It from bit — a concrete attempt

Alexandre Furtado Neto*

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Abstract

A model of the universe is developed using a constructive approach. It is a deterministic, discrete, finite (including time), spatially three-dimensional structure with an array of integer registers attached to each node. Information (bits) travels through the lattice mainly as spherical wavefronts at the speed of light, being eventually reissued when interacting. These collisions are assisted by an omni-reaching superluminal messenger and by a binding property. Motion is achieved with the combination of a kinematic rule plus a borrow/return scheme with the vacuum. The asymmetry of matter and antimatter and the Cosmic Microwave Background Radiation are explained when a new charge, the duality, is added. Moreover, as an economic theory, it requires a single, *de facto,* input parameter. A quantitative analysis is initiated when the bird's eye view used to develop the automaton core gives way to the use of operator mechanics in a small incision in the CA grid. In short, Physics (it) is conjectured to emerge from this ontological, unified picture as the system evolves from a highly symmetric unphysical hologram pattern of registers defined at a sub-Planckian scale to a physical, everlasting Poincaré cycle in a toric lattice of a cellular automaton. In particular, it predicts that gravity, like the other static forces, is not quantized and that interaction between matter and antimatter is repulsive.

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I. INTRODUCTION

Wheeler [1] coined the aphorism 'it from bit'. With this, he meant that anything physical, any *it*, derives its existence from discrete binary choices, or *bits.* This gives support to the notion that information has an ontological nature. The concept implies that physics, particularly quantum physics, isn't really about reality, but just our best description of what we observe. The Title of this paper suggests that it was taken to the ultimate consequences: The universe is described by a bit pattern in it.

I will build a model of the universe from a minimum set of assumptions, aiming at the simplest solution possible. Only plain logic, elementary integer math and a hint of topology will be used.

In this regard, cellular automata (CAs) are mathematical idealizations of physical systems in which space and time are discrete. Their attractiveness comes from the notion that simple rules can lead to very complex behavior, tending to long and interesting evolutions. The success of the cellular automaton model in classical physics can be assessed as early as 1986 with the article of Ref. [2], unleashing the power of Navier-Stokes equations, never stop surprising.

The idea of modeling our universe using CAs is not new, many authors (e.g. [3, 4, 5, 6, 7, 8, 9, 10, 11]) see discreteness as a solution 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. Wolfram [4], for instance, studied systematically the rules of one dimensional automata, while G. 't Hooft studied them from a Hamiltonian perspective, focusing on local models, while H.T. Elze made use of a variational principle, coupled with sampling theory [7, 8].

Quantum Theory (QT) and General Relativity (GR) are both, as we know, very accurate. The former for the microcosm, the latter for the macrocosm, but they do not fit well into Planck's scale, hence the search for a unifying theory. They are rooted in a Lagrangian/Hamiltonian formalism where the masses

*email: alexandre.com@yahoo.com

of particles enter *ad hoc* into the equations. However, despite its resounding success, QT gives us a somewhat blurred image of the universe and difficult interpretation, ignoring any underlying ontology.

Here the automaton has the simplest architeture, comprising a couple of cubic grids closed on themselves as a 3-torus where an array of *registers* (formatted integer numbers) is attached to each cell. The cell has a processor, or logical circuit, and interacts with its six nearest neighbors only (von Neumann convention). The lattices are updated in turns. Preons, wavefronts of registers, pulsate in unison. Thus we are facing a deterministic model, where nothing is left to chance.

When we delve deeper into the subatomic scale to define the grid of the automaton, the length of Planck l_P seems to be the natural candidate as the distance between its cells. But it is precisely on this scale that the conflict between QT and GR arises, so the granularity of the lattice is required to be sub-Planckian. Observe that the automaton's lattice has a role like that of a new Ether, so perfect Lorentz invariance is impossible in all cases. But given that most events of interest have little speed variation relative to the CMBR, this is not a big hurdle, and an emergent, quasi-relativistic symmetry is expected. As with Bohmian mechanics, nonlocality comes from the factory.

The approach adopted in this endeavor is a constructive one [12, 13]. That is, whenever possible, I try to adapt the laws of physics to the sub-Planckian realm, probing the adequate heuristics.

II. THE CELLULAR AUTOMATON

In this section, I define the ingredients that compose the automaton, that is, the relevant bit patterns used hereinafter. Information has an ontological meaning in this context[1].

Definition 1. *A register* ($\mathcal{R}$) is a formatted N-integer ($\sim$ 4500 bits), partitioned into several fields as shown in Table 1. In an empty cell, $\mathcal{R}_0 \equiv 0$, with the exception of vector $\vec{s}$, that contains initially the absolute coordinates of the cell. Frequency f is the number of overlapped preons (a non-overlapping preon has $f = 1$, which corresponds to a wavelength of $SIDE$ grid units).

Definition 2. The *cellular automaton* is a dual Euclidean lattice closed on itself as a torus with three spatial dimensions ($SIDE^3$), where an array of $SIDE^2$ registers, the *stack*, is attached to each cell. The distance between cells is L and the clock period (counted by the t register) is T, a discrete, Newtonian, time dimension added to justify motion. Each lattice is alternatively *principal* (read-only) or *dual* (draft), which implies in local time reversability[2]. D is the main diagonal of the lattice. The spatial lattices play the role of a preferred inertial frame and are the fabric of spacetime.

Definition 3. The symbol *color* is the concatenation of the bits c_2, c_1, c_0. Conjugation is defined as $j \equiv (c_2 + c_1 + c_0 < 2)\, \boldsymbol{xor}\, q$, or alternatively using the *majority function*

$$mj \equiv (\sim c_2 \,\boldsymbol{and}\, c_1 \,\boldsymbol{and}\, c_0)\, \boldsymbol{or}\, (c_2 \,\boldsymbol{and} \sim c_1 \,\boldsymbol{and}\, c_0)\, \boldsymbol{or}\, (c_2 \,\boldsymbol{and}\, c_1 \,\boldsymbol{and} \sim c_0)\, \boldsymbol{or}\, (c_2 \,\boldsymbol{and}\, c_1 \,\boldsymbol{and}\, c_0),$$

$$j = q\, \boldsymbol{xor} \sim mj.$$

The color is neutral N, if $c_2 + c_1 + c_0 = 0$ or antineutral $\overline{N}$, if $c_2 + c_1 + c_0 = 3$.

Definition 4. A *preon*[3] is a spherical wavefront of information hopping from register to register (such information is hereafter simply called *register* for brevity) occupying the same w address in all stacks, expanding at the speed of light $c = {}^{L}\!/\!_{LIGHT}$ (one light step is $LIGHT = 2D$ clock ticks). A preon is *real* ($g = d$) or *virtual* ($g \neq d$); *matter* (j is *true*) or *antimatter* (j is $false$). The total number of preons is $SIDE^2$, which matches the size of a stack. The *seed* is a special, unique, register in this wavefront with $|\overrightarrow{p}| > 0$. There is no distinction between upper and lower indices in the notation. It should be noted that the ξ property is not a preon property, but a cell property.

Definition 5. A *flash* is a cubic wavefront of records that spreads occupying all the registers in the grid, ordered by address w, expanding at maximum superluminal speed $s = {}^{L}\!/\!_{T}$. The duration of this omni-reaching pattern is $FLASH = {}^{3SIDE^3}\!/\!_{2}\,T$.

Definition 6. Charge d serves to separate the universe in two. One, dubed *Orbis*, contains most matter with $d = 0$ and most antimatter with $d = 1$. The other, *Geminae*, contains most matter with $d = 1$ and most antimatter with $d = 0$.

[1] Ontology is actually an always receding rule marking the frontier of the unfathomable.

[2] Observe that actually there are three times considered in the CA operation: the processor clock, the lattice time t and the light pace c. None of these, however, correspond to the emergent, relativistic, *proper time*.

[3] The word preon was coined by Jogesh Pati and Abdus Salam in 1974.

Definition 7. The values of the d and g properties define four *zones*. If $d = g$, the zone is *real*, otherwise the zone is *virtual*.

Definition 8. The sign of property b serves to define if the affected preon in an interaction must be reissued (equal) or simply having properties reversed (different). This opens up the possibility for antipodal particles, such as those obtained by parametric down conversion [14].

Definition 9. The *momentum offset* χ is the distance of the current register address and the seed register.

Definition 10. The *total phase* Φ is the normalized product of the sinusoidal phase ϕ_{sin}, the visit track ξ, and the momentum offset χ.

Definition 11. *Unpaired* ($\mathbb{U}$) is a non-overlapping preon with $f = 1$. It works like a charge fragment.

Definition 12. A static force *messenger* $\mathbb{U}_m$ is a special $\mathbb{U}$ with $f = 0$. When a preon is reissued, its wavefront continues as a $\mathbb{U}_m$. It is an active spot if $m = true$. Either it carries the static electromagnetic ($\vec{s} \neq \vec{0}$) or the gravity force ($\vec{s} = \vec{0}$).

Definition 13. *Pair* ($\mathbb{P}$) are two overlapping preons with some or all opposite charges. The components of the pair are identified by the indices P and P', respectively. In particular, $b^P = b^{P'}$, $f^P = f^{P'} = 2$ and the coincident seeds are $\vec{p}^P = \pm\vec{p}^{P'}$. Those charges with opposite values have no effect on the dynamics, except in the case of charge q which, even having opposite values, expose its force and dragging with it the spin or magnetic force $\vec{s}$ in quadrature thereby allowing the interaction with $\mathbb{U}$s.

Definition 14. An *Eden* $\mathbb{P}$ ($\mathbb{P}_E$) has opposite values d, g, c_2, c_1, c_0, ω, q, $\vec{p}$, and $\vec{s} = \vec{0}$.

Definition 15. A raw universe $\mathbb{P}$ ($\mathbb{P}_U$) is similar to a $\mathbb{P}_E$ except that its preons d properties are the same and $\vec{p}_P = \vec{p}_{P'}$ in the seeds.

Definition 16. A vacuum $\mathbb{P}$ ($\mathbb{P}_{vac}$) is similar to a $\mathbb{P}_U$ except that it has neutral color charge, $g^P = g^{P'}$ and $\vec{s}^P = -\vec{s}^{P'} \neq \vec{0}$. They are the raw material for creating $\mathbb{P}_K$s and photons.

Definition 17. A photon $\mathbb{P}$ ($\mathbb{P}_\gamma$) is a $\mathbb{P}_{vac}$ with frequency $f > 2$.

Definition 18. A gluon $\mathbb{P}$ ($\mathbb{P}_{glu}$) is like a $\mathbb{P}_{vac}$, but with its preons having explicit color charges ($color \neq N, \overline{N}$).

Definition 19. A neutral weak $\mathbb{P}$ ($\mathbb{P}_Z$) is like a $\mathbb{P}_{vac}$, but with its preons having the same weak charge.

Definition 20. A charged weak $\mathbb{P}$ ($\mathbb{P}_W$) is like a $\mathbb{P}_Z$, but with its preons having the same electric charge.

Definition 21. In a kinetic $\mathbb{P}$ ($\mathbb{P}_K$), a modified $\mathbb{P}_{vac}$, we have $\vec{s}^P = \vec{s}^{P'} = \overrightarrow{0}$. Swarms of $\mathbb{P}_K$s form the rest mass and the linear momentum of quarks and electrons.

Definition 22. A *multi-pair* ($\mathbb{MP}$) is made of identical $\mathbb{P}_\gamma$s. Its frequency is the total number of preons that it contains, replicated in the f register of each preon.

Definition 23. The single *de facto* input parameter of the theory is $SIDE \approx 10^{64}$ (see Section A.). An auxiliary constant is also used: $\tau = {}^{SIDE}/_{32}$. They are used to generate an out of scale representation of the world[4].

III. SUB-PLANCKIAN SCALE DYNAMICS

Essentially, the dynamics is composed of an unphysical initialization step followed by an eternal basic cycle.

[4]Note the extreme economy when compared with the at least 17 SM parameters.

Table 1: Partitioning of *register* into fields.

Field	**Name**	**Type**	**Values**
t	Clock (*)	UI	Incremented in unison after each T seconds
$\vec{o}$	Origin	SV	$\{null$ or N_D possible directions$\}$. $\lvert\overrightarrow{p}_2\rvert$ =preon radius
$\vec{p}$	Momentum	SV	$\{null$ or N_D possible directions$\}$
$\overrightarrow{s}$	Spin	SV	$\{null$ or N_D possible directions$\}$
$\vec{v}$	Seed target	SV	$\{null$ or N_D possible directions$\}$
q	Charge	BIT	$\{0, 1\}$
ω	Chirality	BIT	$\{0, 1\}$
c_0	Color	BIT	$\{0, 1\}$
c_1	Color	BIT	$\{0, 1\}$
c_2	Color	BIT	$\{0, 1\}$
g	Gravity	BIT	$\{0, 1\}$
d	Duality	BIT	$\{0, 1\}$
b	Bond	2 SI	$\left\{-(SIDE/2)^2 \ldots +(SIDE/2)^2-1\right\}$
φ_{sin}, φ_{cos}	Quadrature phase	2×SI	$2\times\{-SIDE/2\ldots+(SIDE/2-1)\}$
f	Frequency	UI	$\{1\ldots SIDE-1\}$
ξ	Footprint	SI	$\{-SIDE/2\ldots+(SIDE/2-1)\}$
m	Kinetic messenger	BIT	$\{false, true\}$
h	Flash x preon	BIT	$\{false, true\}$
code	Interaction code	UI	$\{NOPE\ldots REISSUE\}$

The formats are: BIT, classical bit; SI, signed integer; UI, unsigned integer; SV, signed 3D-vector, with $N_D = \pi\,(SIDE/2)^2$ possible directions. The default length of fields is $ORDER$, where $ORDER = \log_2 SIDE$. A few additional numeric fields are used for flash management etc.

(*) It is agreed little-endianness and the t register is the least significant field.

A. Concepts

Information propagates either as a preon or as a flash. Both entities use a special rule to avoid self-access conflict. Flashes simply diffuse as fast as possible, while preon wavefronts expand synchronized according to [15] (see Section B. for further details). Preons have a quadrature phase (φ_{sin}, φ_{cos}) dependent on their frequency f. The well known CORDIC algorithm [16] can be used to implement this feature.

The odds of a preon being reissued by wrapping are practically nil, actually, it is reissued at the contact point by default when interacting, yet very rarely, with another preon if their seed registers coincide and/or certain additional rules are met, in particular, the strength of their sinusoidal phase relation and if they are not overlapping. The seeds drift toward their maximum total phase Φ values. It is as if they execute a random walk on their expanding wavefronts.

A bond property allows particle components to remain connected. Bonded preons share a common b field value. When a preon is reissued, it can induce other bonded preons with the same b to reissue too. In such a case there is a *collapse* and all its bonded peers assume opposite properties via flash. Preons absolutely bonded are not reissued, but have properties changed (see Definition 8). The wavefront of the reissued preon continues as $\mathbb{U}_m$s, which vanish by wrapping. These messengers can be equipped to carry the static forces (electric, magnetic and gravity).

The duality charge d is used to separate the universe into two branches, helping to explain the apparent observed asymmetries, especially the empirical absence of antimatter. As a general rule, all perceived asymmetries are recovered globally.

Gravity acts between preons belonging to a real zone in the same universe or between a matter preon of a real zone in Orbis and antimatter of Geminae, either attractively or repulsively.

The weak charge ω is associated to congruency. Its force acts between all preons in the same universe, but constrained by a handedness rule.

Some properties, e.g., sine phase, cannot be used directly, but must first be compared against a standard PWM sequence (see Figure 2), ruling out the need for an interaction detection mechanism based on an explicit pseudorandom number generator.

B. Initialization

The initialization configuration of the universe at $t = 0$ forms a "hologram" H, a sheet perpendicular to the z axis selected to contain all the symmetrically configured $SIDE^2$ preons (see Algorithm 4 in the Appendix). This idea was inspired by the *Holographic Principle* of 't Hooft ([17]). Since $SIDE$ is a power of two, I initialized the momentum direction of $\lfloor SIDE^2/3 \rfloor$ preons for each x, y, z direction, and the remaining $SIDE$ preons in the $\pm z$ direction in the hologram. This last condition ensures quantization of charge, conform [18] (see also Section A.). From this lowest state of entropy $\mathcal{S}_0$, the preons of the hologram begin to spread as almost perfect spherical wavefronts ($\mathbb{U}$s), combining massively to form completely symmetric $\mathbb{P}$s, the *Eden*. A few $\mathbb{U}$s, though, escape this aggressive pairing, the *mavericks*.

The mavericks are capable to quickly demolish Eden and introduce a bit of chaos necessary to generate a nontrivial universe. The variety is also enforced by a charge bit swapping procedure.

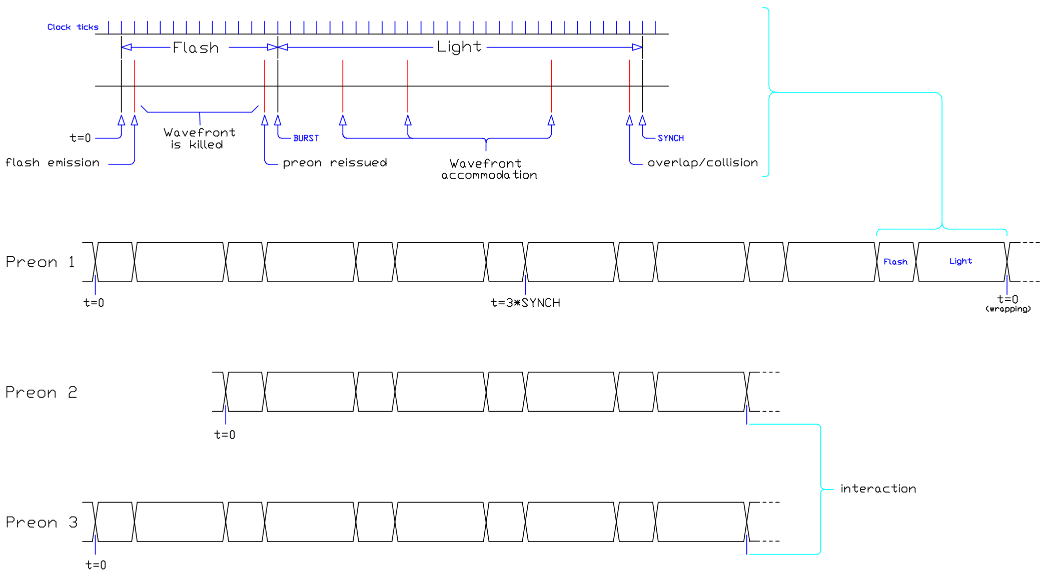
This initialization step ends when a steady state situation is reached, the eternal and very long Poincaré, consisting of countless *basic cycles*, with constant entropy $\mathcal{S}_P$.

C. Basic cycle

The time frame is segmented into two steps: one, when the flashes are active, has a duration of $FLASH$ time units. The other, when preons are active, has a duration of $2D$ time units. This segmentation is to avoid undesired superposition of a preon wavefront with a flash on a common layer (w address). An interaction is detected at the last tick of a time frame. This event marks the wavefront settling in a new light step, when only then can the properties of the registers in the draft lattice be updated. Note that from a physical standpoint, the flash operation is transparent and perceived as instantaneous (see Figure 1).

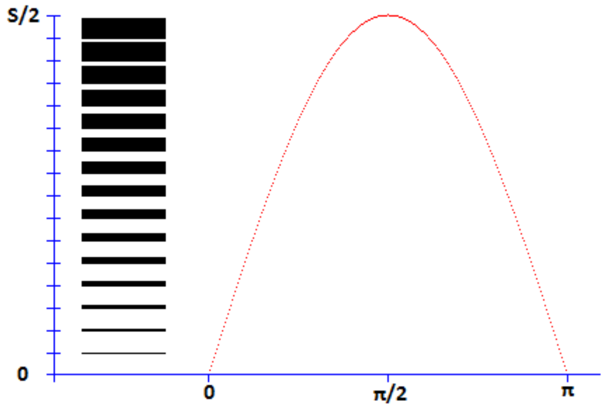
As they spread, preons leave an ephemeral trail in the visited cells (ξ), but long enough for interference purposes (decays like $\xi = SIDE \cdot 2^{-t/\tau}$). Only bonded preons can interfere using this feature. Then, after interacting, preons begin to share a common code, their bonding, not before a flash changes the spin and momentum properties of its prior absolutely bonded peer, even if spacelike separated. The aforementioned trail also serves to join successive $\mathbb{MP}$s that form a beam. This spin change indirectly affects other properties like polarization.

Figure 1: The CA time frame.



The time frame is shown above along with three preons. One is reissued by wrapping, while the other two interact midway. Note that during the accommodation phase, the wavefront is unstable. That's why every comparison of preons is made on the last tick of the clock. The flash step is actually repeated $SIDE^2$ times.

Figure 2: Integer to bit map.



A typical half cycle phase signal is shown against the standard PWM sequence for $S = 512$ (see Section A. and function $pwm()$ in Algorithm 1).

D. Interactions

Prior to interaction, the status is updated, which includes $\mathbb{P}$ detection, $\mathbb{MP}$ formation, footprint decay and definition of bonding sign, used to distinguish antipodal particles. The detection of the interaction type is done by convolving the registers in dimension w. The resulting type is one of $\mathbb{U} \times \mathbb{U}$, $\mathbb{U} \times \mathbb{P}$, or $\mathbb{P} \times \mathbb{P}$. Interactions involving an $\mathbb{MP}$, by construction, occur simultaneously in all its components.

If a preon is involved in an interaction, it is reissued, but if it is also real then $m = true$ in its $\mathbb{U}_m$ at the contact point, which is equivalent to a gravitational effect.

The electromagnetic and strong interactions occur circumscribed to each of the four zones. The weak force is the only force allowed between the real and virtual zones in the same universe.

The $\mathbb{U} \times \mathbb{U}$ interaction involving non-collinear spins causes the realignment of the spins 180° apart, perpendicular to their original spin directions and share their bond values. The $\mathbb{U}$s must be similar to interact in this way. It is the *cohesive force* or fifth force, if you prefer. With this scheme, the following trends are enforced: Orbis is seggregated from Geminae, the 1/3, 2/3 behavior of the strong force manifests itself and the separation of real and virtual particles becomes evident. A $\mathbb{P}$ may also be created in this process, if said $\mathbb{U}$s are partially $(q,\ w,\ color)$ symmetric, resulting in mutual annihilation to a $\mathbb{P}_\gamma$, which in turn can spread to bonded partners.

The electrostatic, magnetostatic and gravitational forces are supported by the special case $\mathbb{U} \times \mathbb{U}_m$. Each active spot on the expanding $\mathbb{U}_m$ is capable of instruct the $\mathbb{U}$s found on its way to capture a $\mathbb{P}_{vac}$ and change it to a $\mathbb{P}_K$ to satisfy the attraction/repulsion requirements of each force. The spots are created just once in the gravitational case, while are created multiple times, increasing every time a bonded $\mathbb{U}$ is found in the other cases, requiring that the electromagnetic info is passed to the spot. When leaving the near field of an elementary fermion, there will be $n = SIDE/2$ spots. In the electrical and gravitational forces, the $^1/_{r^2}$ law is achieved thanks to geometry. As for the magnetic force, $\mathbb{U}$'s momentum direction is aligned perpendicularly to the propagation direction, then the $\mathbb{U}$'s spin direction is updated taking into account the duality charge (rotates in reverse). Static forces then have 'infinite' range.

The $\mathbb{U} \times \mathbb{P}$ interactions are the germ of all *fermion x boson* interactions. They are divided into:

- **Demolition**
  If $\mathbb{P} \equiv \mathbb{P}_E$ or $\mathbb{P} \equiv \mathbb{P}_U$ then the partners are reissued. Charge exchange will generate the necessary variety, while momentum variety is obtained through a bisector process. The remaining cases below are only allowed inside a zone.

- **Acceleration**
  If $\mathbb{P} \equiv \mathbb{P}_{vac}$ and $\mathbb{U}$'s messenger bit m is set and $\mathbb{U}$ and $\mathbb{P}$ are both real or both virtual and $\vec{p}_U = \vec{p}_P$ then the messenger bit is reset, $\mathbb{P}'s$ spin is zeroed and the momentum directions of both $\mathbb{P}$'s preons equate that of the $\mathbb{U}$, becoming a $\mathbb{P}_K$. In other words, the $\mathbb{U}$ is accelerated.

- **Electromagnetic interaction**
  It is triggered when a $\mathbb{U}$ interacts with a $\mathbb{P}_\gamma$. The spins of the interacting seeds must match, which is like looking for a needle in a haystack. The filter also includes the PWM masking of the dot product of the 'Poynting vector', i.e. the composition of the quadrature phase φ_{sin}, with the spin of the interacting $\mathbb{U}$, but first the cosine component may be inverted or not depending on the weak charge of the $\mathbb{U}$. All overlapping preons ($\mathbb{MP}$) are reissued simultaneously, with immediate reorganization in identifiable arrangements of preons (newly formed particles).

- **Mass formation**
  If $\mathbb{P} \equiv \mathbb{P}_{vac}$ and the interacting seeds have opposite spins then the $\mathbb{P}_{vac}$ is changed to a $\mathbb{P}_K$ by making $\vec{s}^P = \vec{s}^{P'} = \vec{0}$. The newly formed $\mathbb{P}_K$ will integrate the rest mass of the fermion.

- **Formation of a $\mathbb{P}_{glu}$ via strong force**
  If $\mathbb{P} \equiv \mathbb{P}_{vac}$ and $\mathbb{U}$ has explicit color charge (is a quark component with register $color \neq N$ and $color \neq \bar{N}$) then a $\mathbb{P}_{glu}$ is formed by assigning the $\mathbb{U}$'s color to $\mathbb{P}$ and the inverted color to $\mathbb{P}'$.

- **Strong force**
  If $\mathbb{U}$ and $\mathbb{P}$ have non trivial colors then the $\mathbb{U}$ exchanges colors with either $\mathbb{P}$ or $\mathbb{P}'$.

- **Weak force**
  If the chirality rules are satisfied then all preons bonded to the weak charged $\mathbb{P}$ or to the $\mathbb{U}$ are reissued.

- **Default inertial effect**
  If none of the above happens, and $\mathbb{P} \equiv \mathbb{P}_K$, it moves the target $\mathbb{U}$ one light step in the direction of the momentum of $\mathbb{P}_K$ (that is, the $\mathbb{P}_K$ is reissued at the point aimed by the momentum vector on its surface, while the $\mathbb{U}$ is reissued at the point pointed on its surface by the parallel transported momentum vector of the $\mathbb{P}_K$ — the primordial mechanism of inertia (see Figure 3).

Finally, during a $\mathbb{P} \times \mathbb{P}$ interaction, these conditions can be detected:

- **Cancellation**
  Almost anti-aligned $\mathbb{P}_K$s can cancel and return to vacuum. For this, the partners have $f = 2$, $b = 0$ and all bonded peers $f = f - 4$.

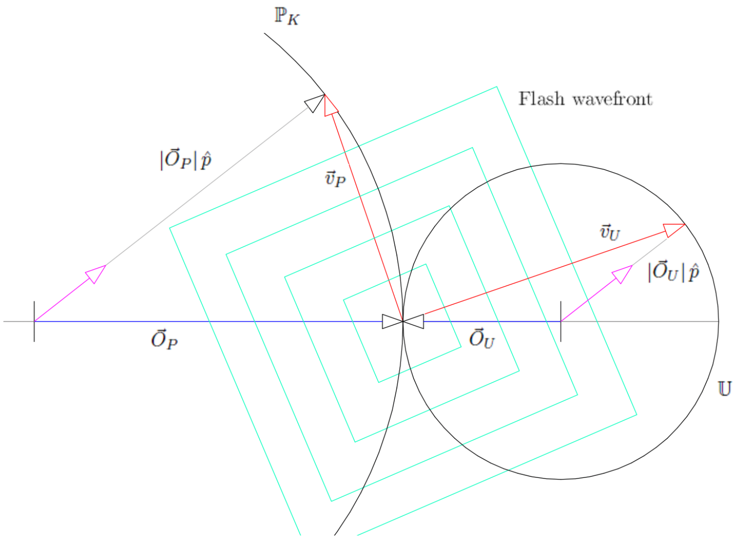
- **Pairing**
  Almost aligned $\mathbb{P}_K$s are reissued, therefore, they will gradually pile up. This is part of the photon release process.

- **Gluon-gluon interaction**
  Color registers of the $\mathbb{P}$s can be exchanged.

- **Cohesive force in the W and Z bosons**
  Similar to $\mathbb{U} \times \mathbb{U}$ cohesion, but involving the weak force.

- **Pair antialigning**
  Pairs are antialigned using momentum exchange with the vacuum.

Figure 3: Inertia mechanism.



Vectors $\vec{v}_U$ and $\vec{v}_P$ are used to update the respective seed registers in a $\mathbb{U}x\mathbb{P}_K$ interaction.

- **Formation of W and Z bosons**
  These bosons self form from their fragments.

The exact rules implementing the ideas above are shown in the Appendix using a pseudocode form.

IV. QUANTITATIVE ANALYSIS

The global perspective used to develop the CA core now needs to be relaxed to extend its usefulness. To this end, subsystems relatively independent of the rest of the universe must be constructed. The reader is warned that, being a new field of research, the results are still very incipient. But first it is necessary to estimate the size of the universe.

A. The size of the universe

Redshift is defined as

$$z = \frac{f_{em} - f_{obs}}{f_{obs}}.$$

The most redshifted galaxy known is GN-z11, with a factor of $z = 11.9$ (see [19]) and light-travel distance $d = 1.173164 \times 10^2\, m$, while that of the CMBR is $z = 1,100$. Combining these values, we obtain $SIDE\,[m] = 2 \times 1.084 \times 10^{28}\, m$, and using $L = l_P/8$ (and $T = t_P/8$), results in 5.42×10^{63}, or adjusting it to the required granularity

$$\begin{aligned} SIDE &= 16\,(3^n + 1)\,, \\ &\approx 5.09 \times 10^{63}, \end{aligned}$$

where l_P and t_P are Planck's length and time, respectively, and $n = 131$.
This initial value for $SIDE$ can be refined using a model of gravity messengers intersecting with a straight line between the two universes and comparing blackbody spectra.
By the way, according to this model, the observable universe is Orbis itself in its fullness.

An upper bound for the discrete time dimension T_{MAX}, or Poincaré period, is given by

$$T_{MAX} < \prod_{m=1}^{N^2} \left(N^3 - m - 1\right) = \frac{\left(N^3 - N^2 - 1\right)\left(N^3 - N^2\right)_{N^2}}{N^3 - 1},$$

where $N \equiv SIDE$ and $(a)_n$ is the Pochhammer symbol (rising factor).

B. Operator mechanics to the rescue

Starting from ideas contained in the book 'The cellular automaton interpretation of quantum mechanics' (CAI) in [7], the ontological states, namely the CA states, form a basis for a huge, but not infinite, Hilbert space. Using Dirac notation, a physical state $|A\rangle$, where A may stand for a particular set of values involving all elements of the incision V, is called an ontological state if it is a state our deterministic system can be in. This ontological state dressed as a ket $|A\rangle$ is known as a *beable.* I agree with 't Hooft that it also represents a classical state, like resulting from a measurement. So

$$\langle A|B\rangle \equiv \delta_{AB}.$$

We assume henceforth that this basis has been identified, which corresponds to the patterns generated by the dynamics.

A quantum state $|\psi\rangle$ is defined as the superposition of ontological states, requiring that

$$|\psi\rangle = \sum_A \lambda_A |A\rangle, \quad \sum_A |\lambda_A|^2 = 1,$$

where λ_A is allowed to be a complex or negative number.

As soon as we have a Hilbert space, we are free to perform any basis transformation needed.

The CA evolution can be described by permutations between its states. The evolution of ontological states using a permutation operator can be naturally extended to quantum states. In matrix notation we have

$$U(t) = \begin{pmatrix} 0 & . & . & . & 0 & e^{i\phi_N} \\ e^{i\phi_1} & 0 & . & . & . & 0 \\ 0 & e^{i\phi_2} & 0 & . & . & 0 \\ 0 & 0 & e^{i\phi_3} & 0 & . & 0 \\ . & . & . & . & . & . \\ 0 & . & . & 0 & e^{i\phi_{N-1}} & 0 \end{pmatrix}.$$

Applied to

$$|A(t)\rangle = U(t)|A(0)\rangle$$

and

$$|\psi(t)\rangle = U(t)|\psi(0)\rangle.$$

It is mathematically convenient to express the evolution operators in exponential form

$$U(\delta t) = e^{-iH\delta t},$$

or, in general.

$$U(t) = e^{-iHt},$$

where t is now a continuous variable and H is a Hermitian operator. From the above, 't Hooft calculated the Hamiltonian

$$H\delta t = \pi - i \sum_{n=1}^{N} \frac{1}{n} \left(U(n\,\delta t) - U(-n\,\delta t) \right)$$

for finite systems. We are forced to conclude that there is always a Hamiltonian and that the system obeys the Schrodinger equation

$$\frac{d}{dt}|\psi(t)\rangle = -H|\psi(t)\rangle. \tag{1}$$

The most general state of a system is not $|\psi\rangle$. Instead, the general state is the density matrix ρ. But the unitary operator applied to the density matrix $\rho \rightarrow \rho' = U\rho U^\dagger$ must be replaced by the most general map, the **quantum operation**, given by

$$\rho \rightarrow \rho' = \mathcal{E}(\rho) = \sum_k M_k \rho M_k^\dagger \quad \text{with} \quad \sum_k M_k^\dagger \rho M_k' = 1 \ ,$$

where the set $\{M_k\}$ is called **Kraus operators**.

However, here I depart from the CAI prescription because this unitary evolution lasts until a measurement is made. The collapse of the wavefunction is not a mere artifact, but is deeply rooted in the most basic CA structure, being a concrete set of rules, reappearing during measurements as a multiple preon phenomenon.

Energy is an ill-defined concept in Physics (an interesting discussion about this topic can be found in Ref. [20]). In Eq. 1, something like energy is conserved in time, represented by the Hamiltonian operator[5].

I strive to adhere to the Copenhagen doctrine as far as possible for obvious reasons. In view of this, the Born rule is embodied into this quantitative analysis: The probability that a state $|\psi\rangle$ is found to agree with the properties of another state $|\varphi\rangle$, must be given by

$$P = |\langle\varphi|\psi\rangle|^2$$

Other theoretical tools are also available, such as the average measured value of an observer $\mathcal{O}$

$$\langle\mathcal{O}\rangle = \langle\psi(t)|\mathcal{O}|\psi(t)\rangle\,.$$

As it happens, the machinery of operator mechanics can be used to calculate probabilities in events and ensembles as usual.

Another important difference between the CAI and my CA is the explicit non-locality embedded in the CA rules, enforced by the bond property.

A quantum state A is in a superposition if it is in both states $|A_1\rangle$ and $|A_2\rangle$ simultaneously

$$|A\rangle = \frac{|A_1\rangle + |A_2\rangle}{\sqrt{2}}.$$

In an entangled state of two subsystems A and B

$$|AB\rangle = \frac{|A_1\rangle|B_1\rangle + |A_2\rangle|B_2\rangle}{\sqrt{2}}$$

neither subsystem is in a superposition state. Instead, they are umbilically connected via the bond property, so $|A_1\rangle$ and $|B_1\rangle$ are statistically correlated, and $|A_2\rangle$ and $|B_2\rangle$ are also statistically correlated, therefore, no dead-alive cat appears (see [21] for further arguments).

V. DISCUSSION

Physics is conjectured to emerge from the above model, paving a new avenue toward a full-fledged unification theory, beyond the Standard Model. In this Section I try to clarify some aspects.

A. Topology

Why the torus? Simply put, this combable 3-manifold (the fourth dimension represented by the stack is irrelevant for the discussion) is the simplest topological structure capable of holding a 3D universe and charge quantization. The finitude of the universe is a necessary condition to reach this quantization. The trapped magnetic flux obtained with the asymmetry in momentum direction in the z direction in the hologram, which itself is a bidimensional torus, completes the quantization requirements of Reference [18].

Spaveri and Haug in [22] have shown that the Sagnac effect cannot be perfectly explained using Einstein synchronization (Special Relativity). This finding favor the preferential frame adopted in the CA without the need for superluminal light propagation as inferred by the authors cited.

Nature loves symmetry but abhors absolute symmetry, so the toroidal topology with its trapping property comes in handy for a seamless break in symmetry at automaton startup, avoiding the greedy formation of an unbreakable Eden, which results otherwise in a dull, featureless universe.

Since space has an odd number of spatial dimensions, parity inversion maps a handed object to its incongruent counterpart. Last but not least, cosmological observations favor a multi-connected rather than a simply connected universe (see [23]).

[5]Intuitively, we are led to associate energy with the number of preons, but it seems to be misleading.

B. Isotropy

Instrumental to create a credible universe in a lattice is the notion of isotropy, hardly if ever achieved by previous attempts. Complete three-dimensional isotropy is guaranteed with the synchronization scheme adopted above (from [15]) applied to a Euclidean lattice. There is no need for a diamond lattice or foam structure for that matter, the Euclidean grid suffices.

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, where n is two times the diameter of the universe D (space diagonal)

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

In order to synchronize the preons forming a wavefront, each preon register receives the value

$$t = \lceil 2D\,|\overrightarrow{\sigma}|\,+0.5\rceil, \tag{2}$$

where $D = 2\,(SIDE - 1)$ (space diagonal).

The ubiquitous application of this mechanism would guarantee a perfectly isotropic universe. But the way the hologram is built (see Section B.), with a privileged direction necessary for quantization of charge, may affect the dynamics, in particular the electromagnetic coupling constant α. This has been recently confirmed in [24]. The universe then has a huge dipole structure.

C. The cosmic microwave background radiation (CMBR)

Photons generated by antimatter in Geminae may escape and navigate as far as Orbis, being decohered along the way, being perceived as an isotropic, homogeneous blackbody spectrum at $T = 2.7K$. The decohered preons contribute to Orbis's vacuum. This naturally refutes the Big Bang paradigm [25, 26].

D. Symmetries

The organization of preons driven by their charge content is schematically shown in Figure 4. As ever, Lie groups symmetries and other SM features are expected to emerge from these raw concepts.

The fact that the laws of nature appear to distinguish between left and right, parity violation, enchants scientists already several decades ago (for a philosophical review, see Pooley [27]). The observed asymmetries, like parity violation, are recovered when the universe is considered as a whole.

E. Conservation laws

1. *Linear momentum*

The $\vec{p}$ property of $\mathbb{U}$s do not affect directly the motion of particles, but are just carriers of the direction of future $\mathbb{P}_K$s. Momentum is expressed by $\mathbb{P}_K$s acting in a common direction. $\mathbb{P}_K$s are captured from the vacuum by $\mathbb{U}$s to form the mass of fermions, if the $\mathbb{U}$ has $m = true$, it dictates the direction of the $\mathbb{P}_K$ to accelerate the particles. Meanwhile, some antialigned $\mathbb{P}_K$s are being returned to vacuum. In turn, photons transport momentum between remote sites. All in all, this dynamic equilibrium results in momentum conservation.

2. *Angular momentum*

Angular momentum is a byproduct of linear momentum combined with spin effects. Again, there is a situation of equilibrium that is equivalent to angular momentum conservation.

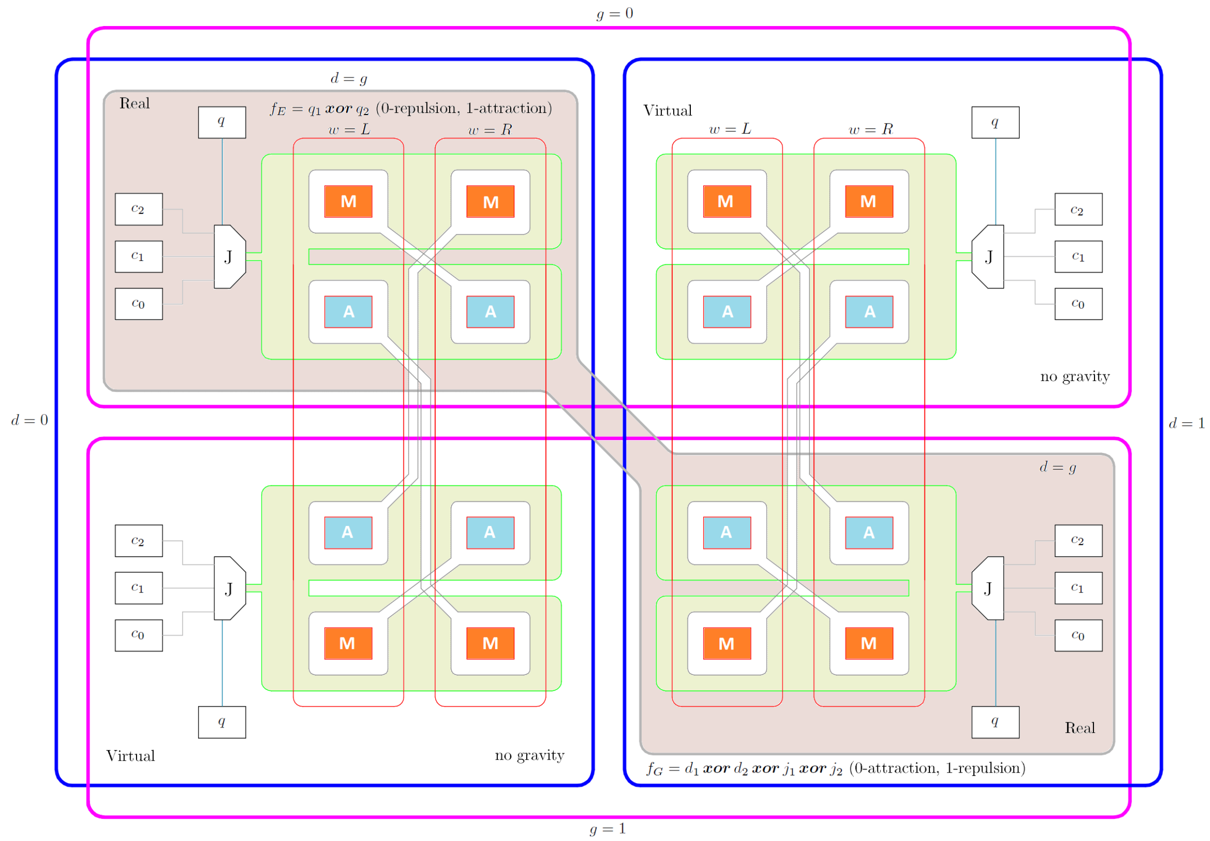
F. Entropy

The postulated static messenger and flash mechanisms imply an arrow of time, preserving the Second Law from the beginning, per universe, despite the tacit existence of other arrows of time such as the tautological thermodynamic arrow.

Can perhaps entropy be lowered if we conjecture that the creation of black holes gives opportunity to $\mathbb{P}$s recombine as Eden $\mathbb{P}$s, thereby escaping the singularity trap[6] therefore decreasing the number of microstates and keeping entropy of the closed universe constant ($\mathcal{S}_P$), or is it that the modeled universes are doomed to thermal death? Sethna in [28], p. 95 has an instructive point of view, concluding that in a closed universe, entropy remains constant. A famous approach to the theme is found in Eddington

[6] This escape is reminiscent of Hawking radiation [29].

Figure 4: Symmetries and charge content.



Both the color charges and electric charge, despite acting within the zones, also influence the weak interaction through the conjugation gate J. The electric and gravitational forces can be attractive or repulsive, as explained by the formulas shown, but gravity is restricted to the connected diagonal zones (see Section D.).

[30]. Entropy would behave like the sand in an hourglass being alternately inverted. In a given universe, sometimes it would be increasing, sometimes decreasing. The same reasoning can be extended to other cases, like CPT invariance.

G. Lorentz invariance

Observe that the automaton's lattice has a role like that of a new Ether, so perfect Lorentz invariance is impossible in all cases. The speed of light is constant relative to the preferred reference frame, the CA lattice. The constant speed of relativity verified by an observer is not a principle, but an emergent feature, being actually approximately constant. But given that most events of interest have little speed variation relative to the CMBR, this is not a big hurdle, so an emergent, quasi-relativistic symmetry is expected. Notice also that $\mathbb{P}_K$s acting on a normally spherical nucleus, will tend to turn it into a pancake shape as its kinetic energy rises significantly.

H. The non-signaling principle

Flashes propagate between each light step, so that they are perceived as superluminal, but nowhere does this seems to open the possibility of carrying information. Technically speaking, there is no way to "surf" a flash to send a message, so the principle of non-signaling is preserved.

I. Bridge to quantum and classical mechanics

Classicality is necessary for observers to agree about the same observation of the physical world. The following evidence suggests that this theory attains classical mechanics in some suitable limit.

First of all, note that "if classicality were reached only probabilistically, it would be an intrinsically unstable theory, which sometimes is reached, and other times it is not" (Scandolo et al. [31]). The decoherence mechanism induced by measurement is the cause for this. Besides decoherence, in the cited paper, the authors require that the system satisfies three axioms (1-causality, 2-the product of two pure states is a pure state, 3-information locality) in order to rule out holistic behavior.

The theory satisfies the three axioms above and so has no holistic behavior, possessing well defined classical states and observers therefore supporting the notion of realism.

As for the measurement itself, it can rely, for example, on cumulative effects of inpinging particles on a medium (Stern-Gerlach, double slit etc.), that remain stable for a long time (sufficient for an observer to perceive), or through linear amplification resulting in a pattern identified as the pointer as in [32]. The measurement problem then changes focus to how to define subsystem separability [33] and how to identify observables in a single subsystem of a composite system.

A crucial observation is that the model is disconnected from practical space and time units. Only when the H_2 molecule, say, can be identified will it be possible to effectively map it to the real world. A future scenario includes the use of machine learning to tweak the few input parameters to reproduce a proportional pattern before applying the mapping procedure.

J. A glance at the conjectured behavior

Let us imagine now a running CA and contemplate it. After entering the Poincaré cycle, the universe is divided into two universes, each containing a couple of overlapping real and virtual zones. During this accommodation process, most part of matter/antimatter are annihilated, but a significant fraction of them migrates from Orbis to Geminae where they remain sheltered by gravity (and vice versa). There they continue to act gravitationally, being perceived as dark matter.

The unavoidable Poincaré cycle implies therefore that time, besides being discrete, is finite too.

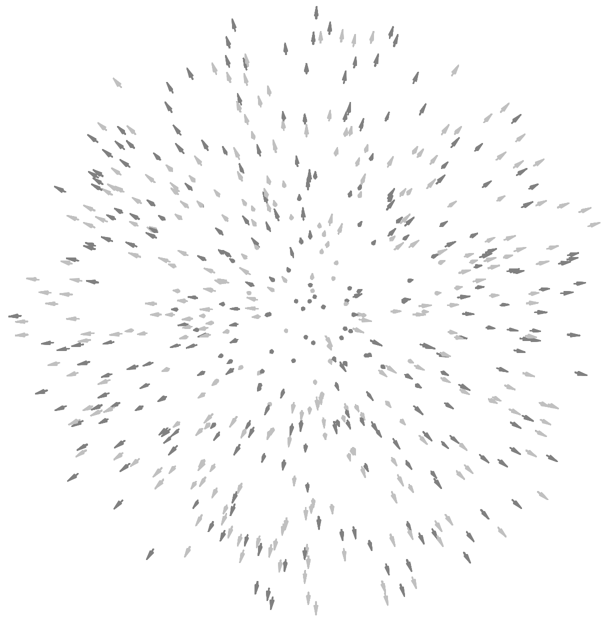
1. *Fermions*

Preons tend to aggregate to form elementary fermions, composed of a definite (quantized) quantity of $\mathbb{U}$s surrounded by a cloud of $\mathbb{P}_K$s in equilibrium. This cloud generates the particle's mass if emitting gravity messengers (in the real case). Additional aligned $\mathbb{P}_K$s give the particle linear momentum. This clustering is extended to form composite fermions (nuclei, mesons etc.). Bound states of the electromagnetic and gravitational forces form all known matter structures, including black holes.

The picture of fermion spin first envisaged by Hofer (see [34]), with all individual spins pointing inward or outward appears in the CA, exposing a clear ontological view (see Figure 5).

An intriguing feature is that the virtual zones are amorphous due to the absence of gravity — a thin powder or gas indeed, but no planet or star is ever formed.

Figure 5: Spin-up in an elementary fermion.



All preons have their spins pointing outward in this fermion, that is, it is in the spin-up state. $\mathbb{P}_K$s that make up the bulk of the fermion, do not appear in this drawing (see Section 1.).

The square inverse behavior of the Coulomb and gravitational interactions is justified via geometrical argument by the spherical expansion of the preon and the constant number of active points in the $\mathbb{U}_m$s. As for the inverse cubic of the magnetic force, it also comes for free due to the dipole structure of the interaction. The magnetic effects of a still charged particle cancels out due to spherical symmetry. The $\mathbb{P}_K$s can break the spherical symmetry of the cloud of preons, which passes into an oval configuration and consequently induces a magnetic dipole, which acts naturally following a $1/r^3$ law.

2. *Collapse*

When an interaction occurs involving multiple preons, the wreak havoc caused by the reissue of preons may result in the dissolution of the involved partners, reorganizing themselves immediately afterwards, probably (elastic scatterings), but not necessarily (inelastic scattering), in the same particles. This explains, for example, spin flipping.

3. *Atomic electronic decay*

A pure *photon* (γ) is an $\mathbb{MP}$ with no explicit electric, weak or strong charge, carrying zero or multiples of $SIDE$ angular momentum units. A practical photon, or light beam, is made of multiple $\mathbb{MP}$s.

Photons are normally released in an atomic electronic decay, shaped by the spherical harmonics originating from charge quantization. This is the main explanation for the ubiquitous presence of all sort of quanta. The primary quantized quantity, is truly the electric charge, all the others being derived from this. The process of photon emission is as follows:

1. Pairs of $\mathbb{P}_K$s are formed by the exchange of preons with the vacuum until acquiring perfect antialignment;
2. Two of those pairs can be aligned since their net momentum is zero. Eventually, a large number of $\mathbb{P}_K$s get aligned in two opposite directions;
3. If a $\mathbb{U}$ interacts with an external $\mathbb{P}_\gamma$, it instructs all its $\mathbb{MP}$ components pointing to a single direction (the spin of the interacting $\mathbb{U}$, which is equivalent to a random vector out of a solid angle of 4π steradians) to change from a $\mathbb{P}_K$ to a $\mathbb{P}_\gamma$, being now free to expand, featuring a photon;
4. As a result, all the abandoned, collinear, $\mathbb{P}_Ks$ now contribute to the recoil of the atom. In other words, momentum is conserved.

In summary, it describes the stimulated emission mechanism. Spontaneous emission is a particular case for faint fields.

4. *Bremsstrahlung*

Photons are also produced when charged particles are accelerated/decelerated (*bremsstrahlung).* In this scenario, the spectrum is continuous since it has nothing to do with spherical harmonics. The accumulated $\mathbb{P}_K$s generated from the $\mathbb{P}_m$s eventualy are unfolded as $\mathbb{P}_\gamma$s in an arbitrary direction triggered by a $\mathbb{U}x\mathbb{P}$ interaction. Just like the above case, a photon is deployed. Notice that these emissions do not affect the particle trajectory, it simply gets rid of the excess energy.

5. *Quarks*

Quarks are emergent patterns formed inside hadrons, so are permanently confined by the strong force. These patterns tend to shrink to a point at higher momenta (partons). They recruit $\mathbb{P}_{vac}$s, turning them into $\mathbb{P}_K$s, like electrons do. Heavier quarks are special radial resonance states.

6. *Gluons*

A *gluon* is a cluster of $\mathbb{P}_{glu}$s acting cooperatively to keep quarks together. They also capture $\mathbb{P}_{vac}$s turning them into $\mathbb{P}_K$s, like quarks and electrons. That is one reason why the mass of a proton is much greater than that of an electron.

7. *Mass spectrum*

Since in this model electrons and quarks are composite particles made of a mixture of $\mathbb{U}$s, continuously harvested $\mathbb{P}_K$s equilibrated by the cancellation mechanism, they can possess radial vibration, like a pulsating sphere [35]. These resonance states add to form the mass spectrum. Only real fermions manifest mass through gravity messengers when their preons are reissued.

8. *The W and Z bosons*

In the electron, the number of $\mathbb{U}$s is $SIDE/2$ due to electric charge quantization. In the W and Z bosons, the number of $\mathbb{P}_W$s and $\mathbb{P}_Z$s do not follow the quantization rule, so they tend to accumulate lots of components. This growing process is bounded by the cancellation effect, just like in the case of almost antialigned $\mathbb{P}_K$s. Since the mass in the case of real particles is directly related to the number of preons, those particles are very heavy. The difference of mass between the W and Z bosons is because the W acts with maximum P-symmetry, while the Z is a mix of left and right components. The short lifetime of the isolated W and Z bosons is due to the interaction between them with a $\mathbb{U}$ belonging to a virtual zone.

9. *Superposition*

A fermion is in a superposition state when one part of the spins of its $\mathbb{U}$s points inward while the other part points outward. Remember that a fermion is formed by a huge number of preons considering the difference between the atomic and Planck scales (10^{-12} and 10^{-33}, respectively). The notion of 'infinite' Hilbert spaces necessary for contextuality in QT is therefore supported by an underlying ontological mini universe associated to each elementary particle. Thanks to its extremely fine granularity, enough room is left for continuous models like classical physics and QT, with its amazing qubits and quantum algorithms — a complete theory, in Einsteinian terms.

10. *Weak decay*

The rate of decay that unstable particles, in particular atomic nuclei, present is due mainly to the casual interaction of real particles with virtual W and Z particles. For all practical purposes, this is completely random. A simplified model of this process clearly shows an exponential decay curve of the Gamow type. These processes include direct/inverse beta decay. In the free neutron decay, for instance, the negative charge surrounding the proton has $\vec{s} = \vec{0}$ bonded by $\mathbb{P}_K$s. Additional $\mathbb{P}_K$s can also give velocity to the neutron. When reorganizing after a collapse, the negative registers acquire spins in pairs with counterpart in pairs from the pool of $\mathbb{P}_K$s to recover the electron. The shuffling of momentum directions divides perfectly between the products of the reaction thereby conserving momentum. The $\mathbb{P}_K$s that received spin form the antineutrino.

11. *The role of bonding*

In addition to the role of the particle component aggregator, bonding is also the source of non-local phenomena in general (coherence, entanglement etc.), which in turn leads to a non-classical theory. It had to be introduced to enforce conservation laws and, in consequence, is responsible by the observed non-classical correlations. The vanishing value for bond in the $\mathbb{U} \times \mathbb{U}_m$ interaction can be interpreted as a gravitational decoherence mechanism. It is responsible for the redshift observed in the cosmos (tired photons). The ultimate example is the CMBR, made of "very tired" photons.

12. *Gravity*

$\mathbb{U}_m$s, according to this model, cannot be screened in anyway, so the action of gravity on a falling body affects equally all its parts. No deformation or effects whatsoever can be locally detected, thereby trivially preserving the equivalence principle. A testable hypothesis is that gravity is an adiabatic process, like the Coulomb force. Since $\mathbb{U}_m$ emission/detection is not conditioned to AM transfer, gravity is not quantized, thereby giving support to semiclassical gravity. Gravity bends the light, modifying its phase gradually.

13. *The double-slit experiment*

For bosons, there is a straightforward explanation based on preon phases, while for fermions, that in this model do not spread like the abstract wavefunction, the words of Hofer in Reference [34] p.7,8 fit perfectly:

> ... The key observation for their model is that every atomic scale system has a discrete interaction spectrum. This means that every interaction of such a system with a single photon or electron can only cause observable changes in the particle's dynamics, if a discrete amount of energy is exchanged, typically corresponding to the excitation of single lattice vibrations. Given this fact, it is impossible that the particle acquires a continuous lateral momentum. Consequently, it also cannot be detected in intermediate regions, unless its trajectory is additionally determined by thermal broadening of the actual interaction.

14. *Stern-Gerlach*

Any spherical asymmetry in the spin configuration of a fermion produces magnetic effects, whence the origin for the two lines in the inteferometer.

15. *Elitzur-Vaidman bomb test*

Support to Elitzur-Vaidman bomb test (see [36]) is granted. Referring to the idealized inteferometer of Fig. 6, the test can be simply stated as

if not *exploded* $\wedge$ *clicked*(2) **then**
| bomb is live
end

The constructive/destructive interference obtained when a dud is in place can only be obtained if the beam is formed by multiple preons, as is precisely what happens in practice.

16. *The Higgs*

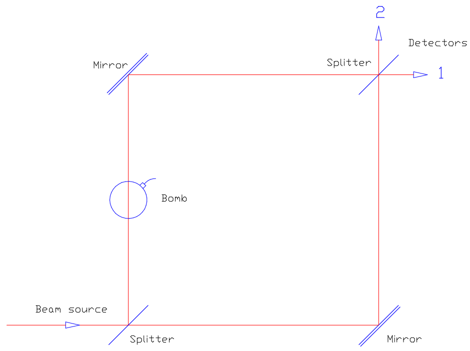
The CA mechanism do not make use of concepts directly linked to the Higgs boson. Patterns generated in an operational implementation, theoretical or computational, of the model can perhaps be interpreted including this particle.

17. *The cell processor problem and the block universe*

The way things have been presented so far leads us to the conclusion that a cell processor is needed in each network address, with the seemingly insurmountable problem of how to explain this supra universe entity (I do not think we live within a simulation anyway).

The conundrum crumbles into smoke when we introduce the concept of a block universe. No dynamics exists anymore, there are just connected clusters of information. Conceptually, the universe simply IS. All in all, after this short philosophical digression, for practical reasons, we cannot get rid of a physical implementation of this device.

Figure 6: Elitzur-Vaidman bomb test.



Detecting a live bomb using an interferometer (see Section 15.).

K. Conclusive remarks

In short, this manuscript contemplates a causal, finite and superdeterministic (since observers are preon patterns too, statistical independence is impossible, so bye bye free will[7], welcome realism) three-dimensional universe based on a toric cellular automaton, with no possibility of backward travel in time and no possibility of sending superluminal signals. A universe without a beginning and without an ending (modulo the unphysical initialization step). Continuing, the theory is free from philosophical nightmares like many worlds, Boltzmann brains, relativistic twins, solipsism, or additional spatial dimensions [37, 38, 39, 40]; no thermal death, no dark-energy, no dead-alive cat, no inflation, and no supersymmetric particles are also apparent [41, 42]. Rather it vindicates the Ether in a well defined role. Thanks to its extremely fine granularity, enough room is left for continuous models like classical physics and QT, with its amazing qubits and quantum algorithms — a complete theory, in Einsteinian terms.

There is no need to enforce any gauge fields. The axioms are self-sufficient to explain the observed forces, symmetries, redshift, curvatures and the spacetime illusion. The explanation for this is because measurement instruments, as well as observers, are all made of preons.

Information always propagates between past and future in the CA, in a definite time direction, so this is certainly a causal theory.

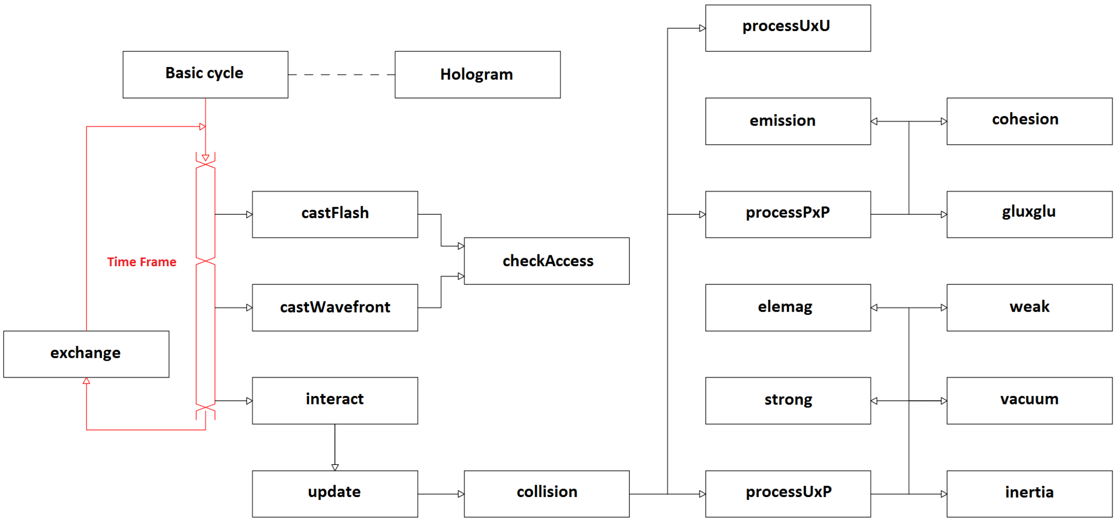
The theory presents a “mass gap”, “quark confinement”, and “chiral symmetry breaking” therefore satisfies the Wightman axioms [43]. Violation of Bell-type inequalities are expected, induced by the intrinsic non-locality. It predicts that gravity, like the other static forces, is not quantized.

The blackbody spectrum of CMBR is explained as formed by very ’tired’ photons coming from the antimatter in Geminae.

Finally, except for assisting in the development of the basic mechanisms, the physical construction of such an automaton for directly solving complex molecules and beyond, is hard to predict, but Moore’s aged law will certainly help in this regard. Its complete usefulness will firstly come through mathematical analysis in the approximation of large numbers. A first attempt at a quantitative analysis using operator mechanics was performed. Putting it another way, the smallness of the Planck scale implies that the only effective, large scale laws that one can ever expect to derive are statistical ones. So the common objection against QT of being just a recipe for calculating probabilities also applies to the envisaged products stemming from this model, either as a blessed *turbo-QT-GR formalism* or an entirely new recipe, because determinism belongs to the sub-Planckian diminutive scale.

[7]The author is reluctant to interpret the charge shuffling in Algorithm 22 as the equivalent to the free will source in Reference [44].

Figure 7: Block diagram.



The relationship between the main routines is highlighted in this figure.

Appendix: algorithms

Here are gathered all the rules of information exchange between cells of the cellular automaton. They are the essence of this work, intended to possess an **axiomatic** character.

Firstly, some conventions used in the algorithms

$\wedge$	logic AND
$\vee$	logic OR
and	boolean AND
or	boolean OR
xor	boolean XOR
$\sim$	boolean NOT
mod	binary modulo
$\gg$	binary shift right
$\ll$	binary shift left
$\leftrightarrow$	charge bits swapping
$\Leftarrow$	$\mathcal{R}$ copy
$\overset{\circ}{\Leftarrow}$	$\mathcal{R}$ copy, except ξ
$\triangleright$	Comment

The concatenation of bits d, g, c_2, c_1, c_0, ω, and q is called ρ. All operations involving vectors are normalized modulo $SIDE/2$. The number of von Neumann directions $\vec{d_i}$ is $NDIR = 6$. Sometimes a non-zero value is considered a logic $true$ while a zero value is a logic $false$ in conditional clauses. Unless otherwise stated, all data is read from the principal lattice. Data changes are always made to the dual lattice.

A block diagram of some pseudocode modules is shown in Figure 7.

```
▷ PWM mask.  Returns true if a match occurred.
▷ Definition:  ROOT = √SIDE = 1 ≪ ORDER/2.
function pwm(n) begin
│ return n mod ROOT < n/ROOT
end
```

Algorithm 1: Integer to bit.

A static binary gradient is used in interactions. It maps an unsigned integer to a bit (it is illustrated in Figure 2).

```
▷ Returns a value of modulo SIDE.
function dot(a⃗, b⃗) begin
│ prod = x_a x_b + y_a y_b + z_a z_b
│ return sgn(prod) (|prod| ≫ (ORDER − 1))
end
```

Algorithm 2: Dot product.

Normalized discrete dot product (invoked by the symbols $\overrightarrow{a} \bullet \overrightarrow{b}$).

```
▷ Parameter anti defines the case.
function aligned(ℙ_1, ℙ_2, anti) begin
│ ▷ Calculate the alignment
│ dot = p⃗_1 • p⃗_2
│ ▷ Compare with the desired direction
│ if anti then
│ │ δ = dot + SIDE/2
│ else
│ │ δ = dot − SIDE/2
│ end
│ ▷ Return the masked module squared
│ return pwm(2 ∗ δ^2/SIDE)
end
```

Algorithm 3: Pair alignment test.

Tests that the pairs are approximately (anti)aligned.

```
▷ Builds a highly symmetric plane.
if s⃗_z = 0 then
    f = 1
    φ_cos = SIDE^2
    ▷ Dispose charges uniformly
    d = s⃗_x < SIDE/2
    g = s⃗_y < SIDE/2
    tiling = (s⃗_x mod 2) xor (s⃗_y mod 2)
    if tiling then
        clr = N
    else
        clr = N̄
    end
    ω = tiling
    q =∼ w
    ▷ Calculate momentum
    if s⃗_y = SIDE − 1 then
        p⃗_x = 0, p⃗_y = 0, p⃗_z = 2 d − 1        ▷ create a couple of 'arrows of space'
    else
        ▷ Distribute p⃗ uniformly in all six directions
        p = 2 (s⃗_x mod 2) − 1
        switch [(SIDE s⃗_y + s⃗_x) /2] mod 3 do
            case 0 do
                p⃗_x = p, p⃗_y = 0, p⃗_z = 0
            case 1 do
                p⃗_x = 0, p⃗_y = p, p⃗_z = 0
            case 2
                p⃗_x = 0, p⃗_y = 0, p⃗_z = p
            end
        end
    end
end
s⃗ = 0⃗
go to cycle
```

Algorithm 4: The hologram.

The configuration of the CA at startup. The possibility of getting a topologically trapped magnetic flux is exploited.

```
▷ Executes a complete time frame.
cycle
    exchange()
    frame = t^{dual}_{w=0} mod SYNCH
    if frame < FLASH then
        castFlash()
    else if frame = SYNCH − 1 then
        interact()
    else
        castWavefront()
    end
end
```

Algorithm 5: Basic cycle.

Each automaton cell continuously executes this sequence, covering a time frame after initialization. The called functions are synchronized, in the sense that they spend the same number of processor cycles to complete.

```
▷ Exchange principal with dual.
procedure exchange() begin
    ▷ Explore the stack
    for w = 0 to SIDE^2 − 1 do
        R_w ⇐ R_w                                ▷ full transfer
        t_w = t_w + 1
        if R_w ≡ R_0 then
            t_w = t_w^dual mod SYNCH             ▷ prevents overflow
        end
    end
end
```

Algorithm 6: Exchange lattices.

```
▷ Flash diffusion.
procedure castFlash() begin
    ▷ Explore the stack
    for w1 = 0 to SIDE^2 − 1 do
        ▷ Flash fragment?
        if h_w1 then
            ▷ Cast to all von Neumann directions
            gflag = true
            for dir = 0 to NDIR − 1 do
                if checkAccess(dir, f_org_w1 (vector)) then
                    ▷ Get the neighbor of dual in the direction dir
                    R^nual = getNeighbor(dual, dir)
                    h_nual = true
                    bdir_nual = dir                       ▷ save direction
                    f_org_nual (vector) = f_org_nual (vector) + d_dir (vector)   ▷ update flash origin vector
                    ▷ Activate gravitational spot if due
                    if gflag ∧ p_w1 (vector) ≠ 0 (vector) ∧ d_w1 = g_w1 then
                        m_nual = true
                        gflag = false
                    end
                end
            end
            ▷ Nonlocal operations
            nonlocal(w1)
            ▷ Detect if seed register
            if p_w1 (vector) ≠ 0 (vector) ∧ v_w1 (vector) = 0 (vector) then
                ▷ Prepare preon seed to be launched at the last tick of a flash
                o_w1 (vector) = 0 (vector)
                h_w1 = false
            else
                ▷ Change to U_m (wavefront destruction)
                f_w1 = 0
            end
        end
    end
end
```

Algorithm 7: Flash diffusion.

This omni-reaching code is used for preon wavefront destruction and non-local effects.

```
▷ Nonlocal operations.
procedure nonlocal(w1) begin
    for w2 = 0 to SIDE^2 − 1 do
        if w1 = w2 then
            continue
        end
        if f_{w2} > 0 ∧ |b_{w2}| = |b_{nual}| then
            ▷ Catch antipodal partners
            \vec{s}_{nual} = −\vec{s}_{w1}; \vec{p}_{nual} = −\vec{p}_{w1}
            ▷ Same particle?
            if b_{w1} = b_{w2} then
                switch code_{w1} do
                    case DECOHERE do
                        if link_{w1} = w2 ∨ link_{w2} = w1 then
                            ▷ This ages photons
                            b_{w1} = b_{w2} = w1 ∗ w2
                        end
                    case CANCEL do
                        f_{w2} = f_{w2} − 4
                    case ANTIALIGN do
                        if ℙ_{w2} ≡ ℙ_{vac} ∧ aligned(ℙ_{w1}, ℙ_{w2}, true) ∧ \vec{o}_{w1} = \vec{o}_{w2} ∧ \vec{p}_{w1} ≠ \vec{p}_{w2}
                         then
                            ▷ Swap momentum with vacuum
                            \vec{p}^P_{w1} ↔ \vec{p}^P_{w2}
                            \vec{p}^{P'}_{w1} ↔ \vec{p}^{P'}_{w2}
                            return
                        end
                    case ANNIHIL0 do
                        if q_{w2} = 0 then
                            q_{w2} = 1; \vec{s}_{w2} = \vec{0}; f_{w2} = 1; b_{w2} = 0; \vec{o}_{w2} = \vec{0}
                        end
                    case ANNIHIL1 do
                        if q_{w2} = 1 then
                            q_{w2} = 0; \vec{s}_{w2} = \vec{0}; f_{w2} = 1; b_{w2} = 0; \vec{o}_{w2} = \vec{0}
                        end
                    case INERTIA do
                        if w_1 = w_2 ∧ \vec{v}_{w1} ≠ \vec{0} then
                            \vec{v}_{w1} = \vec{v}_{w1} − vecd_{dir}
                            if \vec{v}_{w1} = \vec{0} then
                                \vec{p}_{nual} = \vec{p}_{w1}
                            end
                        end
                    case COLLAPSE do
                        f_{w2} = 1; b_{w2} = 0; \vec{o}_{w2} = \vec{0}
                    end
                end
            end
        end
    end
    if code_{w1} = CANCEL then
        f_{w1} = 2; b_{w1} = 0
    end
end
```

Algorithm 8: Nonlocal operations.

```
▷ Prepare this preon for a flash.
procedure trigger(w) begin
    t_w = 0
    h_w = true
    f_org_w = 0⃗                          ▷ reset flash origin vector
    bdir_w = 0
end
```

Algorithm 9: Trigger a flash.

```
▷ Seek an interacting partner.
procedure interact() begin
    ▷ Update the stack
    update()
    ▷ Convolve the stack
    for w1 = 0 to SIDE^2 − 1 do
        for w2 = 0 to SIDE^2 − 1 do
            if w1 = w2 ∨ (f_1 = f_2 = 0 ∧ m_1 = m_2 = false) then
                continue
            end
            code = collision(w1, w2)
            code_w1 = code_w2 = code
            if code = OK ∨ code = INERTIA then
                return
            end
            if code = NOPE then
                continue
            end
            if f_1 = 1 then
                trigger(w1)
            else if f_1 >= 2 then
                trigger(w1)
                trigger(w1′)
            end
            if f_2 = 1 then
                trigger(w2)
            else if f_2 >= 2 then
                trigger(w2)
                trigger(w2′)
            end
            return
        end
    end
end
```

Algorithm 10: Interaction quest.

```
▷ Charge bits are swapped at a circular fashion.
procedure swap(R_1 R_2) begin
  ▷ Swap charges
  switch (w_1 + t_1) mod 5 do
    case 0 do
      c2_{w1} ↔ c2_{w2}
    case 1 do
      c1_{w1} ↔ c1_{w2}
    case 2 do
      c0_{w1} ↔ c0_{w2}
    case 3 do
      ω_{w1} ↔ ω_{w2}
    case 4 do
      q_{w1} ↔ q_{w2}
    end
  end
  ▷ Swap spins
  if (w2 + t2) mod 2 = 0 then
    if s⃗_1 = s⃗_2 = 0⃗ then
      s⃗_1 = p⃗_2
      s⃗_2 = −p⃗_2
    else if s⃗_1 = −s⃗_2 then
      s⃗_1 = s⃗_2 = 0⃗
    end
  end
end
```

Algorithm 11: Charge and spin swapping.

The variety of the products of a collapse is enforced by this code.

```
▷ Synchronized wavefront expansion.
procedure castWavefront() begin
    if R ≡ R_0 then
        ▷ Not a preon
        return
    end
    ▷ Brand new preon?
    if t = FLASH ∧ o⃗ = 0⃗ then
        ▷ Reset quadrature variables
        φ_sin = 0; φ_cos = SIDE^2
        f = 1
        h = false
    end
    ▷ Not ripe?
    if t ≤ synch then
        return
    end
    ▷ Cast to all von Neumann directions
    sel = 0
    Φ_last = 0
    for dir = 0 to NDIR − 1 do
        if checkAccess(dir, o⃗) then
            ▷ Get the neighbor of dual in the direction dir
            R^nual = getNeighbor(dual, dir)
            R^nual ⇐(ξ) R^dual                    ▷ preserve ξ
            ▷ Calculate drift gradient
            if p⃗ ≠ 0⃗ then
                ▷ Calculate momentum offset
                χ_dir = |p⃗_nual − p⃗_pri|
                ▷ Calculate total phase
                Φ_dir = ξ_dir + φ_dir^sin + χ_dir
                if Φ_dir ≥ Φ_last then
                    sel = dir
                end
                Φ_last = Φ_dir
            end
            ▷ Synchronize wavefront
            synch_nual = SYNCH (|o⃗_nual| + 0.5)
            dir_nual = dir
            o⃗_nual = o⃗_nual + d⃗_dir
        end
    end
    if p⃗ ≠ 0⃗ then
        R_sel = getNeighbor(dual, sel)
        p⃗_sel = p⃗
    end
    R = R_0
end
```

Algorithm 12: Preon broadcasting.

The next positions of the current register of the expansion of the wavefront are calculated.

```
▷ The von Neumann direction dir is tested at node n⃗.
function checkAccess(dir, n⃗) begin
    ▷ Calculate new position
    n⃗ = n⃗ + d⃗_dir
    ▷ Wrapping constraint
    S = SIDE/2
    if n_x = S+1 ∨ n_x = −S ∨ n_y = S+1 ∨ n_y = −S ∨ n_z = S+1 ∨ n_z = −S then
        return false
    end
    if |n_x| > |n_y| then
        if |n_x| > |n_z| then
            return d_x n_x > 0
        else
            return d_z n_z > 0
        end
    else if |n_x| < |n_y| then
        if |n_y| > |n_z| then
            return d_y n_y > 0
        else
            return d_z n_z > 0
        end
    else
        if |n_x| > |n_z| then
            return d_x n_x > 0
        else
            return d_z n_z > 0
        end
    end
end
```

Algorithm 13: Propagation consistency.

This function avoids self-access conflict in flashes and preons. Alternatively, the first message from a non-empty input pipe arriving to a cell is accepted in a hardware implementation.

```
▷ Updates prior to interaction.
procedure update() begin
    ▷ Prepare environment
    for w = 0 to SIDE^2 − 1 do
        ▷ Footprint decay
        if t_w mod τ = τ − 1 then
            ξ_w = ξ_w/2
        end
        ▷ Not a preon?
        if f_w = 0 ∨ o⃗_w ≠ 0⃗ then
            continue
        end
        ▷ Dismantle the old configuration
        f_w = 1; b_w = 0; k_w = −1
        swap(last, w)
    end
    ▷ ℙs detection
    pairing(0x1c, false)                ▷ W boson fragment
    pairing(0x1d, false)                ▷ Z boson fragment
    pairing(0x3f, false)                ▷ Universe fragment
    pairing(0x7f, false)                ▷ Eden fragment
    pairing(0x07, true)                 ▷ Gluon fragment
    pairing(0x0b, true)                 ▷ Gluon fragment
    pairing(0x13, true)                 ▷ Gluon fragment
    pairing(0x1f, true)                 ▷ Gluon fragment
    f = pairing(0x1f, false)            ▷ Photon fragment
    ▷ Multipair formation
    r⃗ = 0⃗; b = 0
    first = −1; last = −1
    for w = 0 to SIDE^2 − 1 do
        ▷ Photonic pair?
        link = k_w^dual
        if f_w^dual = 2 ∧ link ≥ 0 ∧ (ρ_w xor ρ_link) = 0x1f ∧ (clr_w^dual = N ∨ clr_w^dual = N̄)
         then
            if b = 0 then
                b = b_w                 ▷ this will be the common bond value
                r⃗ = p⃗_w                 ▷ reference for antipodal symmetry
                first = link
            end
            f_w = f; f_k = f
            if last ≥ 0 then
                k_link = last
            end
            ▷ Define bonding sign
            if r⃗ ≠ 0⃗ ∧ p⃗_w = −r⃗ then
                b_w = b_k = −b
            else
                b_w = b_k = +b
            end
            ▷ Update φ_sin and φ_cos
            cordic(|o⃗_w|, f_w)
            last = w
        end
    end
    if last ≥ 0 then
        k_first = last
    end
end
```

Algorithm 14: Status update.
Classify all the elements of cell and update variables.

```
▷ Returns the overall frequency.
function pairing(type, color) begin
    flag = false; last = 0; f = 0
    ▷ Explore the stack
    for w = 0 to SIDE^2 − 1 do
        ▷ Not a preon?
        if f_w ≠ 1 ∨ o⃗_w ≠ 0⃗ then
            continue
        end
        ▷ Pairing
        if flag ∧ color ∧ (clr_w = N ∨ clr_w = N̄ ∨ clr_last = N ∨ clr_last = N̄) then
            continue
        else if flag ∧ ρ_w xor ρ_last ≠ type then
            continue
        end
        if flag then
            f_w = 2; f_last = 2; k_w = last
            b_w = w ∗ last; b_last = b_w^dual
            cordic(|o⃗_w|, 2)
            φ_last^sin = φ_w^sin; φ_last^cos = φ_w^cos
            flag = false
            f = f + 2
        else
            flag = true
        end
        last = w
    end
    return f
end
```

Algorithm 15: Pairing.
Form pairs of a given type, neutral or colored.

```
▷ Detects and executes a collision.
function collision(R¹, R²) begin
    ▷ Overlapping preons do not interact
    if o⃗₁ ≠ o⃗₂ then
        ▷ Update interaction phase
        if b₁ ≠ 0 ∧ e₁ = b₂ then
            φ₁ = φ_sin 1 + ξ₁
            φ₂ = φ_sin 2 + ξ₂
        else
            φ₁ = φ_sin 1
            φ₂ = φ_sin 2
        end
        ▷ UxU interaction
        if (f₁ = 1 ∨ f₂ = 1) ∧ (f₁ + f₂ ≤ 2) then
            code = processUxU(R¹, R²)
            if code ≠ NOPE then
                return code
            end
        ▷ To continue, seeds must clash
        else if p⃗₁ ≠ 0⃗ ∧ p⃗₂ ≠ 0⃗ then
            ▷ Remaining preon-preon interactions
            if φ¹φ² > 0 ∧ (pwm(2|φ¹|) and pwm(2|φ²|)) ∧ pwm(2|s⃗¹ • s⃗²|) then
                if f₁ > 1 ∧ f₂ = 1 then
                    code = processUxP(R¹, R²)
                    if code ≠ NOPE then
                        return code
                    end
                else if f₁ = 1 ∧ f₂ > 1 then
                    code = processUxP(R², R¹)
                    if code ≠ NOPE then
                        return code
                    end
                else if f₁ > 1 ∧ f₂ > 1 then
                    code = processPxP(R¹, R²)
                    if code ≠ NOPE then
                        return code
                    end
                end
            end
        end
    end
    return NOPE
end
```

Algorithm 16: Collision detection.
This code detects and executes a collision between preons.

```
▷ Interaction between naked charges.
function processUxU($\mathbb{U}_1$, $\mathbb{U}_2$) begin
    ▷ Is the register a messenger active spot?
    if $f_1 = 0 \wedge m_1$ then
        ▷ Are partners in real zones?
        if $\vec{s}_1 = \vec{0} \wedge d_1 = g_1 \wedge d_2 = g_2$ then
            ▷ Gravity force
            if $d_1$ xor $d_2$ xor $j_1$ xor $j_2$ then
                $\vec{p} = +\vec{o}_1$                        ▷ repulsive
            else
                $\vec{p} = -\vec{o}_1$                        ▷ attractive
            end
            ▷ Instructs the $\mathbb{U}$ to capture a $\mathbb{P}_{vac}$ and change it to a $\mathbb{P}_K$
            if $\vec{p}_2 = \vec{p}$ then
                $m_2 = true$                     ▷ $\mathbb{U}_2$ is now a hunter
                return $OK$
            end
        ▷ Are partners in the same zone?
        else if $d_1 = d_2 \wedge g_1 = g_2$ then
            ▷ Are partners bonded?
            if $b_1 = b_2$ then
                if $\vec{p}_2 \neq \vec{0}$ then
                    ▷ Turn on a new active spot on $\mathbb{U}_m$
                    $m_1 = true$
                    ▷ Pass E.M. properties to the spot
                    $q_1 = q_2$; $\vec{s}_1 = \vec{s}_2$
                    return $OK$
                end
            ▷ Electromagnetic static force
            else
                ▷ Instructs the $\mathbb{U}$ to capture a $\mathbb{P}_{vac}$ and change it to a $\mathbb{P}_K$
                if $t_1$ mod 2 then
                    $\vec{p} = [2(q_1 \text{ xor } q_2) - 1](\vec{o}_1 - \vec{o}_2)$        ▷ Coulomb messenger
                else
                    $\vec{p} = (2d_2 - 1)[\vec{s}_1 \times (\vec{o}_1 - \vec{o}_2)]$        ▷ magnetic messenger
                end
                if $\vec{p}_2 = \vec{p}$ then
                    $m_2 = true$                 ▷ $\mathbb{U}_2$ is now a hunter
                    return $OK$
                end
            end
        end
    ▷ Are partners in the same zone?
    else if $d_1 = d_2 \wedge g1 = g2$ then
        ▷ Are partners similar?
        if $\rho_1 = \rho_2$ then
            if $b_1 > 0 \vee b_2 > 0$ then
                $b^1 = b^2 = max(b^1, b^2)$                         ▷ bond spreading
            else
                $b^1 = b^2 = w^1 * w^2$
            end
            $\vec{s}^{U1} = -\vec{s}^{U2} = \vec{s}^{U1} \times \vec{s}^{U2}$                  ▷ spin realignment
            $f_1 = f_1 + 1; f_2 = f_2 + 1$                    ▷ deBroglie wave
            return $REISSUE$
        ▷ Complementary properties?
        else if $(c_2^1 \text{ xor } c_2^2) \wedge (c_1^1 \text{ xor } c_1^2) \wedge (c_0^1 \text{ xor } c_0^2) \wedge (q^1 \text{ xor } q^2)$ then
            ▷ Annihilation
            return $COLLAPSE$
        end
    end
    return $NOPE$
end
```

Algorithm 17: $\mathbb{U}$x$\mathbb{U}$ interaction.

Direct interaction of charge fragments. Helps in the formation/destruction of fermions.

▷ `Effects caused by charges.`

function `processUxP`($\mathbb{U}$, $\mathbb{P}$) **begin**

▷ `Is there a` $\mathbb{U}_m$?

if $f_U = 0 \wedge m_U$ **then**

▷ `Light bending`

$\varphi_P = \varphi_P + 1$ ▷ `Photon decoherence`

if $f_P > 2 \wedge pwm(\phi^P_{sin})$ **then**

return $DECOHERE$

end

return OK

▷ `Eden demolition`

else if $\mathbb{P} \equiv \mathbb{P}_E$ **then**

$d_U \leftrightarrow d_P$

$\vec{p}_P = normalize(\vec{p}_U + \vec{p}_P)$

$\vec{p}_{P'} = \vec{p}_P$

return $REISSUE$

▷ `Universe seggregation`

else if $\mathbb{P} \equiv \mathbb{P}_U$ **then**

$g_U \leftrightarrow g_P$

$\vec{p}_P = normalize(\vec{p}_U + \vec{p}_P)$

$\vec{p}_{P'} = \vec{p}_P$

return $REISSUE$

else if $\mathbb{P} \equiv \mathbb{P}_{vac}$ **then**

▷ `vacuum interaction`

$code = vacuum(\mathbb{U}, \mathbb{P})$

if $code \neq NOPE$ **then**

return $code$

end

▷ `electromagnetic interaction`

$code = elemag(\mathbb{U}, \mathbb{P})$

if $code \neq NOPE$ **then**

return $code$

end

▷ `strong interaction`

$code = strong(\mathbb{U}, \mathbb{P})$

if $code \neq NOPE$ **then**

return $code$

end

▷ `weak neutral/charged current`

$code = weak(\mathbb{U}, \mathbb{P})$

if $code \neq NOPE$ **then**

return $code$

end

else if $\mathbb{P} \equiv \mathbb{P}_K \wedge b_U = b_P$ **then**

▷ `Inertia (see Figure 3)`

$\vec{v}^P = |\vec{o}^P|\,\hat{p}^P - \vec{o}^P$

$\vec{v}^{P'} = \vec{v}^P$

$\vec{v}^U = |\vec{o}^U|\,\hat{p}^P - \vec{o}^U$

return $INERTIA$

end

return $NOPE$

end

Algorithm 18: $\mathbb{U}$x$\mathbb{P}$ interaction.
The germ of all fermion/boson interaction.

```
▷ Electromagnetic processes.
function elemag(𝕌, ℙ) begin
    ▷ Looking for a needle in a haystack
    if d_U = d_P ∧ g_U = g_P ∧ s⃗_U = s⃗_P then                    ▷ same zone?
        ▷ Apply duality twist
        if d_U then
            s⃗ = s⃗_U
        else
            s⃗ = −s⃗_U
        end
        ▷ Apply weak handedness
        if ω_U then
            φ = φ_sin
        else
            φ = −φ_sin
        end
        ▷ Form the 'Poynting vector'
        Ê = (1/(|o⃗_P| ∗ |s⃗_P|)) ∗ o⃗_P × s⃗_P
        B̂ = (1/|o⃗_P|) ∗ Ê × o⃗_P
        E⃗ = φ_sin ∗ Ê
        B⃗ = φ_cos ∗ B̂
        if pwm(2 ∗ |E⃗ • s⃗_P|) then                                ▷ electric effect
            ▷ Change this and all bonded preons to ℙ_K s
            return COLLAPSE
        else if pwm(2 ∗ |B⃗ • s⃗_P|) ∧ pwm(2 |s⃗^P1 • s⃗^P2|) then     ▷ magnetic effect
            ▷ Change this and all bonded preons to ℙ_K s
            return COLLAPSE
        end
    end
    return NOPE
end
```

Algorithm 19: Electromagnetic interaction.
This heuristics was built having in mind the QED phenomenology.

```
▷ Vacuum interaction.
function vacuum(𝕌, ℙ_vac) begin
    ▷ U real x P real or U virtual x P virtual
    if (d_U = g_U ∧ d_P = g_P) ∨ (d_U ≠ g_U ∧ d_P ≠ g_P) then
        ▷ Enforce momentum conservation
        if m_U ∧ p⃗_U = p⃗_P then
            ▷ Static force or gravitational acceleration
            s⃗_P = s⃗_P' = 0⃗
            m_U = false
            return REISSUE
        end
        ▷ Restricted to a zone
        if d_U = d_P then
            if (clr_U = N ∨ clr_U = N̄) ∧ s⃗_U = −s⃗_P then
                ▷ ℙ_K formation (rest mass)
                s⃗_P = s⃗'_P = 0⃗
                return REISSUE
            end
            if clr_U ≠ N ∧ clr_U ≠ N̄ then
                ▷ Gluon formation
                clr^P = clr^U
                clr^P' =∼ clr^U
                return REISSUE
            end
        end
    end
    return NOPE
end
```

Algorithm 20: The vacuum.

$\mathbb{P}_{vac}$s are collectively called *a vacuum* and are available to be recruited by the $\mathbb{U}$s to form $\mathbb{P}_K$s or $\mathbb{P}_{glu}$s.

```
▷ Quark x gluon interaction.
function strong(𝕌, ℙ) begin
    ▷ Happens inside a zone
    if d_U = d_P ∧ g_U = g_P ∧ clr_U ≠ N ∧ clr_U ≠ N̄ ∧ ℙ ≡ ℙ_glu then
        if t^U mod 2 = 0 then
            clr^U ↔ clr^P
        else
            clr^U ↔ clr^P'
        end
        return REISSUE
    end
    return NOPE
end
```

Algorithm 21: Strong interactions.

Does the simplicity of this piece of code live up to the complexity of QCD?

```
▷ Lepton against Z or W boson.
function weak(𝕌, ℙ) begin
    if ω_P = ω_P' then
        ▷ Conjugate the relevant bits
        σ_U = g_U xor ω_U xor j_U
        σ_P = g_P xor ω_P xor j_P
        ▷ Happens inside a universe
        if d_U = d_P ∧ σ_U = σ_P then
            return COLLAPSE
        end
    end
    return NOPE
end
```

Algorithm 22: Weak current.
Simple reissue of all bonded preons takes place if chirality rule is satisfied.

```
▷ Input:  two weak pairs.
function cohesion(ℙ_1, ℙ_2) begin
    if b_1 = b_2 then                                      ▷ cohesion force
        ▷ Spin realignment
        s⃗^P1 = −s⃗^P2 = s⃗^P1 × s⃗^P2
        s⃗^P1' = −s⃗^P1
        s⃗^P2' = −s⃗^P2
        ▷ Cancel excess pairs
        if aligned(ℙ_1, ℙ_2, true) then                    ▷ antialigned?
            return CANCEL
        end
    ▷ Formation of W, Z bosons
    else if ∼(w_P xor g_P) then                            ▷ chirality?
        return REISSUE
    end
    return NOPE
end
```

Algorithm 23: Weak particle cohesion.
Operation for forming or maintaining weak bosons.

```
▷ Interactions between pairs.
function processPxP(ℙ1, ℙ2) begin
    ▷ Valid inside a zone?
    if d^{P1} ≠ d^{P2} ∨ g^{P1} ≠ g^{P2} ∨ not pwm(φ^{sin}_{P1} ∗ φ^{sin}_{P2}) then
        return NOPE
    end
    ▷ Both pairs electric?
    if q_{P1} = q_{P1'} ∧ q_{P2} = q_{P2'} then
        q_{P1} =∼ q_{P1}; q_{P2} =∼ q_{P2}
    end
    ▷ Both pairs weak?
    if w_{P1} = ω_{P1'} ∧ ω_{P2} = ω_{P2'} then
        ω_{P1} =∼ ω_{P1}; ω_{P2} =∼ ω_{P2}
    end
    ▷ Non trivial colors?
    if clr_{P1} ≠ N ∧ clr_{P1} ≠ N̄ ∧ clr_{P2} ≠ N ∧ clr_{P2} ≠ N̄ then
        gluxglu(ℙ1, ℙ2)
    ▷ Same charge structure?
    else if (ρ_{P1} = ρ_{P2} ∧ ρ_{P1'} = ρ_{P2'}) ∨ (ρ_{P1} = ρ_{P2'} ∧ ρ_{P1'} = ρ_{P2}) then
        ▷ Trivial spin?
        if s⃗_{P1} = s⃗_{P1'} = s⃗_{P2} = s⃗_{P2'} = 0⃗ then
            if aligned(ℙ1, ℙ2, false) then                                  ▷ aligned?
                return REISSUE                              ▷ piling up
            else if aligned(ℙ1, ℙ2, true) ∧ p⃗1 ≠ −p⃗2 then
                return CANCEL
            end
        ▷ ℙ_K formation via weak charge
        else if ℙ1 ≡ ℙ_vac ∧ (ℙ2 = ℙ_Z ∨ ℙ2 = ℙ_W) then
            s⃗1 = 0
            return REISSUE
        ▷ Weak inertia
        else if ℙ1 ≡ ℙ_K ∧ (ℙ2 = ℙ_Z ∨ ℙ2 = ℙ_W) ∧ b1 = b2 then
            v⃗^P = |o⃗^P| p̂^P − o⃗^P
            v⃗^{P2} = |o⃗^{P2}| p̂^P − o⃗^{P2}
            v⃗^{P2'} = v⃗^{P2}
            return INERTIA
        ▷ Same weak charge?
        else if ω_{P1} = ω_{P2} = ω_{P1'} = ω_{P2'} then
            return cohesion(ℙ1, ℙ2)
        end
    ▷ Try to antialign two ℙ_K for photon formation
    else if s⃗_{P1} ≠ 0⃗ ∧ s⃗_{P1'} ≠ 0⃗ ∧ s⃗_{P1} = s⃗_{P2} = 0⃗ then
        return ANTIALIGN
    else
        return NOPE
    end
    return REISSUE
end
```

Algorithm 24: ℙxℙ interactions.

Boson formation/destruction procedures.

```
▷ Match pairs.
procedure antialign(ℙ_vac, ℙ_K) begin
    ▷ Explore the stack
    for i = 0 to SIDE^2 do
        w = (w_1 + i) mod SIDE^2
        ▷ Test bonded candidates
        if o⃗_w = o⃗_K ∧ p⃗_w ≠ p⃗_K ∧ b_w = b_K ∧ aligned(ℙ_w, ℙ_K, true) then
            ▷ Swap momentum with vacuum
            p⃗^P_vac ↔ p⃗^P_w
            p⃗^P'_vac ↔ p⃗^P'_w
        end
    end
end
```

Algorithm 25: Formation of antialigned $\mathbb{P}$s.

Pairing refinement for photon formation is done with the help of the vacuum until a perfect match is found.

```
▷ Gluon-gluon interaction
procedure gluxglu(ℙ_1, ℙ_2) begin
    if t^P1 mod 2 = 0 then
        clr^P1 ↔ clr^P2
    else
        clr^P1' ↔ clr^P2'
    end
end
```

Algorithm 26: Gluon-gluon interaction.

The unfiltered nature of this interaction enforces strong confinement.

References

[1] Wheeler, J.A. *Information, physics, quantum: the search for links*, In Complexity, entropy and the physics of information (ed. W. Zurek). Reading, MA: Addison-Wesley (1990).

[2] Frisch, U., B. Hasslacher, and Y. Pomeau *Lattice-gas automata for the Navier-Stokes equation*, Phys. Rev. Lett. **56**, 1505 (1986).

[3] Zuse, K. *Rechnender raum*, Elektronische Datenverarbeitung, **8**, 336-344 (1967).

[4] Wolfram, S. *A new kind of science*, Wolfram Media, {23-60}, 112, and 865-866 (2002).

[5] Gardner, M. *The fantastic combinations of John Conway's new solitaire game "life"*, Sci. Am. **223**, 120-123 (1970).

[6] Feynman, R. *The character of the physical law*, MIT, ISBN 0 262 56003 8 (1967).

[7] 't Hooft, G. *The cellular automaton interpretation of quantum mechanics*, In: van Beijeren, H., et al. (eds.) Fundamental Theories of Physics. Springer, Berlin (2016).

[8] Elze, H.T. *Action principle for cellular automata and the linearity of quantum mechanics*, Phys. Rev. A **89** 012111 (2014).

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

[10] Fredkin E. *An introduction to digital philosophy.* Int. J. Theor. Phys. **42** (2): 189–247 (2003).

[11] Margolus N. *Universal cellular automata based on the collisions of soft spheres*, Adamatzky A. (eds) Collision-Based Computing. Springer, London (2002).

[12] Ozhigov Y. *Constructive physics*, arXiv: 0805.2859 (2008).

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

[14] Burnham, D. C., Weinberg, D. L. *Observation of simultaneity in parametric production of optical photon pairs*, Phys. Rev. Lett. **25** (2): 84. (1970).

[15] Case, J., D. Rajan, and A. Shende *Spherical wave front generation in lattice computers*, Int. J. Comput. Inf. (1994).

[16] Volder, J. *The CORDIC trigonometric computing technique*, IRE Trans. Electronic Computing, Vol EC-8, pp330-334 (1959).

[17] 't Hooft, G. *The holographic principle*, opening lecture. Subnucl. Ser. **37**, 72–100 (2001).

[18] Smith, W.D. *Charge quantization, the topology and 3-dimensionality of the universe, and abolishing monopoles*, https://www.semanticscholar.org (2000).

[19] J. Amos *Hubble sets new cosmic distance record*, BBC News. (2016).

[20] Capobianco, and S., T. Toffoli *Can anything from Noether's theorem be salvaged for discrete dynamical systems?*, in Calude et al. (eds.), Proceedings of the Unconventional Computation 2011 conference, Lecture Notes in Computer Science **6714**, 77-88 (2011).

[21] Hobson, A. *Solving the measurement problem within standard quantum theory*, arXiv: 1910.08591 (2019).

[22] Spavieri, G. and E. Haug *Why the Sagnac effect favors absolute over relative simultaneity*, Phys. Essays. **32** 10.4006/0836-1398-32.3.331 (2019).

[23] Lachieze-Rey M., and J.P. Luminet *Cosmic topology*, Phys. Rept. **254** (1995).

[24] Wilczynska, M.R. et al. *Four direct measurements of the fine-structure constant 13 billion years ago*, Science Advances (2020).

[25] Lemaître, G. *The beginning of the world from the point of view of quantum theory*, Nature. **127** (3210) (1931).

[26] Alpher, R.A.; H. Bethe; G. Gamow *The origin of chemical elements*, Physical Review. **73** (7): 803–804. (1948).

[27] Pooley, O. *Handedness, parity violation, and the reality of space*, in K. Brading and E. Castellani, Symmetries in physics: philosophical reflections, Cambridge University, pp. 250–280 (2003).

[28] Sethna, J.P. *Statistical mechanics: entropy, order parameters, and complexity*, Oxford University (2006).

[29] Hawking, S.W. *Particle creation by black holes*, Commun. Math. Phys. **43**, 199 (1975).

[30] Eddington, A.S. *The nature of the physical world*, London (1929).

[31] Scandolo, C.M., *et al.* *Is it possible to be objective in every physical theory?*, arXiv: 1805.12126v1 (2018).

[32] Tirandaz, A., *et al.* *Classicalization of quantum state of detector by amplification process*, arXiv: 1704.04630v2 (2019).

[33] Hansen, A., S. Wolf *Contextuality: it's a feature, not a bug*, arXiv: 1902.02088v2 (2019).

[34] Hofer, W.A. *Elements of physics for the 21st century*, J. Phys.: Conf. Ser. **504**, 012014 (2014).

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

[36] Elitzur, A.C., and L. Vaidman *Quantum mechanical interaction-free measurements*, Found. Phys. **23**, 987-97 (1993).

[37] DeWitt, B.S. *Quantum mechanics and reality: Could the solution to the dilemma of indeterminism be a universe in which all possible outcomes of an experiment actually occur?*, Physics Today **23**, 9, 30 (1970).

[38] Carroll, S. *From eternity to here: the quest for the ultimate theory of time*, New York: Penguin (2010).

[39] Langevin, P. *The evolution of space and time*, Scientia, **X**: 31–54 (translated from the French: "L'évolution de l'espace et du temps") (1911).

[40] Witten, E. *String theory dynamics in various dimensions*, Nucl. Phys. **B443** 85 (1995).

[41] Amendola, L., and S. Tsujikawa *Dark Energy: Theory and observations*, Cambridge University Press (2010).

[42] Witten, E. *Supersymmetry and Morse theory*, J. Differential Geom. **17**, no. 4, 661–692 (1982).

[43] Jaffe, A., and E. Witten *Quantum Yang-Mills theory*, http://www.claymath.org/prizeproblems/yangmills.htm (2002).

[44] Bopp, F.W. *An intricate quantum statistical effect and the foundation of quantum mechanics*, arXiv: 1909.01391v2 (2020).