Periodic waveguided multiverse as a source of dark matter and dark energy

I A Gribov
Institute for Time Nature Exploration of the Moscow State University, Faculty of Biology, Division of General Ecology, Leninskiye Gory 1-12, Moscow 119991, Russia
E-mail: jgribov@yandex.ru

Abstract. Sources of dark matter (DM) and dark energy (DE) could be co-existing standard-model (SM)-universes. The proposed four-dimensional (4D)-multiverse—periodic chain of identical (parallel, quasi-flat) three-dimensional (3D)-waveguides—mimics adjacent identical SM-like universes, immersed in global 4D-Euclidean space. The quasi-classical Maxwellian-like waveguided normal modes simultaneously create quantized 3D-rest-mass particles (from electron to higher masses) with co-emergent basic physical laws (special relativity, quantum mechanics) plus weak Newtonian gravity with equivalence principle. The basic novelties are: The nearest adjacent SM-like-universes show evident charge-parity-time plus ±M_{gr} (gravity charges) symmetries—matter–antimatter antigravity—the dark energy nature; the nearest even (odd) 3D-universes become SM-decoupled, DM-like gravitating, disclosing the dark matter and DM–DE fine-tuning nature. The proposed corresponding weightless superfluid vacuum-medium concept discloses the Planckian \( h \), light speed \( C \) constants nature as propagating massless quasiparticles-magnons—attractive–repulsive odd spin-1 photons and spin-3 gravitons; explains the quantum double-split, entanglement, etc phenomena and the 3D-waveguided quasi-optical nature of the least-action principle. This concept predicts: The matter–antimatter antigravity; only antimatter (the only SM mediator between matter and dark matter) able detect dark matter particles; the only possibility create dark matter particles is the antiparticles–antiparticles collision (never done), realizable even in low-energy colliders.

1. Introduction
Extremely dominating cosmological phenomena of dark energy (DE) and dark matter (DM) are recognized today as the biggest physical problems—as theoretical challenges to the standard-model (SM) of elementary particles and to the cosmological standard model, as writes Weinberg [1]. Basic symmetry groups, related to the elementary particles of the SM, are the special unitary groups of degree \( n \), denoted SU(\( n \)), they are the Lie groups of \( n^2 \) unitary matrices with determinant 1. The SM of particle physics, a gauge quantum field theory contains the internal symmetries of the unitary product group SU(3) \( \times \) SU(2) \( \times \) U(1). The SM is very well tested and is described by these three (gauge invariant) symmetry groups, where the SU(3) belongs to the strong forces of quantum chromodynamics (QCD), the SU(2) \( \times \) U(1) to the electroweak, and the U(1) to the electromagnetic (EM) interactions. The product in the group theory is an operation that takes two groups G and H and constructs a new group, denoted G \( \times \) H. For example, the U(1) is called an Abelian group (because its product is commutative), it physically corresponds to the non-self-interacting photons behavior, but the simplest non-Abelian group (which product is noncommutative) is the SU(2) group, it is well known from
the description of spin one-half particles and physically corresponds to self-interacting photons behavior.

Our observable large-scale universe is almost flat and according to modern cosmology its total mass-energy density is expected to have critical value. Mass-energy density, according to Einsteinian mass \( m \) and energy \( E \) equivalence \( E = mc^2 \), is the amount of energy stored in a given system or region of space per unit volume, where \( C = C_3 \) is usual three-dimensional vector of the constant light velocity in our 3D space. If this critical total mass-energy density is taken as 100\%, then the well known ordinary matter (OM), described by the SM, surprisingly contains only near \( \simeq 5\% \) of the total critical mass-energy density and the vastly dominating rest (dark energy \( \simeq 70\% \) plus dark matter \( \simeq 25\% \)), keeping together the large-scale universe flatness, have yet unknown nature \[1\]. The dark energy nature is traditionally connected to the positive (repulsive) vacuum energy density. There are some popular dark matter candidates, e.g. the SM-extended—supersymmetric, heavy (weakly interacting) massive particles (WIMPs) or very light axions, etc. These and many other hypothetical dark matter candidates where not yet confirmed after many experiments, using various matter-made detectors \[2\]. The DE–DM fine-tuning problem also looks unsolvable, because the dark matter and dark energy natures remain physically disconnected \[1\].

The dark energy and dark matter phenomena (including the DE–DM fine-tuning) require new physical paradigms beyond our single SM universe frames. The simplest heuristic concepts of this type naturally assume the co-existing composite ensembles of the intrinsically physically SM-equal, but mutually dark and mostly gravitationally interacting SM universes. The oldest multiversal concept of the mutually dark SM ensembles describes two coexisting dark mirror SM universes, it was initiated by Lee and Yang \[3\] and later sufficiently elaborated by Okun and Pomeranchuk \[4\]. If this mirror dark matter exists it must be the SM-like self-interacting (as our ordinary matter does) and may take the form of mirror dark matter planets, stars and galaxies.

The mutually dark ensemble of many coexisting SM copies (with different Higgs masses, but without embedding four-dimensional (4D)-space and without 4D-spatial co-ordering) was recently proposed by Arkani-Hamed \textit{et al} with the goal to stabilize the electroweak hierarchy; this model expects heavier neutrinos, additional radiation, larger axion mass and supersymmetry below 10 TeV \[5\]. Notably, these concepts are related only to the dark matter nature—the dominating dark energy phenomena (with an emergent antigravity) have no place in them.

The promising concepts of an overlapped co-interacting composite SM ensemble are very simple, because they do not invent new exotic SM particles as new—extremely stable and hidden dark matter candidates. They economically use the existing stable SM-particles and somehow combine mutually hidden—dark SM universes, co-existing and co-interacting in all points of our global three-dimensional (3D)-space, to explain the dominating DE–DM phenomena. These SM concepts have some definite experimental predictions. They are testable, contrary to the popular, but never directly testable inflationary multiverse concepts by Linde \[6\], because these physically different bubbles-universes are spatially disconnected—non-interacting and cannot cause (explain) the vastly dominating observable dark energy and dark matter miracles \[7\].

The problem is that all symmetric ordinary matter (OM) and antimatter (AM) sectors in the SM ensembles, mentioned above, are traditionally non-separable—both belong to the same physical 3D-space. In this case our ordinary matter (together with its antimatter) must be both SM-decoupled of dark matter, which belongs to other coexisting SM universes. So, the antimatter sector is excluded as the SM mediator between ordinary matter and dark matter and there is no predicted antigravity between OM–AM, as also between dark matter and dark antimatter (DAM), co-emergent—predicted in the 4D-spatial periodic waveguided multiverse (PWM) concept in consideration \[8\]. The proposed co-ordered periodic SM ensemble, simultaneously explains the hidden DE–DM nature together with the DE–DM fine-
tuning phenomena and it is indirectly—cosmologically verified on the weightless-composite large-scale universe model, recently developed together with Trigger and Rukhadze, where the gravitationally repulsive (OM–DM) and (AM–DAM) galactic and antigalactic clusters are survived of annihilation—equally presented in our observable composite universe [9–12]. Importantly, the elementary massive SM-fermions–antifermions are co-emergent in the foliated PWM-concept and are intrinsically identical in these SM universes. They arise in the 3D-waveguides as the non-linear, 4D-light-dynamical (double-winding) vortexes—quite similar to the bifurcation-like (doubling period) processes in the chaos theory, universally described by Feigenbaum constant [13]. This single constant could describe many free SM-constants, as proposed by Manasson [14].

The further text is organized as follows: section 2 presents the periodic waveguided multiverse concept; section 3 outlines the quasi-classical, 3D-waveguided emergence of elementary—quantized rest masses, with the co-emergent—united special relativity (SR) and quantum mechanics (QM) in the 3D-waveguide; section 4 shows the co-emergence of the periodic weak Newtonian gravity and antigravity together with the expanded equivalence principle (EP) in the PWM; section 5 outlines the emergent nature of intrinsically identical (adjacent, but hyperspatially divided—anti-gravitating) massive fermions and antifermions in the PWM; section 6 sets forth the consequently weightless-composite superfluid PWM vacuum concept; section 7 shows the united nature (and the enormous quantitative difference) of gravitational and electrostatic potentials on the strained quasi-flat 3D-membrane in this vacuum-medium; section 8 explains the nature of hidden Higgs field in the PWM; section 9 reveals the 3D-waveguided nature of Yang–Mills theory and SU(3) × SU(2) × U(1) symmetry [15]; section 10 shows the united quarks and gluons confinement and asymptotic freedom nature in the PWM; section 11 discusses the united (even—attractive and repulsive) spin \( S = 1 \) photons and spin \( S = 3 \) gravitons nature (as quasiparticles—magnons) in the superfluid PWM vacuum; section 12 compares the PWM multiverse with the periodic 3D-branes multiverse of the string theory (ST), as also the emergent 4D-electromagnetic nature of the 3D-mass particles in the 3D-waveguide with the basic string concept in the ST; part 13 describes the method of elementary dark matter particles creation in the AM–AM collisions, as one of possible laboratory tests of the PWM concept.

2. The periodic waveguided multiverse concept

The SM-like concept in consideration is sufficiently different of the mentioned above hypothetical SM ensembles, it predicts the symmetrically emergent OM–AM, DM–DAM with antigravity and the promising OM–DM-mediating property of antimatter with opportunities to detect cosmic dark matter, as also create its particles (dark matter electrons and protons, etc) even in low-energy colliders, using the mediating antimatter particles, providing enough simple tests of the PWM in the laboratory.

The PWM is supposed to be an endless periodic hyperspatially-ordered \( n \)-chain of quasi-flat co-adjacent 3D-waveguides—3D-universes, where each 3D-waveguide \( W_n \) has its individual natural number \( n \) in the periodic chain. They are literally parallel, (intrinsically identical) quasi-flat SM-like universes—3D-waveguides. Each 3D-waveguide \( W_n \) physically behaves as the SM-like (roughly) 3D-spatial universe, confining its SM-like particles in the very thin 4D-dimensional bulk inside the 3D-waveguides [8]. These identical PWM waveguides are framed-formed by parallel, quasi-flat, double-sided 3D-boundaries—elastic, strongly strained-quasiflat 3D-membranes \( M_n, L_0 \)-periodically placed in global Euclidean 4D-space (where our universe \( W_0 \) is shaped by two quasi-parallel 3D-membranes \( M_0 \) and \( M_1 \), the nearest adjacent antiuniverse \( W_1 \) is shaped by 3D-membranes \( M_1 \) and \( M_2 \) and so on). We fix the thickness \( L_0 \) of the standard 3D-waveguide-module near 1 pm (Compton length of electron), starting from the minimal rest mass energy, corresponding to electron mass. In this case some basic features of our 3D-mass
particles and some 3D-fundamental physical laws become not only united, but all simultaneously co-emergent in the frames an effective, (experimentally testable) low-energy physics.

The PWM concept was initially based on two things: The quasi-classical, 3D-waveguided Maxwellian 4D-electromagnetism (EM); the correspondingly 4D-expanded concept of 3D-photon by Einstein, which is confined in the 3D-waveguide. In this 4D-spatial case the pure 3D-waveguided-dynamical SR and QM, together with the weak Newtonian gravity and equivalence principle (EP) are simultaneously emergent and united. Some of these remarkable uniting-waveguided properties are not new. Feynman mentioned in his famous lectures some miraculous properties of flat two-dimensional (2D)-waveguides, where the pure waveguided EM-dynamics unites the simultaneously emergent (as pure EM-waveguided) SR- and QM-like features [16]. Feynman also discussed in his lectures so called 2D electro-mechanical membrane analogy 2D-(EMMA) and he noted, this 2D-analogy could be also correctly expanded to the 3D-membrane properties (to the 3D-EMMA) [16]. We expanded this amazing analogy to the quite similar 3D gravitomechanical membrane analogy 3D-(GRAMMA). The natural 3D-(EMMA-GRAMMA) combination in the 3D-waveguide is fundamentally crucial for the PWM unification of gravity and electrostatic potentials on the 3D-membrane. Indeed, a thin strained flat 3D-membrane will slightly $\pm L$-deviate from its plane position (under a normally acting (3D quasi-point-like) mechanical 4D-force, equal to a $\pm$ electrostatic charge or gravity mass) with the exactly emergent curved 3D-surfaces—materialized Newtonian gravity or Coulomb electrostatic potentials $U = \pm k/r$, (as two opposite gravity and electrostatic charges), where $r$ is our usual 3D-distance (along the 3D-waveguide) between point $r = 0$ and other points of this slightly deviated quasi-flat 3D-membrane, the coefficient of proportionality $k$ (in case of the gravity potential) is expressed in terms of its 3D bulk tension, empirically determined by the Newtonian gravitational constant $G$ [8]. The proposed 3D-waveguided-enlargement in the PWM is remarkable—it shows simultaneous emergence of the united (pure 4D-wave-dynamical, 3D-waveguided) versions of the SR, QM, together with the weak Newtonian gravity and antigravity and the emergent-enlarged equivalence principle (EP), arising totally independently of the General Relativity (GR) by Einstein. The EP is pure empirical basis of the GR, so the PWM-EP emergence sufficiently expands the GR-paradigm itself, incorporating the OM–AM antigravity in it.

The emergent periodic gravity and antigravity in the PWM plays its new crucial physical role—this allows physically non-contradictory formation of the hidden (weightless-superfluid) vacuum-medium concept, filling the periodically co-adjacent 3D-waveguides. This step was never possible in physics without the expanded GR (and Newtonian gravity), adopting the gravity masses symmetry, naturally arising in the PWM. Moreover, the proposed (vacuum-medium—particles–holes) concept is the necessary condition, providing simultaneous co-emergence of the nearest co-adjacent OM–AM–DM–DAM universes with the exact gravity-antigravity symmetry and the OM–DM attractive gravity in the PWM [8].

The proposed hyper-spatial $W_n$ order discloses the pure multiversal matter and antimatter nature with the inevitably emergent $\pm M_{gr}$ and the geometrically obvious charge-parity-time (CPT)-like symmetry for adjacent—SM-coupled $W_{2n}$ and $W_{2n+1}$ flat 3D-waveguides, realizing novel—periodic adjacent-repulsive matter–antimatter universes–antiuniverses (as the extensively searched-hidden dark energy phenomenon nature). Each pair of the 4D-spatially separated (SM-decoupled) $W_{2n}$ and $W_{2n+2}$ universes are mutually dark, but still gravitationally attractive as dark matter does [8]. The SM-decoupled OM–DM in the PWM predict that the dark matter particles detection is not possible, using only ordinary-matter-made detectors. Fortunately, AM plays role of the natural both-sided SM mediator between ordinary matter and dark matter in the OM–AM–DM chain and this predicts that only combined OM–AM detectors will be able detect dark matter particles [17]. This also predicts impossibility to create dark matter particles in conventional collisions of OM–OM or OM–AM particles—predicts the only one way to create dark matter particles via AM–AM collisions (even in low-energy colliders),
where dark matter electrons, protons, etc can be created in DM–AM particles pairs. The AM–DM visibility asymmetry can be detected in Wilson chamber [17, 18]. The EM-communication between ordinary matter and dark matter antennas could be also realizable only by a receiver, containing mediating AM particles, collected in a magnet trap [19].

The totally gravitationally neutral (weightless) multiverse arises as our weightless-composite universe with the equally presented OM–DM and AM–DAM clusters, [9–12]. Indeed, the gravity charges symmetry and repulsive gravity also exist between the adjacent DM–DAM counterparts in the PWM [8].

3. The emergent quantized rest masses, SR and QM in the 3D-waveguide
Kaluza introduced the additional hypothetical (cyclical) spatial dimension in the 4-dimensional (three space and one time) GR by Einstein, with the aim to unify the GR and EM [20], but a physical sense of his unifying cyclical condition was never clear and this way of the gravity and EM unification did not distinguished empirically enormously weaker gravity from the EM. The hypothetical cyclical coordinate by Kaluza was sharply critiqued by Einstein and Grommer—they assumed the additional dimension must be identical to out three identical spatial dimensions [21]. This very deep Einsteinian idea brings physical clarity in the formal unifying concept by Kaluza, because the additional equal (orthogonal) 4-th dimension $L$ automatically expands our physical 3D-space to 4D-Euclidean space with four equal orthogonal spatial coordinates, where Einsteinian gauged $C_3$-photons (moving in our 3D-Euclidean space with the 3D light velocity $C_3$) can be naturally expanded to gauged $C_4$-photons (moving in the expanded 4D-Euclidean space with the same universal constant 4D light velocity $C_4 = C_3$). How to adopt this promising Einsteinian idea about four equal spatial dimensions to our 3D-universe and classical 3D-physics? We must assume our quasiflat Euclidean 3D-universe is a very thin quasiflat 3D-waveguide with a quasi-constant $L_0$-thickness between two parallel flat 3D-boundaries. They are two strained quasi-flat 3D-membranes with the isotropic Euclidean 4D-bulk space between them, where the steady reflected (4D-gauged) $C_4$-photons fly along polygonal $C_{4t}$-trajectories (as usual $C_3$-photons between two parallel 2D-mirrors) and pure wave-dynamically acquire the classically quantized (elementary) 3D rest masses with the emerged 3D-SR and 3D-QM properties, where 4D-EM photons remain locally 4D-gauge invariant with $C_4 = \text{const}$ [8]. These elastic quasi-flat boundaries (3D-membranes) must have properties of ideal electric conductors, totally reflecting and confining 4D-EM waves (4D-photons—4D-excitations) inside this waveguided 3D-universe. The proposed 3D-waveguided geometry together with the corresponding quasi-classical 3D-waveguided EM-dynamics have some remarkable physical properties (in case of flat 2D-waveguides in our 3D-space they are partially mentioned by Feynman [16]), which unites and expands the basic physical laws. The proposed 4D-dimensionality is like the common 4D-dimensionality of classical Diracian spinors, describing basic SM fermions (electrons, neutrinos, second and third-generation leptons, quarks) with the spinor representation by the corresponding Clifford algebra in the 4D-spacetime. Kaluzian cyclical condition obtains its obvious physical sense as the vibrating 4D-waves in the 3D-waveguided 4D-electrodynamics.

A full 4D-light-dynamical quasiparticles-energy $E$ in the 3D-waveguide is $E(\alpha) = h\nu_4 = h\nu_0/\cos\alpha$, and its 3D-velocity $V$ is defined as projection $C_{x,y,z}$ of the full 4D-velocity $C_4$ on our 3D-plane:

$$\sin\alpha = V/C_4 = C_{x,y,z}/C_4; \quad \cos\alpha = \sqrt{1 - V^2/C_4^2}.$$  

The 4D-photon can pass along the 3D-waveguide $L_0$ if two polygonal parallel wave trains AB and KS have the same wave phase (co-phase condition) on the line AK ⊥ AB. The wave-paths difference $\Delta l$ is $\Delta l = AB + BK$, figure 1(a). The $\Delta l$-interval must contain one integer wavelength $\lambda_4$ equal to the cathetus $AC = AB + BC = AB + BK = \lambda_4$ in the square triangle.
Figure 1. The 3D-waveguided co-phase condition (a) creates the emergent quantized rest mass (normal \( OL \)-cross-section of the 4D-wave) with the co-emergent (united) 3D-SR and 3D-QM features, where de Broglie wave simultaneously arises as its \( OX \)-cross-section; (b) shows the (4D-spatial by the nature) SR momentum-energy relation by Einstein.

\[
hv = h\nu_0/(1-P^2/C^4)^{1/2},
\]
\[
P_L = M_0C_4 = \text{const}
\]
\[
E_L = E_0 = M_0C_4 = \text{const}
\]
\[
P_L = M_0C_4 = \text{const}
\]
\[
E = MC_4^2
\]
\[
\lambda_{\text{de Broglie}} = \lambda_0/\sin \alpha = \lambda/\sin \alpha,
\]
\[
M_0C_4 \cos \alpha = M_0C_4 = \text{const.}
\]

4. The emergent periodic gravity and antigravity in the PWM
Quantized 3D-massive 4D-photons will move inside the confining 3D-waveguide with constant 4D-light velocities along polygonal trajectories (like our 3D-photons in empty 3D-space, confined between two parallel mirrors), realizing the inertia law by Newton, if the 3D-waveguide has strictly parallel 3D-membranes—3D-boundaries. Tiny non-parallelism with \( \beta(x) \approx 0 \) between these 3D-membranes will create a 3D-longitudinal gravity-like acceleration along the 3D-waveguide, proportional to this angle, as it will be shown below.

Notably, only very tiny deformations (keeping these 3D-membrane quasi-flat), according the 3D-EMMA by Feynman [16], create the Poisson-like equations plus the superposition law for electrostatic-like or gravity-like potentials. They are mathematically similar:

\[
U(r) \propto \pm \delta L_0(r) \propto \pm k/r,
\]
where \( \delta L_0(r) \approx 0 \) are tiny spherically symmetric \( L \)-deviations of the initially flat 3D-membrane under normal point-like \( L \)-force, acting in the point \( r = 0 \), where \( r \) is our usual
Figure 2. The LX-cross-section of the quasi-flat 3D-waveguide (a) shows the longitudinal (OX) weak 3D-waveguided gravity acceleration mechanism, emergent between slightly non-parallel 3D-membranes $M_0$ and $M_1$, directed in a tiny opening of this 3D-waveguide; (b) shows the LX-cross-section of two quasi-flat co-adjacent 3D-waveguides with the oppositely directed equal 3D-waveguided openings, created by the slightly turned 3D-membrane $M_0$, with the resulting opposite gravitational accelerations for gravity masses $(+M_{gr})$ and $(-M_{gr})$, living in two co-adjacent 3D-waveguides.

3D-distance (along the 3D-waveguide) between point $r = 0$ and other points of this slightly deviated quasi-flat 3D-membrane, the coefficient of proportionality $k$ (in case of the gravity potential) is expressed in terms of its 3D bulk tension, empirically determined by the Newtonian gravitational constant $G$.

The slightly unparalleled state of two framing 3D-membranes of the 3D-waveguide can be caused by normal local forces, creating by the hollow (nonsingular) 4D-spherinders—elementary 4D-light-springs—the elementary PWM particles, described below.

The accelerating waveguided gravity force is $f_x = \Delta P_x/\Delta t$ for the $C_4$-dynamical mass particle $M$ is the average momentum change $\Delta P_x$ along the quasi-optical segments $AB + BK$ over one time period $\Delta t = (AB + BK)/C_4$, figure 2(a). This calculation is very simple, because $P_L = M_0 C_4$ = const and

$$g_x \simeq \frac{dL_0}{dx} C_4^2 / L_0 \simeq \beta(x) C_4^2 / L_0, (\beta(x) \simeq 0).$$

The non-parallelism can be created by a huge normal force $F_L = \delta P_L/\delta T = M_0 e C_4^2 / 4L_0$, caused by the compressed elementary 4D-spherinder (the PWM-elementary mass particle), deforming these framing, strained—initially parallel and flat—3D-membranes. It acts exactly as a spherically symmetric 3D-electrostatic and gravity charge—(3D-EMMA–GRAMMA), following Feynman [16] and creates tiny symmetric $-1/r$ deformations of the 3D-membranes, with the resulting PWM gravity and antigravity 3D-laws by Newton, as its first derivation $1/r^2$ is proportional to the $\beta(x) \simeq 0$.

The EP (previously pure empirical basis of the GR by Einstein) is naturally emerged in the 3D-waveguided gravity. Indeed, the acceleration equation (5) will give the same 3D-acceleration for higher rest masses—higher normal 3D-waveguided $k$-modes (where $k$ is positive natural number), because all their polygonal trajectories and 4D light velocities remain identical, if they have identical initial 3D-velocities (as it is for different gravity masses, freely falling in the same gravity field). So, this 3D-waveguided gravity mechanism discloses a sufficiently deeper 4D-basis...
Figure 3. Two opposite Newtonian gravity potentials are emergent on two opposite sides of the same strained quasi-flat 3D-membrane, created by opposite normal $L$-pressure, causing by matter pencil (above) and antimatter anti-pencil (below).

for the GR by Einstein, and the 3D-waveguided PWM expansion of the classical GR seems to be quite natural [8].

The $C_3t$-dynamical interval of the pseudo-Euclidean 4D-spacetime concept by Minkowski acquires its totally new geometrical and physical sense in the 4D-Euclidean—3D-waveguide, where the abstract global linear interval $C_3t$ is equal to the broken 3D-waveguided-polygonal 4D-length $C_4t$ (in the 4D-quasi-optical case). So, the global straight $C_3t$ interval by Minkowski of the 4D-spacetime is reduced to the physically transparent universal $C_4t$-dynamical parametrization—to the 4D-polygonal mass particle dynamics. Notably, the 3D-waveguided quasi-optical dynamics obviously follows the least-time principle by Huygens-Fermat in the expanded 4D-optics and discloses the 3D-waveguided nature of the basic mechanical Lagrangian and Hamiltonian principle of the least action [8].

Figure 2(b) shows the emergent antigravity in two identical co-adjacent 3D-waveguides, where waveguided accelerations have opposite directions for matter and antimatter, living in these co-adjacent 3D-waveguides and figure 3 illustrates this phenomenon.

5. The nature of intrinsically identical massive fermions and antifermions in the PWM
Yang–Mills theory, basis of the SM, generalized ideas of the noncommutative gauge groups, describing the EM-like fields that, unlike the Maxwellian electromagnetic field, interact with themselves [15]. It is naturally to assume that the 4D-light-quanta—$C_4$-photons (massless 4D-quasiparticles), stacked in the very thin 3D-waveguide, acquire very big 4D-EM energy density, creating their non-linear self-attraction, like it is postulated for the self-interacting Yang–Mills fields. The corresponding self-interacting effect creates identical twisting co-phased 4D-electron-cells, shortly 4D-(e-cells) or 4D-(e-loops) with identical fixed 3D-radii, identical in all 3D-waveguides—3D (3D-universes) of the PWM (figure 4). The 4D-gauge EM-theory is now locally conserved, because the confined EM-photon keeps constant absolute value of its $C_4$-velocity inside the 4D-(e-cell).
Figure 4. Part (a) displays the pure dynamical doubled (relativistic by the nature) quantized electron rest mass momentum $MC_4 = 2M_0C_4$, arising in the co-phased electron-spherinder, with pure relativistically emergent fermionic 3D-spins $S = 1/2$ and quantized gravity mass and electrostatic charge. Part (b) shows 2D-cross-section $LX$ of the hollow fermionic electron–electron spherinder, shortly ee-spherinder, with two identical curved self-attracting 4D-photons with opposite spins, living on its co-phased surface, arising inside the quasi-flat 3D-waveguide $W_0$, the ee-spherinder creates bilateral normal 4D-light pressure $F_L$ on bounding quasi-flat 3D-membranes $M_0$ and $M_1$, whose tiny curved 3D-surfaces correspond to the exactly Newton- and Coulomb-like gravity potentials $U = k/r$.

Indeed, a non-relativistic co-phased condition assumes that the e-loop has a sufficiently high radius $R_0$ and contains only one de Broglie length $\lambda_{\text{deBroglie}} = \lambda_4 / \sin \alpha = 2\pi R_0$, with one winding period, where $\sin \alpha = V/C_4$. We await here very small e-loop radius (it must be in some orders smaller as, e.g., the first electron orbit in the hydrogen atom—with a correspondingly very small de Broglie length—sufficiently relativistic 3D-velocity $V_e$, near the $C_4$).

The relativistically twisting e-loop-length will have the corresponding length-contraction factor $L_4 = \sqrt{1 - V^2/C^2}$ and the searched stable relativistic co-phase condition will be reached when the single de Broglie wavelength winds twice around this relativistically contracted loop [8]. In this case the length-contraction factor must be $1/2$ and $\sqrt{1 - V^2/C^2} = 1/2, C_L = C_4/2 = C/2, V = C\sqrt{3}/2, \alpha = \pm 60^\circ$. This creates the sufficiently relativistic-dynamical rest mass energy of the e-spherinder $E = M_eC^2$, where $L$-momentum $P_L = \pm M_0C_4$ is const, and the electron (inertial) rest mass $M_e = 2M_0$ is doubled (pure relativistic by the nature)—with two symmetrically acting gravitational half-masses $M_{0gr}$, giving together $2M_{0in} = 2M_{0gr}$, as shown in figure 4.

So, the relativistic e-loop-length is derived after $720^\circ$ double-winding around the e-loop with the resulting $R_{\text{rel}} = \lambda_{\text{deBroglie}}/4\pi$. Thus, the searched radius $R_{\text{de}(\text{rel})}$ of the double-winding electron-spherinder is

$$R_{\text{de}(\text{rel})} = \lambda_{\text{e, Compton}}/(4\pi \sin 60^\circ) = (2/4\pi\sqrt{3})(h/M_eC_4) \simeq 0.1\lambda_{\text{e, Compton}},$$

where $\lambda_{\text{e, Compton}}$ is Compton length of electron and the $L_0$ thickness of the 3D-waveguide in the PWM. This doubling-winding jump simultaneously creates the basic electron features: The fermionic-Diracian e-loop spin $S = 1/2$, with the relativistically confined-hidden spin $S = 1$ 4D- photon inside (intrinsically bosonic EM-quasiparticle); the correct intrinsic magnetic moment of the electron-hole, containing two (hidden-opposite $L$-coaxial) elementary Diracian-like magnet
monopoles; explains the nature of so called trembling movement of electron [8]. Notably, this 3D-waveguided relativistic doubling-winding effect, which creates the (e\(^{-}\), e\(^{-}\))-spherinder—shortly ee-spherinder, where two identical curved self-attracting 4D-photons (two electrons with opposite spins) can exist, corresponds to the same class of the doubling-period-bifurcations, common in the classical chaos theory by Feigenbaum [13], the conceptually-classically applied to the electron and proton doubling-period structures, proposed by Manasson [14]. But the (dissipative) chaos-theoretical concept alone cannot explain the enormous proton-vortex and electron-vortex stability. In the PWM-superfluid vacuum, described below, it is possible because in the superfluid always simultaneously coexist two common fractions: The ideal—superfluid, holding the very stable soliton-like dynamical 4D-vortexes (4D-spherinders) of friction and inevitable decay, with the corresponding ideal theoretical Hamiltonian-descriptions in the SM and also the dissipative fraction, which realizes the transitional—dissipative, bifurcation-like transformations, common in the chaos theory.

6. The weightless superfluid PWM vacuum concept

Einstein claimed some essential physical properties for the hypothetical ether: It must be a non-ponderable—(non-gravitating) media; the corresponding waves in this media must be transverse (as the transverse light waves) and, thus must be of the nature of a solid body [23]. Anderson, Laughlin and Pines suppose that all fundamental physical laws are emergent, like in superconductivity and superfluidity, as result of a many-body interaction at low temperature and these laws emerge out of a many-body interaction and will simply disappear if one tries to take it apart to a single-particle level [24, 25]. In his times Einstein could not take in consideration a new promising ether analogy with superfluid. The most suitable, well-investigated superfluid properties has \(^{3}\)He superfluid in its \(^{3}\)He-A phase, consisting of bosonic Cooper pairs at very low temperature (with slightly higher temperature and pressure as its second superfluid phase B). Indeed, as summarizes Volovik, the superfluid \(^{3}\)He-A at very low temperature gradually acquires from nothing almost all the (effective theory) symmetries which we know today in high energy physics: (an analogy of Lorentz invariance, local gauge invariance, elements of general covariance, the SU(3) × SU(2) × U(1) symmetry), so, the quantum vacuum of the SM is also assumed to be a fermionic system and the ultimate goal is to reveal the still unknown structure of the superfluid ether [26].

The never possible weightlessness of any thinkable vacuum-medium in the classical GR was the basic obstacle to create the GR-consistent superfluid vacuum theories (SVT) before. Indeed, even empty quantum vacuum of the quantum electrodynamics (QED) vastly contradicts to the classical GR, predicting enormously big cosmological constant, which also can be reduced to zero under the proposed totally gravity and antigravity symmetric QED [12]. The proposed composite (fermion–antifermion) superfluid and weightless PWM vacuum structure contains the searched properties: It does not contradict to the PWM-expanded GR; it is similar to the \(^{3}\)He-A-like quantum Fermi liquid at low temperature; its bosonic—Cooper-like pairs are now extremely robust till very high temperatures; its quasi-particles-physics must also contain the SM complex with its basic SU(3) × SU(2) × U(1) symmetry group.

This surprising conceptual step inverts (turns over from head to foots) the classical QED, because our massive OM fermions are now very rare elementary Diracian-like holes (decoupled fermion–antifermion pairs) in the totally dominating, but perfectly symmetric-hidden vacuum-medium (weightless and frictionless superfluid). So, the miraculous QED-fields are hidden dense PWM superfluids by the nature and virtual fermion–antifermion pairs are created not from nothing, but from spinless, chargeless—weightless medium [8].

The (vacuum-emptiness—matter-fullness)-inversion prohibits understanding the cosmological Hubble expansion as steady creation of huge additional volumes of cosmological vacuum from nothing and supports the cosmological concept with the Hubble-expanded distances between
weightless OM–DM and AM–DAM matter and antimatter clusters in the perfectly stable vacuum with the correspondingly stable quasi-Euclidean spatial metrics, recently proposed in [9]. The fully symmetric (spinless, chargeless, weightless) quantum PWM superfluid vacuum, totally dominating over rare OM–AM, AM–DM and DM–DAM elementary holes, must keep the unbroken PWM baryons-antibaryons symmetry (in the total baryonic sum must keep its basic neutrality), including the unbroken OM–AM, AM–DM and DM–DAM baryons symmetries, building the weightless-composite universe on the large scale [9–12].

The famous QM double-split experiments with the surprisingly self-interfering single (elementary, non-divisible) electron can now be trivially understood from the conceptual view of electrons, etc as elementary holes in the vacuum-superfluid. Indeed, the electron-hole itself is nothing, but it is stable and forms the surrounding—fundamentally non-local-coherent, widely spatially distributed (“dandelion”-like) collective deformations—electrostatic and gravity fields around this (e−)-hole in the superfluid vacuum-medium. So, the spatially so distant coherent parts of this (e−)-“dandelion” can naturally interfere with each other, forming common double-split QM interference phenomena.

The nature of the quantum entanglement between two elementary particles (electrons-holes or photons-quasiparticles, being now both fundamentally collective—non-local many-particles phenomena in the PWM vacuum) has the same physical nature as the miraculous single electron self-interference in the double-split experiment, because two elementary (e−)-holes create two spatially distributed (e−)-“dandelions”, simultaneously non-locally connected with each other everywhere in this globally quantum-coherent superfluid, independently of a distant between these (e−)-holes. This spinless composite superfluid has obvious diamagnetic properties, with inevitably arising common spin waves fluctuations on the ground state of this diamagnetic medium, reminding the fluctuating quantum field theory (QFT)-vacuum behavior. So, it is now easy to assume that the superposition of the determined elementary particle wave function in the QM (e.g. electron wave function) with the steady fluctuating PWM vacuum ground state causes the inevitable—pure statistical elementary particle behavior, at the first time understood and formulated by Max Born, but stoically rejected by Einstein.

The fermionic electron spin $S = 1/2$ does not depend on the thickness $L_0$ of the 3D-waveguide and is $L_0$-scale invariant. The universal nature of the fundamental constant 3D-speed of light can be also easily interpreted (in the fermion–antifermion superfluid) as the spin $S = 1$ waves (quasiparticles—3D-photons) propagation, like the Lorentz-invariant propagation of common spin waves quasiparticles—magnons in the condense-matter physics. Importantly, these quasiparticles never perceive the underlying cellular-atomic condensate texture, which is perfectly hidden of their secondary existence (as the non-local many-particles phenomena).

The universal physical nature of the Planckian constant $\hbar$ and the Einsteinian photons quanta nature also can be easily explained in this context. The physical nature of the so universal Planckian constant $\hbar$ is still unknown. This constant was pure heuristically introduced by Max Planck more than 100 years ago as a proper parameter; it was not derived based on first principles. The hidden universal $\hbar$ nature becomes clear in frames of the cellular superfluid PWM vacuum concept, described above. It corresponds to the minimal bosonic quantum action $\hbar/2\pi$, which is needed for very quick disturbing spin-overturn of the most stable composite spin $S = (1/2) - (1/2) = 0$ ground-state of the elementary (e−, e−)-spherinder, shortly ee-spherinder or ee-cell, into the disturbed $S = (1/2) + (1/2) = 1$ one, as the minimal spin $S = 1$ wave micro-quantum in this superfluid, which is immediately transferred (with the linear speed of light) to its neighboring cell and so on—without loss of its light-dynamic energy in the ideal-frictionless medium.

The Einsteinian 3D-photons quanta also can be naturally described as secondary superfluid condensates of the elementary (bosonic) Planckian micro-actions $\hbar/2\pi$, which condense into the
stable Bose–Einsteinian drops—photons and propagate without distortion with the 3D-light speed in empty superfluid as spin $S = 1$ quasiparticles (magnons) [8]. These light-drops move with the speed of light $C_3$ in vacuum and their linear size along this vector $C_3$ is relativistically reduced exactly to zero. So, we perceive these restless photons as point-like particles.

Pauli exclusion principle and the correspondingly anti-symmetric fermionic QM wave function also support the proposed, mentioned above PWM fermionic-holes concept. Indeed, there cannot be more than 2 ($e^-$)-holes in the filled ee-cell—in the ee-spherinder in its filled ground state, occupying the same place, because only two different ($e^-$)-holes with $S = 1/2$ and $S = -1/2$ are simultaneously possible in the same ee-cell. So, the fermionic anti-symmetric QED wave function nature is also connected with the hidden-cellular PWM vacuum structure, where our elementary fermions is its elementary holes. The composite electron–positron ($e^-e^+$) superfluid concept can be easily projected onto the naturally thinkable finer-grained fermion–antifermion superfluids, like (muon–antimuon)-and (tau–antitau)-superfluids, etc, where our basic physical constants and elementary spins (spin $S = 1/2$, spin $S = 1$, $C$, $h$ remain the grain-scale invariant.

Indeed, the fermionic electron spin $S = 1/2$ of the ee-spherinder does not depend on the thickness $L_0$ of the 3D-waveguide and is scale invariant. Therefore, the $e^-e^+$ composite concept of the superfluid can be easily projected onto finer-grained (fermion–antifermion) superfluids, reminding a miraculous doll—Russian matrioshka. This surprising consequence indicates the 4D-volume of the 3D-waveguide is filled with a finer-grained superfluid vacuum, for example, the (muon–antimuon) superfluid, (where the 4D-photon is propagated with the invariant 4D-light speed, and that was indeed postulated at the beginning of this article). If to take these (muon–antimuon)-grains into account, this increases the accuracy of the calculations and gives enough accurate theoretical value of the fine structure constant $\alpha \approx 3M_e/2M_{\mu \mu}$ [8]. Notably, this constant together with many other free SM constants can be expressed via only one Feigenbaum constant of the period-doubling chaos theory, indicating, that all three families of leptons (electron, muon and tau) are created in the double-period-bifurcation cycles [14], (being pure relativistic in our interpretation above).

7. The nature of gravitational and electrostatic potentials on the 3D-membrane

Figure 5 shows the mechanical—3D-membraned-united nature of the gravity and electrostatic potentials. The correspondingly very smooth 3D-membrane ($-1/r$)-deformations are negative gravitational potentials, created by ($e^-$)-hole, figure 5(a), or symmetric—positive gravitational potentials, created by ($e^+$)-anti-hole, figure 5(b). Figures 5(e), 5(d) show two opposite electrostatic polarizations—tiny opposite coaxial shifts inside the double (electron–positron) double-cells—composite atoms of the weightless superfluid vacuum, caused by the aroused ($e^-$)-holes, disclosing the quantized-elementary electrostatic charge nature of electron in the PWM. These tiny opposite polarizations symmetrically deform-corrugate the dividing 3D-membrane and are naturally associated with oppositely directed electrostatic fields, which disappear if the shift is zero, figure 5(c).

We assume, the much stronger—periodic corrugated stretching, figures 5(e), 5(d) belong to the electrostatic potential, which arises only via the vacuum (cell-anticell) polarizations and simply cannot arise in classical emptiness—without the proposed neutral—cellular superfluid tissue (in this case could be no differences between gravitational and electrostatic charges of electron in the PWM). We estimated ratio between integral energies, accumulated by the same very thin 3D-membrane in the smooth gravitational and much stronger—corrugated electrostatic micro-streaks, caused by the single elementary electron-hole (one matter electron) in this very dense electron–positron vacuum-medium and obtained the theoretical ratio, near to the empirically known for electron: $F_{el}/F_{kr}$ in order of $10^{42}$ [8].
Gravity potential $U \sim 1/r < 0$

Electrostatic fields $E_{el.}(r)$

Fieldless vacuum double-cells

**Figure 5.** The opposite smooth $1/r$ gravity potentials (a), (b) are caused by the electron and positron holes; (e), (d) schematically show a corrugated—much stronger as the gravitational—electrostatic $1/r$ potentials, emerged on the same dividing 3D-membrane in the polarized electron–positron vacuum, caused by a distant ($e^-$)-hole, that distinguishes and unites gravity and electrostatic potentials of electron; (c) shows the field-less ground vacuum state (without polarizations and gravity deformations), where this strained 3D-membrane becomes flat.

8. **The nature of hidden Higgs field in the PWM**

The PWM superfluid atoms are Cooper-like composites $e^- e^+$ double-cells which are spatially co-ordered, $L$-orientated double ee-spherinders—compressed 4D-EM-springs, caused by the $L_0$-waveguided EM-boundary conditions. This resembles the $L$-spontaneous symmetry breaking Higgs field in the SM of particle physics. These $L$-ordered compressed 4D-EM-springs very densely fill the 3D-waveguides (like compressed springs in a multilayered spring-mattress), and create a huge internal $\pm L$-pressure inside them. Therefore, there must be a counterbalancing internal quasi-mechanical 4D-bulk-tension, strictly stabilizing the 3D-waveguides-geometry. This opposite tension can be physically associated with the internal elastic-gluing Higgs field, which phonon-like (spinless-bosonic) $L_0$-oscillations are massive scalar Higgs bosons with $S = 0$. In this case Higgs boson acquires its dynamical mass non-contradictory—by the same universal 3D-waveguided ($L_0$-segmented) way (as all other elementary mass particle of the SM) and they also must have their $L_0$-periodic Higgs–anti-Higgs partners in the PWM. The SVT-like analogue of the SM low-mass Higgs bosons was recently experimentally observed in superfluid $^3$He-B [27].
9. The 3D-waveguided nature of Yang–Mills-theory and SU(3) × SU(2) × U(1) symmetry

The SM, Yang–Mills theory, QM and SR, including famous Einsteinian equation between mass and energy $E = mc^2$, all operate with pure 3D speed of light $C = C_3$, but it is now physically totally wrong 3D-dimensionality, because we need sufficiently one more dimension (speed of light $C = C_4$) for mass-creation in the 3D-waveguided universe. Our 3D-massive particle moves as 4D-massless with the universal quasi-constant 4D-speed of 4D-light inside the 3D-waveguide. Indeed, all massive particles are surprisingly massless in the SM, because it uses the global Minkowski 4D-space-time, which has no segmenting boundaries. It is 4D-global and the 3D-waveguided 3D-mass creation mechanism is fully overlooked. That is why the classical Yang–Mills theory—fundamental basis of the SM—describes all particles as massless. Notably, the Yang–Mills theory is a kind of non-linear generalization of the Maxwellian EM, describing and unifying three basic forces (EM, weak and strong), but it does not include gravity force. So, the 3D-waveguided EM must describe similar non-linear EM behavior and interactions of the 4D-photons (e.g. perfect fermionic 4D-spherinders and bosonic 4D-gluons), which all travel 4D-electromagnetically at the 4D-speed of light $C_4$ in the 3D-waveguide. This gives the SM-theoretical illusion that gluons, providing the most of proton or neutron mass, are also described as massless SM particles. They must be a kind of the non-linearly behaving 4D-photons in the 3D-waveguide, and they are naturally confined (invisible for experimenters), because they arise and live only in narrow closed 4D-bulk between two $L$-coaxial 3D-spherinders.

Each filled ground-state of the EM-fermionic 4D-spherinder has two electron vortexes, twisting in opposite directions and their summary spin is zero. This two electrons (ee-electrons) ground-state behaves as a scalar boson. All our basic stable, massive fermions arise as single (fermionic) holes in these $W_0$-spherinders (ee-electrons, uu-quarks, dd-quarks, etc). They have different vortex radii, but identical (fermionic) spin structure. The simplest particle is electron, living on the 3D-surface of the single 4D-spherinder. Its planar 3D-cross-section is 2D-sphere with SU(2) rotation group, which belongs to the EM-like symmetry groups of the weak forces SU(2) × U(1), figures 6(a), 6(b).

Electron neutrino spin $S = 1/2$ naturally arises in the ee-spherinders, filling the superfluid $e^-e^+$ vacuum. The relaxed ee-spherinder has two electron states with opposite spins and its summary spin $S = 1/2 - 1/2 = 0$ in the undisturbed-ground spin state, but each e-spin wave winds twice (double-period-like) around surface of the ee-spherinder and its spin $S = 1/2$ consists of two parts $S = 1/4 + 1/4$. This double-winding structure can be reversibly disturbed so that these two $(1/4)$-units turn on in opposite directions and eliminate each other. In this case the summary spin of the ee-spherinder will have the disturbed-fermionic spin $S = 1/2 + 0$ of e-neutrino, moving with the speed of light [8]. This way can arise also muon and tau neutrino in their corresponding superfluids.

The ee-spherinder (with two elementary electron charges) is created by two EM-nonlinear 4D-photons, twisting in opposite directions around the $L$-axes along its curved surface. If we pump higher 4D-EM modes $k$ into the lightest—the 3D-spatially biggest, where $k = 1$—ee-spherinder, its $R_e$-radius in the confining 3D-waveguide will be smaller and smaller as $R_e/k$ and its EM-energy density will correspondingly increase.

This will create increasing EM non-linearity with a resulting abrupt bifurcation (Feigenbaum-like doubling-period in chaos theory, common in fluids and electro-generators [13, 14]). We assume, the 4D EM non-linearity will abruptly create second stable coaxial 3D-spherinder, e.g., $R_e/(k + 1)$ or smaller inside the $R_e/k$-spherinder, figure 6(c, d). The proposed coaxial double 3D-spherinder looks very much as the united proton-neutron structure, where the bigger spherinder can carry two filled massive fermionic states (two u-quarks), and the smaller can carry two slightly more massive dd-quarks. The uud-holes in this system (proton) must have electrostatic charge $Q = 1$ and slightly heavier udd-holes (neutron) must have zero charge with
resulting $Q_u = 2/3$, $Q_d = -1/3$. The filled uudd-state is massive and has electrostatic uud-d-charge. We proposed above the medial vacuum concept as the physically weightless composite superfluid, where our elementary particles (and antiparticles) are Diracian-like particles–holes in the corresponding electron–positron, proton–antiproton vacua. Notably, the proposed double-spherinder structure fully explains the quarks confinement nature, because the smaller 4D-spherinder is automatically totally confined inside the bigger one and this confinement (in our 3D-sense) is very much like if the smaller 2D-sphere is confined inside a slightly bigger one and spherical 3D-layer between them is filled with a very elastic rubber. They have almost identical masses and (almost identical) very small radii (fermionic uu- and dd-spherinders), building the proposed here 4D-proton-neutron structure—they are 3D-massive in the 3D-waveguide. This structure trivially solves the so-called mass gap problem in the 3D Yang–Mills theory, because the minimal—electron mass gap naturally arises in the 3D-waveguide.

10. The quarks-gluons confinement and asymptotic freedom nature in the PWM
Two difficult SM-problems remain the quarks confinement problem in proton (neutron) and their surprising asymptotic freedom, discovered by Gross, Wilczek and Politzer [28], because quarks in proton are free of mutual interactions if they are at the same spatial point. The 3D-waveguided physical nature of the quarks confinement and the asymptotic freedom and the related extraordinary proton stability become simultaneously clear in the proposed L-coaxial double-spherinder structure of proton, where the smaller d-spherinder is totally confined inside the bigger uu-spherinder. A thin L-coaxial 4D-bulk between these coaxial 2D-spheres expands...
Figure 7. The $LX$ cross-section of two almost coaxial proton-neutron uu- and dd-spherinders with slightly $\delta R$-shifted parallel $L$-axes is shown. This shift creates the backward (3D-membraned by the nature) QCD-strong-like force $F = -k\delta R$, always returning them into the equilibrium coaxial position, simultaneously illustrating the 3D-waveguided-membraned nature of the quarks-gluons confinement, the asymptotic freedom phenomena, disclosing unity of the strong, gravity and electrostatic forces.

SU(2) symmetry to SU(3). The Platonic 3D-shadow cross-section of this 4D-double-spherinder is our spherical 3D-layer, shaped by two concentric 2D-spheres.

This coaxial uud position is the state of stable equilibrium, where mutual uud interactions become zero. The co-axial position of two $L$-springing ud-spherinders is a point of stable equilibrium. It is easy to show that a mutual parallel shift $r$ of these $L$-axes from the coaxial state creates a centripetal—restoring springy force $f = -kr$, normal to the axes $OL$, acting on two ends of the $L_0$-spherinders, always restoring the co-axial—equilibrium position of the uu- and dd-spherinders (figure 7). Our planar 3D-cross-section of these 4D-spherinders creates two co-centric, charged-massive 2D-spheres (uu- and dd-spheres). The mentioned above strong forces keep their extremely precise co-central symmetry. The 3D-waveguided gravity, electrostatics and the confining QCD-strong forces are physically united on the 3D-membrane, because the QCD-strong forces also arise as 3D-membrane-mechanical interaction between two coaxial ud-spherinders, providing the PWM quarks common asymptotic freedom in the coaxial position (when 3D-positions of the average quarks mass centers coincide under very fast rotation). The proposed (strictly co-axial) ud-spherinders structure of proton-neutron naturally explains, why three SM-point-like elementary quarks, confined as uud- and udd-baryons, both esquire so enormously high spherical symmetry, verified in many precise experiments.

11. The spin $S = 1$ photons and spin $S = 3$ gravitons nature in the superfluid vacuum

The Maxwellian EM theory and the Einsteinian GR one are classical (pre-quantum) theories. The quantum electrodynamics (QED) established quantization of the classical EM fields in form of Einsteinian photons, and postulated existence of massive charged fermionic fields,
Figure 8. The ground—spinless state of periodically bounded fermion–antifermion spherinders in the periodic PWM vacuum is shown as a vertical spinless L-column (left side). Our visible ordinary matter photons are confined in our $W_0$ universe, adjacent—visible for us AM antiphotons are confined in the $W_{-1;1}$ antiuniverses, non-adjacent—invisible for us dark matter photons in the $W_{-2;2}$ dark matter universes, dark antiphotons in the $W_{-3;3}$ dark antimatter antiuniverses and are spin $S = 1$ $C_3$-magnons quanta (the left side); our 3D-gravitons, antigravitons and dark matter gravitons (the right side) are composite antiphoton-photon—antiphoton triplets (spin $S = 3$ of the $C_3$-magnons quanta), with the switched-off EM.

where spontaneous particle–antiparticle pairs are created from miraculous emptiness. We go further and literally invert the traditional vacuum and particles paradigm, assuming the global periodic 3D-waveguided structure is densely filled by the totally dominating but surprisingly hidden (simultaneously weightless, frictionless, charge-less, spinless) PWM vacuum medium—extraordinary robust superfluid with very high inertial mass density [8]. It recalls the hidden absolute space concept by Newton. This medium is always hidden of us (living as its bosonic quasiparticles and very rare defects—massive fermions-holes). We assume all the emergent and robust basic physical laws, etc aroused in an abrupt phase transition—starting below its critical temperature as $W_n$-layered-coupled quantum Bose–Einstein condensates (BEC). The PWM structure reminds a 4D-periodic elastic liquid 3D-mica-crystal with very thin periodically placed 2D-boundaries; the 3D-membranes mechanically act like strained 2D-boundaries between water and oil. They keep their quasi-flatness—the minimal 3D-membraned energy and strictly divide coupled fermion–antifermion pairs, living in two adjacent 3D-waveguides. The necessary weightless coupled electron–positron $e^−e^+$ double-cells have very huge electrostatic coupling energy $E_c$, needed to create decoupled electron and positron pair $E_c = 2M_eC^2$, so, these double-cells decay only at temperature about $10^{10}$ K.

Feynman and co-authors traditionally consider the GR-gravity as the universally attractive force with positive $M_{gr}$. They choose the even spin $S = 2$ for graviton, because only even spins lead to attractive forces, so that they need to consider only spins $S = 0$ and $S = 2$, and perhaps $S = 4$ if $S = 2$ fails, and there is nothing to forbid the existence of two spin $S = 1$ fields, but gravity cannot be one of them, because one consequence of the spin $S = 1$ is that likes repel, and un-likes attract. This is in fact a property of all odd-spin theories [29, p 30].

The PWM-expanded EP has the symmetric gravity and antigravity with opposite $±M_{gr}$ gravity charges and this requires the odd-spin gravitons—symmetrical composite bosons with odd spin $S = 3$ structure, where one photon is coupled to two symmetrically adjacent
Figure 9. The 3D-waveguided emergent Newtonian (OM–OM)-gravity between two fermion-holes (a); the emergent Newtonian (OM–AM)-antigravity between fermion and antifermion holes (b); the Newtonian OM–DM half-gravity between fermion and dark matter fermion holes, preventing their massive bodies conglomeration in cosmic space (c); the absence of any gravity between more L-distant SM universes in the PWM (d).

antiphotons. The proposed composite spin \( S = 3 \) graviton structure simultaneously contains the required physical properties: The same 3D light-speed \( C_{ph} = C_{gr} \); the switched off sensitivity to all ordinary matter and antimatter electrostatic charges and EM-fields; the tracing of the attractive ordinary matter gravity and repulsive antimatter antigravity; the ordinary matter and antimatter gravitons have the overlapped (OM–DM-attractive) gravity potentials (figure 8).

Figure 9 illustrates the strict correspondence between the quantum gravity (graviton-triplet description) above and the classical (also triplet) 3D-membraned gravity, arising between ordinary matter and dark matter fermion-holes, figure 9(c). More distant dark universes, like the \( W_{-3} \) and \( W_{3} \) dark antimatter anti-universes, have no any gravity interaction with our ordinary matter, because OM–DAM (classical triplets) and correspondent quantum graviton-triplets do not overlap each other, figures 8, 9(d).

Figure 10 displays the PWM system of the odd OM–DM and the even AM–DAM galaxies and antigalaxies with 3 visible for us OM (\( W_{0} \)), AM (\( W_{1} \)), and AM (\( W_{-1} \)) universes, all other more L-distant are dark and the SM-decoupled of OM. Super-massive nonsingular black holes (BH)s and white holes (WH)s are schematically shown in the galactic and antigalactic centers, where framing 3D-membranes become symmetrically L-so-pressed, adjoined and flat. Importantly, these flat spherical areas (with exactly flat gravity potentials) inside the PWM-BHs or PWM-WHs have \( L_{0}/2 \) gravity potential levels and exactly the same—Schwarzschild radii, as it is in the GR by Einstein [8]. The PWM elementary fermions are hollow—nonsingular, as it was shown below, so this obviously forbids existence of microscopic BHs, theoretically possible in the GR, because it operates with classical—point-like, singular mass particles.
Figure 10. The present, large-scale–PWM is formed of the mutually gravitationally repulsive 4D \( L \)-columns and \( L \)-anti-columns, correspondingly built of gravitationally pairwise coupled galactic clusters (even \( W_{2n} \) universes) and—antigalactic clusters (odd \( W_{2n+1} \) antiuniverses). Nonsingular black holes (BH)s and white (WH)s holes are shown in the galactic and antigalactic centers, where framing 3D-membranes become adjoined and flat. Our Milky-Way galaxy is confined in our \( W_0 \) universe, only three (transparent) universes are visible—with our OM galaxies and two AM antigalaxies. All other periodic (shadow-dark) universes and antiuniverses are SM-decoupled of our \( W_0 \) universe and dark.

12. The ST and PWM concepts comparison

The string theory (ST) had its origins in the investigation of quark confinement. It postulates mechanically vibrating elastic 1D-strings of tiny Planck length near \( 10^{-35} \) m, which are also postulated to be identical everywhere. Their mechanical vibration modes mimic (non-singular, classically quantized) elementary mass particles, instead of classical point-like (singular, non-quantized) mass particles, according prominent string-theorist Witten [30]. Unfortunately, there are some obvious problems of the ST-verification: Too tiny starting scales are experimentally unreachable (never testable too high-energy scales); too many vibrating modes (in added compactified ST space dimensions) create impenetrable forests of about \( 10^{500} \) consistent ST-vacua, figure 11(a). The most promising achievement of the ST is its quantum gravity theory (QGT), which incorporates the exactly Einsteinian GR (based on the classical empirical EP with universally attractive gravity) and the ST-QGT consequently predicts even spin \( S = 2 \) graviton. This is obviously wrong graviton spin in the PWM-QGT, because this (even) \( S = 2 \) automatically forbids the OM–AM repulsion, naturally emergent (classically predicted) in the PWM, which needs \( S = 3 \) graviton, figure 11(b). Remarkably also, the SM base of quark confinement is the non-abelian Yang–Mills theory and it is not mechanical theory—it is based on the modified Maxwellian EM versions. The proposed PWM concept has the same EM-beating heart, enriched by the emergent (3D-waveguided) quantized massive EM modes, simultaneously
Figure 11. The ST paradigm (a), is never directly testable (too small Planck length scales), has too rare predictions—inclu des the ST quantum gravity concept with (wrong in the PWM), even graviton spin \( S = 2 \); the PWM concept (b) is easily testable—has very low-energy scales (big \( L_0 \)-length scale), unites co-emergent SR, QM and gravity, etc, establishes the weightless-composite vacuum-medium concept, gives the united explanation of the DE-DM phenomena—predicts gravity charges symmetry (OM–AM antigravity), dark matter particles properties, including the composite spin \( S = 3 \) graviton.
deep Einsteinian intuition was on the right track, but the miraculous EM-mechanism of mass creation was totally hidden in frames of the global (non-segmented, as it is in the 3D-waveguide) 4D-spacetime. The EM mass nature becomes very simple and universal in the proposed PWM-expanded 4D-space, with the 3D-waveguided-geometry, where behind the abstract boundary-less 4D-spacetime arises $L_0$-segmented 4D-space. The proposed EM mass creation mechanism not only creates quantized elementary mass particles, it immediately incorporates—unites the co-emergent 3D-SR, 3D-QM and 3D-gravity, whose unity was totally hidden behind the abstract substitution of the (overlooked) physical 4D space (in the 3D-waveguide) by the global 4D-spacetime. Now the pure 4D spatially expanded 4D-arena, creating our basic 3D-physics, arises as the $L_0$-foliated Euclidean 4D-space and $Ct$ coordinate by Minkowski is correspondingly reduced to the broken—polygonal 4D-length (as the universal 3D-waveguided $C_4$-dynamical parameter). The non-linear EM creates in the 3D-waveguide massive (self-confined, hollow) relativistic $L$-axial vortexes (the Einsteinian-like clots, mentioned above), with the universal fermionic spin—the 4D-spherinders, naturally disclosing the basic SM symmetries.

A 3-brane sweeps out a $(3+1)$-dimensional volume in space-time called its worldvolume. Flat 3D-membranes look quite similar to the plane 3D-branes of the ST, but these plane 3D-objects are physically radically different, because our effective—low-energy 3D-physics (mass particles, physical laws, etc) can be physically emerged only via the 4D-bulk between two 3D-membranes and the 4D-bulk has its surely effective fundamental thickness $L_0$ about 23 orders bigger as the basic Planck length scale of the ST. The 3D-waveguided (low-energy) alternative to the 3D-brane concept shows that some basic ideas of the ST could be totally false of physical reality, like the too small Planck scales. The extremely thin single 3D-brane cannot alone contain and confine our low-energy 3D-universe. Moreover, the 3D-membranated unification of gravity, electrostatics and strong force works in the PWM only if our vacuum is the weightless—foliated cellular (spherinder–antispherinder) superfluid medium and proton-neutron consist of two coaxial 4D-spherinders.

Figure 11 shows schematically some basic differences between the ST concept (left), predicting spin $S = 2$ quantum gravity theory, but the PWM concepts (right), gives the united explanation of the DE–DM phenomena with the novel testable predictions. The basic ST string hypothesis is never directly testable, because it starts from the Planck length scale (23 orders smaller as the PWM length scale). The PWM concept predicts the classical matter and antimatter gravity charges symmetry with their mutual antigravity and corresponding unites QED with the quantum gravitodynamics (QGD), arising in the PWM—predicts the spin $S = 3$ graviton.

13. Dark matter particles creation in the antiparticles–antiparticles collisions

The proposed method involves the collision between antiparticles (positrons with positrons, antiprotons with antiprotons or positrons with antiprotons) in colliders, generating the elementary dark matter particles. Ordinary matter (electron and proton), antimatter (positron and antiproton) and dark matter (electron and proton) in the PWM are intrinsically identical and have positive inertial masses which conveniently carry their mechanical kinetic energy.

The collision energy must be enough to decouple at least one composite (coupled) atom (fermion–antifermion double-cell) in the neutral vacuum medium—create at least one symmetric pair of elementary holes (our elementary fermion and antifermion). It is obvious that in the antiparticle–antiparticle collision either a pair of holes—positron ($e^+$)-hole and electron ($e^-$)-hole, or a symmetric pair of (positron and dark matter electron) holes arise with equal probability. This needs a small kinetic impact collision energy $E > 2M_eC^2$ about 1 MeV for the (positron and dark matter electron) pair creation and $E > 2M_pC^2$ about 2000 MeV for (antiproton and dark matter proton) pair creation. We show schematically below collisions between two positrons. Manifestations of the created elementary dark matter particles could be registered by the conventional detectors of elementary charged particles (e.g., by the
Figure 12. The symmetrically arising (SM-predicted—both visible) electron–positron pair in electron–positron collisions (a); the symmetrically arising (SM-predicted—both visible) electron–positron pair in positron–positron collisions (b); the PWM-predicted— asymmetrically arising pair of (visible positron) and invisible dark matter electron in the positron–positron collisions (a*), (b*), where dark matter electron, etc remains invisible in Wilson chamber and this predicted phenomenon can be detected in colliders; mutually dark $W_{-1}$ and $W_1$ positrons have no EM-interactions (c).

The main sign of the dark matter electron appearance is the unusual—only one-sided curved track of visible antimatter positron in the (positron and dark matter electron) pair, or one-sided bubbles-train of visible antimatter antiproton in (antiproton and dark matter proton) pair. The two symmetrical conventional visible tracks of the created (electron and positron) pairs in the electron-electron collision and (proton and antiproton) pairs in the proton–proton collisions show no creation of the elementary dark matter particles. Figure 12 shows symmetrically arising OM–AM (left) and AM–DM pairs (right) in the positron–positron collisions, where dark electron remains invisible (right) and this is detectable by this asymmetry, comparably to the left cases.

The OM–DM mediating property of AM can be also used as a direct-detector of elementary dark matter particles, as it was earlier proposed by the author [17]. Its basic sensor-element consists of charged antiparticles (positrons, etc), captured in a conventional vacuumed Penning trap. The easily controllable production volume of dark matter particles in colliders can be used for calibration of these dark matter direct-detectors.
14. Conclusions

Sources of dark matter and dark energy could be coexisting standard-model SM universes, like the SM mirror-universes. The proposed novel (co-ordered) PWM concept contains the simplest periodic chain of quasi-flat 3D-waveguides–(3D-universes) $W_n$, immersed into a global Euclidean 4D-space, where the period (the 3D-waveguide thickness) $L_0$ is near 1 pm (Compton length of electron). The 3D-waveguided, Maxwellian-like 4D-electrodynamics creates co-emergent 3D-fermions—ordinary matter (OM), antimatter (AM), dark matter (DM) and dark antimatter (DAM) with the co-emergent special relativity, quantum mechanics, weak Newtonian gravity and expanded equivalence principle.

The adjacent, intrinsically identical $W_{2n}$ and $W_{2n+1}$ SM universes realize the SM coupled, emergent OM–AM universes–antiuniverses with the co-emergent CPT-like and $\pm M_{gr}$ gravity masses symmetries (with the OM–AM antigravity as the dark energy nature).

The minimally separated $W_{2n}$ and $W_{2n+2}$ SM universes are SM decoupled, dark but gravitating, disclosing the dark matter, DE–DM fine-tuning nature.

The OM–AM antigravity property requires (and for the first time allows) the consistent inverted 3D-vacuum–particle paradigm—the hidden-weightless PWM vacuum concept. This vacuum is a $^3$He-like, very dense, but gravitationally weightless and frictionless superfluid of Cooper-like (composite) bosonic pairs—(coupled fermions–antifermions)—robust atoms of our hidden medial vacuum and its emptiness is our natural illusion. Our elementary particles (as it is proposed) are very rare Diracian-like holes (the decoupled bosonic pairs) in this inertially very dense and extremely robust superfluid vacuum, which fully determines very stable physical existence—frictionless physical behavior of OM–AM–DM–DAM and bosonic force carriers (photons–antiphotons, gravitons–antigravitons, etc) in the PWM vacuum—from elementary particles to the Hubble expansion and the large-scale universe properties.

The basic physical laws, including the SR, the QM, the Newtonian gravity and fundamental $SU(3) \times SU(2) \times U(1)$ symmetry group of the SM, describing EM, electroweak and strong forces seem to be emergent low-energy phenomena in this superfluid-vacuum (like superfluidity in the liquid helium at low temperature). The 3D-membraned unification of the basic physical forces in the PWM confirms Einstein’s prophetic idea of their uniting geometrization. The SM symmetry group corresponds to the proposed hollow (nonsingular) vortex-like structures of basic elementary particles (single ee-spherinders of electron-vortex and double uudd-spherinders—quarks-spherinders—building blocks of proton and neutron complex, where the ud quarks and gluons confinement with the asymptotic freedom phenomena find simple and united explanation.

The PWM superfluid vacuum concept also explains the united massless photons and gravitons nature as the spin-waves in it, with repulsive–attractive (spin $S = 1$)-quasiparticles photons–antiphotons, as also repulsive–attractive gravitons–antigravitons—composite triplets of photons with odd spin $S = 3$ and with the resulting exactly light speed for gravitons—gravitational waves propagation that was recently experimentally verified in the observations of gravitational waves from a binary black hole merger [32].

The PWM-concept corresponds to the recently developed, totally gravitationally neutral-composite large-scale universe model, which provides the unified explanation to the miraculous cosmological DE–DM phenomena (as to the DE–DM-fine-tuning nature), observed on the large-scale universe [9–12].

The PWM-concept predicts: The (OM–AM)-antigravity [8, 33], which will be tested in the positronium gravity test [34] and in the anti-hydrogen gravity tests at CERN [35–37]; the only antimatter-particles (as the only (OM–DM)-SM-mediators in the chain of the nearest OM–AM–DM universes) can detect cosmic dark matter particles (dark matter electrons, protons, etc), that explains why so many OM-made detectors did not detected dark matter particles; the only possibility to create dark matter particles is the AM–AM collision of antiparticles with antiparticles (never done), but realizable even in low-energy colliders; the usual EM-
communication between ordinary matter and dark matter antennas could be possible but only if our ordinary matter receiver–antenna, contain EM-mediating antimatter particles, collected in a Penning trap [16–18].

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Appendix A. Abbreviations
The used in the text abbreviations are as follows: PWM—periodic waveguided multiverse; 2D—two-dimensional; 3D—three-dimensional; 4D—four-dimensional; EM—electromagnetism; CPT—charge-parity-time; YMT—Yang–Mills theory; e−e+—electron–positron; ee-spherinder—(electron–electron)-spherinder; BEC—Bose–Einstein condensates; SM—standard model; QFT—quantum field theory; GR—general relativity; EP—equivalence principle; OM—ordinary matter; AM—antimatter; DM—dark matter; DAM—dark antimatter; DE—dark energy; EMMA—electro-mechanical membrane analogy; GRAMMA—gravitomechanical membrane analogy; ST—string theory; QED—quantum electrodynamics; QCD—quantum chromodynamics; QGD—quantum gravitodynamics; SVT—superfluid vacuum theories.

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