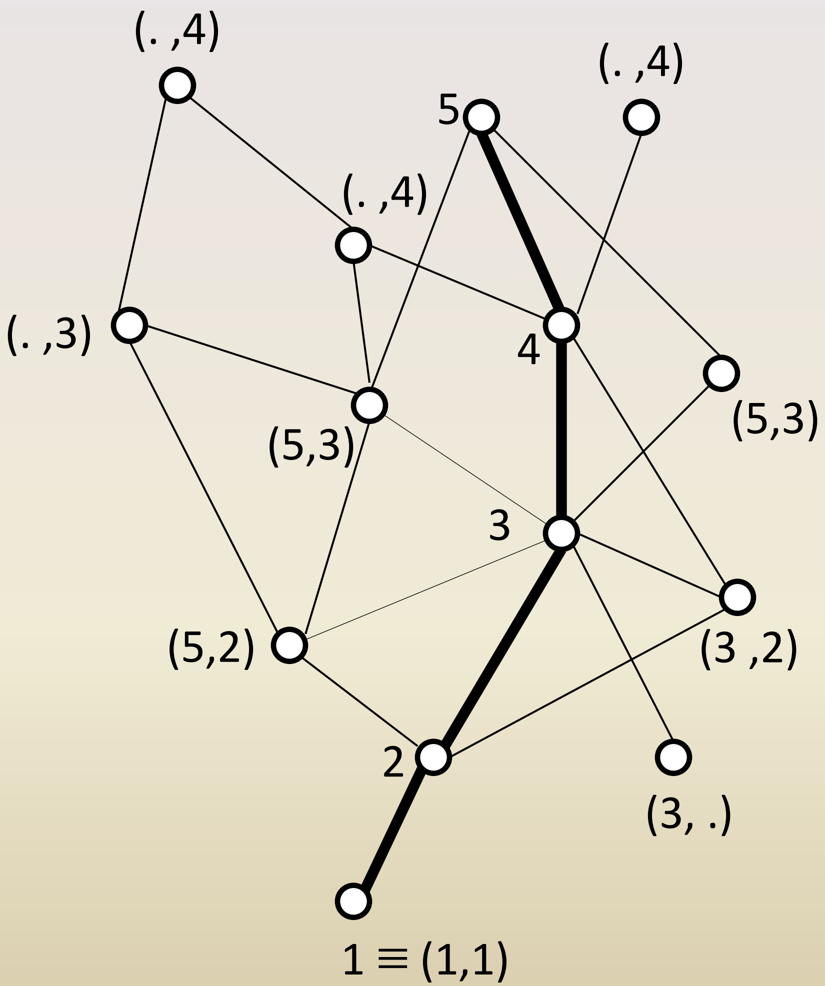
Distinguish a Chain (Observer Chain)

Quantify its elements with a
non-decreasing
sequence of numbers.



Quantification via Chain Projection

Quantify additional elements by projection onto the chain.



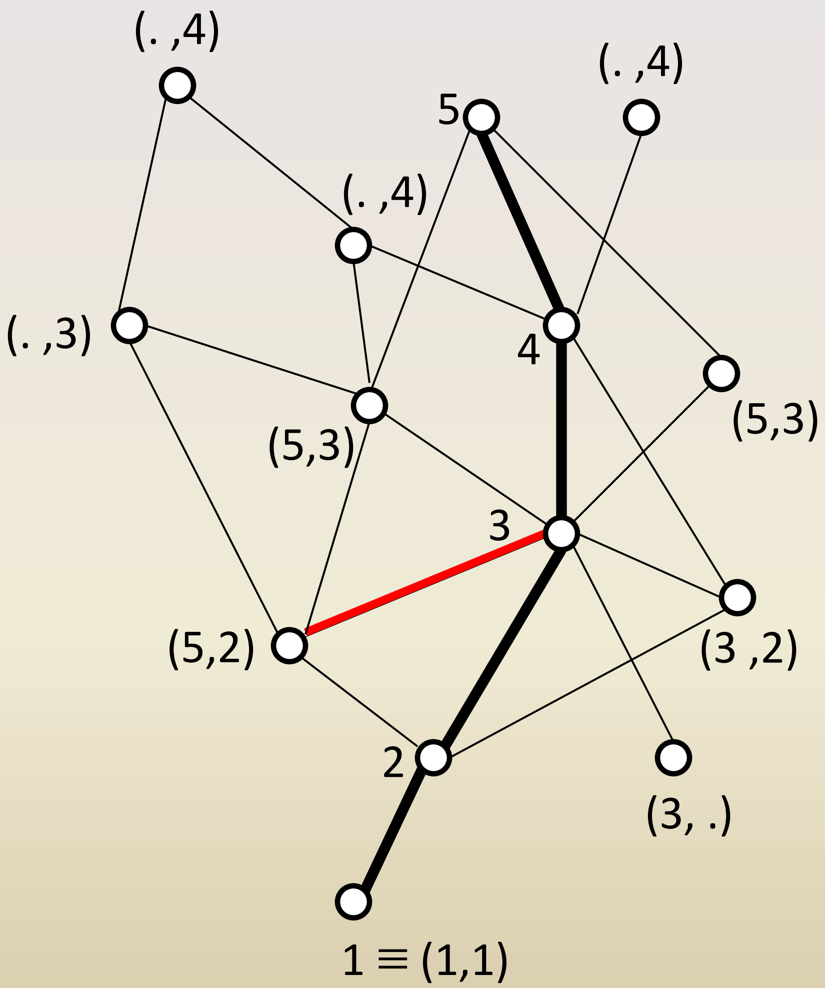
Intervals

Intervals can be defined by pairs of events

4-numbers (5,3;2,3)

pair (5-3,2-3) = (2,-1)

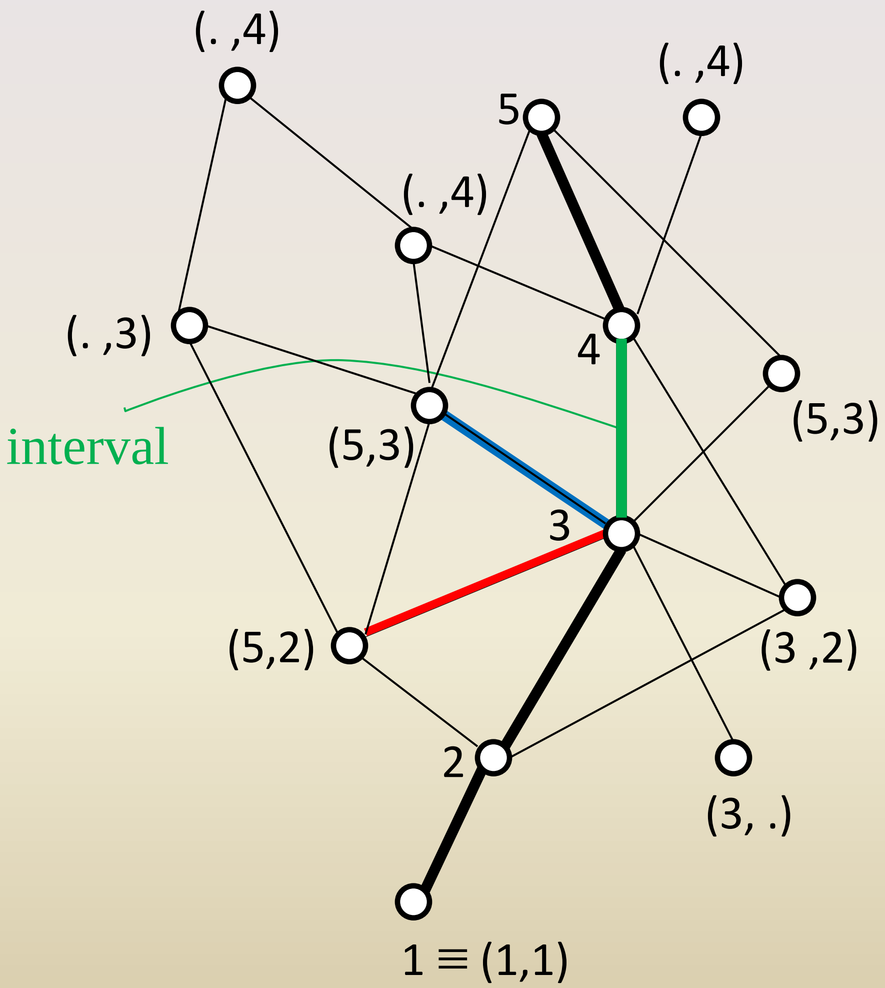
scalar (2)(-1) = -2



Intervals

Intervals can be defined by pairs of events

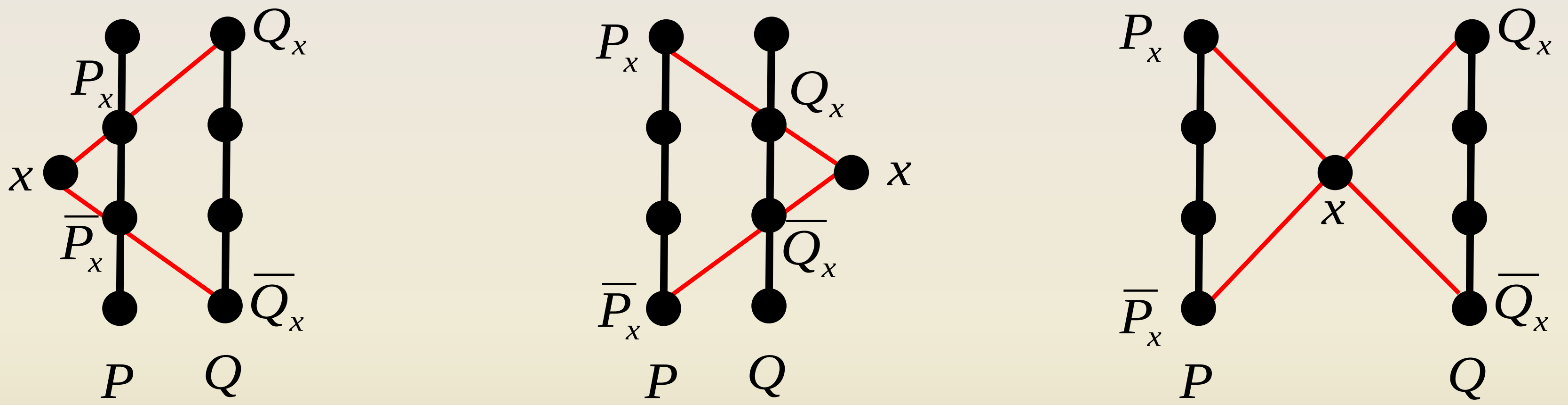
4-numbers	(5,3;2,3)
pair	(5-3,2-3) = (2,-1)
scalar	(2)(-1) = -2
pair	(5-3,3-3)=(2,0)
scalar	(2)(0) = 0
pair	(4-3,4-3) = (1,1)
scalar	(1)(1) = 1



Chains Induce Structure

Collinearity

An element x is said to be collinear with a finite chain P and a finite chain Q , iff the projections of x onto P, can be found by first projecting x onto Q and then onto P , and vice versa by interchanging the roles of P and Q.



$$QP_x = Q_x \qquad PQ_x = P_x \qquad Q\overline{P}_x = Q_x$$

$$\overline{Q}\,\overline{P}_x = \overline{Q}_x \qquad \overline{P}\,\overline{Q}_x = \overline{P}_x \qquad \overline{Q}P_x = \overline{Q}_x$$

Collinearity allows some chains to be *ordered*

Coordinated Chains Measure the Same Length for One Interval

Coordinated Chains

A set of chains are coordinated if an interval on one projects onto an interval of the same length on the others.

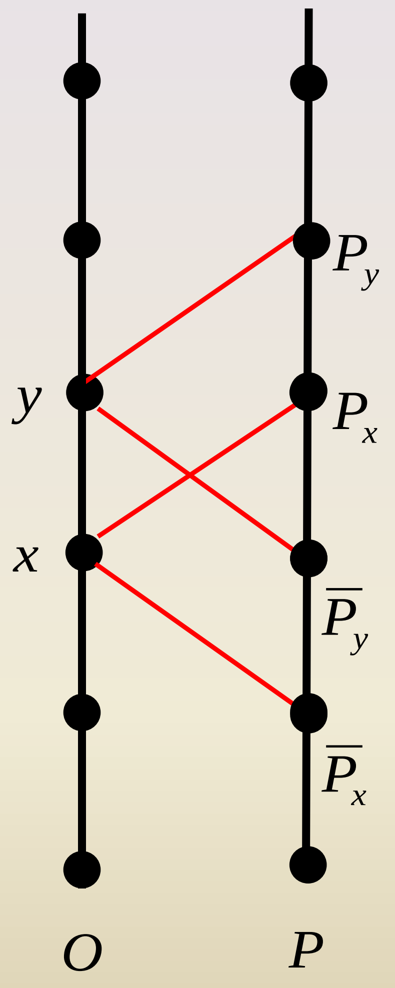
$$v(y) - v(x) = v(P_y) - v(P_x)$$

$$v(y) - v(x) = v(\overline{P}_y) - v(\overline{P}_x)$$

$$[x, y]|_P : (v(P_y) - v(P_x), v(\overline{P}_y), v(\overline{P}_x))$$

Equivalently, intervals can be quantified by forward projections alone using two coordinated chains.

$$[x, y]|_{OP} : (v(y) - v(x), v(P_y) - v(P_x))$$

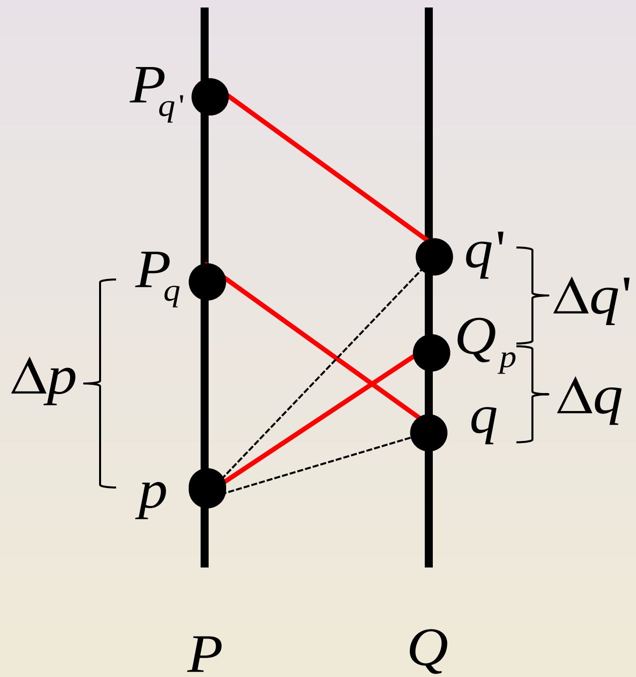


Distance Between Coordinated Chains

Distance Between Coordinated Chains

The distance between each pair of chains is found through chain projection using:

-Associativity of joining distances across chains
-arbitrary choice of events on the chains



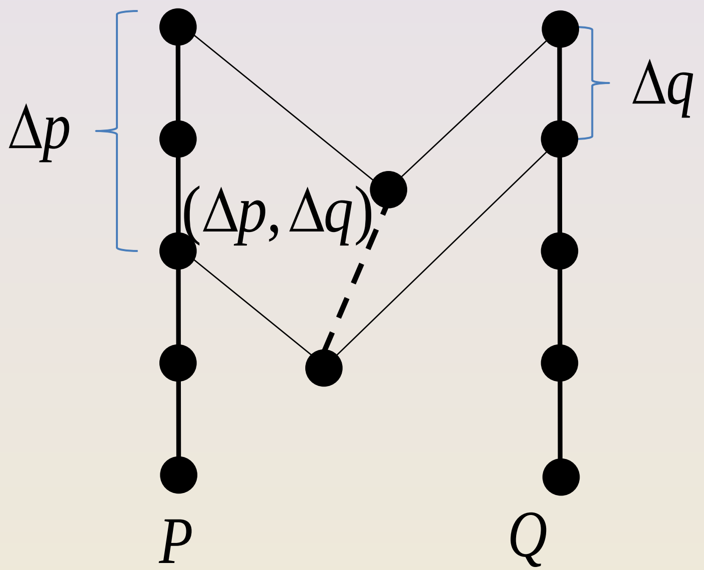
$$[p,q]|_{PQ} = (v(P_q) - v(p), v(q) - v(Q_p)) = (\Delta p, \Delta q)$$

$$D([p,q]) \propto |\Delta p - \Delta q|$$

$$D([p,q]) \propto |\Delta p - \Delta q'|$$

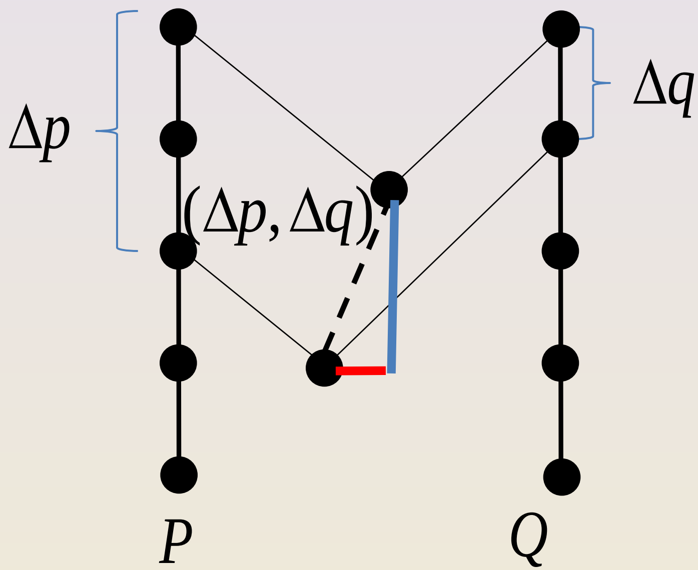
The Minkowskian Form Emerges from the Pair and Scalar Quantifications

Minkowski



$$(\Delta p, \Delta q) = \left(\frac{\Delta p + \Delta q}{2}, \frac{\Delta p + \Delta q}{2} \right) + \left(\frac{\Delta p - \Delta q}{2}, \frac{-(\Delta p - \Delta q)}{2} \right)$$

Minkowski

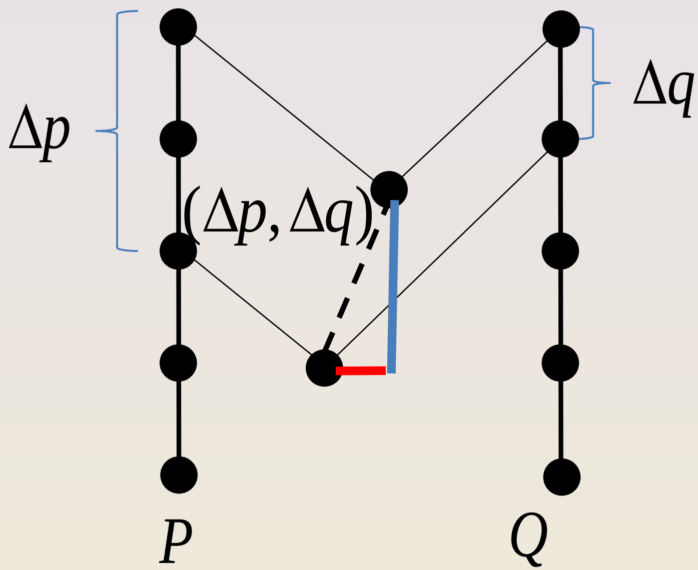


$$(\Delta p, \Delta q) = \left(\frac{\Delta p + \Delta q}{2}, \frac{\Delta p + \Delta q}{2} \right) + \left(\frac{\Delta p - \Delta q}{2}, \frac{-(\Delta p - \Delta q)}{2} \right)$$

Symmetric
(Δt,Δt)

Antisymmetric
(Δx,-Δx)

Minkowski



$$(\Delta p, \Delta q) = \left(\frac{\Delta p + \Delta q}{2}, \frac{\Delta p + \Delta q}{2}\right) + \left(\frac{\Delta p - \Delta q}{2}, \frac{-(\Delta p - \Delta q)}{2}\right)$$

Interval Scalar $$\Delta p \Delta q = \left(\frac{\Delta p + \Delta q}{2}\right)^2 - \left(\frac{\Delta p - \Delta q}{2}\right)^2$$

$\Delta p \Delta q = \Delta t^2 - \Delta x^2$ ***The Minkowskian Form***

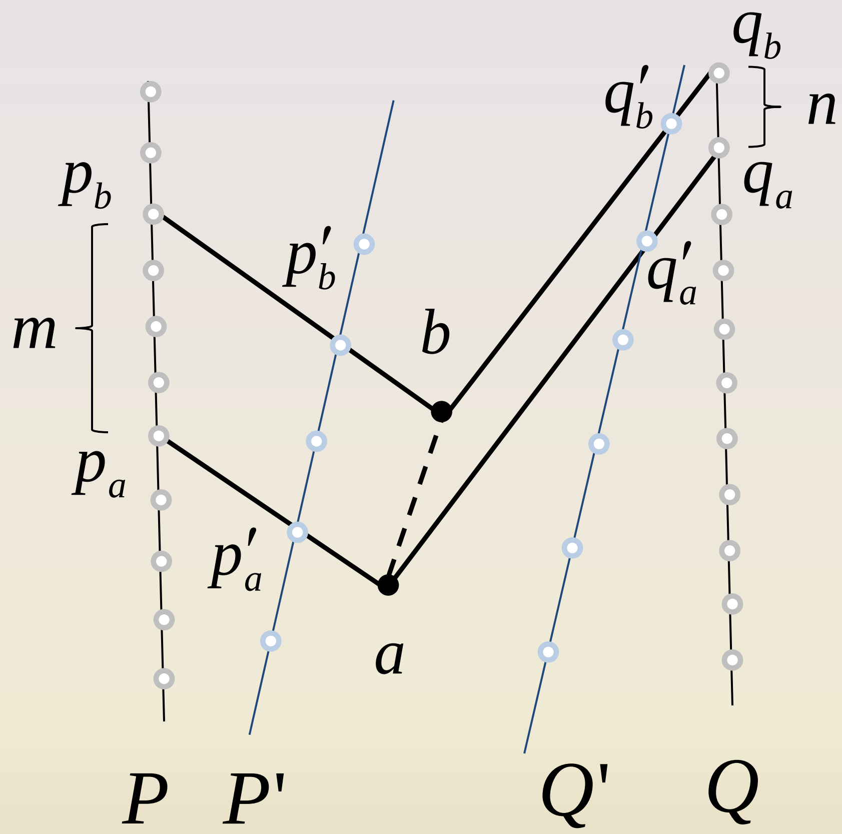
Changes from one Observer Chain to another is given by Lorentz Transformations

Transformations

$$(\Delta p', \Delta q') = \left(\Delta p\sqrt{\frac{n}{m}}, \Delta\, q\sqrt{\frac{m}{n}} \right)$$

$$\Delta p' \Delta q' = \Delta p \Delta q$$

Scalar is preserved
Equivalent to Bondi's K-calculus



Lorentz Transformation

$$(\Delta p' , \Delta q') = \left(\Delta p \sqrt{\frac{n}{m}} , \Delta q \sqrt{\frac{m}{n}} \right)$$

$$\left(\frac{\Delta t' + \Delta x'}{2} , \frac{\Delta t' - \Delta x'}{2} \right) = \left(\left(\frac{\Delta t + \Delta x}{2} \right) \sqrt{\frac{n}{m}} \; , \left(\frac{\Delta t - \Delta x}{2} \right) \sqrt{\frac{m}{n}} \right)$$

$$\begin{cases} \Delta t' = \dfrac{1}{\sqrt{1-\beta^2}} \Delta t + \dfrac{-\beta}{\sqrt{1-\beta^2}} \Delta x \\ \\ \Delta x' = \dfrac{-\beta}{\sqrt{1-\beta^2}} \Delta t + \dfrac{1}{\sqrt{1-\beta^2}} \Delta x \end{cases}$$

Lorentz Transformation with

$$\beta = \frac{m-n}{m+n}$$

$\beta \in [0,1]$ has a maximum invariant value of 1.

CONCLUSIONS

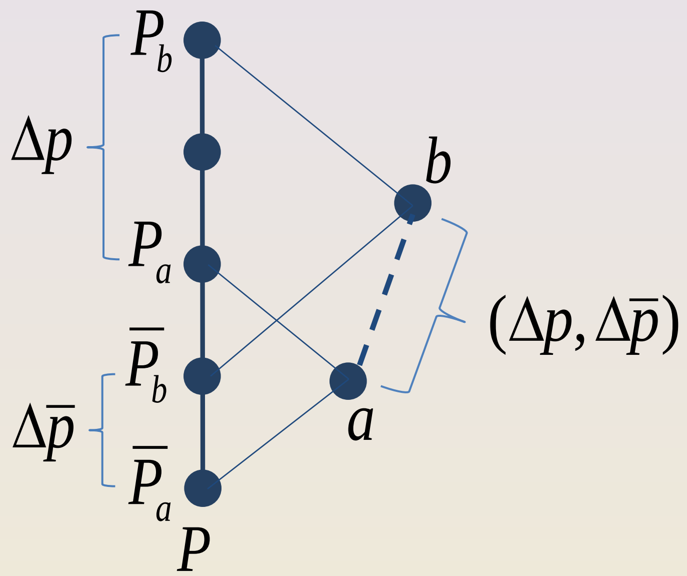
Treating the universe as a network of events and quantifying the network results in the Minkowski metric and Lorentz transformations in the case where observers are coordinated.

This suggests that the mathematics of space and time emerges as the unique means for an embedded observer to quantify the network.

Knuth K.H., Bahreyni N. 2012.
arXiv:1209.0881v1 [math-ph]

Intervals Can Be Quantified with 4, 2 and 1 Numbers

Quantification of a Generalized Interval



The generalized interval $[a,b]$ can be represented by

Four numbers $(P_a, P_b \,;\, \overline{P}_a, \overline{P}_b)$

Two numbers (**pair**) $(P_a - P_b \,;\, \overline{P}_a - \overline{P}_b) \equiv (\Delta p, \Delta\overline{p})$

One number (**scalar**) $(P_a - P_b)(\overline{P}_a - \overline{P}_b) = (\Delta p)(\Delta\overline{p})$