On Emergent Physics, "Unparticles" and Exotic "Unmatter" States

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Emergent physics refers to the formation and evolution of collective patterns in systems that are nonlinear and out-of-equilibrium. This type of large-scale behavior often develops as a result of simple interactions at the component level and involves a dynamic interplay between order and randomness. On account of its universality, there are credible hints that emergence may play a leading role in the Tera-ElectronVolt (TeV) sector of particle physics. Following this path, we examine the possibility of hypothetical high-energy states that have fractional number of quanta per state and consist of arbitrary mixtures of particles and antiparticles. These states are similar to "un-particles", massless fields of non-integral scaling dimensions that were recently conjectured to emerge in the TeV sector of particle physics. They are also linked to "unmatter", exotic clusters of matter and antimatter introduced few years ago in the context of Neutrosophy.

1 Introduction

Quantum Field Theory (QFT) is a framework whose methods and ideas have found numerous applications in various domains, from particle physics and condensed matter to cosmology, statistical physics and critical phenomena [1, 2]. As successful synthesis of Quantum Mechanics and Special Relativity, QFT represents a collection of *equilibrium* field theories and forms the foundation for the Standard Model (SM), a body of knowledge that describes the behavior of all known particles and their interactions, except gravity. Many broken symmetries in QFT, such as violation of parity and CP invariance, are linked to either the electroweak interaction or the physics beyond SM [3–5]. This observation suggests that unitary evolution postulated by QFT no longer holds near or above the energy scale of electroweak interaction (≈ 300GeV) [6,7]. It also suggests that progress on the theoretical front requires a framework that can properly handle *non-unitary evolution* of phenomena beyond SM. We believe that fractional dynamics naturally fits this description. It operates with derivatives of non-integer order called *fractal operators* and is suitable for analyzing many complex processes with long-range interactions [6–9]. Building on the current understanding of fractal operators, we take the dimensional parameter of the regularization program $\varepsilon = 4-d$ to represent the order of fractional differentiation in physical space-time (alternatively, $\varepsilon = 1 - d$ in one-dimensional space) [10, 11]. It can be shown that ε is related to the reciprocal of the cutoff scale $\varepsilon \approx ({}^{\mu_0}/_{\Lambda})$, where μ_0 stands for a finite and arbitrary reference mass and Λ is the cutoff energy scale. Under these circumstances, ε may be thought as an infinitesimal parameter that can be continuously tuned and drives the departure from equilibrium. The approach to scale invariance demands that the choice of this parameter is completely arbitrary, as long as $\varepsilon \ll 1$. Full scale invariance and equilibrium field theory are asymptotically recovered in the limit of physical space-time ($d = 4$) as $\varepsilon \to 0$ or $\Lambda \to \infty$ [11, 12].

2 Definitions

We use below the Riemann-Liouville definition for the one-dimensional left and right fractal operators [13]. Consider for simplicity a space-independent scalar field $\varphi(t)$. Taking the time coordinate to be the representative variable, one writes

$$ {}_0D_L^{\alpha}\,\varphi(t) = \frac{1}{\Gamma(1-\alpha)}\frac{d}{dt}\int_0^t (t-\tau)^{-\alpha}\varphi(\tau)d\tau\,, \tag{1}$$

$$ {}_0D_R^{\alpha}\,\varphi(t) = \frac{1}{\Gamma(1-\alpha)}(-\frac{d}{dt})\int_t^0 (\tau-t)^{-\alpha}\varphi(\tau)d\tau\,. \tag{2}$$

Here, fractional dimension $0 < \alpha < 1$ denotes the order of fractional differentiation. In general, it can be shown that α is linearly dependent on the dimensionality of the space-time support [8]. By definition, α assumes a continuous spectrum of values on fractal supports [11].

3 Fractional dynamics and 'unparticle' physics

The classical Lagrangian for the free scalar field theory in 3+1 dimensions reads [1–2, 14]

$$ L = \partial^{\mu}\varphi\partial_{\mu}\varphi - m^2\varphi^2, \tag{3}$$

and yields the following expression for the field momentum

$$ \pi = \frac{\partial L}{\partial(\frac{\partial\varphi}{\partial t})} = \frac{\partial\varphi}{\partial t}\,. \tag{4}$$

It is known that the standard technique of canonical quantization promotes a classical field theory to a quantum field theory by converting the field and momentum variables into operators. To gain full physical insight with minimal complications in formalism, we work below in 0+1 dimensions. Ignoring the left/right labels for the time being, we define the field and momentum operators as

$$\varphi \to \widehat{\varphi} = \varphi \,, \tag{5}$$

$$\pi \to \widehat{\pi}^{\alpha} = -\, i \, \frac{\partial^{\alpha}}{\partial \left|\varphi\right|^{\alpha}} \equiv -iD^{\alpha}. \tag{6}$$

Without the loss of generality, we set $m = 1$ in (3). The Hamiltonian becomes

$$H \to \widehat{H}^{\alpha} = -\frac{1}{2}\, D^{2\alpha} + \frac{1}{2}\, \varphi^2 = \frac{1}{2}\left(\widehat{\pi}^{2\alpha} + \varphi^2\right). \tag{7}$$

By analogy with the standard treatment of harmonic oscillator in quantum mechanics, it is convenient to work with the destruction and creation operators defined through [1–2, 14]

$$\widehat{a}^{\alpha} \doteq \frac{1}{\sqrt{2}}\left[\widehat{\varphi} + i\widehat{\pi}^{\alpha}\right], \tag{8}$$

$$\widehat{a}^{+\alpha} \doteq \frac{1}{\sqrt{2}}\left[\widehat{\varphi} - i\,\widehat{\pi}^{\alpha}\right]. \tag{9}$$

Straightforward algebra shows that these operators satisfy the following commutation rules

$$\left[\widehat{a},\, \widehat{a}\right] = \left[\widehat{a}^{+\alpha},\, \widehat{a}^{+\alpha}\right] = 0\,, \tag{10}$$

$$\left[\widehat{a}^{+\alpha},\, \widehat{a}^{\alpha}\right] = i\left[\widehat{\varphi},\, \widehat{\pi}^{\alpha}\right] = -\alpha\,\widehat{\pi}^{(\alpha-1)}. \tag{11}$$

The second relation of these leads to

$$\widehat{H}^{\alpha} = \widehat{a}^{+\alpha}\,\widehat{a}^{\alpha} + \frac{1}{2}\,\alpha\widehat{\pi}^{(\alpha-1)}. \tag{12}$$

In the limit $\alpha = 1$ we recover the quantum mechanics of the harmonic oscillator, namely

$$\widehat{H} = \widehat{a}^{+}\widehat{a} + \frac{1}{2}\,. \tag{13}$$

It was shown in [6] that the fractional Hamiltonian (12) leads to a continuous spectrum of states having non-integer numbers of quanta per state. These unusual flavors of particles and antiparticles emerging as fractional objects were named “*complexons*”. Similar conclusions have recently surfaced in a number of papers where the possibility of a scale-invariant “hidden” sector of particle physics extending beyond SM has been investigated. A direct consequence of this setting is a continuous spectrum of massless fields having non-integral scaling dimensions called “un-particles”. The reader is directed to [15–21] for an in-depth discussion of “un-particle” physics.

4 Mixing properties of fractal operators

Left and *right* fractal operators (L/R) are natural analogues of *chiral* components associated with the structure of quantum fields [8, 9]. The goal of this section is to show that there is an inherent mixing of (L/R) operators induced by the fractional dynamics, as described below. An equivalent representation of (1) is given by

$${}_0D_L^{\alpha}\,\varphi(t) = \frac{1}{\Gamma(1-\alpha)}\left(-\frac{d}{dt}\right)\int\limits_t^0 \left[-(\tau-t)\right]^{-\alpha}\varphi(\tau)\,d\tau\,, \tag{14}$$

or

$$\begin{aligned} {}_0D_L^{\alpha}\,\varphi(t) \;&=\; \frac{(-1)^{-\alpha}}{\Gamma(1-\alpha)}\left(-\frac{d}{dt}\right)\int\limits_t^0 (\tau-t)^{-\alpha}\varphi(\tau)\,d\tau = \\ &=\; (-1)^{-\alpha}\,{}_0D_R^{\alpha}\,\varphi(t)\,, \end{aligned} \tag{15}$$

$${}_0D_R^{\alpha} = (-1)^{\alpha}\,{}_0D_L^{\alpha} = \exp(i\pi\alpha)\,{}_0D_L^{\alpha}\,. \tag{16}$$

Starting from (2) instead, we find

$${}_0D_L^{\alpha} = (-1)^{\alpha}\,{}_0D_R^{\alpha} = \exp(i\pi\alpha)\,{}_0D_R^{\alpha}\,. \tag{17}$$

Consider now the one-dimensional case $d = 1$, take $\alpha = \varepsilon = 1 - d$ and recall that continuous tuning of ε does not impact the physics as a consequence of scale invariance. Let us iterate (16) and (17) a finite number of times ($n \geqslant 1$) under the assumption that $n\varepsilon \ll 1$. It follows that the fractal operator of any infinitesimal order may be only defined up to an arbitrary dimensional factor $\exp(i\pi n\varepsilon) \approx 1+(i\pi n\varepsilon) = 1-i\tilde{\varepsilon}$, that is,

$${}_0D^{\varepsilon}_{L,R}\,\varphi(t) \approx \left[{}_0D^{0}_{L,R} - i\,\tilde{\varepsilon}\right]\varphi(t) \tag{18}$$

or

$$i\,{}_0D^{\varepsilon}_{L,R}\,\varphi(t) = \left[i\,{}_0D^{0}_{L,R} + \tilde{\varepsilon}\right]\varphi(t)\,, \tag{19}$$

where

$$\lim_{\varepsilon\to 0} D^{\varepsilon}_{L,R}\,\varphi(t) = \varphi(t)\,. \tag{20}$$

Relations (18–20) indicate that fractional dimension $\tilde{\varepsilon}$ induces: (a) a new type of mixing between chiral components of the field and (b) an ambiguity in the very definition of the field, fundamentally different from measurement uncertainties associated with Heisenberg principle. Both effects are *irreversible* (since fractional dynamics describes irreversible processes) and of *topological nature* (being based on the concept of continuous dimension). They do not have a counterpart in conventional QFT.

5 Emergence of “unmatter” states

Using the operator language of QFT and taking into account (6), (18) can be presented as

$$\widehat{\pi}^{\varepsilon}\varphi(t) = \widehat{\pi}^{\varepsilon}\varphi(t) - \tilde{\varepsilon}\widehat{\varphi}(t)\,. \tag{21}$$

Relation (21) shows that the fractional momentum operator $\widehat{\pi}^{\varepsilon}$ and the field operator $\widehat{\varphi}(t) = \varphi(t)$ are no longer independent entities but linearly coupled through fractional dimension $\widetilde{\varepsilon}$. From (11) it follows that the destruction and creation operators are also coupled to each other. As a result, particles and antiparticles can no longer exist as linearly independent objects. Because $\widetilde{\varepsilon}$ is continuous, they emerge as an *infinite spectrum of mixed states*. This surprising finding is counterintuitive as it does not have an equivalent in conventional QFT. Moreover, arbitrary mixtures of particles and antiparticles may be regarded as a manifestation of "unmatter", a concept launched in the context of Neutrosophic Logic [22–24].

6 Definition of unmatter

In short, unmatter is formed by matter and antimatter that bind together [23, 24].

The building blocks (most elementary particles known today) are 6 quarks and 6 leptons; their 12 antiparticles also exist.

Then *unmatter* will be formed by at least a building block and at least an antibuilding block which can bind together.

Let's start from neutrosophy [22], which is a generalization of dialectics, i.e. not only the opposites are combined but also the neutralities. Why? Because when an idea is launched, a category of people will accept it, others will reject it, and a third one will ignore it (don't care). But the dynamics between these three categories changes, so somebody accepting it might later reject or ignore it, or an ignorant will accept it or reject it, and so on. Similarly the dynamicity of <A>, <antiA>, <neutA>, where <neutA> means neither <A> nor <antiA>, but in between (neutral). Neutrosophy considers a kind not of di-alectics but tri-alectics (based on three components: <A>, <antiA>, <neutA>).

Hence unmatter is a kind of intermediary (not referring to the charge) between matter and antimatter, i.e. neither one, nor the other.

Neutrosophic Logic (NL) is a generalization of fuzzy logic (especially of intuitionistic fuzzy logic) in which a proposition has a degree of truth, a degree of falsity, and a degree of neutrality (neither true nor false); in the normalized NL the sum of these degrees is 1.

7 Exotic atom

If in an atom we substitute one or more particles by other particles of the same charge (constituents) we obtain an exotic atom whose particles are held together due to the electric charge. For example, we can substitute in an ordinary atom one or more electrons by other negative particles (say π^-, anti-Rho meson, D^-, D_s^-, muon, tau, Ω^-, Δ^-, etc., generally clusters of quarks and antiquarks whose total charge is negative), or the positively charged nucleus replaced by other positive particle (say clusters of quarks and antiquarks whose total charge is positive, etc.).

8 Unmatter atom

It is possible to define the unmatter in a more general way, using the exotic atom.

The classical unmatter atoms were formed by particles like (a) electrons, protons, and antineutrons, or (b) antielectrons, antiprotons, and neutrons.

In a more general definition, an unmatter atom is a system of particles as above, or such that one or more particles are replaces by other particles of the same charge.

Other categories would be (c) a matter atom with where one or more (but not all) of the electrons and/or protons are replaced by antimatter particles of the same corresponding charges, and (d) an antimatter atom such that one or more (but not all) of the antielectrons and/or antiprotons are replaced by matter particles of the same corresponding charges.

In a more composed system we can substitute a particle by an unmatter particle and form an unmatter atom.

Of course, not all of these combinations are stable, semi-stable, or quasi-stable, especially when their time to bind together might be longer than their lifespan.

9 Examples of unmatter

During 1970–1975 numerous pure experimental verifications were obtained proving that "atom-like" systems built on nucleons (protons and neutrons) and anti-nucleons (anti-protons and anti-neutrons) are real. Such "atoms", where nucleon and anti-nucleon are moving at the opposite sides of the same orbit around the common centre of mass, are very unstable, their life span is no more than 10^{-20} sec. Then nucleon and anti-nucleon annihilate into gamma-quanta and more light particles (pions) which can not be connected with one another, see [6, 7, 8]. The experiments were done in mainly Brookhaven National Laboratory (USA) and, partially, CERN (Switzerland), where "proton–anti-proton" and "anti-proton–neutron" atoms were observed, called them $\bar{\mathrm{p}}\mathrm{p}$ and $\bar{\mathrm{p}}\mathrm{n}$ respectively.

After the experiments were done, the life span of such "atoms" was calculated in theoretical way in Chapiro's works [9, 10, 11]. His main idea was that nuclear forces, acting between nucleon and anti-nucleon, can keep them far way from each other, hindering their annihilation. For instance, a proton and anti-proton are located at the opposite sides in the same orbit and they are moved around the orbit centre. If the diameter of their orbit is much more than the diameter of "annihilation area", they are kept out of annihilation. But because the orbit, according to Quantum Mechanics, is an actual cloud spreading far around the average radius, at any radius between the proton and the anti-proton there is a probability that they can meet one another at the annihilation distance. Therefore nucleon—anti-nucleon system annihilates in any case, this system is unstable by definition having life span no more than 10^{-20} sec.

Unfortunately, the researchers limited the research to the consideration of $\bar{\mathrm{p}}\mathrm{p}$ and $\bar{\mathrm{p}}\mathrm{n}$ nuclei only. The reason was that they, in the absence of a theory, considered $\bar{\mathrm{p}}\mathrm{p}$ and $\bar{\mathrm{p}}\mathrm{n}$ “atoms” as only a rare exception, which gives no classes of matter.

The unmatter does exists, for example some messons and antimessons, through for a trifling of a second lifetime, so the pions are unmatter (which have the composition uˆd and udˆ, where by uˆ we mean anti-up quark, d = down quark, and analogously u = up quark and dˆ = anti-down quark, while by ˆ means anti), the kaon K^+ (usˆ), K^- (uˆs), Phi (ssˆ), D^+ (cdˆ), D^0(cuˆ), D_s^+ (csˆ), J/Psi (ccˆ), B^- (buˆ), B^0 (dbˆ), B_s^0 (sbˆ), Upsilon (bbˆ), where c = charm quark, s = strange quark, b = bottom quark, etc. are unmatter too.

Also, the pentaquark Theta-plus (Θ^+), of charge $^+1$, uuddsˆ (i.e. two quarks up, two quarks down, and one anti-strange quark), at a mass of 1.54 GeV and a narrow width of 22 MeV, is unmatter, observed in 2003 at the Jefferson Lab in Newport News, Virginia, in the experiments that involved multi-GeV photons impacting a deuterium target. Similar pentaquark evidence was obtained by Takashi Nakano of Osaka University in 2002, by researchers at the ELSA accelerator in Bonn in 1997–1998, and by researchers at ITEP in Moscow in 1986.

Besides Theta-plus, evidence has been found in one experiment [25] for other pentaquarks, Ξ_5^-(ddssuˆ) and Ξ_5^+(uussdˆ).

D. S. Carman [26] has reviewed the positive and null evidence for these pentaquarks and their existence is still under investigation.

In order for the paper to be self-contained let’s recall that the *pionium* is formed by a π^+ and π^- mesons, the *positronium* is formed by an antielectron (positron) and an electron in a semi-stable arrangement, the *protonium* is formed by a proton and an antiproton also semi-stable, the *antiprotonic helium* is formed by an antiproton and electron together with the helium nucleus (semi-stable), and *muonium* is formed by a positive muon and an electron.

Also, the *mesonic atom* is an ordinary atom with one or more of its electrons replaced by negative mesons.

The *strange matter* is a ultra-dense matter formed by a big number of strange quarks bounded together with an electron atmosphere (this strange matter is hypothetical).

From the exotic atom, the pionium, positronium, protonium, antiprotonic helium, and muonium are unmatter.

The mesonic atom is unmatter if the electron(s) are replaced by negatively-charged antimessons.

Also we can define a mesonic antiatom as an ordinary antiatomic nucleous with one or more of its antielectrons replaced by positively-charged mesons. Hence, this mesonic antiatom is unmatter if the antielectron(s) are replaced by positively-charged messons.

The strange matter can be unmatter if these exists at least an antiquark together with so many quarks in the nucleous. Also, we can define the strange antimatter as formed by a large number of antiquarks bound together with an antielectron around them. Similarly, the strange antimatter can be unmatter if there exists at least one quark together with so many antiquarks in its nucleous.

The bosons and antibosons help in the decay of unmatter. There are 13+1 (Higgs boson) known bosons and 14 antibosons in present.

10 Chromodynamics formula

In order to save the colorless combinations prevailed in the Theory of Quantum Chromodynamics (QCD) of quarks and antiquarks in their combinations when binding, we devise the following formula:

$$\mathbf{Q} - \mathbf{A} \in \pm \boldsymbol{M3}\,, \tag{22}$$

where $\boldsymbol{M3}$ means multiple of three, i.e. $\pm\boldsymbol{M3} = \{3\cdot k \,|\, k \in Z\} = \{\ldots, -12, -9, -6, -3, 0, 3, 6, 9, 12, \ldots\}$, and $\mathbf{Q}$ = number of quarks, $\mathbf{A}$ = number of antiquarks.

But (22) is equivalent to:

$$\mathbf{Q} \equiv \mathbf{A}(\mathbf{mod3}) \tag{23}$$

($\mathbf{Q}$ is congruent to $\mathbf{A}$ modulo 3).

To justify this formula we mention that 3 quarks form a colorless combination, and any multiple of three ($\boldsymbol{M3}$) combination of quarks too, i.e. 6, 9, 12, etc. quarks. In a similar way, 3 antiquarks form a colorless combination, and any multiple of three ($\boldsymbol{M3}$) combination of antiquarks too, i.e. 6, 9, 12, etc. antiquarks. Hence, when we have hybrid combinations of quarks and antiquarks, a quark and an antiquark will annihilate their colors and, therefore, what’s left should be a multiple of three number of quarks (in the case when the number of quarks is bigger, and the difference in the formula is positive), or a multiple of three number of antiquarks (in the case when the number of antiquarks is bigger, and the difference in the formula is negative).

11 Quantum chromodynamics unmatter formula

In order to save the colorless combinations prevailed in the Theory of Quantum Chromodynamics (QCD) of quarks and antiquarks in their combinations when binding, we devise the following formula:

$$\mathbf{Q} - \mathbf{A} \in \pm \boldsymbol{M3}\,, \tag{24}$$

where $\boldsymbol{M3}$ means multiple of three, i.e. $\pm\boldsymbol{M3} = \{3\cdot k \,|\, k \in Z\} = \{\ldots, -12, -9, -6, -3, 0, 3, 6, 9, 12, \ldots\}$, and $\mathbf{Q}$ = number of quarks, $\mathbf{A}$ = number of antiquarks, with $\mathbf{Q} \geqslant 1$ and $\mathbf{A} \geqslant 1$.

But (24) is equivalent to:

$$\mathbf{Q} \equiv \mathbf{A}(\mathbf{mod3}) \tag{25}$$

($\mathbf{Q}$ is congruent to $\mathbf{A}$ modulo 3), and also $\mathbf{Q} \geqslant 1$ and $\mathbf{A} \geqslant 1$.

12 Quark-antiquark combinations

Let's note by q = quark ∈ {Up, Down, Top, Bottom, Strange, Charm}, and by a = antiquark ∈ {Up, Down, Top, Bottom, Strange, Charm}.

Hence, for combinations of n quarks and antiquarks, n ⩾ 2, prevailing the colorless, we have the following possibilities:

— if n = 2, we have: qa (biquark — for example the mesons and antimessons);

— if n = 3, we have qqq, aaa (triquark — for example the baryons and antibaryons);

— if n = 4, we have qqaa (tetraquark);

— if n = 5, we have qqqqa, aaaaq (pentaquark);

— if n = 6, we have qqqaaa, qqqqqq, aaaaaa (hexaquark);

— if n = 7, we have qqqqqaa, qqaaaaa (septiquark);

— if n = 8, we have qqqqaaaa, qqqqqqaa, qqaaaaaa (octoquark);

— if n = 9, we have qqqqqqqqq, qqqqqqaaa, qqqaaaaaa, aaaaaaaaa (nonaquark);

— if n = 10, obtain qqqqqaaaaa, qqqqqqqqaa, qqaaaaaaaa (decaquark);

— etc.

13 Unmatter combinations

From the above general case we extract the unmatter combinations:

— For combinations of 2 we have: qa (unmatter biquark), (mesons and antimesons); the number of all possible unmatter combinations will be $6 \cdot 6 = 36$, but not all of them will bind together.

It is possible to combine an entity with its mirror opposite and still bound them, such as: uu^, dd^, ss^, cc^, bb^ which form mesons.

It is possible to combine, unmatter + unmatter = unmatter, as in ud^ + us^ = uud^s^ (of course if they bind together);

— For combinations of 3 (unmatter triquark) we can not form unmatter since the colorless can not hold.

— For combinations of 4 we have: qqaa (unmatter tetraquark); the number of all possible unmatter combinations will be $6^2 \cdot 6^2 = 1{,}296$, but not all of them will bind together;

— For combinations of 5 we have: qqqqa, or aaaaq (unmatter pentaquarks); the number of all possible unmatter combinations will be $6^4 \cdot 6 + 6^4 \cdot 6 = 15{,}552$, but not all of them will bind together;

— For combinations of 6 we have: qqqaaa (unmatter hexaquarks); the number of all possible unmatter combinations will be $6^3 \cdot 6^3 = 46{,}656$, but not all of them will bind together;

— For combinations of 7 we have: qqqqqaa, qqaaaaa (unmatter septiquarks); the number of all possible unmatter combinations will be $6^5 \cdot 6^2 + 6^2 \cdot 6^5 = 559{,}872$, but not all of them will bind together;

— For combinations of 8 we have: qqqqaaaa, qqqqqqqa, qaaaaaaa (unmatter octoquarks); the number of all possible unmatter combinations will be $6^4 \cdot 6^4 + 6^7 \cdot 6^1 + 6^1 \cdot 6^7 = 5{,}038{,}848$, but not all of them will bind together;

— For combinations of 9 we have: qqqqqqaaa, qqqaaaaaa (unmatter nonaquarks); the number of all possible unmatter combinations will be $6^6 \cdot 6^3 + 6^3 \cdot 6^6 = 2 \cdot 6^9 = 20{,}155{,}392$, but not all of them will bind together;

— For combinations of 10: qqqqqqqqaa, qqqqqaaaaa, qqaaaaaaaa (unmatter decaquarks); the number of all possible unmatter combinations will be $3 \cdot 6^{10} = 181{,}398{,}528$, but not all of them will bind together;

— etc.

I wonder if it is possible to make infinitely many combinations of quarks/antiquarks and leptons/antileptons… Unmatter can combine with matter and/or antimatter and the result may be any of these three.

Some unmatter could be in the strong force, hence part of hadrons.

14 Unmatter charge

The charge of unmatter may be positive as in the pentaquark Theta-plus, 0 (as in positronium), or negative as in anti-Rho meson, i.e. u^d, (M. Jordan).

15 Containment

I think for the containment of antimatter and unmatter it would be possible to use electromagnetic fields (a container whose walls are electromagnetic fields). But its duration is unknown.

16 Summary and conclusions

It is apparent from these considerations that, in general, both "unmatter" and "unparticles" are non-trivial states that may become possible under conditions that substantially deviate from our current laboratory settings. Unmatter can be thought as *arbitrary* clusters of ordinary matter and antimatter, unparticles contain *fractional numbers of quanta* per state and carry *arbitrary spin* [6]. They both display a much richer dynamics than conventional SM doublets, for example mesons (quark-antiquark states) or lepton pairs (electron-electron antineutrino). Due to their unusual properties, “unmatter” and “unparticles” are presumed to be highly unstable and may lead to a wide range of symmetry breaking scenarios. In particular, they may violate well established conservation principles such as electric charge, weak isospin and color. Future observational evidence and analytic studies are needed to confirm, expand or falsify these tentative findings.

Submitted on June 26, 2008 / Accepted on July 19, 2008

References

1. Weinberg S. The quantum theory of fields. Volume 1: foundations. Cambridge University Press, London, 1995.
2. Zinn-Justin J. Quantum field theory and critical phenomena. Oxford University Press, Oxford, 2002.
3. Hagiwara K. et al. *Phys. Rev. D*, 2002, v. 66, 010001-1; Nir Y. CP violation and beyond the Standard Model. XXVII SLAC Summer Institute, 1999; Rogalyov R.N. arXiv: hep-ph/0204099.
4. Bigi I.I. and Sanda A.I. CP violation. Cambridge University Press, 2000; Yao W.M. et al. *Journal of Phys. G*, 2006, v. 33(1).
5. Donoghue J.F. et al.. Dynamics of the Standard Model. Cambridge University Press, 1996.
6. Goldfain E. *Chaos, Solitons and Fractals*, 2006, v. 28(4), 913.
7. Goldfain E. *Intern. Journal of Nonlinear Sciences and Numerical Simulation*, 2005, v. 6(3), 223.
8. Goldfain E. *Comm. in Nonlinear Science and Numer. Simulation*, 2008, v. 13, 666.
9. Goldfain E. *Comm. in Nonlinear Science and Numer. Simulation*, 2008, v. 13, 1397.
10. Ballhausen H. et al. *Phys. Lett. B*, 2004, v. 582, 144.
11. Goldfain E. *Chaos, Solitons and Fractals*, 2008, v. 38(4), 928.
12. Goldfain E. *Intern. Journal of Nonlinear Science*, 2007, v. 3(3), 170.
13. Samko S.G. et al. Fractional integrals and derivatives. Theory and applications. Gordon and Breach, New York, 1993.
14. Ryder L. Quantum field theory. Cambridge University Press, 1996.
15. Georgi H. *Phys. Rev. Lett.*, 2007, v. 98, 221601.
16. Georgi H. *Phys. Lett. B*, 2007, v. 650, 275.
17. Cheung K. et al. *Phys. Rev. D*, 2007, v. 76, 055003.
18. Bander M. et al. *Phys. Rev. D*, 2007, v. 76, 115002.
19. Zwicky R. *Phys. Rev. D*, 2008, v. 77, 036004.
20. Kikuchi T. et al. *Phys. Rev. D*, 2008, v. 77, 094012.
21. Goldfain E. A brief note on “un-particle” physics. *Progress in Physics*, 2008, v. 28, v. 3, 93.
22. Smarandache F. A unifying field in logics, neutrosophic logic. Neutrosophy, neutrosophic set, neutrosophic probability. Am. Res. Press, 1998.
23. Smarandache F. Matter, antimatter, and unmatter. CDS-CERN, EXT-2005-142, 2004; *Bulletin of Pure and Applied Sciences*, 2004, v. 23D, no. 2, 173–177.
24. Smarandache F. Verifying unmatter by experiments, more types of unmatter, and a quantum chromodynamics formula. *Progress in Physics*, 2005, v. 2, 113–116; *Infinite Energy*, 2006, v. 12, no. 67, 36–39.
25. Chubb S. Breaking through editorial. *Infinite Energy*, 2005, v. 11, no. 62, 6–7.
26. Carman D.S. Experimental evidence for the pentaquark. *Euro Phys. A*, 2005, v. 24, 15–20.
27. Gray L., Hagerty P., and Kalogeropoulos T.E. Evidence for the existence of a narrow p-barn bound state. *Phys. Rev. Lett.*, 1971, v. 26, 1491–1494.
28. Carrol A.S., Chiang I.-H., Kucia T.F., Li K.K., Mazur P.O., Michael D.N., Mockett P., Rahm D.C., and Rubinstein R. Observation of structure in p-barp and p-bard total cross cections below 1.1 GeV/c. *Phys. Rev. Lett.*, 1974, v. 32, 247–250.
29. Kalogeropoulos T.E., Vayaki A., Grammatikakis G., Tsilimigras T., and Simopoulou E. Observation of excessive and direct gamma production in p-bard annihilations at rest. *Phys. Rev. Lett.*, 1974, v. 33, 1635–1637.
30. Chapiro I.S. *Physics-Uspekhi* (*Uspekhi Fizicheskikh Nauk*), 1973, v. 109, 431.
31. Bogdanova L.N., Dalkarov O.D., and Chapiro I.S. Quasinuclear systems of nucleons and antinucleons. *Annals of Physics*, 1974, v. 84, 261–284.
32. Chapiro I.S. New “nuclei” built on nucleons and anti-nucleons. *Nature-USSR*, 1975, no. 12, 68–73.
33. Barmin V.V. et al. (DIANA Collaboration). *Phys. Atom. Nucl.*, 2003, v. 66, 1715.
34. Ostrick M. (SAPHIR Collaboration). *Pentaquark 2003 Workshop*, Newport News, VA, Nov. 6–8, 2003.
35. Smith T.P. Hidden worlds, hunting for quarks in ordinary matter. Princeton University Press, 2003.
36. Wang M.J. (CDF Collaboration). In: *Quarks and Nuclear Physics 2004*, Bloomington, IN, May 23–28, 2004.