Matter, Space, and Rishons

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Abstract

I rephrase my earlier arguments that vital information on the emergence of space is buried in particle physics, and - in particular - in the Harari-Shupe (HS) rishon model of leptons and quarks. First, it is argued that matter and space should be treated more symmetrically than they are in the Standard Model. Then, a generalization of Born's matter-and-space-relating concept of reciprocity is introduced. A simple analogy between the resulting phase-space picture and the original HS model is pointed out. It is stressed that in the advocated view of the rishon model the concept of "compositeness" is completely different from its standard understanding, implying one-dimensionality of rishons, and thus the non-existence of "preons".

Keywords:
matter; hadrons; leptons and quarks; rishons; emergent space

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1 Introduction

In paper [1] a conjecture was put forward that essential information on the emergence of macroscopic space should be accessible from the study of the properties of matter at the hadronic mass and distance scales. In particular, it was argued that important clues are contained in the Harari-Shupe (HS) subparticle (rishon) model of leptons and quarks [2, 3].

Given no experimental indication of the existence of “preons”, the argument “from the rishon model” is probably discarded by most readers as irrelevant. Such an attitude must stem from the macroscopic conception of “compositeness” which dominates in our minds forcing the majority to think of rishons as of ordinary particles. Actually, in the phase-space-inspired version [3, 4] of the HS model the words “to be composed of” mean something completely different than in the original model [2]. Since, despite earlier arguments (see [5]), this difference in meaning remains essentially unnoticed, we argue here anew that the HS model should *not* be treated as a preon model. I think that its most promising interpretation should be phrased in the language of phase space and its symmetries.

The main aim of this essay is to convince the reader that rishons should be viewed as strictly *one-dimensional* “objects” which, therefore, cannot be regarded as subparticles. We point out also that the phase-space-motivated interpretation of the rishon model offers an unorthodox perspective on quark confinement. This perspective suggests a close connection of the non-existence of free individual quarks with the idea of the emergence of 3D macroscopic space. In this essay we present some of the arguments of [1] in a rephrased form. We focus on the heuristics, hoping that in this way the whole conception could be conveyed to an interested reader in a lucid and digestible form.

2 Matter in Space

Our current understanding of the small structures of the world is summarized by the Standard Model (SM) of elementary particles. Since we want to address the meaning of particle “compositeness”, we start with a brief description of the relevant underlying concepts. Among them an important ingredient is our everyday conception of the world as a 3D container through which spatially extended 3D “real material things” move as time flows. These “things” are characterized by physical concepts, abstracted from detailed observations of the macroscopic world and best defined for freely moving objects. In addition to the notion of a thing’s 3D location specified by vector $\mathbf{x} = (x_1, x_2, x_3)$, these are the concepts of the constant-in-time quantities: energy E, momentum vector $\mathbf{p} = (p_1, p_2, p_3)$, and mass m. The latter concept links energy and momentum, with the relevant relativistic dispersion relation being (in units in which speed of light $c = 1$)

$$E^2 = \mathbf{p}^2 + m^2. \tag{1}$$

Note that in this formula - which describes the basic property of free relativistic classical things - the dependence on the space of locations is totally absent.

2.1 Matter and the Reductionist Picture

The standard reductionist picture consists of a set of steps in which big "real" material 3D things are viewed as composed of spatially smaller and less massive but otherwise similar "real" material 3D things. The components are best identified when their mutual interactions vanish. In our macroscopic world this happens when the components are spatially well separated from each other. In order to avoid infinite regress, the reductionist procedure has to stop somewhere. The relevant "atomicity" assumption postulates then the existence of some underlying indivisible units of matter. In the current theoretical picture of the SM, the role of these "atoms" is played by elementary particles. Those particles that can be spatially separated are identified by the condition that the macroscopically motivated classical constraint of Eq. (1) be satisfied.

As we go down the reductionist ladder, the macroscopic classical "reality" of matter slowly dissappears. For example, in the quantum microscopic world the dispersion relation (1) ceases to be exactly satisfied and the concept of virtual particles appears. Despite this clear indication of a loss of the "reality" of matter, influenced by our everyday macroscopic experience and the time-proven reductionist ideas, we are continually tempted to ask: from what kind of subparticles is matter composed at the nuclear level? at the hadronic level? at the level of quarks and leptons? Yet, as the appearance of particle virtuality at the classical-to-quantum transition suggests, further substantial changes in our conception of matter should be expected at each subsequent major step down the reductionist ladder.

In fact, many physicists suggested that at the level of elementary particles the concept of ("real") matter should be replaced by the abstract concept of symmetry. When in 1964 Murray Gell-Mann first introduced quarks as components of hadrons [7], he thought of them as of quantum fields satisfying an abstract symmetry. He was apparently concerned with the danger of treating quarks as ordinary "material" particles as the last sentence of his original paper demonstrates: *"A search for stable quarks of charge -1/3 or +2/3 (...) at the highest energy accelerators would help to reassure us of the non-existence of real quarks."* Today, the statement that "hadrons are composed of quarks" accepts the "reality" of quarks, though subject to a confinement-related correction of the meaning of hadron "compositeness". Indeed, in the SM, strong interactions between component quarks vanish not at large but at small separations. May we then consider quarks as truly "real"? Are the correponding quark dispersion relations not affected by confinement?

The symmetry of particle interactions and the pattern of lepton-quark generation are probably the most important ingredients of the SM. Over the years, the relevant SM symmetry group has been identified as $U(1) \otimes SU(2)_L \otimes SU(3)_C$ with group factors describing the symmetries of the electromagnetic, weak, and strong interactions, respectively. Yet, despite its many particular successes, the SM leaves unanswered the fundamental question: why is the world governed by the $U(1) \otimes SU(2)_L \otimes SU(3)_C$ symmetry group?[1] What physical principle could explain the relevance of this particular symmetry? Should we seek an explanation of this symmetry in terms of "real" subparticles of the reductionist paradigm, or assume it as a fundamental input that does not need any further explanation? Or perhaps one should look for another kind of explanation? And what about the pattern of lepton-quark generation?

2.2 The Rishon Model

Driven by the repeated successes of the reductionist approach, the concept of "explanation" was usually understood in particle or subparticle terms. Prompted by such thinking, a subparticle explanation of the basic features of the SM symmetry group and the lepton-quark generation structure was proposed some 40 years ago by Harari and Shupe in their rishon model of composite leptons and quarks [2].

The HS model assumes that each member of a single generation of leptons and quarks is built from two spin-1/2 subparticles (or their antiparticles): the "rishons" T and V of electric charges $Q_T = +1/3$ and $Q_V = 0$. Due to some unknown confinement mechanism, these rishons are combined in *ordered* sets of three as shown in Table 1 for the upper ($I_3 = +1/2$) components of weak isospin doublets (eg. ν_e, e^-). As charge Q is related to weak isospin I_3 and hypercharge Y through

$$Q = I_3 + Y/2, \tag{2}$$

we have $Y_T = +1/3$, $Y_V = -1/3$, and the rishon structure of lepton and quark charges translates into a corresponding structure of hypercharges. Likewise, the eight states of $I_3 = -1/2$, ie. e^-, d_R, d_G, d_B and $\bar{\nu}_e$, $\bar{u}_R$, $\bar{u}_G$, $\bar{u}_B$ are composed of rishon antiparticles $\bar{T}$, $\bar{V}$.

Although the HS model nicely explains both the appearance of the $U(1) \otimes SU(3)_C$ part of the SM symmetry group and the pattern of lepton-quark generation, it exhibits many shortcomings that are induced by the assumed particle nature of the components (see [3, 4, 5]). Regarding these shortcomings as deadly for the reductionist view of the model, one may seek a different explanation of the SM symmetries (the $U(1) \otimes SU(3)_C$ symmetry group in particular): not in terms of a "rishonian" rung on the reductionist ladder but in terms of a link between the

[1] Simply pointing out some larger symmetry group is not sufficient. The relevant symmetry should follow from a deep physical principle.

Table 1: Rishon structure of leptons and quarks with a third component of weak isospin $I_3 = +1/2$

	e^+	$\bar{d}_R$	$\bar{d}_G$	$\bar{d}_B$	ν_e	u_R	u_G	u_B
	TTT	TVV	VTV	VVT	VVV	VTT	TVT	TTV
Q	+1	+1/3	+1/3	+1/3	0	+2/3	+2/3	+2/3
Y	+1	-1/3	-1/3	-1/3	-1	+1/3	+1/3	+1/3

quark-lepton rung and some macroscopic classical concepts that were not considered earlier. We may recall here Bohr's words: *"It should be made clear that this theory*[2] *is not intended to explain phenomena in the sense in which word 'explains' has been used in earlier physics. It is intended to combine various phenomena, which seem not to be connected, and to show that they are connected."* Why should we not think therefore of linking some previously unconnected micro and macro concepts? Why should we not try to link the successful features of the HS model with some properties of macroscopic reality?

3 Matter and Space

In the SM the elementary particles (the "atoms") and the background they move in (the "container") are treated as essentially disjoint concepts. This is not so in the thinking that contributed to Einstein's creation of General Relativity (GR), in which gravitational forces are reduced to aspects of space geometry. According to this way of thinking, the existence and/or properties of space are induced by (or related to) the existence of matter. For example, space may be viewed as a structure defined by relations between chunks of matter. Consequently, the SM picture of the "container" space through which material things move must be seen as an over-simplified description of the situation: it misses the matter-related nature of space. Thus, the SM appears as a hybrid "cq" theory that mixes in an asymmetric way the classical macroscopic (space, "c") and the quantum microscopic (matter, "q") aspects of reality [10]. Keeping in mind the basic role played in the SM by matter and interaction symmetries, we think that, in a future deeper theory, matter and space should also be treated symmetrically.

[2] Bohr's model of atom

3.1 The Symmetry of Reciprocity

A possible candidate for the matter-space symmetry was proposed by Max Born. He observed [11] that while in formula (1) the mass of free physical bodies appears in association with momentum only (ie. *not* with position), various other important physical formulas, such as eg. Hamilton's equations of motion, the classical expression for the angular momentum $\mathbf{J} = \mathbf{x} \times \mathbf{p}$ as well as the position-momentum quantum commutation rules $[x_j, p_j] = ih$ (or the related classical position-momentum Poisson brackets) exhibit exact symmetry under the position-momentum interchange.

This symmetry of "reciprocity" suggests the existence of a new physical constant κ of dimension [momentum/position] that permits the expression of momenta as *proportional* to positions, according to

$$\begin{aligned} \mathbf{p} &= \kappa \mathbf{x}, \\ \mathbf{x} &= -\kappa^{-1} \mathbf{p}. \end{aligned} \tag{3}$$

Constant κ does not have much to do with the quantum Planck constant h of dimension [momentum $\times$ position] which permits the expression of momenta as *inversely* proportional to positions. Born speculated that the ordinary concept of mass (and thus that of matter) should be generalized and should include the classical position variable $\mathbf{x}$ (and thus the concept of space), probably via some analogue of dispersion formula (1).

Now, reciprocity treats matter and space as symmetry-related concepts that may be transformed into each other. It might be therefore of interest in various gravity-related contexts. Indeed, the role of reciprocity as a guiding principle in search of a proper approach to quantum gravity has been pointed out recently by Buoninfante [12] who noticed that reciprocity permits to *"incorporate already in flat space (...) a fundamental acceleration scale corresponding to a maximal limiting value a_P"*. In fact, limits on acceleration may be argued to be more fundamental than corresponding limits on distance: after all, it is acceleration that describes the strength of matter-induced gravitational field and its connection with the properties of space.

With the Planck (maximal) acceleration being

$$a_P = c^2/l_P = m_P c^3/h \approx 2.2 \times 10^{53}\ cm/s^2 \tag{4}$$

($m_P = 5.5 \times 10^{-5}\ g$ and $l_P = 4 \times 10^{-33}\ cm$ are Planck's mass and length), we obtain [1]

$$\kappa_P = a_P^2 h/c^4 = 4.04 \times 10^{38}\ g/s \equiv \kappa_C = c^3/G. \tag{5}$$

This equation gives the maximum ('classical') value of κ, reached at the surface of a Planck-size black hole, and defined by two classical constants: c and Newton's gravitation constant G.

With Einstein's gravitational field equation involving cosmological constant Λ in addition to c and G, one may define another ('quantum') value of κ [1]:

$$\kappa_Q = h\Lambda = 0.79 \times 10^{-82} g/s, \tag{6}$$

which is 120 orders of magnitude smaller than κ_C, and thus may be considered minimal. The corresponding value of acceleration $a_Q = \sqrt{\kappa_Q c^4/h} = c^2\sqrt{\Lambda} \approx 9.8 \times 10^{-8}\ cm/s^2$ is of the order of MOND acceleration $a_M = 1.2 \times 10^{-8}\ cm/s^2$ [13]. Thus, κ_Q defines the minimal value of acceleration a_Q below which departures from the standard picture of gravitational forces are expected to appear.[3]

When the atomicity postulate is added, reciprocity suggests that apart from the "atoms of matter" (exhibiting a discrete spectrum of masses associated through (1) with momentum vector $\mathbf{p}$), there should be "atoms of space" (associated with position vector $\mathbf{x}$). Actually, the "atoms" of space need not be as tiny as the "natural" unit of Planck length suggests. The only essential argument that points towards this diminutive distance scale is provided by the dimensional analysis. Yet, such an analysis is not trustworthy as its results depend on the choice of constants considered to be fundamental [14]. Since Einstein's field equation involves three universal classical constants: c, G, and Λ, one has to decide which two of them should be selected to supplement h in the dimensional analysis of the "natural" scales for quantum gravity. The standard Planck's mass and length scales m_P and l_P follow if h, G, and c are used. The choice of h, G and Λ instead leads to the hadronic mass and length scales [1]:

$$m_H = \left((h^2/G)\sqrt{\Lambda/3}\right)^{1/3} \approx 0.35 \times 10^{-24}\ g, \tag{7}$$

$$l_H \approx 0.64 \times 10^{-12}\ cm, \tag{8}$$

and to a rough estimate of the slope α' of hadronic Regge trajectories [1]

$$\alpha' = \left(\frac{3G^2}{h\Lambda}\right)^{1/3} \approx 55 \times 10^{21}\ cm^2/(gs) \approx N^{1/3}c^2/\kappa_P. \tag{9}$$

Here $N = 3c^3/(hG\Lambda) = 1.54 \times 10^{121}$.

The obtained scales are in an order-of-magnitude agreement with their hadronic values. While this agreement is very good for hadronic mass scale, the estimated string slope scale of Eq. (9) differs from the experimental hadronic value of $\alpha' = 0.38 \times 10^{21} cm^2/(gs)$ by a factor of 100 or so. Such a factor is quite acceptable when the large number multiplicative factor of approximately 10^{40} between $\kappa_H \approx (\kappa_C^2\kappa_Q)^{1/3} = c^2(\frac{h\Lambda}{3G^2})^{1/3} \approx 2.4\ g/s$ and $\kappa_P \equiv \kappa_C = 4.04 \times 10^{38}\ g/s$ is taken into account [1]. It is hard to believe that this double coincidence of the estimated

[3] Such departures are in fact observed in astrophysical settings for $a < a_M$. They are well explained in the framework of modified Newtonian dynamics (MOND) [13].

and the measured hadronic mass and string slope scales does not tell us something important about the hadronic involvement in the emergence of ordinary space from a quantum quark layer.

The two sets of alternative scales (l_P, m_P and l_H, m_H) estimated by the dimensional analysis probably correspond to different limiting aspects of space-related quantum effects (see Fig. 1 in [15]).

3.2 Beyond Reciprocity

With the help of κ, the two relevant 3D invariants $\mathbf{p^2}$ and $\mathbf{x^2}$ may be combined to form the matter-and-space symmetric expression $\mathbf{p^2} + \mathbf{x^2}$ (in units in which $\kappa = 1$). In this way, the concepts of the 3D matter (momentum) and 3D position spaces get unified into that of a 6D phase-space in which matter and space variables may be treated on more equal footing [4].

If κ exists, then for any object in our 3D world each of the three perpendicular directions is associated with a pair of physically different (position and momentum) variables of the same dimension, which, consequently, may be freely exchanged. Thus, we may generalize the symmetry of reciprocity to that of an exchange (permutation) symmetry for individual momentum and position coordinates, ie.

$$\begin{aligned} p_i &= \kappa x_i, \\ x_i &= -\kappa^{-1} p_i, \end{aligned} \tag{10}$$

with specific fixed i, as shown in Table 2.

The four even and four odd sets of exchanges suggest a generalization of the classical association (1) of the standard concept of mass (or particle) with momentum (ie. the dispersion relation involving vector (p_1, p_2, p_3)) to eight such associations (involving the eight ordered triplets on the left in the last column of Table 2, ie. (p_1, p_2, x_3), (p_1, x_2, p_3), ..., (x_1, x_2, x_3); (p_1, x_2, x_3), ..., (p_1, p_2, p_3), each playing the role of the ordinary momentum vector (p_1, p_2, p_3)).

Note the similarity between the eight sets of generalized momentum triplets shown in Table 2 and the eight sets of ordered three-rishon states shown in Table 1. This similarity may be used as a starting heuristic for the phase-space-based preon-less interpretation of the rishon model, involving in particular a further departure from the macroscopic dispersion relation (1), which will be discussed shortly. According to this interpretation, there is a correspondence between the dimensionality of ordinary space and the number of colors. A somewhat different (relativity-inspired) version of this idea was proposed by Hidezumi Terazawa who conjectured that a *"space-color correspondence may become a clue to a possible relation between fields (or matter) and space-time"* [16].

[4] Thus, the principle of reciprocity provides the reason for the extension of rotational symmetry from 3D to 6D.

Table 2: Permutations of individual momentum and position components of 6D phase space vector $(\mathbf{p};\mathbf{x}) = (p_1, p_2, p_3; x_1, x_2, x_3)$

Sector	Exchange	Momentum; position
Odd number of exchanges		
Blue	$x_3 \leftrightarrow p_3$	$(p_1, p_2, x_3; x_1, x_2, p_3)$
Green	$x_2 \leftrightarrow p_2$	$(p_1, x_2, p_3; x_1, p_2, x_3)$
Red	$x_1 \leftrightarrow p_1$	$(x_1, p_2, p_3; p_1, x_2, x_3)$
Reciprocity	$\mathbf{x} \leftrightarrow \mathbf{p}$	$(x_1, x_2, x_3; p_1, p_2, p_3)$
Even number of exchanges		
Red	$(x_3, x_2) \leftrightarrow (p_3, p_2)$	$(\mathbf{p}_R; \mathbf{x}_R) = (p_1, x_2, x_3; x_1, p_2, p_3)$
Green	$(x_1, x_3) \leftrightarrow (p_1, p_3)$	$(\mathbf{p}_G; \mathbf{x}_G) = (x_1, p_2, x_3; p_1, x_2, p_3)$
Blue	$(x_2, x_1) \leftrightarrow (p_2, p_1)$	$(\mathbf{p}_B; \mathbf{x}_B) = (x_1, x_2, p_3; p_1, p_2, x_3)$
Identity	$\mathbf{x} \rightarrow \mathbf{x}$, $\mathbf{p} \rightarrow \mathbf{p}$	$(p_1, p_2, p_3; x_1, x_2, x_3)$

3.3 The Changing Meaning of "Compositeness"

The classical reductionist scheme is based on the concept of a physical division of macroscopic 3D matter into smaller and less massive 3D things. This simple conception of compositeness cannot be used in the phase-space-based view of the HS model since the component rishons cannot be treated as 3D objects. Indeed, the analogy existing between eg. the triplet of the generalized ("red" sector) momentum $\mathbf{p}_R = (p_1, x_2, x_3)$) and the ordered set of three rishons (TVV) suggests the association of each of the three rishons with *one* dimension of ordinary 3D space only. With a single rishon (in a given ordered set of three) viewed as corresponding to only one direction in the ordinary 3D world, the (3D) concept of spin cannot be assigned to the rishon in question: thus, in the phase-space interpretation the individual rishons do not possess spin. By a similar analogy, the set of three rishons (eg. (TVV)) cannot be rotated in 3D space and still remain ordered in the same way, ie. as (TVV) (since some admixtures of (VTV) and (VVT) would have to appear - compare the situation for the triplets of generalized momentum in Table 2).

According to the SM, the lowest rung of the reductionist ladder involves leptons and confined quarks. In line with our interpretation of the HS model, going further "down" (ie. below the lepton-quark rung) requires a bold departure from the remnants[5] of the macroscopic conception of "real" matter - and points towards a completely different understanding of the compositeness of matter-and-space. Due to a change in the dimensionality assigned to rishons, an individual rishon cannot be thought of as a "thing", and an additional rung of "rishonian components" below that of leptons and quarks cannot be thought of as composed of ordinary matter. Thus, the process of a division of "real" particles into smaller similar 3D stuff terminates at the lepton/quark level. At the "subsequent" level, the words "to be composed of" totally change their meaning [8] and are understood as referring to the construction of 3D things from objects of lower dimensionality (1D). Thus, in this approach *preons do not exist*.

For the benefit of a general reader let me point out that in the phase-space-inspired version of the HS model the rishons play the role quite analogous to that of regular polygons in the Plato's atomistic conception of matter[6] [17]. The emerging five regular polyhedrons (the Platonic solids) that in Plato's atomism correspond to the classical elements of fire, air, water, earth, and the Universe/aether are then the analogues of leptons and quarks.

The above heuristic on the possible phase-space-related meaning of the HS model and the one-dimensionality of rishons may be replaced with more refined mathematical arguments using Clifford algebra of nonrelativistic phase space. In particular, it can be shown that the structure of the internal quantum numbers of a lepton-quark generation naturally follows from this algebra when the classical position and momentum variables are replaced by the noncommuting quantum ones. For details (and the choice of even permutations), see [3],[6].

Our arguments in favour of the existence of a close connection between matter and space have led us to the language of phase space and an extension of the symmetry of reciprocity. In this language the appearance of the $U(1) \otimes SU(3)_C$ symmetry and the pattern of lepton-quark generation are quite naturally explained by a link to the macroscopic classical world. Technically speaking, the $U(1) \otimes SU(3)_C$ symmetry arises as a subgroup of six-dimensional rotations in *classical* phase space. With the physical principle underlying the appearance of $U(1) \otimes SU(3)$ being identified with the relevance of a phase-space-based classical description of reality, I suspect that some extension of this description should explain the appearance of $SU(2)_L$ as well.

4 Speculations

According to the phase-space-inspired view of the rishon model, the lowest (lepton and quark) rung of the reductionist ladder involves a loss of macroscopic spatial separability and rotational symmetry. Indeed, in the permutation-induced classical

[5]The word "remnants" is used because quark confinement precludes the applicability of Eq. (1).

[6]or to the scalene and isosceles right-angled triangles, considered by him to be the indivisible units from which these polygons and further constructs may be built.

description, the individual colored "objects" are associated with rotationally and translationally non-invariant analogues of expression (1), in which $\mathbf{p}^2$ is replaced by expressions such as

$$\mathbf{p}_R^2 = p_1^2 + x_2^2 + x_3^2. \tag{11}$$

Eq.(11) leads to a further departure from (1), ie. to a rotationally and translationally non-invariant generalisation of the classical dispersion relation. For the red sector it reads

$$E^2 = \mathbf{p}_R^2 + m^2. \tag{12}$$

One may discard such formulas together with the phase-space interpretation of the HS model as unapplicable to the real rotationally covariant macroscopic world. Yet, a different, speculative point of view is also possible. According to this alternative view (to which I subscribe), the *individual* "colored objects" may exhibit rotationally non-invariant features and still be considered physically acceptable if only they can conspire to form rotationally covariant composite systems at the more macroscopic level.

Now, restoration of rotational covariance requires the cooperation of three sectors of objects satisfying three differently modified dispersion relations. These are the sectors of "red", "green", and "blue" objects with their generalized momenta being $\mathbf{p}_R = (p_1, x_2, x_3)$, $\mathbf{p}_G = (x_1, p_2, x_3)$, $\mathbf{p}_B = (x_1, x_2, p_3)$, that together make the formation of standard vectors (like (p_1, p_2, p_3)) possible. Similarly, restoration of rotational covariance at the rishon level should require the cooperation of the corresponding rishon triplets (TVV), (VTV), (VVT), ie. the cooperation of three differently colored quarks. Furthermore, due to the position dependence of the generalized dispersion relations (eg. Eq.(12)), the individual colored quarks do not possess the classical reductionist feature of spatial separability, and require cooperation of other quarks (or antiquarks) in the formation of translationally invariant (string-like/flux-tube) structures.

In brief, it is the non-standard ("confining") nature of dispersion relations like (12) that is hidden behind the non-existence of individual colored objects in our macroscopic, classical world. Furthermore, it is the requirement of a proper rotational and translational behaviour, imposed upon the underlying quark structures, that is supposed to lie at the origin of the emergence of ordinary 3D space. In our view, the rudiments of the emerging matter-defined 3D space are formed via the construction of colorless hadron-level structures.

It is at the hadronic level, when - with the help of quark conspiracy - the effective 3D point may be successfully constructed, that a talk about the extension to special relativity could be started. Yet, the absence of c in the successful formulas for both hadronic scales (mass and string slope, Eqs.(7,9)) seems to indicate the relative unimportance of special relativity at the deep quantum level.[7]

[7] It should be stressed that the continuous relativistic spacetime, used as a background in the SM, constitutes a theory-based idealized extrapolation of a concept defined by Einstein with the

We viewed the non-standard form of the modified dispersion relations (12) as expressing in the phase-space-induced language the stringy nature of quark confinement. This form suggests that QCD - with its input of conceptually standard dispersion relations for quarks and universal continuous background spacetime - provides a significantly simplified and idealized description of the long-distance confining fluxtube aspects of inter-quark forces. Although all our theories are idealizations or approximations, the question emerges how QCD could generate rotationally noninvariant fluxtubes that would correspond to the stringy formulas (11,12) of our scheme. I believe we could learn this from studies of long-distance properties of hadrons. In fact, I suspect that in its treatment of the confined behaviour of quarks QCD misses something that does not appear at short distances. There are phenomenological hints from baryon spectroscopy that it may be so [20]. Namely, the standard constituent quark model and lattice QCD both predict the existence of many more (by a factor of 2 or so) excited baryonic states than seen experimentally. The continuing absence of these states from the observed spectrum (see [21]) may indicate that in excited baryons some internal spatial degrees of freedom are missing, thus hinting again at the connection of strong interactions with the emergence (or construction) of space [15].

5 Synopsis

1) The analogy between the phase-space-permutation-induced pattern of the sets of generalized momenta and the rishon structure of leptons and quarks leads to the interpretation of rishons as one-dimensional "objects". Consequently, rishons should not be viewed as subparticles, and the HS model should not be regarded as a preon model.
2) Our view of the HS model associates the structure of a single generation of leptons and quarks with the appearance of $2 \times (1 + 3)$ ways in which sets of generalized momenta (or positions) appear in a matter-space symmetric approach.
3) This view provides also a classical macroscopic reason for the appearance of the $U(1) \times SU(3)_C$ symmetry and suggests a simple interpretation for the origin of the non-existence of individual colored quarks. It supports the idea that the rudiments of ordinary 3D space begin to emerge through the formation of hadrons.

help of *macroscopic* objects (clocks and rods) [18]. It is not matter-defined at the microscopic quantum level since atomic-, hadronic-, or quark-size rods and clocks do not exist [19]. Yet, as argued above, the world of quarks does possess properties that seem to allow the construction (emergence) of the rudiments of hadron-defined 3D space.

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