A Scenario for Asymmetric Genesis of Matter

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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 atomic matter can be described in terms of *symmetric* preons, which are created in the early universe. It is proposed that matter-antimatter asymmetry can be caused by torsion induced stochastic correlations in charge density fluctuations of preons and antipreons. The subsequent preon combinatorial mechanism forms quarks and leptons, and finally the three lightest elements without explicit symmetry violations.

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1 Introduction

1.1 Physical Motivation

In search of a next structural level of matter beyond the standard model (SM) particles we have to make Gedanken experiments to see if we can find by logical analysis something interesting. While the SM is able to describe all available accelerator data an old but unsolved problem is that the universe consists of matter without antimatter to an accuracy of 10^{-10}.

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 $-\frac{1}{3}$. 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 global supersymmetry. 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 ± indicates charge ±1.

The simple and surprising message from (1.1) is that on the first line the hydrogen consists of matter particles only, the electron and the quarks, but the second line is matter-antimatter *symmetric*. Thus, the matter-antimatter asymmetric universe can be easily represented as a collection matter-antimatter symmetric constituents. But to organize these constituents to form quarks and leptons is rather difficult. We propose a heuristic model how this may happen. It is seen from (1.1) that superons unify baryons and leptons and eliminate the need for a priori quantum numbers B and L.

1.2 Preon Physics

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, without reference to the Sakharov conditions [3].

The preon model of Finkelstein [4, 5], 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, 6] 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. The more realistic case of inflaton as classical Bose condensate is mentioned. Superons are created from vacuum during (i) early inflation or (ii) reheating. It is assumed that positive and negative charge superons are distributed equally smoothly in space. When an electron is formed from a stochastic density fluctuation of three negative charge superons it leaves 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 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 re-

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[1] Harari [7] and Shupe [8] 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 [9]. Ultimately a theory

inforced by replacing global supersymmetry with local supersymmetry to obtain supergravity [10] 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 [11].

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 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 description is given of how superon cosmology differs from the cosmological standard model. In section 4 the main proposal of this note, a solution to baryon and lepton asymmetric genesis is presented. 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 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, 6] 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 [6, 11]

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

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

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of quantum gravity is needed. Recall that the quark model was very successful in the 1960's before the introduction of chromodynamics.

and its spin $\frac{3}{2}$ superpartner the gravitino $\tilde{G}$. The massless Rarita-Schwinger field $\tilde{G}$ obeys the curved spacetime equation [10] (full details in [11])

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

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 [10]. The helicity $\pm\frac{1}{2}$ component of the gravitino includes the Goldstino, or the inflatino [12].

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 (details are e.g. in [12, 13, 14]). 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 $10^{-6}M_{\mathrm{Pl}}$, and ϕ depends on t only for isotropy and homogeneity. The action is

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

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 $\epsilon_V = \frac{1}{2}M_{\mathrm{Pl}}^2\Big(\partial_\phi V(\phi)/V\Big)^2$ and $\eta_V = M_{\mathrm{Pl}}^2\Big(\partial_\phi^2 V(\phi)/V\Big)$. 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 $T_R \sim 10^{15}$ GeV and the inflaton couples to superon-antisuperon pairs and the gravitinos, provided T_R is sufficiently large compared to Λ_{cr}. 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 $M_{\mathrm{Pl}}^2/M_{grino}^3$. 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

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

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 ($N_{DF} = 19.25$) as compared to the standard model ($N_{DF} = 106.75$) 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 [15], 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 [16].

4 Matter Asymmetry

One may naively expect the universe to be matter-antimatter symmetric, which is not the case experimentally [17]. The magnitude of baryon (B) asymmetry is indicated by the ratio $r_B = (N_{\mathrm{B}} - N_{\bar{\mathrm{B}}})/N_{\mathrm{photons}}$, 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)) $H : p + e = u + u + d + e = \sum_{l=1}^{4}\left[m_l^+ + m_l^- + m_l^0\right]$ where $u_k = \epsilon_{ijk}m_i^+m_j^+m^0$, $d_k = \epsilon_{ijk}\frac{1}{\sqrt{2}}m^-(m_i^0m_j^0 + m_i^-m_j^+)$ (k = 1, 2, 3 for color) and $e = \epsilon_{ijk}m_i^-m_j^-m_k^-$ (the neutrino is $\nu = \epsilon_{ijk}\frac{1}{\sqrt{2}}m_i^0(m_j^0m_k^0 + m_j^-m_k^+)$) (for details it may be necessary to consult [2]).

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, i.e. from present time towards $t \sim 0$, the converse from $t \sim 0$ onwards 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 [18] 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[3]. 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.

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

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).[4] 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 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.[5]

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

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

[5] We have tried to find a dynamical reason for the value of r_B but without success.

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.

5.1 Large Correlation Length

Suppose now that the superons are created during the early inflation instead of reheating.[6] 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.

One may assume that there is an initial asymmetry in spacetime. Such a possible asymmetry is discussed in [19], and it is due to torsion 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

$$E = M \pm \frac{1}{NM_{\mathrm{Pl}}^2} \tag{5.1}$$

where N is the superon wave function normalization, and the ± 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 $10^{-7}\mathrm{GeV}^{-1}$ 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 $M_{\mathrm{Pl}} \sim 10^{19}$ 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

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[6] This idea was suggested to us by R. Brandenberger.

for the length scale $\sim 10^{-11}$ GeV^{-1}. This is of the order of the Cartan radius of the electron $r^e{}_{\text{Cartan}}$. Thus the superons are pulled inside quarks and leptons, or corresponding antiparticles, within a region of size $\sim \lambda^3_{cor}$. 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 perhaps for scalars). Baryons and leptons are treated in a unified way in terms of superons without introducing a priori B and L quantum numbers. 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 $N^{sup}_{DF} = 19.25$ and $N^{SM}_{DF} = 106.75$ (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 be the dominating process.

Based on heuristic arguments, we have disclosed in section 4 the main proposal of this note, the 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 details of quantum gravity, or a new force, may be involved.

The case with correlation length larger than the current cosmological horizon was considered in subsection 5.1. An initial asymmetry was created by a torsional effect in the high density early universe. The alternative microscopic correlation length in subsection 5.2 is $\lambda_{cor} \sim 10^{-11}$ GeV$^{-1} \approx r^e{}_{\text{Cartan}}$. Though the approaches in these subsections are different, in a more complete analysis they may be connected.[7]

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, no C or other symmetry breaking arguments were needed. The value of the ratio $r_B = (N_{\text{B}} - N_{\bar{\text{B}}})/N_{\text{photons}}$ can be explained in the scenario but could not be predicted. The scenario is readily extensible to more detailed studies in cosmology and supergravity.

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[7] 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.

Acknowledgemet

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[8] 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.

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