The fifth force

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Abstract

A fifth force, the Cohesion Force, becomes necessary when building a toy universe based on a fully deterministic, Euclidean, 4-torus cellular automaton using a constructive approach. Each cell contains one integer number forming bubble-like patterns propagating at speeds at least equal to that of light, interacting and being reemitted constantly. The collective behavior of these integers looks like patterns of classical and quantum physics. The four forces of nature plus the new one are unified. In particular, the graviton fits nicely in this framework. Although essentially nonlocal, it preserves the no-signalling principle. This flexible model predicts three results: i) if an electron is left completely alone (if even possible), still continues to emit low frequency fundamental photons; ii) neutrinos are Majorana fermions; and, last but not least, iii) gravity is not quantized. Pseudocode first version implementing these ideas is contained in the appendix.

Keywords: cellular automaton, graviton, beyond Standard Model, unification, nonlocality, Majorana fermion

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"It always bothers me that according to the laws as we understand them today, it takes a computing machine an infinite number of logical operations to figure out what goes on in no matter how tiny a region of space and no matter how tiny a region of time

-Richard Feymann"

1 Introduction

Cellular automata are mathematical idealizations of physical systems in which space and time are discrete. The idea of modeling our universe using cellular automata is not new, discreteness is seen by many authors (Refs. [1–7] form a small list) as a cure for the divergences of the Standard Model (SM), and is supported by the existence of a fundamental Planck volume, suggesting that structures smaller than this tiny volume should not be relevant to the theory. This cellular automaton can be regarded as a model beyond the SM.

Quantum mechanics (QM), despite its resounding success, gives us a slightly blurry image of the universe due to it being based on the uncertainty principle, in point particles and its most accepted interpretation be based on probabilities. Recent results of experimental physics, which surpasses by far the accuracy achieved by the predictions of QM, require a new model of the universe in which QM is just a limiting case.

Can nature be modeled as a cellular automaton? The model described here is meant to investigate this possibility. The emergence of a unified theory of physics is the ultimate goal of a final version based on this approach. Here the automaton is a couple of simple cubic grids closed on themselves as a 4-torus where one *tile* (formatted integer number) is attached to each cell. The cell has a processor, or logical circuit, and interacts with its eight nearest neighbors only (von Neumann convention). Preons are modified under the tick of a central clock. A reduced number of basic rules is analyzed and an even smaller number is presented in algorithmic form and implemented as a proof-of-principle computer program. The Planck length is the natural candidate to be used as the distance between the automaton cells.

The approach adopted in this work is a constructive one. Whenever possible, I try to emulate directly the laws of physics, probing the most adequate heuristics. Notice that this line of research was apparently abandoned a long time ago as not promissing. See Zuse [1] for an early attempt. The resumption of this path is due to the tremendous development of computers, including the massive use of GPUs, allowing the analysis of basic models of the Planck scale much more quickly.

On the other hand, I'm not saying that the Universe is a vast computer, in fact, I'm attempting to model Planck scale physics using a cellular automaton. Except for developing the basic principles, the construction of an automaton for directly solving cosmological problems, or even complex molecules, is inconceivable. Its complete usefulness will only be possible through statistical mechanics or direct mathematical analysis, which is far beyond the scope of the present contribution. Furthermore, this automaton can not be considered either quantum or classical. Actually, the regularities or patterns generated by the system is that might be considered quantum-like or classical-like. They have no *a priori* meaning.

This work is presented in seven sections. In Section 1, I described the context in which this work was done, the previous efforts by generations of researchers and the main idea. In Section II, general concepts are presented as gears of the automaton. In Section 3, the dynamical variables energy, momentum, and angular momentum are covered. In Section 4, the four forces of nature are described and a fifth force, unveiled. In Section 5, the patterns associated with elementary particles were identified and classified. In Section 6, all the knowledge is compacted and systematized as a theory, including pseudocode in the appendix. Finally, I conclude in Section 7.

2 Basic concepts

In this and in the next three sections, some concepts are loosely explored before the rigorous sistematization of the model in Section 6. A mixture of automaton basics, expected emergent patterns and description of parts of the SM are presented in order to familiarize the reader with the new model.

2.1 The cellular automaton

The cellular automaton is a dual Euclidean lattice 4-torus of dimension SIDE, where a single *tile* is attached to each lattice cell. The lattice is an abstract entity used to organize the cells. The distance between cells is L and the clock period (p_1) is T. Each lattice is alternatively principal (read-only) or dual (draft). D is the main diagonal of the lattice. Three dimensions are spatial and the fourth corresponds to internal degrees of freedom. When propagating as a spherical wavefront at the speed of light, tiles are called a *preon*. When diffusing as a superluminal wavefront at the maximum speed allowed in the automaton, they form a *burst*. Finally, when propagating in isolation at the speed of light the tile is a *graviton* (GRAV).

Bursts are just low level messengers, so support the no-signalling principle. Typical information driven by a burst is information for the reissue of a preon. 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.

2.2 Tile properties

Tiles are formatted in many integer fields ($p_0 ... p_{26}$) representing signed or unsigned integer values of variable sizes or as vectors in 3d space. Normalization of vector components, if necessary, is done in a $D/2$ length. Detailed description of all properties can be seen in Table 1.

2.3 Combinations of preons

Isolated preons act as fragments of charge (Us). Two overlapping preons can form a preon pair (P). Three overlapping preons can form a preon triad (Tr). Us typically interact with other Us, Ps and Tr's. Ps can sometimes interact with other Ps or Tr's. Elementary particles are composite systems os Us, Ps and Tr's, carrying HBAR/2 quantity of intrinsic angular momentum, in the case of fermions, or HBAR, in the case of bosons. Ps are further subclassified as VCPs, forming the vacuum; EMP, are responsible by the static EM forces; GLP, form gluons; MSP, form mesons; MGP, contribute to the emergence of the mass of particles; PHP, form the photons; PMPs, are available for particle pairs formation; NTPs compose neutrinos; KNPs translate Us in 3d space. Table 2 shows properties of all Ps.

2.3.1 Relation with other peers

Ps interact with each other, modifying their respective phases. It is done through the mentioned footprint property (p_{18} field). This results in interference and explains the double slit pattern. A P has the conjugated properties of its components preons cancelled. Only the unpaired properties allow interaction with other preons.

Table 1: Tile fields

Field	Name	Type	Values
p_1	Universal clock	UI	Incremented in unison after T seconds
p_2	Role	UI3	UNDEF, REAL, VIRT, GRAV
p_3	Messenger	UI2	UNDEF, PLAIN, FORCING, COLL, FORMING
p_4	Helicity	UI1	0, right; 1; left
p_5	Level (4^{th} coordinate)	UI	$0..SIDE$
$\overrightarrow{p}_6$	Origin	SV	*null* or N_D possible directions. $\lvert\overrightarrow{p}_6\rvert$ =preon radius
$\overrightarrow{p}_7$	Momentum direction	SV	*null* or N_D possible directions
p_8	Charge	SI2	0, ± 1
p_9	Chirality	SI2	0, ± 1 (RMLAM, RM, LM)
p_{10}	Color and conjugation	UI6	R G B R' G' B' (LEPT: 111000, ANTILEPT: 000111)
p_{11}	Gravity	UI1	ON, OFF
$\overrightarrow{p}_{12}$	Spin	SV	*null* or N_D possible directions
p_{13}	Entanglement	3 UI	$0..SIDE^3$, avoids conflicts and allows decoherence
p_{141}	Sinusoidal phase	SI	$-SIDE/2..+SIDE/2$ (*Direct Form Oscillator*, DFO) [12]
p_{142}	Cosine phase	SI	Auxiliary value
p_{143}	Frequency	UI	Combined energy/LM
p_{144}	Modified	UI1	0, 1 (avoids multiple increments of DFO)
p_{145}	Ramp	UI	$0..log_2(SIDE)$
p_{15E}	Electric polarization	UI1	ON, OFF
p_{15M}	Magnetic polarization	UI1	ON, OFF
p_{16}	Interaction	UI4	UNDEF, U, P, B, C, G, UXP, CXP, UXC, UXU, PXP, UXG, WZ, HADRON
p_{17}	Last visit	UI	Number of LIGHTs (property of the cell)
p_{18}	Interference	SI	$-SIDE/2..+SIDE/2$
$\overrightarrow{p}_{19}$	Return path	SV	Used to find OP
p_{200}	Current direction	UI3	$0..NDIR-1$, used to avoid concurrent access
p_{201}	Final time	UI	Wavefront t_f
p_{21}	Pair type	UI4	Complements p_{16} info, cf. Definition 11
p_{22}	Invite	UI	Used in pair formation logic
p_{23}	Timeout	UI	Timeout of virtual particles
p_{24}	Distance	UI	Distance in the w dimension
p_{25}	Diagonal	UI	Diagonal spiral counter
$\overrightarrow{p}_{26}$	Burst origin	SV	*null* or N_D possible directions
p_{260}	Burst direction	UI3	$0..NDIR-1$, used to avoid concurrent access

$\mathbf{p}_2$		$\vec{p}_6$		$\vec{p}_7$		$\mathbf{p}_8$		$\mathbf{p}_9$		$\mathbf{p}_{10}$		$\vec{p}_{12}$		$\mathbf{p}_{13}$		$\mathbf{p}_{21}$	**Obs.**
1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2		U_1, U_2
V	V	$\vec{\partial}$	$\vec{\partial}$	Ø	Ø	q	$-q$	h_1	h_2	c	$\bar{c}$	Ø	Ø	0	0	**VCP**	$q = \{0, \pm 1\}$
R	R	$\vec{\partial}$	$\vec{\partial}$	$\vec{d}$	$\vec{d}$									e	e	**KNP**	$\vec{d} \neq \emptyset$
V	V	$\vec{\partial}$	$\vec{\partial}$	$\vec{d}$	$-\vec{d}$					c_1	c_2	$\vec{v}$	$-\vec{v}$	e	e	**GLP**	
R	R	$\vec{\partial}$	$\vec{\partial}$	$\vec{d}$	$-\vec{d}$			q	0			$\vec{v}$	Ø	e	e	**NTP**	$q \neq 0$
r	r	$\vec{\partial}$	$\vec{\partial}$	$\vec{d}$	$-\vec{d}$									e	e	**MGP**	
V	V	$\vec{\partial}$	$\vec{\partial}$			q	$-q$			c_1	c_2	$\vec{v}$	$-\vec{v}$	e	e	**MSP**	
r	r	$\vec{\partial}$	$\vec{\partial}$			q	$-q$			c	$\bar{c}$			e	e	**PHP**	$c = LEPT$
V	V	$\vec{\partial}$	$\vec{\partial}$			q	q					$\vec{v}$	$-\vec{v}$	e	e	**EMP**	$v \neq \emptyset$
r	r	Ø	Ø					h_1	h_2					0	0	**PMP**	$h = \{0, \pm 1\}$

Table 2: Properties of preon pairs (Ps).

2.3.2 Vacuum pair

VCP's entanglement field value is zero and the individual preons spin directions are undefined (set to null). Its purpose is to keep the balance of energy and momenta. Their collective behavior is the vacuum. This sea of VCPs permeates all regions of the lattice (3d space), being statistically very homogeneous.

The most important aspect of the vaccum is that it serves as a reservoir of energy for EMPs and the creation of virtual particle pairs. For example, in the electrostatic attraction/repulsion, the particles are accelerated, so they need kinetic energy, recruiting KNPs. Where does this energy come from? From the vacuum, of course. Similarly, when the particle is decelerated, KNPs change back to the vacuum, even if delayed by the bremsstrahlung mechanism. This mechanism coupled with the compensation mechanism (see 3.1.3) supports the notion of potential in physics.

The number of VCPs is supposed to be just the amount allowing the Coulomb force. When recruited by a U, a VCP can have its spin directions defined in any one of the N_D directions possible.

2.3.3 Electromagnetic pair

EMPs create static forces, *i.e.*, the Coulomb attraction/repulsion and the magnetic one. They are created from VCPs when one of its entanglement fields receives the value of the entanglement field of a U, but the directions of spins remain undefined. Once reemitted by a U, the EMP receives the spin direction of its origin U. When this EMP interacts with another U, it is reemitted as a KNP, that is, it has its direction defined. The choice of direction takes into account the sign of the electric charges involved, coded by the nonzero value of the p_8 field. After an EMP is emitted, it can be again reemitted as a KNP, stimulated by the Us forming the fermion.

When an EMP is emitted by a U, it may interact with another U. This interaction has a small probability to occur however (see 4.1.4). The effect of the electric EMP is to line up the spin with the radial direction and reemission of the EMP as a KNP. The magnetic effect is line up the target charge spin with the cross product of the original charge spin and the direction source-target and then reemission of the EMP as a KNP.

There are no EMP equivalents to the other forces beyond the electromagnetic one.

2.3.4 Kinetic pair

One of KNP's entanglement fields values is nonzero and the spin direction is that of its individual forming preons. This object is responsible for the spatial translation of fundamental particles and therefore

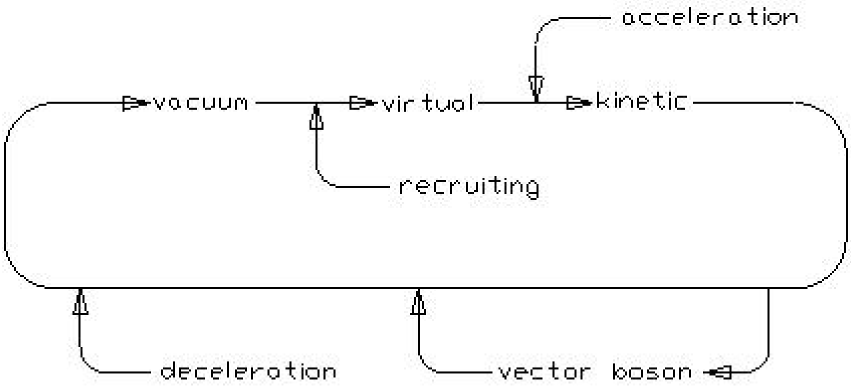

Figure 1: Life cycle of a KNP (see text).

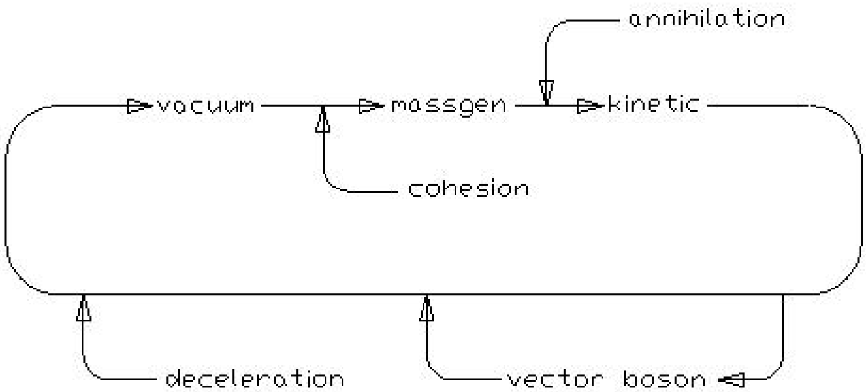

Figure 2: Life cycle of an MGP (see text).

contributes to the relativistic mass. The virtual pairs formed by the two halves of the KNP pair, due to having opposite properties, cancel out mutually.

Moreover, KNP can be considered the unit of linear momentum, and therefore contributes to the inertia of material bodies. Fig. 1 shows the life cycle of a KNP.

2.3.5 Massgen pairs

A preon pair where both entanglement field values are nonzero and the direction is non trivially defined is called a MGP. The value of its entanglement field takes the same value as that of the host U. This object is responsible for generating the rest mass of particles.

Actually, there are three types of MGPs related to one of these three forces: electromagnetic, weak and strong. MGPs are reemitted from one of their poles when interacting with the host U. It forces the direction of the U to its own direction. The virtual pairs formed by the two halves of the MGP, due to having opposite properties, cancel out mutually. MGPs, along with KNPs, are responsible for the creation of pairs of gravitons.

Fig. 2 shows the life cycle of a generic MGP.

2.3.6 Photonic pair

A PHP has trivial color charge combination. A set of PHPs plus HBAR quantity of angular momentum form a photon. If a PHP pair never interacts, it will shrink to a point at the opposite side of the universe, being naturally reemitted, since its origin vector vanishes there. It is a pure topological consequence.

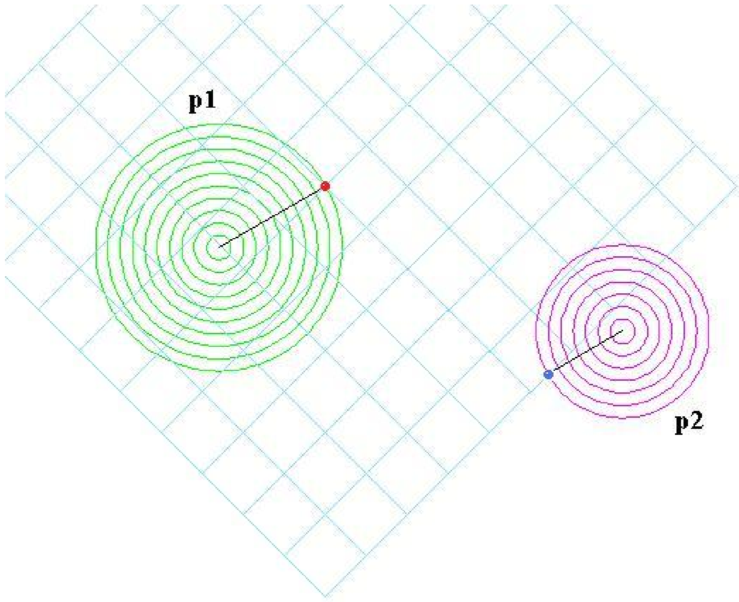

Figure 3: A preon and its twin.

2.3.7 Gluonic pair

A GLP has nontrivial color field p_{10} combination. A set of GLPs plus HBAR quantity of angular momentum form a gluon. If real, it is a duo-graviton generator.

2.3.8 Mesonic pair

MSPs form mesons. As in the case of gluon, the real MSP is a duo-graviton generator.

2.3.9 Axionic pair

Template pair for future investigation of dark matter. An axionic charge should be added to the preon structure. In this pair, all other charges are inactive, but gravitons are emitted normally, accounting for the observed 75% extra mass in the cosmos.

2.4 Preon and its twin

Every preon has a twin preon with opposite spin direction. Whenever this property changes, this fact is comunicated to its twin by a burst, as illustrated in Fig. 3.

2.5 Isotropy

Isotropy is a consequence of the fact that preons propagate as a nearly perfect wavefront. With the solution above, I fully solved the isotropy problem. Clearly, isotropy granularity depends on the size SIDE of the universal cube. Considering all combinations of normalized 3d vectors that can be formed with that value, it can be stated that the number of possible directions N_D can be calculated as

$$N_D = 2\pi\,(SIDE/2)\,.$$

For $SIDE = 128$, we have approximately $N_D = 102{,}943$ Ps. This number expresses the best isotropy possible in such a small automaton.

A key ingredient to achieve an isotropic behavior on an automaton is the generation of an isotropic wavefront. One difference between mine and most 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

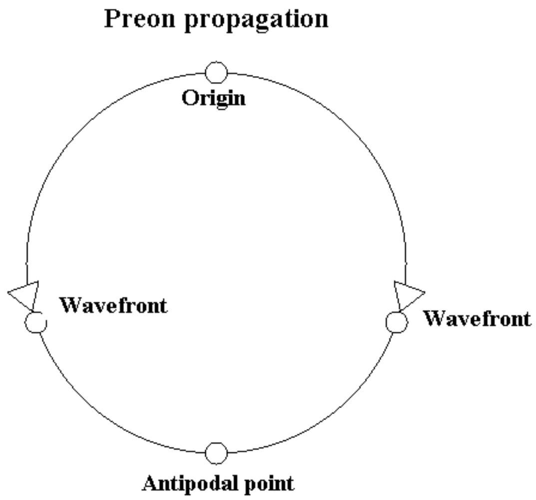

Figure 4: Preons elements composing a wavefront meet at the other side of the universe, as illustrated by the one-dimensional case shown.

Shende [11]. 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 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

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

In order to synchronize the preons forming a wavefront, it receives the value

$$t = \lceil 2D\,|p_6|\; + 0.5\rceil.$$

Actually, to avoid undesired superposition of a preon wavefront with a burst or gravitons on a common shell (w address), the time frame is segmented in two steps: one, when the bursts are active, has a duration of BURST time units. The other, when preons and gravitons are active, has a duration of $2\,D$ time units. The entire frame is termed SYNCH.

2.6 Effect of the torus closing

This effect is best illustrated in a one-dimensional torus as shown in Fig. 4. The two components of the wavefront meet on the other side of the universe. When this limit is reached, burst and graviton tiles vanish, while preons are reemitted from a cell selected on the main diagonal of the lattice. This cell is calculated using the $p_{25} = BURST$ condition, where field p_{25} counts the number of positive steps executed by a preon tile.

2.7 Entanglement

Entanglement is one of the mechanisms responsible for the formation of preon clouds (particles), namely the entanglement field property designated p_{13}, with lenghth $3 \cdot SIDE$. When preons interact, they come to share a common entanglement field value given by

$$p_{13}^1 = p_{13}^2 = p_5^1 \cdot p_5^2 + SIDE. \tag{1}$$

This operation is possible only if the interacting preons have the same electric charge. In the case of interaction with a preon pair, only the half having the same electric charge matters.

At the particle level, entanglement is an average of the individual preon values. When two preon clouds interact, a common value for the entanglement fields is gradually spread by repeated application of expression (1). The gradual loss of entanglement due to interaction with the environment resembles a *decoherence* mechanism.

To test if two tiles are entangled, the following criterion is used:

$$\begin{cases} true & if\ |p^1_{13} - p^2_{13}| > SIDE \\ \\ false & otherwise \end{cases}$$

Entanglement is an important component of the *cohesion force* and is the origin of non-classical correlations.

3 Dynamical variables

3.1 Energy

3.1.1 Definition

Energy is the square root of the number of preons, so a property of a preon cloud (particle) or region. It is related to the sum of the contribution of each preon: one unit in the case of Us, two units in the case of Ps and three units in the case of Tr's. In this way, energy is a perfectly global conserved quantity.

Energy is directly related to mass, when expressed by the number of graviton generators.

3.1.2 Principle of conservation of energy

This principle in the automaton can be seen in two different aspects: absolutely and physically. Since preons are never gained or lost and energy is the square root of the number of preons, energy is always globally conserved.

In the physical conservation of energy scene, this means that, for example, the attraction/repulsion energy acquired by particles originating from the VCPs changed to virtual and latter to KNPs must be compensated during deceleration, changing the excess kinetic energy back to VCPs, except in the rare occasions when occurs electromagnetic interaction, or, in other words, bremsstrahlung. This loan/return facility, as well as the simple transfer of KNPs, can be identified with the concept of *potential* of classical and quantum mechanics. The bremsstrahlung mechanism can therefore be seen as a delay in the return of the preons loaned by vacuum. This mechanism resembles a classical mass-spring system with damping.

A study on the application of Noether's theorem to discrete systems and consequent energy conservation due to time translation invariance can be found in [34].

3.1.3 Compensation mechanism

KNPs that accumulate around a charge fragment (U), are subject to a cancellation mechanism that causes them to return to the vacuum. The selection of the cancelled couple of pairs is based on their degree of anti-alignment. The typical example is that of a body resting on the surface of a planet, where it accumulates KNPs due to the action of gravitons and those arising from electromagnetic reaction. Without a compensation mechanism, this accumulation would grow with no bounds.

The recruiting, acceleration and deceleration may be due to one of these three forces: electromagnetic, weak or strong. The vector boson can be the photon, the weak particles W/Z or the gluon. They are responsible for a delay in the return of the KNP to vacuum (bremsstrahlung).

3.2 Linear momentum

3.2.1 Definition

The linear momentum of a fermion is the resultant of the total KNPs contained therein. Photons, in turn, carry a quantity of momentum directly related to their frequency.

3.2.2 Inertia

Definition KNPs are responsible for the spatial translation of fundamental particles and therefore contribute to the relativistic mass. Moreover, the KNP can be considered the unit of linear momentum and kinetic energy, and therefore contributes to the inertia of material bodies.

Simple inertial mechanism A KNP translates a U through 3d space. In the simplest scenario, the U and the KNP form a simple inertial system. The pair interacts with the U making it move one light step in the p_7 direction. This interaction is a privileged one, by passing the normal EM filtering due to the coincident entanglement fields of the U and one of the KNP. If left undisturbed, this system would cross the automaton forever following a statistically straight trajectory.

The role of EMPs The Us use EMPs as intermediates for expressing the static forces. It is an adiabatic proccess (one preon at a time and not chunks of HBAR/2). They carry electric polarity (*e.g.* Coulomb force) and spin information, so that the correct direction of the KNPs are defined at the destination system.

3.3 Angular momentum

3.3.1 Spin

Intrinsic angular momentum arises naturally from the adopted structure of preons when their $\vec{p}_{12}$ fields have non trivial values. Magnetic interaction must be configured such that the average angular momentum transmitted in a short radius equals that average obtained using a long radius, so that the minimum angular momentum transmitted by a photon always amounts exactly one HBAR. Spin is a generator of rotations, being considered an intrinsic AM.

3.3.2 Orbital AM

Orbital AM is a collective property of preon clouds which resembles classical angular momentum.

3.3.3 Harvesting mechanism

Each U in a charged fermion is capable of capturing one VCP, changing it to a special resonant P with the sole aim of accumulate AM, forming a Tr. The resonant Tr's emit just one graviton, keeping the particle's mass stable. Since there are exactly HBAR/2 Us in a fermion, in the end, the total AM stored will amount HBAR units. The capture of this special pair does not prevent the U of emitting EMPs normally. Other Us which have not yet acquired their resonant pairs inhibit the release of the captured resonant pairs. A photon carries away the stored AM when a total of HBAR/2 Tr's are formed.

Whenever all the Us of one particle have harvested their resonant pairs as described above, thereby avoiding mutual inhibition, a fundamental photon is released, gaining energy from the surplus KNPs (those not involved in the final eigenstate, *i.e.* the MGPs) as it expands. This is a continuous process, meaning that, as soon as the pairing process is completed, a fundamental photon is emitted and a new one starts to take form. The KNPs capture is selective: only those preons related to the cloud are candidates (entanglement affinity), otherwise, all KNPs in the universe would be swallowed up by the photon.

3.4 Time

Time at the automaton level is not a dynamical variable, but a parameter guiding its evolution. It is Newtonian and discrete. However, taking into consideration that the universe just described is finite and perfectly deterministic, there's a Poincaré cycle associated to it, and as such, time can be embedded in an extended lattice, forming a block universe [31]. Of course, no practical gain is achieved with this procedure.

4 The four forces

When completed, this automaton will hopefully contemplate the four forces of nature: electromagnetic, weak, strong, gravity. Besides, there is a fifth force in the automaton, tacitly implied in the SM, the *cohesion force*, which groups preons in clouds, but explicitly described in the automaton model.

Interactions are performed following this priority list: gravity force, cohesion force, strong force, weak force, E.M. force. The first one that occurs, inhibits all others.

4.1 Electromagnetic force

The electromagnetic force is a consequence of the combined action of electric charge and spin. It is a U x P interaction, where Ps are energy and momentum carriers between Us. Aspects of this force include the electric charge distribution, PWM coding, charge quantization, spin, Coulomb force, linear momentum transfer, angular momentum transfer, sine wave generation, magnetic interaction, electromagnet x permanent magnet, photon, bremsstrahlung. These topics are covered in the following itens.

4.1.1 Electric charge

Definition The electric charge property is encoded in the p_8 field of an active preon. It can assume the values $\{0, \pm 1\}$. Us carry one kind of ± 1 charge in one hemisphere while the other is filled with zeroes. The pole is defined by the spin field p_{12}.

Electromagnetic sinusoidal phase

Overview The sine wave or sinusoid is a mathematical curve that describes a smooth repetitive oscillation, like in the electromagnetic case. In the automaton, there is a basic sine wave function implemented as a direct-form oscillator with the $\cos(\omega t)$ parameter calculated *a priori* to fit the entire universe. The evolution of this sine wave is controlled by the Ps during propagation and can be called one or more times (higher frequency) in each light step. The phase value of a preon is stored in the p_{14} field, a five integer structure.

Direct-form oscillator The sinusoidal waveform is represented by a rational number based generator built especially to keep the accumulated error in amplitude within the limits of one length unit. Three constants are required for the sine wave generation. Clearly, they depend on the size of the automaton implementation.

$$\begin{aligned} k &= 2\cos(\omega T), \\ U_1 &= SIDE\sin(-2\omega T), \\ U_2 &= SIDE\sin(-\omega T). \end{aligned}$$

At the beginning of each wave do

$$u_0 = 1;\ u_1 = U_1;\ u_2 = U_2.$$

The evolution law is

$$\begin{aligned} u_3 &= k\,u_2 - u_1, \\ u_1 &= u_2, \\ u_2 &= u_3. \end{aligned}$$

Example The algorithm above was first tested in a small program developed outside the automaton.

The graph in Fig. 5 shows the algorithm being called once and three times by light step in a grid of 512x512 points. The horizontal axis would be any direction in 3d space while the vertical axis could be associated with the value of the phase at one point.

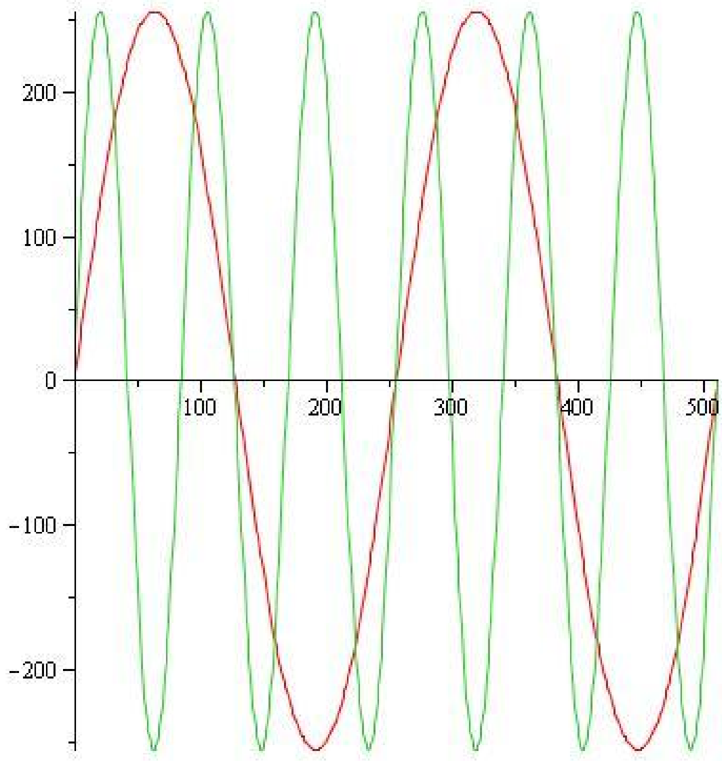

Figure 5: Sinusoidal patterns.

PWM form This discretized wave is not used directly, but must be converted to a PWM sequence, to conform to the electromagnetic filtering convention, ruling out the need of an interaction detection mechanism based on a pseudorandom generator.

Preon fields involved As seen above, the electric and magnetic fields of photons propagate following a sinusoidal pattern. The value of this phase is encoded in the p_{14} fields of preons. The usable wave is PWM encoded. To meet these needs, the p_{14} field must be substructured as follows:

- *en* (energy), an unsigned integer which counts the number of Ps composing the photon.
- *a1* and *a2*, unsigned integers with the calculated amplitudes
- *ramp*, unsigned integer incremented at each light pass.
- *pwm*, boolean integer carrying the pwm signal

The longest wavelength The wavelength of the weakest 'photon', corresponding to exactly one P, is the size SIDE of the universal cube.

4.1.2 Charge quantization

The reasoning that leads to quantization can be described as follows. Since the universe in this model is a system closed on itself, charge quantization is an emergent phenomenon. Us tend to group in clouds containing the same amount of elements. Let's call the total amount of Us UPTOTAL. It is expected that a random initial configuration of Us will stabilize in equal sized (HBAR/2) islands of Us after a long enough number of clock ticks[1]. This conclusion can be inferred from experiments of Bose-Einstein

[1]The name HBAR was coined after Planck's reduced constant $\hbar$, which, strictly speaking, is not a constant, but since annihilation is a rare event, it may be safely considered so.

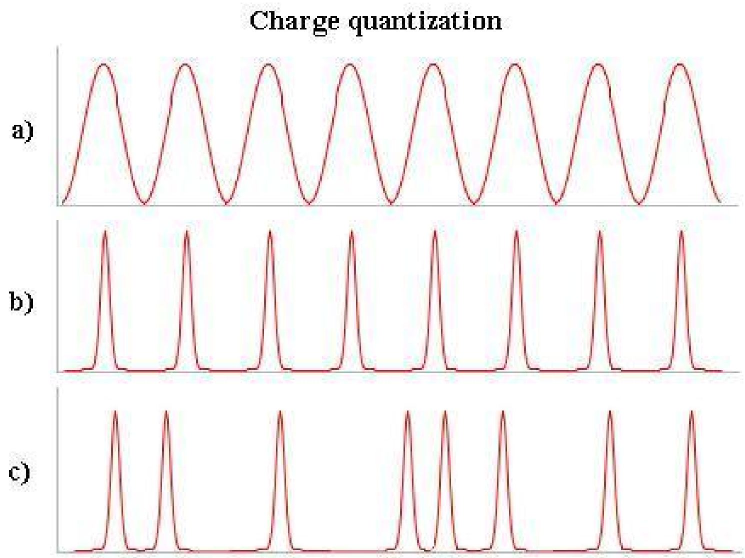

Figure 6: Us with the same electric sign tend to form a stationary, sinusoidal pattern of longitudinal waves circumventing the universe (drawing a). In a second stage, due to the cohesion force, the original charge pattern shrinks in clumps of HBAR/2 preons like the configuration shown in b), preserving the segmentation of the Us, which in the three dimensional case, would be spherical islands of charge. Part c) shows the rich configuration of islands as the automaton evolves.

condensates where magnetic vortices are quantized due to perfect fluid characteristics of the condensate and the fact that it is a closed system.

HBAR can be calculated from the input parameters as

$$HBAR = \frac{SIDE}{SIDE - UPTOTAL}.$$

Considering charge space and assuming random initial distribution of preons that survived the massive annihilation that formed the initial Ps, and that the universe is a closed system, then the charge distribution tends to form a stationary, sinusoidal pattern of longitudinal waves circumventing the universe (drawing *a)* at Fig. 6).

In a second stage, due to the cohesion force, which tends to unite charges of equal sign in preon clouds, the original charge pattern shrinks in clumps like the configuration shown in *b)*, preserving the segmentation of the Us, which in the three dimensional case, would be spherical islands of charge.

Part *c)* shows the random configuration of quantized U islands as the automaton evolves.

Angular momentum quantization, therefore, can be seen as a consequence of charge quantization. Preservation of the primordial electric charge quantization is reinforced by the way vector bosons transport angular momentum in chunks of HBAR, resulting in a self correcting mechanism.[2]

4.1.3 Spin

Spin of fermions In a fermion, the spins tend to align either outward or inward, as shown in Fig. 7. These states correspond to either spin up or spin down. This model was inspired in the Hofer electron [20].

It is also worthwhile to take a look at the work by E. Santamato, F. De Martini [33], where the 'intrinsic helicity' resembles the field p_{12}, and is the generator of the spin-statistics relation.

Spin of bosons In bosons, spin is the resultant of the collective action of all preons composing it. This resultant is exactly HBAR due to the way bosons are formed. Additional angular momentum can also be transported in bunches of bosons and considered orbital angular momentum, but is also quantized

[2] A different way to quantization through the Feigenbaum universality can be seen in Manasson [35], while Smith [36] explains it in terms of a topologically trapped magnetic field.

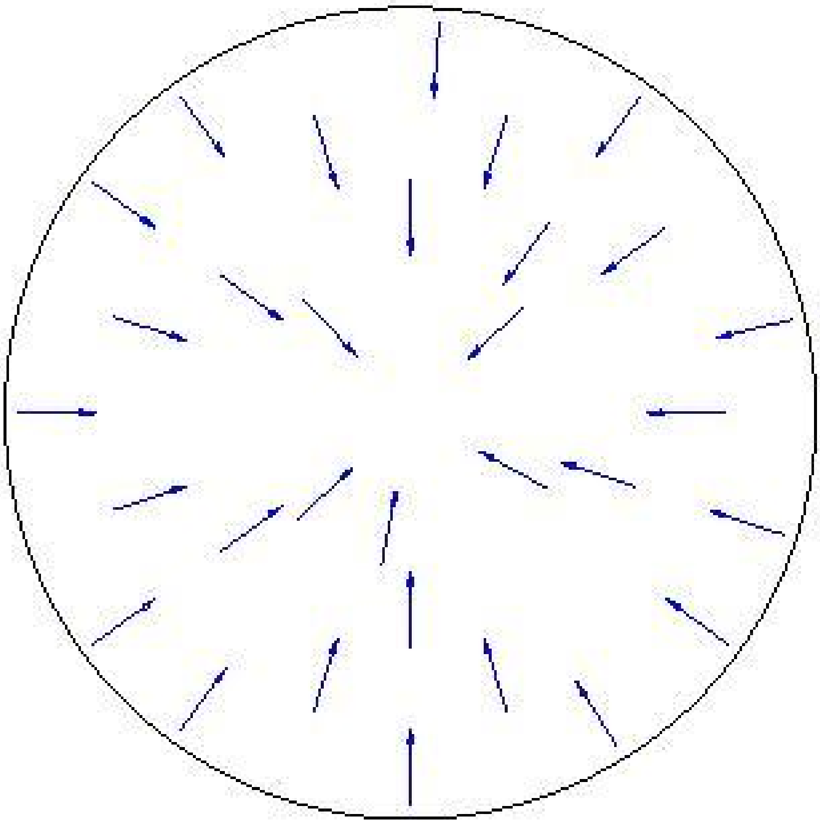

Figure 7: Spin pattern for fermions. Spin up conventionally is the case when all preons are pointing outward. Spin down is when all preons spins are pointing inward.

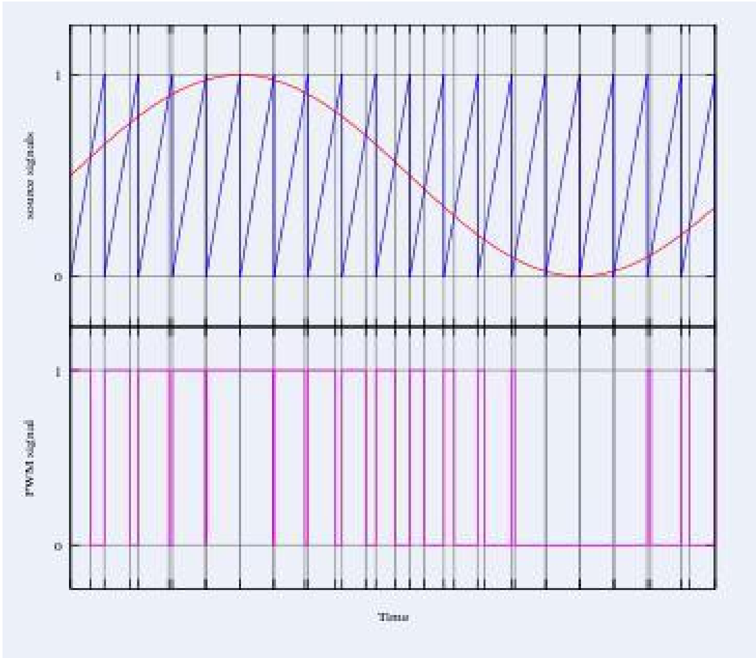

Figure 8: Simplest PWM scheme, which is used in the cellular automaton.

in multiples of HBAR. Bosons transport angular momentum in an informational pattern resembling Archimedes' spiral [37].

4.1.4 Electromagnetic interaction

Overview The electromagnetic interaction is a direct consequence of preons properties: electric charge phase of the U, spin orientation, wavefront sinusoidal phase of the P. These phases are always present whether in the virtual or in the real photon (see 5.1.5 below for a full description of the photon).

PWM The sinusoidal phase and polarization use a PWM scheme convert amplitudes to pulses is the simple method illustrated by Fig. 8 taken from [28].

In the case of the sinusoidal wavefront phase, at regular intervals, similar ramps are generated and compared against the sine wave. What is the size of this interval? It must be long enough to allow an undetected discretization using our measurement instruments but, at the same time, short enough to cover the energy range seen in nature. Ultra-high-energy gamma rays [32] have a wavelength shorter than $1.24 \cdot 10^{-20}$m. Planck length is $1.6 \cdot 10^{-35}$m. Taking into consideration the given data, I propose that the ramp interval is of the order $1 \cdot 10^{10}$ Planck lengths. This value is represented by the input parameter RAMP, defined in 6.1.

This simple scheme seems handy for our purpose because it produces thin pulses, reflecting the relatively low interactivity of the electromagnetic force.

The adoption of PWM was inspired in the work by Qi-Ming Chen and Re-Bing Wu [29].

Polarization Conceptualy, when a PHP propagates, its spin direction rotates around the propagation direction (see 5.1.5 for more details). Since this direction is undefined, except at the moment of detection, then the direction of the vector s pair is only known (calculated) at that precise moment.

Electromagnetic filtering When a PHP intersects a U, it rarely if ever interacts with this charge. This interaction depends on the phase of the electromagnetic wavefront, which has a sinusoidal shape encoded as a PWM pulse train, and also on the polarization phase, once again coded as PWM, allowing a simple AND comparison for the interaction to occur. The presence of a graviton inhibits the E.M. mechanism just described (4.1.10). Moreover, after the electromagnetic filtering, whether a Coulomb or

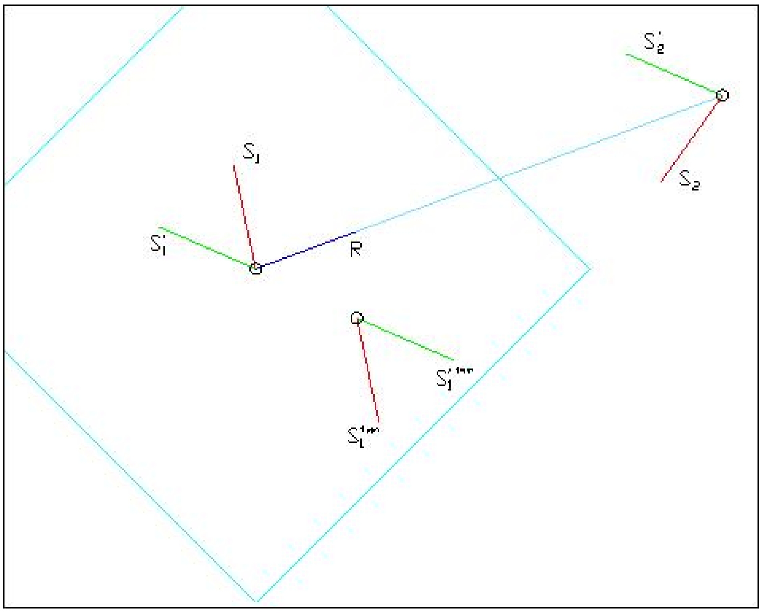

Figure 9: Spin interaction at the preon level that results in the magnetic force. The twin pair must be correctly aligned.

a magnetic interaction occurs, is decided upon the result of a test on the polarization angle (see 4.1.4). The net result at the particle level is expected to reflect the electromagnetic coupling constant alpha $\sim 1/137$.

The interaction at the preon level must necessarily be extremely rare, since electrons, for instance, are composed by a myriad of Us.

4.1.5 Coulomb force

The Coulombic or electrostatic force is a virtual mechanism, meaning that it is not tied to the need of transporting quantized angular momentum. It is much like the magnetic force, although, in the latter case, the effect is perpendicular to the propagation direction.

The chain of events that leads to Coulomb's force can be described as follows: One VCP interacts with a U (charge), being reemitted from the position of the charge as a static pair (virtual photon). When this virtual pair interacts electromagnetically with a second charge (also a U), it is regenerated as a KNP, thereby accelerating the second charge, setting the spin directions according to the nonzero entanglement field (positive or negative acceleration), and also inheriting the radial repulsive/attractive phase.

4.1.6 Magnetic interaction

Interaction at the preon level When a static pair, or virtual photon (VP), pointing to direction S_1 interacts magnetically with a U, after passing the E.M. filter test, with spin pointing to the S_2 direction, it transforms itself to a KNP with direction perpendicular to the transported spin direction S_1 (spin of the origin U) and the radial direction R (normalized cross product). Let us call this new perpendicular direction P. Each P is able to carry exactly one basic unit of AM, neither more nor less.

The origin U has its spin direction changed to the P direction too. Therefore, to keep things perfectly balanced, its twin peer S_1'must be hunted in the entire universe by a superluminal mechanism (cyan cube), forcing it to the opposite direction $P\prime$.

Fig. 9 shows schematically the magnetic interaction at the preon level described above. The twin pair partners may be space-like separated. It tacitly shows that $S_1' = P$ and $S'_{1\,twin} = P\prime$.

Interaction at the particle level Magnetic effect on a target system (particle, say) is relevant only if there is a difference in velocity between the two clouds, thereby breaking the symmetry that cancels

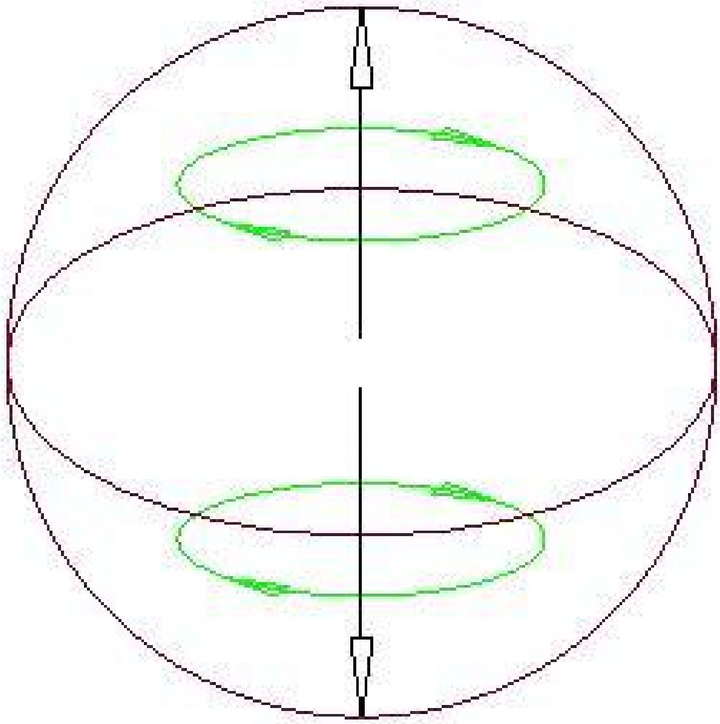

Figure 10: The induced rotation for each electric charge sign uses the convention shown. The up arrow means positive charge.

the effect over the target system.

These cancellations are due to the fact that both hemispherical charge distributions induce rotations in the same direction as shown in Fig. 10. The particle Us (charge fragments) are continuously recruiting VCPs to act as static preon pairs (virtual photons). The magnetic effect of the cloud on a distant charge cancels statistically due to the symmetry of the distribution of spins. In other words, a still charge exerts no magnetic force on another still charge, as shown in Fig. 10.

If an electron is in motion, the KNPs (which support the cloud made of moving charged or Us) break the spherical symmetry of the cloud, which passes into an oval configuration and consequently induces a magnetic dipole. This helps to explain the Stern-Gerlach [14] experiment.

4.1.7 Angular momentum transfer at the destiny

When a photon is detected, that is, one of its Ps interacts with a U of the target particle, and if the photon is absorbed, it collapses immediately, releasing its AM content.

Studies about the magnetic force which influenced this section can be found in [15] and [16].

4.1.8 Bremsstrahlung

The accumulated KNPs due to decelerated charged particle may be released in the form of one or more real photons, if there is angular momentum available. This is a rare event tied to the strength of the electromagnetic interaction. When energy emission does not occur, elastic scattering results: The excess KNPs return to the vacuum during deceleration and new KNPs are recruited during reacceleration, with suitable new spin alignment. Bremsstrahlung can then be seen as a delay in the devolution of loaned Ps from the vacuum.

4.1.9 Equivalence of an electromagnet and a permanent magnet

To emphasize the double face of the magnetic force, the following comparison is presented.

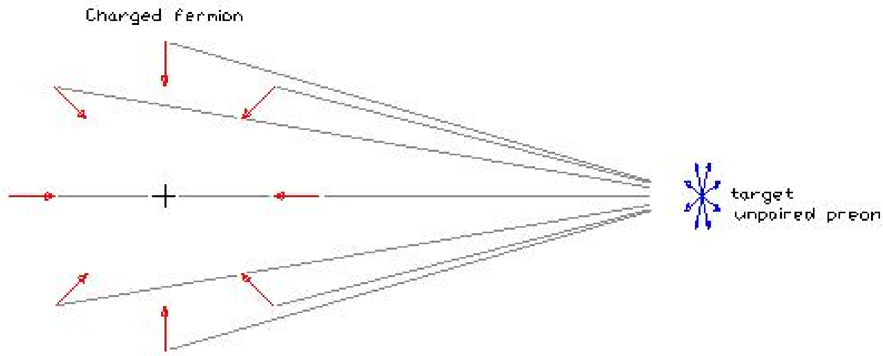

Figure 11: Spin effect cancellation. The charged fermion at left has all its spins pointing inward or outward in average.The effect on an unpaired preon inherits this symmetric distribution, so no magnetic net effect results.

Electromagnet Us are continually recruiting Ps from the vacuum to act as static Ps (virtual photons). Furthermore, the Hofer electrons circulating in the electromagnet can be visualized as a spherical cloud where all the rotation vectors are pointing outward (or inward).

The magnetic effect of the cloud on a distant charge vanishes statistically due to the symmetry of the distribution of rotations. In other words, a stationary charge exerts no magnetic force on another charge.

If the electron is moving, the KNPs that maintain a charged preon in motion breaks the spherical symmetry of the cloud, which passes into an oval configuration and, consequently, induces a magnetic dipole.

Permanent magnet In the case of permanent magnet, by construction, there is a similar magnetic dipole, due solely to the alignment of spins. The constant flow of virtual pairs favors the magnetic interaction to the detriment of the electric interaction (statistically speaking).

4.1.10 Connection with gravity

The presence of a graviton at the cell where the electromagnetic interaction is being calculated prevents it from occurring. This, together with emmision of gravitons by KNPs, hopefully turns the automaton into a realistic one, contributing to the emergence of relativistic effects and converging to the observed coupling constant *alpha*.

4.2 Weak force

4.2.1 Definition

In particle physics, the weak force (now part of the electroweak theory) is one of the four fundamental interactions of nature. It is responsible for radioactive decay, which plays an essential role in nuclear processes [19]. The consequence is the change of 'flavor' of particles.

In the Standard model, weak charge is known as weak isospin. The table below shows isospin values for left-handed fermions (right-handed fermions have isospin zero).

Generation 1			Generation 2			Generation 3		
Fermion	Symbol	Weak isospin	Fermion	Symbol	Weak isospin	Fermion	Symbol	Weak isospin
Electron neutrino	ν_e	$+1/2$	Muon neutrino	ν_μ	$+1/2$	Tau neutrino	ν_τ	$+1/2$
Electron	e^-	$-1/2$	Muon	μ^-	$-1/2$	Tau	τ^-	$-1/2$
Up quark	u	$+1/2$	Charm quark	c	$+1/2$	Top quark	t	$+1/2$
Down quark	d	$-1/2$	Strange quark	s	$-1/2$	Bottom quark	b	$-1/2$
All right-handed particles and left-handed antiparticles have weak isospin of 0. Right-handed antiparticles have the opposite weak isospin.								

In the automaton, the weak force arises due to the interaction of preon pairs with weak charged preons (p_9 field) which can assume the values 0 and ± 1. These values are used to filter if a weak interaction occurs or not. The weak isospin quantum number (with values $+1/2$, $-1/2$) shown in the table above is associated with the presence or absence of a smashed lepton bound to a proton/antiproton. All fermions contain some quantity of 'weak preons', that is, having nonzero p_9 property.

It is postulated that half of the preons have $p_9 = 0$ and the other half $p_9 = \pm 1$, equally and globally divided between positive and negative electric charges (parameter WTOTAL).

Flavor is the combination of the mode of radial vibration and the presence or not of a charged lepton next to the proton from the perspective of the automaton.

4.2.2 Weak bosons

Three bosons are the intermediate agents of weak interactions, the W+, W- and the Z.

4.2.3 Weak filtering

At the preon level The weak interaction may occur between a PMP and a U with non-trivial weak charge. PMPs may interact between themselves since they possess non-trivial weak charge.

At the particle level The charged weak bosons interact with the weak charged components of fermions when HBAR quantity of angular momentum is involved which therefore make charge transfer possible.

The Z boson contains equal parts of positive and negative PMP.

4.2.4 Virtual mechanism

In one scenario, weak charged Us start harvesting VCPs, causing radial vibration about the weak charges, in the form of weak MGPs. The absence of entanglement in any other pair is the signal to inhibit graviton formation, therefore the vibrational patterns do not contribute to the particle's mass. This harvesting process results in collected MGPs (radial vibration) which remain stable up to a threshold around 80 GeV. Unlike in the electromagnetic case, the only observable radial vibration mode is the fundamental one. This process can be hindered by other processes as well, that's why a neutron in the deuteron and in many other nuclei are stable. If there is enough angular momentum available, the newly formed weak boson starts to propagate, inhibiting temporarily the electrostatic attraction/repulsion (inverse or direct beta decay) properties of the found Us. This boson (whether real or virtual) is inherently unstable, so, a short time afterwards, all weak MGPs associated with this vibrational mode revert automatically to VCPs.

4.2.5 On shell mechanism

At the other scenario, instead of harvesting Ps from the vacuum, the captured Ps, which are converted to MGPs, originate from an existing photon and therefore do not revert to the vacuum, but rather decay into other particles. In this case, the MGPs contribute to manifest the weak boson's heavy mass.

4.2.6 Direct beta decay

When the W particle is formed, it inhibits the electric attraction property of the negative electric shell bonded to the proton thereby setting the charge free. Neutron decay is the typical weak force process of this kind.

4.2.7 Inverse beta decay

When the W boson forms, it inhibits the repulsion property of the negative electric shell, allowing the conversion of a proton into a neutron. Electron capture is the typical weak force process of this kind.

4.3 Strong force

One of the four fundamental forces, it is the result of the direct action of color charged preons. It is responsible for the formation of atomic nuclei, in the form of quarks, gluons and mesons. The main results obtained from QCD and deep inelastic scattering experiments [13] are used to drive the definition of the gluon to be used in the automaton.

4.3.1 Color charge

The strong force is centered about the concept of color charge, represented in the automaton by a 6 bit field named p_{10}. Three bits are for colors and three bits for anticolors. The types of color bits activated define if a lepton or baryon is matter or antimatter, or more generally, distinguishes a particle from its antiparticle.

The preons contributing to the strong force are:

- Baryonic preon, 1 color or 1 anticolor bit activated
- Gluonic preon, one color and one different anticolor bits activated
- Mesonic preon, one color and corresponding anticolor bits activated

The next tables show all combinations possible:

	R	**G**	**B**	**R'**	**G'**	**B'**
baryonic	1	0	0	0	0	0
baryonic	0	1	0	0	0	0
baryonic	0	0	1	0	0	0
antibaryonic	0	0	0	1	0	0
antibaryonic	0	0	0	0	1	0
antibaryonic	0	0	0	0	0	1

	R	**G**	**B**	**R'**	**G'**	**B'**
mesonic	1	0	0	1	0	0
mesonic	0	1	0	0	1	0
mesonic	0	0	1	0	0	1

	R	G	B	R'	G'	B'
gluonic	1	0	0	0	1	0
gluonic	1	0	0	0	0	1
gluonic	0	1	0	1	0	0
gluonic	0	1	0	0	0	1
gluonic	0	0	1	1	0	0
gluonic	0	0	1	0	1	0

In the first table, the non-reacting combinations used in the charged leptons were excluded, and are shown below:

	R	G	B	R'	G'	B'
baryonic	1	1	1	0	0	0
antibaryonic	0	0	0	1	1	1

4.3.2 Strong interaction

At the preon level It is a UxP or PxP interaction. Unlike the E.M. case, which passes an AND test involving three properties, the strong interaction is executed immediately if it passes an AND test between the interacting preons c fields. If there are three active bits in the c field, like in the last table above, the strong interaction is suppressed.

At the particle level Likewise in the E.M. case, the interaction is ruled by angular momentum quantization. The strong transaction only occurs when an amount of HBAR units of angular momentum has been gathered.

4.3.3 Quark

Quarks in the automaton are emergent patterns formed inside hadrons (see 5.4 below), which can be rephrased as 'quarks are permanently confined inside hadrons'. Colored charged preons tend to group in subclouds of same color, the quarks. At higher energies, these clouds also tend to shrink to a common point (parton model). One third of the Us forming the proton, for instance, has the red color bit set to one, and so on for the green and blue cases.

4.3.4 Gluon

In particle physics, gluons are elementary particles that cause quarks to interact through the strong force, and are indirectly responsible for the binding of protons and neutrons together in atomic nuclei in patterns known as mesons.

Here, the gluon is a cloud of GLPs carrying at least one multiple of HBAR angular momentum units. It is responsible for the transport of color in the interior of baryons and mesons, maintaining the preon cloud highly cohesive. Unlike photons in the electromagnetic force, gluons act aggressively, interacting readily with quarks ($\alpha = 1$), and with other gluons.

The gluon is composed by a mixture of some of the nine types of strong preon pairs described below:

mixed:

r g', g r', b r'
r b', g b', b g'

colorless:

r r’, g g’, b b’

The mixtures are defined as

r g’ + g r’
b r’ + r b’
g b’ + b g’

r r’ + g g’
r r’ + b b’
g g’ + b b’

If the gluon is real, the GLPs composing it are duo-graviton generators. Interaction of the gluon is an extension of the mechanism used by the photon, where filtering is done exchanging colors to maintain the host particle color neutral, obsfuscating the E.M. filtering.

4.4 Gravity force

Gravity is a long range, very weak force responsible for large scale phenomena, such as planets, stars and black holes, which are kind of huge bound states.

4.4.1 The graviton

Definition The graviton is a preon devoid of all its properties, but with the activity a field of all its wavefront preons set to NOGRAVIT, except one, which is set to GRAVITON. It may be emitted by a U, the single graviton, or by a P, the duo-graviton.

When its wavefront converges to the opposite side of the universe (2.6), the graviton simply vanishes (its a field is reset to 0 and its origin vector o field modulus overflows). KNPs, along with MGPs and GLP, are generators of gravitons.

Single graviton When a U is reemitted, its old wavefront can continue propagating as a graviton.

Duo-graviton After a P is reemitted, its old wavefront can continue to propagate in the form of a duo-graviton. The Ps that form duo-gravitons are MGP, KNP and EMP. Ps linked to virtual particles do not generate gravitons, that’s why, in the weak force sector, a young and an old free neutrons have the same mass.

How the graviton acts After formed, only one point of the graviton’s wavefront remains active. The effect of a graviton on visited particles is to convert an eventual superposing VCP and convert it to a KNP pointing to the origin vector of the graviton.

Differently from the case of the virtual pair, which is polarized and degradé, gravitons act punctually (ballistic trajectory), leading naturally to an inverse square law.

The value GRAVITON of the a field cited above works as a gravity charge and is not a conserved quantity, being created or destroyed according to the circumstances.

The action of the graviton cannot be screened in any way. It is always ready to play its role until eventually vanishing as described above. It implies too, that in general, a graviton hits the target twice while piercing the preon.

4.4.2 Mass

Mass refers to the total amount of graviton generator preons in a given region, preon cloud or particle. It is classified as rest mass or relativistic mass. The rest mass is caused by Us and MGPs alone.

A preon form that contributes to mass, *i.e.* generate gravitons, besides the above mentioned includes the KNP. The mass of an elementary particle is the square root of the total amount of contributing preons inside the particle. Since preons never stand still, they must be kept inside the particle by some mechanism (see cohesion in 4.5). preon pairs attached to the U and not involved with the translation of the particle form its rest mass m_0, the MGPs. The total amount of preons involved form the particle's relativistic mass. Virtual particles (composed of virtual pairs) and static preon pairs do not generate gravitons, so do not contribute to mass.

Rest mass The rest mass m_0 of a particle is related to the sum of the energies of the Us (presumably HBAR/2 preons having the same charge) and preon pairs forming a steady state (radial vibration) around these Us relative to the absolute referential (automaton lattice). The different patterns forming the particles, compose a mass spectrum (see 4.4.7 below).

Relativistic mass The relativistic mass of a fermion is formed by its rest mass plus the KNPs energy contribution, $m = m_0 + m_k$.

4.4.3 Gravitational interaction

The collapse wave, which acts superluminally, does not destroy the preon completely, just erase all its fields, with the exception of the origin vector (o field), and a singular point on the surface, which is marked with the value GRAVITON (all others preons on the surface are marked with the value NOGRAVIT). This simplified wave, or 'bullet', acts as the graviton, capable of, in rare occasions, induce the target preon (unpaired or not) to arrest a VCP and convert it to a KNP pointing to the direction where the gravitational wave started. So every time a preon is reissued, a correspondent 'graviton' is released. The combined effect of these special preons is what is known as gravitation. A natural expectation of such a mechanism is the emergence of Newton's constant G and Einstein's field equations.

4.4.4 Example scenarios

To illustrate the graviton mechanism, let's consider three related scenarios.

The first is a small mass (ball) placed above a massive object (the Earth, say). The gravitons from the Earth that hit the ball eventually cause the hijack of a VCP changing it to a KNP, so the ball accelerates towards the center of the Earth.

Next, the ball is at rest on the surface of the Earth. The gravitons continuously deposit KNPs on the ball trying to accelerate it to the the center of the Earth, but are hindered by the KNPs produced by the electromagnetic reaction forces which maintain the ball on the same position. As time passes by, the accumulation of Ps with opposite direction would increase rapidly if left undisturbed. The excess Ps however are actually reverted to vacuum by a KNPs compensation mechanism seen previously, so that their population remains minimized.

Yet another situation involves a circular orbit. The ball is now orbiting the Earth in a perfect circular motion. At one moment it has a group of KNPs pointing tangentially to the orbit path and another group of KNPs pointing to the the center of the Earth. A short moment afterwards, the ball will have moved by the combined action of all KNPs, that is, following the hyponetuse of a hypothetical right triangle. There, those KNPs originating from the gravitons are consumed to rotate the tangent KNPs by the just amount. And the process goes on with the ball following a perfect circular path.

4.4.5 Spacetime

In the cellular automaton, spacetime is not a starting point as usual. A region of the universe can be compared with other regions or with the rest of the universe through its boundary. The concentration of mass distorts differently the 'physics' from region to region. Here, light does not follow geodesical paths of a warped spacetime described by a metric, curvature etc. as pictured in general relativity, since the automaton is essentially a rigid lattice, so the solution to this conundrum lies entirely in the changing in the

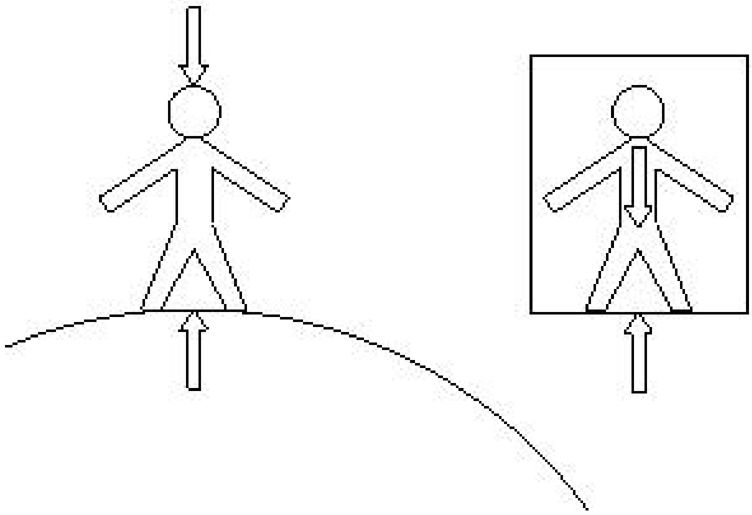

Figure 12: The Equivalence Principle says that the observer at the accelerated box experiments the same weight as the observer on the surface of the Earth. That is, gravitation force is equal to inertial force.

preon structures due to the combined action of gravity and the other forces, causing red/blue shiftings etc. So spacetime is an emergent structure, as a mean field approximation of underlying microscopic degrees of freedom represented by preons.

4.4.6 Equivalence principle

In the drawing of Fig. 12, all arrows represent an acceleration of absolute value g, the gravity acceleration, approximately 10 m/s^2.

The principle says that the observer at the accelerated box experiments the same weight as the observer on the surface of the Earth. That is, gravitation force is equal to inertial force.

Gravitons emitted by Earth's mass accumulate KNPs on the body capable of accelerate it by g. To counter this effect, so that the body remains on the surface of the planet, a chain of KNPs are transmitted via electromagnetic forces through the feet of the observer up to his head. This chain of events gives the observer the feeling of weight.

In the box, the acceleration of 1 g caused by the rocket, is transmitted directly to the observer's feet, giving him the same feeling of heaviness as his twin on Earth.

The comparison between the two cases from the perspective of KNPs, apparently corroborates the principle of equivalence, which will now be considered a theorem.

4.4.7 Mass spectrum

The challenge One of the greatest challenges a new foundational theory of nature must face is figuring out a way to calculate the masses of elementary particles from first principles. In the SM they enter as *ad hoc* parameters. Attempts to resolve this long sought problem can be seen in Nambu [21] and Hansson [22].

In what follows, I contemplate the possibility that the enigma might be solved by considering the masses as consequence of the radial vibration of preon clouds, with no need for a Higgs mechanism or Yukawa coupling.

Radial vibration modes Since leptons are, in this model, composite particles, they can possess radial vibration, like a pulsating sphere [23]. Leptons and quarks are resonant energy forms of a common type. The muon is the first excited state of the radial vibrational state of the electron, the tau is the second, so there is just one kind of lepton: the electron. Neutrinos carry away the excess angular momentum.

For quarks, the charm is the first excited state of the radial vibrational state of the up. The top is the second radial vibrational state of the up. The strange is the first radial vibrational state of the down.

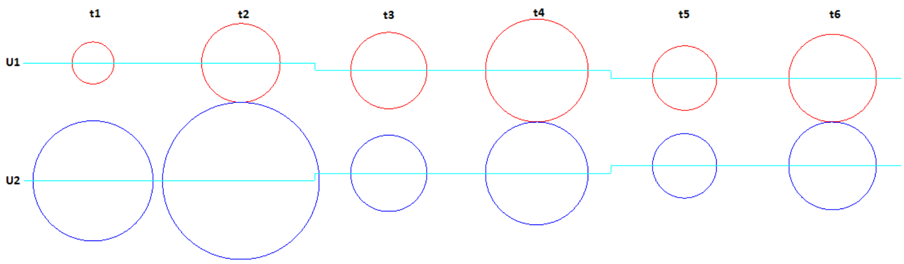

Figure 13: Collision of Us generating the cohesion force.

The bottom is the second radial vibrational state of the down. The down is formed when the up captures a charged lepton. We therefore are led to conclude that there is just one kind of quark, the up.

The decay of heavier quarks into lighter ones is done through virtual W bosons, which give or take the negative electric charge in the path of these decays as dictated by the SM and confirmed experimentally.

On the other hand, this explains the neutron structure: The neutron is essentially an electron stripped of angular momentum and very close to a proton, like an energetic hydrogen atom. It is glued to the proton by the electromagnetic force. Due to lepton number conservation, an antineutrino must be included in the balance. In other words, the neutron is a *udd* baryon.

Therefore, the amount of MGPs trapped in these resonance modes gives rise to the mass of the particles when they emit duo-gravitons in addition to the gravitons emitted by their Us.

4.4.8 Arrow of time

A cosmological model that apparently is compatible with the automaton now being developed is well described by the work by Barbour, Koslowski and Mercati, Identification of a Gravitational Arrow of Time.

Since interactions are based in AND boolean operations, the processes are irreversible in time, so we have also an E.M. arrow of time.

CMB is a preferred reference frame....TODO. Freeman Dyson has emphasized that no conventional experiment is capable

of detecting individual gravitons TODO BICEP2 results TODO Black hole complementarity TODO and large scale structure (LSS). TODO No-hair conjecture TODO

4.5 Cohesion force

4.5.1 Definition

Force that maintains a group of preons in clouds or, in other words, elementary particles. Four mechanisms are responsible for the force: collision of Us, UxV interactions, MGP contribution and KNP contribution.

4.5.2 Collision of Us

Clashing Us are reemitted from their origin point with the smallest shift in the direction of the other U (see Fig. 4.5.1). If their entanglement fields are different, both will be replaced by a common value given by Eq. 1.

4.5.3 UxV interactions

In Fig. 14, the U is reemitted when interacts with the vacuum, capturing a VCP, changing it to a virtual pair (not shown). In average, the U remains at the same region as a result of vacuum homogeneity. In each iteration, the U's spin is inverted, otherwise it would disperse rapidly. The position of the successive reemissions resembles a random walk, suggesting a bridge to QM, *cf.* [24].

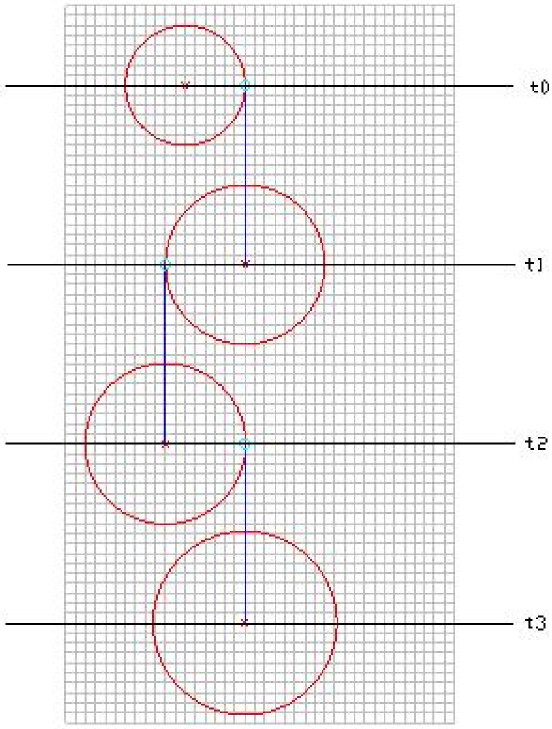

Figure 14: Cohesion force resulting from interaction of a U with the vacuum.

4.5.4 MGP contribution

The MGPs associated with a group of Us (charge fragments), vibrate radially around the charges, giving the particle its rest mass. They follow the cohesion due to the interaction described above.

4.5.5 KNP contribution

By the same token, KNPs associated with the particles translation are driven by the cohesion dynamics of the charges. KNPs contribute to the cohesion force. In the absence of MGPs, they move the Us at the speed of light as shown in Fig. 14.

5 Particles

Elementary particles are self-organizing patterns formed by a huge number of preons. They are generally classified as

- Bosons, having integer intrinsic spin
- Fermions, having half integer intrinsic spin

They may be also classified as

- Real, if the energy used to create them came from a real vector boson
- Virtual, if the energy used to create them came from the vacuum

These basic particles cooperate to form stable systems, or bound states, such as atoms, or in exotic temporary configurations like mesons. These combinations and the fact that they decay allow to classify particles more generally as

- Virtual particles

- Unstable complex particles
- Unstable elementary particles
- Stable complex particles
- Stable elementary particles
- Neutrinos

Particles are created or annihilated under many interactions possible. Their masses are a consequence of their capacity of generating gravitons.

5.1 Bosons

5.1.1 Boson fragments

Spare Ps (isolated bosons) are used as real and virtual bosons or as static pairs (EMP), such as in the case of the electrostatic force.

5.1.2 Virtual bosons

If the energy used to construct the boson comes directly from the vacuum, it is considered a virtual boson. It does not generate gravitons and quickly disappears, returning its energy to the vacuum.

5.1.3 Real bosons

Real bosons, on the other hand, are formed by pairs aggregated by an outgoing quantized angular momentum amounting at least one multiple of HBAR, as in the case of the photon. Additional properties, namely color charge and weak charge, contribute to the formation of other elementary bosons, the gluons, mesons and the W and Z weak bosons.

Bosons interact with other bosons or with itself through the footprint p_{18} field. Their collective behavior follows a Bose-Einstein statistics distribution.

5.1.4 The boson of gravitation

A different type of boson is responsible for the force of gravity, the graviton. Gravitons are remnants of the reemission of real preons. When a real preon is reemitted, a graviton is released from the contact point, tangentially to the preon spherical surface.

5.1.5 The photon

A photon is a compact, concentric, sequence of a variable number of PHPs released from a single electrically charged cloud. At the time of its creation, all its preons share a common entanglement field (p_{13}) value inherited from the emitter particle. The photon carries exactly one HBAR quantity of intrinsic angular momentum besides linear momentum, which is a direct function of its energy.

Photon emission Emission of the forming photon is triggered when the amount of collected angular momentum reaches exactly one HBAR. In other words, when all Us have an associated P, forming triads (Tr), thereby avoiding mutual inhibition.

Some of the Ps populating an electron are synchronized with the Us, that is, they form one and the same wavefront (Tr). Since there are HBAR/2 unpaired preons, there may be at most this amount of synchronized pairs. When these pairs eventually get all their spins aligned, they stop to inhibit each other, as well as some of the KNPs associated with the electron through their entanglement fields. Since each of them have a basic unit of angular momentum, at the instant they are released, they carry exactly HBAR units of angular momentum. This process characterizes the creation of a photon and its frequency is the *zitterbewegung*. The rapid response (preons don't grow too much) in the case of the strong force explains the small size of the nucleus.

The released PHPs can then be classified in two groups: one in which all spin directions are aligned and the other in which the directions are diverse, *i.e.*, statistically random.

During expansion, the PHPs update the sinusoidal phase structure (p_{14x}). A capture event is transmitted to the whole wavefront by a burst, so that all preons in a wavefront have the same phase value. Each PHP in a photon contributes to advance the algorithm in all their siblings, thereby guaranteeing that all of them operate at the same frequency. This mutual reconaissance is done via a burst.

The simultaneity of the advance operation is avoided since each captured P is in its own expanding sphere (w address).

Fundamental photon Us in an elementary particle (preon cloud) are constantly harvesting VCPs and forming Tr's, accumulating their angular momentum. When they are simultaneously released, they form a photon that can aggregate more Ps, if available (similar entanglement fields). If not available, it is considered a *fundamental photon*. In terms of fundamental units (automaton units), this fundamental photon has square root of HBAR units of energy, HBAR units of angular momentum, HBAR units of linear momentum and SIDE/HBAR grid units wavelength.

It can be concluded that the model, although still mostly incomplete, is able to make the remarkable prediction that if an electron is left completely alone (if even possible), still continues to emit weak (low frequency) fundamental photons exactly alike at an approximately constant rate. Moreover, if the fundamental photon can explain the Casimir effect deserves further investigation.

The travelling photon A travelling or freely propagating photon is a group of concentric PHPs where all have the same entanglement field value. At least one multiple of HBAR/2 pairs have their spins with the same orientation, the remaining pairs are pointing randomly.

Light-matter interaction When the travelling photon interacts with a U belonging to a distant particle, the following chain of events happens:

- the target U (belonging to a fermion, for instance) emits a burst
- the collapsing wave interacts with all preons with the same entanglement field (p_{13}) value
- all affected Ps are reemitted at the impact point.
- linear momentum and angular momentum are naturally transferred to the target system
- it is also possible that the photon is reemitted, leaving part of its energy in the target system
- the photon can also be shattered into Us (pair formation)

If the photon's target is an atom, three typical interactions can happen, with probabilities depending on the photon's energy and the atomic number Z.

- photoelectric effect
- Compton scattering
- pair production

Photon polarization The photon is circularly polarized since the component PHPs are also polar (linear polarization, for instance, is an emergent feature of systems of photon beams). The photon described here is a naive entity, while photons found commonly in experiments are actually beams of these pure photons, which may acquire additional emergent properties, such as orbital angular momentum and elliptic polarization.

The spin fields of a PHP rotate about the radius of propagation, that is, are circularly polarized, following transversally the sinusoidal phase of the photon. The polarization angle is calculated from the origin vector length, synchronized with the sinusoidal phase and used to diplace two squared cosine PWM patterns, one associated to the electric and one to the magnetic interaction, which are dephased by 90°. This mechanism is illustrated by Fig. 15, which depicts this concept of polarization used in the automaton. Since a preon propagates isotropically as a preon, *i.e.* for all directions, polarization is calculated at the moment of interaction.

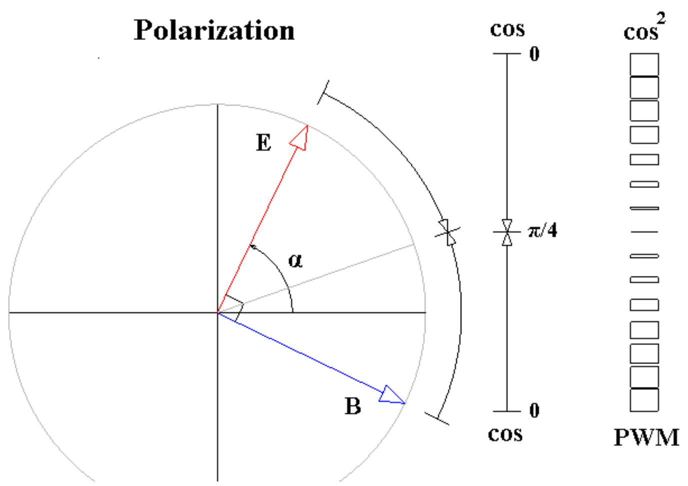

Figure 15: Polarization concept used in the cellular automaton. The angle of polarization is converted to two squared cosine PWM patterns associated with the electric and magnetic interactions, respectively.

The same accumulation reasoning used for the sinusoidal phase (subsection 4.1.1) is applied to the polarization case. Programatically, the electric PWM is calculated if

$$light \,\mathbf{mod}\, cycle < cycle/8,$$

otherwise the magnetic PWM is calculated if

$$light \,\mathbf{mod}\, cycle < cycle/4,$$

where *light* is the light step counter and *cycle* is the sinusoidal wavelength in light step units.

5.1.6 The W and Z bosons

The W and Z bosons are known as the weak vector bosons. The W boson is formed by a quantity of HBAR/2 electrically charged ($W^{\pm}$), left-handed, unpaired preons (Us), plus a huge number of weak MGPs resonating around the weak Us, and are each other's antiparticles. In the caso of the Z, the Us have no electric charge, so the Z is electrically neutral and is its own antiparticle. All W bosons are left-handed so they interact only with left-handed quarks.

5.2 Boson decay

Bosons, except the photon, decay by implosion. This implosion can be retarded by several mechanisms. While photons evolve always growing the distances between their components, other bosons have their distances shortened, until they melt in a single cell, becoming raw material.

5.2.1 Neutrinos

Neutrinos are leftovers of weak interactions. They balance angular momentum in these interactions. They are composed of NTP pairs, which carry the weak charge.

5.3 Fermions

5.3.1 Definition

An elementary fermion in the automaton model is an object composed of many preons. It carries exactly HBAR/2 Us and a definite number of MGPs besides available KNPs. At rest, the total amount of MGPs expresses the rest mass m_0 of the fermion. When it accelerates, additional KNPs are incorporated to the fermion, thereby increasing its mass (relativistic mass). The intrinsic angular momentum of the system is exactly HBAR/2, *i.e.*, equals the number of Us. Additional processes related to the weak and strong forces occur simultaneously. Fermions can combine to form nuclei, atoms and higher order structures. They also produce Fermi-Dirac statistics [25].

If the spin fields distribution is not perfectly spherically symmetric, it can exhibit a stable magnetic moment.

5.3.2 Combinations of fermions

The table below exemplifies the relation between color and matter/antimatter particles.

	c+	c-
e+		n2
e-	n1	
p+	n1	
p-		n2

c-color, e-electron, p-proton
n1-matter, n2-antimatter, n1 > n2

5.3.3 Classification of fermions

Fermions are grouped into leptons and baryons. Leptons are further subdivided in two types: electrons and neutrinos (three flavors each). Electrons are charged while neutrinos are neutral. The proton and the neutron are baryons, which are also classified as hadrons of spin 1/2.

5.3.4 Bosonic behavior of composite fermions

When a pair of fermions are entangled, their Us form partial Ps, changing the behavior of the system from fermionic to bosonic. The bosonic behavior is a function of the number of entangled constituents. A study of this phenomenon based on QM can be seen in [26].

5.3.5 Lepton number conservation

It arises naturally in the automaton operation, caused by the weak interaction. Conservation of angular momentum requires that lack or excess of angular momentum be transported by neutrinos or embedded in a photon.

$$\begin{aligned} \mu^- &\rightarrow e^- + \bar{\nu}_e + \nu_\mu \\ \mu^- &\rightarrow e^- + \gamma \end{aligned}$$

The first expression can be (simplifying) described in automaton terms as folows: A virtual W- starts to take shape around the *muon*, extracting energy from the vacuum. When emitted, it desarms the electromagnetic properties of the muon. The angular momentum and part of the MGPs and KNPs of the destroyed muon will be used to build the new electron. When the W disappears, returning to the vacuum, two situations may arise concerning the remnant MGPs and KNPs: they either divide in opposite angular momenta and opposite colors, forming a pair of neutrinos, or they come together to form a photon.

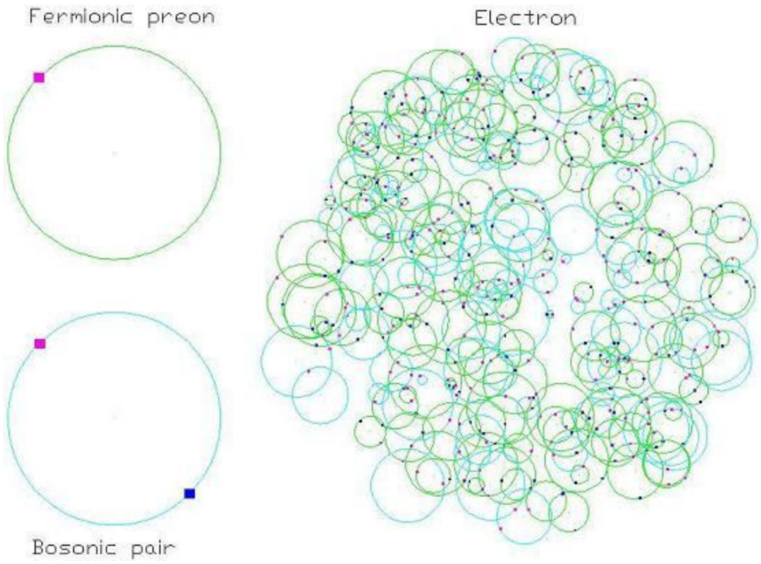

Figure 16: A swarm of preons forming an electron.

5.3.6 Electron

The electron is a fermion where all Us have negative charge and neutral colors. Its accompanying MGPs vibrate radially in the fundamental E.M. mode, which amounts to its rest mass (m_e). Higher order modes give rise to the muon and the tau.

Its HBAR/2 Us have spins in average pointing inward or outward (spin up, spin down).

Fig 16 shows a simplified view of an electron. Two kinds of objects are present: Us (green circles) with negative charge (magenta square) and MGPs (cyan circles), where both charges are present. The preons are shown at different stages of evolution.

In the electron, either free or forming a hydrogen atom, the bits of color are set to RGB, while in the case of the positron, they are set to R'G'B'.

Moreover, for each electron version there also exists a corresponding neutrino. Equally, for each these six leptons, there are their six antimatter counterparts (complementary color bits). Additional KNPs can be incorporated to the electron accelerating it.

An alternative study on non-punctual electrons can be checked in [27].

5.3.7 Neutrino

The neutrino is a particle formed by Ps alone, that's why it is a neutral particle. It carries exactly HBAR/2 of orbital AM, so behave like fermions. They are leftover from weak interactions.

Neutrinos are a partial mass version of its partner particle (e, μ, τ), but with the same frequency (a bold assertion necessary to explain the difference between ν_e, ν_μ and ν_τ), they are required to close the angular momentum balance in the weak force interactions.

When released in a weak force process, like during free neutron decay, the neutrino carries with it the weak charge, since this is the only force neutrinos interact with. This weak charge causes the neutrino becomes continuously emitting virtual Z bosons, allowing them to elastically scatter with other weak charged particles.

This model does not predict the existence of sterile neutrinos [28]. On the other hand, a running automaton will confirm if "neutrinoless double-beta decay" really happens and provide a possible answer to why the observable universe is made of matter and not antimatter.

Due to their simple structure, neutrinos are their own antiparticles. In this sense, they can be considered Majorana fermions.

5.4 Hadrons

5.4.1 Definition

A hadron is a composite particle made of quarks held together by the strong force in a similar way as molecules are held together by the electromagnetic force [28].

5.4.2 Baryons

Overview In particle physics, a baryon is a composite subatomic particle made up of three quarks. It participates in the strong interaction.

Proton The proton is a particle (preon cloud) much like the electron's cloud, but with a crucial difference: color force is involved. The colored charges inside the proton tend to group in patterns called quarks. Gluons serve as the vector bosons of the strong force, keeping the proton's parts tightly cohesive. The proton's mass derives in part from MGPs associated with the positive electric charge (Us) and in part by its component gluons. The 'recipe' for a proton follows:

- HBAR/2, strong, positive, entangled, baryonic Us, equally divided between colors R, G and B;
- Spins are spherically aligned on average;
- The Coulomb repulsion generated by UXV and UXP interactions tend to keep the Us apart;
- Cohesive UXU interactions tend to keep all Us together, generating the respectives KNPs;
- Strong UXU interactions tend to form three groups (quarks) of equal color Us, forming converging KNPs;
- MGPs coexist in the fundamental mode of vibration about the Us (quarks' mass), contributing to the proton's mass;
- Gluons form a cloud due to PXP interaction, and also contribute to the mass of the proton;
- Gluons interact with quarks, generating KNPs by color exchange between the cloud and the quarks, helping in the attraction of the baryonic Us;
- Since the strong force acts aggressivelly, compacting the colored components, the volume of the proton is then much smaller than that of the electron and the proton's net mass is high, since the frequent reemissions will generate a great quantity of gravitons;
- Additional KNPs can give the proton momentum.

There is an antimatter version of the proton, the antiproton, carrying positive electric charge and complementary white (neutral) combination of colors.

Neutron The neutron is a particle (preon cloud) formed by a definite number of Us endowed with positive electric charge and equal proportion of the three color charges, mixed with the number of MGPs and gluons needed to approximately form the proton's mass. This cloud is surrounded by a shell of the same number of negative Us without color charge, bounded to the protonic core by a number of virtual pairs sufficient to approximately form the electron's mass.

Both in the case of the neutron and in the proton, KNPs can give them speed.

The neutron can be imagined as a proton where a smashed electron, lacking angular momentum, is closely bounded to. This crushed electron is so close to the proton, that it is influenced by the intense electric attraction of the positive core keeping the electron constituents tightly bound to the proton. There are two mechanisms to undo this rigid system. One is through high energies collisions. The other is under the action of the W boson using weak interactions.

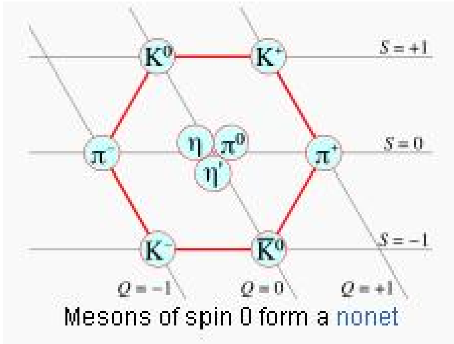

Figure 17: Mesons from the SM.

Free neutron decay Under the action of the weak charges, the Us start to harvest VCPs, causing radial vibration around the weak charges. This harvesting process takes about 14 minutes for the free neutron, the time needed to gather VCPs to form virtual MGPs amounting one hundred protons ($\sim 80\,GeV$), which is the fundamental resonance mode of the radial vibration about the weak charges. Weak MGPs collected after resonance propagate away until timeout (WTTL). When one HBAR of angular momentum units is collected, we have a W boson. The W starts to propagate but lasts for a short period. During this time it inhibits the electromagnetic properties of the negative charges preons only, because they don't have color charge, setting them free. Finally, the temporary Ps forming the W revert automatically to VCP.

In order to conserve angular momentum, a small amount of KNPs carrying the weak charge and the excess angular momentum (HBAR/2) needed to balance the angular momentum carried by the electron is released, the antineutrino. Additional KNP might give the antineutrino kinetic energy. Although quantized, this angular momentum (HBAR/2), is of orbital nature, not intrinsic as in the case of charged fermions.

The W starts to propagate, but lasts for a short period due to its huge mass. During this time, it inhibits the electromagnetic properties of the negative charged preons only, because they don't have color charge, setting them free. Finally, the temporary Ps forming the W revert automatically to a VCP.

In order to restore the released electron spin, the MGP with the excess HBAR/2 AM is released as an antineutrino, kept united by weak virtual PXP interactions and therefore carrying the weak charged preons. Additional KNPs might give the antineutrino kinetic energy. Although quantized, this angular momentum (HBAR/2), is of orbital nature, not intrinsic, as in the case of charged fermions.

5.4.3 Hadrons and the IGM model

Following the IGM model in [30], a high energy hadron can be visualized as two or three valence quarks around a compact group of gluons. Momentum is divided between the gluons and quarks, so valence quarks are fast while gluons are stopped in the central rapidity region. That study is, therefore, a good reference for the expected behavior of hadrons in my model.

5.5 Mesons

5.5.1 Overview

In particle physics, a meson is a strongly interacting boson, that is, a hadron with integer spin. In the SM, mesons are composite (non-elementary) particles composed of an even number of quarks and antiquarks. All known mesons are believed to consist of a quark-antiquark pair, the so-called valence quarks, plus a "sea" of virtual quark-antiquark pairs and virtual gluons.

In the automaton, charged mesons can be imagined as part of a fractured baryon and as such are short lived particles, products of very high-energy interactions in matter, between particles made of quarks. These bosons are responsible for the nuclear force gluing protons and neutrons in nuclei. The exchange of pions can be viewed in terms of the more fundamental interaction of quarks exchanging gluons.

Fig. 17, taken from Wikepedia, shows how mesons are organized according to the SM, exhibiting a well defined Lie group structure.

5.5.2 The pion

In particle physics, a pion (or a pi meson, denoted with the Greek letter pi: π) is any of three subatomic particles: π_0, π_+, and π_-. Each pion consists of a quark and an antiquark and is therefore a meson. In the automaton, the pion is formed by the amount of quarks to the three varieties with spin 0 and electric charges ± 1 or 0. The $\pi-$ decays to a $\mu-$ which is a particle of spin 1/2. So, in order to enforce spin conservation, an antineutrino must carry away the same inverse amount of angular momentum in orbital form.

5.6 Annihilation

In annihilation, partners are identified by their opposite properties (charge etc.). In order to keep momentum balance, a pair of bosons (generally photons) must be created. The direction of the spins of each pair is 180° apart, which forces the separation of the resultant particles. These directions are calculated (cross product) from the origin $\overrightarrow{p}_6$ fields of the two source photons. One of those photons can be immediatelly absorbed by a nearby system, resulting in single photon formation.

The entanglement is propagated to all preons of both particles. The electric attraction continues inexorably until complete annihilation of the partners. The original linear momentum must somehow be carried by the particles or transferred to a nearby system.

5.6.1 Partial annihilation

Partial annihilation occurs when a fermion and an antifermion with some different properties interact. This is a special kind of decay, as in the case of an electron and an antimuon.

6 Theory

In this section, the concepts presented above are rigorously stated, forming the model's theoretical description, using a constructive approach [8, 9].

6.1 Ontology

Definition 1. Property *formats*: SI, signed integer; SI3, 3-bit SI; UI, unsigned integer; SV, signed 3d-vector, with $N_D = \pi\,(SIDE/2)^2$ possible directions. The default length is SIDE. Pulse width modulation (PWM)[3] is used to encode some properties, using the constants $STEP = log_2\,(SIDE)\ and\, NSTEPS = SIDE/STEP$.

Definition 2. Sine constants: $K = 2\,cos\,(2\pi/SIDE)$, $U_1 = SIDE \cdot sin\,(-2\,2\pi/SIDE)$, $U_2 = SIDE \cdot sin\,(-2\pi/SIDE)$.

Definition 3. *Tile* is a formatted (p_1, p_2, ...) N-integer (see Table 1).

Definition 4. The *cellular automaton* is a dual Euclidean lattice 4-torus of dimension SIDE, where a single tile is attached to each cell. The distance between cells is L and the clock period (p_1) is T. Each lattice is alternatively principal (read-only) or dual (draft). D is the main diagonal of the lattice.

Definition 5. A *preon* is a spherical wavefront of tiles ($p_2 \equiv REAL$ or $VIRT$), expanding at the speed of light $c = L/LIGHT$.

Definition 6. *Graviton* (G) is a tile where $p_2 \equiv GRAV$ and that propagates in a straight line at the speed of light, it vanishes after traveling the distance of $SIDE/2$ units in the direction of its spin.

Definition 7. Schedule time (ST) is the time a tile waits to synchronize with the rest of the wavefront. Activation time (AT) is the moment when all tiles in a wavefront are synchronized.

[3] The use of PWM precludes the use of a pseudorandom generator whatsoever.

Definition 8. Contact point (CP) is the x, y, z address where two preons start an interaction. Origin point (OP) is the initial cell of a preon.

Definition 9. A *burst* is a cubic wavefront ($p_3 \neq NONE$), expanding at the maximum speed $s = {}^{L}/_{T}$, a superluminal messenger. Indices T and V mean T*ransported* and V*isited* tiles, respectively. Also $s = 2\,D\,c$.

Definition 10. *Unpaired* (U) is a non-overlapping preon ($p_2 \equiv REAL$ or $VIRT$). It works like a charge fragment.

Definition 11. *Pair* (P) are two overlapping preons classified as:

VCP: $p_2^1 = p_2^2 = VIRT$, $\overrightarrow{p}_7^1 = \overrightarrow{p}_7^2 = \overrightarrow{0}$, $p_8^1 = p_8^2 = 0$, $p_9^1 = p_9^2 = 0$, $p_{10}^1 = \bar{p}_{10}^2$, $\overrightarrow{p}_{12}^1 = \overrightarrow{p}_{12}^2 = \overrightarrow{0}$, $p_{13}^1 = p_{13}^2 = 0$
EMP: $p_2^1 = p_2^2 = VIRT$, $\overrightarrow{p}_7^1 = \overrightarrow{p}_7^2 = \overrightarrow{0}$, $p_8^1 = -p_8^2$, $p_9^1 = p_9^2 = 0$, $p_{10}^1 = \bar{p}_{10}^2$, $\overrightarrow{p}_{12}^1 = \overrightarrow{p}_{12}^2 \neq \overrightarrow{0}$
GLP: $p_2^1 = p_2^2 = VIRT$, $p_{10}^1 \neq 0$, $p_{10}^2 \neq 0$, $p_{10}^1 \neq \bar{p}_{10}^2$, $\overrightarrow{p}_{12}^1 = -\overrightarrow{p}_{12}^2$
MSP: $p_2^1 = p_2^2 = VIRT$, $p_8^1 = \{0, \pm 1\}$, $p_8^2 = \pm p_8^1$, $p_9^1 = \{0, \pm 1\}$, $p_9^2 = \{0, \pm 1\}$, $p_{10}^1 \neq 0$, $p_{10}^2 \neq 0$, $p_{10}^1 = \bar{p}_{10}^2$, $p_{12}^1 = \pm p_{12}^2$
KNP: $p_2^1 = p_2^2 = REAL$, $\overrightarrow{p}_7^1 = \overrightarrow{p}_7^2$
NTP: $p_2^1 = p_2^2 = REAL$, $p_9^1 \neq 0$, $\overrightarrow{p}_{12}^1 \neq 0$, $\overrightarrow{p}_{12}^2 = 0$
MGP: $\overrightarrow{p}_7^1 = -\overrightarrow{p}_7^2$
PHP: $p_8^1 = -p_8^2$, $p_9^1 = -p_9^2$, $p_{10}^1 = (ANTI)LEPT$, $p_{10}^2 = \bar{p}_{10}^1$, $\overrightarrow{p}_{12}^1 = -\overrightarrow{p}_{12}^2$

Definition 12. *Triad* (T_r) are three overlapping preons where two form a virtual pair (B)read and the third (C)heese works like a U. The Bs can be complementary leptonic tiles (photonic T_r), or strong/antistrong (gluonic T_r, a mix of 3 colors/anticolors e.g. $RG\overline{B}$), or yet chiral/antichiral tiles.

Definition 13. The *Vacuum* is the set of all VCPs.

Definition 14. *Energy* is the square root of the number of real and virtual preons in a region. *Kinetic energy* is represented by KNPs.

Definition 15. *Particles* are classified as bosons (HBAR intrinsic spin) and fermions(HBAR/2 intrinsic spin). They are *real*, if their energy comes from a real boson ($p_2 \equiv REAL$), or *virtual*, if their energy comes from the vacuum ($p_2 \equiv VIRT$). Some may carry additional KNPs and orbital angular momentum (OAM).

Definition 16. Meson is a boson made of MSPs. It can be electrically charged.

Definition 17. A *fermion* is formed by HBAR/2 Us, plus a number of MGPs defined by resonances about the charges and a variable number of KNPs.

Definition 18. *(Anti)Lepton* is a fermion where all their Us are (anti)leptonic.

Definition 19. *(Anti)Baryon* is a fermion with neutral net color, where all their Us are (anti)strong.

Definition 20. A *neutrino* is a special fermion made of HBAR/2 $NTPs$.

Definition 21. *Mass* is the rate of gravitons released by a particle.

Definition 22. Linear momentum (LM) of a fermion is the resultant of all KNPs contained therein, while bosons carry a quantity of LM directly related to their frequency.

Definition 23. Charge distribution

`SF:` $\sum_t^{SIDE} \left(p_{10}^{bit} = 1\right) = SIDE$, $\sum_t^{SIDE} p_{10}^t = \sum_t^{SIDE} \bar{p}_{10}^t$.
`EMF:` $\sum_t^{SIDE} (p_8^t = +1) = {}^{SIDE}/_{2}$, $\sum_t^{SIDE} (p_8^t = -1) = {}^{SIDE}/_{2}$.
`WF:` $\sum_t^{SIDE} (p_9^t = 0) = {}^{SIDE}/_{2}$, $\sum_t^{SIDE} (p_9^t = +1) = {}^{SIDE}/_{4}$, $\sum_t^{SIDE} (p_9^t = -1) = {}^{SIDE}/_{4}$.

Definition 24. The *input parameters* (most with proposed values) are $SIDE = 1 \cdot 10^{62}$, $L =$*one Planck length*, $T =$ *Planck time*$/3 \cdot SIDE$, $RAMP = 1 \cdot 10^{10}$ *Planck lengths*, $LOST = log_2\,(SIDE)$ and $HBAR$. They are used for mapping to the real world.[4]

[4] HBAR must be inferred from experimental data. Since it varies extremely slowly and reflects the present cosmological era of the universe, it is represented by a constant.

6.2 Dynamics

The main concepts exploited in order to give life to the automaton are succintly described:

- Most low level patterns (e.g. pair detection and UXG interaction) are detected by mutual comparisons in the w dimension in three steps of SIDE clock ticks each;
- The *Reciprocity Principle* states that preons occupying the same 3d address, composing, for example, a Tr, all arrive at the same results (*e.g.* $p_{16} = CH$) independently;
- At most a pair with the same origin is allowed in dimension w;
- Vector rotation uses the CORDIC method *cf.* [10];
- Isotropy and spherical wavefront generation are achieved applying the method described in Ref. [11];
- A visit-once-tree (see Fig. 20) is used to avoid cell access conflicts;
- The sinusoidal phase is done by means of a *Direct Form Oscillator cf.* [12];
- KNPs translate other preons in space;
- Energy is borrowed from the vacuum when a particle accelerates (VCP→KNP);
- Energy is returned to vacuum when a particle decelerates (KNP→VCP);
- Quantization is achieved with the help of triads (Tr), entanglement and bursts;
- Static forces manifest themselves at the tile level (adiabatic), not at the particle (quantized) level, through EMPs which generate KNPs;
- Energy return to vacuum can be retarded by vector bosons. The photon being a long range case (Bremsstrahlung);
- Self-interference derives from a track left by the preons on the visited cells, inspired by work of Sciarretta [7];
- A mechanism converts opposite KNP pairs to VCP pairs, thereby avoiding unbounded accumulation;
- The p_{13} entanglement field is the main mechanism used to give dynamic identity to elementary particles;
- When real preons are reemitted, their wavefronts continue propagation as a G;
- Gs induce a KNP formation on all Us encountered, until the Gs vanish by wrapping;
- A superluminal collapse mechanism, always involving HBAR basic units of AM, induces both low energy interactions, pair formation and hadronization;
- MGPs form stationary patterns around Us, contributing to the mass spectrum;
- Spontaneous decay happens with the help of virtual preons;
- When annihilation occurs, the formed pairs reorganize in variable configurations;
- The electrical and magnetic interactions are guided by results obtained by application of Maxwell equations;
- The weak and strong interactions follow rules inspired in the SM;
- Neutrinos are used for AM conservation in weak interactions.

The pseudocode in the Appendix is the full axiomatic representation of this dynamics. When omitted, most arguments apply *mutatis mutandi* to antiparticles.

7 Conclusion

The construction of a cellular automaton describing the basic laws of nature is a long-term goal, requiring the synergy of many researchers. In this contribution, I presented a tentative solution developed in five sections: the context of the work and previous efforts; general concepts the automaton mechanism; the patterns associated with elementary particles were identified and classified; and the theory with respective pseudocode as an appendix. A fifth force is explicited, the Cohesion Force, responsible for the formation of elementary particles, clustering groups of preons.

Interpretation of the present, flexible, model, as well as the first results of an implementation under construction (see Fig. 18), suggest some qualitative resemblance to QM, the SM and experimental data [14, 17–20]. Charge quantization gives rise to AM quantization. Spherical wavefront and isotropy are perfectly achieved. The results also suggest that the relativistic energy-momentum relation emerges naturally (see Fig. 19) and that ensembles can produce definite expected values (Ehrenfest theorem). The no-signalling principle is preserved, fundamental photons are emitted constantly by matter, and neutrinos are Majorana fermions. Since graviton emission is not conditioned to AM transfer, gravity is therefore not quantized.

Except for developing the basic principles, the construction of such an automaton for directly solving cosmological problems, or even complex molecules, is inconceivable. Its complete usefulness will mainly come through statistical mechanics or direct mathematical analysis in the approximation of large numbers.

With this toy model, incomplete, inaccurate, I began the first attempt at a unified model of nature using this constructive approach.

References

[1] Konrad Zuse: *Rechnender Raum*, Elektronische Datenverarbeitung, 8, 336-344 (1967).

[2] S. Wolfram: *A New Kind of Science*, Wolfram Media, {23-60}, 112, and 865-866 (2002).

[3] M. Gardner: *The fantastic combinations of John Conway's new solitaire game "life"*, Scientific American 223, 120-123 (1970).

[4] T. Ostoma, M. Trushyk: *Cellular automata theory and physics*, arXiv:physics/9907013v1 [physics.gen-ph] (1999).

[5] G. 't Hooft: *The fate of the quantum*, arXiv:1308.1007v1 (2013).

[6] H.T. Elze: *Action principle for cellular automata and the linearity of quantum mechanics*, arXiv: 1312.1615v1 (2013).

[7] A. Sciarretta: *A discrete spacetime model for quantum mechanics*, arXiv:1506.00817v1 [quant-ph] (2015).

[8] Y. Ozhigov: *Constructive physics*, arXiv:0805.2859 [quant-ph] (2008).

[9] V.V. Kornyak: *Discrete dynamical models: combinatorics, statistics and continuum approximations*, arXiv:1501.07356 [quant-ph] (2015).

[10] J. Euh, J. Chittamuru, W. Burleson: *CORDIC vector interpolator for power-aware 3d computer graphics*, Journal of VLSI Signal Processing Systems, Volume 39 Issue 1-2 (2005).

[11] J. Case, D. Rajan, A. Shende: *Spherical wave front generation in lattice computers*, Journal of Computing and Information (1994).

[12] P. Symons: *Digital waveform generation*, Cambridge University Press (2014).

[13] V. Bagnulo *Deep Inelastic Scattering*, Thesis 38.4001/6, The University of Winnipeg (2006).

[14] D.J. Griffiths: *Introduction to Quantum Mechanics*, Prentice-Hall, p. 155. (1995).

[15] D. Vokoun et al. *Magnetostatic interactions and forces between cylindrical permanent magnets*, J. Magn. Magn. Mater (2009).

[16] J.H. Field *Quantum electrodynamics and experiment demonstrate the non-retarded nature of electrodynamical force fields*, arXiv:0706.1661v3 (2007).

[17] F.O. Durães, F.S. Navarra, G. Wilk: *The interacting gluon model: a review*, arXiv:hep-ph/0412293 (2004).

[18] F. Mandl and G. Shaw: *Quantum Field Theory*, John Wiley and Sons (1984).

[19] G. Rajasekaran: *Fermi and the theory of weak interactions*, arXiv:1403.3309 [physics.hist-ph] (2014).

[20] W.A. Hofer: *Elements of physics for the 21st century*, arxiv: 1311.5407v1 (2013).

[21] Y. Nambu *An Empirical Mass Spectrum of Elementary Particles*, Prog. Theor. Phys. 7, 595-596 (1952).

[22] J. Hansson *Physical origin of elementary particle masses*, arXiv:1402.7033 [physics.gen-ph]. (2014).

[23] D. Itô *Cohesive force of electron and Nambu's mass formula*, Prog. Theor. Phys. **47**, no. 3 (1972).

[24] D. Ceperley *The Simulation of Quantum Systems with Random Walks*: A New Algorithm for Charged Systems, J. Comput. Phys 51. 4044422 (1983).

[25] T. Nguyen, R. Nanguneri, J. Parkhill *How electronic dynamics with Pauli exclusion produces Fermi-Dirac statistics*, arXiv:1411.5324 [quant-ph] (2015).

[26] M.C. Tichy, P.A. Bouvrie, K. Mølmer *How bosonic is a pair of fermions?*, arXiv:1310.8488 [quant-ph] (2013).

[27] E.T. Jaynes *Scattering of light by free electrons*, The Electron. Kluwer Academic, Dordrechtp p. 1 (1991).

[28] Wikipedia, the free encyclopedia.

[29] Qi-Ming Chen, Re-Bing Wu *Pulse width modulation for simulating time-dependent quantum systems*, arXiv:1607.04054v1 [quant-ph] (2016).

[30] F.O. Durães, F.S. Navarra, G. Wilk *The interacting gluon model: a review*, arXiv:hep-ph/0412293 (2004).

[31] A. McKenzie *Proposal for an experiment to demonstrate the block universe*, arXiv:1603.08959 [physics.pop-ph] (2016).

[32] H.P. Vankov, N. Inoue,K. Shinozaki *Ultra-high energy gamma rays in geomagnetic field and atmosphere*, http://arxiv.org/abs/astro-ph/0211051v1 (2008).

[33] E. Santamato, F. De Martini *The "intrinsic helicity" of the elementary particles and the proof of the spin-statistics theorem*, arXiv:quant-ph/1408.0941v1 (2014).

[34] S. Capobianco, T. Toffoli *Can anything from Noether's theorem be salvaged for discrete dynamical systems?*, arXiv: 1103.4785v2 (2011).

[35] V.A. Manasson *Are Particles Self-Organized Systems?*, arXiv:0803.3300v1 [physics.gen-ph] (2008).

[36] W.D. Smith *Charge quantization, the topology and 3-dimensionality of the universe, and abolishing monopoles*, Citeseer (2000).

[37] J.A. Macken *The universe is only spacetime*, http://onlyspacetime.com/ (2015).

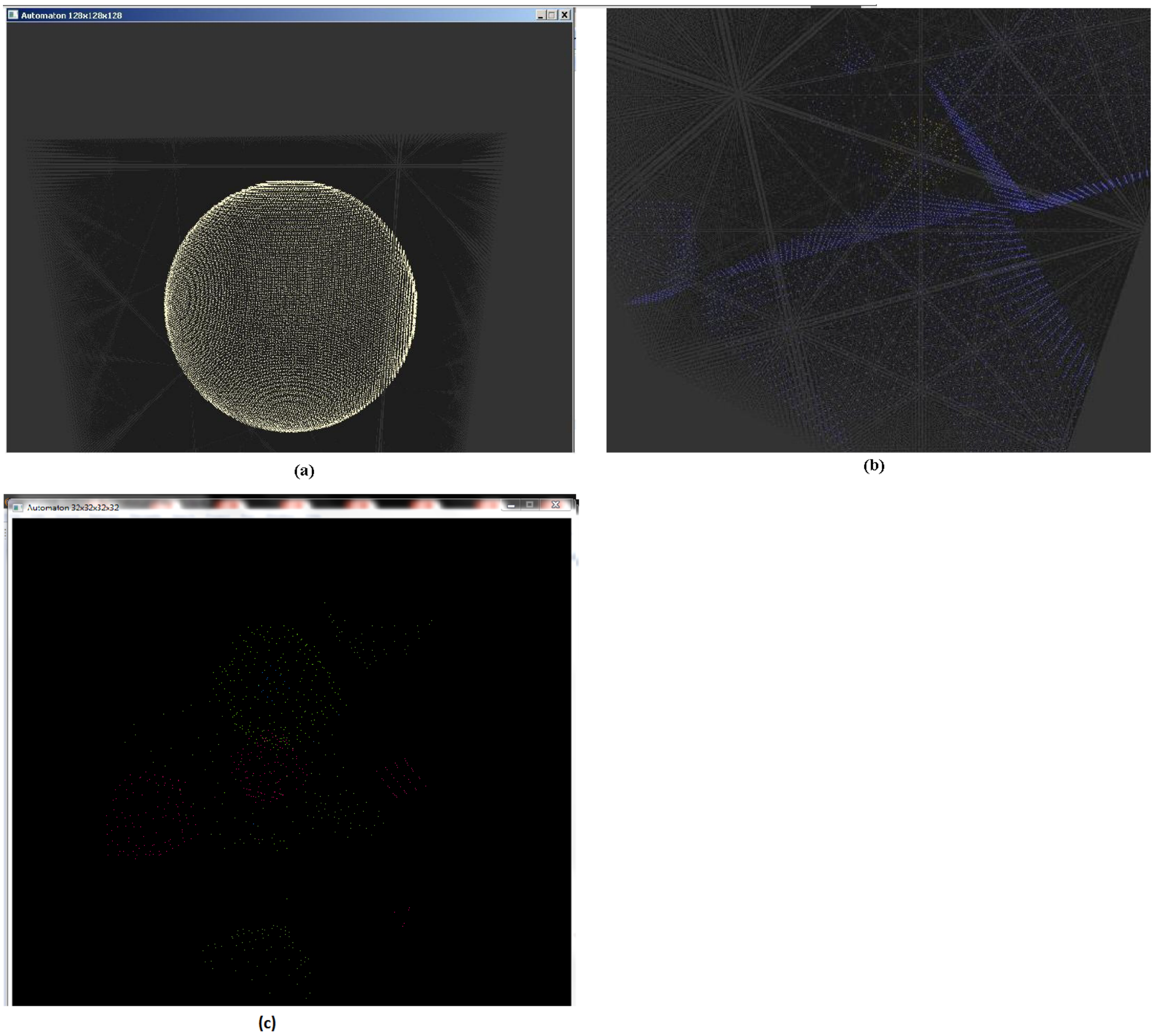

Figure 18: Results obtained by a C-language implementation: In (a) it is shown a pure wavefront; in (b) a burst, distorted by wrapping and a preon near the center; in (c) it is shown the vacuum, an ST based image, so preons don't look so round as in (a), taken AT.

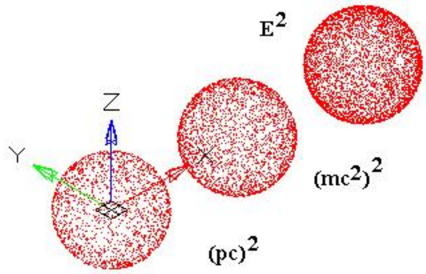

Figure 19: Energy-momentum relation as preon concentration. Each point represents a preon origin. Since the automaton tiles forming the particles are essentially spherical preons, they are more or less confined to the region of the particle. In average, either the preons that form the rest mass and those contributing to the kinetic energy (or momentum) have approximately the same radii. It can be visualized as two superimposing spherical surfaces with different numbers of preons. If those surfaces were allowed to inflate to give the same density of preons on their surfaces, the pythagorean relation ($R_c^2 = R_a^2 + R_b^2$) would be restored.

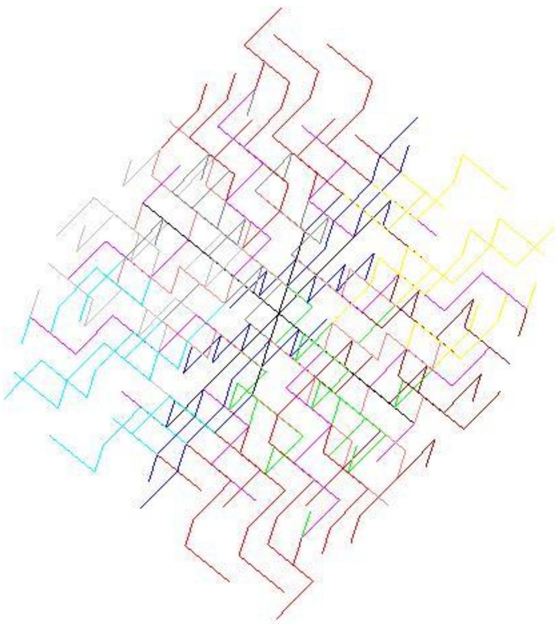

Figure 20: Exploration tree. This scheme guarantees that each cell is visited just once.

Appendix: pseudocode

Can be implemented as a central processor (this version), one processor per cell, or logic gates only solutions, with appropriate adaptations. In practice, a GPU-based solution proved sufficient to study and visualize the basic processes. The pseudocode is divided in two section. One is related to the basic information exchange mechanism, the other reflects the Planck scale physics *per se*.

A Framework

Implements the basic mechanisms of information exchange in the automaton.

```
▷ Top routine (assuming the automaton has already been initialized)
function automaton () begin
    loop
        cycle()
    end loop
end

▷ One automaton cycle
function cycle () begin
    for each cell do
        pairClassification ()
    end do
    for each cell do
        patterns2 ()
    end do
    for each cell do
        patterns3 ()
    end do
        if p_3 ≠ UNDEF
            expandBurst ()
        else if p_2 = GRAV
            expandGraviton ()
        else
            expandPreon ()
        end if
    end do
    flipLattices ()
end

function flipLattices () begin
    xchg = dual_0
    dual_0 = pri_0
    pri_0 = xchg
end

function expandBurst() begin
    if p_1^1 = SYNCH then
        p_1^2 = 0
        if p_2^1 = REAL then
            p̄_1^2 = INFINITY
            p_2^2 = GRAV
        end if
    else if p_1^1 = BURST
        return      ▷ p1 must complete one full SYNCH
    end if
```

```
    for each $dir$ in $NDIR$ do
        if $isAllowed\left(dir, p^1_{26}, p^1_{260}\right)$
            Tile *nual = getNual(dir)
            boolean gr = nual->p2 == GRAV
            int p1 = nual->p1
            Tuple p6
            tupleCopy(&p6, nual->p6)
            copyTile(nual, dual)
            if dual->p2 = GRAV
                nual->p2 = REAL    ▷ must transport to OP
                nual->p1_ = 1000000
                if gr
                    nual->p2 = GRAV
                        nual->p1_ = p1
                        tupleCopy(&nual->p6, p6)
                end if
                nual->p260 = dir
                addTuples(&nual->p26, dirs[dir])
            end if
        end for
        dual->p3 = UNDEF
        if isEqual(pri->p19, pri->p0)
            ▷ Reemit
            dual->p25 = BURST
        end if
    else if dual->p1 = 0 and dual->p2 = GRAV
        tupleCross(pri->p12, pri->p6, &dual->p12)
        normalizeTuple(&dual->p12)
        resetTuple(&dual->p6)
        dual->p203 = BURST
    else if pri->p2 != GRAV
        cleanTile(dual)
    end if
end

▷Visit-once-tree, as shown in Fig. 20
function $expandTree$ () begin
    if ($p_2 = UNDEF$ and $p_3 = UNDEF$) or ($p_1 - p_{202} \leq p_{203}$) then
        return
    end if
    ▷ Reemit from OP when maximum expansion
    if $p^1_3 = UNDEF$ and $p_6.x = SIDE/2$ then
        $\overrightarrow{p}^{1*}_{19} = \overrightarrow{p}^1_0 - \overrightarrow{p}^1_6$
        $burst\,(false)$
        return
    end if
    ▷ Activation time (AT)
    for $i = 0$ to $5$ do
        if $p^{1*}_6.x + dirs[i].x = SIDE/2 + 1$ or $p^{1*}_6.y + dirs[i].y = SIDE/2 + 1$ or $p^{1*}_6.z + dirs[i].z = SIDE/2 + 1$ then
            continue
        end if
        if $p^{1*}_6.x + dirs[i].x = -SIDE/2$ or $p^{1*}_6.y + dirs[i].y = -SIDE/2$ or $p^{1*}_6.z + dirs[i].z = -SIDE/2$ then
            continue
        end if
```

if $isAllowed\,(dir)$ **then**
$nual = getNual\,(i)$
$nual = dual$
$p_6^{nual} = dirs[i]$
$p_{200}^{nual} = i$
$p_{201}^{nual} = p_{201}^{nual} + 1$
$p_{202}^{nual} = p_1$
if $p_3^{nual} = UNDEF$ **then**
$p_{203}^{nual} = 2 \cdot D \cdot |\overrightarrow{p}_6^{nual}|$
else
$p_{203}^{nual} = 0$
end if
end if
end do
if $p_3^1 \neq UNDEF$ **and** $p_{19}^1 = p_0^1$ **then**
$reemit\,()$
else
$dual \leftarrow \varnothing$
end

function $updateDual(b)$ **begin**
if $p_3 \neq UNDEF$ **then**
$updateMessenger\,(b)$
else
$updateWavefront(b)$
end if
$dual \leftarrow \varnothing$
end

function $updateMessenger\,(b)$ **begin**
if $|p_6.x| = \frac{SIDE}{2}$ **or** $|p_6.y| = \frac{SIDE}{2}$ **or** $|p_6.z| = \frac{SIDE}{2}$ **then**
$b \leftarrow \varnothing$
else
$p_{200} = dir$
$p_{201} = p_{201} + 1$
$p_{202} = p_1$
$p_{203} = 0$
if $p_2 = REAL$ **then**
$p_2 = GRAV$
end if
end if
end

function $updateWavefront\,()$ **begin**
if $|p_6| < \frac{SIDE}{2}$ **then**
if $p_{201} = 0$ **and** $dir = 0$ **then**
$p_{200} = 1$
else if $p_{200} = 1$
$p_{200} = 0$
end if
$p_{201} = p_{201} + 1$
$p_{202} = p_1$
$p_{203} = 2D|p_6|$
else if $p_2 \neq GRAV$ **and** $p_{200} = 1$ **then**
$burst\,(UNDEF)$
$p_{203} = 4 \cdot SIDE \cdot D$
else

```
        dual ←∅
    end if
    p_144 = 1      ▷ Sine phase changed
        p_201 = p_201 + 1
        p_202 = p_1
        p_203 = 2D|p_6|
    if p_2 = GRAV then      ▷ Graviton extinction
        if p_6^G = →0 then
            p_2^G = UNDEF
            p_11^G ≡ OFF
        else if
            calculate unique tile where p_11 = ON
        end if
    end if
end
▷ Tests whether the direction dir is a valid path in the visit-once-tree.
boolean function isAllowed(dir) begin
    x = p6.x + dirs[dir].x
    y = p6.y + dirs[dir].y
    z = p6.z + dirs[dir].z
    level = abs(x) + abs(y) + abs(z)
    ▷ x-axis
    if x > 0 and y = 0 and z = 0 and dir = 0 then
        return true
    else if x < 0 and y = 0 and z = 0 and dir = 1 then
        return true
    end if
    ▷ y-axis
    else if x = 0 and y > 0 and z = 0 and dir = 2 then
        return true
    else if x = 0 and y < 0 and z = 0 and dir = 3 then
        return true
    end if
    ▷ z-axis
    else if x = 0 and y = 0 and z > 0 and dir = 4 then
        return true
    else if x = 0 and y = 0 and z < 0 and dir = 5 then
        return true
    end if
    ▷ xy plane
    else if x > 0 and y > 0 and z = 0 then
        if level mod 2 = 1 then
            return (dir = 0 and p_200 = 2)
        else
            return (dir = 2 and p_200 = 0)
        end if
    else if x < 0 and y > 0 and z = 0 then
        if level mod 2 = 1 then
            return (dir = 1 and p_200 = 2)
        else
            return (dir = 2 and p_200 = 1)
        end if
    else if x > 0 and y < 0 and z = 0 then
        if level mod 2 = 1 then
            return (dir = 0 and p_200 = 3)
        else
```

```
        return (dir = 3 and p_200 = 0)
    end if
else if x < 0 and y < 0 and z = 0 then
    if level mod2 = 1then
        return (dir = 1 and p_200 = 3)
    else
        return (dir = 3 and p_200 = 1)
    end if
end if
▷ yz plane
else if x = 0 and y > 0 and z > 0 then
    if level mod2 = 0 then
        return (dir = 4 and p_200 = 2)
    else
        return (dir = 2 and p_200 = 4)
    end if
else if x = 0 and y < 0 and z > 0 then
    if level mod2 = 0 then
        return (dir = 4 and p_200 = 3)
    else
        return (dir = 3 and p_200 = 4)
    end if
else if x = 0 and y > 0 and z < 0 then
    if level mod2 = 0 then
        return (dir = 5 and p_200 = 2)
    else
        return (dir = 2 and p_200 = 5)
    end if
else if x = 0 and y < 0 and z < 0 then
    if level mod2 = 0 then
        return (dir = 5 and p_200 = 3)
    else
        return (dir = 3 and p_200 = 5)
    end if
end if
▷ zx plane
else if x > 0 and y = 0 and z > 0 then
    if level mod2 = 1 then
        return (dir = 4 and p_200 = 0)
    else
        return (dir = 0 and p_200 = 4)
    end if
else if x < 0 and y = 0 and z > 0 then
    if level mod2 = 1 then
        return (dir = 4 and p_200 = 1)
    else
        return (dir = 1 and p_200 = 4)
    end if
else if x > 0 and y = 0 and z < 0 then
    if level mod2 = 1 then
        return (dir = 5 and p_200 = 0)
    else
        return (dir = 0 and p_200 = 5)
    end if
else if x < 0 and y = 0 and z < 0 then
    if level mod2 = 1then
```

```
            return (dir = 5 and p_200 = 1)
        else
            return (dir = 1 and p_200 = 5)
        end if
    else
    ▷ spirals
        x_0 = x + SIDE/2
        y_0 = y + SIDE/2
        z_0 = z + SIDE/2
        switch level mod 3 do
            case 0
                if x_0 ≠ SIDE/2 and y_0 ≠ SIDE/2 then
                    return (z_0 > SIDE/2 and dir = 4) or (z_0 < SIDE/2 and dir = 5)
                end if
                break
            case 1
                if y_0 ≠ SIDE/2 and z_0 ≠ SIDE/2 then
                    return (x_0 > SIDE/2 and dir = 0) or (x_0 < SIDE/2 and dir = 1)
                end if
                break
            case 2
                if x_0 ≠ SIDE/2 and z_0 ≠ SIDE/2 then
                    return (y_0 > SIDE/2 and dir = 2) or (y_0 < SIDE/2 and dir = 3)
                end if
                break
        end switch
    end if
    return false
end
```

B Physics

Implements the axiomatic rules that mimic nature behavior.

```
▷ Burst, P, G detection
▷ Field p_16 is resolved by mutual comparison in the w dimension
function pairClassification () begin
    dual ← principal      ▷ Start with a copy of last value
    if pairFormation () or interference () or isGraviton () then
        return
    end if
    p^1_16 = U
    if burstInteraction () then
        return
    end if
    ▷ Mutual visit to resolve p_16 (indices: 1, principal; 2, neighbor)
    neighbor = principal − p_5
    nual = dual − p_5
    for all neighbor ≠ principal do
        if p_2 = REAL or p_2 = VIRT then
            if p^1_6 = p^2_6 then
                if tangled (t_1, t_2) and p^2_144 = 1 then        ▷ Evolve sinusoidal phase
                    p^2_144 = 0
                    incrDFO (t_2)
                end if
```

▷ Timeout of virtual pairs (P→ VCP)
if $p_{23} = 0$ **and** $p_2 = VIRT$ **then**
  $p_{13} = 0$
  $\overrightarrow{p}_{12} = \overrightarrow{0}$
end if
if $p_2^1 = VIRT$ **and** $p_2^2 = VIRT$ **and** $\overrightarrow{p}_{12}^1 = \overrightarrow{0}$ **and** $\overrightarrow{p}_{12}^2 = \overrightarrow{0}$ **then**
  $p_{16}^1 = P$
  $p_{21}^1 = VCP$
  return
▷ Neutrino detection NTP
if $(\overrightarrow{p}_{12}^1 = \overrightarrow{0}$ **or** $\overrightarrow{p}_{12}^2 = \overrightarrow{0})$ **and** $(\overrightarrow{p}_{12}^1 \neq \overrightarrow{0}$ **or** $\overrightarrow{p}_{12} \neq \bar{0}$ **or** $p_2^1 = REAL)$ **then**
  $p_{16}^1 = NTP$
end if
if $\overrightarrow{p}_{12}^1 \neq \overrightarrow{0}$ **and** $\overrightarrow{p}_{12}^1 = -\overrightarrow{p}_{12}^2$ **then**
  ▷ Spins are defined
  if $p_2^1 = p_2^2$ **then**
    $p_{16}^1 = P$
  ▷ Detect weak MGP
  if $p_9^1 = LM$ **and** $conjug\left(p_{10}^1\right) = 1$ **and** $p_9^2 = LM$ **and** $conjug\left(p_{10}^2\right) = 1$ **then**
    $p_{21} = MGP$
  else if $p_9^1 = RM$ **and** $conjug\left(p_{10}^1\right) = -1$ **and** $p_9^2 = RM$ **and** $conjug\left(p_{10}^2\right) = -1$
then
    $p_{21} = MGP$
  ▷ Detect GLP
  else if $p_{10}^1 = RED$ **and** $p_{10}^2 = ANTIGREEN$ **then**
    $p_{21} = GLP$
  else if $p_{10}^1 = GREEN$ **and** $p_{10}^2 = ANTIRED$ **then**
    $p_{21} = GLP$
  else if $p_{10}^1 = BLUE$ **and** $p_{10}^2 = ANTIRED$ **then**
    $p_{21} = GLP$
  else if $p_{10}^1 = RED$ **and** $p_{10}^2 = ANTIBLUE$ **then**
    $p_{21} = GLP$
  else if $p_{10}^1 = GREEN$ **and** $p_{10}^2 = ANTIBLUE$ **then**
    $p_{21} = GLP$
  else if $p_{10}^1 = BLUE$ **and** $p_{10}^2 = ANTIGREEN$ **then**
    $p_{21} = GLP$
  ▷ Detect KNP
  else if $p_2^1 = REAL$ **and** $p_2^2 = REAL$ **and** $\overrightarrow{p}_7^1 \neq \overrightarrow{0}$ **and** $\overrightarrow{p}_7^1 = \overrightarrow{p}_7^2$ **then**
    $p_{21} = KNP$
  ▷ Detect MSP
  else if $p_{10}^1 = RED$ **and** $p_{10}^2 = ANTIRED$ **then**
    $p_{21} = MSP$
  else if $p_{10}^1 = GREEN$ **and** $p_{10}^2 = ANTIGREEN$ **then**
    $p_{21} = MSP$
  else if $p_{10}^1 = BLUE$ **and** $p_{10}^2 = ANTIBLUE$ **then**
    $p_{21} = MSP$
  ▷ Detect PHP
  else if $p_{10}^1 = LEPT$ **and** $p_{10}^2 = ANTILEPT$ **then**
    $p_{21} = PHP$
  else if $p_{10}^1 = ANTILEPT$ **and** $p_{10}^2 = LEPT$ **then**
    $p_{21} = PHP$
  ▷ Detect EMP
  else if $p_2^1 = REAL$ **then**
    $p_{21} = EMP$
  end if
end if

```
        end if
      end if
    end do
end

▷ Resolves p16 for additional cases
▷ (PXP, UXP, UXG interactions; WZ; HADRON)
function patterns2 () begin
    if p2 = UNDEF then
        return
    end if
    if p16 = P then
        ▷ Mutual visit to resolve p16
        neighbor = principal − p5
        nual = dual − p5
        for all neighbor ≠ principal do
            if principal = neighbor then
                continue
            end if
            if p16^2 = P then
                PXPinteraction (neighbor, nual)
            end if
        end do
        return
    else if p16 ≠ U then
        return
    end if
    ▷ Mutual visit to resolve p16
    neighbor = principal − p5
    nual = dual − p5
    for all neighbor ≠ nual do
        if p16 = P then
            UXPinteraction ()
        else if p16 = GR then
            UXGinteraction ()
        end if
    end do
end

▷ UXU, UXTr detection
function patterns3 () begin
    if p2 = UNDEF then
        return
    end if
    ▷ Mutual visit to resolve p16
    neighbor = principal − p5
    nual = dual − p5
    for all neighbor ≠ principal do
        if p16^1 = WZ and p21^2 = VCP then
            p16^2 = MGP
            continue
        end if
        if p16^1 = HADRON and p21^2 = VCP then
            p16^2 = MGP
            if p5^1 > p5^2 then
                ▷ VCP2 → GLP_bar
                p21^2 = GLP
```

$p^2_{10} = p^1_1 \bmod 8$
else
▷ VCP2 → MSP-
$p^2_{21} = MSP$
$p^2_8 = -1$
end if
continue
end if
if $p^1_{16} \neq U$ **or** $p^1_{16} \neq CH$ **then**
continue
end if
if $p^1_8 \neq 0$ **then**
if $p^1_8 = p^2_8$ **then**
$cohesion\,(neighbor, nual)$
else
$annihilation\,(neighbor, nual)$
end if
end if
$entangle\,(dual, nual)$
end do
end

function $burstInteraction()$ **begin**
if $p^T_3 \in \{PLAIN,\, FORCING,\, COLL\}$ **and** $\overrightarrow{p}^T_{19} = CP$ **then** ▷ Reemission point found
$\overrightarrow{p}^T_6 = \overrightarrow{0}$
if $p^T_3 = COLL$ **then**
$p^T_3 = FORMING$ ▷ Not superluminal
else
$p^T_3 = UNDEF$
end if
▷ Photon formation I
else if $p^T_3 = FORCING$ **and** $p^T_{16} = U_1$ **and** $p^2_{16} = U_2$ **and** $tangled\,(U_1,\, U_2)$ **then**
$reemit(U_2,\, PLAIN,\, OP_{U2})$
else if $p^T_3 = COLL$ **and** $p^V_{16} = P$ **and** $tangled\,(T,\, P)$ **then** ▷ Photon is collapsing
$reemit(P,\, PLAIN,\, CP_{emitter})$
▷ Photon formation II
else if $p^T_3 = FORCING$ **and** $p^T_{16} = C$ **and** $p^V_{16} = B$ **and** $tangled\,(C,\, B)$ **then**
$reemit(B,\, PLAIN,\, OP_C)$
else if $p^T_3 = PLAIN$ **then**
if $p^T_2 = REAL$ **and** $p^T_6 = p^V_6$ **and** $p^T_5 = p^V_5$ **then** ▷ Graviton emission
$p^V_2 = GRAV$
$p^V_{11} = OFF$
else
$p^V_2 = UNDEF$
$resetDFO\,(V)$
end if
if $p^T_{13} = p^V_{13}$ **and** $\overrightarrow{p}^V_{12} = -\overrightarrow{p}^{emitter}_{12}$ (old) **then** ▷ Pairment of twin tiles spin
$\overrightarrow{p}^V_{12} = -\overrightarrow{p}^{emitter}_{12}$ (new)
end if
end if
end

function $UXPinteraction()$ **begin** ▷ Non-leptonic Ps act like a U in the KNP case
$p^U_{16} = UXP$
if $p^U_6 = p^P_6$ **then**
▷ Tr detected

$p_{16}^{P} = BR$
$p_{16}^{U} = CH$
if $|\overrightarrow{p}_{6}^{C}| \geq LOST$ **then** ▷ The triad is undone
$p_{16}^{C} = U$ ▷ Cheese →U
$p_{16}^{B} = P$
▷ Fundamental photon
$reemit(C, PLAIN, OP_{C})$
$reemit(B, PLAIN, OP_{B})$
end if
end if
if $p_{21}^{P} = KNP$ **then** ▷ Inertia
$p_{19}^{P} = \hat{p}_{7}^{P}|\overrightarrow{p}_{6}^{P}| + \overrightarrow{p}_{6}^{P}$
$p_{19}^{UC} = p_{19}^{P} + \overrightarrow{p}_{6}^{U} - \overrightarrow{p}_{6}^{P}$
▷ Move the preons
$reemit(P, PLAIN, p_{19}^{P})$
$reemit(U|C, PLAIN, p_{19}^{U|C})$
else if $p_{21}^{P} = EMP$ **then** ▷ Static EM forces
if $EMFilter\,(U, P)$ **then** ▷ Electric force
$\overrightarrow{p}_{7}^{P} = sgn\left(p_{8}^{U} p_{8}^{P}\right) \cdot \left(\overrightarrow{p}_{6}^{P} - \overrightarrow{p}_{6}^{U}\right)$
$entangle(U, P)$
$p_{8}^{P} = 0$ ▷ EMP is just a messenger
▷ Generate KNP
$reemit\,(U, PLAIN, OP_{U})$
$reemit\,(P, PLAIN, CP)$
else if $EMFilter\,(U, P) \wedge pwm(|p_{12}^{P} \cdot p_{12}^{U}|)$ **then** ▷ Magnetic force
$\overrightarrow{p}_{7}^{P} = sgn\left(p_{8}^{U} p_{8}^{P}\right) \cdot \left(\overrightarrow{p}_{12}^{U} \times \overrightarrow{p}_{6}^{P}\right)$
$p_{12}^{U} = \overrightarrow{p}_{7}^{P}$
$entangle(U, P)$
▷ Generate KNP
$reemit\,(U, PLAIN, OP_{U})$
$reemit\,(P, PLAIN, CP)$
end if
else if $p_{21}^{P} = PHP$ **then** ▷ Light-matter interaction
$\overrightarrow{v} = \overrightarrow{p}_{12}^{P} \times \overrightarrow{p}_{6}^{P}$
$rotate(\overrightarrow{v}, p_{141}^{P})$
$c = \overrightarrow{v} \cdot \overrightarrow{p}_{12}^{U}$
$p_{15E}^{U} = pwm\left(c^{2}\right)$
$p_{15M}^{U} = pwm\left([SIDE - c]^{2}\right)$
if $EMFilter\,(U, P) \wedge \left(p_{4}^{U} \neq p_{4}^{P}\right) \wedge p_{15E}^{P}$ **then**
$reemit\,(P, COLL, CP)$
$reemit\,(U, PLAIN, OP_{U})$
else if $EMFilter\,(U, P) \wedge \left(p_{4}^{U} \neq p_{4}^{P}\right) \wedge p_{15M}^{P}$ **then**
$reemit\,(P, COLL, CP)$
$reemit\,(U, PLAIN, OP_{U})$
end if
else if $p_{21}^{P} = MGP$ **then** ▷ Charged-bosons interaction with matter
if $p_{8}^{P} \neq 0$ **or** $p_{10}^{P} \neq LEPT$ **or** $p_{9}^{P} \neq 0$ **then**
$p_{18}^{P} = SIDE$
▷ Neutrino emission
if $p_{8}^{U} \neq 0$ **and** $p_{9}^{U} = -1$ **and** $p_{9}^{P} = -1$ **and** $\overrightarrow{p}_{12}^{U} = \overrightarrow{0}$ **then**
$\overrightarrow{p}_{12}^{U} = \overrightarrow{p}_{12}^{P}$
$p_{2}^{P} = REAL$
$p_{21}^{P} = NTP$
$reemit\,(U, PLAIN, OP_{U})$ ▷ Reemit weak charge
$reemit\,(P, PLAIN, OP_{U})$ ▷ Generate neutrino

end if
end if
else if $p_{21}^P = GLP$ **and** $p_{10}^U \neq LEPT$ **then** ▷ Gluon-quark interaction
if $p_{10}^U = p_{10}^{P2}$ **then** ▷ Color exchange
$p_{10} = p_{10}^{P2}$
$p_{10}^{P2} = p_{10}^U$
$p_{10}^U = p_{10}$
p_{21}^P=VCP ▷ Virtual gluon returns to vacuum
end if
else if $p_{21}^P = MSP$ **and** $p_{10}^U \neq LEPT$ **then** ▷ Meson-matter interaction
if $p_{10}^U = p_{10}^P$ **or** $p_{10}^U = \bar{p}_{10}^P$ **then**
$p_{21}^P = KNP$
$p_7^P = p_6^U$
end if
else if $p_{16}^P = VCP$ **then** ▷ Vacuum-charge interactions
▷ Define spins for all cases
if $p_5^U < p_5^P$ **then**
$\overrightarrow{p}_{12}^P = \overrightarrow{p}_{12}^U$
else
$\overrightarrow{p}_{12}^P = -\overrightarrow{p}_{12}^U$
end if
if $p_{11}^U = ON$ **then** ▷ Graviton processing
$p_{11}^U = OFF$ ▷ Start KNP formation
$p_7^P = p_7^U$ ▷ Radial direction was defined previously
$p_{13}^P = p_{13}^U = p_{13}^U - 1$ ▷ Decoherence
▷ Release attractive KNP
$reemit\,(U, PLAIN, OP_U)$
$reemit\,(P, PLAIN, CP)$
else if $p_9^U = 0$ **and** $p_{10}^U = LEPT$ **then** ▷ Electric charge
$p_2^P = VIRT$
$p_{13}^P = p_{13}^U$ ▷ Inherit entanglement
$p_8^P = p_8^U$ ▷ Both tiles of pair inherit U's charge!!
▷ Release EMP
$reemit\,(U, PLAIN, OP_U)$
$reemit\,(P, PLAIN, CP)$
else if $p_{16}^U \neq CH$ **then** ▷ Triad formation I
if $p_5^U > p_5^P$ **then**
$p_{10}^P = p_{10}^U$
$p_8^P = p_8^U$
$p_9^P = p_9^U$
else
$p_{10}^P = \bar{p}_{10}^U$
$p_8^P = -p_8^U$
end if
$p_{13}^P = p_{13}^U$ ▷ Inherit entanglement
if $p_{12}^U \cdot p_6^U > 0$ **then** ▷ Update helicity
$p_4^U = p_4^P = 0$
else
$p_4^U = p_4^P = 1$
end if
▷ Release triad components
$reemit\,(U, PLAIN, CP)$
$reemit\,(P, PLAIN, CP)$
else if $p_{10}^U \neq LEPT$ **then** ▷ Strong charge
$p_{18}^P = SIDE$
$p_{13}^P = p_{13}^U$

if $p_1 \mod 2 = 0$ **then** ▷ Color exchange
$p_{10}^{V2} = p_{10}^{U} \gg 4 \mid p_{10}^{U} \ll 2$
else
$p_{10}^{V2} = p_{10}^{V2} = p_{10}^{U} \ll 4 \mid p_{10}^{U} \gg 2$
end if
$p_{10}^{V1} = p_{10}^{U}$
$p_{10}^{U} = p_{10}^{V2} \gg 3 \mid p_{10}^{V2} \ll 3$
▷ Release gluon components
$reemit\,(U, PLAIN, OP_U)$
$reemit\,(P, PLAIN, CP)$
else if $p_9^U \neq 0$ **then** ▷ Weak charge x VCP
$p_9^P = p_9^U$ ▷ Temporarily inherits weak charge
$p_{18}^P = SIDE$ ▷ Reset decay TTL
$p_{13}^P = p_{13}^U$
if $p_5^U < p_5^P$ **then**
$\overrightarrow{p}_{12}^{P} = \overrightarrow{p}_{12}^{P}$
$\overrightarrow{p}_{7}^{P} = \overrightarrow{p}_{6}^{U}$
else
$\overrightarrow{p}_{12}^{P} = -\overrightarrow{p}_{12}^{U}$
$\overrightarrow{p}_{7}^{P} = -\overrightarrow{p}_{6}^{U}$
end if
▷ Release weak MGP
$reemit\,(U, PLAIN, OP_U)$
$reemit\,(P, PLAIN, CP)$
end if
else if $p_{16}^P = BR$ **and** $p_{13}^U = p_{13}^B \neq 0$ **and** $p_{17}^B > 0$ **then**
if $p_8^U \neq 0$ **or** $p_{10}^U \neq LEPT$ **or** $p_9^U \neq 0$ **then**
$p_{17}^B = SIDE$
end if
else if $p_8^U \neq 0$ **and** $\overrightarrow{p}_{12}^{U} = -\overrightarrow{p}_{12}^{P}$ **and** $p_{21}^P = NTP$ **then** ▷ Neutrino absorption
$\overrightarrow{p}_{12}^{U} = \overrightarrow{p}_{12}^{P} = \overrightarrow{0}$
$p_{16}^P = VCP$ ▷ $NTP \rightarrow VCP$
$p_9^U = p_9^P$ ▷ Preserve weak charge
end if
end

function $UXUinteraction()$ **begin** ▷ Includes UXC interactions
if $p_8^1 = -p_8^2$ **and** $p_{10}^1 = \bar{p}_{10}^2$ **then** ▷ Fermions annihilation
$\overrightarrow{v} = \overrightarrow{p}_6^1 \times \overrightarrow{p}_6^2$
if $p_5^1 > p_5^2$ **then**
$\overrightarrow{p}_{12}^{1} = \overrightarrow{v}$
$\overrightarrow{p}_{12}^{2} = -\overrightarrow{v}$
else
$\overrightarrow{p}_{12}^{1} = \overrightarrow{v}$
$\overrightarrow{p}_{12}^{2} = -\overrightarrow{v}$
end if
▷ Reemit Us to from CP to form a P
$reemit\,\big(U^1, COLL, CP)\big)$
$reemit\,\big(U^2, COLL, CP)\big)$
$p_{13}^{U1} = p_{13}^{U2} = SIDE/2$
else if $p_8^1 = p_8^2$ **and** $p_{10}^1 = p_{10}^2$ **then** ▷ Cohesion force
if $p_5^1 > p_5^2$ **then**
$p_{19}^1 = OP$
$p_{19}^2 = CP$
else
$p_{19}^1 = CP$

$p_{19}^2 = OP$
end if
$entangle(U_1, U_2)$
▷ Reemit interacting Us
$reemit\left(U_1, FORCING, p_{19}^1\right)$
$reemit\left(U_2, FORCING, p_{19}^2\right)$
end if
end

function $PXPinteraction()$ **begin**
if $tangled(P_1, P_2)$ **then**
if $p_{21}^{P1} = PHP$ **and** $p_{21}^{P2} = KNP$ **and** $EMFilter()$ **then** ▷ KNP accretion by photon
$p_{143}^{P1} = p_{143}^{P1} + 1$
$p_{143}^{P2} = p_{143}^{P2} + 1$
▷ *Reemit Ps*
$reemit(P_1, PLAIN, CP)$
$reemit(P_2, PLAIN, CP)$.
else if $p_{21}^{P1} = p_{21}^{P2} = KNP$ **then** ▷ KNP excess cancellation
$proj = \overrightarrow{p}_7^1 \cdot \overrightarrow{p}_7^2$
if $proj > 0$ **and** $pwm(proj.SIDE)$ **then** ▷ KNPs →VCPs
$p_2^{P1} = p_2^{P2} = VIRT$
$\overrightarrow{p}_{12}^{P1} = \overrightarrow{p}_{12}^{P2} = \overrightarrow{0}$
$\overrightarrow{p}_7^{P1} = \overrightarrow{p}_7^{P2} = \overrightarrow{0}$
end if
else if $p_{10}^1 \neq LEPT$ **and** $p_{10}^2 \neq LEPT$ **then** ▷ Gluon-gluon interaction
▷ Reemit gluons
$reemit(P_1, PLAIN, CP)$
$reemit(P_2, PLAIN, CP)$
end if
else if $p_{21}^1 = MGP$ **and** $p_{21}^2 = MGP$ **and** $p_9^1 = LEFT$ **and** $p_9^2 = LEFT$ **and** $p_8^1 \neq 0$ **and** $p_8^1 = -p_8^2$ **then** ▷ W pair annihilation
$reemit(P_1, PLAIN, CP)$
$reemit(P_2, PLAIN, CP)$
else if $p_{21}^1 = KNP$ **and** $p_{21}^2 = KNP$ **then** ▷ Head-on collision
$proj = \overrightarrow{p}_7^1 \cdot \overrightarrow{p}_7^2$
if $proj > 0$ **and** $pwm(proj.SIDE)$ **then**
$p_2^{P1} = p_2^{P2} = REAL$
$p_7^{P1} = -p_7^{P2}$
▷ MGP formation
$reemit(P_1, PLAIN, CP)$
$reemit(P_2, PLAIN, CP)$.
end if
endif
end

function $UXGinteraction()$ **begin**
$p_{11}^U = ON$ ▷ KNP formation promise
$p_7^U = -p_6^G$ ▷ Direction of future KNP
end

boolean function $pairFormation()$ **begin**
if $\overrightarrow{p}_6^1 \neq \overrightarrow{0}$ **then**
return false
end if
for all forward w-neighbor t_2 **do** ▷ Preserve the reciprocity principle
if $\overrightarrow{p}_6^2 = \overrightarrow{0}$ **and** $tangled(t1, t2)$ **then**
if $p_8^1 = -p_8^2$ **then**

$\triangleright$ $l\,\bar{l}$ or $q\,\bar{q}$ formation
$p_{22}^1 = p_5^2$
if $p_{10}^1 \neq LEPT$ **and** $p_{10}^1 \neq ANTILEPT$ **and** $p_{10}^1 = \bar{p}_{10}^2$ **then**
$p_{16}^1 = U$
else
$p_{16}^1 = U$
end if
else $p_8^1 = p_8^2 = 0$ **and** $p_9^1 \neq 0$ **and** $p_9^2 = -p_9^1$ **then**
$p_{16}^1 = WZ$
else $p_8^1 = p_8^2 = 0$ **and** $(p_9^1 \neq 0$ **or** $p_9^2 \neq 0)$ **then**
$p_{16}^1 = P$
if $p_5^1 > p_5^2$ **then**
$p_{21}^1 = MGP$
else
$p_{16}^1 = WZ$
end if
else $p_8^1 = p_8^2 = 0$ **and** $p_{10}^1 = \bar{p}_{10}^1$ **then**
$p_{16}^1 = HADRON$
if $p_1^1 \,\mathbf{mod}\, 2 = 0$ **then**
if $p_5^1 > p_5^2$ **then**
$p_{21}^1 = GLP$
else
$p_{21}^1 = \overline{GLP}$
end if
else
if $p_5^1 > p_5^2$ **then**
$p_{21}^1 = MSP+$
else
$p_{21}^1 = MSP-$
end if
end if
end if
$\triangleright$select one option
if $p_{22}^1 > p_{22}^2$
$p_{22}^1 = p_{22}^2$
end if
end if
end do
return true
end if
return false
end

boolean function $interference\,()$ **begin**
if $p_1 - p_{202} \leq p_{203}$ **then**
if $p_1\, mod\, (3\, SIDE) = 0$ **then**
$\triangleright$ The cell was not visited
$p_{17} = p_{17} + 1$ $\triangleright$ Count steps since last visit
$\triangleright p_{18}$ decays absolutely and exponentially
if $p_{18} > 0$ **then**
$p_{18} = p_{18} \cdot \left(SIDE - \frac{SIDE}{2\,p_{17}} \right)$
if $p_{18} < 0$ **then**
$p_{18} = 0$
end if
else if $p_{18} < 0$ **then**
$p_{18} = p_{18} \cdot \left(SIDE + \frac{SIDE}{2\,p_{17}} \right)$

if $p_{18} < 0$ **then**
$p_{18} = 0$
end if
end if
return true
else
▷ The cell was visited
$p_{17} = 0$
$p_{18} = p_{18} + p_{14}$ ▷ Track left
return false
end if
end

boolean function *isGraviton* () **begin**
if $p_2 = GRAV$ **then**
if p_{11} **then**
$p_{16} = GR$
▷ G extinction
if $\overrightarrow{p}_6 = \overrightarrow{0}$ **then**
$p_{16} = UNDEF$
$p_2 = UNDEF$
$p_{11} = OFF$
end if
else
$p_{16} = UNDEF$
end if
return true
end if
return false
end

function *EMFilter* (U, P) **begin**
return $p_{11}^U \wedge pwm\left(p_{14}^U\right) \wedge pwm\left(p_{15}^P\right) \wedge pwm\left(p_{18}^P\right)$
end

boolean function $pwm(n)$ **begin**
return $(n \,\mathbf{mod}\, STEP < n/NSTEPS)$
end

function $entangle(t1, t2)$ **begin**
$p_{13}^{t1} = p_{13}^{t2} = p_5^{t1} \cdot p_5^{t2} + SIDE$
end

boolean function $tangled(t1, t2)$ **begin**
if $|p_{13}^{t1} - p_{13}^{t2}| > SIDE$ **then**
return false
else
return $pwm\left(\frac{\left(p_{13}^{t1} - p_5^{t1} \cdot p_5^{t2}\right)\left(p_{13}^{t2} - p_5^{t1} \cdot p_5^{t2}\right)}{SIDE}\right)$
end if
end

▷ Prepares the tile as the seed of a new preon or burst expansion.
function *reemit* $(t, p_3, \overrightarrow{p}_{19})$ **begin**
$p_3^t = p_3$
$p_{200}^t = 0$
$p_{201}^t = 0$
$p_{202}^t = 0$
if $p_3 = UNDEF$ **then**

$p_{203} = 0$
else
$p_{203} = 2 \cdot D + 0.5$
end if
$\overrightarrow{p}^{t}_{6} = \overrightarrow{0}$
$p_{11} = OFF$
$\overrightarrow{p}^{t}_{19} = \overrightarrow{p}_{19}$
$resetDFO\,(t)$
end

function $resetDFO\,(t)$ **begin**
$p^{t}_{141} = U_1$
$p^{t}_{142} = U_2$
end

function $incrDFO\,(t)$ **begin**
$u_3 = K \cdot p^{t}_{142} - p^{t}_{141}$
$p^{t}_{141} = p^{t}_{142}$
$p^{t}_{142} = u_3$
end

▷ Rotates vector $\overrightarrow{v}$ about $\overrightarrow{p}_6$ by the angle θ,
function $rotate(\overrightarrow{v}, \theta)$ **begin**
rotates $\overrightarrow{v}$ about $\overrightarrow{p}_6$ by the angle θ, using a 3d CORDIC resolver ▷ *cf.* [10]
end

▷ Returns +1 if matter, -1 if antimatter, 0 otherwise
boolean function $conjug\,(c)$ **begin**
if $c \odot LEPT \neq 0$ **and** $c \odot ANTILEPT = 0$ **then**
return +1
else if $c \odot ANTILEPT \neq 0$ **and** $c \odot LEPT = 0$ **then**
return -1
else
return 0
end

▷ Emits a burst preserving the origin tile if CP.
function $burst\,(cp)$ **begin**
for $i = 0$ **to** 5 **do**
$nual = getNual(i)$
$nual \leftarrow dual$
$p^{nual}_{3} = PLAIN$
$p^{nual}_{200} = i$
$p^{nual}_{201} = 1$
$p^{nual}_{202} = p_1 - 1$
$p^{nual}_{203} = 0$
$p^{nual}_{6} = dirs[i]$
end do
if not cp **then**
$dual \leftarrow \varnothing$
end if
end