Elementary Particles of Matter in a Cellular Automaton Framework

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Abstract

Elementary Particles of Matter in a Cellular Automaton Framework

A model representing a grid of circular counters maintaining mutual fault-tolerant synchronization by a distributed operational rule is considered. The importance of this model named CAETERIS is due to the initial supposition that it may correspond to a Cellular Automaton EThER InfraStructure underlying the physical world. In this work, further analysis of the given model was performed that revealed some additional characteristic features to be paralleled with those of fundamental physics. Being treated as a sort of excitable media the CAETERIS model portrays elementary particles of matter as traveling waves solutions in the form of helix cylinders. The produced solutions can be exactly matched with the whole spectrum of stable elementary particles: protons, electrons, three types of neutrinos, and photons. Amalgamation of these solutions creates a collection of basic unstable long-lived particles: neurons, muons, and tauons whose decay follows the scheme of week interactions. The absolute nature of the cellular automaton medium is undetectable for the material formations providing an impression of relativity. The rotation-propagation congruity of traveling helix cylinder waves determines an upper bound on the pace of material particles to be identified with the cardinal speed of light restriction. Periodic alterations of traveling wave solutions give a concrete connotation to the otherwise abstract entity of the de Broglie wave whose length appears inversely proportional to the particles momentum. Different traveling waves exercise the same rotational impacts irrespective of variations in their mass and speed linked to the activities behind. So, the diverse material particles have the same value of

spin and for any given orientation of measurement the directions of these values are either “up” or “down” as rotational impacts flip with every half-turn. The decisive experiments of electron-proton deep inelastic scattering expose sampling of the protons temporal states rather than probing their spatial structure. In such an interpretation quarks may not exist as isolated entities. Propagation of neutrinos is associated with their transformations from one type to another imposing a miniscule creeping relocation over the regular translation of helix cylinder waves. The allegedly observed effect of superluminal neutrinos would corroborate the given model, yet it does not distort the phenomena of the basic physics as a subtle supplementary artifact.

Keywords: Cellular automaton, elementary particles, computational physics.

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Chapter 1

Introduction

Existing physics theories, which are usually in the form of mathematical equations, describe the physical world in different aspects and at different levels. However, these theories do not necessarily represent the fundamental basis of our universe. Physical universe is a dynamic system where matters interact in space-time. These interactions are exhibit extremely complex behaviors at different level. These theories do not represent the underlying driving mechanism of nature as long as they are based on varying assumptions that might be inadequate. Quantum mechanics properties conflicting with the principle of classical relativity are one example of such inadequation. There are some branches of incompatible mechanisms of modern physics which prevent the emergence of theory of everything (TOE), one of the main objectives of twentieth century.

Cellular Automata (CA) can generate extremely sophisticated pattern at the top level by employing simple dynamic rules in the underlying level. Thus, the proposed cellular automata model [1] can incorporate the whole diversified concepts of the physics

universe. The strange phenomenon entanglement involved non-signaling interactions can naturally be explained under cellular automaton framework by the communication through common memory, and the quantum weirdness can be resolved by the interactive holography mechanism [2]. According to the analysis of CAETERIS, we found the given cellular automaton model resembles our physical universe in different aspects. Notably, the elementary particles of matter of the proposed cellular automaton give a concrete presentation of the de Broglie waves.

This thesis is arranged as follows: Chapter 2 presents the definition of mutual synchronization cellular automaton mechanism. First, we give a characteristic example of cellular automaton, “Game of Life”. Then, according to the analysis of vortices in the ether and the failure of previous attempts of searching the rule of universe by different author, we are able to reveal certain properties of the given cellular automaton mechanism that can meet the specifications of the physical world. A formal description of the CA model is presented.

In Chapter 3, we have analyzed the given cellular automaton model in different aspects and found correspondence to the characteristic features of fundamental physics. The helicoidal solution with two type kernel could be exactly matched the spectrum of stable elementary particles. The helicoidal rotation-propagation congruity restricts the pace of material particles which gives the upper bound speed. With the study of the relation between holicoidal wave property and the speed of matter, the model gives a concrete description of de Broglie wave. The rotational impacts of matter results the same value of spin for any give direction of measurement. Probing electron sampling the state of proton in the given model implies that quarks may not exist as isolate entities. The

reconfiguration process of stable particles creates the almost stable particles: neutrons, muons, and tauons whose decay interprets week interactions. The small relocation of caterpillar creeping type propagation of neutrinos allows neutrino traveling beyond upper bound speed without undermining the conventional relativity which may follows the observed effect of superluminal neutrinos.

In Chapter 4 we summarize the physical features of Cellular Automaton EThER InfraStructure. These results, support the supposition that mutual synchronization under the given cellular automaton framework could represents the ultimate mechanism of our physical universe.

Chapter 2

Cellular Automaton Modeling

In this chapter, we introduce the cellular automata concept and reconsider luminiferous aether as the uniform medium of nature. Further analysis suggests that cellular automaton framework is the best candidate of luminiferous aether displaying an “imaginary physics” responsible for the ultimate mechanism of nature. At the end of this chapter, we present the formal description of the given mutual synchronization mechanism.

2.1. Cellular Automata concept

Cellular automaton (CA) is a discrete dynamical system that consists of a regular grid of cells. Each cell is in finite-state variable arranged on a uniform grid. The overall dynamics is determined by a finite rule, by which each cell changes its states at every step according to the states of itself and its neighborhood. Cellular automaton is able to model continuum systems such as fluids and they could be realized exactly by digital hardware. Cellular automata have been applied to many fields of science and technology

such as theoretical biology, mathematics, and physics, as a computational tool and as a conceptual construction. Cellular automata is a common concept which already be studied by many authors to discover the rule of physical universe. The classical physical concept of luminiferrous ether can be also treated as a sort of a cellular automaton [1]. The cellular automata approach interprets the physical world by an informational form rather than the material reality. The informational universe in the cellular automata construction generates the complex behaviors similar to the real physical world.

2.1.1. Characteristic example: The Game of life

A general form of cellular automaton transition rule looks as follows:

$$X_i^t = F\left(X_i^{t-1}, \{X_q^{t-1}\}\right) \tag{2.1}$$

where X_i^t is the state value of a certain cell i at the time step t. {q} is the neighborhood of cell i. An interesting cellular automaton model may generate sophisticated patterns which should avoid degrading into “silence” or irregularities.

Conway’s game of life is the well know example of Cellular automata. Its evolution is determined by its initial state, it doesn’t require further input. The universe of the Game of Life is an infinite two-dimensional orthogonal grid of square cells, each of which is in one of two possible states, “alive” or “dead”. Every cell interacts with its eight neighbors, which are the cells that are horizontally, vertically, or diagonally adjacent.

According to the rule, “Game of life” is organized in the network of Cellular automata. Each cell has two states: 1 represents active state, and inactive 0. At one

moment, the state of a cell is determined by the number of immediate neighbor in active state at last step. At each step in time, the following transitions occur:

$$X^t = \begin{cases} X^{t-1} & if\ Q = 2 \\ 0, & if\ Q = 0,1,4,5,6,7,8 \\ 1, & if\ Q = 3 \end{cases} \quad (2.2)$$

Where X^t is state of a single cell at the time step t, Q is the number of its neighbor in active state.

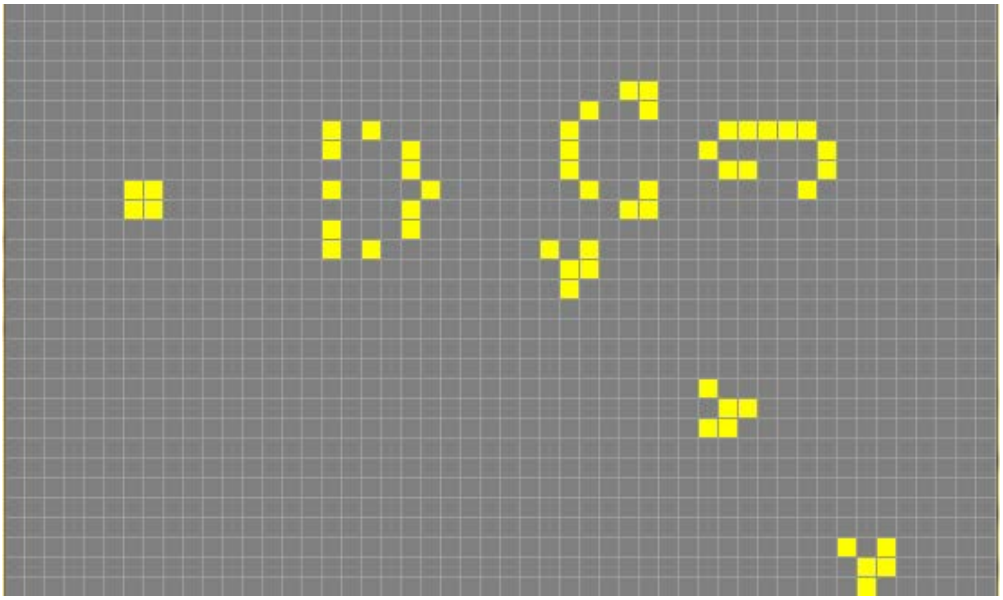


Figure 1 Conway's "Game of Life"

The universe of the "Game of Life" is an infinite two-dimensional orthogonal grid of cells in two states. Every cell interacts with its eight neighbors. The illusion motion of "Game of Life" produces stable relocating patterns.

"Game of life" is the best example of cellular automaton, which shows an "imaginary physics". In such configurations, cellular automaton displays some propagating patterns, which feud to be identified with elementary particles of matter.

2.1.2. Problems solved by cellular automata

Cellular automaton is a discrete dynamical system that can be used as computational tools. With fast growing of computer technology, processor become cheaper, wires dissipate more heat, and signals spend more time on long distance communication. Systolic array processor, first introduced by H.T. Kung and Charles E. Leiserson, is example adapted the concept of cellular automaton. CA processor consist of a grid of cells, each cell only interact with its neighbors via electric charge, magnetism, or vibration wirelessly. In such processor, faster, scalable parallel computing can be performed directly. Other cellular automaton applications could vary from algorithms, cryptography to biology, chemistry.

Ultimately, physics as a dynamic system as well could be simulated in a cellular automaton framework [2]. With the idea of “imaginary physics” which contract to “real physics”, cellular automaton simulates physical phenomena by employing merely space-dependent computation rather than mathematical approximation. In other word, cellular automaton is not only looking for a mere numerical relation in physics system, but it is exploring the properties of real structure of physics universe.

2.2. Modeling of fundamental physics

In the past several centuries, the history of physics is the evolution of its mathematical model. Computer science has a unique position to understand new aspects of physics based on an engineering point of view. The cellular automata approach with proper configurations can displays the whole complexity of an informational physics world in different aspects on the top of underlying structure.

2.2.1. Vortices in the Ether

Ether was believed as the medium of light propagation. The concept of ether as a mechanical medium has been replaced later by the theory of relativity and quantum theory in modern physics. The rejection of ether comes from several reasons: the experiments failed to detect mechanical motion ether drag, which can only showed that ether drag doesn't exist, instead of ether doesn't exist. The concept of drag is not applicable for the cellular automata model. Ether might exist if it does not have drag property at all [1]. Ether originally believed as the medium of light particles that has been rejected by Einstein photoelectric effect which demonstrated that light also contain wave-like property. Particles do not need a medium to travel, however, in the given CA informational infrastructure, particles of matter are on the top level of the underlying structure which allows the existence of uniform medium. Furthermore, if ether appears immobile for external observations but moves along with a closed system for internal observations, the properties of ether would be compatible with special relativity. Before this, a rejection of cellular automaton is that its element could behave as an absolute

universal medium like ether may incompatible with the relativity. The "motionless" informational activity in cellular automata complies with these requirements.

According to Kelvin’s theory of vortex atoms [3], atoms are made up of unalterable vortices in the ether with characteristic modes of vibration. Thomson thought that atoms made of etherial vortices would explain the indestructibility of atoms and the experimental observation that elements, when ignited, emit characteristic frequencies of light. And he believed that nothing is manifestly non-explainable by ether.

In the view of cellular automaton approach that the failure of ether theories is because its mechanical constructions which provide monotonic functions in the expression of the transition rule [1]. This causes the problems with indestructibility of vortices of ether which is primordial constituents of matter and the medium of light propagation. Ether theory was completely abandoned by the introduction of relativity. However, the structure of the physical world can be implemented if mechanical ether is replaced by an appropriate cellular automaton construction.

2.2.2. Search for the Rule of the Universe

The question is that whether if the universe is a cellular automaton. Although there is no a tools to evaluate the natural structure, Many authors have tried to build up such physical world in this discrete framework. The viewpoint that a theory of a physical phenomenon doesn’t not necessary meant to construct its mechanical model. We can start to establish the system from the ination constructionfor.

Marvin Minsky [4]studied how physical universe can fits into a discrete, dynamic vacuum with certain constraints such as maximal speed, time contraction. In such a system, each equals size space should contain same amount of information due to its discrete structure. However, it's still unclear that how does these constraints (complexity of physics) emerge in both macro scale and micro scale.

Konrad Zuse who agrees that cellular automata may compatible with determination and causality developed the informational particles in such digitalization procedures in which the behavior of digital particle may similar as physical particles [5]. Cellular automata should be a good candidate of constructing the physical world, though there still a question that how to make the system compatible with both determinism and modern physics.

Edward Fredkin proposed the idea that every quantity concept of physics would finally become discrete and finite [6]. The discrete space-time state model of physics he developed exposes a new direction of the microscopic physics. A repeated issue of fundamental physics is that is our universe discrete or continuous. If the answer is discrete, the theory of everything could be developed from such computing model [7]. Fredkin handles three problems: universality, reversibility and symmetries in his salt model [8]. However, there lake the configuration of how does the model satisfy locality, and compatible with classical deterministic physics with quantum behavior.

In [9], Stephen Wolfram believes that the description of nature world should base on rules instead of mathematical equations. Wolfram has great achievement on building computational tool to solve complex problems. So, the question is that is it possible to

develop the whole complexity of physical universe by using this computational equipment. Another work of Wolfram [10] [11]is that to classify all of 1-dimensional cellular automation which has 2^8 =256 different rules into 4 categories. However, there is nothing exciting about physics except only several interesting pattern.

All these attempts by different author in the last several decades had been failed to construct a model of the physical world. The success of cellular automata comes from mutual synchronization.

2.2.3. The rule of mutual synchronization

There are several issues and difficulties of cellular automaton model representing the physical world. Cellular automaton with the absolute universal medium may not compatible with the principle of relativity. The rejection of ether because of failure detection of ether drag which may not necessary to show the inexistence of ether if the concept of ether drag is not applicable. In the given cellular automaton model, the uniform cell medium are immobile for external observations which allow it compatible with special relativity.

It seems difficult to find mediation of the quantum mechanics behavior of physics and classical deterministic model. Locality and causality are the main issue of interpreting physical world using quantum mechanics behavior. Quantum mechanics behavior is built on the system level. Entanglement could be implemented by the communication through common memory. It has been attempt to interpret quantum mechanics by “hidden variables”. A model of this information processing medium can be

implemented by cellular automata where appears the wiriness of quantum mechanics behavior at the top level without undermining the conventional relativity on the basic level.

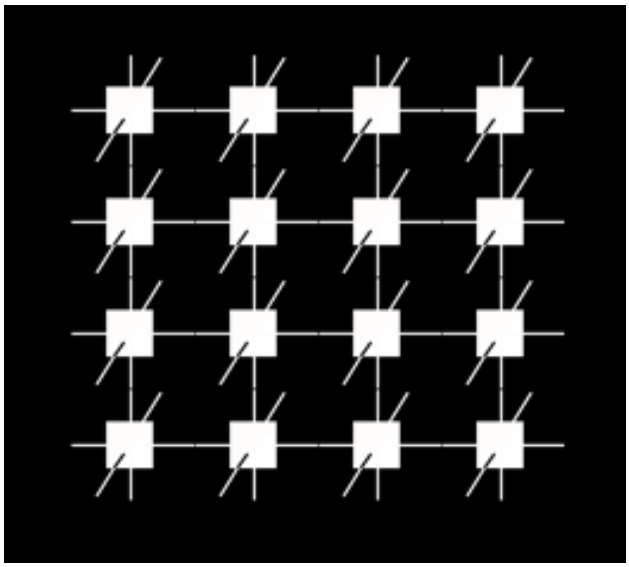


Figure 2 Cellular Automaton Mutual Synchronization Mechanism of Nature

The mutual synchronization cellular automaton employs self-clocking mechanics and a dynamic rule of distributed fault-tolerant phase averaging. The underlying structure has two non-linear designs. "Imaginary Physics" build up at the higher level of such framework.

Some features of the given cellular automaton framework as following:

(1) Complementary condition: discretization of phase changes
(2) Dimensionless parameters (artifacts of the design): α=1/137 and ε ~1040
(3) Arbitration protocol to avoid deadlocks: CP violation and irreversibility of Time
(4) Two classes of solutions: "slow" spiral waves and "fast" diffusion spread
(5) Two global periodic cycles: matter formation and diffusional wave trains
(6) The origin of non-locality --- establishment of a holographic mechanism

A completely uniform discrete scalar cellular structure should be able to generate the intrinsic symmetries of the physical universe. In the given cellular automaton, two non-linear factors have been employed. Basic properties of this model are presented in Figure 2.

An ideal mutual synchronization mechanism was discovered in the attempt of resolve controversies of wave-particle duality [12]. A self-clocking network implements a informational physical process of creating “something out of nothing” satisfies the requirement of scheme of quantum transitions. Under such framework, the given mechanism may displays the whole phenomena of the physical world including transformations of elementary particles, interactions with these elementary particles, and the explanation of the initialization of physical universe. So, if the physics works as this way, the whole richness of the physical world condenses in a plain sentence: “All physical phenomena are different aspects of the high-level description of distributed processes of mutual synchronization in a network of digital clocks” [13].

Cellular automaton as a distributed, dynamic system, maintain working of the whole world works properly. Several scientists who have attempted to developed physics on cellular automaton structures cannot success without the introduction of a clocking mechanism. From an engineering point of view, such distributed system should maintain its functionality even though part of it has been broke. Similarly, in the cellular automaton clock is the crucial component of the system without which any dynamic system cannot accomplish its goal. So, in the cellular automaton structure with fault-tolerant mutual synchronization each cell of it owns independent clock. These clocks must be synchronized because they might drift apart over time.

The key feature of a physical world model is that it should establish a space-time continuum which has the properties of inertial and it should obey the principle of relativity.

In our model, digital clock is the primitive element which consists of a pulse generator and a circular counter with a periodical reset after Z counts. The value of clock is determined by its counter, represent as i/Z, where i is the value of its counter. In such dynamic network, clocks are organized by a rule of phase averaging. If $Z \gg 1$, the discrete system can be treated as a continuous approximation. It's easy to approximated the phase of clocks by a medium whose phase θ with mod 2π operation. Now, we get an approximately continuous, periodic, dynamic system with mutual synchronization by interacting with neighbors. The mechanism of the synchronization defined as follow:

$$\theta_i' = \sum_{j \in Q} a_{ij}\theta_j \ (mod\ 2\pi) \tag{2.3}$$

where $\theta_j$is distribution of phase in certain neighborhood Q. a_{ij} is the influence coefficients of mutual synchronization [1].

This relation of the clocks network can be approximated by continuous space-time.

$$\frac{\partial\theta}{\partial t} = -b\theta + D_1\Delta\theta + D_2\Delta^2\theta + \cdots \tag{2.4}$$

Δ is Laplace operator, b is small coefficient, $D_1, D_2 \cdots$ are the phase diffusion coefficients. The equation which behaved as the transformational rule of our cellular

automaton network can provide the diversification of physical world by the two non-linear factors which will be discussed later.

2.2.4. Presenting the cellular automaton mechanism

The principle of relativity, the quantum mechanics behavior of matter cannot be reconciled with a classical deterministic model, the intrinsic symmetries of the physical universe are the three main issues preventing cellular automaton represents the mechanics of physics world. In the given cellular automaton model, adapts arbitration protocol to avoid deadlocks, and used distributed fault-tolerant synchronization as transformational rule. There are two artifacts of the design resulting in dimensionless parameter: α=1/137 and $\varepsilon \sim 10^{40}$.

The rule of mutual synchronization can describe an informational physical universe which presents formal similarities with the real physical world. We now are trying to find the solutions for synchronization mechanism of cellular automaton in the form of helicoidal propagating wave:

$$\theta = f(z - vt)$$
$$\frac{d\theta}{dr} = 0 \qquad (2.5)$$
$$\frac{d\theta}{d\varphi} = const$$

where θ is the phase of uniform medium, φ is uniform rotation of the angle coordinate, r is the constant radius. The equations above described a rotation-propagating

traveling formation with constant speed v along the axis of a cylinder with radius r, and the formation has uniform rotation with angle coordinate φ.

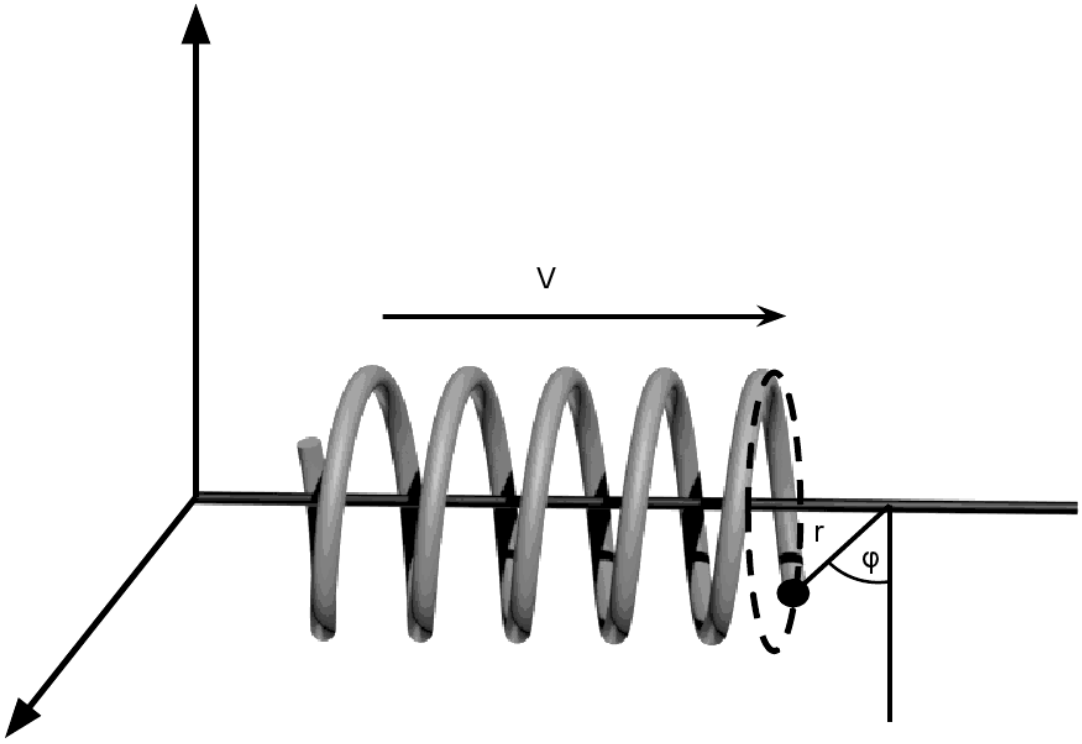


Figure 3 Helicoidal Solutions

Intended solution of fault-tolerant mutual synchronization in the form of rotation-propagation wave with constant speed v along cylinder axis produces steady-state propelling kernel. Propagation of the steady-state solutions stir up random distribution of phases in the surrounding network. The elementary particles of matter is interpreted by the configuration of sychro formation which generated by such rotation-propagation activity.

According to the property of the rotation-propagation form, the differential operators in cylindrical coordinates remain only partial derivatives with respect to axis z, so the solutions in the form of rotation-propagation wave are determined by:

$$-vf'(s) = -bf(s) + D_1 f''(s) + D_2 f^{IV}(s) \tag{2.6}$$

where s = z – vt. The characteristic equation for the solutions in the form of $e^{\lambda t}$ as following:

$$D_2\lambda^4 + D_1\lambda^2 + v\lambda - b = 0 \tag{2.7}$$

According to the analysis in [1], the estimates of the four roots of the characteristic equation as follow:

$$\lambda_1 = \frac{b}{v} \tag{2.8}$$

$$\lambda_2 = -\frac{v}{D_1} \tag{2.9}$$

$$\lambda_{3,4} = \pm i\sqrt{\frac{D_1}{D_2}} \tag{2.10}$$

And the general solution can be express as:

$$f(s) = A_1 e^{\lambda_1 S} + A_2 e^{\lambda_2 S} + A_3 \cos\left(\left|\lambda_{3,4}\right| s + \gamma_0\right) \tag{2.11}$$

where A_1 , A_2 , A_3 , and γ_0 are arbitrary constants.

Chapter 3

Analysis of the Cellular Automaton EThER InfraStructure (CAETERIS)

3.1. Properties of the material formations

The synchro formations generated by characteristic solutions in rotation-propagation form of the developed cellular automaton framework portray elementary particles in our material world. The basic characteristic solutions and their combinations under CAETERIS surprisedly coincide with fundamental physical phenomenon. Rather than finding a mathematical statement to describe different aspect of physical universe, CAETERIS builds an “imaginary physics” system from “zero level”, and creates “patterns” paralleled with those in fundamental physics.

3.1.1. Spectrum of elementary particles of matter

The proposed cellular automaton model contains a set of synchro excitations in the form of spiral kernels that corresponds to the spectrum of stable elementary particles of matter.

Elementary particles of matter are the solitons in the cellular automaton model which presents as helicoidal traveling wave propelling by rotation. Along with the generatrix of the spiral solutions, there are only three basic type phase dependence provide by rotation-propagation solutions: increasing exponent, a decreasing exponent, or a sinusoid. Amount these solutions, exponentially increasing kernel and exponentially decreasing kernel which are interpreted as proton and electron respectively. When the velocity of them equals to c, upper bound speed of nature, they provide electromagnetic fields and photons. Sinusoidal kernels are interpreted as neutrinos which has smooth phase dependence compared to the other two kernels. The angle of attack results the mass of particles of matter so that the mass of neutrinos are substantially less than other particles [14]. Unstable, decaying neutron from linear combination of these functions will consider later in the weak interaction.

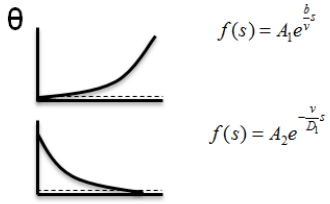
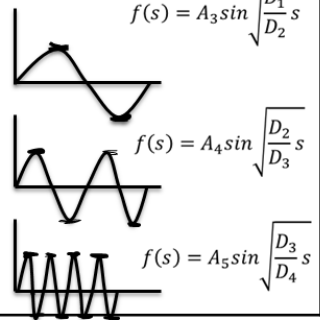
Type of kernel	PHASE DEPENDENCES	PROPAGATION SPEED	
		intermediate V < C	maximum V = C
Real exponents *increasing* *decreasing*	θ  $f(s) = A_1 e^{\frac{b}{v}s}$ $f(s) = A_2 e^{-\frac{v}{D_1}s}$	Proton Electron	Electro-Magnetic Field Photon
Imaginary exponents	θ  $f(s) = A_3 sin\sqrt{\frac{D_1}{D_2}}s$ $f(s) = A_4 sin\sqrt{\frac{D_2}{D_3}}s$ $f(s) = A_5 sin\sqrt{\frac{D_3}{D_4}}s$		Neutrinos *electron* *muon* *tauon*

Figure 4 Spectrum of Stable Elementary Particles

The generated synchro formation corespond to the spectrum of stable elementary particles of physics. There are three basic patterns of phase dependence: exponentially decreasing, exponentially increasing, and sinusoidal. A steady-state solution could be a liner combination of basic pattern as long as it statisfies rotation-propagation congruity. When v < c, the momotonic exponential kernels and their combinations provide the material particles: protons, electrons, and neutrons. When v = c, they conduct as electromagnetic fields and photons. The sinusoidal kernels are defined as neutrinos: electron neutrino, muon neutrino, and tauon netrino.

3.1.2. Two non-linearity factors

There are many variants of cellular automata that have been developed for different purposes. Cellular automaton should avoid oversimplification and overcomplication. In order to develop a meaningful cellular automaton mechanism, the given model comprises two non-linearity factors: phase periodicity and the gap on phase change. These non-linearity factors lead to the diversification of the physical universe. They prevent the dissipating of the on cellular automaton formation into a uniform distributions.

An important condition is that cellular automaton as distributed system should maintain its functionality even though part of it has been broken. From an engineering point of view, a distributed system is necessary to perform activities at roughly the same time. With the introduction of fault-tolerant mutual synchronization, given cellular automaton were organized its activities on a self-clocking network with a dynamic rule of phase averaging. Any system cannot be operational without such type mechanism.

Fault-tolerant mutual synchronization employs the gap on the phase change in which difference in between neighboring nodes phase cannot be too small. The condition of gap on the phase change can be expressed as follow:

$$\frac{d\theta}{dL} \geq GAP_PHASE \tag{3.1}$$

where θ is the value of phase of a certain element, L is a distance in some direction.

Thus, once the spatial derivative of the phase becomes smaller than the threshold presented in (3.1) the value of the phase drops to zero. This has interesting consequences

for the properties of the elementary particles of matter. The manifestation of the GAP_PHASE results in the possibility of solutions in the form of constant phase "stretching pulses". These solutions present fast diffusion spreading a certain constant value of phase along a straight line, so the derivative of phase along this straight line is exactly zero. There is a small gap in the value of phase in the immediate envelop surrounding the constant phase line due to condition (3.1). The resultant composition stabilizes this "stretching pulse", and it disintegrates basically only from the end. It has been assumed that such a construction constitutes the stretching pulse mechanism that is responsible for the phenomenon of gravitation [15]. As a point of discernment, the suggested stretching pulse mechanism of gravitation naturally exposes the extra attraction attributed to an undetected substance of "dark matter". Actually, in the framework of the developed cellular automaton model of the elementary particles of matter the substance of "dark matter" does not exist anyhow.

3.1.3. Helicoidal rotation-propagation congruity

Rotation-propagation congruity limited the speed of motion of the kernel. This upper bound interprets as the speed of light, c, which is the maximum possible speed for the propagating matter in the realm of cellular automata.

The phase circulation over a closed path must achieve the full phase reverse of 2π through a certain number of minimal fractional steps which determine the radius r and rotational speed. The standards of length l_s and time t_s are extension and duration of the full reverse of phase 2π respectively. The rotation-propagation congruity requires that the changes of phase along the generatrix should coincide with those along the kernel's circle.

So, supposed the propagation is $\Delta s = s_1 - s_2$, and the corresponding duration interval is $t_p = \frac{\Delta s}{v}$. In the meantime, the change of phase $f(s_2) - f(s_1)$ should takes $\Delta t_r = f(s_2) - f(s_1) * t_s/2\pi$ due to the rotation. The condition of rotation-propagation congruity requiring $\Delta t_p = \Delta t_r$ can be written as

$$\frac{f(s_2) - f(s_1)}{s_2 - s_1} = \frac{2\pi}{t_s * v} \tag{3.2}$$

The rotation-propagation congruity holds for all intervals of the given structure. It satisfied exactly only if $f(s)$ were a straight line. According to the solution (2.5), rotation-propagation congruity can hold approximately. Therefore, the propelling kernels can be approximated as propagating spirals vibrating within certain limits where their integrity can be preserved.

The minimum discretization step of the phase change determine the pace of phase change along kernel's circle which is $2\pi/l_s$. The pace of phase change along the generatrix, $f(s_2) - f(s_1)/s_2 - s_1$, cannot be less than it. So, we get an upper bound on the kernels' propagation speed, v:

$$v \leq \frac{l_s}{t_s} = c \tag{3.3}$$

Synchro formations having the structure of rotation-propagation travelling waves form are subject of limitation of speed. The upper bound of speed of the given cellular automaton framework for the elementary solutions portray as the speed of light in our physical universe, and this upper bound on speed is determined by the properties of internal structure of the given cellular automaton.

The kernel with increasing and decreasing exponents interpret as proton and electron propagating under the upper bound speed. At the upper bound speed these exponents transform into photons and components of the electromagnetic field.

For the neutrinos, they can move only with the maximum speed of light, c. It will be shown in section 3.4.2 that neutrinos might slightly exceed the maximum speed of light because of their auxiliary relocation along with the generatrix.

On the other side, the propagation speed might reach a lower limit for purpose of maintaining integrity. This artifacts of the design of speed is α•c where α is a dimensionless structure constant, and this lower limit on the speed corresponds to $\frac{1}{137} \cdot c$, the speed of electron on the first orbit of the Bohr's atom.

3.1.4. Physical meaning of the de Broglie wave

Cellular automaton excitations combine the properties of particles and waves. The appearing solutions are in agreement with the de Broglie wavelength equation:

$$\lambda = \frac{h}{mv} \tag{3.4}$$

The de Broglie wave describes the wave-particle duality of matter is generally regarded as an abstract property of physics. The wavelength is inversely proportional to the momentum of elementary particles. Wave property of matter described by Schr¨odinger's wave function interprets as the probabilities of measurement of given matter. However, the probabilities interpretation of matter in quantum mechanics could not compatible with the principle of relativity. Interactive holography builds on the top of given cellular automaton model allows quantum mechanics behavior.

Helicoidal solutions behave as isolated elementary particles exhibit periodic activities that could constitute a wave, while in time and space presents waves. According to the de Broglie wave function, the wavelength of for material particle is inversely proportional to its momentum. The periodic property of synchro formations in time and space presents waves also coincide with the de Broglie wavelength equation (see figure 5).

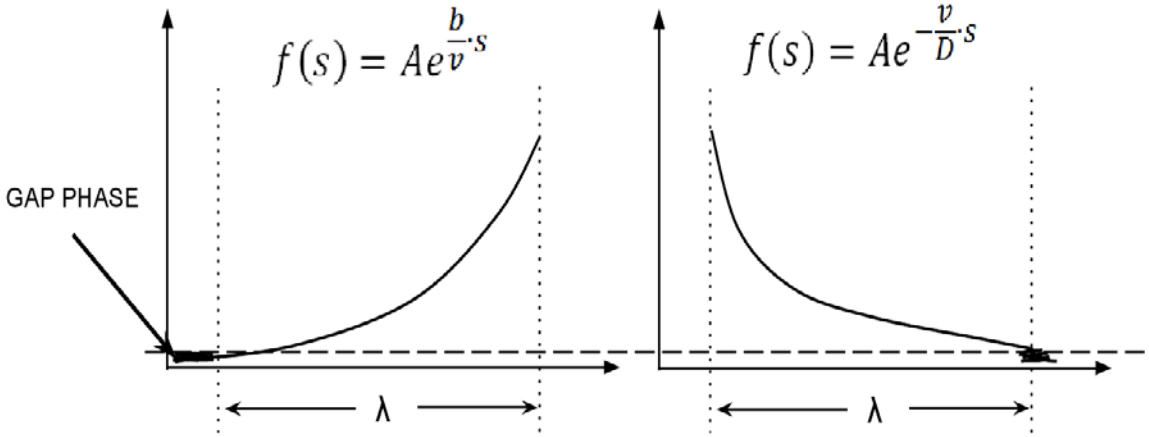


Figure 5 Explanation of the de Broglie Wave

The rotation-propagation kernel disorder when it crosses the condition of gap phase. Wavelength of traveling sychro formation is identified as the interval of reaching the gap phase. In the case of exponential increasing kernel, the length lamda is reversely proportional to the velocity of the travelling particle. The relation also can be satisfied in the case of exponential decreasing kernel. The agreement of the de Broglie wavelength equation endows synchro formations with wave-particle duality and presents a concrete description of the de Broglie wave.

Consider the property of v first and we have two type kernel exponent.

$$f(s) = \exp\left(\frac{b}{v} \cdot s\right) \tag{3.5}$$

which is the increasing exponent. When v increase, f(s) goes down, so the interval of rotation, λ, decrease correspondingly with f(s).

Let's consider the decreasing exponent:

$$f(s) = \exp\left(\frac{-v}{D} \cdot s\right) \tag{3.6}$$

In this case, when v increases, the f(s) also goes down, and the interval that it occupies, λ, also decreases in accordance with f(s).

3.1.5. Interpretation of spin peculiarities

Spin in the given cellular automaton model is the result of rotation of the kernel. In the rotation-propagation solution, elementary particles of matter are travelling in the same form. Mass and speed are the quantities resulted from propagation, and the spin is result from the rotation. So, different traveling waves perform the same rotational impacts which are unrelated to the difference of their mass and speed.

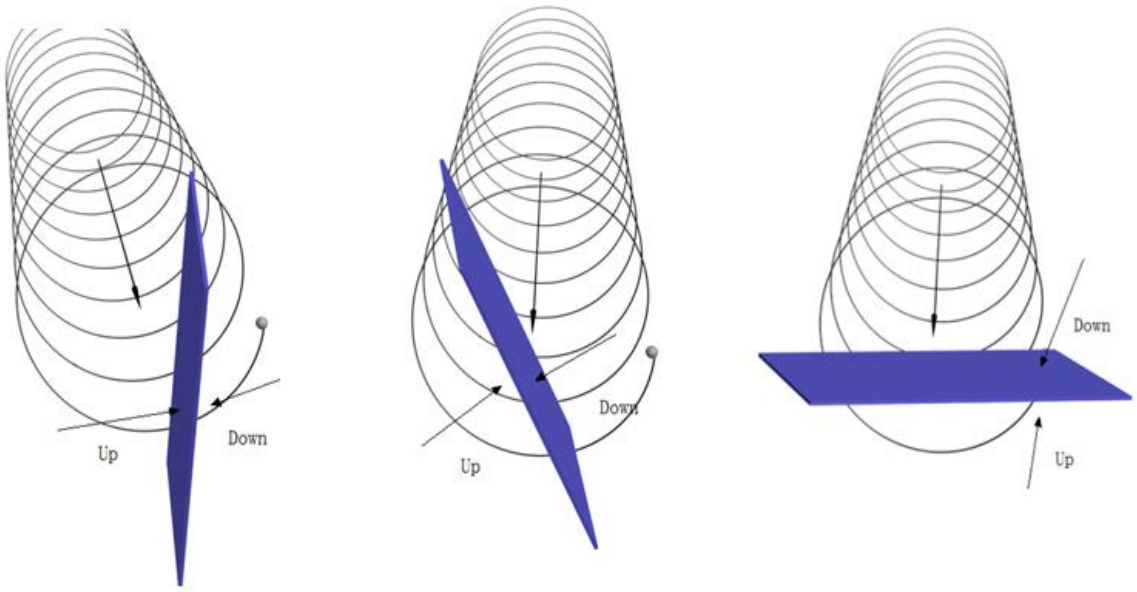


Figure 6 Interpretation of Spin

The spin outcome for any given direction of measurement is either "up" or "down" as rotational impacts flip with every half-turn. Spin is the result of rotational impact only.

Further, the generated synchro excitations perform the rotation and propagation at the same time, thus they are not strictly orthogonal to the kernel's axis. Along with genertrix line the synchro excitations are initiated is tilted to a certain degree forward and

sideways. The effect contributes to the dependence of mass on speed and to the property of spin. For any given direction of measurement, the directions of these spin are either “up” or “down” as rotational impacts flip with every half-turn.

The value of spin is not determined by the type of synchro excitations for any direction of measurement, the outcome value of spin could be either up or down which involved in the process of quantum transitions.

3.2. Internal structure of the proton

3.2.1. The manifestation of phase periodicity

The standard model considering that the internal structure of proton consists of three quarks which are tightly bound by super-strong force. In 1968, Stanford Linear Accelerator Center (SLAC) perform the deep inelastic scattering experiment, in which high energy electrons scatter from point-like “partons” in the proton [16], provide the first evidence of the surmised existence of quarks [17]. Quarks later were considered have six different flavors: up, down, strange, charm, bottom, and top. According to the standard model, quarks are the spatially separated sub-particles insides proton.

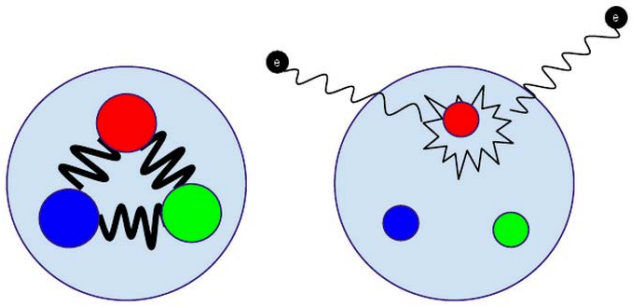


Figure 7 High Energy Electrons Scatters from Partons in the Proton

The deep inelastic scattering experiment where high energy electrons scatter from partons are considered as spatially separated sub-particles.

This type of interpretation of quarks described by Quantum Chromo Dynamics makes proton a composite structure, which employs uncommon notions to describe the complicated properties of quark such as asymptotic freedom, confinement, and a large amount of arbitrary parameters. Also, there is a contradiction in the value of the cosmological constant raised by the high density of energy of vacuum.

The theory of quark is abstract which emphasize the symmetry of elementary particle. It tried to classify the elementary particles based on the symmetry consideration of the elementary particle properties. Standard model considered physical universe is a recursive application of the paradigm that with lesser components interact by exchanging force carriers.

So, if we interpret parton as a single particle alternating in time, i.e. a given particle changing state in time. In such interpretation, the internal structure of proton can be simplified as the picture of the sub-nuclear world [17]. Thus, the deep inelastic scattering could be considered as the process of that electrons collide with proton in different time rather than collide with different partons. This experiment is the process of sampling temporal status of proton.

3.2.2. Interpretation of quarks

Although there are many indirect experiment providing evidence for the existence of quarks, most of scientists believe cannot observe quarks directly. The theory of quark is based on the symmetry consideration of the elementary particle properties. However,

this symmetry property of elementary particles produce compound structure of proton which consider proton consisted of spatially separated sub-particles quarks. This construction gave rise to the complicated properties of quarks and is not always consistent.

Furthermore, if our universe works as the way that the recursive paradigm described, any recursion should come to an end at a certain level. As the description of standard model, the leptons do not have further internal structure, while the hadrons have. The complications of property of quarks might suggest that the level of sub-nuclear physics need to be changed. So, if our universe works the way as cellular automaton, we might have the proper level to describe the internal structure of sub-nuclear physics.

In our cellular automaton approach, elementary particles of matter are the helicoidal propagating wave. Along with generatrix, the state of particles is changed according to different kernels. Proton is the traveling wave with exponential increasing kernel. With the period function, the increasing exponential characteristic solution which decides the state of proton changing in time showed as the figure 8.

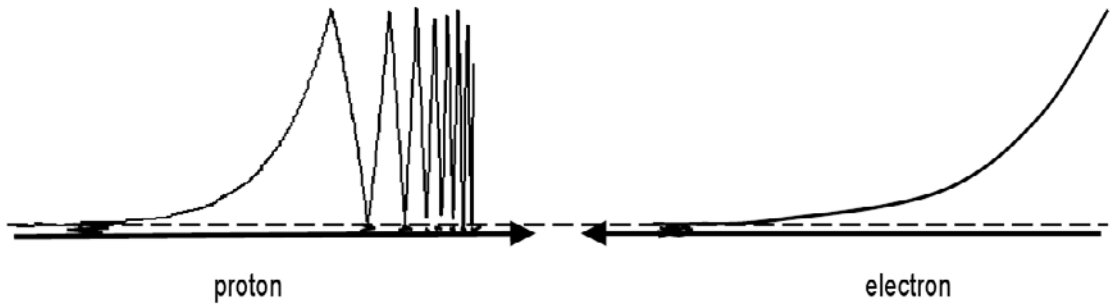


Figure 8 Probing Electron Samples Phase Variation of Proton

Probing electron samples the temporal states of protons. Quarks may not exist as isolated entities.

In this situation, the monotonically increasing scattering state shift could produce the resonance behavior of the elastic scattering. However, the decreasing kernel cannot induce such effect. The collision of two collective excitations in the cellular automata network interprets as the collision of two elementary particles of matter. The deep inelastic scattering experiment is the process that sampling the phase of proton by collides with high energy scattering electrons. Thus, hadrons and leptons should have different internal structure, and the difference is because of the different behavior of the corresponded collective excitation [17].

3.2.3. Particles orientations and collisions

Figure 9 Prediction: Different Collision Outcomes with Same Relative Speed

If our physics works similar to this structure, the orientations affect the properties of particle. Thus, there are two types of collisions, head to head collision and head to rear collision. In both cases, particles are collided with same relative speed, but the outcomes of head to head collision should be different from the head to rear collision because according to this structure these are two different processes.

3.3. Weak interactions

3.3.1. Durable almost stable configuration

Weak interaction is responsible for decay of unstable particles of matter. In the Standard Model, weak interaction is considered as the process of exchange bosons and the decayed particles transform into other type particles. In the given cellular automaton, weak interactions include the connection of elementary particle of matter. Complex units at higher level of the fundamental structure could reconstruct from the basic synchro formation in two ways. One is the linear combinations of elementary solutions which generate new types kernels. The other one is to combine several synchro formations generated by different kernels in a composite structure with overlapping clusters of synchronized structures. Neutrinos are involved in decay processes. With composite kernels, reconfiguration processes of synchronization patterns obey the condition of rotation-propagation congruity and it keeps the constituents of complex synchronization units from falling apart. Week force as reconfigurational determinant should prevent disintegrating propelling kernels.

3.3.2. Structure of neutron, muon, and tauon

Neutron, muon, and tauon are result of weak interactions are composite kernels consist of linear combinations of three fundamental solutions. Synchro formations traveling across the cellular automaton framework may interact with each other. The travelling kernels might hold together if the combinations of them satisfy the condition of

rotation-propagation congruity. Such “force” cause by the internal property of given cellular automaton framework binding the synchro formations could correspond to physics concept weak force. Different weights of elementary solutions determine the displaying properties of the generated unstable particles. Further analysis gives a natural explanation of the contrary phenomenon of straightforward expectation, e.g. neutron has greater mass than proton though proton contains electricity while neutron doesn’t.

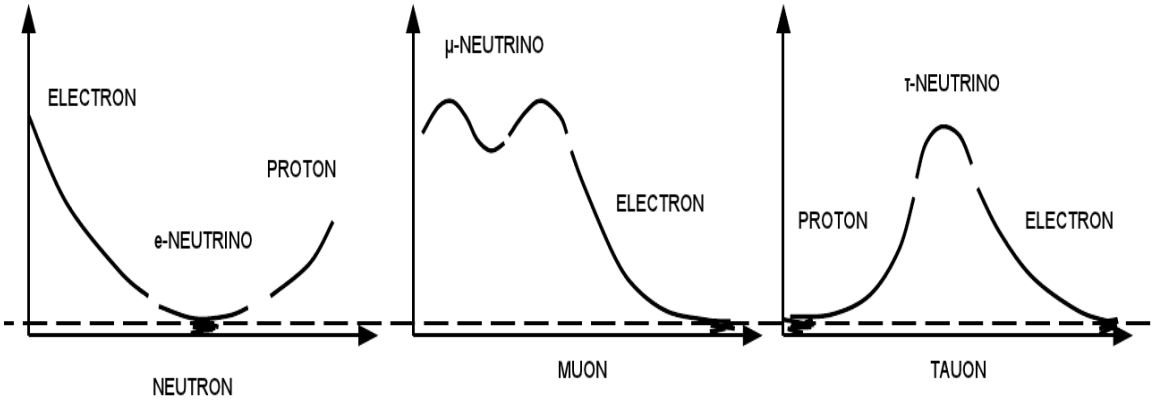


Figure 10 Structure of Neutron, Muon and Tauon

Linear combinations of the basic helicoidal solutions induce weak interactions if satisfy the rotation-propagation congruity. Neutron with disturbance points has greater mass than proton. The properties of muon are similar to electron, except for much greater mass. Tauon significant influence of increasing exponent has higher instability and hadronic features.

The structure of neutron consists of the three elementary patterns: e-pattern, p-pattern and n-pattern. The disintegration process of neutron produces the three type particles. The structure of neutron has two non-monotonic points and it is mostly determined by p-pattern. The two points induce the disturbance which makes the total

mass of neutron configuration is greater than proton. The lifetime of a free neutron is the longest one among the three almost stable particles.

The structure of muon consists of e-pattern and n-pattern. muon behave similar to electron but much greater mass since e-pattern is the primary property of muon structure and there are two disturbance points of it. The stability of muon is in the middle of the three type non-stable particles.

Mass is increasing from electron to muon to tauon because of the sinusoidal frequency intensifies.

The structure of tauon also includes three elementary patterns: e-pattern, p-pattern and n-pattern. However, it is significantly influence of increasing exponent, p-pattern with two non-monotonic points. According to the figure, it’s easy to find out that tauon has most intense phase dependence which is easier to break into separated synchro formations in order to satisfy the condition of rotation-propagation congruity. Thus, it has higher instability and hadronic features since it was significantly influence by increasing exponent.

3.4. Properties of neutrino

3.4.1. Theoretical hypothesis of neutrino

In the given cellular automaton framework, the sinusoidal kernels are identified as neutrino. Due to rotation-propagation congruity, neutrinos may best satisfy the condition when they travelling with upper bound speed, speed of light. Neutrino formations involve various size neighborhoods which produce several solutions with diminishing size. Neutrinos formations have smooth phase dependence because of their longer distance of neighborhoods. In particular, the solution of neutrino express as follow:

$$f(s) = A_3 \cdot \cos\left(\sqrt{\frac{D_1}{D_2}}s + \gamma_0\right) \tag{3.7}$$

It can get various sinusoidal type solutions:

$$-vf'(s) = -bf(s) + D_1 f''(s) + D_2 f^{IV}(s) + D_3 f^{VI}(s) \tag{3.8}$$

The corresponding characteristic equation is:

$$D_3\lambda^6 + D_2\lambda^4 + D_1\lambda^2 + v\lambda - b = 0 \tag{3.9}$$

So, we have a series of neutrinos type sinusoidal steady-state solutions with different neighborhood order. These solutions may interpret as different types neutrinos: electron neutrino with neighborhood size of 5, muon neutrino with size of 7 and tauon neutrino with size of 9.

3.4.2. Neutrino transformations

The disturbance of underlying cellular automaton may cause traveling neutrinos type sinusoidal steady-state solutions neighborhood size changed.

In this case, neutrinos may transform from one to another corresponding to the neighborhood size. So, transformations of neutrino associate with larger–smaller–larger neighborhoods oscillations. This creeping caterpillar type motion of neutrino transformation imposes a small relocation on the top of underlying cellular automaton framework.

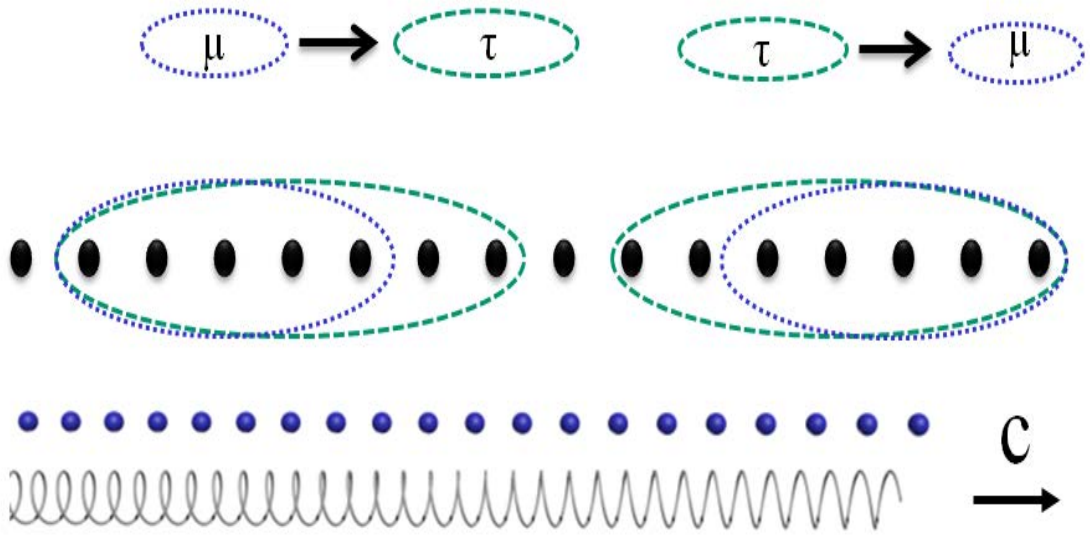


Figure 11 "Creeping Caterpillar" Effect on Propagating Neutrino

The propagating process of neutrinos involve transformation between different type configuration. The "Creeping caterpillar" travelling process with small relocation as a subtle addition on top of the basic physics accelerates neutrino over rotation-progation limit, speed of light. However, appearance of this effect does not undermine the conventional relativity; it does not violate the condition of rotation-propagation conguity at the underlying cellular automaton framwork.

The speed of neutrino could be express as follow [12]:

$$v = (1 + \delta) \cdot c \tag{3.10}$$

Where $\delta \approx 2.5 \times 10^{-5}$. When neutrino is propagating with speed of light, miniscule relocation effect may cause neutrino propagating over rotation-propagation congruity which determines speed of light limit. Thus, all of the three types neutrino have ability propagating over than the speed of light. The creeping effect as a subtle addition on top of the basic physics accelerates neutrinos. However, appearance of this effect does not undermine the conventional relativity.

Neutrinos are important when exploring our universe because of its ability of traveling a great distance in space, while other particles can only travel a relatively short distance. E.g. photon might obscure by dust, and cosmic rays could not over the Greisen-Zatsepin-Kuzmin limit [18]. Therefore, if the source of neutrino is 1billion light year far from earth, there'll be about 2.5×10^4 year gap between the fact and what we presume.

Chapter 4

Conclusion

The Cellular Automaton model given in this work exposes computational structure of physics rather than seeking analytical mathematical description of relations in physics system. Under the distributed mutual fault-tolerant synchronization mechanism, the given cellular automaton represents the dynamics of physical universe. Further analysis has revealed remarkable characteristic features of the given model which are matched to the fundamental physics. Synchro formations of helicoidal solutions travelling in a rotation propagation wave form portray the elementary particles of fundamental physics. The underlying synchronization processes yields basic kernels are matched to the whole spectrum of stable elementary particles: protons, electrons, three flavors of neutrinos, and photons. Condition of rotation-propagation congruity of helicoidal propagating solutions as the internal property of the system determined the upper bound speed of the elementary particles and this feature provides an impression of relativity. The linear combinations of basic kernels introduce weak interaction while satisfy the condition of rotation-propagation congruity. As the result of weak interaction, amalgamation of these solutions creates unstable long-lived particles: neurons, muons, and tauons. The given model also naturally explained unexpected properties of these

particles via the viewpoint of their internal structure. Two nonlinear factor of mutual basic structure produce the diversification of physical universe. Helicoidal solutions under the present a concrete description of the de Broglie wave. Gap phase determines the length of traveling helix cylinder waves which appear inversely proportional to the particles momentum. Spin is only the result of rotational impact, so different traveling wave-like particles have the same value of spin for any direction of measurement. Mass and speed as the effect of propagation activities do not influence the measurement of spin. Deep inelastic scattering provides the evidence of the existence of sub-particle quarks. However, probing electron sampling the temporal status of proton suggests that quark do not exist as spatial separated entities. Propagation processes of neutrinos involve transformations between different flavor neutrinos, and this happen while the distance of neighborhoods of synchro formations change. A small relocation imposed by the effect of transformation of “creeping” propagating neutrinos accelerates neutrinos over the speed of light. Superluminal neutrino as a subtle addition at the top level of cellular automation framework is a subtle effect of the relocation which does not undermine the principle of relativity of basic physics.

References

[1] S. Berkovich, Mutual synchronization in a network of digital clocks as the key cellular automaton mechanism of nature, Rockville, MD: Synopsis, 1986.

[2] G. Vichniac, "Simulating Physics with Cellular Automata," *Physica,* vol. 10, pp. 96-116, 1984.

[3] Kelvin, "On vortex atoms," *the Royal Society of Edinburgh,* vol. VI, 1867.

[4] M. Minsky, "Cellular Vacuum," *International Journal of Theoretical Physics* , vol. 21, pp. 537-551, 1982.

[5] K. Zuse, "The computing universe," *INTERNATIONAL JOURNAL OF THEORETICAL PHYSICS,* vol. 21, pp. 589-600, 1982.

[6] E. Fredkin, "A computing architecture for Physics," *the 2nd conference on Computing frontiers,* 2005.

[7] E. Fredkin, "An Introduction to Digital Philosophy," *International Journal of Theoretical Physics,* vol. 42, pp. 189-247, 2003.

[8] E. Fredkin, "Digital mechanics: an informational process based on reversible universal cellular automata," *Physica D,* vol. 45, no. 1-3, pp. 254-270, 1990.

[9] S. Wolfram, A New Kind of Science, Wolfram Media, Inc, 2002.

[10] S. Wolfram, "Computation theory of cellular automata," *Communications in Mathematical Physics* , vol. 96, no. 1, pp. 15-57, 1984.

[11] S. Wolfram, "Cellular automata as models of complexity," *Nature,* vol. 311, pp. 419-424, 1984.

[12] S. Berkovich, "Quantum Mechanics as Information Processing in a Network of Phase-Interlocked Coupled Oscillators," *GWU-IIST,* 1984.

[13] S. Berkovich, "Spacetime and matter in cellular automaton framework," *Nuclear Physics,* vol. 6, pp. 452-454, 1989.

[14] S. Berkovich, "Cellular automaton modeling of the phenomena of fundamental physics," *Nineteenth annual pittsburgh conference,* 1988.

[15] S. Berkovich, "An Operational Mechanism Featuring Gravity Amplification," [Online]. Available: http://www.telesio-galilei.com/tg/images/stories/documents/discussion/Operational_Mechanism_Gravity.pdf.

[16] M. Peskin and D. Schroeder, An introduction to quantum field theory, Addison–Wesley, 1995.

[17] S. Berkovich and V. Krasnopolsky, "On the interpretation of quarks as time-alternating states," *American Physical Society 1990 Spring Meeting,* vol. 35, no.

4, p. 951, April 1990.

[18] G. Zatsepin and V. A. Kuzmin, "Upper Limit of the Spectrum of Cosmic Rays," *Experimental and Theoretical Physics Letters,* vol. 4, pp. 78-80, 1966.

[19] S. Berkovich, "A comprehensive explanation of quantum mechanics: the keyword is interactive holography," http://www.bestthinking.com/topics/science/.

[20] M. Breidenbach, "Observed Behavior of Highly Inelastic Electron–Proton Scattering," *Physical Review Letters,* 1969.

[21] Jason, "Jason's Life Page," [Online]. Available: http://entropymine.com/jason/life/.

[22] N. Margolus, T. Toffoli and G. Vichniac, "Cellular Automata Supercomputers for Fluid-Dynamics Modeling," *Physical review letters,* vol. 56, no. 16, pp. 1694-1696, 1985.

[23] F. Miller, A. Vandome and J. McBrewster, Cellular automaton: Elementary cellular automaton, Brian's Brain, Conway's Game of Life, Langton's ant, Rule 90, Rule 110, Rule 184, Codd's cellular automaton, Alpha Press, 2009.

[24] D. S. M.E. Peskin, An introduction to quantum field theory, Addison–Wesley, 1995.

[25] S. Berkovich, "Physical world as an internet of things," *2nd International Conference on Computing for Geospatial Research & Applications,* 2011.

[26] J. Crutchfield, "The Calculi of Emergence: Computation, Dynamics, and Induction," *Oji International Seminar*, 1994.

[27] H. Kragh, "The Vortex Atom: A Victorian Theory of Everything," *Centaurus*, vol. 44, no. 1-2, pp. 32-114, 2002.

[28] D. Miller and E. Fredkin, "Two-state, reversible, universal cellular automata in three dimensions," *2nd conference on Computing frontiers*, 2005.

[29] J. Qin and S. Berkovich, "Physical meaning of the de Broglie waves," *American Physical Society, APS March Meeting 2012, February 27-March 2, 2012, abstract #Z30.013.*

[30] R. Feynman, "Simulating Physics with Computers," *International Journal of Theoretical Physics*, vol. 21, p. 467, 1982.

[31] S. Berkovich and H. M. A. Shargi, Constructive Approach to Fundamental Science: Selected Writings, San Diego: University Readers, 2010.