A Scenario for Asymmetric Matter Genesis

Risto Raitio*
02230 Espoo, Finland

February 29, 2020

Abstract

A previous preon scenario for the standard model particles, based on unbroken global supersymmetry, is developed further to provide a natural physical reason for the observed matter-antimatter asymmetry. Without any symmetry violations, a stochastic mechanism for asymmetric genesis of matter in the early universe is proposed. Within this scenario the black hole information paradox seems to be an artifact due to fundamental particle choice. With global supersymmetry made local the scenario can be extended to supergravity.

PACS 12.60.Rc

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

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

1 Introduction

In fundamental physics, when one goes towards smaller and smaller length scales beyond, say 10^{-18} m, the symmetries describing physics may change. The hadron symmetries in the standard model need not be as relevant as before. Or rather, perhaps they are derived quantities of a smaller scale theory, which is our target.

The original version [1] of this scenario for substructure of the standard model particles supposed the subconstituents to have charge $\frac{1}{3}$, spin $\frac{1}{2}$ and a heavy mass. The model was modified in terms of the same fields but having light mass [2]. Here we investigate how the matter-antimatter asymmetric universe can be created 'unconditionally' from C symmetric preons, i.e. without reference to the Sakharov conditions [3] (for a review see [4]).

As shown by Finkelstein [5, 6], this kind of preon model (his as well as ours) can be extended to possess 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, 7] without the superpartner problem. This is satisfying because present experimental evidence indicates that standard model superpartners may not exist.

The matter-antimatter asymmetry is considered starting from the hydrogen atom which includes asymmetric matter components only. But when the proton and the electron are described in terms of preons one notices that the atom is preon-antipreon *symmetric* - in fact, all atoms are. Furthermore, preons provide a novel unified picture of quarks and leptons, different from traditional grand unified theories.

The major challenge in the scenario, preon "confinement" inside quarks and leptons, is still without solution, but it is no more mere speculation as in [1]. Namely the preon, or superon (synonyms here), scenario can be self-consistently reinforced 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 and by constructing realistic models for supergravity. Explicit models are beyond the scope of this note.

The article is organized as follows. In section 2 a very brief description is given of how superon cosmology differs from the cosmological standard model.

[1]Harari [8] and Shupe [9] 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.

In section 3 the main result of this note, the natural connection between superons and ordinary atomic matter asymmetry is presented. A solution to baryon and lepton asymmetric genesis is proposed. Section 4 is a brief description of a framework for developing supergravity models on the basis of the superon scenario. Conclusions and a brief discussion of the black hole information paradox as a kind of coordinate artifact are given in section 5.

This concise note should be considered a concept analysis necessary for going beyond the long time esteemed standard model with calculations.

2 Difference with Standard Cosmology

It is commonly believed that the universe started in a process called Big Bang, be it one time or cyclic without singularity. The details of cosmology are beyond the scope of this note. The focus is in the role of superons forming the contents of the present universe.

The laws of physics are unknown before the Planck time $\sim 10^{-43}$ s. The temperature of the universe at that time was $\sim 10^{32}$ K or $\sim 10^{19}$ GeV and the length scale was $\sim 10^{-35}$ m. As time flowed on different phases occurred in the universe according to the cosmological standard model: (i) inflation between 10^{-35}–10^{-32} s followed by (re)heating, (ii) grand unified theory phase transition at temperature $\Lambda_{cr} \sim 10^{16}$ GeV, (iii) electro-weak symmetry breaking at 10^{-12} s with a temperature 240 GeV and (iv) the quark-gluon to hadron phase transition at T = 140 MeV.

In the present scenario, at the temperature $\Lambda_{cr} \sim 10^{16}$ GeV a transition takes place in which superons transform into standard model particles [2]. The universe enters the standard model phase. The strong and weak non-Abelian gauge interactions operate only (i) when $T < \Lambda_{cr}$, and (ii) between the three light superon composite states, as they do between the SM particles. But above Λ_{cr} they do not contribute at all - in any case their non-Abelian standard model couplings are small.

3 Matter Asymmetry

After protons have been formed at about $t \sim 10^{-6}$ s one would expect on general field theory grounds the universe to be matter-antimatter symmetric, which is not the case experimentally [12]. The magnitude of baryon (B) asymmetry is usually 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 preon level a *symmetric* collection of preons and antipreons as follows

$$\begin{aligned} H \equiv p + e &= u + u + d + e \\ &= \sum_{l=1}^{4} \left[m_l^+ + m_l^- + m_l^0 \right] \end{aligned} \tag{3.1}$$

where $u_k = \epsilon_{ijk} m_i^+ m_j^+ m^0$, $d_k = \epsilon_{ijk} \frac{1}{\sqrt{2}} m^- (m_i^0 m_j^0 + m_i^- m_j^+)$ (k = 1, 2, 3) and $e = \epsilon_{ijk} m_i^- m_j^- m_k^-$ (the neutrino is $\nu = \epsilon_{ijk} \frac{1}{\sqrt{2}} m_i^0 (m_j^0 m_k^0 + m_j^- m_k^+)$) [2]. This preon structure is the basic physical reason for matter-antimatter asymmetry in the present scenario. While the process in (3.1) is obvious from left to right the converse is more complicated.

Superons are formed pairwise at the end of inflation when universe enters the phase of reheating. Within the scenario, superons form combinatorially (mod 3) states of three preons [13] at temperature $< \Lambda_{cr}$ fulfilling 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 [13].

With 12 superons in (3.1) several four superon states are formed, all being 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 nucleons, and subsequently for the reactions

$$n\ e^+ \longleftrightarrow \nu_e\ p \quad \text{and} \quad \mathrm{n}\ \nu_\mathrm{e} \longleftrightarrow \mathrm{p}\ \mathrm{e}^- \tag{3.2}$$

The ratio $\frac{N_n}{N_p} = \exp(-(m_n - m_p)/T)$ is close to one before times « 1s, which is also the scenario estimate. At $T = 0.7$ MeV, or $t \sim$ 1s, the reaction rate of (3.2) 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 $\frac{1}{7}$. Other groups of 12 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. In a simulation with N»12 preons all of them will end up bound in SM particles.

There still is the problem: preons are C symmetric. Preons in one region of the universe can form quarks and leptons with charges like in uud and e^-, or 3.1 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.

The advantage of the present scenario, as compared to the standard model or other field theory, is that the global H and $\bar{H}$ abundances need *not* be the same. This is because the preon combination process into quarks and leptons, and finally into H and $\bar{H}$ is stochastic. To illustrate the idea, there may be more regions producing H than $\bar{H}$, or vice versa.[2] 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

[2] Stricktly speaking, one should discuss continuous densities of particles or atoms.

some one σ. Then, starting from interfacing regions, any excess of H or $\bar{H}$ is 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 $r_B \sim 10^{-10}$. To do so, there must be in the early universe one part per billion more baryons in their regions than antibaryons in the corresponding regions.

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 present scenario explains how this r_B value can be obtained but it does not predict it.

4 Supergravity

In this section a brief glance for future developments of superon models is given. 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 when the current situation in the search of standard model superpartners is taken at face value.

In the N=1 supersymmetric model 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 [10] (full details in [11])

$$\epsilon^{\lambda\rho\mu\nu}\gamma_5\gamma_\mu D_\nu \tilde{G}_\rho = 0 \tag{4.1}$$

where $\epsilon^{\lambda\rho\mu\nu}$ is the Levi-Civita symbol and the γs are the Dirac matrices. This the graviton supermultiplet.

Secondly, as introduced in [7, 1, 2], there are the massless fields the 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 with spin up or down.

The third supermultiplet is the spin $\frac{1}{2}$ fermion m^+ obeying the Dirac equation and two scalar superpartners $\tilde{s}^+_{1,2}$ [1, 2]. The free massless Lagrangian for the chiral multiplet is of the form [7, 11]

$$\mathcal{L} = -\frac{1}{2}\bar{m}^+ \not{\partial} m^+ - \frac{1}{2}(\partial \tilde{s}^+_i)^2 - \frac{1}{2}(\partial p)^2, \; i = 1, 2 \tag{4.2}$$

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.

5 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 preon 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. Baryons and leptons are treated in a unified way in terms of superons.

The black hole information paradox is partly, if not wholly, faded out because the superon quantum numbers are not destroyed by classical black holes. A vacuum black hole emits Hawking radiation from the vicinity of its horizon, where an observer sees a local temperature $T = \frac{1}{4\pi\sqrt{2M(r-2M)}}$. In our scenario the hole emits superons if $T \gg \Lambda_{cr}$. According to Page [14], a hole with a mass $M = 10^{16}$g emits ultrarelativistic electrons and positrons, which may approximate superons for this argument, with a lifetime proportional to M^3. The superons in turn will evolve like in the bang of our early universe and give rise to an asymmetric genesis of baryons and leptons. Therefore, what fell into the hole will for the most part come back again provided that the r_B is the same as in the Big Bang.[3] The black hole information paradox seems to be an artifact due to 'coordinate', i.e. fundamental particle quantum number, choice. A more detailed analysis is needed to clarify this point.

Based on plausible arguments, we have disclosed in this note a natural physical origin of the observed matter-antimatter asymmetry in the universe starting from C symmetric superons. No symmetry breaking arguments were used. 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.

References

[1] Risto Raitio, A Model of Lepton and Quark Structure. Physica Scripta, 22, 197 (1980). PS22,197, viXra:1903.0224 [4]

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

[4] 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.

[3] 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).

[4] Antonio Riotto and Mark Trodden, Recent Progress in Baryogenesis, Annual Review of Nuclear and Particle Science 49 (1) 35-75 (1999). arXiv:hep-ph/9901362

[5] 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

[6] 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

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

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

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

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

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

[12] 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

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

[14] Don N. Page, Particle emission rates from a black hole: Massless particles from an uncharged, nonrotating hole, Physical Review D. 13 (2): 198–206 (1976). 10.1103/PhysRevD.13.198