A Wess-Zumino Scenario for Visible and Dark Matter with Matter-antimatter Asymmetry

Risto Raitio*
02230 Espoo, Finland

October 21, 2020

Abstract

We extend a previous Wess-Zumino Lagrangian inspired preon model of visible matter to include the dark sector with both bosonic and fermionic fields. The bosonic sector is assumed to be axion-like particles. They candidates for both dark matter and dark energy depending on the axion masses. A compatible supergravity model is cited for inflation. We propose a novel mechanism for the creation of the matter-antimatter asymmetric universe. Dark matter consists mainly (some 90%) of bosonic particles and e.g. primordial black holes and the rest is fermionic particles or celestial bodies. Dark matter is more smoothly distributed in the universe than visible matter.

PACS 98.80.Cq, 12.60.Rc

Keywords: Standard Model and Beyond, Supersymmetry, Preons, Dark Matter, Inflation, Baryon and Lepton Genesis

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

Contents

1 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 dark matter (DM) and matter-antimatter asymmetry issue. Our main clue is supersymmetry which we suppose to be unbroken. The experimental situation in the search of the SM superpartners indicates, in our opinion, that the standard model is not supersymmetric.

This note is based on our earlier work on supersymmetric preons [1, 2] which only have global quantum numbers that are not eaten by black holes. Following Finkelstein [3, 4, 5] we extended our scenario to include the symmetry group *SLq(2)* [2], which has preons and SM fermions in its $j = \frac{1}{2}$ and $\frac{3}{2}$ representations, respectively. Both scenarios agree physically with the standard model. Harari [6] and Shupe [7] have also proposed preon models of this type. All four models are physically equivalent with each other and the standard model but their preon symmetries are different from ours.

The purpose of this note is to (i) introduce candidates for dark matter and dark energy that follow from the Wess-Zumino model (WZ) [8], and (ii) propose a matter-antimatter asymmetric genesis in the preon scenario. The asymmetry is possible without C or CP violation specifically due to preon level processes. A WZ derived no-scale mini supergravity model for inflation, presented in the literature, is a natural choice within our scheme. Until a proper symmetry or dynamics is found the Lagrangian is is written as a sum of three similar terms, one for each generation of quarks and leptons.

The article is organized as follows. In section 2 we summarize briefly the setup of our preon scenario, which turned out to be quite similar to the global supersymmetry model of Wess and Zumino. In the WZ Lagrangian, the pseudoscalar and its superpartners are assumed to be the dark sector, which is considered in section 3. Dark particles participate inflation as spectator fields yielding candidates for cold dark matter and dark energy. Standard model matter is produced in reheating by coupling to the inflaton in a no-scale WZ supergravity model, with hints from string theory, as described in section 4. In section 5 the scenario for the creation of matter-antimatter asymmetric universe by charge symmetric preons is proposed. The idea behind the asymmetry is that the *same* twelve C symmetric preons may form both matter and antimatter (but not simultaneously), see (5.1). In section 6 the total Lagrangian with three generations is presented. Conclusions are given in section 7. - The original contributions of this author are the supersymmetric preon (superon) scenario for the visible and dark sector particles, and the mechanism for producing the asymmetric universe. The inflationary model potential and the axions are adopted from the literature. Our purpose is to present in a mini review a coherent physical picture of the Wess-Zumino based model for fundamental particles and the cosmological inflation.

2 Superon scenario

We briefly recap the superon scenario of [1, 2], which turned out to have close resemblance to the simplest N=1 globally supersymmetric 4D model, namely the free, massless Wess-Zumino model [8, 9] with the kinetic Lagrangian including three neutral fields

$$\mathcal{L}_{\rm WZ} = -\frac{1}{2}\bar{m}\partial\!\!\!/ m - \frac{1}{2}(\partial s)^2 - \frac{1}{2}(\partial p)^2 \tag{2.1}$$

where m is a Majorana spinor, the scalar s and pseudoscalar p are real fields (metric is mostly plus). The scalars can be written in complex form $s + ip = S\exp^{i\theta}$.

We assume that the pseudoscalar p is the axion [10], and denote it below as a. It has a fermionic superparther, the axino n, and a bosonic superpartner, the saxion s^0.

In order to have visible matter we assume the following charged chiral field Lagrangian

$$\mathcal{L}_{-} = -\frac{1}{2}m^{-}\partial\!\!\!/ m^{-} - \frac{1}{2}(\partial s_i^{-})^2, \quad i = 1, 2 \tag{2.2}$$

The first generation standard model particles are formed combinatorially (mod 3) of three superons, one charged $m^{\pm}$, with charge $\pm\frac{1}{3}$, and one neutral m^0, as composite states below an energy scale Λ_{cr} [2], see lower part of Table 1.[1] Second and third generation particles are discussed in section 6.

Confinement of superons within quarks and leptons can be caused by an attractive gravity-like intense interaction (yet to be defined), or by rotation

[1]The indexes in table 1 look, and are, color indexes but no $j \propto M^2$ excitations are known.

charge sharing [4]. The deconfnement temperature Λ_{cr} is in principle calculable but at present it is accepted as a free parameter. Numerically $\Lambda_{cr} \sim 10^{10-16}$ GeV, close to the temperature at the beginning of inflation. The R-parity in the scenario is simply $P_R = (-1)^{2\times spin}$.

The detailed interactions for superons are an open question in our scenario at the moment. The needed would require extending the Lagrangians (2.1) and (2.2) to full local supersymmetry, which is a task for the future. In section 4 we discuss a boson sector interaction potential for inflation within a mini supergravity model.

3 Dark Matter

For a general introduction to dark matter, see e.g. [13]. Here we start from the Lagrangian (2.1). Literature on dark matter, dark energy, and axions is extensive, see e.g. [14, 15, 16, 17] (we recommend the first of these for an extensive discussion, with references and figures). In this section we patch our failure to consider the pseudoscalar of (2.1) in [2].

The supperpartners of the axion a are the fermionic axino n, and the scalar saxion s^0, as indicated in Table 1.[2] Dark matter consists of all these three particles. The axino n may appear physically as single particle or three n composite o gas, or a large astronomical object. The fermionic DM behaves naturally very differently from bosonic DM, which may be dust, gas or Bose-Einstein condensate.

Other candidate forms of DM include primordial black holes (PBH). They can be produced by gravitational instabilities induced from scalar fields such as axion-like particles or multi-field inflation. It is shown in [19] that PBH DM can be produced only in range of 10^{-15} or 10^{-12} of the Solar mass (2×10^{30} kg). Dark photons opens a rich phenomenology described [20]. We also mention another supergravity (with the graviton-gravitino supermultiplet) based model [21], which may help to relieve the observed Hubble tension [22].

Table 1: Superon content of Dark Matter and the Standard Model particles.

Dark Matter	Superon state
boson(system)	axion, s^0
o	$\epsilon_{ijk} n_i n_j n_k$
SM Matter	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	$\epsilon_{ijk} m_i^0 m_j^0 m_k^0$

[2]In this note we mostly talk about all spin zero particles freely as scalars.

The axion was originally introduced to solve the strong CP problem in quantum chromodynamics (QCD) [10]. Axions, or axion-like particles (ALP), occur also in string theory in large numbers (in the hundreds), they form the axiverse. The axion masses extend over many orders of magnitude making distinct candidate components of dark matter. Ultra-light axions (ULA), with masses 10^{-33} eV $< M_a < 10^{-20}$ eV, roll slowly during inflation and behave like dark energy before beginning to oscillate (as we see below). The lightest ULAs with $M_a \lessapprox 10^{-32}$ are indistinguishable from dark energy. Higher mass ALPs, $M_a \gtrapprox 10^{-25.5}$ eV behave like cold dark matter [14].

The fermionic axino n is supposed to appear, like the m superons, as free particle above $T > \Lambda_{cr}$ and below Λ_{cr} in composite states. If the mass of the axino composite state o is closer to the electron mass rather than the neutrino mass it may form 'lifeless' dark stars in a wide mass range. These are not distributed quite like ordinary stars in the universe if they are spectators during inflation as discussed in section 4.

The bosonic objects axion a and saxion s^0 may form very interesting objects. The masses of these bosonic objects, and possible other axion-like particles (ALPs), may vary from the MeV scale down to $M_H \sim 10^{-33}$ eV, roughly the Hubble scale. Ultra-light bosons with masses $\ll$ eV can form macroscopic systems like Bose-Einstein condensates, such as axion stars [11, 12]. Due to the small mass the occupation numbers of these objects are large, and consequently, they can be described classically. These boson fields of mass of the order of 10^{-22} eV are a strong candidate for cold dark matter. Quantum mechanically, their Compton wavelength is of the order of 10^{16} m.

Axions are treated in this section as spectator fields during inflation [15, 16, 17].[3] The axion is massless as long as non-perturbative effects are absent. When these effects are turned on the PQ symmetry is broken and the axion acquires a mass. A minimally coupled scalar field in General Relativity has an action

$$S = \int d^4x\sqrt{-g}\Big[-\frac{1}{2}(\partial\phi)^2 - V(\phi)\Big] \tag{3.1}$$

In the Friedmann-Lemaitre-Robertson-Walker metric with potential $V = \frac{1}{2}M_a^2\phi^2$ [4] the axion equation of motion is

$$\ddot{\phi}_0 + 2\mathcal{H}\dot{\phi}_0 + M_a^2 a^2\phi_0 = 0 \tag{3.2}$$

where ϕ_0 is the homogeneous value of the scalar field as a function of the conformal time τ, a is here the cosmological scale factor, and dots denote derivatives with respect to conformal time.

At early time t_i $M_a \ll H$ and the axion rolls slowly. If the initial velocity is zero it has equation of state $w_a \equiv P_a/\rho_a \simeq -1$. Consequently the axion is a

[3] On the other hand, the axion can cause the inflation as well [18].

[4] This is an adequate approximation over most of the parameter space observationally allowed provided $f_a < M_{\rm Pl}$. The potential is anyway unknown away from the minimum without a model for nonperturbative effects.

component of dark energy. With $t > t_i$ the temperature and H decrease and the axion field begins oscillate coherently at the bottom of the potential. This happens when

$$M_a = 3H(a_{osc}) \tag{3.3}$$

which defines the scale factor a_{osc}. Now the number of axions is roughly constant and the axion energy density redshifts like matter with $\rho_a \propto a^{-3}$. The relic density parameter Ω_a is

$$\Omega_a = \left[\frac{1}{2a^2}\dot{\phi}_0^2 + \frac{M^2 a}{2}\phi_0^2\right]_{M_a^2=3H} a_{osc}^3/\rho_{crit} \tag{3.4}$$

where ρ_{crit} is the cosmological critical density today. Explicit estimates for the relic density are given in [14]. This applies to all axion-like particles, if there are many like in string theory.

When radiation and matter match in ΛCDM the Hubble rate is $H(a_{eq}) \sim 10^{-28}$ eV. Axions with mass larger than 10^{-28} eV begin to oscillate in the radiation era and may provide for even all of dark matter. The upper limit of the ultralight axion mass fraction Ω_a/Ω_{DM}, where Ω_a is the axion relic density and Ω_{DM} is the total DM energy density parameter, varies from 0.6 in the low mas end 10^{-33} eV to 1.0 in the high mass limit 10^{-24} eV. In the middle region Ω_a/Ω_{DM} is constrained to be below about 0.05 [14].

The dark fermions may be at this stage be approximated as fermion-antifermion pairs. Their behavior would follow that of scalar particles.

4 Inflation and Supergravity

This section is a brief review of work done by other authors. It is included because CMB measurements offer data of inflation in the relevant energy region for testing of supergravity.

At the beginning of inflation, $t = t_i \sim 10^{-36}$ s, the universe is modeled by gravity and a scalar inflaton with some potential $V(\phi)$. The Einstein-Hilbert action is

$$S = \int d^4x\sqrt{-g}\Big(\frac{1}{2}R - \frac{1}{2}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi - V(\phi)\Big) \tag{4.1}$$

Inflation ends at $t_R \approx 10^{-32}$ s when the inflaton, which is actually coherently oscillating homogeneous field, a Bose condensate, reaches the minimum of its potential. There it oscillates and decays by coupling to particles produced during inflation, as described in section 5. This causes the reheating phase, or the Bang.

The CMB measurements of inflation can be well described by a few simple slow-roll single scalar potentials in (4.1). One of the best fits to Planck data [23] is obtained by one of the very oldest models, the Starobinsky model [24]. The action is

$$S = \frac{1}{2}\int d^4x\sqrt{-g}\Big(R + \frac{R^2}{6M^2}\Big) \tag{4.2}$$

where $M \ll M_{\rm Pl}$ is a mass scale. Current CMB measurements indicate scale invariant spectrum with a small tilt in scalar density $n_s = 0.965 \pm 0.004$ and an upper limit for tensor-to-scalar ratio $r < 0.06$. These values are fully consistent with the Starobinsky model (4.2) which predicts $r \simeq 0.003$.

The model (4.2) has the virtue of being based on gravity only physics. Furthermore, the Starobinsky model has been shown to correspond to no-scale supergravity coupled to two chiral supermultiplets. Some obstacles have to be sorted out before reaching supergravity. In this section we follow the review by Ellis, García, Nagata, Nanopoulos, Olive and Verner [25].

The first problem with generic supergravity models with matter fields is that their effective potentials do not provide slow-roll inflation as needed. Secondly, they may have anti-deSitter vacua instead of deSitter ones. Thirdly, looking into the future, any new model of particles and inflation should preferably be consistent with some string model properties. These problems can be overcome by no-scale supergravity models. No-scale property comes from their effective potentials having flat directions without specific dynamical scale at the tree level. This has been derived from string models, whose low energy effective theory supergravity is.

Other authors have studied the implications of superstring theory to inflationary model building focusing on scalar fields in curved spacetime [18] and the swampland criteria [26, 27, 28]. These studies point out the inadequacy of (slow roll) single field inflation. We find it important to first establish a connection between the Starobinsky model and supergravity

The bosonic supergravity Lagrangian includes a Hermitian function of complex chiral scalar fields ϕ_i which is called the Kähler potential $K(\phi^i, \phi^*_j)$. It describes the geometry of the model. In minimal supergravity (mSUGRA) $K = \phi^i \phi^*_i$. Secondly the Lagrangian includes a holomorphic function called the superpotential $W(\phi^i)$. This gives the interactions among the fields ϕ^i and their fermionic partners. K and W can be combined into a function $G \equiv K + \ln|W|^2$. The bosonic Lagrangian is of the form

$$\mathcal{L} = -\frac{1}{2}R + K^j_i \partial_\mu \phi^i \partial^\mu \phi^*_j - V - \frac{1}{4}{\rm Re}({\rm f}_{\alpha\beta}){\rm F}^\alpha_{\mu\nu}{\rm F}^{\beta\mu\nu} - \frac{1}{4}{\rm Im}({\rm f}_{\alpha\beta}){\rm F}^\alpha_{\mu\nu}\tilde{\rm F}^{\beta\mu\nu} \quad (4.3)$$

where $K^j_i \equiv \partial^2 K/\partial\phi^i \partial\phi^*_j$ and ${\rm Im}({\rm f}_{\alpha\beta})$ is the gauge kinetic function of the chiral fields ϕ^i. In mSUGRA the effective potential is

$$V(\phi^i, \phi^*_j) = e^K \left[|W_i + \phi^*_i W|^2 - 3|W|^2\right] \quad (4.4)$$

where $W_i \equiv \partial W/\partial\phi^i$. It is seen in (4.4) that the last term with negative sign may generate AdS holes with depth $-\mathcal{O}(m^2_{3/2} M^2_{\rm Pl})$ and cosmological instability. Solution to this and the slow-roll problem is provided by no-scale supergravity models. The simplest such model is the single field case with

$$K = -3\ln(T + T^*) \quad (4.5)$$

where T is a volume modulus in a string compactification. Now the the Lagrangian (4.3) becomes as

$$\mathcal{L} = \frac{3}{(T+T^*)^2}\partial^\mu T \partial_\mu T^* = \frac{1}{12}(\partial_\mu K)^2 + \frac{3}{4}e^{2K/3}|\partial_\mu (T-T^*)|^2 \tag{4.6}$$

The single field (4.5) model can be generalized to include matter fields ϕ^i with the followng Kähler potential

$$K = -3\ln(T+T^* - \frac{1}{3}|\phi_i|^2) \tag{4.7}$$

The corresponding Lagrangian is

$$\mathcal{L} = \frac{1}{12}(\partial_\mu K)^2 + e^{K/3}|\partial_\mu \phi^i|^2 + \frac{3}{4}e^{2K/3}|\partial_\mu (T-T^*) + \frac{1}{3}(\phi_i^* \partial_\mu \phi^i - \phi^i \partial_\mu \phi_i^*)|^2 - V \tag{4.8}$$

where

$$V = e^{2K/3}V' = \frac{V'}{\left((T+T^*) - |\phi^i|^2/3\right)^2} \tag{4.9}$$

and

$$V' \equiv |W_i|^2 + \frac{1}{3}(T+T^*)|W_T|^2 + \frac{1}{3}\left(W_T(\phi_i^* W^{*i} - 3W^*) + h.c.\right) \tag{4.10}$$

The no-scale Starobinsky model is now obtained with some extra work from the scalar potential (4.9) and (4.10) with two fields taking ϕ as the inflaton and assuming $\langle T \rangle = \frac{1}{2}$. For the superpotential the Wess-Zumino form is introduced [29]

$$W = \frac{1}{2}M\phi^2 - \frac{1}{3}\lambda\phi^3 \tag{4.11}$$

which is a function of ϕ only. Then $W_T = 0$ and from (4.10) $V' = |W_\phi|^2$ and the potential becomes as

$$V(\phi) = M^2 \frac{|\phi|^2 |1 - \lambda\phi/M|^2}{(1 - |\phi|^2/3)^2} \tag{4.12}$$

The kinetic terms in (4.8) can be written now

$$\mathcal{L} = (\partial_\mu \phi^*, \partial_\mu T^*)\Big(\frac{3}{(T+T^* - |\phi|^2/3)^2}\Big)\begin{pmatrix} (T+T^*)/3 & -\phi/3 \\ -\phi^*/3 & 1 \end{pmatrix}\begin{pmatrix} \partial^\mu \phi \\ \partial^\mu T \end{pmatrix} \tag{4.13}$$

Fixing T to some alue one can define the canonically normalized field χ

$$\chi \equiv \sqrt{3}\tanh^{-1}\left(\frac{\phi}{\sqrt{3}}\right) \tag{4.14}$$

By analyzing the real and imaginary parts of χ one finds that the potential (4.12) reaches its minimum for $\mathrm{Im}\chi = 0$. $\mathrm{Re}\chi$ is of the same form as the

Starobinsky potential in conformally transformed Einstein-Hilbert action [30] with a potential of the form $V = \frac{3}{4}M^2(1 - e^{-\sqrt{2/3}\phi})^2$. when

$$\lambda = \frac{M}{\sqrt{3}} \tag{4.15}$$

Most interestingly, λ/M has to be very accurately $1/\sqrt{3}$, better than one part in 10^{-4}, for the potential to agree with measurements.

5 Matter-Antimatter 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

$$\begin{aligned} p + e^- &:= u^{2/3} + u^{2/3} + d^{-1/3} + e^- \\ &:= \sum_{l=1}^{4} \left[m_l^+ + m_l^- + m_l^0\right] =: \bar{p} + e^+ \end{aligned} \tag{5.1}$$

where the superscript is the charge of the particle and $\pm$ indicates charge ± 1. It follows from (5.1) 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 conserve neither B nor L.

In this scenario superons are created as spectator fields when inflation starts and the metric still has significant quantum fluctuations. There is small but non-zero probability for three m^- superons to spontaneously form an electron at time $t \gtrapprox t_i$. This formation has interesting consequences if there is some asymmetry in spacetime like one caused by torsion which leads to a difference in fermion, like superon, masses. The torsional correction to a fermion mass is $M_t = M + a/M_{\text{Pl}}^2$ where $a \propto 1$ [31]. For an antifermion the correction term is negative. In the environment at $t \sim t_i$ this mass difference needs not be small. The heavier superon is expected to create subtle order and cause movement of the lighter superons in spacetime towards it. It generates a small correlation length λ_{cor}, and a corresponding 3D volume, within which different superon charge states are differentiated. Therefore when three m^- superons are about to form an electron the correlated region contains antifermions m^+ and m^0 which in turn form u and d quarks.

Inflation is advanced by the potential (4.11). During inflation the length scale λ_{cor}, and the corresponding volume, expand exponentially causing, in the first approximation, only matter production inside it by repeating the same mechanism of the heavier m^- superons (electrons) correlating with the lighter m^+ and m^0 superons (quarks). The inflaton decay takes place after the inflaton has reached the minimum of its potential and it couples to the quarks and leptons while vibrating in its ground state causing reheating. The SM particles have now no antiparticles to annihilate with. Without further interactions we have $r_B \approx 0$. The expansion, reheating and all the later processes ultimately produce what we see as the observed universe.[5]

We expect roughly twice as much visible matter from the m^+ and m^0 than fermionic dark matter from the n. The fraction of n of all matter today is about 2.5%. Therefore there should be about ten times more bosonic dark matter and e.g. primordial black holes than fermionic dark matter. All dark matter is more smoothly distributed in the universe because they were spectators during inflation and remained so after the Bang of visible matter.

When inflation started the first formed three superon state could be any composite state in table 1. Our universe was built up originally around an electron. A universe inflating around a positron will form a universe with anti-matter only. These two types of universes dominate during very early inflation when matter density is high enough for torsion to appear. Thirdly, there are radiation dominated visible matter universes from annihilating leptons (e^-, ν), quarks (u, d) and their antiparticles. As a result of superons being created in huge numbers there is a multitude of each type of these three universes. This can be called a *tripleverse* scenario of the universe predicted by the Wess-Zumino supergravity.

6 Three Generations of Quarks and Leptons

It is known that the number of quark colors is three, we provided arguments for the tripleverse and may be we need three or more) axions for model building. Consequently, it is tempting to extend the multi-idea to the Lagraingian $\mathcal{L} = \mathcal{L}_{\mathrm{WZ}} + \mathcal{L}_-$ and propose one $\mathcal{L}_i$ for each generation of quarks and leptons

$$\mathcal{L} = \sum_{i=1,2,3} \mathcal{L}_i \tag{6.1}$$

where the first term denotes the (u, d, e^-, ν), the second the (c, s, μ, ν_μ) and the third the (t, b, τ, ν_τ) generation standard model particles. Each SM particle should have its own Higgs doublet from its $\mathcal{L}_i$. A better idea would be that the three generations, differing only in mass, form a group or other mathematical structure (like spin and charge do).

The author has the (unorthodox) hunch that the present superstring theory in ten dimensions may be too voluminous in the extra dimensions. Is there some symmetry which would reduce the dimensions, or project out physical content from the full string theory? Tentatively, we propose a scenario for this in the form (6.1).

[5]This idea of λ_{cor} growing exponentially was suggested to us by R. Brandenberger.

7 Conclusions

The present scenario is a bottom up approach to particle structure beyond the standard model. By splitting the standard model fermions into three constituents it has been possible to define a scenario for visible matter. Taking advantage of the preonic level structure of matter, indicated in (5.1), we have found a mechanism which makes it possible to create matter-antimatter asymmetric universe from C symmetric superons. The Lagrangian $\mathcal{L}_{\rm WZ}$ (2.1) includes a bosonic sector which provides for axion-like particles. They are promising candidates for dark matter if $M_a \gtrapprox 10^{-25.5}$ eV and dark energy if $M_a \lessapprox 10^{-32}$.

In the bosonic sector of the WZ model a natural model for supergravity potential for inflation is adopted from literature, which gives an excellent fit to CMB data. The scenario uses some of hints from string theory.

In a nutshell, starting from the Wess-Zumino Lagrangian (2.1) we propose a unified picture of quarks, leptons, dark sector and the early inflationary period of the creation of the asymmetric universe. It may cover a huge energy range: up to over fifty orders of magnitude. To prove or disprove the scenario presented above, more detailed Lagrangians have to be written and much phenomenological work is to be carried out with current data while waiting for more precision experiments to be carried out in the years to come. A crucial next step is to find the mathematics of gluing the fermionic superons back into standard model particles.

Acknowledgemet

I thank Robert Brandenberger for advice about inflationary processes. All errors are naturally on my responsibility.

References

[1] Risto Raitio, A Model of Lepton and Quark Structure. Physica Scripta, 22, 197 (1980). PS22,197, viXra:1903.0224 [6]

[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

[6]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.

[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] Robert Finkelstein, A Possible Relation Between the Magnetic Pole and the Gravitational Field. arXiv:2005.04003

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

[9] Jose Figueroa-O'Farrill, BUSSTEPP Lectures on Supersymmetry, Lectures delivered at the 30th and 31st British Universities Summer Schools in Theoretical Elementary Particle Physics (BUSSTEPP) held in Oxford 2000 and in Manchester in 2001. arXiv:hep-th/0109172

[10] Roberto D. Peccei and Helen R. Quinn, CP Conservation in the Presence of Pseudoparticles, Phys. Rev. Lett. 38 (25) 1440–1443 (1977).

[11] Davide Guerra, Caio F. B. Macedo, and Paolo Pani, Axion boson stars, JCAP 09 (2019) 061. arXiv:1909.05515

[12] Lorenzo Annulli, Vitor Cardoso, Rodrigo Vicente, Stirred and shaken: dynamical behavior of boson stars and dark matter cores. arXiv:2007.03700

[13] S. Profumo, L. Giani, and O. F. Piattella, An Introduction to Particle Dark Matter. Lectures delivered by S. Profumo at the Third José Plínio Baptista School on Cosmology, September 2016 arXiv:1910.05610

[14] Renée Hlozek, Daniel Grin, David J. E. Marsh, and Pedro G. Ferreira, A search for ultralight axions using precision cosmological data, Phys. Rev. D 91, 103512 (2015) arXiv:1410.2896

[15] David J. E. Marsh, Axions and ALPs: a very short introduction, 13th Patras Workshop on Axions, WIMPs and WISPs, Thessaloniki, May 2017. arXiv:1712.03018

[16] David J. E. Marsh, Axion Cosmology, Physics Reports, Vol. 643 (2016). arXiv:1510.07633

[17] Howard Baer, Ki-Young Choi, Jihn E. Kim, Leszek Roszkowski, Dark matter production in the early Universe: beyond the thermal WIMP paradigm, Physics Reports 555 (2015) 1.

[18] Evan McDonough, Alan H. Guth, and David I. Kaiser, Nonminimal Couplings and the Forgotten Field of Axion Inflation. arXiv:2010.04179

[19] Yermek Aldabergenov, Andrea Addazi, and Sergei V. Ketov, Primordial black holes from modified supergravity. arXiv:2006.16641

[20] Pierre Fayet, The U boson, interpolating between a generalized dark photon or dark Z, an axial boson and an axionlike particle. arXiv:2010.04673

[21] Jonathan L. Feng, Arvind Rajaraman, and Fumihiro Takayama, Superweakly Interacting Massive Particles, Phys.Rev.Lett.91:011302,2003. arXiv:hep-ph/0302215

[22] Kyriakos Vattis, Savvas M. Koushiappasy, and Abraham Loeb, Late universe decaying dark matter can relieve the H_0 tension, Phys. Rev. D 99, 121302 (2019). arXiv:1903.06220

[23] N. Aghanim et al., Planck 2018 results. VI. Cosmological parameters. arXiv:1807.06209

[24] A. Starobinsky, A New Type of Isotropic Cosmological Models without Singularity, Phys. Lett. B, Vol. 91, 1 (1980) .

[25] John Ellis, Marcos A. G. García, Natsumi Nagata, Dimitri V. Nanopoulos, Keith A. Olive and Sarunas Verner, Building Models of Inflation in No-Scale Supergravity. Review submitted to IJMPD. arXiv:2009.01709

[26] T. D. Brennan, F. Carta and C. Vafa, The String Landscape, the Swampland, and the Missing Corner. arXiv:1711.00864

[27] Lavinia Heisenberg, Matthias Bartelmann, Robert Brandenberger, and Alexandre Refregier, Model Independent Analysis of Supernova Data, Dark Energy, Trans-Planckian Censorship and the Swampland. arXiv:2003.13283

[28] Weijie Jin, Robert Brandenberger, and Lavinia Heisenberg, Axion Monodromy Inflation, Trapping Mechanisms and the Swampland. arXiv:2010.04999

[29] John Ellis, Dimitri V. Nanopoulos, Keith A. Olive, No-Scale Supergravity Realization of the Starobinsky Model of Inflation, Phys. Rev. Lett. 111, 111301 (2013) arXiv:1305.1247

[30] K. S. Stelle, Gen. Rel. Grav. 9 (1978) 353; B. Whitt, Phys. Lett. 145B (1984) 176.

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