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Unification of Quantum and Relativistic Measurements

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The notions of observation differ substantially between quantum mechanics and special / general relativity (SR and GR) and represents a barrier to a consistent understanding of quantum spacetime. I will firstly review these differing approaches to observation (or measurement), and secondly, outline an approach to address this.

Quantum Measurement
Quantum measurement has a *non-deterministic* aspect. The theory of measurement in quantum mechanics is highly developed (Braginsky, 1995), although the 'measurement problem'(classical-quantum divide) persists. Measurements may either weakly or strongly impact the unitary evolution of the quantum system. In all forms however, indeterminism remains a factor. Even in the most sophisticated quantum measurement protocols, such as continuous observation of quantum jumps (Minev, 2019), a baseline indeterminism remains.

Relativistic Measurement
In SR/GR measurement outcomes are deterministic, however there are also *observer-specific*: a reported value can depend upon the observer. In SR, relative velocity determines certain measurement outcomes. In GR, the coordinate system (state of motion) plays this role. Nevertheless, for a specified *system-observer relationship*, outcomes can be uniquely determined. In the case of SR, definite outcomes are tied to the Lorentz boost, and so are conditional on a definite relative velocity between system and observer.
While classically velocity definiteness is axiomatic, for quantum systems it is quite the opposite.

Momentum Basis
Can *non-deterministic* and *observer-specific* measurements be reconciled? Notice that velocity uncertainty (i . e . momentum superposition) will lead to relativistic indeterminacy. Momentum super-position renders the Lorentz boost indeterminant. For a consistent picture, we can also attribute measurement indeterminacy of quantum systems to momentum superposition, so that quantum uncertainty becomes a natural consequence of relativity. It follows that momentum (or velocity) is the preferred basis for quantum superposition. This also leads to a many-spaces ontology [3].

[1] Braginsky and Khalili, Quantum Measurement, Cambridge University Press, 1995.

[2] Minev ZK et al. 200 Nature Vol 570 13 June 2019 https://doi.org/10.1038/s41586-019-1287-z

[3] Sharp JC. One Universe, Many Spaces: A Non-Local, Relativistic Quantum Spacetime 10.20944/preprints201805.0003.v1

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