A Scenario for Asymmetric Genesis of Matter

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Abstract

We use a previous supersymmetric preon model to propose a heuristic mechanism for the creation of the matter-antimatter asymmetric universe during its early phases. The asymmetry is predicted with probability 1.0 by the charge symmetric model. The baryon-photon ratio is not quantitatively obtained.

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Introduction. There is no actual experimental need for another pointlike structural level of matter below the standard model (SM) particles.We take, however, the liberty of making a Gedanken experiment to see if we can by logical analysis find something applicable for a pivot point to vault beyond the SM. The motivation is that there are old, but still unsolved problems within the SM including the matter-antimatter asymmetry issue.

This note is based on our earlier work on preons [1, 2]. Inspired by Finkelstein [3, 4, 5] we have extended our scenario to include the symmetry group *SLq(2)* [2]. Both scenarios agree physically with the standard model.[1]

Superon scenario. We briefly recap the superon scenario of [1, 2, 6] in the N=1 supersymmetric model. The most familiar field is the photon γ, which has a neutral spin $\frac{1}{2}$ superpartner, the photino $\tilde{\gamma}$, denoted in [2] by $\tilde{m}^0$. 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 free massless Lagrangian for the chiral multiplet is of the form [6]

$$\mathcal{L} = -\frac{1}{2}\bar{m}^+ \not{\partial} m^+ - \frac{1}{2}(\partial \tilde{s}^+_i)^2 - \frac{1}{2}(\partial p)^2, \; i = 1, 2 \tag{0.1}$$

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 as three superon composite states below an energy scale Λ_{cr}. Binding is caused by an attractive gravity-like strong interaction (yet to be defined), or by rotation charge sharing [4]. Λ_{cr} is in principle calculable but at present it is accepted as a free parameter. Numerically $\Lambda_{cr} \sim 10^{14-15}$ GeV.

Table 1: Superon content of the Standard Model particles

SM	Superon state
e^-	$\epsilon_{ijk} m_i^- m_j^- m_k^-$
u_k	$\epsilon_{ijk} m_i^+ m_j^+ m^0$
d_k	$\epsilon_{ijk} m^- m_i^0 m_j^0$
ν	$\epsilon_{ijk} m_i^0 m_j^0 m_k^0$

Inflation. We adopt for the early universe the view advocated by Barrau [9], in which things are looked at as being rolled back in time from present to a ‘beginning’ of the universe using general relativity as a guide. It is assumed that the universe is closed, as supported by the Planck data [10]. This means

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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 some of their preon symmetries are different from ours.

that the Big Bang singularity does not appear any more in a universe with a positive curvature mixed with an effective cosmological constant. Now the standard cosmological principle leads to a bounce before inflation.

This kind of universe never reaches the Planck density. The bounce takes place at the inflationary scale, which is by a factor of about one thousand below the Planck scale [9]. Inflation is followed by reheating, which takes place at a temperature of $T_R \simeq 10^{16}$ GeV. Assuming the energy scale of inflation corresponding to this value, then about 65 e-foldings of expansion would be required for the scales observed now in cosmology [9]. The parameter Λ_{cr} must be below T_R by a factor of ten or more.

At the beginning of inflation, $t = t_i \sim 10^{-35}$s, the universe consists of gravity and a scalar inflaton with a potential $V(\phi)$. The Einstein-Hilbert action is

$$S = \int d^4x\sqrt{-g}\Big(\frac{1}{2}R - \frac{1}{2}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi - V(\phi)\Big) \tag{0.2}$$

When inflation ends at $t_R \approx 10^{-32}$s the inflaton, which is actually coherently oscillating homogeneous field, a Bose condensate, couples to free superon pairs, m^+m^-, $m^0\bar{m}^0$, and s^+s^-. This causes the Bang. When the temperature decreases to $\Lambda_{cr} \sim 10^{15}$ GeV superons form composite states combinatorially (mod 3).

Asymmetry. Any bunch of superon-antisuperon pairs m^+m^- and $m^0\bar{m}^0$, in multiples of six, will form either hydrogen or anti-hydrogen atoms, see (0.3).

$$\begin{aligned} p + e^- &:= u^{2/3} + u^{2/3} + d^{-1/3} + e^- \\ &:= \sum_{l=1}^{4}\left[m_l^+ + m_l^- + m_l^0\right] =: \bar{p} + e^+ \end{aligned} \tag{0.3}$$

where the superscript is the charge of the particle and ± indicates charge ±1. It follows from (0.3) that superons unify baryons and leptons and eliminate the need for a priori quantum numbers B and L on the fundamental level - e.g. black holes do not conserve B and L.

Since the formation of matter, H or $\bar{H}$, is stochastic their abundances are not necessarily equal in different parts of the universe, nearby or faraway. Consequently, the total numbers of H and $\bar{H}$ in the universe need not be equal. The probability of them being equal is 0. At high temperature, the H and $\bar{H}$ annihilate leaving an excess of either one. Which one wins is a matter of charge redefinition so we can speak of the universe as made of electrons and protons until nucleosynthesis begins. But to organize these superons to make the asymmetric matter in the early universe is not as straightforward as writing (0.3). We propose a heuristic model how this may happen.

Starting from their creation time, superons of all charge states are evenly distributed all over the primordial universe. Consider twelve superons, like in (0.3), as an example. Within the model assumption, twelve superons form four groups of three superons[2]. All these are leptonic, radiation or mixed quark-

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

lepton states. These include $uude^-$ (pe^-), $ude^-\nu$ (β-decay) and free u and d quarks for nucleon formation for time $t > 10^{-6}$s. Other groups of twelve superons are $\bar{d}\bar{d}\bar{d}e^-$, $\bar{d}d\bar{d}d$, $\nu\nu e^+e^-$ and $\nu\nu\nu\nu$. These cases provide photons and neutrinos.

Superons in one region of the universe can form one or more quarks and leptons with charges like in uud and e^-, or (0.3) first line. But in other regions of the universe the *same* superon states may combine differently forming a $\bar{u}\bar{u}\bar{d}$ and e^+, or $\bar{p}$ e^+ pair. The matter-antimatter symmetry prevails unless the volume of proton-electron regions is larger than the volume of antiproton-positron regions (or vice versa). Compared to the standard model, or other field theory, the advantage of the present scenario is that the global H and $\bar{H}$ abundances need not be the same.

Like charge superons have Coulomb repulsion between them. If the knot model is taken to be a physical model of structure of matter, as we are apt to try, the electric charge appears in a trefoil line crossing and the binding of the superons is due to rotation charge sharing [4].

Statistically $r_H = N_{\bar{H}}/N_H$ can vary between zero and ∞, the expectation value being $\langle r_H \rangle = 1$. This 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. 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 $r_B \sim 10^{-10}$ for nucleosynthesis to proceed. It ensures that nucleons collide and react properly to produce the observed abundances of the three lightest elements. So there must be in the early universe one part per ten billion more baryons than antibaryons. The present scenario explains how the $r_B \neq 1$ ratio can be obtained but it does not predict its numerical value.

The major difference with our scenario and the standard model of cosmology is that at temperatures above Λ_{cr}, like during inflation, the effective fields are the free fields described by the superon model. When the temperature decreases below Λ_{cr} superon containing universe enters the standard model phase. The strong and weak non-Abelian gauge interactions begin to operate between the three superon composite states, 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 would be small.

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

$$T_R \sim \left(90/N_{DF}\pi^2\right)^{1/4} \sqrt{M_{\rm Pl}\Gamma_{tot}} \tag{0.4}$$

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 $N_{DF}^{sup} = 23$ as compared to the standard model

$N_{DF}^{SM} = 106.75$ of particles. The superon model value of N_{DF} has experimental support from the Starobinsky potential (though not a bounce model) with $N_{DF} = 20.58$ in [11], where several inflationary potentials are tested. The result can be considered indicative of generic models with $N_{DF} \ll 100$.

Conclusions. The key result of the present note is that unbroken supersymmetry is in harmony with the general experimental situation: all the necessary fundamental fields and their superpartners are in the basic supermultiplets to begin with. Baryons and leptons are treated in a unified way in terms of superons. Below Λ_{cr} this scenario is physically equivalent to the standard models of particles and cosmology. Above Λ_{cr} our scenario has fewer degrees of freedom, which in turn makes the asymmetry possible without C- or CP-violation. A ratio $r_B = (N_{\rm B} - N_{\bar{\rm B}})/N_{\rm photons} \neq 1$ is predicted in the scenario but its numerical value could not be given.

Acknowledgemet

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