

THE RELATIVISTIC ORIGIN OF QUANTUM INDETERMINACY

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APPROACH

I will outline an argument related spacetime with quantum indeterminacy. Although the approach is philosophical / interpretational, there are physical consequences.

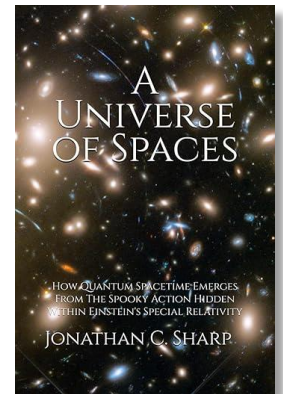
I am interested in issues such as the following, which (although relating relativity and QM) are not addressed by QM or QFT:

- *the quantum measurement problem*
- *quantum (Bell) non-locality*
- *ontology of quantum mechanics and spacetime*
- *quantum spacetime, as a precursor to quantum gravity*
- *Interpretation of quantum mechanics*
- ***Quantum indeterminacy (subject of today's talk)***

Approach: I will discuss the interpretation of special relativity within the framework of a many-spaces quantum spacetime (Sharp, 2024).

- (1) Mariani, The Determinacy Problem in Quantum Mechanics. Foundations of Physics (2024) 54:73
- (2) Del Santo and Gisin 2021, The relativity of indeterminacy arXiv:2101.04134v1).

For more on these topics and the Many-Spaces Quantum Spacetime, see: *A Universe of Spaces (Amazon)* J.C. Sharp (2024)



QUANTUM INDETERMINACY

Problem:

What is the origin of quantum indeterminacy?

(Is this even an answerable question?)

Outline

1. Disagreements between inertial observers
2. The status of these disagreements
3. Spacetime indeterminacy
4. Quantum indeterminacy

...key point: observational disagreements should be interpreted as physically real.

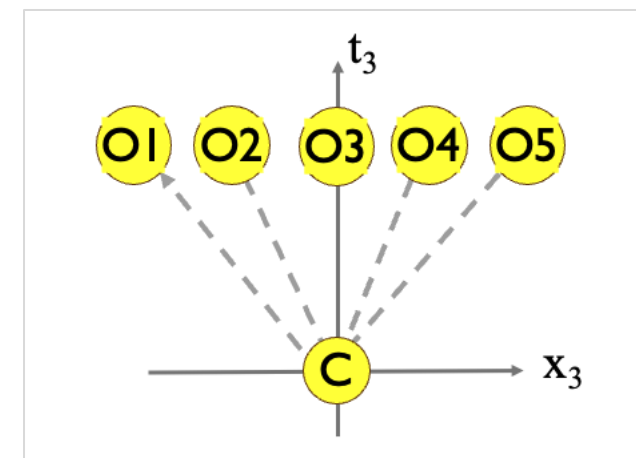
I) INERTIAL OBSERVERS DISAGREE

Inertial observers agree on **laws**
....but disagree on **observations**

Special Principle of Relativity (PoR):

If a system of coordinates K is chosen so that, in relation to it, physical laws hold good in their simplest form, the same laws hold good in relation to any other system of coordinates K' moving in uniform translation relatively to K .

—Albert Einstein: *The Foundation of the General Theory of Relativity, Part A, §1*



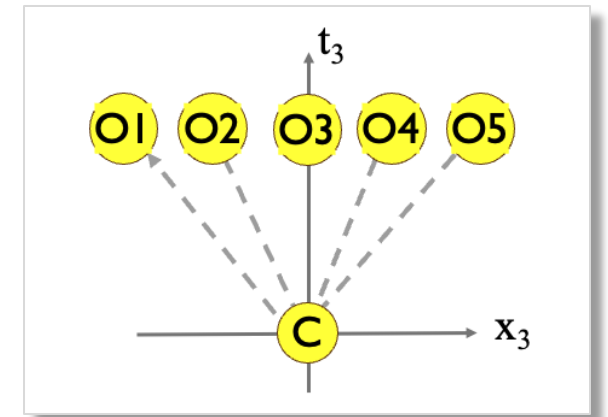
inertial observers

Agreement on physical laws is significant only because *inertial observers disagree on observations*. For example, each has their own proper time (which is non-negotiable; and not an arbitrary choice of coordinates).

2) STATUS OF THESE DISAGREEMENTS

Following the Principle of Relativity (PoR):

We should treat all observations as equally valid (physically real): we should co-consider the **ensemble of all inertial observers.**

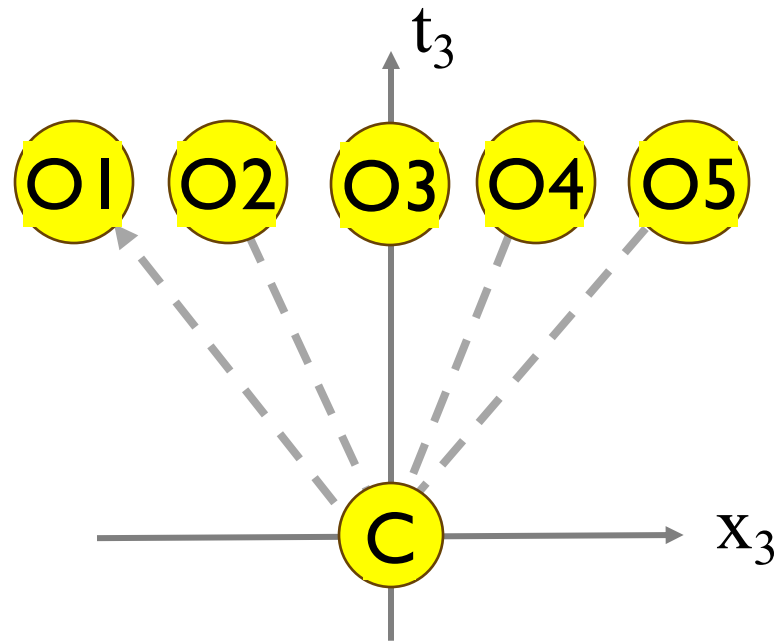


inertial observers

1. We should NOT *reject observations as unphysical (or irrelevant)*, just because they are observer-specific, and not objective, not invariant. (If we discard observation, what is left?)
2. We should NOT *select one preferred observer* (not even an “arbitrary” one, for calculation purposes). There is no physical justification for such a selection and a flagrant violation of the PoR.

Adopting this “ensemble approach” is a crucial step. Typically, various combinations of the first two positions (“rejection” and “selection”) are taken.

CONSIDER: AN ENSEMBLE OF INERTIAL OBSERVERS



Consider a set of inertial observers; each observer O_i occupies its own inertial reference frame.

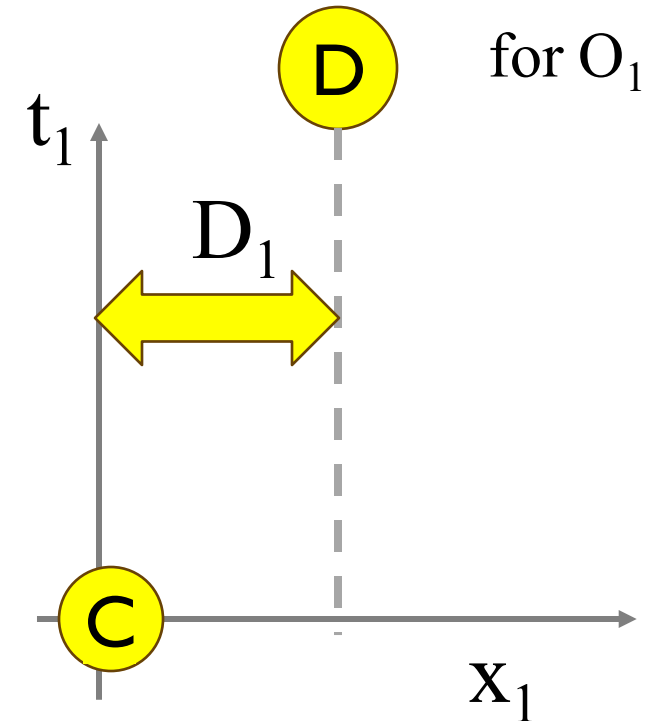
All inertial observers O_i are (were) *simultaneously colocated* at C (the best we can do).

Subsequently, they diverge.

DEFINITION: C-RELATIVE DISTANCE

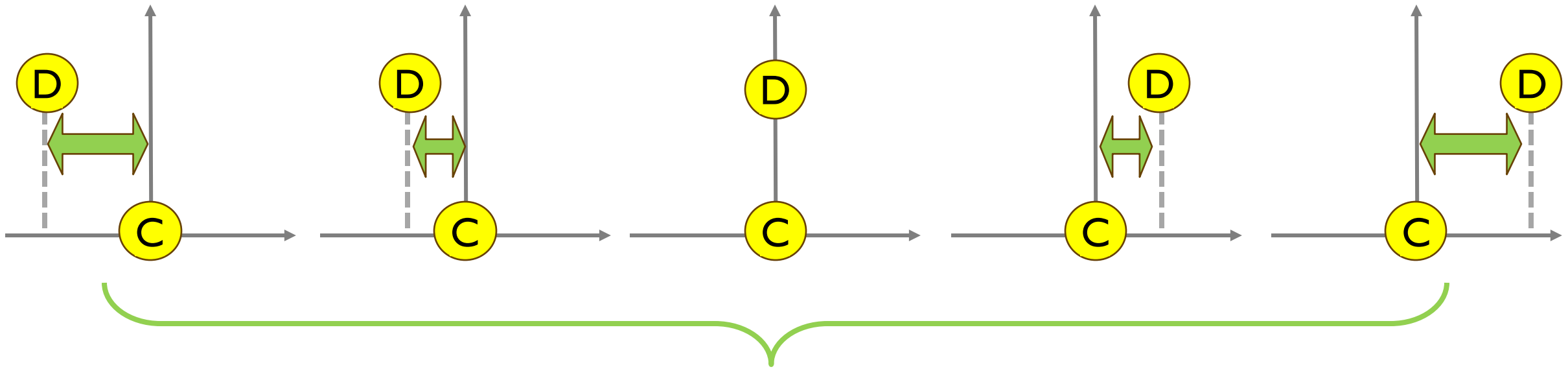
Definition:
C-Relative Distance, D_i is the spatial distance of event D , from C , as reported by observer O_i

- This is an observer-specific spatial distance
- It is not an objective spacetime interval

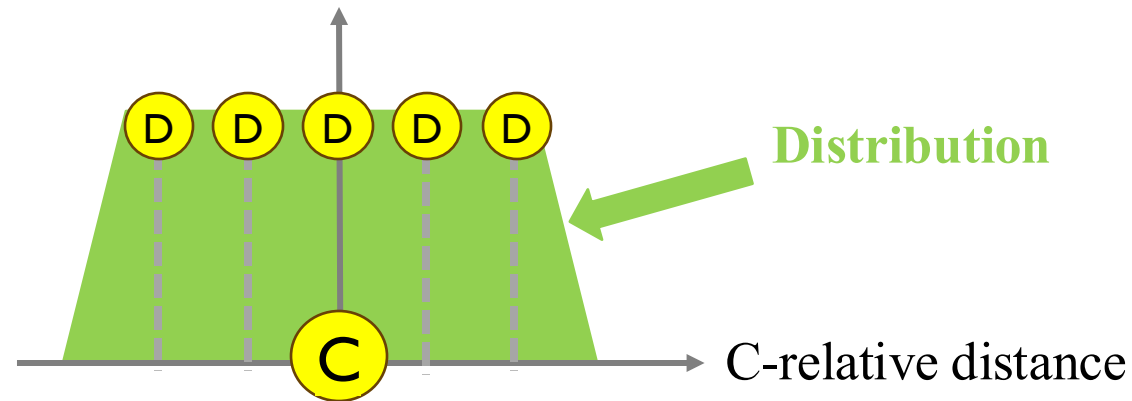


Consider two events, an event C , and a later, time-like separated event D , lying in the future light-cone of event C .

FOR AN ENSEMBLE, THERE IS A DISTRIBUTION OF C-RELATIVE DISTANCES



These disagreements happen at any velocity and would have been familiar even to Galileo. *The standard interpretation is that these disagreements are quite unremarkable, merely signifying the absence of any privileged spatial origin. Here we will adopt a different interpretation.*



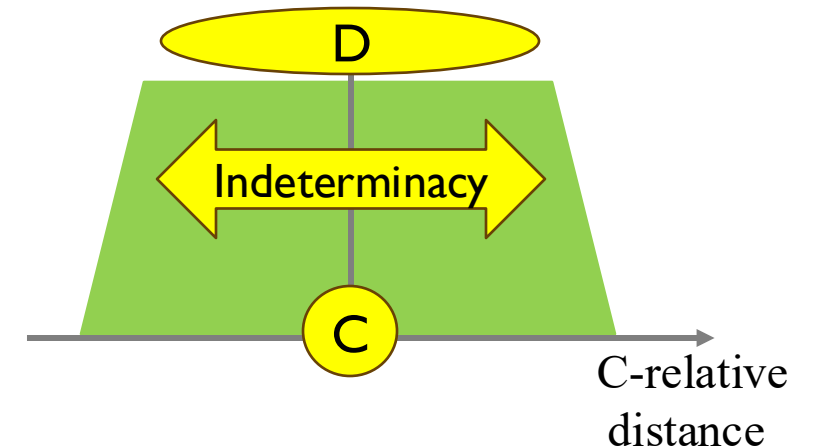
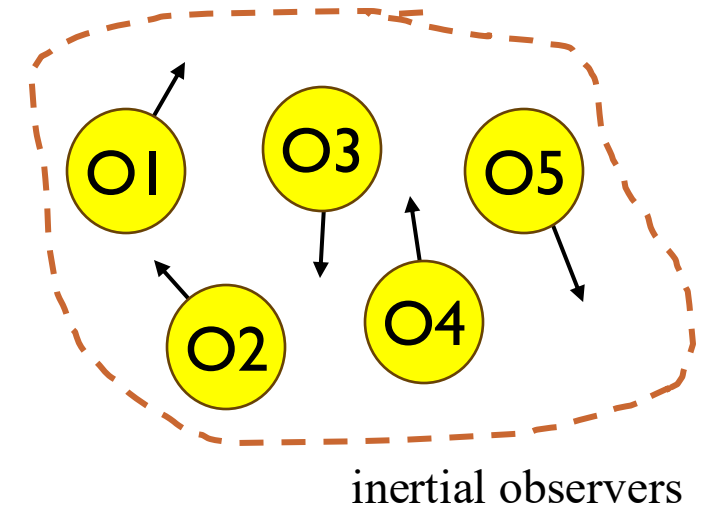
DISTRIBUTION \rightarrow INDETERMINACY

Even given the best possible synchronization / colocation, this distribution of C-relative values implies **indeterminacy**. (Because we are taking observation seriously)

I call this spatial indeterminacy property of the distance distribution **inertial ensemble indeterminacy (IEI)**.

Claims:

1. *There is no procedure for generating an objective (deterministic) value.*
2. *Any probe of the ensemble-as-a-whole can only yield an indeterministic outcome.*



WHEN IS INDETERMINACY SEEN?

IEI will be manifested given:

1. an ensemble (composite system) with elements related by Lorentz boost (velocities)
2. an integration mechanism, so that the entire system-as-a-whole may be interrogated

Case 1: Classical inertial ensemble

No observation of inertial indeterminism predicted - there is no mechanism to integrate the individuals into an ensemble. Simply re-naming a set of observers “an ensemble”, does not make any physical difference.

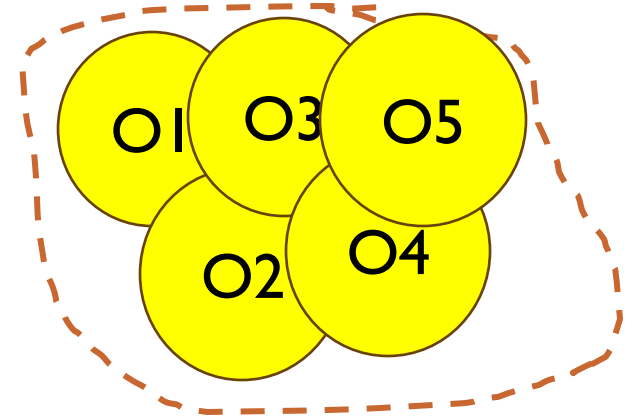
Case 2: Quantum momentum superposition

Inertial indeterminism is predicted to be seen, because (as we know from quantum theory) a quantum system is a single system, with elements related by the Lorentz boost (velocity).

IMPLICATIONS FOR QUANTUM INDETERMINACY

Argument:

1. A quantum momentum superposition has *quantum indeterminacy* (by definition), but also fulfills the conditions to manifest *inertial ensemble indeterminacy (IEI)* (single system).
2. Assuming that there is only a type, the two types of indeterminacy must be identical: the source of quantum indeterminacy is inertial indeterminacy.
3. Also, any probe of the whole system (quantum measurement) can only yield an indeterministic outcome (as is true) (e.g., does not return the mean value)



Is this circular logic?

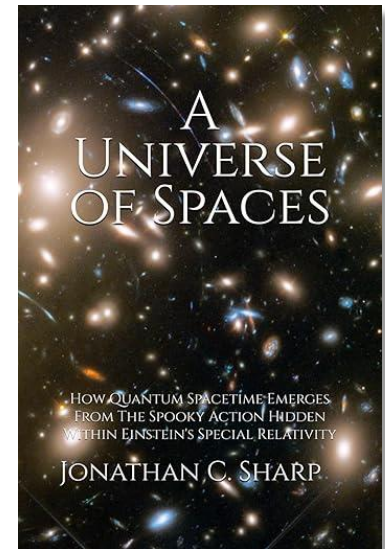
- No, the spacetime arguments given do correctly predict the indeterminacy of “integrated inertial Lorentz-boost ensembles” (quantum systems); it just seems odd and unexplained why such systems exist at all. That requires a larger discussion of the many-spaces quantum spacetime (Sharp, 2024).

CONCLUSIONS

- *Spacetime indeterminacy* is the origin of *quantum indeterminacy*
- *Philosophy*: there is no justification for neglecting the observational disagreements between inertial observers. This is as important in special relativity as the agreements on physical laws.
- *Context*: First, *quantum spacetime*, then *quantum gravity*
- *Deeper*: A much fuller explanation will involve a many-spaces ontology, that is a separate topic:-

This is in context of a larger project:

- Many-spaces quantum spacetime ontology
- Momentum as the fundamental basis
- Bell quantum nonlocality - explained
- Book: *A Universe of Spaces* (Amazon, 2024)
- “*How quantum spacetime emerges from the spooky action hidden within Einstein’s special relativity*”



Amazon

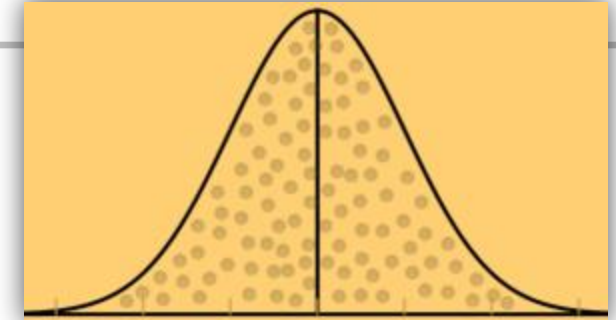
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RELATION TO EXISTING THEORIES

	Attitude of this work
Special Relativity (SR)	SR is foundational, but a new interpretation / ontology (physical picture) is proposed.
GR / Quantum Gravity	quantum spacetime >> quantum gravity!
Quantum Interpretations	a new spacetime-driven interpretation of QM (many-spaces) <i>A Universe of Spaces (Amazon) J.C. Sharp (2024)</i>
Philosophy of Quantum Indeterminacy	There are various proposals relating to indeterminacy, but mostly based on analysis of specific interpretations

- (1) Mariani, The Determinacy Problem in Quantum Mechanics. Foundations of Physics (2024) 54:73
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2B) MORE ON THESE OPTIONS



What are the various options for dealing with a distribution of values?

	Strategy		Interpretation	Example
a)	Rejection	No value from the distribution ever represents reality. Instead, other types of quantity are real.	“The distribution is non-physical”	A common approach to non-invariant quantities in relativity
b)	Selection	Select one value and discard the rest. Because the distribution is not fully real (actualized)?	“The distribution represents potential or possibility”	Quantum measurement (Born Rule)
c)	Ensemble	No action is required. Simply accept that all values are physically real.	“The distribution represents reality” (<i>metaphysical indeterminacy</i>)	Quantum superposition state. <i>Ensemble of inertial observers</i>

SUBMITTED ABSTRACT

Problem: Indeterminacy is a foundational principle of quantum physics. The fact that pure quantum systems possess properties with no definite single sharp value is a fundamental expression of this quantum indeterminacy. For example, an electron within an atom possesses no definite value of linear momentum. Although, in isolation, indeterminacy is not inherently problematic, there is arguably an inconsistency between quantum indeterminacy and the presumed definiteness of classical relativistic spacetime. We may ask: How is it that indeterminate quantum matter exists within a determinate spacetime? Mariani (1) discusses potential epistemic, semantic and ontological sources of quantum indeterminacy, while Gisin (2) and co-workers have proposed a new principle of "finiteness of information density" as a source of indeterminacy, related to the ontological status of the infinitely precise real numbers.

Aims: The aims of this work are to: a) to show that the source of quantum indeterminacy currently stands as an open question; b) to show that there is a fundamental (albeit latent) source of indeterminism arising from the principle of relativity; c) to show that the quantum measurement process has all the properties predicted to manifest this latent indeterminacy.

Argument in outline: Within the framework of special relativity, for an ensemble of coexisting inertial observers, there is irreconcilable disagreement on measurements of spatial and temporal intervals. For a classical system, observers remain independent so can "agree to disagree", and the conflict is benign and essentially just epistemic. However, in the corresponding quantum scenario (with each observer now part of one momentum superposition) disagreement at the observer level entails indeterminacy for the system as a whole. The argument turns on issues of spacetime ontology, quantum interpretation and quantum reference frames.

Discussion: In summary, it is proposed that long familiar relativistic disagreements emerge as the fundamental source of quantum indeterminacy. This is part of a program on a many-spaces quantum spacetime (Sharp, 2024).