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Quantum Clocks and Time

In general relativity, the picture of spacetime assigns an ideal clock to each spacetime point. Being ideal, gravitational effects due to these clocks are ignored and the flow of time according to one clock is not affected by the presence of surrounding clocks. However, if time is defined operationally, as a pointer position of a physical clock that obeys the laws of quantum mechanics and general relativity, such a picture is at most a convenient fiction. We show that the mass-energy equivalence implies gravitational interaction between the clocks, while the superposition of energy eigenstates leads to a non-fixed metric background. Based only on the assumption that both quantum mechanics and general relativity are valid in this situation, we show that the clocks necessarily get entangled through time dilation effect, which eventually leads to a loss of coherence of a single clock. Hence, the time as measured by a single clock is not well-defined. However, the general relativistic notion of time is recovered in the classical limit of clocks.

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