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Gravitationally neutral dark matter–dark antimatter universe crystal with epochs of decelerated and accelerated expansion

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Abstract. A large-scale self-similar crystallized phase of finite gravitationally neutral universe (GNU)—huge GNU-ball—with spherical 2D-boundary immersed into an endless empty 3D-space is considered. The main principal assumptions of this universe model are: (1) existence of stable elementary particles–antiparticles with the opposite gravitational “charges” (M_{+gr} and M_{-gr}), which have the same positive inertial mass $M_{in} = |M_{\pm gr}| \geq 0$ and are equally presented in the universe during all universe evolution epochs; (2) the gravitational interaction between the masses of the opposite charges” is repulsive; (3) the unbroken baryon–antibaryon symmetry; (4) $M_{+gr} - M_{-gr}$ “charges” symmetry, valid for two equally presented matter–antimatter GNU-components: (a) ordinary matter (OM)–ordinary antimatter (OAM), (b) dark matter (DM)–dark antimatter (DAM). The GNU-ball is weightless crystallized dust of equally presented, mutually repulsive (OM+DM) clusters and (OAM+DAM) anticlusters. Newtonian GNU-hydrodynamics gives the observable spatial flatness and ideal Hubble flow. The GNU in the obtained large-scale self-similar crystallized phase preserves absence of the cluster–anticluster collisions and simultaneously explains the observable large-scale universe phenomena: (1) the absence of the matter–antimatter clusters annihilation, (2) the self-similar Hubble flow stability and homogeneity, (3) flatness, (4) bubble and cosmic-net structures as 3D–2D–1D decrystallization phases with decelerative ($a \leq 0$) and accelerative ($a \geq 0$) expansion epochs, (5) the dark energy (DE) phenomena with $\Lambda_{vacuum} = 0$, (6) the DE and DM fine-tuning nature and predicts (7) evaporation into isolated huge $M_{\pm gr}$ superclusters without Big Rip.

1. Introduction

The standard cosmology (SC)—the Λ -CDM-model—includes two vastly dominating, but yet unknown “invisible” gravitating components (a) attractive cold dark matter (CDM) $\simeq 28\%$, (b) repulsive dark energy (DE) $\simeq 68$ percents (the hypothetical cosmological constant $\Lambda > 0$) and our visible attractive Ordinary Matter (OM) $\simeq 4\%$ [1]. The nature of steady 3D-spatial flatness and the DE and CDM fine-tuning are unknown. The universe has some mysterious large-scale (LS) properties: the LS-homogeneity and isotropy, the LS-flatness [1] and the LS-structure of the giant “foam bubbles” with surprisingly empty voids about 10^8 light-years diameter [2], (varying of 11 to 150 Mpc) and occupying about 50 percent of its volume, “but until now, no exhaustive and fully consistent theory has been found” of the origin of the LS-foam structure [3].



The unexplained steady LS-flatness and LS-uniformity require negligible (10^{-59}) deviations from the initial universe uniformity at the Planck scales [4]. The nature of DE, driving accelerating expansion of the universe (Perlmutter *et al* 1999 [5], Riess, Schmidt, *et al* 1998 [6]), is unknown. The salvatory (but physically isolated) idea of Hyper-Inflation (HI) hypothesizes that Big Bang was started as a super-fast (superluminal) and super-large initial expansion of 3D-hypersphere (Guth 1981 [7]). The HI was proposed to solve the LS-homogeneity and the LS-flatness problems. Indeed, the whole visible universe area immediately became almost flat and almost homogeneous “speck” on it via the initial HI phase, but these SC-problems are solved at the cost of going far beyond the available cosmological scales and physical experience. Moreover, the HI says nothing about the basic DE and DM cosmological problems and some recently discovered LS-anomalies [8]. We need a holistic cosmological alternative to the SC and HI, disclosing the united physical nature of the dominating DE and DM [9], creating the basic LS-properties.

The Λ -CDM model is based on (a) the direct cosmological application of Einstein’s General Relativity (GR) [10] (where attractive gravitational mass of the universe equals the inertial (index “inert”) mass $M_{Univ.(inert)} = M_{Univ.(gr)} > 0$), including (b) the dominating attractive CDM, (c) the empirical cosmological principle (CP) and (d) the cosmological constant $\Lambda > 0$, associated with the hypothetical antigravitating DE-density of vacuum.

Encouraging holistic alternatives to the Λ -CDM and HI-cosmology are “weightless”—gravitationally neutral universe (GNU) concepts with $\Lambda = 0$: (A) the Dirac–Milne universe [11] and (B) spatially finite composite GNU-ball [12]. The Dirac–Milne GNU [11] is filled with a homogeneous mixture of equal parts of Ordinary Matter (OM) and Ordinary Antimatter (OAM) with the hypothetical mutual OM/OAM antigravity, naturally preserving their annihilation (keeping the fundamental baryon/antibaryonic symmetry). The OM/OAM antigravity idea of going back to the L. Schiff paper [13], assuming opportunity for gravitational repulsion between elementary particles and antiparticles. Importantly, the holistic GNU-concepts totally replace the HI-idea, because the gravitational neutrality simultaneously and naturally explains (a) the LS-flatness and homogeneity (as we will show below), (b) the Hubble flow, (c) the miracle DE-nature as the antigravity between equally presented particles and antiparticles (with $\Lambda = 0$). The Dirac–Milne GNU [11] (like the Λ -CDM and HI model) is based on the GR+CP and includes the paradigm of elastic (steadily expanding) space metric. The Dirac–Milne GNU [11] has some serious limits—it does not predict (a) the accelerated expansion of the universe [5,6], does not explain (b) the LS-uniformity, (c) the foam-like structure and (d) some significant LS-deviations from the CP [8]. Moreover, the model [11] includes only two equal OM/OAM fractions, but denies presence of the (vastly dominating) DM/DAM-fractions in the GNU, which must be equally incorporated into the GNU-consistent composite model [12]. The effects of DM gravity can be seen in the rotation of galaxies and gravitational lensing, etc. [9]. Notably, two opposite—equally presented composite $M_{+gr(OM+DM)} = |M_{-gr.(OAM+DAM)}|$ GNU-fractions with positive and negative “gravity charges” (and antigravity between them) and $M_{in(OM+DM)} = M_{in(OAM+DAM)} > 0$ where predicted in [14,15] and [16]. These equally presented composite GNU-fractions sufficiently enlarge and survive the DM/DAM-expanded cosmological gravitational neutrality paradigm, based on the unbroken fundamental baryon-antibaryon-like symmetry and the expanded “gravity charge” symmetry along the whole universe history. They are the basic ingredients in the GNU-ball-concept [12] and the crystallized GNU-ball model below.

Note, that the GNU hypothesis leads to generalization of the fundamental symmetry $CPT \rightarrow M_{gr}CPT$ for particles and antiparticles. In particular, the necessity of this generalization follows from [16].

2. The GNU-ball as a self-similarly expanding crystal of M_{+gr} and M_{-gr} clusters

The more general concept of the GNU-ball [12] is developed here conceptually as a giant weightless GNU-crystal, that clarifies the physical nature of (a) the self-recovering mechanism, providing LS-density uniformity and quasi-flatness of the Hubble flow in the expanding universe without the strict initial density conditions, mentioned above, (b) the LS-foamed structure creation and (c) the decelerating \rightarrow accelerating epoch transition as structural DE-manifestations during the GNU-ball expansion. Importantly, the proposed in [12] finiteness of the GNU-ball (with 2D-spherical borders), immersed into empty and endless space around it, becomes crucial for existence and deviations of the ideal Hubble flow—the decelerating \rightarrow accelerating cosmological epochs transition. The observable radial Hubble-like expansion is possible in the model under consideration only if the GNU-ball has limited radius and expands to outside empty infinite space. The weightless GNU-ball is filled with a homogeneous, crystallized gravitationally neutral mixture of the $M_{\pm gr}$ clusters with zero gravity mass density $\rho_{gr} = \rho_{gr(OM+DM)} + \rho_{gr(OAM+DAM)} = 0$ on the large scale universe and the positive inertial mass density $\rho_{inert} = \rho_{gr(OM+DM)} + |\rho_{gr(OAM+DAM)}| = 2\rho_{gr(OM+DM)} > 0$ [12, 14, 15]. On the first, approximation the weightless GNU-ball will expand quasi-inertial into the empty infinite space with the static metric and zero vacuum energy ($\Lambda = 0$). The CP in the GNU-ball model is in fact invalid, but could arise as an “illusion” (only for the quasi-centered GNU-ball observer, occasionally living in galactic clusters near the universe-ball center [12]). The GR-corrections to the weak—Newtonian gravity are very small in ordinary cosmology [17] and become even more negligible in the weightless GNU-ball [12].

The simplest hydrodynamic model of a spherically symmetric GNU-ball expansion at the request of the spatial inertial density ρ_{inert} homogeneity ($\rho_{gr} = 0$, $\rho_{inert} > 0$) on the large scale leads to a solution providing the Hubble law ($r \sim V_r t$) in the expanded distances between clusters and observed uniform radial density $\rho(r, t) \sim 1/t^3$. This solution follows from the equations of (a) continuity for the density of the number of clusters $n(r, t)$ and (b) motion for the case of spherically symmetric $M_{\pm gr}$ clusters expansion in the absence of forces

$$\frac{\partial n}{\partial t} + \frac{1}{r^2} \frac{\partial(r^2 n V_r)}{\partial r} = 0, \quad \frac{\partial V_r}{\partial t} + V_r \frac{\partial V_r}{\partial r} = 0. \quad (1)$$

Requiring the spatially uniform density (on the large scales) and setting $V_r = H(t)r$, we obtain from (1)

$$\frac{\partial n}{\partial t} + 3nH(t) = 0, \quad \frac{\partial H(t)}{\partial t} + H^2(t) = 0. \quad (2)$$

Solution of equation (2) for the originally uniformly spatially distributed matter and antimatter, expanding at time t_0 from a small sphere of an initial radius $R(t = t_0)$, has the form ($t > t_0$), corresponding the above-described

$$n(t) = \frac{3Nt_0^3}{4\pi R^3(t = t_0)t^3} = \frac{3N}{4\pi V_R^3 t^3}; \quad H(t) = \frac{1}{t}; \quad V_R = \frac{R(t = t_0)}{t_0}, \quad (3)$$

$$R(t) = R(t = t_0) \frac{t}{t_0}, \quad V_R(t) = \frac{R(t = t_0)}{t_0} = const \equiv V_R; \quad t > t_0. \quad (4)$$

Here $V_R(t)$ is the velocity of the ball boarder $R(t)$. For the velocity corresponding to the radius r we obtain the Hubble relation $V_r = r/t$.

There is interest to describe the free matter expansion under the condition of spatially homogeneous density on the kinetic level. This problem is on the stage of preliminary consideration and cannot be included in the present work.

It is clear that when applied to the problem of the gravity-neutral expanding universe the solution $H(t) = 1/t$ means that the current age of the universe $T_{\text{univ}} = 1/H(t)$ where t is the current time. Thus, this model corresponds to the Hubble law and, taking into account the measured approximate value of $H(t) = 67.8(\text{km/s})/\text{Mpc}$, provides value for the age of the universe $T_{\text{Univ.}} \simeq 14.5 \times 10^9$ years. This value can solve the age discrepancy problem in the SC. Obviously, it is necessary to explain a hidden physical mechanism, self-levering the LS universe density. Such a hidden cosmological mechanism is naturally emerged in the crystalloid GNU-ball model and is described below.

3. Boundary DE-effects of instability in $1D_{\text{GNC}}$, $2D_{\text{GNC}}$ and $3D_{\text{GNC}}$ crystals

Let us assume that $M_{\pm\text{gr}}$ clusters, mentioned above, uniformly fill the GNU-ball and (according cosmic observations [18] there is no any mutual annihilations, so, Newtonian gravitational repulsion energy $U_{\text{gr}} \sim M_{\text{gr}}^2/r > 0$ between the nearest $M_{+\text{gr}}$ and $M_{-\text{gr}}$ clusters must be much larger than their relative kinetic energy $U_{\text{gr}} \gg E_{\text{kin}} = M_{\text{inert}}V^2/2$, (we take here $r = b$, where b is an average distance between them and suppose that their relative velocity V is much smaller the velocity of light c). This condition is simultaneously the crystallization condition for the gravitationally neutral Newtonian GNU-“plasma”, similar to the crystallization condition in the electrostatic dusty plasma [19]. Galaxy clusters can be roughly considered as point-like masses, because they typically have a diameter of 2 to 10 Mpc and are relatively compact (looking point-like), comparably to typical voids diameters (of 11 to 150 Mpc) [2,3].

There are many types of instabilities in the models of gravitationally-neutral systems. We skip (for shortness) some aspects of instability, e.g., instability normal to the 1D-line or 2D-plate of GNCs, and show only the most instructive for cosmology instabilities—on the boundaries, indicating their accelerative expansion in all cases below. For example, the calculated radial outward instability forces for cosmologically very important empty spherical bubbles (voids), covered by 2D-GNC are in contrast with their relative angular stability, keeping the angular 2D-GNC-order under the simultaneous accelerative radial expansion. Below are examples of the DE_{GNC} -boundaries instability in the gravitationally neutral crystals (GNC):

(a) $1D_{\text{GNC}}-DE_{0D(\text{bound})}$ for 1D-line segment: $F(a) = F_{l(\text{repuls.})} = \sum F_{\text{xn}} = m_{\text{in}}a_x \simeq +0.8Gm^2/(bx^2) \simeq 0.8G\rho_{\text{in}}$ (outward DE-repulsion at the ends).

(b) $1D_{\text{GNC}}-DE_{1D(\text{bound})}$ for 1D-ring of radius R (masses $m_{\pm\text{gr}}$, $\rho_{l(\text{inert})} = |m_{\pm\text{gr}}|/\alpha R$): $F(b) = F_{r(\text{repuls.})} = m_{\text{inert}}a_r \simeq +1.3G|m_{\pm\text{gr}}|\rho_{l(\text{inert})}/R > 0$, (radial repulsive DE-force from the ring center).

(c) $2D_{\text{GNC}}-DE_{1D(\text{bound})}$ for flat quadratic 2D-lattice (masses $m_{\pm\text{gr}}$, side of the square b , $\rho_{2D(\text{inert})} = |m_{\pm\text{gr}}|/b^2$): $F(c) = F_{\parallel(\text{repuls.})} \simeq 0.45[Gm^2/b^2] > 0$, (outward DE-repulsion at boundaries parallel to the plane).

(d) $3D_{\text{GNC}}-DE_{2D(\text{bound})}$ obtained for cubic 3D-lattice (masses $m_{\pm\text{gr}}$, side of the cube b), $\rho_{3D(\text{inert})} = |m_{\pm\text{gr}}|/b^3$: $F(d) = F_{\perp(\text{repuls.})} \simeq 0.3Gm^2/b^2 > 0$, (outward $\perp DE_{2D\text{bound}}$ -repulsion at the 2D-border).

(e) $2D_{\text{GNC}}-DE_{2D(\text{spher.bound})}$ for 2D-lattice on a R -sphere (masses $m_{\pm\text{gr}}$, $b = \alpha R$, $\rho_{2D(\text{inert})} = |m_{\pm\text{gr}}|/\alpha^2 R^2$): $F(e) = F_{r(\text{repuls.})} \simeq 1.6Gm(m/b)/R > 0$, (radial repulsive DE-force, inflating the $2D_{\text{GNC}}$ -voids outward).

The $m_{\pm\text{gr}}$ “atoms” in a perfect cubic $3D_{\text{GNC}}$ -crystal with period $2b$ are obviously stable in local b -periodic wells of the harmonic potential (where above $\rho_{3D\text{gr.}} = 0$, $\rho_{3D(\text{inert})} = m/b^3 > 0$) and homogeneity of the crystal density will be self-leveled. Only $m_{\pm\text{gr}}$ particles on the 2D-border of the $3D_{\text{GNC}}$ -crystal will be unstable and will be intended to “condense” [15,16] with their $m_{\pm\text{gr}}$ neighbors into a bigger surface masses $nm_{\pm\text{gr}}$. Let us now imagine a spherical 2D-bubble, aroused (via masses $m_{\pm\text{gr}} \rightarrow \pm nm$ condensations) in the regular cubic $3D_{\text{GNC}}$ -crystal with masses ($m_{\pm\text{gr}}$ and period $2b$), and now the R-sphere of the bubble is covered by a quasi-

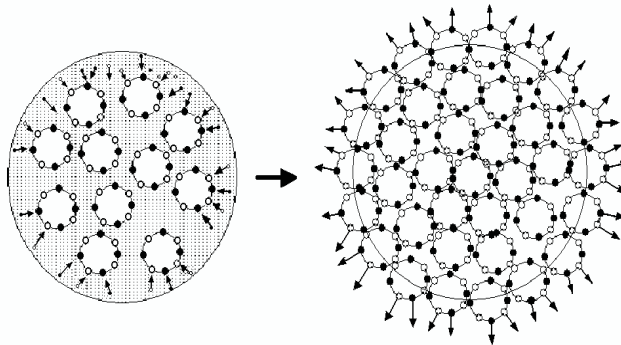


Figure 1. The decelerated Epoch I (left) and the accelerated Epoch II (right).

quadratic $2D_{\text{GNC}}$ -crystal with masses $nm_{\pm gr}$ with the same period $2b$. This R -bubble starts to grow and expand inside the $3D_{\text{GNC}}$ -crystal if the radial outward force $F(e)$ becomes bigger as the opposite proximal force $F(d)$, i.e., $F(e) > F(d)$:

$$1.6Gnm(nm/b)/R > 0.3Gm^2/b^2 \rightarrow 1.6n^2 > 0.3R/b. \quad (5)$$

If all entire masses $m_{\pm gr}$ of this $3D$ -crystal (filling the R -ball with volume $4\pi R^3/3$) are condensed on the R -bubble surface $4\pi R^2$ into the $2D$ -crystal with masses $nm_{\pm gr}$ and the same period $2b$, this creates

$$nm4\pi R^2/b^2 = m(4/3)\pi R^3/b^3 \rightarrow n = R/3b. \quad (6)$$

Using (6) in (5) we obtain

$$1.6n^2 > 0.3R/b \rightarrow R > 2b \quad (7)$$

as a rough condition for the R -bubble expansion, predetermining inevitable formation of a hollow, growing $2D_{\text{GNC}}$ -bubbles inside the $3D_{\text{GNC}}$ crystal, whose embryos will arise everywhere from density fluctuations (Figure 1, left). This means inevitable nonstop process of $3D_{\text{GNC}} \rightarrow 2D_{\text{GNC}}$ phase transition into a totally foamed $2D_{\text{GNC}}$ structure, which we observe now (figure 1, right). So, $F(e) = F_{DE(\text{void})} \sim 1/R_{\text{void}}$ decreases with the growth of cosmic voids in the totally foamed universe. This discloses the self-leveling (density and R_{void}) mechanism in the totally foamed phase of the GNU-ball -the cosmic foam is mechanically self-balanced via the process of a self-similar quasi-uniform (Hubble) expansion. The angular $2D_{\text{GNC}}$ -void self-stability levers average $2D$ -density on the voids surfaces. But voids on the GNU-ball boundary ($r \sim R_{U\text{niv.}}$) will be instable, with accelerated radial expansion into an empty space around the GNU-ball (figure 1, right).

4. The decelerated and accelerated epochs nature of the universe expansion

The previous decelerated Epoch I is connected with the process of sporadic creation and accelerated grow of plenty isolated bubbles inside the self-similarly and self-homogeneously expanding $3D_{\text{GNC}}$ -universe system. These growing bubble surfaces literally condensed and sucked “inside”, as “vacuum cleaners” the low dense $3D_{\text{GNC}}$ -body, slightly retarding the total self-similar GNC-ball expansion (figure 1, left, $a_{U\text{niv.}} < 0$, the Epoch I). But the complete foaming created the transition from the Epoch I to the Epoch II (figure 1, right, $a_{U\text{niv.}} > 0$), where “vacuum cleaners” finished the $3D$ -GNC-phase and started the uncompensated accelerated expansion of the universe-ball near the ball boundary with obvious instability-penetration inside the universe-ball.

5. Internal potential own-energy of the cubic and quadratic GNC-“modules”

We roughly associate (repulsive $\rho_{U_{gr+}}^{\text{GNC}} \simeq U_{gr+}^{\text{mod}}$) and (attractive $\rho_{U_{gr-}}^{\text{GNC}} \simeq U_{gr-}^{\text{mod}}$) gravity energies densities in the GNC-universe with full own positive and negative gravitational energies U_{gr+}^{mod} and U_{gr-}^{mod} , accumulated in a single (minimal with $\sum m_{\text{gr}} = 0$) cubic or quadratic modules of the Newtonian GNU-crystals, (see equations (8), (10) below). For example, the isolated quadratic module ($m; b$) contains four equal $m_{\pm\text{gr}}$ point masses (clusters) with the repulsive part $U_{\text{quadr.gr+}} = +4Gm^2/b > 0$ and the attractive part $U_{\text{quadr.gr-}} = -2Gm^2/(b\sqrt{2}) < 0$, (where G is Newtonian gravity constant), the module has $\sum m_{\text{gr}} = 2m_{\text{gr}} - 2m_{\text{gr}} = 0$ and $\rho_{\text{inert}} = m_{\text{inert}}/b^2 = m/b^2 > 0$ for a corresponding $2D_{\text{GNU}}$ -crystal [14]. The resulted ratio (10) of the repulsive and attractive potential gravity energy parts for the quadratic module does not depend of b .

The ratio $K_{\text{GNC}(cub)}^{3D}$ of its own internal gravitational DE-like repulsive energy $U_{\text{rep.gr}}^{3D}$ to the attractive energy $U_{\text{attr.gr}}^{3D}$ also does not depend on b and its numerical ratio $K_{\text{GNC}(cub)}^{3D}$ equals

$$K_{\text{GNC}(cub)}^{3D} = \frac{U_{\text{rep.gr}}^{3D}}{|U_{\text{attr.gr}}^{3D}|} \simeq \frac{62_{\text{rep.gr.}(percent)}}{38_{\text{attr.gr.}(percent)}} > 1. \quad (8)$$

$K_{\text{GNC}(cub)}^{3D} > 1$ predetermines future decrystallization—“evaporation” with the accelerative boundaries expansion of the gravitational “Newtonian $3D_{\text{GNC}}$ ”, described above. On the contrary, a similar Electrostatically Neutral Crystal (ENC) (cubic “module” from 8 Coulomb charges $\pm q$) will be self-compressed, providing the ENC stability, because

$$K_{\text{ENC}(cub)}^{3D} = \frac{U_{\text{rep.el}}^{3D}}{|U_{\text{attr.el}}^{3D}|} = \frac{1}{K_{\text{GNC}(cub)}^{3D}} \simeq \frac{38_{\text{rep.gr.}(percent)}}{62_{\text{attr.gr.}(percent)}} < 1. \quad (9)$$

A quadratic “module” of the $2D_{\text{GNC}}$ -crystal (4 masses $m_{\pm\text{gr}}$ with $\sum m_{\text{gr}} = 0$) has $K_{\text{GNC}(quadr)}^{2D}$ of its internal DE-repulsive gravity energy to the attractive gravity energy [14]:

$$|K_{\text{GNC}(quadr)}^{2D}| = \frac{U_{\text{rep.gr}}^{2D}}{|U_{\text{attr.gr}}^{2D}|} = \frac{4}{\sqrt{2}} \simeq \frac{74_{\text{rep.gr.}(percent)}}{26_{\text{attr.gr.}(percent)}} \quad (10)$$

and corresponds to the present foamed Epoch II, which coincides with the not so spatially deep WMAP data (2008) [20] for a relatively later—foamed Epoch II. Indeed, $K_{\text{GNC}(quadr)}^{2D} \simeq K_{\text{WMAP}} \simeq 2.83$, where

$$K_{\text{WMAP}} = \frac{\rho_{\text{DE}}}{\rho_{\text{DM}} + \rho_{\text{OM}}} \quad (11)$$

More deep cosmos—Planck (2013) gives $K_{\text{Planck-exp.}} = \frac{\rho_{\text{DE}}}{\rho_{\text{DM}} + \rho_{\text{OM}}} \simeq \frac{68_{\text{rep.gr.}(percent)}}{32_{\text{attr.gr.}(percent)}} [1]$ (as a mixture of two Epochs I + II). Taking the average value of $K_{\text{GNC}(quadr)}^{2D}$ and $K_{\text{GNC}(cub)}^{3D}$, we get

$$\frac{K^{3D} + K^{2D}}{2} = \frac{(74 + 62)/2}{(26 + 38)/2} \simeq \frac{68_{(percent)}}{32_{(percent)}} \simeq K_{\text{Planck}} = \frac{\rho_{\text{DE}}}{\rho_{\text{DM}} + \rho_{\text{OM}}}, \quad (12)$$

coinciding well with the $K_{\text{Planck-exp.}}$, roughly covering the impact of two cosmic Epochs I + II: (I) The earlier cosmological Epoch I of the decelerated self-similar expansion; (II) The contemporary—totally foamed cosmological Epoch II of the smooth self-similar accelerated expansion, with the maximal acceleration closer to the universe-ball boundary. We note, that the GNC-universe is uniform and weightless on scales $R \gg b$ (where $b \simeq 2Mpc$ [12, 21]).

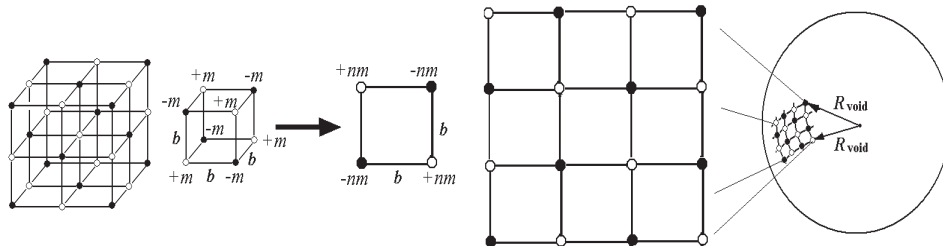


Figure 2. The early $3D_{\text{GNC}}$ -universe (left from the arrow) and Contemporary $2D_{\text{GNC}}$ -foamed universe (right from the arrow).

6. 3D-Euclidity of the GNU-crystal (contrary to the Dirac–Milne universe)

The observed large-scale Euclidean—flat space geometry demands the miracle critical energy density condition $\rho_{crit.} = \rho_{vac.crit.}^{rep.} + (\rho_{DM} + \rho_{OM})^{attr.} = (\Lambda_{crit.}/8\pi G) + \rho_{DM} + \rho_{OM}$ in the Λ -CDM—Friedmann equation [1], [20] (here we put the velocity of light $c=1$). The very small positive-repulsive $\Lambda_{crit.} > 0$ in the Λ -CDM-universe contains surprisingly dominating $\simeq 70$ percent of the total energy density $\rho_{crit.}$, where the astrophysically measured part of matter energy density, $(\rho_{DM} + \rho_{OM})^{attr.} > 0$, including DM and OM, creates modest $\simeq 30$ percent in the total energy density $\rho_{crit.}$ [1]. The Friedmann-like equation could be derived classically for weak Newtonian gravity and antigravity also for the single GNU-ball (with center O and radial symmetry), but it will be valid only for the central spherical coordinate system in the GNU-ball. The energy densities ratios coincidences (10) and (12) show that the necessary hypothetical $\Lambda_{crit.} > 0$ could be physically naturally exchanged by the positive—repulsive gravity energy density $\rho_{U_{gr+}}^{\text{GNC}} > 0$ (the matter/antimatter antigravity) in the crystalloid GNU-ball (with $\Lambda = 0$). The repulsive gravity energy density $\rho_{U_{gr+}}^{\text{GNC}} \sim 1/b$, and it is roughly the same everywhere inside the homogeneous GNC-ball, but it slows down with the time t , because b quasi-linearly increases as $b(t) \sim t$, contrary to the $\Lambda_{crit.}(t) = const.$ in the Λ -CDM-universe. Notably, the GNU-ball model is resulted from the expanded unbroken baryon/antibaryon-like OM/OAM and DM/DAM symmetries with the correspondingly added gravity “charges” symmetries, mentioned above.

Importantly, here we obtain physically transparent explanation to the resulting steady DE and DM fine-tuning and the exactly Euclidean steady large-scale geometry, reformulating the critical energy density condition $\rho_{crit.} = \rho_{\Lambda_{crit.}}^{rep.} + \rho_{DM+OM}$. We must connect the experimentally measurable (the large-scale) energy density $\rho_{(DM+OM)}$ in [1,20] with the corresponding gravity energy density in the GNU-crystal. Notably, the equation $K_{\text{Planck}} = \rho_{\Lambda_{DE}}^{\text{Planck}} / \rho_{DM+OM}^{\text{Planck}}$ implicitly contains the same energy density $\rho_{(DM+OM)inert}^{\text{Planck}}$, equally presented in the Λ -CDM and in the 3D-GNU-crystal. Indeed, we simultaneously observe and simultaneously consider the visible matter (DM+OM) clusters, using the visible OM-markers and the antimatter (DAM+OAM) anticlusters, using the also visible OAM-markers. Therefore, the Planck inertial mass density $\rho_{(DM+OM)inert}^{\text{Planck}}$ is the sum:

$$\rho_{(DM+OM)inert}^{\text{Planck}} = \rho_{(DM+OM)inert}^{\text{GNC}} + \rho_{(DAM+OAM)inert}^{\text{GNC}} = 2\rho_{(DM+OM)inert}^{\text{GNC}}. \quad (13)$$

Therefore, the amount of the “critical energy density” $\rho_{crit.}^{\text{Planck}} = \rho_{\Lambda_{crit.}}^{rep.} + \rho_{DM+OM}^{\text{Planck}}$, generating Euclidean geometry with $k = 0$ in the Friedmann equations, contains the same energy density $\rho_{DM+OM}^{\text{Planck}}$ as existing in the GNU-crystal. Notably, the total positive repulsive gravity energy density $\rho_{U_{gr+}}^{\text{GNU}} > 0$ in the GNU-crystal perfectly replaces the positive—repulsive vacuum energy density $\rho_{\Lambda_{crit.}}^{rep.} > 0$ ($\simeq 70$ percents), presented in equation $\rho_{crit.}^{\text{Planck}} = \rho_{\Lambda_{crit.}}^{rep.} + \rho_{DM+OM}^{\text{Planck}}$. This

approximate conformity comes from the ratios (10), (12) and $\rho_{\Lambda_{crit.}}/\rho_{DM+OM}^{exp.}$ in [1, 20]. For example, the approximate coincidence

$$\rho_{\Lambda_{crit.}}/\rho_{DM+OM}^{WMAP} \simeq \rho_{U_{gr+}}^{2D-GNC} / |\rho_{U_{gr-}}^{2D-GNC}| = \frac{4}{\sqrt{2}} \simeq \frac{74}{26} \quad (14)$$

is connected with $K^{2D} \simeq \frac{74}{26}$ valid for the foamed 2D-GNU-crystal phase and $K^{3D} \simeq \frac{62}{38}$ is valid for the 3D-GNC. The average ratio $(K^{3D} + K^{2D})/2 \simeq 68/32$ from (12) corresponds to K_{Planck} :

$$\frac{K^{3D} + K^{2D}}{2} = \frac{\rho_{U_{gr+}}^{2D+3D}}{|\rho_{U_{gr-}}^{2D+3D}|} \simeq K_{Planck} = \frac{\rho_{\Lambda_{crit.}}^{Planck}}{\rho_{DM+OM}^{Planck}}. \quad (15)$$

The ratio (12) $\rho_{\Lambda_{crit.}}^{WMAP}/\rho_{DM+OM}^{WMAP} \simeq K^{2D}$ corresponds well to the necessary critical energy density $\rho_{\Lambda_{crit.}}^{WMAP}$ [20], related to the foamed 2D-GNU-crystal phase. The ratio (12) $\rho_{\Lambda_{crit.}}^{Planck}/\rho_{DM+OM}^{Planck} \simeq K^{(2D+3D)/2} \simeq 68/32$ corresponds well to the mixed [(2D+3D)/2]-GNU-crystalline phases. Roughly, the same ratios physically directly follows from the gravitational neutrality condition $\rho_{gr} = 0$ in the GNU-crystal and from the resulting positive (repulsive) $\rho_{U_{gr+}}^{GNC}$ and negative $\rho_{U_{gr-}}^{GNC}$ gravity energy densities, which are both non-zero and are presented in the definite proportion in the GNU-crystal $\rho_{U_{gr+}}^{GNC}/|\rho_{U_{gr-}}^{GNC}| \simeq 70/30 \simeq 2$. We note, the used own energy density ratios $K_{GNC(quadr)}^{2D}$ and $K_{GNC(cub)}^{3D}$ correspond very well to the positive and negative energy density ratios in the corresponding crystals—these approximate ratios are robust to the way of their account.

So, it is mistakenly insert $\rho_{gr} = 0$ in the Friedmann-like equation, simultaneously using $\Lambda = 0$ (as it was done in [11]). Indeed, this dramatically reduces the GNU with non-zero $\rho_{inert} = m/b^3 > 0$ to the totally matter-free Dirac–Milne universe [11], etc. with the loosed $\rho_{U_{gr+}}^{GNC}$ and the resulting wrong 4D-flat Minkowski’s space-time metric and hyperbolic 3D-space section [11] (instead of the flat—Euclidean space in the observations [1,20] and in the investigated GNU-crystal). The GR was historically formulated only for matter—for positive gravity “charges” (via the basic Equivalence Principle with resulting equality between energy-mass-gravity ($E = M_{inert} = M_{gr}$)). The expanded GR^{GNU} in the large-scale GNU-system must take in consideration equally presented matter (OM+DM) and antimatter (OAM+DAM) clusters with opposite gravity “charges” and the resulting non-equal attractive/repulsive gravity energy densities with $K^{2D} \simeq K^{3D} \simeq 2$, which form together the resulting steady quasi-Euclidean space geometry with the obviously steady DE and DM fine-tuning and the inevitable decrystallization creating the decelerated and accelerated [5,6] expansion Epochs. The described hypothesis about the GNC-approach discloses the transparent physical nature of the so called “negative” pressure, traditionally associated with the non-zero vacuum energy density $\rho = \Lambda_{crit.}/8\pi G$, corresponding in the GNC-universe-ball to the slightly reformulated precious Einsteinian prevision of the antigravity—intuitive insertion of the Λ -term in his GR-cosmological concept 100 years ago [10].

7. The self-levered homogeneity in the Newtonian GNU-crystal

A self-levering mechanism, keeping the “frozen” GNU-crystal homogeneity (enough deeply inside the GNU-ball), is illustrated for one-dimensional crystalloid case (see figure 3 above). A local, slightly denser area (in the middle of the line *aa*) will push the less dense surrounding area on its boundaries, till it will rich the same average density (the line *bb*). It is an illustration of the self-levering mechanism in the GNU-crystal.

A similar, but too simplified crystalloid GNC-universe approach has been considered by Villata [22]. In [22] the accelerative expansion epoch is considered, but the previous decelerative epoch, mentioned above, is absent.

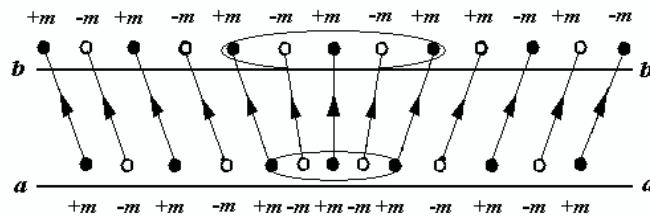


Figure 3. Illustration of the self-leveling density mechanism in the GNU-crystal (1D-case).

Importantly, the [22] approach ignores, like the [11] does, the fundamentally dominating DM /DAM presence in the GNC-model: “there seems to be no need for mysterious matter in addition to the well-known baryonic matter to explain the phenomena for which dark matter is usually invoked”. In [22] an asymmetric local crystalline structure is proposed. This proposal is based on antimatter location in voids, believing that antimatter is invisible and “an antimatter mass concentrated close to the assumed void center” [23]. Contrary to [22] and [23], the composite (OM+DM) clusters and (OAM+DAM) anticlusters both optically visible in the considered GNC-universe, and are symmetrically—regularly distributed together along the void’s surfaces, as 2D-crystalloid structure, where the devastated voids inside are almost empty (see figure 1 above).

8. Conclusion

The proposed cosmological model of the (quasi-Newtonian) Gravitational Neutral Crystalloid (GNC)-universe-ball shows the sufficiently new crystal-like state, partly close to the common Coulomb crystals. Indeed, the Newtonian GNCs and the ENC-Coulomb crystals have similar ordering mechanisms, keeping regularity, stability and leveling spatial homogeneity (via mutual gravitational repulsion ($U_{rep.gr} \sim 1/r > 0$) of M_{+gr} and M_{-gr} clusters, like the mutual electrostatic repulsion ($U_{rep.el} \sim 1/r > 0$) of electrostatic charges. However, the evolution of the expanded and cooled GNC-universe (contrary to the conventional crystallization process with growing dimensionality order in the Coulomb-ENC: 0D-1D-2D-3D), is the opposite “decrySTALLIZATION” into the observed bubble-structure and filamentary cosmic net—the progressive dimensional GNC-“evaporation” 3D-2D-1D—0D stages plus condensation [16] into a more super-heavy GNC-“atoms” (M_{+gr} and M_{-gr} clusters). The GNC-universe-ball model gives the united physical explanation of the observed steady Euclidean geometry inside the GNU-ball with the correspondingly steady DE and DM fine-tuning, the homogeneous and the self-similar (Hubble-like) expansion on the large-scale universe. It shows (a) the hidden GNC-foaming mechanism (b) discloses the basic physical nature of DE-manifestations, including the Hubble-Epoch I \rightarrow the Hubble-Epoch II—3D \rightarrow 2D transition, observationally approximately 5 billion years ago. Endlessly growing GNC-distances (period $2b$) between M_{+gr} and M_{-gr} clusters in space with zero vacuum energy ($\Lambda = 0$) [12], (contrary to the dramatic spatial metric expansion in the Λ -CDM-cosmology), will create lonely superclusters (evaporated “super-atoms” of the GNC-universe-ball), where $U_{rep.gr} \rightarrow 0$, $a_{Univ.} \rightarrow 0$. Indeed, the “cosmic acceleration may have already peaked and that we are currently witnessing its slowing down” [24]. This expects an overlong “thermal life” of these lonely $M_{\pm gr}$, superclusters with more and more heavy M_{+gr}^{BH} Black Holes (BHs), attracting matter and repealing antimatter within M_{+gr} superclusters and M_{-gr}^{WH} White Holes (WHs), attracting antimatter and repealing matter within M_{-gr} superclusters [14]. These evaporation/condensation processes assume conservation the general laws of physics—without destroying the superclusters in a “Big Rip”. The GNU-crystal concept gives the united explanation of the basic LS-cosmological DE and DM etc. phenomena without the hyperinflation and with zero vacuum energy density. The future antihydrogen

gravity test, crucial for verification of the GNC-universe concept described above, will be realized very soon (2016–2017) at CERN [25–27].

9. Abbreviations

The used in the text abbreviations are as follows: SC—standard cosmology; Λ -CDM— Λ -cold dark matter; GR—general relativity; CP—cosmological principle; OM—ordinary matter; OAM—ordinary antimatter; DM—dark matter; DAM—dark antimatter; DE—dark energy; LS—large-scale; HI—hyper-inflation; GNU—gravitationally neutral universe; GNC—gravitationally neutral crystal; ENC—electrostatically neutral crystal; WMAP—Wilkinson microwave anisotropy probe.

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References

- [1] Ade P A R *et al* 2013 Planck 2013 results. XVI. Cosmological parameters *Preprint* arXiv:1303.5076v3
- [2] El-Ad H and Piran T 1997 *Astrophys. J.* **491** 421
- [3] Capozziello S *et al* 2004 *Astron. Astrophys.* **420** 847
- [4] Grupen C 2005 *Astroparticle physics* The International Series of Monographs on Physics (Berlin: Springer)
- [5] Perlmutter S *et al* 1999 *Astrophys. J.* **517** 565
- [6] Riess A G *et al* 1998 *Astron. J.* **116** 1009
- [7] Guth A 1981 *Phys. Rev. D* **23** 347
- [8] Perivolaropoulos L 2014 *Galaxies* **2** 22–61 (*Preprint* arXiv:1401.5044v1)
- [9] Einasto J 2013 Dark matter *Preprint* astro-ph.CO /arXiv:1308.2534 v1
- [10] Einstein A 1917 *Preussische Akademie der Wissenschaften, Sitzungsberichte* **8** 142
- [11] Benoit-Levy A and Chardin A 2012 *Astron. Astrophys.* **537** 1
- [12] Trigger S A, Gribov I A and Rukhadze A A 2015 *Engineering Physics* **9** 22
- [13] Shiff L I 1958 *Phys. Rev. Lett.* **1** 254
- [14] Gribov I A 2013 From the waveguided gravity to the periodic waveguided Multiverse as united solution of DE, DM and SUSY-mysteries *Preprint* viXra:1304.0135v1
- [15] Gribov I A and Trigger S A 2014 Jeans instability and anti-screening in gravitational-antigravitational model of universe *Preprint* arXiv:1404.7122v1
- [16] Trigger S A and Gribov I A 2015 *J. Phys.: Conf. Ser.* **653** 012121
- [17] Alfvén H 1984 *J. Astrophys. Astr.* **5** 79
- [18] Cohen A G, Rujula A D and Glashow S L 1998 *Astrophys. J.* **495** 549
- [19] Fortov V E, Iakubov I T and Khrapak A G 2006 *Physics of Strongly Coupled Plasma* (Oxford Science Publication)
- [20] Hinshaw G *et al* 2008 Five-year Wilkinson microwave anisotropy probe (WMAP1) observations: Data processing, sky maps, and basic results *Preprint* arXiv:0803.0732v2
- [21] Chernin A D *et al* 2009 Dark energy and the mass of the local group *Preprint* arXiv:0902.3871v1
- [22] Villata M 2013 On the nature of dark energy: the lattice universe *Preprint* arXiv:1302.3515v1
- [23] Villata M 2012 Dark energy in the local void *Preprint* arXiv:1201.3810v1
- [24] Shaeeloo A, Sahni V and Starobinsky A A 2009 *Phys. Rev. D* **80** 101301
- [25] Andersen G B *et al* 2011 *Nat. Phys.* **7** 55
- [26] Aghion S *et al* 2013 (AEGIS Collaboration) Prospects for measuring the gravitational free-fall of antihydrogen with emulsion detectors five-year Wilkinson microwave anisotropy probe (WMAP1) observations: Data processing, sky maps, and basic results *Preprint* arXiv:1306.5602v1
- [27] Chardin G *et al* 2011 Proposal to measure the gravitational behaviour of antihydrogen at rest GBAR *Preprint* CERN-SPSC-2011-029/SPSC-P-342