How can the Standard model Higgs and also the extensions of the Higgs to Yukawa’s scalars be interpreted in the spin-charge-family theory and to what predictions about the Higgs does this theory lead?

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Abstract

This contribution is to show how does the spin-charge-family theory interpret the assumptions of the standard model, and those extensions of this model, which are trying to see the Yukawa couplings as scalar fields with the family (flavour) charges in the fundamental representations of the group. The purpose of these contribution is i.) to try to understand why the standard model works so well, although its assumptions look quite artificial, and ii.) how do predictions of the spin-charge-family theory about the measurements of the scalar fields differ from predictions of the standard model, which has only one scalar field - the Higgs - and also from its more or less direct extensions with Yukawas as the scalar dynamical fields with the family charge in the fundamental or anti-fundamental representation of group.

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I. INTRODUCTION

When the standard model of the elementary particles and fields was proposed more than 35 years ago it offered an elegant new step in understanding the origin of fermion and boson fields and the interactions among them.

It postulated: i.) The existence of the family members - coloured quarks and colourless leptons, both left and right handed, the left handed members distinguishing from the right handed ones in the weak and hyper charges. ii.) The existence of the gauge fields to the observed charges of the family members. iii.) The existence of the scalar field, the Higgs, which takes care of the masses of weak gauge fields and fermions and is chosen to have the charges, the weak one and the hyper one, in the fundamental representations of the weak group, just like fermions, to "dress right handed" family members with the weak and the right hyper charge and to interact with the gauge fields to bring masses only to $Z_m$ and $W_m^\pm$. iv.) The existence of the families. v.) The existence of the Yukawa couplings, taking care of the masses of fermions, together with the Higgs.

The standard model never has the ambition to explain its own assumptions, leaving the explanation of the open questions to the next step of the theory.

While all the so far observed fermions are spinors with the charges in the fundamental representations of the charge groups and all the bosons are vectors in the adjoint representations with respect to all the charges, are the Higgs field and its anti-Higgs scalars with the charges in the fundamental representations of the weak charge group. Therefore, quite a strange object, which reminds us on a supersymmetric particle (but it is not because it does not fit the so called R parity requirements).

Although the standard model leaves many questions unanswered, yet it is, without any doubt, a very efficient effective theory: There is so far no experiment which would help to show the next step beyond the standard model.

In the literature there are several proposals trying to go beyond the standard model, most of them just extending the ideas of the standard model, like: i.) A tiny extension is the inclusion of the right handed neutrinos into the family. ii.) The $SU(3)$ group is assumed to describe – not explain – the existence of three families. iii.) Like Higgs has the charges in the fundamental representations of the groups, also Yukawas are assumed to be scalar fields, in the bi-fundamental representation of the $SU(3)$ group. iv.) Supersymmetric theories
assuming the existence of partners to the existing fermions and bosons, with charges in the opposite representations, adjoint for fermions and fundamental for bosons.

Let me comment on the standard model as it is seen from the point of view of the spin-charge-family theory [1,2,4], which is, to my knowledge, the only proposal in the literature which is offering the mechanism for generating families, not just postulating families with an appropriate choice of a family group.

I shall comment also on the extensions of the Higgs scalar fields to the Yukawa dynamical fields carrying the family triplet or anti-triplet charges, depending on the handedness of fermions and distinguishing also among the family members. These extensions [9–11] are meant as an effective stage to help to learn from the experiment something about the nature of the scalar fields.

Although effective interactions can have quite unexpected shapes and yet can be very useful (as it is the case, for example, with the by experiments suggested spin-spin interaction in several models in the solid state and the liquid crystal physics where the effective interaction of the electromagnetic origin among many electrons and nuclei can be effectively expressed with the spin-spin interaction) yet it is hard to accept that effective theories of the type where the SU(3) groups are used to describe the family quantum number, introducing the scalar dynamical fields with the family charges in the fermionic like representations, can make useful predictions for new experiments, where searches depend strongly on the proposed theories behind. To my understanding at this stage of physics a new more general understanding of fermion and boson fields is needed.

Let me in what follows briefly present the standard model and its extension with the family group added and the spin-charge-family theory and comment with the last one the standard model and its extensions.

II. THE MOST URGENT OPEN QUESTIONS IN THE ELEMENTARY PARTICLE PHYSICS

To my understanding any new step in theoretical explanation of the standard model assumptions must answer the following most urgent open questions:

• What is the origin of families? How many families there are at all?
What is the origin of the scalar fields (the Higgs)? Where do their masses (the Higgs mass) and correspondingly the masses of the gauge fields originate?

What is the origin of the fermions masses, where do Yukawa couplings originate?

Where does the dark matter originate?

There are also several other questions which may not be so urgently answered, like: Where do dark energy originate? What is the origin of charges, and correspondingly of the gauge fields? And several others.

The spin-charge-family theory \[1, 2, 6-8\] seems promising in answering these and several other open questions.

### III. THE ASSUMPTIONS OF THE STANDARD MODEL

The standard model assumes before the electroweak break:

i.) Three massless families of fermions, each one containing quarks and leptons in the fundamental (spinor) representations with respect to the spin and the charges as presented in table \[\text{I}\] Members of each of the three \((i = 1, 2, 3)\) before the electroweak break massless (so far observed) families are assumed to fit the experimental data. Each family contains the left handed weak charged quarks and the right handed weak chargeless quarks, belonging to the colour triplet \((1/2, 1/(2\sqrt{3})), (-1/2, 1/(2\sqrt{3})), (0, -1/(\sqrt{3}))\). The existence of the corresponding anti-fermion is assumed for each family member of any family. (Let me add that in the spin-charge-family theory all these properties of one family follow from the simple starting action, from where also family members follow.)

ii.) Three massless gauge fields of the hyper charge \((Y)\), the weak charge \((\vec{\tau}^1)\) and the colour charge \((\vec{\tau}^3)\) are assumed as presented in table \[\text{II}\] They all are vectors in \(d = (1 + 3)\), in the adjoint representations with respect to the weak, colour and hyper charges, \(Q = \tau^{13} + Y\). (In the spin-charge-family theory all these gauge fields follow from the simple starting action with vielbeins and two kinds of the spin connection fields as the only gauge fields follow.)

iii.) The Higgs field, the scalar in \(d = (1 + 3)\), is assumed to be in the fundamental representation with respect to the charges. And there is the anti-Higgs. (In the spin-charge-family theory there are several scalar fields, all with the charges in the adjoint representations with respect to all the charge groups, which follow from the simple starting action.)
TABLE I: Properties of one family of quarks and leptons, right handed $\nu$ is included. $\tau^{13}$ defines the third component of the weak charge, $Y$ the hyper charge, $Q = Y + \tau^{13}$ is the electromagnetic charge.

| name          | $\alpha$ | hand- | weak | hyper | colour | elm |
|---------------|----------|-------|------|-------|--------|-----|
|               | $-4iS^{03}S^{12}$ | $\tau^{13}$ | $Y$  | $Q$   |        |     |
| $u^i_L$       | -1       | $\frac{1}{2}$ | $\frac{1}{6}$ | colour triplet | $\frac{2}{3}$ |
| $d^i_L$       | -1       | $-\frac{1}{2}$ | $\frac{1}{6}$ | colour triplet | $-\frac{1}{3}$ |
| $\nu^i_L$     | -1       | $\frac{1}{2}$ | $-\frac{1}{2}$ | colourless | 0     |
| $e^i_L$       | -1       | $-\frac{1}{2}$ | $-\frac{1}{2}$ | colourless | $-1$  |
| $u^i_R$       | 1        | weakless | $\frac{2}{3}$ | colour triplet | $\frac{2}{3}$ |
| $d^i_R$       | 1        | weakless | $-\frac{1}{3}$ | colour triplet | $-\frac{1}{3}$ |
| $\nu^i_R$     | 1        | weakless | 0     | colourless | 0     |
| $e^i_R$       | 1        | weakless | -1    | colourless | $-1$  |

TABLE II: Vector gauge fields in $d = (1 + 3)$, the gauge fields of the hyper, weak and colour charges.

| name          | hand- | weak | hyper | colour | elm |
|---------------|-------|------|-------|--------|-----|
|               | edness | charge | charge | charge |     |
| hyper photon  | 0      | 0     | 0     | colourless | 0   |
| weak bosons   | 0      | triplet | 0     | colourless | triplet |
| gluons        | 0      | 0     | 0     | colour octet | 0   |

IV. THE ASSUMPTIONS OF THE SPIN-CHARGE-FAMILY THEORY

There exist two kinds of the Clifford algebra objects. i.) The Dirac one, $\gamma^a$, is used to describe the spin of fermions. In the Kaluza-Klein-like theories the spin in higher dimensions together with the angular moments manifest, after the appropriate breaks of symmetries, as the charges and the spin in $(1+3)$. ii.) The second kind, I call it $\tilde{\gamma}^a$, anti-commuting with
TABLE III: Higgs is a scalar field in $d = (1+3)$, with the charges in the fundamental representation of the charge groups.

The Dirac one, describes families, since it forms the equivalent representations with respect to the first one (what means that $S^{ab}$ apply on each family in the same way).

Accordingly there exist beside vielbeins two kinds of spin-connection fields in gravity. The spin-charge-family theory is assuming the simplest action in $d = (1 + 13)$:

$$ S = \int d^d x \ E \mathcal{L}_f + \int d^d x \ E \ (\alpha \ R + \tilde{\alpha} \ \tilde{R}), $$

with the Lagrange densities for spinors and for gauge fields as follows

$$ \mathcal{L}_f = \frac{1}{2} (\bar{\psi} \gamma^a p_{0a} \psi) + h.c., \quad p_{0a} = f^\alpha_a p_{0a} + \frac{1}{2E} \{ p_{a}, E f^\alpha_a \} - , $$

$$ p_{0a} = p_a - \frac{1}{2} \hat{S}^{ab}_{a} \omega_{ba} - \frac{1}{2} \hat{\tilde{S}}^{ab}_{a} \tilde{\omega}_{ba}, $$

$$ R = \frac{1}{2} \{ f^{[a} f^{b]} \} (\omega_{aba} - \omega_{aca} \omega_{c}^{b} - \omega_{cba}) + h.c. , $$

$$ \tilde{R} = \frac{1}{2} f^{[a} f^{b]} (\tilde{\omega}_{aba} - \tilde{\omega}_{aca} \tilde{\omega}_{c}^{b} + h.c. . $$

The action (2) manifests in $d = (1+3)$, after the breaks of symmetries (chosen to lead to the measured properties of fermions and bosons) and before the electroweak break, the families of left handed weak charged quarks and leptons and right handed weakless quarks and leptons. Just as it is assumed by the standard model, except that an additional (broken) $U(1)$ charge exists and that there are also right handed neutrinos. The right handed neutrinos have nonzero value of this additional $U(1)$ charge. And there are four (rather then assumed three) families.

Before the electroweak break there are therefore four massless families of quarks and leptons and four massive families. After the electroweak break there are two groups of four massive families. The off diagonal and diagonal mass matrices of family members are determined on the tree level by the dynamical scalar fields, the gauge fields of the

| name         | hand-edness | weak charge | hyper charge | colour charge | elm |
|--------------|-------------|-------------|--------------|---------------|-----|
| Higgs$_u$    | 0           | $\frac{1}{2}$ | $\frac{1}{2}$ | colourless    | 1   |
| Higgs$_d$    | 0           | $-\frac{1}{2}$ | $\frac{1}{2}$ | colourless    | 0   |
charges originating in $\tilde{\gamma}^a$. To the diagonal terms also the scalar fields originating in $\gamma^a$, $s \geq 5$ contribute. In loop corrections both fields start to contribute coherently. The scalar dynamical fields determine also masses of $Z_m$ and $W^\pm_m$. For more information the reader is kindly asked to see the refs. [3, 4] in this proceedings and in the references therein.

All scalar and vector bosons have all the charges, except the weak charge in the adjoint representations of the charge gauge groups. All the scalar fields contributing to the masses of the lower four families are doublets with respect to the weak charge. All fermions have all the charges in the fundamental representations with respect to all the groups. The family quantum numbers are here included.

The only assumptions in this theory are that before the breaks of the symmetries the simplest action for fermions and bosons is taken, in which the only internal degrees of freedom are the two kinds of a spin, determined by $\gamma^a$ and $\tilde{\gamma}^a$, respectively, requiring accordingly besides the vielbeins the two kinds of the spin connection fields, and that the breaks (phase transitions) lead to measured phenomena.

After the breaks the first kind of spin manifests in $(1 + 3)$ the spin and all the charges, while the second one manifests the families.

V. PREDICTIONS OF THE SPIN-CHARGE-FAMILY THEORY

The spin-charge-family theory predictions are so far:

i.) There are two groups of four families in the low energy regime. The fourth of the lowest four families waits to be measured. The fifth stable family constitute the dark matter. More about these topics can be found in the refs. [3, 4].

ii.) The scalar fields, which are responsible for the mass matrices of fermions and correspondingly for their masses and mixing matrices, manifest effectively as the Higgs field and the Yukawa couplings. Effectively means that they are several dynamical fields with the family charges in the adjoint representations of while with respect to the weak charge they are doublets, like it is the standard model Higgs.

Accordingly, I expect that future searching for scalar fields will show up that there are several dynamical scalar fields, not just one, and that each one couples differently to different family members. More about this topic can be read in the ref. [4].

iii.) What is evident from the spin-charge-family theory is that besides the known gauge...
fields also the scalar fields are the interaction fields. Accordingly, since they effectively are representing also Yukawas, indeed also Yukawas are the interacting fields, although in the standard model hidden within the Higgs.

iv.) There are no supersymmetry in the low energy regime. Even Higgs, which is very close to a supersymmetric particle being a scalar with the charges in the fundamental representations of the charge groups, is only effectively working as it does. In the spin-charge-family-theory it is the operator $\gamma^0 \gamma^s$, $s = 7, 8$, which transforms the right handed family members into the corresponding left handed ones, ”doing the dressing job” of the Higgs and of $\gamma^0$.

iv.) There are also several other predictions, not yet enough studied to be commented here.

VI. HOW ARE THE STANDARD MODEL AND ITS EXTENSIONS SEEN FROM THE POINT OF VIEW OF THE SPIN-CHARGE-FAMILY THEORY?

As already discussed above, the standard model assumed the existence of a scalar field which has charges in the fundamental representations of the charged groups. As I have shown in the ref. [4], one can define an operator which does effectively the Higgs job.

The extensions of the standard model [9–11], where also Yukawas are taken as dynamical fields under the assumption that there are several family $SU(3)$ groups, one for the left handed quarks and two for the right handed quarks and similarly (not quite because of the right handed neutrinos) for the leptons. Then there are scalar dynamical fields assumed, again (under the influence of the Higgs) in the fundamental representations of these family groups.

VII. CONCLUSIONS

Let me conclude this discussion by again pointing out that the spin-charge-family theory does answer the questions, which are, to my understanding, the most urgent to be answered for any new successful step beyond the standard model. I doubt that trying to explain only one of the ”urgent open questions” presented above, can bring a new insight into the assumptions of the standard model.
The \textit{spin-charge-family} theory offers not only the answer to the question why we have more than one family, and how many there are, it explains also the origin of the Higgs and the Yukawa couplings, of the charges and the gauge fields.

Correspondingly it predicts the fourth and the stable fifth families. There are also other open questions, which the theory is offering the answers for.

According to these predictions there is no supersymmetric particles at the low energy regime. But, without doubts, there are additional families and several additional dynamical fields - interactions. Work is in progress.

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