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# Dark Energy and Dark Matter as Relative Energy between Quarks in Nucleon

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## Abstract

Dark energy and dark matter in the universe are assigned to the positive and negative, respectively, "hidden" relative energies between the diquark and quark in nucleon in the scalar strong interaction hadron theory, SSI. The origin of the "darkness" is that quarks cannot be observed individually.

## Keywords

Relative Energy among Quarks, Scalar Strong Interaction Hadron Theory, Dark Energy, Dark Matter

## 1. Introduction

The mass-energy density of the dominant cosmic constituents averaged over the entire universe is [1]

$$\textit{Dark energy: Dark matter: Ordinary matter} \approx 68.3\%:26.8\%:4.9\% \qquad (1.1)$$

For the dark energy, there are various models: cosmological constant, quintessence, interacting dark energy… [1] ([2] pp. 497-500). For the dark matter, there are baryonic models and the more popular non-baryonic models: axions, neutrino with finite mass, WIMPs… ([3] pp. 123-125). None of them has any connection with any theory supported by laboratory measurements. The general consensus is that we do not what these dark constituents are.

The scalar strong interaction hadron theory SSI [4] [5], hereafter denoted by [I, II] has been relatively successful in accounting for low energy hadronic data. However, it contains "hidden", unobservable relative energies between the quarks. The physical role of these energies has been in general unknown.

The purpose of this paper is to show that the dark constituents in the universe can be identified as such "hidden" relative energies between quarks that condense into nucleons in the early universe.

## 2. Starting Wave Equations

The starting point is the SSI equations of motion for diquark-quark baryons ([6] (2.9)), [I, II (9.3.16)]. In these references, the quartet part in these equations has been separated off from their doublet or spin 1/2 part which reads [I, II (10.0.6)]:

$$\partial_I^{a\dot{b}}\partial_{II}^{\dot{f}e}\partial_I^{e\dot{f}}\chi_{0\dot{b}}\left(x_I,x_{II}\right)=-i2\left(M_b^3+\Phi_b\left(x_I,x_{II}\right)\right)\psi_0^a\left(x_I,x_{II}\right) \tag{2.1a}$$

$$\partial_{I\dot{b}c}\partial_{II\dot{e}h}\partial_{I\dot{h}e}\psi_0^c\left(x_I,x_{II}\right)=-i2\left(M_b^3+\Phi_b\left(x_I,x_{II}\right)\right)\chi_{0\dot{b}}\left(x_I,x_{II}\right) \tag{2.1b}$$

Here, $x_I$ is the coordinate of the diquark, $x_{II}$ that of the quark, $\partial_I=\partial/\partial x_I\cdots$, and $\chi_0$ and $\psi_0$ the wave functions of the doublet baryons. The undotted and dotted spinor indices $a$, $b$, $e$… run from 1 to 2, $2M_b$ is the sum of the quark masses and $\Phi_b$ the strong diquark-quark interaction potential.

## 3. Laboratory and Relative Spaces

Since quarks cannot be observed, their coordinate spaces are converted into an observable laboratory space $X^\mu$ for the baryon and a relative space $x$ between the diquark and the quark via the linear transformation given above ([7] (6.2)) or by ([6] (5.1)), [I, II (3.1.3a)]

$$x^\mu=x_{II}^\mu-x_I^\mu,\ \ X^\mu=\left(1-a_m\right)x_I^\mu+a_m x_{II}^\mu \tag{3.1}$$

For observable particles, $a_m$ is often determined by that $X^\mu$ is the center of mass of these particles. If these particles have equal mass, $a_m$ = 1/2. Such kind of determination cannot be done here because quarks are not observable individually. $a_m$ has been taken to be an arbitrary real constant and represents a new degree of freedom which underlies the present assignments of the dark constituents in §5-6 below.

The relative space $x = (x^0, \underline{x})$ is "hidden" [I, II (3.1.3)] and cannot be observed. If it were observable, then (3.1), with a given $a_m$, leads to that both the diquark at $x_I$ and quark at $x_{II}$ can be seen, contrary to experience. This can also be seen directly in the first of (3.1) in which the right side members cannot be measured; hence $x^\mu$ is also "hidden", independent of $a_m$. Nevertheless, the bulk of hadron physics in SSI lies in such "hidden" spaces.

The baryon wave functions in (2.1) are factorized into the form of [I, II (10.1.1)],

$$\begin{aligned}\chi_{0\dot{b}}\left(x_I,x_{II}\right)&=\chi_{0\dot{b}}\left(\underline{x}\right)\exp\left(-iK_\mu X^\mu+i\omega_K x^0\right)\\ \psi_0^a\left(x_I,x_{II}\right)&=\psi_0^a\left(\underline{x}\right)\exp\left(-iK_\mu X^\mu+i\omega_K x^0\right)\end{aligned} \tag{3.2}$$

$$K_\mu=\left(E_K,-\underline{K}\right)\ \ \text{[I,II (3.1.6)]} \tag{3.3}$$

where $E_K$ is the energy of the baryon and $\underline{K}$ its momentum. $x^0$ is the relative time and $-\omega_K$ the associated relative energy in the "hidden" relative space and cannot be observed within SSI.

In spherical coordinates, $\underline{x} = (r, \theta, \phi)$ [I, II (3.1.7b)], the doublet wave functions in (3.2) with total angular momentum $j$ = 1/2 and orbital angular momentum $l$ = 0 read [I, II (10.2.3)]

$$\psi_0^1(\underline{x}) = g_0(r)Y_{00}(\theta,\varphi) + if_0(r)\sqrt{\frac{1}{3}}Y_{10}(\theta,\varphi),\quad \psi_0^2(\underline{x}) = if_0(r)\sqrt{\frac{2}{3}}Y_{11}(\theta,\varphi) \quad (3.4)$$

where the $Y$'s are the usual spherical harmonics. $\chi_{0\dot{a}}$ is found by changing the signs of $f_0(r)$ in (3.4).

## 4. Radial Wave Equations in Relative Space, Solutions and Results

Consider baryons at rest, $\underline{K} = 0$. $a_m = 1/2$ is set as in the meson case [I (3.5.7)], [II (5.7.2)]. Similarly, the "hidden" relative energy $-\omega_0 = 0$ is also set following the meson case [I (3.5.6)], [II (5.7.1)]. Insertion of (3.1-4) into (2.1) using [I, II (3.1.4)] leads to the radial wave equations ([6] (6.9)), [I, II (10.2.12)]

$$\left[\frac{E_{0d}^3}{8} + M_b^3 + \Phi_{bd}(r) + \frac{E_{0d}}{2}\Delta_0\right]g_0(r) + \left(\frac{E_{0d}^2}{4} + \Delta_0\right)\left(\frac{\partial}{\partial r} + \frac{2}{r}\right)f_0(r) = 0 \quad (4.1a)$$

$$\left[\frac{E_{0d}^3}{8} - M_b^3 - \Phi_{bd}(r) + \frac{E_{0d}}{2}\Delta_1\right]f_0(r) - \left(\frac{E_{0d}^2}{4} + \Delta_1\right)\frac{\partial}{\partial r}g_0(r) = 0 \quad (4.1b)$$

where the subscript $d$ denotes doublet and [I, II (10.2.2a)] gives the diquark-quark strong interaction potential

$$\Phi_{bd}(r) = \frac{d_b}{r} + d_{b0} + d_{b1}r + d_{b2}r^2 + d_{b4}r^4 \quad (4.2)$$

Here, the nonlinear potential $\Phi_{cd}(\underline{x})$ [I, II (10.2.2)] vanishes for large normalization volume $\Omega_{cb} \to \infty$ in [I, II (10.3.14)]. The $d_b$'s are unknown integration constants.

The two coupled third order equations (4.1) have been converted into six first order equations [I (10.7.5)], [II (10.4.5)] which have been treated numerically for the neutron in [I §11.1.1], [II §11.1.2]. Due to the large number of unknown $d_b$ constants, (4.1-2) could not be solved as a conventional eigenvalue problem. A less ambitious approach has been adopted; the known mass of the neutron is used as input and the $d_b$'s are adjusted such that $g_0(r)$ and $f_0(r)$ converge at large $r$. The so-obtained neutron wave functions are plotted in [I Figure 12.1], [II Figure 11.1b] and led to the nearly correct predictions of the neutron life and the electron asymmetry parameter $A$ or the neutrino asymmetry parameter $B$ [II Table 12.1] in its beta decay. These results support the basic correctness of SSI in the baryon sector.

## 5. "Hidden" Relative Energy, Dark Energy and Dark Matter

If $a_m = 1/2$ and $-\omega_0 = 0$ used in (4.1) were not assumed, (4.1) will be modified by

$$E_{0d} \to E_{0d} - 2E_{0d}\left[a_m - \frac{1}{2} - \frac{\omega_0}{E_{0d}}\right] \quad (5.1)$$

This relation leads to that $E_{0d}$, hence also (4.1), remain unchanged if the bracket in (5.1) vanishes or

$$a_m = \frac{1}{2} + \frac{\omega_0}{E_0} \quad (5.2)$$

which was first written down in 1993 in the basic SSI paper ([7] (6.6)) or [I, II (3.1.10a)] for mesons at rest, unaware of its present implication. This condition removes the dependence of the unknown relative energy $-\omega_0$ in the meson wave equations in the relative space [I, II (3.1.8)] as well as those in the baryon case mentioned beneath [I, II (10.1.1)].

The choice $a_m = 1/2$ and $-\omega_0 = 0$ in (4.1) is thus a special case of (5.2). Since $a_m$ can be any real constant in (3.1), the relative energy $-\omega_0$ in (5.2) also can become any real constant energy, albeit "hidden" or not observable within the framework of SSI.

The rest frame baryon energy $E_{0d}$ in (4.1) is the baryon mass, observable in SSI, and will behave as ordinary matter in external gravitational fields. The associated relative energy $-\omega_0$ appears next to, and is on the same footing with, $E_{0d}$ in (5.1) is however "hidden", not observable in SSI, but will similarly interact with external gravitational fields and is interpreted as dark energy, which is obtained if $a_m < 1/2$ is chosen in (5.2). If the associated relative energy $-\omega_0$ is negative, obtainable if $a_m > 1/2$ and also not observable within SSI, it will analogously interact with external gravitational fields and is assigned to represent dark matter, since it is expected to attract positive energy-matter.

The origin of the "darkness" is that quarks cannot be observed which led to (3.1).

## 6. Cosmological Implications

### 6.1. Dark Energy, Dark Matter and Formation of Nucleons

In the standard big bang model, hot quark-gluon plasma with fully relativistic $u$ and $d$ quarks was present when the universe was about 10 $\mu$s old ([2] §12.10). In SSI, this situation will be modified due to the much greater quark masses [I, II Table 5.2], Further, this plasma contains quarks only; gluons are not needed and appear later in hadrons formed by these quarks which then acquire "colors" or internal degrees of freedom characterized by internal coordinates $z_I$, $z_{II}$ and $z_{III}$ [I, II §2.3.2], [II Sec. 14.2-3]. As the universe expands and the density of this plasma drops to a *freeze-out* density, hadrons are formed, eventually preceded by formation of diquarks.

Each of the rest frame hadrons can have $a_m \neq 1/2$ in (3.1) and a relative energy $-\omega_0$ is thereby created via (5.2) and becomes dark energy or represents dark matter depending upon whether this energy is >0 or <0.

In a pion, the mass of its quark and antiquark are nearly the same. If the pion coordinate $X$ coincides with the quarks' center of mass, $a_m \approx 1/2$. If it coincides with the center of number of quarks, $a_m = 1/2$. In these cases, (5.2) produces little or no relative energy $-\omega_0$. However, $a_m \neq 1/2$ is allowed; then relative energy will be produced but will also vanish later when these pions decay into leptons or photons.

For a nucleon, the mass of its diquark is about twice that of its quark. Or, equivalently, the number of quarks in its diquark is twice that of its quark. This causes that the center of mass, or of number of quarks, if identified as the nucleon coordinate $X$, does not lie in the middle between the diquark and the quark but lies closer to the diquark than to the quark. This corresponds to a lower $a_m = 1/3$ which by (5.2) leads to a positive relative energy $-\omega_0 = E_{0d}/6$ which now persists because the proton does decay. Extrapolating this tendency, the dark energy assigned to this positive relative energy $-\omega_0 > 0$ should prevail over the dark matter with negative $-\omega_0 < 0$, in qualitative agreement with data (1.1). The dark energy and dark matter in (1.1) are as old as the nucleons in the universe.

If a nucleon with $a_m < 1/2$ (dark energy) and another nearby one with $a_m > 1/2$ (dark matter) were created simultaneously, the associated dark energy region will tend to expand outwards, leaving behind the associated dark matter region. This also agrees qualitatively with the observed dominance of dark energy in outer regions of the universe.

To reach the large ratios in (1.1), (5.2) yields $a_m \approx -13.4$ for nucleons contributing to the observed dark energy. Such nucleons lie $13.4 \times r$, where $r$ is the diquark-quark distance, from the diquark. For nucleons contributing to the observed dark matter, $a_m \approx 6$. Such nucleons lie $5 \times r$ from the diquark. Both types of nucleons thus lie far away from the both constituents of the nucleon. It is presently unknown why $a_m$ took such values.

By lowering the $a_m$ values further to still larger negative values, greater dark energies can be created. This provides a mechanism for the self regenerating universe ([2] §11.14). By choosing $a_m \to -\infty$ for even a single nucleon created in the early universe, the dark energy of the entire universe can in principle be generated. If $a_m \to -\infty$ were chosen, an infinitely strong "hidden" energy sink can also in principle be created by this single nucleon. If this nucleon happens to be in a black hole, it can perhaps cancel out the infinite mass density in this black hole and make it to behave like an object with finite mass density gravitationally, as has been observed. Here, care is needed because there are different kinds of infinities, as is exemplified in [I, II §7.5.4].

## 6.2. Nucleons in Motion

In general, nucleons are in motion and $\underline{K} \neq 0$ in §4. The presence of a given direction renders that variable separations in (3.4) as well as the radial equations (4.1) are no longer possible. This problem has thus not been treated in SSI.

If the "hidden" relative energy $-\omega_K \neq 0$ here, it will couple to $\underline{K} \neq 0$. Inserting (3.1-3) together with (5.2), with the subscript 0 replaced by $K$, into (2.1), leads to a set of equations that replace (4.1). The factors $(K\omega_K)^n$, where $n = 0, 1, 2, 3$, appear in these equations and partially characterize such couplings. Thus, an aggregate of nucleons with different $K$ values will produce a distribution of relative energies $-\omega_K$.

### 6.3. Relative Time and Energy in Mesons

The associated relative time $x^0$, also "hidden", can be integrated over to become a large constant $\int dx^0 = \tau_0 \to \infty$ which in the meson case enters [I, II (7.4.6b)] and generates the gauge boson mass $M_W$, rendering the Higgs boson superfluous.

Relative energies between quark and antiquark in mesons are usually very small. One relative energy between the $d$ and $\bar{s}$ quarks in neutral kaon $K^0$ has been estimated to be ≈30 eV [II (13.4.6)] in connection with *CP* violation considerations of the $\bar{K}^0 - K^0$ system. *CP* violation is commonly considered to be the cause of matter-antimatter asymmetry in the universe ([2] §12.12); it has been exemplified by that in the neutral kaon system ([2] §11.18).

## 7. Conclusions

The assignment of the dark constituents in the universe to the "hidden" relative energies between the diquark and quark in nucleons puts them to be in contact with a first principles' hadron theory SSI supported by data.

A nucleon with the arbitrary transformation constant $a_m$ in (3.1) chosen to be ≈1/2 behaves like ordinary matter, a nucleon with $a_m$ << 1/2 behaves like dark energy and a nucleon with $a_m$ >> 1/2 is interpreted to represent dark matter. Why $a_m$ takes on these different values is not known. How these different manifestations of such nucleons are eventually distributed in the universe has also not been investigated presently.

## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

## References

[1] Wikipedia (2019) Dark Energy.

[2] Harwit, M. (2006) Astrophysical Concepts. 4th Edition, Springer, Berlin.

[3] Longair, M.S. (2011) High Energy Astrophysics. 3rd Edition, Cambridge University Press, Cambridge

[4] Hoh, F.C. (2011) Scalar Strong Interaction Hadron Theory. Nova Science Publishers, Hauppauge, Denoted by I.

[5] Hoh, F.C. (2019) Scalar Strong Interaction Hadron Theory. II Nova Science Publishers, Hauppauge, Denoted by II.

[6] Hoh, F.C. (1994) *International Journal of Theoretical Physics*, **33**, 2125. https://doi.org/10.1007/BF00673960

[7] Hoh, F.C. (1993) *International Journal of Theoretical Physics*, **32**, 1111. https://doi.org/10.1007/BF00671793