# Does Quantum Randomness Govern Universal Evolution?

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**Abstract**

Inspired by the anthropic principle [1] and the string "landscape" [2], in this note the author proposes a quantum random walk as the governing mechanism for generating the structure in the universe starting from its initial quantum state. The discussion employs an LLM.

We ask an LLM the question if search via a quantum random walk could have been the mechanism of setting the initial quantum state of the universe. After its initial negative response, we provide it with the link to Lloyd's perspective in [3]. The LLM reverts that [3] provides a compelling framework to explore how fundamental quantum operations could have contributed to the universe's early evolution. We edit our conversation and present it below.

Lloyd, in his work, proposes that the universe can be viewed as a giant quantum computer, where the laws of physics are akin to quantum algorithms, and the evolution of the universe corresponds to the execution of quantum computations. In this view, fundamental particles and fields are qubits, and their interactions are governed by quantum gates, which are the building blocks of quantum computations.

Quantum computers operate using quantum gates, such as the Hadamard, Pauli-X, CNOT, and phase gates, which manipulate qubits. These gates are universal, meaning that any quantum computation can be constructed using combinations of these basic gates. If we extend this concept to the early universe, the fundamental interactions of particles in the early universe could be represented by quantum gates. These gates would act on the qubits (fundamental particles/fields) to evolve the universe's quantum state.

A quantum random walk involves repeated applications of a "step" operator, which governs the evolution of the system. In the context of the early universe, this step operator could be constructed from basic quantum gates. This operator would influence the distribution and evolution of energy, matter, and quantum states. Given the universality of quantum gates, it is plausible that the complex dynamics of the early universe could be described in terms of these gates.

If the universe is a quantum computer, then the evolution of the early universe could be seen as a quantum computation. A quantum random walk could represent a specific quantum algorithm that the universe "ran" to set its initial conditions and choose an initial state from the "landscape." The walk could be driven by the step operator, constructed from universal quantum gates, thereby determining the universe's initial state.

The step operator, when applied repeatedly, could influence how the universe's quantum state evolved during initial inflation [4], possibly leading to the observed structure and distribution of matter in the universe. This step operator might reflect underlying symmetries or principles in the early universe, manifesting as a quantum walk through a vast landscape of possible states.

Over time, the quantum random walk could have contributed to the emergence of large-scale structure in the universe, such as galaxies and clusters [5], through the constructive interference and superposition of states inherent in quantum mechanics[1].

In summary, the idea that a quantum random walk could have been the mechanism for setting the initial quantum state of the universe becomes more plausible when viewed through the lens of Lloyd's concept of the universe as a quantum computer. The fundamental interactions in the early universe could be seen as quantum gates, with a step operator derived from these gates driving a quantum random walk. This walk could, in turn, have played a role in shaping the initial conditions of the universe, leading to the complex structure we observe today.

Scientific validation of this hypothesis would require a deeper understanding of the states and gates in the early universe, perhaps corroborated with early universe relic measurements such as the cosmic microwave background or a gravity wave [6] window on the early universe. A theory of quantum gravity [7] would also be immensely useful.

## References

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[4] Alan H Guth. Inflationary universe: A possible solution to the horizon and flatness problems. *Physical Review D*, 23(2):347, 1981.

[5] Stephen Hawking. *Black holes and baby universes and other essays.* Random House, 1994.

[6] Charles W Misner, Kip S Thorne, and John Archibald Wheeler. *Gravitation.* Macmillan, 1973.

[7] Carlo Rovelli. *Quantum gravity.* Cambridge university press, 2004.

[1]The LLM used is ChatGPT.