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Informational arrow of time in an extended two-qubit Page-Wooters model

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Abstract The Page-Wooters (PaW) mechanism explains time as a relational phenomenon within a globally stationary quantum state. In a seminal optical realization, Moreva et al. demonstrated that conditioning on a clock photon yields apparent dynamics,

while an external perspective sees stasis. We extend this framework by introducing auxiliary quantum systems that model the observer's incomplete access to the universe. In a two-qubit PaW toy model, global unitaries act on subsystems of the total state, and tracing out inaccessible degrees of freedom induces effective noise on the observed system. This transformation converts reversible correlations into irreversible entropy growth. We show that the von Neumann entropy of conditional system states increases monotonically across successive clock readings, thereby defining an informational arrow of time. Analysis of dephasing and depolarizing channels illustrates how limited access to the universe naturally yields temporal asymmetry, providing an information-theoretic route to time's arrow in finite quantum systems.

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