The Impact of the Energy-Time Indeterminacy Relation on the Ontology of Spacetime

Draft Abstract

Unlike the indeterminacy relation between position and momentum, the energy-time relation has yet to receive a solid formal mathematical treatment as its sibling. Since, according to many quantum theorists, time appears only as a parameter in the formalism of quantum mechanics and not as an operator/observable is sufficient to doubt the foundational value of the energy-time relation. In spite of this void, experimental evidence seems now overwhelming for setting the energy-time relation on solid physical grounds.

The extraordinarily fast decay of resonance particles, for instance, indicate that the time indeterminacy, Δt, is given by its short lifetime. This gives rise to a large indeterminacy in the energy of the particle and therefore to its mass as well, sometimes up to 20% of the overall energy-mass of the particle.[i] Similarly, the decay of the nuclei of ^{57}Co into ^{57}Fe gives an indeterminate width ΔE for the intermediate state of decay with lifetime Δt. Their product results in Planck's constant, confirming the particular relation between energy and time.

Concerns persist, however, about the lack of a general formalization and meaning of the energy-time relation, especially when compared to the position-momentum relation. Paul Busch has recently argued that there is no universal energy-time relation, but rather a series of energy-time relations that vary, and can be appropriately justified, in different contexts.[ii] This, I will argue, rests on the nature of the different meanings of time in those different contexts, what Busch terms the "ambiguity concerning time in quantum theory." Hence, in the earlier examples, time stood for the lifetime of a resonance particle. While later, in the decay of ^{57}Co nuclei decay, time stood for the lifetime of the intermediate state between decays. Other times the time can be the independent measurement of a laboratory clock. In some situations, according to some, time can be identified as a quantum observable possessed by some system as a property.

Once some of these different energy-time relations and their respective notions of time are examined in concrete experiments, like the ones above, I will argue for an ontological indeterminacy interpretation of the relation and not just a mere epistemological uncertainty relation. This indeterminacy relation of energy-time entail that a system's status is intrinsically dependent on the time. In an extreme idealized case, when the time of a system (in whatever aspect time is taken to be) is set precisely, what we would normally call an instant, $\Delta t \to 0$, then the energy of the system is fully indeterminate, $\Delta E \to \infty$, and therefore the system ceases to have well defined boundaries.

Then the ontological consequences of this interpretation of the time-energy relation are examined for events in spacetime and for the nature of spacetime itself.

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[i] Greenstein and Zajonc. *The Quantum Challenge: Modern Research on the Foundations of Quantum Mechanics.* Sudbury, MA: Jones and Bartlett Publishers, 2006, p. 62.
[ii] Paul Busch. "The Time-Energy Uncertainty Relation" in *Time in Quantum Mechanics*, eds. J. G. Muga, R. Sala Mayato, I.L. Egusquiza, Springer-Verlag, Berlin (2002) pp. 69-98. 2nd edition in preparation