Speed of the wavefunction collapse

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Abstract

Speed of the wavefunction collapse is calculated assuming the universe is a vast cellular automaton.

Keywords: cellular automaton, wavefunction collapse

Whether nature is a cellular automaton or at least if an automaton can be used to simulate Planck scale physics is a long researched subject. The concept was originally discovered in the 1940s by Stanislaw Ulam and John von Neumann. Conway's Game of Life, a two-dimensional cellular automaton helped to increase interest in the subject. A partial list of publications on cellular automata includes [1–9]. Emergence of a unified theory of physics is the goal of a final version based on this approach. The Planck length is the natural candidate to be used as the distance between the automaton cells[1]. Quantum mechanics would emerge as a limiting case of this more comprehensive theory.

On the other hand, the wave function collapse is another aspect of quantum physics thoroughly debated by physicists. One of the recent works is a paper by A. Jabbs [11], in which he analyzes the reduction of a pair of wavepackets in their center frame (see references there for additional related works).

In this letter, we calculate the collapse speed assuming the Universe is a 3d cellular automaton[2] whose cells can only communicate with their six imediate neighbor cells (von Neumann convention). This automaton is closed on itself as a torus. Time is Newtonian, i.e. absolute, but discrete, ruled by the automaton's clock. Moreover, the automaton's lattice forms a preferred reference frame.

A key ingredient to achieve an isotropic behavior on an automaton is the generation of an isotropic wavefront. One difference between ours and some of the cited automata is that light speed is not one lattice spacing per clock tick, but is a larger count. Isotropic propagation of a wavefront is achieved in the limit when the number of cells tends to infinity by using the approach developed by Case, Rajan and Shende in [13]. The novel feature of that work is that, to obtain the isotropy, is required for each expansion step, executing n steps of the basic algorithm of the

[1] A comprehensive discussion of what would be the shortest distance in the context of quantum gravity can be seen in [10]. There, L. J. Garay shows that the uncertainty principle, the constancy of the speed of light, and the equivalence principle all converge to the same limit.

[2] For an opposite view see Wharton [12].

automaton, where n is two times the diameter of the universe D (space diagonal). Henceforth we will refer either to lattice speed s or to light speed c. Then we have the relation

$$s = 2\,D\,c,$$

where D is given by

$$D = int((SIZE - 1)\lceil\sqrt{3}\rceil)$$

and $SIZE$ is the side of the universal cube.

An important remark is in order here: The fact that the speed of information transfer from cell to cell, s, is so high does not mean that information in the physical sense travels faster than the speed of light. It is just an internal mechanism to equalize wavefronts and other physical properties. Being nonlocal in the strict sense, it does not mean that the modeled physics should be necessarily nonlocal.

While the wavefront during the spread of the wave function is synchronous in order to guarantee a perfectly spherical shape, the wavefront in the collapse phase is asynchronous and therefore much faster, or superluminal, fitting entirely between two consecutive light steps. In the case of the collapse step, the total raw time necessary for the operation is given by the recurrence relation

$$\begin{aligned} a_0 &= 7 \\ a_n &= 2a_{n-1} - 1, \end{aligned}$$

which can be recast as the function

$$f(n) = 12 \times 2^{n-1} + 1,$$

where $n = order - 2$ and $order = \log_2 SIZE$, assumed an integer[3].

We are now able to calculate the collapse speed for the preferred frame based on the assumptions above:

$$\begin{aligned} v_c &= \frac{2D}{2 \times 12 \times 2^{n-1} + 1}, \\ v_c &= \frac{int((2^{order} - 1)\lceil\sqrt{3}\rceil)}{12 \times 2^{order-3} + 1}, \\ v_c &\approx \frac{10^3\sqrt{3}}{12} \approx 144\,c. \end{aligned}$$

The 2 in the denominator of the first expression for v_c reflects a complete handshake protocol. Notice that this result covers the worst case scenario, where the objects involved are at the greatest distance allowed by the model, that is, on the opposite side of the universe.

[3] Considering the diameter of the visible universe as 28 gigaparsecs and the distance between cells the Planck length, we get for the parameter *order* a value of 205.

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