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A quantum cellular automaton extension of quantum field theory

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Quantum cellular automata extend Quantum Field Theory (QFT) to include localized states and observables. They can provide a simple unified framework to describe the Planck scale, the ultra-relativistic regime, along with the usual QFT. The latter is recovered in the "field-limit" of the automaton, for infinitely many time-steps and space-periods, the period of the automaton representing the Planck distance. Lorentz covariance along with all symmetries and dispersion relations are violated, and are recovered only in the relativistic field-limit. The quantum-automaton framework is also relevant for QFT foundations, since it can be derived from principles of pure information-theoretical nature, achieving Wheeler's assertion that "Physics is Information". In this talk I will review the phenomenology occurring in the case of the quantum automaton corresponding to the Dirac field in 1 dimension, in all regimes. The Dirac equation is just the equation describing the pure flow of quantum information. The field-limit is achieved through an analytical approximation, describing very closely the automaton for smooth delocalized states, and leading to a diffusion equation with a drift. Computer simulations will be shown in real-time during the talk, for single-particle states. A fundamental kind of violation of dispersion relations occurring for all such automaton theories is a mass-dependent refraction index of vacuum, predicting that the Planck mass is the maximum particle mass. The new informational principles open totally unexpected routes and re-definitions of mechanical notions (as inertial mass, Planck constant, Hamiltonian, Dirac equation as free flow of information). The automaton can be also considered an "ab-initio quantum" theory, whereas the classical mechanics is recovered from the automaton in terms of the amplitude crest, whereas the Lagrangian is reversely obtained from the unitary of the automaton. The field is eliminated and substituted by localized qubits. For dimension larger than 1 the anti-commutativity of the field is achieved by localized qubits, thus solving the Feynman problem of simulating anti-?commuting fields by a quantum automaton. Here an unexpected role is played by associated Majorana fields (also achieved by qubits): the latter, being prepared in a special vacuum, are simply witnessing the evolution, accounting just for the anti-commutation of Dirac fields.

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