A Scenario for Asymmetric Genesis of Matter

Risto Raitio*
02230 Espoo, Finland

May 5, 2023

First complete version April 2020

Abstract

A previous preon scenario for the standard model particles, based on unbroken supersymmetry, is applied to the problem of matter-antimatter asymmetry. Attention is paid to the fact that the asymmetric hydrogen atom - like all atoms - can be described in terms of *symmetric* preons. Preons are created in the early universe. The matter-antimatter asymmetry is caused by stochastic correlations in charge density fluctuations of preons and antipreons and by the subsequent preon combinatorial mechanism to form quarks and leptons, and finally the three lightest elements. A tentative gravitino mass estimate is given based on minimal interference with nucleosynthesis. With local supersymmetry the scenario can be extended to supergravity.

Keywords: Standard Model and Beyond, Preons, Supergravity, Inflation, Baryon and Lepton Genesis, General Relativity

Journal ref: Journal of High Energy Physics, Gravitation and Cosmology, 9, 654-665 (2023).
DOI: 10.4236/jhepgc.2023.93053.

*E-mail: risto.raitio@gmail.com

Contents

1 Introduction

1.1 Physical Motivation

The structure of the atom was discovered about 110 years ago in a tabletop experiment. The atomic nucleus was found to consist of protons and neutrons, which in turn are formed of quarks. Pointlike quarks were discovered about 50 years ago in the two mile long linear accelerator experiment. There is no logical reason why there should not be a next layer in the structure of matter below quarks and leptons. But energies needed for such explorations are beyond the reach of present technology, let alone economics. The current highest energy accelerator, the Large Hadron Collider, is 27 kilometers in circumference, and it has confirmed the standard model (SM) of elementary particles to high accuracy. Measurements at substantially higher energies are expected only in the late 2030's from space based detectors measuring gravitational waves from the remote past.

Therefore, we have to make Gedanken experiments in search of a next structural level, i.e. beyond the standard model of particles, to see if we can find by logical analysis something interesting. Any results must be compatible with the standard models of particles and cosmology in their regions of validity. Fortunately, astronomical observations have each decade become more abundant and accurate. An old but unsolved problem is that the universe consists of matter without antimatter to an accuracy of 10^{-10}, which is the subject in this note.

Within the SM, the first element, hydrogen H, consists of an electron and three quarks, two u quarks of charge $\frac{2}{3}$, and a d quark of charge $-\frac{1}{3}$. Now we make the thought experiment in our imagination. Suppose that each quark consists of three subquarks. The basic charges are then 0 and $\frac{1}{3}$. The resulting scenario has been proposed in [1, 2]. This next level model supposes that both the electron and the quarks consist of three constituents, called superons (preons), denoted by m. The name is due their property of (unbroken) supersymmetry, which is not a property of the basic SM. The spin of superons is $\frac{1}{2}$, just like for quarks and electrons. The masses of superons are of the same order of magnitude as those of first generation quarks and leptons.

In terms of superons, the electron consists of three superons of charge $-\frac{1}{3}$ yielding spin $\frac{1}{2}$ and charge -1. The u-quark consists of two charge $\frac{1}{3}$ superons and a charge 0 superon. The d-quark includes one charge $-\frac{1}{3}$ antisuperon and two neutral superons. Therefore we can represent the hydrogon atom as the following collection of particles

$$\begin{aligned} H:\ p^{+} + e^{-} &= u^{2/3} + u^{2/3} + d^{-1/3} + e^{-} \\ &= \sum_{l=1}^{4} \left[m_l^{+} + m_l^{-} + m_l^{0} \right] \end{aligned} \tag{1.1}$$

where the superscript is the charge of the particle and $\pm$ indicates charge ± 1.

The simple and surprising message from (1.1) is that on the first line the hydrogen consists (asymmetrically) of matter particles, the electron and the quarks, but the second line is matter-antimatter *symmetric*. Thus, the matter-antimatter asymmetric universe can be represented as a collection matter-antimatter symmetric constituents. How is that possible? The answer proposed here is that the superons are the true fundamental particles of nature. We try to comply to quantum gravity where no global symmetries are allowed. Superons unify baryons and leptons but at the same time eliminate the need for corresponding a priori quantum numbers.

1.2 Preon Physics

In fundamental physics, when one goes towards smaller length scales beyond, say 10^{-18} m, the symmetries describing physics may change. The hadron symmetries of the standard model need not be as relevant as before. Elsewhere, at early times of the universe, the physics of inflation and matter-antimatter asymmetry remain to be discovered. Rather than postulating new particles or larger internal symmetries to solve these problems, a theory of different, smaller symmetry may provide solutions, as we propose here.

The original version [1] of this scenario was proposed for substructure of the standard model particles. The scenario was modified later using the same fields with spin $\frac{1}{2}$ and charge $\frac{1}{3}$ but with light, or zero mass [2]. Here we investigate how the matter-antimatter asymmetric universe can be created within this scenario.

The preon model of Finkelstein [3, 4], as well as ours, has been extended to possess a topological symmetry property of the quantum group SLq(2), which provides consistent representations for quarks, leptons *and* preons. Both scenarios agree with the standard model group structure.[1] Only very recently, we realized that the original scenario [1] obeyed unbroken global supersymmetry [2, 5] without the superpartner problem. This is satisfying because present experimental evidence indicates that standard model superpartners may not exist.

The possibility of matter-antimatter asymmetry in the superon model was mentioned in [2] but without any further reasons. We attempt to fix this shortage in this note. The inflationary model of cosmology is treated in terms of superons. The superpartner of the spin $\pm\frac{1}{2}$ component of the gravitino is the inflaton with a simple harmonic potential. The more realistic case of inflaton as classical Bose condensate is mentioned. The matter forming superons are generated from vacuum during (i) early inflation or (ii) reheating. It is assumed that positive and negative charge superons are distributed equally smoothly in space. If an electron is formed from a stochastic density fluctuation of three negative charge superons it leaves subtly nearby an excess of positive charge superons for quarks to form yielding later protons. If a positron is formed it correlates with antiquarks nearby making antiprotons. The asymmetry is obtained by this process of superons forming proton and electron rich regions throughout space which only slightly dominate over corresponding antiparticle regions in the universe. In case (i) matter particles are produced directly. Annihilations of particles and antiparticles in case (ii) gradually lead to the asymmetry. Furthermore, superons provide a novel unified picture of quarks and leptons, different from traditional grand unified theories.

The major challenge in the scenario, superon confinement inside quarks and leptons, is at the moment without solution. However, this is no more mere speculation as in [1].[2] Namely the superon scenario can be self-consistently reinforced by replacing global supersymmetry with local supersymmetry to obtain supergravity [9] as a framework for model development. From supergravity, it is hoped by many, one may ultimately go towards a UV finite, consistent theory of quantum gravity within superstring or M-theory [10].

The model is based on supersymmetry and Poincaré invariance on the fundamental level. The gauge groups in the model are Abelian. Consequently, this approach has simpler vacuum and it is more constrained than the standard grand unified or superstring theory. The validity of the scheme can be analyzed by phenomenological analyses, as is done below in sections 4 and 5, and by constructing realistic models for supergravity. Explicit models are beyond the

[1]Harari [6] and Shupe [7] have also proposed preon models of this type. All of four models are physically equivalent with each other and the standard model but their preon internal symmetries are different from ours.

[2]For the present we can assume a deep potential well type of interaction for superons to keep them inside a quark or lepton in spite of the Coulomb repulsion between like charge superons. A scalar interaction may be needed to overrule the Weak Gravity Conjecture [8]. Ultimately a theory of quantum gravity is needed. Recall that the quark model was very successful in the 1960's before the introduction of chromodynamics.

scope of this note.

The article is organized as follows. Section 2 is a brief recap of the framework for developing models on the basis of the superon scenario. In section 3 a brief description is given of how superon cosmology differs from the cosmological standard model. In section 4 the main result of this note, a solution to baryon and lepton asymmetric genesis is proposed. Some speculations and proposals are made in section 5 on how a correlation region may expand to the size of the universe, or alternatively the correlation regions may lead to point-like quark and lepton formation. Conclusions and possibilities of relevant experimental measurements at the LISA space detector are given in section 6. This note should be considered a first step *concept* analysis necessary for going beyond the long time esteemed standard model.

2 The Setup

We briefly recap the superon scenario of [1, 2, 5] in the N=1 supersymmetric model. There is the familiar field photon γ and its neutral spin $\frac{1}{2}$ superpartner, the photino $\tilde{\gamma}$, denoted in [2] as $\tilde{m}^0$. They form the vector supermultiplet. The $\tilde{m}^0$ is a Majorana fermion.

The second supermultiplet, the chiral multiplet, consists of the spin $\frac{1}{2}$ fermion m^+ and two scalar superpartners $\tilde{s}^+_{1,2}$ [1, 2]. The roles of the scalars is not discussed here. The free massless Lagrangian for the chiral multiplet is of the form [5, 10]

$$\mathcal{L} = -\frac{1}{2}\bar{m}^+\not{\partial} m^+ - \frac{1}{2}(\partial\tilde{s}^+_i)^2 - \frac{1}{2}(\partial p)^2,\ i = 1,2 \tag{2.1}$$

where p is a pseudoscalar which is not considered here.

The R-parity for the above fields is simply $P_R = (-1)^{2\times spin}$. The m^+ and $\tilde{m}^0$ are assumed to have zero or light mass of the order of the first generation quark and lepton mass scale. The standard model particles are formed below some high energy scale Λ_{cr} of three superon composite states. Λ_{cr} is in principle calculable but at present it has to be accepted as a free parameter.

The next step is to analyze superon gravitational interactions by introducing local supersymmetry. In the graviton supermultiplet there are the graviton G and its spin $\frac{3}{2}$ superpartner the gravitino $\tilde{G}$. The massless Rarita-Schwinger field $\tilde{G}$ obeys the curved spacetime equation [9] (full details in [10])

$$\epsilon^{\lambda\rho\mu\nu}\gamma_5\gamma_\mu D_\nu \tilde{G}_\rho = 0 \tag{2.2}$$

where $\epsilon^{\lambda\rho\mu\nu}$ is the Levi-Civita symbol and the γs are the Dirac matrices. The mass of the gravitino is expected to be non-zero [9]. The helicity $\pm\frac{1}{2}$ component of the gravitino includes the Goldstino, or the inflatino [11].

A future line of development may be introducing extra dimensions. Compactification of extra dimensions has been studies actively beyond 4D, up to 10D superstring theory, 11D supergravity, and even 12D. Eleven has been shown to be (i) the maximum number of dimensions with a single graviton and (ii) the minimum number required of theory to contain the standard model gauge group $SU(3) \times SU(2) \times U(1)$. Within the present model, however, the condition (ii) can be dropped if the current situation in the search of standard model superpartners is taken at face value.

3 Difference with Standard Cosmology

The universe started in a process called Big Bang. The details of cosmology are beyond the scope of this note (more details are e.g. in [11, 12, 13]). The focus is in the role of superons forming the matter of the present universe.

Modeling of the early universe according to the cosmological standard model goes via the following phases: (i) inflation is a period of rapid supercooled expansion between times $t_i \approx 10^{-35}$ s and $t_R \approx 10^{-32}$ s, the temperature drops by a factor of about 10^5, it is driven by the inflaton, and the energy scale at the end of inflation is known from Planck measurements to be $T_R \leqslant 10^{15}$ GeV, which is also the upper bound of the next phase (ii) reheating is the process during which the zero point oscillating inflaton decays, or bangs, into particles and radiation, (iii) electro-weak symmetry breaking takes place at 10^{-12} s with a temperature 240 GeV and (iv) the quark-gluon to hadron phase transition at T = 140 MeV. That is when single baryons, the goal of this note, are formed. The nucleosynthesis of the other two light elements proceeds between 1 s to 20 minutes and its energy scale is 1 MeV.

Below the energy scale T_R one can ignore particles of grand unified or Kaluza-Klein mass and possible stringy states. Instead, all lighter degrees of freedom have to be considered. In the present scenario, at the temperature Λ_{cr} a transition takes place in which superons combine into standard model particles [2]. For superons to participate in reheating the value of Λ_{cr} must be below the reheating temperature T_R. When the temperature decreases below Λ_{cr} superon dominated universe enters the standard model phase. The strong and weak non-Abelian gauge interactions begin to operate between the three light superon composite states when $T < \Lambda_{cr}$, just as they do between the SM particles. Above Λ_{cr} the strong and weak interactions do not contribute at all - in any case their non-Abelian standard model couplings are small.

A scalar field ϕ is assumed to drive the inflation. The simplest potential term of the inflaton ϕ is of the type $V(\phi) = M^2\phi^2/2$, where M is the inflaton mass of the order of $10^{-6}M_{\rm Pl}$ and ϕ depends on t only for isotropy and homogeneity. The action is

$$S = \int d^4x\sqrt{-g}\Big[-\frac{1}{2}M_{\rm Pl}^2 R + \frac{1}{2}\nabla_\mu\phi\nabla^\mu\phi - V(\phi) + \mathcal{L}_{superon}\Big] \tag{3.1}$$

Note the different mass scales of the superon term $\mathcal{L}_{superon}$ and the other terms. At time t_i the inflaton starts the slow roll inflation of the universe with ϕ decreasing from some non-zero value towards zero. The slow roll parameters are $\epsilon_V = \frac{1}{2}M_{\rm Pl}^2\Big(\partial_\phi V(\phi)/V\Big)^2$ and $\eta_V = M_{\rm Pl}^2\Big(\partial_\phi^2 V(\phi)/V\Big)$. Both ϵ_V and $|\eta_V|$ are $\ll 1$.

At reheating the inflaton begins to oscillate around the minimum of its potential and it decays into matter and radiation. The temperature increases back close to $T_i \sim 10^{15}$ GeV and the inflaton couples to superon-antisuperon pairs and the gravitinos, provided T_i is sufficiently large compared to Λ_{cr}.[3] Superon combinatorial processes produce the quarks and leptons (section 4). The inflaton couples also to the electromagnetic field with the coupling $\phi F^{\mu\nu}\tilde{F}_{\mu\nu}$.

If the gravitino is stable it would be a candidate for dark matter. In the present supersymmetric scenario the gravitino is unstable since it may decay gravitationally into superons like the photon and a scalar superon. The gravitino lifetime is long, of the order of $M_{\rm Pl}^2/M_{grino}^3$. For a M_{grino} of the order of 1 TeV the lifetime is 10^5 s which is much later than the end of the period of nucleosynthesis. An energetic gravitino decay product would destroy a nucleus in a mutual collision. Large amounts of gravitinos could destroy most of the nuclei created in nucleosynthesis leaving only hydrogen in the universe, which is not the case. It would be safer to have M_{grino} close to the particle mass scale. A lifetime of 100s would yield a mass of 215 GeV, which would only slightly disturb nucleosynthesis.

The maximum reheat temperature depends on the number of relativistic degrees of freedom as follows

$$T_R \sim \left(90/N_{DF}\pi^2\right)^{1/4}\sqrt{M_{\rm Pl}\Gamma_{tot}} \tag{3.2}$$

where $\Gamma_{tot} = \Gamma_s + \Gamma_f$ is the inflaton total decay rate where in the scalar case $\Gamma_s = g^2/8\pi M_\phi$, g being the scalar-ϕ coupling constant, and for the fermion case $\Gamma_f = h^2 M_\phi/8\pi$, h being the fermion coupling. This would give a factor of 1.5 higher T_R for superon model ($N_{DF} = 23$) as compared to the standard model ($N_{DF} = 118$) of particles.

As an aside, there are some limitations of the treatment in this section. The inflaton has been considered above much simplified as a superposition of asymptotic free single inflaton fields at the beginning of oscillations. More precisely, the inflaton is a coherently oscillating homogeneous field, a classical Bose condensate with a high occupation numbers. Due to its large amplitude it can be treated classically. But the matter fields start in their vacuum state. Therefore they must be treated quantum mechanically. Such a more accurate mechanism, called preheating [14], is based on a Lagrangian $\mathcal{L}_{int} = -1/2g^2\chi^2\phi^2$ where the scalar χ is a placeholder for the highly non-thermal particles of the model one is using. In the present scenario, the inflaton couples to the m^+'s superpartners s_1^+ and s_2^+ [2]. The m^0, the m^+ are included correspondingly with $g_f\bar{\psi}\psi$ terms.

Assuming the energy scale of inflation corresponding to $\sim 10^{16}$ GeV, then about 60 e-foldings of exponential expansion would be required in order that the scales observed now in cosmology would have wavelengths smaller than the Hubble radius at time t_i, the beginning of inflation [15].

[3] Otherwise a 'background' production of standard model particles shows up leading to matter-antimatter symmetry.

4 Matter Asymmetry

One may naively expect the universe to be matter-antimatter symmetric, which is not the case experimentally [16]. The magnitude of baryon (B) asymmetry is indicated by the ratio $r_B = (N_{\rm B} - N_{\bar{\rm B}})/N_{\rm photons}$, which is measured to be $\sim 10^{-10}$.

It is rather curious that the hydrogen atom, noticeably asymmetric baryon and lepton bound state, is on the superon level a *symmetric* collection of superons and antisuperons as follows (see (1.1)) $H : p + e = \ u_R + u_G + d_B + e$ where $u_R = m^+m^+m^0_R$, $d_R = m^-m^0_Gm^0_B$, $e = m^-m^-m^-$, and $\nu = m^0_Rm^0_Gm^0_B$ (R, G, B are for SU(3) color of m^0).[4]

This superon structure of quarks and leptons is the basic physical reason for matter-antimatter asymmetry in the present scenario. While the process in (1.1) is obvious from first to second line the converse is complicated.

Superons are formed abundantly pairwise by coupling to the inflaton. This may happen during early inflation $t \geqq t_i$ (see 5.1) or at preheating $t \geqq t_R$ (see 5.2). Within the scenario, superons form combinatorially (mod 3) states of three superons [17] later at temperature $T < \Lambda_{cr}$. The composites fulfill all charge states 0, $\pm\frac{1}{3}$, $\pm\frac{2}{3}$ and ± 1. These are the standard model quark and lepton first generation states [2]. Their formation takes place via a few stages as we discuss next.

Starting from their formation time, superons of all charge states are evenly distributed all over the universe. Consider twelve superons, like in (1.1), as an example. Within the model assumption, twelve superons tend to form four groups of three correlated or bound superons[5]. All these are leptonic, radiation or mixed quark-lepton states. These include $uude^-$ and $ude^-\nu$ (β-decay). The latter group includes free u and d quarks for nucleon formation, for time $t > 10^{-6}$s. Other groups of twelve superons are $\bar{d}\bar{d}\bar{d}e^-$, $\bar{d}\bar{d}\bar{d}d$, $\nu\nu e^+e^-$ and $\nu\nu\nu\nu$. These cases provide photons and neutrinos.

The basic idea behind the asymmetry is the following. Superons in one region of the universe can form quarks and leptons with charges like in uud and e^-, or (1.1) first line. But in other regions of the universe, nearby or far away, the *same* superons may combine differently forming a $\bar{u}\bar{u}\bar{d}$ and e^+, or $\bar{p}\ e^+$ pair, i.e. an atom of antihydrogen $\bar{H}$. The matter-antimatter symmetry prevails unless the volume of proton-electron regions is larger than the volume of antiproton-positron regions (or vice versa).[6] This is characteristic in the present scenario because the superon combination process into quarks and leptons and finally into H or $\bar{H}$ is stochastic.

Statistically $r_H = N_{\bar{H}}/N_H$ can vary between zero and ∞, the expectation value being $\langle r_H \rangle = 1$, which leads to a radiation dominated universe. But the measure of $r_H = 1$ is zero while the measure of values $r_H \neq 1$ is one. It is

[4]The superons have two dimensional anyon statistics and form composite states by Chern-Simons interaction [21].

[5]Direct annihilations are possible but they return superons, or yield radiation.

[6]Strictly speaking, one should discuss continuous densities of particles or atoms.

reasonable to assume $r_H \neq 1$ within some deviation. Then, starting from interfacing regions, any excess of H or $\bar{H}$ is quickly annihilated away and radiation together with an asymmetric remains of either matter or antimatter universe is obtained (causing at most a redefinition of the sign of charge). The amounts of matter and radiation must satisfy the observed value $r_B \sim 10^{-10}$. Therefore, there must be in the early universe one part per ten billion more baryons in their regions than antibaryons in the corresponding regions. The present scenario explains how this r_B value can be obtained but it does not predict it.[7]

The value of $r_B \sim 10^{-10}$ is needed for nucleosynthesis to proceed. It ensures that nucleons collide and react properly to produce the observed abundances of the three lightest elements.

The nucleon states change due to the reactions

$$n\ e^+ \longleftrightarrow \nu_e\ p \quad \text{and} \quad \mathrm{n}\ \nu_\mathrm{e} \longleftrightarrow \mathrm{p}\ \mathrm{e}^- \tag{4.1}$$

The ratio $N_n/N_p = \exp(-(m_n - m_p)/T)$ is close to one before times $\ll$1s, which is also the scenario estimate. At $T = 0.7$ MeV, or $t \sim 1$s, the reaction rate of (4.1) drops faster than the Hubble expansion rate, and the $\frac{N_n}{N_p}$ ratio decreases to about $\frac{1}{6}$. Before fusing into nuclei some of the neutrons decay and the the ratio drops to $\frac{1}{7}$.

5 Origin of the Correlations

This section contains some tentative thoughts for possible later phenomenological developments on what the origin of the correlations may have been. The correlation length is defined as the distance within which the formation of negative (positive) charge superon composites correlate with formation of positive (negative) charge containing superon composites. This is believed to happen in spite of Coulomb repulsion between like charge superons - recall that quantum chromodynamics confines three u quarks of charge $\frac{2}{3}$. We treat the correlation length formation in two ways, first the case of expanding correlation length in subsection 5.1, and secondly with very small correlation length in subsection 5.2. Experimental result from relevant energy regions are to be expected later in the 2030's at least from the LISA space detector [18].

5.1 Large Correlation Length

Suppose now that the superons are created during the early inflation instead of reheating.[8] Consequently inflaton influences the correlation length λ_{cor}. The simplest case is to consider superons as spectator fields during inflation. In a more detailed model the newly created superon-antisuperon pairs have spin 0 and they may strengthen the inflaton Bose condensate effect. We hope to return to this scheme elsewhere and give here a brief discussion.

[7]We have tried to find a dynamical reason for the value of r_B but without success.
[8]This idea was suggested to us by R. Brandenberger.

One may assume that there is an asymmetry in spacetime. Such an asymmetry is discussed in [19], and it is due to torsion of the geometry in Einstein-Cartan-Kibble-Sciama extension of general relativity. Torsion occurs only for fermions at much higher densities than nuclear matter. The energies of free fermions under such conditions get a correction

$$E = M \pm \frac{1}{N M_{\rm Pl}^2} \tag{5.1}$$

where N is the superon wave function normalization, and the $\pm$ is the superon charge. The correction is small but may still be meaningful. It is supposed to generate a small correlation length, or region of volume $\sim \lambda_{cor}^3$, within which different superon charge states are differentiated. The heavier superon is expected to create subtle order and cause movement of the lighter superons in (quantum) spacetime. Three m^- superons tend to form an electron and the correlated positive superon containing region produces u and d quarks. During inflation this length scale expands exponentially and will finally include what we see as the observed universe. At the end of inflation the universe consists of protons, electrons and the neutral particles n and ν, and radiation. There is practically no need for particle-antiparticle annihilations. Without further interactions we have $r_B \approx 0$.

5.2 Small Correlation Length

The second approach starts from the fact that there are thermal fluctuations. The superon thermal Compton wavelength is $\lambda_T = 1/2\sqrt{MT}$ which is of the order of 10^{-7}GeV^{-1} for a superon mass 0.1 GeV and $T = T_R = 10^{15}$ GeV, which may be rather large for the correlation length λ_{cor}.

Let us try to make it smaller and estimate how scales change in the early universe. The physical length scale at time $t_{Pl} \sim 10^{-43}$ s increases during inflation from $M_{\rm Pl} \sim 10^{19}$ GeV to $M_{inf} \sim 10^{13}$ GeV at time $t_i \sim 10^{-35}$ s. This is much less than the expansion of the universe during the same time. Extrapolating from t_{Pl} to $t_R \sim 10^{-32}$ s on log scale linearly we get an estimate for the length scale $\sim 10^{-11}$ GeV^{-1}. This is of the order of the Cartan radius of the electron ${r^e}_{\rm Cartan}$. Thus the superons are pulled inside quarks and leptons, or corresponding antiparticles, within a region of size $\sim \lambda_{cor}^3$. This should be considered a constant in the scenario and estimate for the size of SM particles.

6 Conclusions and Outlook

The present superon model is based on spacetime symmetries alone and on the proposal that the physical domain of supersymmetry is the superon level instead of the traditional quark and lepton level of the standard model. The key feature of the present scenario is that all the fundamental fields and their superpartners are in the basic supermultiplets to begin with. Therefore no superpartners, light or heavy, need to be searched for experimentally (except for the scalars). Baryons and leptons are treated in a unified way in terms of superons. All standard model particles as well as all inflationary model particles are found in supermultiplets of section 2.

The superon model of section 3 is physically consistent with the standard model of cosmology. The largest numerical difference found so far is in the number of effective relativistic degrees of freedom, N_{DF} which is for superons $N_{DF}^{sup} = 23$ (not counting gluons, W and Z but including the graviton multiplet and the scalars) and $N_{DF}^{SM} = 118$ (for the minimal supersymmetric standard model $N_{DF} > 200$). The reheating temperature T_R is by a factor of 1.5 higher in the superon model as compared to the standard model due to smaller N_{DF}. With $\Lambda_{cr} \approx 10^{14}$ the superon reheating is expected to dominate over the standard model contribution.

Based on plausible arguments, we have disclosed in section 4 the main result of this note, a physical origin of the observed matter-antimatter asymmetry. Its is based on subtle correlations between charged superons which combine later into standard model particles. In (1.1) the idea is so "obviously" true, but a computer simulation is needed to prove the process right or wrong. Furthermore, details of quantum gravity or a new force may be involved.

The Sakharov conditions [20] are of general nature and must be obeyed by every model. When the present scenario analyzed in more detail, it does fulfill these conditions as discussed in [21].

The case with correlation length larger than the current cosmological horizon was considered in subsection 5.1. The asymmetry was created by a torsional effect in the high density early universe. In this case we have to add that if none of the thoughts of this note are found satisfactory after all we may have to comply to the ultimate possibility of superons organizing themselves by pure chance, a possibility we have been trying to avoid. The alternative microscopic correlation length in subsection 5.2 is $\lambda_{cor} \sim 10^{-11}$ GeV$^{-1} \approx {r^e}_{\mathrm{Cartan}}$. Though the approaches in these subsections are different, in a more complete analysis they may be connected e.g. the value of ${r^e}_{\mathrm{Cartan}}$ may hold in subsection 5.1.

A tentative estimate for the gravitino mass is of the order of 200 GeV based on minimal interference between the gravitino decay products and nucleosynthesis. No fields outside the scenario were used. The value of the ratio $r_B = (N_{\mathrm{B}} - N_{\bar{\mathrm{B}}})/N_{\mathrm{photons}}$ can be explained in the scenario but could not be predicted. The scenario is readily extensible to more detailed studies in cosmology and supergravity. Finally, experimental results in the reheating energy region relevant to test the different scenarios are expected in the form of gravitational waves from the LISA space detector [18] in the second half of 2030's.

Acknowledgemet

I warmly thank Professor Robert Brandenberger for correspondence and giving guidance in the treatment of inflation. Any errors and deficiencies are due to the author.

References

[1] Risto Raitio, A Model of Lepton and Quark Structure. Physica Scripta, 22, 197 (1980). PS22,197, viXra:1903.0224 [9]

[2] Risto Raitio, Supersymmetric preons and the standard model, Nuclear Physics B931 (2018) 283–290. doi:10.1016/j.nuclphysb.2018.04.021 arXiv:1805.03013

[3] Robert Finkelstein, On the SLq(2) Extension of the Standard Model and the Measure of Charge, Int. Journal of Modern Physics A, Vol. 32 (2017). arXiv:1511.07919

[4] Robert Finkelstein, The SLq(2) extension of the standard model, Int. Journal of Modern Physics A, Vol. 30, No. 16, 1530037 (2015). doi:10.1142/S0217751X15300379

[5] J. Wess and B. Zumino, Supergauge transformations in four dimensions, Nucl. Phys. B 70 (1974) 39. 10.1016/0550-3213(74)90355-1

[6] H. Harari, A schematic model of quarks and leptons, Phys. Lett. B86, 83 (1979). doi:10.1016/0370-2693(79)90626-9

[7] M. Shupe, A composite model of leptons and quarks, Phys. Lett. B86, 87 (1979). doi:10.1016/0370-2693(79)90627-0

[8] Nima Arkani-Hamed, Luboš Motl, Alberto Nicolis, Cumrun Vafa, The string landscape, black holes and gravity as the weakest force, Journal of High Energy Physics. Springer Nature. 2007 (06): 060–060. arXiv:hep-th/0601001

[9] Daniel Z. Freedman, P. van Nieuwenhuizen, and S. Ferrara, Progress toward a theory of supergravity, Phys. Rev. D 13, 3214 (1976).

[10] Steven Weinberg, The Quantum Theory of Fields: Volume 3, Supersymmetry, Cambridge University Press (2005).

[11] Rouzbeh Allahverdi, Robert Brandenberger, Francis-Yan Cyr-Racine, Anupam Mazumdar, Reheating in Inflationary Cosmology: Theory and Applications. Annu. Rev. Nucl. Part. Sci. 2010. 60:27-51.

[12] Daniel Baumann, TASI Lectures on Primordial Cosmology. arXiv:1807.03098

[13] Kaloian Lozanov, Lectures on Reheating after Inflation, MPA Lecture Series on Cosmology (2018).

[14] J.H. Traschen, R.H. Brandenberger, Particle Production During Out-Of-Equilibrium Phase Transitions, Phys. Rev. D 42, 2491 (1990).

[9] The model was conceived in November 1974 at SLAC. I proposed that the c-quark would be a gravitational excitation of the u-quark, both composites of three 'subquarks'. The idea was opposed by the community and was therefore not written down until five years later.

[15] Robert H. Brandenberger, Beyond Standard Inflationary Cosmology, Modified version of a contribution to "Beyond Spacetime" eds. N. Huggett, K. Matsubara and C. Wuethrich (Cambridge Univ. Press, Cambridge, 2018). arXiv:1809.04926

[16] Laurent Canetti, Marco Drewes, Mikhail Shaposhnikov, Matter and Antimatter in the Universe, New J. Phys. 14 (2012) 095012, DOI:10.1088/1367-2630/14/9/095012. arXiv:1204.4186

[17] Risto Raitio, Combinatorial Preon Model for Matter and Unification, Open Access Library Journal, 3: e3032 (2016). OALibJ 3:e3032

[18] LISA Collaboration, Science with the space-based interferometer LISA. IV: Probing inflation with gravitational waves, JCAP 12, 026 (2016). arXiv:1610.06481

[19] Nikodem J. Popławski, Matter-antimatter asymmetry and dark matter from torsion, Phys. Rev. D83, 084033 (2011). arXiv:1101.4012

[20] A. D. Sakharov, Violation of CP invariance, C asymmetry, and baryon asymmetry of the universe, Journal of Experimental and Theoretical Physics Letters. 5: 24–27 (1967).

[21] Risto Raitio, A Chern-Simons model for baryon asymmetry, Nuclear Physics B Volume 990 (2023) 116174. DOI: 10.1016/j.nuclphysb.2023.116174. arXiv:2301.10452