How far do we understand our Universe at the moment?

Understanding Nature with the Spin-Charge-Family theory

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Ljubljana, Dept. of Physics, FMF, 4th March 2019
Some publications:


- **Phys. Rev. D** 74 073013-16 (2006), with A.Borštnik Bračič,

- **New J. of Phys.** 10 (2008) 093002, arxiv:1412.5866, with G.Bregar, M.Breskvar, D.Lukman,

- **Phys. Rev. D** (2009) 80.083534, with G. Bregar,

How do we gather knowledge - understanding -

- about the laws, which govern the smallest constituents of Nature
- and correspondingly the whole our Universe and might be universes?
- How do we learn about the space-time in which we live?
- How do we learn about the complex systems on all levels of physics?
We observe.
We make experiments.
We make thought experiments, leading to new questions, new ideas.
We make mathematical models, which cover the so far made discoveries, findings, thoughts, ideas.
The models make predictions.
We check predictions by experiments.

We repeat this circle again and again, with more and more knowledge and more and more and more intuition

and with more and more sophisticated experiments
and with more and more hopefully elegant mathematics.
We want to understand:

What is space-time

and

What are the building blocks of our universe

What laws govern its dynamics
fundamental building blocks
quarks and leptons; gluons
weak bosons; photons
gravitons
hadrons: p, n, π
atoms and molecules
matter
planetary systems
galaxies
clusters of galaxies
universe
universes
?
Knowledge was created slowly, step by step, although some of the steps were for a long time present. Like:

- That our Earth is round. Every sailor knew that.
- That our Earth is rotating.
- That Earth is running around the Sun.

We follow the history of the universe through theories, models, experiments up to the hadron formation, before the hadrons we have almost only theories, models,..
The history of our universe

- \(10^{-43} \text{s} \ldots\) The history of our universe started with the Big Bang, as we can guess from models and experiences when treating quantum systems and from observations of properties of our universe.
  - We have no knowledge about the dimension of space-time at the Big Bang. (Was it larger than (3+1)? Was it \(\infty\)?

- The theory, supported by very demanded experiments with scattering particles at high energy, up to 14 TeV (CERN), leads us to conclude that elementary constituents are (very probably) quarks and leptons, interacting with at least four kinds of interactions: colour, weak, electromagnetic and gravity.

- \(10^{-5} \text{s} \ldots\) Quarks and leptons formed hadrons — p, n, ..
3 min... Protons and neutrons made atomic nuclei.

380,000 years... Nuclei and electrons made atoms. Our universe became transparent.

10\(^9\) years... Stars and galaxies started to be formed.

13.8 \cdot 10^9 years... Present time, dominated by dark energy (antigravity) (70%), dark matter (25%), ordinary matter (5%) (0.03% of heavy elements (anything other than hydrogen and helium), 0.3% neutrinos, 0.5% stars, 4% free hydrogen and helium.
It seems acceptable that the observed electromagnetic, weak and colour interactions, the strength of which are so different at low energies, and are becoming more and more equal to higher energies we go, were together with gravity only one - the gravitational one.

We do not know where from the scalar field, needed to cause inflation after the Big Bang (needed for the explanation of the homogeneity and isotropy of the universe and other observations), originate.

There are so many not (yet) understood assumptions in our theories.

Is the law of nature elegant and simple, or it is complicated, that is more and more complicated to higher energies we control our universe, as it looks like if one searches through scientific journals.
More than **50 years ago** the **electroweak (and colour) standard model** offered an **elegant new step** in understanding the origin of fermions and bosons by postulating:

- The existence of the **massless family members** with the charges in the **fundamental representation** of the groups -
  - o the **coloured triplet quarks** and **colourless leptons**,  
  - o the **left handed members** as the weak charged doublets,  
  - o the **right handed weak chargeless members**,  
  - o the **left handed quarks** distinguishing in the hyper charge from the left handed leptons,  
  - o each right handed member having a different hyper charge.

- The existence of **massless families to each of a family member**.
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<thead>
<tr>
<th>α</th>
<th>hand-</th>
<th>weak</th>
<th>hyper</th>
<th>colour</th>
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<td>$\tau^{13}$</td>
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<tr>
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Members of each of the $i = 1, 2, 3$ families, $i = 1, 2, 3$ massless before the electroweak break. Each family contains the left handed weak charged quarks and the right handed weak chargeless quarks, belonging to the colour triplet $(1/2, 1/(2\sqrt{3})), (-1/2, 1/(2\sqrt{3})), (0, -1/(\sqrt{3}))$. **And the anti-fermions** to each family and family member.
The existence of the **massless vector gauge fields** to the observed **charges** of the **family members**, carrying charges in the **adjoint representation of the charge groups**.
Gauge fields before the electroweak break

- Three massless vector fields, the gauge fields of the three charges.

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<thead>
<tr>
<th>name</th>
<th>handedness</th>
<th>weak charge</th>
<th>hyper charge</th>
<th>colour charge</th>
<th>elm charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>hyper photon</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>colourless</td>
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<tr>
<td>weak bosons</td>
<td>0</td>
<td>triplet</td>
<td>0</td>
<td>colourless</td>
<td>triplet</td>
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<tr>
<td>gluons</td>
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<td>0</td>
<td>colour octet</td>
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They all are vectors in $d = (3 + 1)$, in the adjoint representations with respect to the weak, colour and hyper charges.
The **existence of a massive scalar field - the higgs**, carrying the weak charge $\pm \frac{1}{2}$ and the hyper charge $\mp \frac{1}{2}$ as it would be in the **fundamental representation of the groups**, gaining at some step a "**nonzero vacuum expectation values**", breaking the weak and the hyper charge and correspondingly breaking the **mass protection**.

The **existence of the Yukawa couplings**, taking care of the properties of **fermions** and the masses of the **heavy bosons**.
The Higgs’s field, the scalar in $d = (3 + 1)$, a doublet with respect to the weak charge.

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<th>hyper charge</th>
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<td>$\frac{1}{2}$</td>
<td>colourless</td>
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<tr>
<td>$&lt; \text{Higgs}_d &gt;$</td>
<td>0</td>
<td>$-\frac{1}{2}$</td>
<td>$\frac{1}{2}$</td>
<td>colourless</td>
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<td>$&lt; \text{Higgs}_u &gt;$</td>
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<td>colourless</td>
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<td>$0 \cdot \text{Higgs}_d$</td>
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<td>$-\frac{1}{2}$</td>
<td>$-\frac{1}{2}$</td>
<td>colourless</td>
<td>$-1$</td>
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</table>
There is the gravitational field in $d=(3+1)$. 
The standard model assumptions have been confirmed without offering surprises.

The last unobserved field as a field, the Higgs’s scalar, detected in June 2012, was confirmed in March 2013.

The waves of the gravitational field were detected in February 2016 and again 2017.
The *standard model* assumptions have in the literature several explanations, but with many new not explained assumptions, more or less extending the *standard model* groups.

I am proposing the *spin-charge-family theory*, which offers the explanation for

i. all the assumptions of the *standard model*,

ii. for many observed phenomena, making several predictions.

Is my *spin-charge-family theory* the right next step beyond both *standard models*?
There are namely many phenomena

- the **dark matter**,  
- the **matter-antimatter** asymmetry, 
- the **dark energy**, 
- the **observed dimension of space time**,  
- many other phenomena,  

**not yet understood.**

Can the *spin-charge-family theory* explain the observed phenomena?

*********************************************
We try to understand:

▶ What are elementary constituents and interactions among constituents in our Universe, in any universe?

▶ Can the elementary constituent be of only one kind? Are the four observed interactions — gravitational, elektromagnetic, weak and colour — of the common origin?

▶ Is the space-time the so far observed (3 + 1)? Why (3+1)?

▶ If not (3 + 1) may it be that the space-time is infinite?

▶ How has the space-time of our universe started?

▶ What is the matter and what the anti-matter?
Obviously it is the time to make the next step beyond both standard models.
What questions should one ask to be able to find next steps beyond the standard models and to understand not yet understood phenomena?

- Where do family members originate?
- Where do charges of family members originate?
- Why are the charges of family members so different?
- Why have the left handed family members so different charges from the right handed ones?

- Where do families of family members originate?
- How many different families exist?
- Why do family members – quarks and leptons – manifest so different properties if they all start as massless?
How is the origin of the scalar field (the Higgs’s scalar) and the Yukawa couplings connected with the origin of families? How many scalar fields determine properties of the so far (and others possibly be) observed fermions and masses of weak bosons? (The Yukawa couplings certainly speak for the existence of several scalar fields with the properties of Higgs’s scalar.)

Why is the Higgs’s scalar, or are all scalar fields, if there are several, doublets with respect to the weak and the hyper charge?

Do exist also scalar fields with the colour charge in the fundamental representation and where, if they are, do they manifest?
Where do the charges and correspondingly the so far (and others possibly be) observed vector gauge fields originate?

Where does the dark matter originate?

Where does the "ordinary" matter-antimatter asymmetry originate?

Where does the dark energy originate?

What is the dimension of space? $(3 + 1)$?, $((d − 1) + 1)$?, $\infty$?

What is the role of the symmetries—discrete, continuous, global and gauge—in our universe, in Nature?

And many others.
My statement:

- **An elegant trustworthy next step** must offer answers to several open questions, explaining:
  - The origin of the family members and the charges.
  - The origin of the families and their properties.
  - The origin of the scalar fields and their properties.
  - The origin of the vector fields and their properties.
  - The origin of the dark matter.
  - The origin of the "ordinary" matter-antimatter asymmetry.
My statement continues:

- There exist not yet observed families, gauge vector and scalar gauge fields.
- **Dimension of space is larger than 4** (very probably infinite).
- Inventing a next step which covers one of the open questions, might be of a help but can hardly show the right next step in understanding nature.
In the literature NO explanation for the existence of the families can be found, which would not just assume the family groups. Several extensions of the standard model are, however, proposed, like:

- The $SU(3)$ group is assumed to describe – not explain – the existence of three families. Like the Higgs’s scalar charges are in the fundamental representations of the groups, also the Yukawas are assumed to emerge from the scalar fields, in the fundamental representation of the $SU(3)$ group.
SU(5) and SO(10) grand unified theories are proposed, unifying all the charges. But the spin (the handedness) is obviously connected with the (weak and the hyper) charges, what these theories do ”by hand” as it does the standard model, and the appearance of families is not explained.

Supersymmetric theories, assuming the existence of bosons with the charges of quarks and leptons and fermions with the charges of the gauge vector fields, although having several nice properties but not explaining the appearance of families (except again by assuming larger groups), are not, to my understanding, the right next step beyond the standard model.
The Spin-Charge-Family theory does offer the explanation for all the assumptions of the standard model, answering up to now several of the above cited open questions!

The more effort is put into this theory, the more answers to the open questions in elementary particle physics and cosmology is the theory offering.
I shall first make a short introduction into the Spin-Charge-Family theory.

I shall make an overview of achievements so far of the Spin-Charge-Family theory.

I shall report on the possibility that "nature could make a choice" of Grassmann rather than Clifford space to describe the internal degrees of freedom of fermions, what would lead to fermions, still anticommuting (in the second quantization), but with the integer spin [arXiv:1802.05554v1v2].
A brief introduction into the spin-charge-family theory, in which one can

- visualize the structure of the internal space of fermions,
- correspondingly calculate directly handedness, spin, charges and family quantum number,
- observe directly scalar and gauge fields with which fermions — quarks and leptons — interact,
- follow the appearance of families,
- see the origin of dark matter,
- follow the appearance of the matter-antimatter asymmetry,
- ….
The *spin-charge-family* theory proposes

a simple elegant action for a spinor which carries in
d = (13 + 1) only two kinds of spins (no charges) and for
gauge fields:

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

\[
\mathcal{L}_f = \frac{1}{2} (\bar{\psi} \gamma^a p_0 a \psi) + h.c.
\]

\[
p_{0a} = f^\alpha_a p_{0\alpha} + \frac{1}{2E} \{ p_{\alpha}, Ef^\alpha_a \} -
\]

\[
p_{0\alpha} = p_{\alpha} - \frac{1}{2} S^{ab} \omega_{ab\alpha} - \frac{1}{2} \tilde{S}^{ab} \tilde{\omega}_{ab\alpha}
\]
The Einstein action for a free gravitational field is assumed to be linear in the curvature

\[
\mathcal{L}_g = E \left( \alpha R + \tilde{\alpha} \tilde{R} \right),
\]

\[
R = f^{\alpha[a} f^{\beta b]} \left( \omega_{ab\alpha,\beta} - \omega_{ca\alpha} \omega^{c b\beta} \right),
\]

\[
\tilde{R} = f^{\alpha[a} f^{\beta b]} \left( \tilde{\omega}_{ab\alpha,\beta} - \tilde{\omega}_{ca\alpha} \tilde{\omega}^{c b\beta} \right),
\]

with \( E = \det(e^a_{\alpha}) \)

and \( f^{\alpha[a} f^{\beta b]} = f^{\alpha a} f^{\beta b} - f^{\alpha b} f^{\beta a} \).
The only internal degrees of freedom of spinors (fermions) are the two kinds of spin: $\gamma^a$ and $\tilde{\gamma}^a$.

The only gauge fields are the gravitational ones – vielbeins and the two kinds of the spin connections, gauge fields of $\gamma^a$ ($S^{ab}$) and $\tilde{\gamma}^a$ ($\tilde{S}^{ab}$).

- The Dirac spin ($\gamma^a$) in $d = (13 + 1)$ describes in $d = (3 + 1)$ spin and ALL the charges of quarks and leptons and antiquarks and antileptons, left and right handed, explaining all the assumptions about the charges and the handedness of the standard model. J. of Math. Phys. 34 3731 (1993), 43, 5782 (2002) [hep-th/0111257].

- The second kind of spin ($\tilde{\gamma}^a$) describes FAMILIES, explaining the origin of families and their number, J. of Math. Phys. 44 4817 (2003) [hep-th/0303224].

- There is NO third kind of spin.

- C,P,T symmetries in $d = (3 + 1)$ follow from the C,P,T symmetry in $d \geq (13 + 1)$, JHEP 04 165 (2014).
All vector and scalar gauge fields origin in gravity, explaining the origin of the vector and scalar gauge fields, which in the standard model are just assumed, Eur. Phys. J. C 77 (2017) 231:

o in two spin connection fields, the gauge fields of $\gamma^a\gamma^b$ and $\tilde{\gamma}^a\tilde{\gamma}^b$, and in

o vielbeins, the gauge fields of moments

If there are no spinor sources present, then either vector ($\vec{A}_m^A$, $m = 0, 1, 2, 3$) or scalar ($\vec{A}_s^A$, $s = 5, 6, \ldots, d$) gauge fields are determined by vielbeins uniquely.
Spinors interact with
- the vielbeins and

In $d = (3 + 1)$ the spin-connection fields, together with the vielbeins, manifest either as
- vector gauge fields with all the charges in the adjoint representations or as
- scalar gauge fields with the charges with respect to the space index in the "fundamental" representations and all the other charges in the adjoint representations or as
- tensor gravitational fields.
There are two kinds of scalar fields with respect to the space index $s$:

- Those with $(s = 5, 6, 7, 8)$ (they carry zero "spinor charge") are doublets with respect to the $SU(2)_I$ (the weak) charge and the second $SU(2)_{II}$ charge (determining the hyper charge). They are in the adjoint representations with respect to the family and the family members charges.

- These scalars explain the Higgs’s scalar and the Yukawa couplings.

PRD 91 (2015) 6, 065004
Those with twice the "spinor charge" of a quark and $(s = 9, 10, \ldots d)$ are colour triplets. Also they are in the adjoint representations with respect to the family and the family members charges.

- These scalars transform antileptons into quarks, and antiquarks into quarks and back and correspondingly contribute to matter-antimatter asymmetry of our universe and to proton decay.

- There are no additional scalar fields in the spin-charge-family theory, if $d = (13 + 1)$.

Phys. Rev. D 91 (2015) 6, 065004
J. of Mod. Phys. 6 (2015) 2244
Breaks of symmetries is needed after starting with massless

- massless fermion fields

and

- massless boson fields.
$SO(1, 13) \times \tilde{SO}(1, 13) \times$

**BREAK I**

at $E \geq 10^{16}$ GeV

$\downarrow$

$SO(1, 7) \times \tilde{SO}(1, 7) \times U(1) \times SU(3)$

eight massless families

$SO(1, 3) \times SO(4) \times U(1) \times (\tilde{SU}(2)_{SO(1,3)} \times \tilde{SU}(2)_{SO(4)}) \times (\tilde{SU}(2)_{SO(1,3)} \times \tilde{SU}(2)_{SO(4)}) \times SU(3)$

(devided into two groups)

**BREAK II**

$\downarrow$

The Standard Model like way of breaking

$SO(1, 3) \times U(1) \times SU(3)$

$\times$ (two groups of four massive families)
There are two breaks:

The first break is caused by the condensate.

The second break is caused by the nonzero vacuum expectation values of the scalar fields.

- The appearance of the condensate of the two right handed neutrinos, coupled to spin 0, makes the boson gauge fields, with which the condensate interacts, massive. These gauge fields are:
  - All the scalar gauge fields with the space index $s \geq 5$.
  - The vector ($m \leq 3$) gauge fields with the $Y'$ charges — the superposition of $SU(2)_{II}$ and $U(1)_{II}$ charges.

The **condensate** has spin $S^{12} = 0$, $S^{03} = 0$, weak charge $\vec{\tau}^1 = 0$, and $\vec{\tau}^1 = 0, \vec{Y} = 0, \vec{Q} = 0, \vec{N}_L = 0$.

<table>
<thead>
<tr>
<th>state</th>
<th>$\tau^{23}$</th>
<th>$\tau^4$</th>
<th>$Y$</th>
<th>$Q$</th>
<th>$\vec{\tau}^{23}$</th>
<th>$\vec{N}_R^3$</th>
<th>$\vec{\tau}^4$</th>
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<td>\nu_{1R}^{\text{VIII}} &gt; 1$</td>
<td>$</td>
<td>\nu_{2R}^{\text{VIII}} &gt; 2$</td>
<td>1</td>
<td>-1</td>
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</tr>
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Phys. Rev. **D 91 (2015)** 6, 065004,
J. of Mod. Phys. **6 (2015)** 2244,
J. Phys.: Conf.Ser. 845 01, **IARD 2017**
The colour, elm, weak and hyper vector gauge fields do not interact with the condensate and remain massless. J. of Mod. Physics 6 (2015) 2244
At the electroweak break from $SO(1,3) \times SU(2)_I \times U(1)_I \times SU(3)$ to $SO(1,3) \times U(1) \times SU(3)$

- scalar fields with the space index $s = (7, 8)$ obtain nonzero vacuum expectation values,
- break correspondingly the weak and the hyper charge and change their own masses.
- They leave massless only the colour, elm and gravity gauge fields.

All the eight massless families gain masses.

The appearance of the condensate and the nonzero vector expectation values of scalar fields are assumed so far, waiting to be proven.

But all the needed degrees of freedom with the dynamics included are already in the simple starting action. No new degrees of freedom are needed.
To the electroweak break several scalar fields, the gauge fields of twice $\tilde{SU}(2) \times \tilde{SU}(2)$ and three $\times U(1)$, contribute, all with the weak and the hyper charge of the standard model Higgs.

They carry besides the weak and the hyper charge either

- o the family members quantum numbers originating in $(Q,Q',Y')$ or

- o the family quantum numbers originating in twice $\tilde{SU}(2) \times \tilde{SU}(2)$.

The mass matrices of each family member manifest the $\tilde{SU}(2) \times \tilde{SU}(2) \times U(1)$ symmetry, which remains unchanged in all loop corrections, while repetitions of the nonzero vacuum expectation values of the scalar fields, together with loop corrections, both in all orders, give a controllable change of this symmetry.

Knowing the symmetry of mass matrices, reducing the number of free parameters of mass matrices, we fit the parameters to the data.

For accurate enough data we can predict the properties of the fourth families of quarks and leptons, PRD 80, 083534 (2009).
We studied on a toy model of $d = (1 + 5)$ conditions which lead after breaking symmetries to massless spinors chirally coupled to the Kaluza-Klein-like gauge field.,

New J. Phys. 13 (2011) 103027, 1-25,
\(d \geq 1+13\)

and the fourth family

and the fifth family

the dark matter
It is extremely encouraging for the spin-charge-family theory, that a simple starting action contains all the degrees of freedom observed at low energies, directly or indirectly, and that only the o condensate and 

o nonzero vacuum expectation values of all the scalar fields with $s = (7, 8)$

are needed that the theory explains o all the assumptions of the standard model, with the gauge fields, scalar fields, families of fermions, masses of fermions and of bosons included, o explaining also the dark matter, o the matter/antimatter asymmetry, o the triangle anomalies cancellation in the standard model (Forts. der Physik, Prog. of Phys.) (2017) 1700046) and...
The spin-charge-family theory is a kind of a Kaluza-Klein-like theory, but with two kinds of spins.

In $d$-dimensional space there are fermions with two kinds of spins and gravity, represented by two spin connection and vielbein gauge fields.

J. of Mod. Phys. 4 (2013) 823,  
Phys. Rev. D 91 (2015) 6, 065004,  
J. of Mod. Phys. 6 (2015) 2244 [arxiv:1409.4981],  
[arXiv:1607.01618]/v2],  
Eur. Phys. J.C. 77 (2017) 231,  
Forts. der Physik, Prog. of Phys.) (2017) 1700046
A short look "inside" the spin-charge-family theory.
There are only two kinds of the Clifford algebra objects in any $d$:

- The **Dirac $\gamma^a$ operators** (used by Dirac 90 years ago).
- The **second one**: $\tilde{\gamma}^a$, which I recognized in the Grassmann space.

\[
\{\gamma^a, \gamma^b\}^+_+ = 2\eta^{ab} = \{\tilde{\gamma}^a, \tilde{\gamma}^b\}^+_+,
\]
\[
\{\gamma^a, \tilde{\gamma}^b\}^+_+ = 0,
\]
\[
(\tilde{\gamma}^a B : = i(-1)^{n_B} B \gamma^a) |\psi_0 >,
\]
\[
(B = a_0 + a_a \gamma^a + a_{ab} \gamma^a \gamma^b + \cdots + a_{a_1...a_d} \gamma^{a_1} \cdots \gamma^{a_d}) |\psi_0 >
\]

$(-1)^{n_B} = +1, -1$, when the object $B$ has a Clifford even or odd character, respectively.

$|\psi_0 >$ is a vacuum state on which the operators $\gamma^a$ apply.
\[ S^{ab} := \left( \frac{i}{4} \right) (\gamma^a \gamma^b - \gamma^b \gamma^a), \]

\[ \tilde{S}^{ab} := \left( \frac{i}{4} \right) (\tilde{\gamma}^a \tilde{\gamma}^b - \tilde{\gamma}^b \tilde{\gamma}^a), \]

\[ \{ S^{ab}, \tilde{S}^{cd} \} = 0. \]

\( \tilde{\gamma}^a \) define the equivalent representations with respect to \( S^{ab} \).

My recognition:

- If \( \gamma^a \) are used to describe the spin and the charges of spinors,
- \( \tilde{\gamma}^a \) - since it must be used or it must be explained why it does not manifest - it must be used to describe families of spinors.

J. Math. Phys. 34, 3731-3745 (1993),
Variation of the action brings for $\omega_{ab\alpha}$

$$
\omega_{ab\alpha} = -\frac{1}{2E} \left\{ e_{e\alpha} e_{b\gamma} \partial_\beta (Ef^\gamma [e f^\beta_a]) + e_{e\alpha} e_{a\gamma} \partial_\beta (Ef^\gamma [b f^\beta_e])
- e_{e\alpha} e^{e\gamma} \partial_\beta (Ef^\gamma [a f^\beta_b]) \right\}
- \frac{e_{e\alpha}}{4} \left\{ \bar{\Psi} \left( \gamma_e S_{ab} + \frac{3i}{2} (\delta^e_b \gamma_a - \delta^e_a \gamma_b) \right) \Psi \right\}
- \frac{1}{d-2} \left\{ e_{a\alpha} \left[ \frac{1}{E} e^{d\gamma} \partial_\beta (Ef^\gamma [d f^\beta_b]) + \frac{1}{2} \bar{\Psi} \gamma^d S_{db} \Psi \right]
- e_{b\alpha} \left[ \frac{1}{E} e^{d\gamma} \partial_\beta (Ef^\gamma [d f^\beta_a]) + \frac{1}{2} \bar{\Psi} \gamma^d S_{da} \Psi \right] \right\}
$$

IARD, J. Phys.: Conf. Ser. 845 012017 and the refs. therein
and for $\tilde{\omega}_{ab\alpha}$,

$$
\tilde{\omega}_{ab\alpha} = - \frac{1}{2E} \left\{ e_{e\alpha} e_{b\gamma} \partial_{\beta} (E f^{\gamma} [e f^{\beta} a]) + e_{e\alpha} e_{a\gamma} \partial_{\beta} (E f^{\gamma} [b f^{\beta} e])
\right.
\left.
- e_{e\alpha} e^{e\gamma} \partial_{\beta} (E f^{\gamma} [a f^{\beta} b]) \right\} 
- \frac{e_{e\alpha}}{4} \left\{ \bar{\psi} \left( \gamma_e \tilde{S}_{ab} + \frac{3i}{2} (\delta_{b}^{e} \gamma_a - \delta_{a}^{e} \gamma_b) \right) \psi \right\} 
- \frac{1}{d - 2} \left\{ e_{a\alpha} \left[ \frac{1}{E} e^{d\gamma} \partial_{\beta} (E f^{\gamma} [d f^{\beta} b]) + \frac{1}{2} \bar{\psi} \gamma^{d} \tilde{S}_{db} \psi \right]
\right.
\left.
- e_{b\alpha} \left[ \frac{1}{E} e^{d\gamma} \partial_{\beta} (E f^{\gamma} [d f^{\beta} a]) + \frac{1}{2} \bar{\psi} \gamma^{d} \tilde{S}_{da} \psi \right] \right\}
$$

The action for spinors seen from \( d = (3 + 1) \) and analyzed with respect to the standard model groups as subgroups of \( SO(13 + 1) \):

\[
\mathcal{L}_f = \bar{\psi} \gamma^m (p_m - \sum_{A,i} g^{A \tau^A_i} A^A_i) \psi + \left\{ \sum_{s=[7],[8]} \bar{\psi} \gamma^s p_0 \psi \right\} + \left\{ \sum_{s=[5],[6]} \bar{\psi} \gamma^s p_0 \psi + \sum_{t=[9],...[14]} \bar{\psi} \gamma^t p_0 t \psi \right\}.
\]

Fort. der Phys., Progress of Physics (2017) 1700046,
J. of Mod. Phys. 4 (2013) 823,
Covariant momenta

\[ p_{0m} = \{ p_m - \sum_A g^A \vec{\tau}^A \vec{A}_m \} \]

\[ m \in (0, 1, 2, 3), \]

\[ p_{0s} = f_s^\sigma [ p_\sigma - \sum_A g^A \vec{\tau}^A \vec{A}_\sigma - \sum_A \tilde{g}^A \vec{\tau}^A \vec{\tilde{A}}_\sigma ], \]

\[ s \in (7, 8), \]

\[ p_{0s} = f_s^\sigma [ p_\sigma - \sum_A g^A \vec{\tau}^A \vec{A}_\sigma - \sum_A \tilde{g}^A \vec{\tau}^A \vec{\tilde{A}}_\sigma ], \]

\[ s \in (5, 6), \]

\[ p_{0t} = f_t^{\sigma'} (p_{\sigma'} - \sum_A g^A \vec{\tau}^A \vec{A}_{\sigma'} - \sum_A \tilde{g}^A \vec{\tau}^A \vec{\tilde{A}}_{\sigma'} ), \]

\[ t \in (9, 10, 11, \ldots, 14), \]
\[ A_{c}^{Ai} = \sum_{a,b} c^{Ai}_{ab} \omega_{abc} , \]
\[ \tilde{A}_{a}^{Ai} = \sum_{a,b} \tilde{c}^{Ai}_{ab} \tilde{\omega}_{abc} , \]
\[ \tau_{Ai} = \sum_{a,b} c_{ab}^{Ai} S_{ab}, \]
\[ \tilde{\tau}_{Ai} = \sum_{a,b} \tilde{c}_{ab}^{Ai} \tilde{S}_{ab}, \]
\[ \{ \tau_{Ai}, \tau_{Bj} \} = i \delta^{AB} f_{Aijk} \tau_{Ak}, \]
\[ \{ \tilde{\tau}_{Ai}, \tilde{\tau}_{Bj} \} = i \delta^{AB} f_{Aijk} \tilde{\tau}_{Ak}, \]
\[ \{ \tau_{Ai}, \tilde{\tau}_{Bj} \} = 0. \]

- **\( \tau^{Ai} \)** represent the *standard model* charge groups — \( SU(3)_c, SU(2)_w \) — the second \( SU(2)_\| \), the "spinor" charge \( U(1) \), taking care of the hyper charge \( Y \),
- **\( \tilde{\tau}^{Ai} \)** denote the family quantum numbers.
\[ N_{(L,R)}^i := \frac{1}{2} \left( S^{23} \pm iS^{01}, S^{31} \pm iS^{02}, S^{12} \pm iS^{03} \right), \]
\[ \tau_{(1,2)}^i := \frac{1}{2} \left( S^{58} \mp S^{67}, S^{57} \pm S^{68}, S^{56} \mp S^{78} \right), \]
\[ \tau_3^i := \frac{1}{2} \left\{ S^9 \, 12 - S^{10} \, 11, S^9 \, 11 + S^{10} \, 12, S^9 \, 10 - S^{11} \, 12, S^9 \, 14 - S^{10} \, 13, S^9 \, 13 + S^{10} \, 14, S^{11} \, 14 - S^{12} \, 13, S^{11} \, 13 + S^{12} \, 14, \frac{1}{\sqrt{3}} \left( S^9 \, 10 + S^{11} \, 12 - 2S^{13} \, 14 \right) \right\}, \]
\[ \tau^4 := -\frac{1}{3} \left( S^9 \, 10 + S^{11} \, 12 + S^{13} \, 14 \right), \]
\[ Y := \tau^4 + \tau^{23}, \]
\[ Y' := -\tau^4 \tan^2 \vartheta_2 + \tau^{23}, \]
\[ Q := \tau^{13} + Y, \]
\[ Q' := -Y \tan^2 \vartheta_1 + \tau^{13}, \]
and equivalently for family groups \( \tilde{S}^{ab} \).
Families of quarks and leptons and antiquarks and antileptons
Our technique to represent spinors is elegant.

- J. of Math. Phys. **44** 4817 (2003), hep-th/0303224,
The spinors states are created out of nilpotents \((\pm i)\) and projectors \([\pm i]\)

\[
(\pm i) : = \frac{1}{2}(\gamma^a \mp i \gamma^b), \quad [\pm i] : = \frac{1}{2}(1 \pm \gamma^a \gamma^b)
\]

for \(\eta^{aa} \eta^{bb} = -1\),

\[
(\pm) : = \frac{1}{2}(\gamma^a \pm i \gamma^b), \quad [\pm] : = \frac{1}{2}(1 \pm i \gamma^a \gamma^b),
\]

for \(\eta^{aa} \eta^{bb} = 1\)

with \(\gamma^a\) which are usual Dirac operators in \(d\)-dimensional space.

Nilpotents \( \pm i \) and projectors \( \pm i \) are eigensates of the Cartan subalgebra of \( S^{ab} \) and \( \tilde{S}^{ab} \).

\[
S^{ab} (k) = \frac{k^{ab}}{2 (k)}, \quad S^{ab} [k] = \frac{k^{ab}}{2 [k]},
\]

\[
\tilde{S}^{ab} (k) = \frac{k^{ab}}{2 (k)}, \quad \tilde{S}^{ab} [k] = -\frac{k^{ab}}{2 [k]}.
\]
$\gamma^a$ transforms $ab(k)$ into $ab[-k]$, never to $ab[k]$.

$\tilde{\gamma}^a$ transforms $ab(k)$ into $ab[k]$, never to $ab[-k]$. 
One **Weyl representation** of one **family** contains $2^{d-1}$ members, that is in $d = (13 + 1)$ all the **family members** with the **right handed neutrinos included**. It includes also **antimembers**, reachable by either $S^{ab}$ or by $C_N \, P_N$ on a **family member**.


There are $2^{(7+1)/2-1} = 8$ **families**, which decouple into **twice four families**, with the quantum numbers $(\tilde{\tau}^{2i}, \tilde{N}_R^i)$ and $(\tilde{\tau}^{1i}, \tilde{N}_L^i)$, respectively.

$S^{ab}$ generate all the members of one family. The eightplet (represent. of $SO(7, 1)$) of quarks of a particular colour charge

$$ |a \psi_i > \Gamma^{(3,1)} S^{12} \Gamma^{(4)} \tau^{13} \tau^{23} Y \tau^4 $$

<table>
<thead>
<tr>
<th>i</th>
<th>$a \psi_i$</th>
<th>Octet, $\Gamma^{(7,1)} = 1$, $\Gamma^{(6)} = -1$, of quarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$u^c_1$</td>
<td>03 12 56 78 9 1011 1213 14 (+i)(+)</td>
</tr>
<tr>
<td>2</td>
<td>$u^c_1$</td>
<td>-i[+]</td>
</tr>
<tr>
<td>3</td>
<td>$d^c_1$</td>
<td>03 12 56 78 9 1011 1213 14 (+)(+)</td>
</tr>
<tr>
<td>4</td>
<td>$d^c_1$</td>
<td>-i[-]</td>
</tr>
<tr>
<td>5</td>
<td>$d^c_1$</td>
<td>03 12 56 78 9 1011 1213 14 [-i][+]</td>
</tr>
<tr>
<td>6</td>
<td>$d^c_1$</td>
<td>-1 56 78 9 1011 1213 14 (+i)[+]</td>
</tr>
<tr>
<td>7</td>
<td>$u^c_1$</td>
<td>-1 56 78 9 1011 1213 14 (+i)[-]</td>
</tr>
<tr>
<td>8</td>
<td>$u^c_1$</td>
<td>-1 56 78 9 1011 1213 14 (+i)[-]</td>
</tr>
</tbody>
</table>

$\gamma^0 \gamma^7$ and $\gamma^0 \gamma^8$ transform $u_R$ of the 1st row into $u_L$ of the 7th row, and $d_R$ of the 4th row into $d_L$ of the 6th row, doing what the Higgs scalars and $\gamma^0$ do in the Stan. model.
The **anti-eightplet** (repres. of $SO(7, 1)$) of **anti-quarks** of the anti-colour charge, reachable by either $S^{ab}$ or $C_N P_{N}^{(d-1)}$:

| $i$ | $|a\psi_i>$ | $\Gamma^{(3, 1)}$ | $S^{12}$ | $\Gamma^{(4)}$ | $\tau^{13}$ | $\tau^{23}$ | $\gamma$ | $\tau^4$
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>$\bar{d}^{L}_{L}$</td>
<td>03 12 56 78 9 1011 1213 14 $<a href="+">-i</a>$</td>
<td>$\bar{d}^{L}_{L}$</td>
<td>$\bar{d}^{R}_{L}$</td>
<td>$\bar{d}^{L}_{R}$</td>
<td>$\bar{d}^{R}_{R}$</td>
<td>$\bar{u}^{L}_{L}$</td>
<td>$\bar{u}^{R}_{L}$</td>
</tr>
<tr>
<td>34</td>
<td>$\bar{d}^{L}_{L}$</td>
<td>03 12 56 78 9 1011 1213 14 $(+i)[-]$</td>
<td>$\bar{d}^{L}_{L}$</td>
<td>$\bar{d}^{R}_{L}$</td>
<td>$\bar{d}^{L}_{R}$</td>
<td>$\bar{d}^{R}_{R}$</td>
<td>$\bar{u}^{L}_{L}$</td>
<td>$\bar{u}^{R}_{L}$</td>
</tr>
<tr>
<td>35</td>
<td>$\bar{u}^{L}_{L}$</td>
<td>03 12 56 78 9 1011 1213 14 $<a href="+">-i</a>$</td>
<td>$\bar{u}^{L}_{L}$</td>
<td>$\bar{u}^{R}_{L}$</td>
<td>$\bar{u}^{L}_{R}$</td>
<td>$\bar{u}^{R}_{R}$</td>
<td>$\bar{d}^{L}_{L}$</td>
<td>$\bar{d}^{R}_{L}$</td>
</tr>
<tr>
<td>36</td>
<td>$\bar{u}^{L}_{L}$</td>
<td>03 12 56 78 9 1011 1213 14 $(+i)[-]$</td>
<td>$\bar{u}^{L}_{L}$</td>
<td>$\bar{u}^{R}_{L}$</td>
<td>$\bar{u}^{L}_{R}$</td>
<td>$\bar{u}^{R}_{R}$</td>
<td>$\bar{d}^{L}_{L}$</td>
<td>$\bar{d}^{R}_{L}$</td>
</tr>
<tr>
<td>37</td>
<td>$\bar{d}^{L}_{R}$</td>
<td>03 12 56 78 9 1011 1213 14 $(+i)(+)$</td>
<td>$\bar{d}^{L}_{R}$</td>
<td>$\bar{d}^{R}_{L}$</td>
<td>$\bar{d}^{L}_{R}$</td>
<td>$\bar{d}^{R}_{R}$</td>
<td>$\bar{u}^{L}_{L}$</td>
<td>$\bar{u}^{R}_{L}$</td>
</tr>
<tr>
<td>38</td>
<td>$\bar{d}^{L}_{R}$</td>
<td>03 12 56 78 9 1011 1213 14 $[-i][-]$</td>
<td>$\bar{d}^{L}_{R}$</td>
<td>$\bar{d}^{R}_{L}$</td>
<td>$\bar{d}^{L}_{R}$</td>
<td>$\bar{d}^{R}_{R}$</td>
<td>$\bar{u}^{L}_{L}$</td>
<td>$\bar{u}^{R}_{L}$</td>
</tr>
<tr>
<td>39</td>
<td>$\bar{u}^{L}_{R}$</td>
<td>03 12 56 78 9 1011 1213 14 $(+i)(+)$</td>
<td>$\bar{u}^{L}_{R}$</td>
<td>$\bar{u}^{R}_{L}$</td>
<td>$\bar{u}^{L}_{R}$</td>
<td>$\bar{u}^{R}_{R}$</td>
<td>$\bar{d}^{L}_{L}$</td>
<td>$\bar{d}^{R}_{L}$</td>
</tr>
<tr>
<td>40</td>
<td>$\bar{u}^{L}_{R}$</td>
<td>03 12 56 78 9 1011 1213 14 $[-i][-]$</td>
<td>$\bar{u}^{L}_{R}$</td>
<td>$\bar{u}^{R}_{L}$</td>
<td>$\bar{u}^{L}_{R}$</td>
<td>$\bar{u}^{R}_{R}$</td>
<td>$\bar{d}^{L}_{L}$</td>
<td>$\bar{d}^{R}_{L}$</td>
</tr>
</tbody>
</table>

$\gamma^0\gamma^7$ and $\gamma^0\gamma^8$ transform $\bar{d}^{L}_{L}$ of the 1st row into $\bar{d}^{R}_{R}$ of the 5th row, and $\bar{u}^{L}_{L}$ of the 4th row into $\bar{u}^{R}_{R}$ of the 8th row.
Second quantization of fermion fields — in Clifford space manifesting families and family members — of quarks and leptons

▶ Defining the creation operator as

\[ \hat{b}_{1}^{\dagger} = (+i)(+)(+) | (+)(+)(+) || (+)(-)(-), \] and

▶ The annihilation operator as

\[ \hat{b}_{1} = (\hat{b}_{1}^{\dagger})^\dagger = (+)(+)(-) || (-)(-)(-) | (-)(-)(-i), \] and

\[ \hat{b}_{2}^{\dagger} = (\hat{b}_{2}^{\dagger})^\dagger = [-i][-] | (+)(+)(+) || (+)(-)(-) || (-)(-)(-i), \] and

\[ \hat{b}_{2} = (+)(+)(-) || (-)(-) || [-][-i], \]

▶ ......

▶ ......

operating on a vacuum state

\[ |\psi_o > = [-i][-][-] \cdots [-] |0 >. \] for \( d=2(2n+1) \),
One finds the commutation relations for a general fermion field which represents just the observed quarks and leptons \((i = (u^\alpha_{R,L}, d^\alpha_{R,L}, \nu^\alpha_{R,L}, e^\alpha_{R,L}))\) in a massless basis and anti-quarks and anti-leptons, with the family quantum numbers \(\alpha\).

\[
\begin{align*}
\{ \hat{b}^\alpha_i, \hat{b}^{\beta \dagger}_k \} + |\psi_o > &= \delta^\alpha_\beta \delta^i_k |\psi_o >, \\
\{ \hat{b}^\alpha_i, \hat{b}^\beta_k \} + |\psi_o > &= 0 \cdot |\psi_o >, \\
\{ \hat{b}^{\alpha \dagger}_i, \hat{b}^{\beta \dagger}_k \} + |\psi_o > &= 0 \cdot |\psi_o >, \\
\hat{b}^\alpha_i |\psi_o > &= 0 \cdot |\psi_o >, \\
\hat{b}^{\alpha \dagger}_i |\psi_o > &= |\psi^\alpha_i >
\end{align*}
\]

Here the creation and annihilation operators include families. In this case the vacuum state has to be extended.

arXiv:1802.05554
It is worthwhile to notice that "nature could make a choice" of Grassmann rather than Clifford space:

- Also in Grassmann space, namely, one finds the anticommutation relations needed for a fermion field.
- But in this case spinors would have spins and charges in adjoint representations with respect to particular subgroups.
- And spinors and anti-spinors would belong to two separated representations and no families would appear.
Vector gauge fields origin in gravity, in vielbeins and two kinds of the spin connection fields, the gauge fields of $S^{ab}$ and $\tilde{S}^{ab}$.
All the vector gauge fields, \(A^m_{Ai}\), \((m, n) = (0, 1, 2, 3)\) of the observed charges \(\tau^{Ai} = \sum_{s, t} c^{Ai}_{st} S^{st}\), manifesting at the observable energies, have all the properties as assumed by the standard model.

They carry with respect to the space index \(m \in (0, 1, 2, 3)\) the vector degrees of freedom, while they have additional internal degrees of freedom \((\tau^{Ai})\) in the adjoint representations.

They origin as spin connection gauge fields of \(S^{ab}\):

\[
A^m_{Ai} = \sum_{s, t} c^{Aist} \omega_{stm}.
\]

\(S^{ab}\) applies on indexes \((s, t, m)\) as follows

\[
S^{ab} \omega_{stm...g} = i \left( \delta^a_s \omega^b_{tm...g} - \delta^b_s \omega^a_{tm...g} \right).
\]
The action for vectors with respect to the space index $m = (0, 1, 2, 3)$ origin in gravity

\[ \int E \, d^4x \, d^{(d-4)}x \, \alpha \, R^{(d)} = \int d^4x \left\{ -\frac{1}{4} F_{\text{A}m} F^{\text{A}mn} \right\} , \]

\[ \text{A}^{\text{A}i}_{\text{m}} = \sum_{s,t} c^{\text{A}ist} \omega_{stm} . \]

Eur. Phys. J. C. 77 (2017) 231,
Also scalar fields
(there are doublets and triplets)
origin in gravity fields — they are spin connections and vielbeins —
with the space index $s \geq 5$.

Eur. Phys. J. C. 77 (2017) 231,
Phys. Rev. D 91 (2015) 6, 065004,
There are several **scalar gauge fields** with the space index \((s,t,s') = (7,8)\), all origin in the spin connection fields, either \(\tilde{\omega}_{abs}\) or \(\omega_{st's'}\):

- Twice **two triplets**, the scalar gauge fields with the family quantum numbers \((\tilde{\tau}^{Ai} = \sum_{a,b} \tilde{c}^{Ai}_{ab} \tilde{S}^{ab})\) and
- **three singlets** with the family members quantum numbers \((Q,Q',Y')\), the gauge fields of \(S^{st}\).

They are all doublets with respect to the space index \((5,6,7,8)\).

They have all the rest quantum numbers **determined by the adjoint representations**.

They explain at the so far observable energies the Higgs’s scalar and the Yukawa couplings.
The two doublets, determining the properties of the Higgs’s scalar and the Yukawa couplings, are:

<table>
<thead>
<tr>
<th>( A_{78}^{Ai} )</th>
<th>( A_{56}^{Ai} )</th>
<th>state</th>
<th>( \tau_{13} )</th>
<th>( \tau_{23} = Y )</th>
<th>spin</th>
<th>( \tau^4 )</th>
<th>( Q )</th>
</tr>
</thead>
<tbody>
<tr>
<td>((-))</td>
<td>((-))</td>
<td>( A_{7}^{Ai} + iA_{8}^{Ai} )</td>
<td>( + \frac{1}{2} )</td>
<td>( - \frac{1}{2} )</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>((-))</td>
<td>((-))</td>
<td>( A_{5}^{Ai} + iA_{6}^{Ai} )</td>
<td>( - \frac{1}{2} )</td>
<td>( - \frac{1}{2} )</td>
<td>0</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>((+))</td>
<td>((+))</td>
<td>( A_{7}^{Ai} - iA_{8}^{Ai} )</td>
<td>( - \frac{1}{2} )</td>
<td>( + \frac{1}{2} )</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>((+))</td>
<td>((+))</td>
<td>( A_{5}^{Ai} - iA_{6}^{Ai} )</td>
<td>( + \frac{1}{2} )</td>
<td>( + \frac{1}{2} )</td>
<td>0</td>
<td>0</td>
<td>+1</td>
</tr>
</tbody>
</table>

There are \( A_{78}^{Ai} \) and \( A_{78}^{Ai} \) which gain nonzero vacuum expectation values at the electroweak break.

Index \( Ai \) determines the family \((\tilde{\tau}^{Ai})\) quantum numbers and the family members \((Q,Q’,Y’)\) quantum numbers, both are in adjoint representations.
There are besides doublets, with the space index \( s = (5, 6, 7, 8) \), as well triplets and anti-triplets, with respect to the space index \( s = (9, \ldots, 14) \).

There are no additional scalars in the theory for \( d = (13+1) \).

All are massless.

All the scalars have the family and the family members quantum numbers in the adjoint representations.

The properties of scalars are to be analyzed with respect to the generators of the corresponding subgroups, expressible with \( S^{ab} \), as it is the case of the vector gauge fields.

It is the (so far assumed) condensate, which makes those gauge fields, with which it interacts, massive.

The condensate breaks the CP symmetry.
The scalar condensate of two right handed neutrinos couple to all the scalar and vector gauge fields, making them massive.

It does not interact with the weak charge $SU(2)_I$, the hyper charge $U(1)$, and the colour $SU(3)$ charge gauge fields, as well as the gravity, leaving them massless.

J. of Mod.Phys. 4 (2013) 823-847,
J. of Mod.Phys. 6 (2015) 2244-2247,
Phys Rev. D 91 (2015) 6,065004.
Scalars with \( s = (7, 8) \), which gain nonzero vacuum expectation values, break the weak and the hyper symmetry, while conserving the electromagnetic and colour charge:

\[
A_{Ai}^{\text{Ai}} \supset (A_{s}^{Q}, A_{s}^{Q'}, A_{s}^{Y'}, \tilde{A}_{s}^{1}, \tilde{A}_{s}^{2}, \tilde{A}_{s}^{3}, \tilde{A}_{s}^{4}) ,
\]

\[
\tau_{Ai}^{\text{Ai}} \supset (Q, Q', Y', \tilde{\tau}_{s}^{1}, \tilde{N}_{L}, \tilde{\tau}_{s}^{2}, \tilde{N}_{R}),
\]

\( s = (7, 8) \).

\( \text{Ai} \) denotes:

- **family** quantum numbers
  
  \((\tilde{\tau}_{1}, \tilde{N}_{L})\) quantum numbers of the first group of four families and
  
  \((\tilde{\tau}_{2}, \tilde{N}_{R})\) quantum numbers of the second group of four families.

- **And family members** quantum numbers \((Q, Q', Y')\)
$A_{s}^{Ai}$ are expressible with either $\omega_{sts}'$ or $\tilde{\omega}_{abs}'$.

\[
\begin{align*}
\tilde{A}_{s}^{1} &= (\tilde{\omega}_{58s} - \tilde{\omega}_{67s}, \tilde{\omega}_{57s} + \tilde{\omega}_{68s}, \tilde{\omega}_{56s} - \tilde{\omega}_{78s}), \\
\tilde{A}_{s}^{2} &= (\tilde{\omega}_{58s} + \tilde{\omega}_{67s}, \tilde{\omega}_{57s} - \tilde{\omega}_{68s}, \tilde{\omega}_{56s} + \tilde{\omega}_{78s}), \\
\tilde{A}_{Ls}^{N} &= (\tilde{\omega}_{23s} + i\tilde{\omega}_{01s}, \tilde{\omega}_{31s} + i\tilde{\omega}_{02s}, \tilde{\omega}_{12s} + \tilde{\omega}_{03s}), \\
\tilde{A}_{Rs}^{N} &= (\tilde{\omega}_{23s} - i\tilde{\omega}_{01s}, \tilde{\omega}_{31s} - i\tilde{\omega}_{02s}, \tilde{\omega}_{12s} - i\tilde{\omega}_{03s}), \\
A_{s}^{Q} &= \omega_{56s} - (\omega_{910s} + \omega_{1112s} + \omega_{1314s}), \\
A_{s}^{Y} &= (\omega_{56s} + \omega_{78s}) - (\omega_{910s} + \omega_{1112s} + \omega_{1314s}), \\
A_{s}^{4} &= - (\omega_{910s} + \omega_{1112s} + \omega_{1314s}).
\end{align*}
\]
The mass term, appearing in the starting action, is \( (p_s, \text{ when treating the lowest energy solutions, is left out}) \)

\[
\mathcal{L}_M = \sum_{s=(7,8), Ai} \bar{\psi} \gamma^s \left( -\tau^{A_i} A_s^{A_i} \right) \psi = \\
-\bar{\psi} \left\{ \left( + \right) \tau^{A_i} \left( A_7^{A_i} - i A_8^{A_i} \right) + \left( - \right) \tau^{A_i} \left( A_7^{A_i} + i A_8^{A_i} \right) \right\} \psi,
\]

\[
\left( \pm \right) = \frac{1}{2} \left( \gamma^7 \pm i \gamma^8 \right), \quad A_{78}^{A_i} := \left( A_7^{A_i} \mp i A_8^{A_i} \right).
\]
Operators $Y$, $Q$ and $\tau^{13}$, applied on $(A_7^{Ai} \mp i A_8^{Ai})$

$$\tau^{13} (A_7^{Ai} \mp i A_8^{Ai}) = \pm \frac{1}{2} (A_7^{Ai} \mp i A_8^{Ai}),$$

$$Y (A_7^{Ai} \mp i A_8^{Ai}) = \mp \frac{1}{2} (A_7^{Ai} \mp i A_8^{Ai}),$$

$$Q (A_7^{Ai} \mp i A_8^{Ai}) = 0,$$

manifest that all $(A_7^{Ai} \mp i A_8^{Ai})$ have quantum numbers of the Higgs’s scalar of the standard model, "dressing", after gaining nonzero expectation values, the right handed members of a family with appropriate charges, so that they gain charges of the left handed partners:

$(A_7^{Ai} + iA_8^{Ai})$ "dresses" $u_R, \nu_R$ and $(A_7^{Ai} - iA_8^{Ai})$ "dresses" $d_R, e_R$, with quantum numbers of their left handed partners, just as required by the "standard model". 
Ai measures:

either

\( o \) the \( Q, Q', Y' \) charges of the family members

or

\( o \) family charges \( (\vec{\tilde{\tau}}^{1}, \vec{\tilde{N}}_{L}) \), transforming a family member of one family into the same family member of another family, manifesting in each group of four families the \( \tilde{SU}(2) \times \tilde{SU}(2) \times U(1) \) symmetry.
Eight families of $u_R$ (spin 1/2, colour $(\frac{1}{2}, \frac{1}{2\sqrt{3}})$) and of colourless $\nu_R$ (spin 1/2). All have "tilde spinor charge" $\tilde{\tau}^4 = -\frac{1}{2}$, the weak charge $\tau^{13} = 0$, $\tau^{23} = \frac{1}{2}$. Quarks have "spinor" q.no. $\tau^4 = \frac{1}{6}$ and leptons $\tau^4 = -\frac{1}{2}$. The first four families have $\tilde{\tau}^{23} = 0$, $\tilde{N}_R^3 = 0$, the second four families have $\tilde{\tau}^{13} = 0$, $\tilde{N}_L^3 = 0$.

<table>
<thead>
<tr>
<th>$\tilde{N}_R^3 = 0$, $\tilde{\tau}^{23} = 0$</th>
<th>$\tilde{N}_L^3 = 0$, $\tilde{\tau}^{13} = 0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$u_{R1}^{c1}$ $(+i)$ [+]</td>
<td>[+] (+)</td>
</tr>
<tr>
<td>$u_{R2}^{c1}$ [+] (+)</td>
<td>[+] (+)</td>
</tr>
<tr>
<td>$u_{R3}^{c1}$ $(+i)$ [+]</td>
<td>(+) [+L]</td>
</tr>
<tr>
<td>$u_{R4}^{c1}$ [+] (+)</td>
<td>[+L] [+L]</td>
</tr>
</tbody>
</table>

Before the electroweak break all the families are mass protected and correspondingly massless.
 Scalars with the weak and the hyper charge \((\mp \frac{1}{2}, \pm \frac{1}{2})\) determine masses of all the family members \(\alpha\) of the lower four families, \(\nu_R\) of the lower four families have nonzero \(Y' := -\tau^4 + \tau^{23}\) and interact with the scalar field \((A(Y'), \tilde{A^1}_\pm, \tilde{A^N}_L)\).

The group of the lower four families manifest the \(\tilde{SU}(2)\tilde{SO}(1,3) \times \tilde{SU}(2)\tilde{SO}(4) \times U(1)\) symmetry (also after all loop corrections).

\[
M^\alpha = \begin{pmatrix}
-a_1 - a & e & d & b \\
-e^* & -a_2 - a & b & d \\
de^* & b^* & a_2 - a & e \\
b^* & d^* & e^* & a_1 - a
\end{pmatrix}^\alpha.
\]

arxiv:1412.5866
We made calculations, treating quarks and leptons in equivalent way, as required by the "spin-charge-family" theory. Although

- any \((n-1) \times (n-1)\) submatrix of an unitary \(n \times n\) matrix determines the \(n \times n\) matrix for \(n \geq 4\) uniquely,

- the measured mixing matrix elements of the \(3 \times 3\) submatrix are not yet accurate enough even for quarks to predict the masses \(m_4\) of the fourth family members.

- We can say, taking into account the data for the mixing matrices and masses, that \(m_4\) quark masses might be any in the interval \((300 < m_4 < 1000)\) GeV or even above. Other experiments require that \(m_4\) are above 1000 GeV.

- Assuming masses \(m_4\) we can predict mixing matrices.
Results are presented for two choices of $m_{u4} = m_{d4}$, [arXiv:1502.06786v1, arxiv:1412.5866]:

- **1.** $m_{u4} = 700$ GeV, $m_{d4} = 700$ GeV.....$new_1$
- **2.** $m_{u4} = 1200$ GeV, $m_{d4} = 1200$ GeV.....$new_2$

$$|V_{ud}| = \begin{pmatrix}
exp_n & 0.97425 \pm 0.00022 & 0.2253 \pm 0.0008 & 0.00413 \pm 0.00049 \\
new_1 & 0.97423(4) & 0.22539(7) & 0.00299 & 0.00776(1) \\
new_2 & 0.97423[5] & 0.22538[42] & 0.00299 & 0.00793[466] \\
exp_n & 0.225 \pm 0.008 & 0.986 \pm 0.016 & 0.0411 \pm 0.0013 \\
new_1 & 0.22534(3) & 0.97335 & 0.04245(6) & 0.00349(60) \\
new_2 & 0.22531[5] & 0.97336[5] & 0.04248 & 0.00002[216] \\
exp_n & 0.0084 \pm 0.0006 & 0.0400 \pm 0.0027 & 1.021 \pm 0.032 \\
new_1 & 0.00667(6) & 0.04203(4) & 0.99909 & 0.00038 \\
new_2 & 0.00667 & 0.04206[5] & 0.99909 & 0.00024[21] \\
new_1 & 0.00677(60) & 0.00517(26) & 0.00020 & 0.99996 \\
new_2 & 0.00773 & 0.00178 & 0.00022 & 0.99997[9]
\end{pmatrix}.$$
- The matrix elements $V_{CKM}$ depend strongly on the accuracy of the experimental $3 \times 3$ submatrix.
- Calculated $3 \times 3$ submatrix of $4 \times 4 V_{CKM}$ depends on the $m_{4th}$ family masses, but not much.
- $V_{u_i d_4}, V_{d_i u_4}$ do not depend strongly on the $m_{4th}$ family masses and are obviously very small.
- The higher are the fourth family members masses, the closer are the mass matrices to the democratic matrices for either quarks or leptons, as expected.
The stable family of the upper four families group is the candidate to form the Dark Matter.

Masses of the upper four families are influenced:
- by the $\tilde{SU}(2)_{II}SO(3,1) \times \tilde{SU}(2)_{II}SO(4)$ scalar fields with the corresponding family quantum numbers,
- by the scalars $(A^Q_{78}, A^{Q'}_{78}, A^{Y'}_{78})$, and
- by the condensate of the two $\nu_R$ of the upper four families.
Matter-antimatter asymmetry
There are also **triplet** and **anti-triplet** scalars, \( s = (9, \ldots, d) \):

<table>
<thead>
<tr>
<th>[ \mathcal{A}^{Ai}_{ij} ]</th>
<th>state</th>
<th>( \tau_{33} )</th>
<th>( \tau_{38} )</th>
<th>spin</th>
<th>( \tau_{4} )</th>
<th>( Q )</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ A^{Ai}_{9,10} ]</td>
<td>[ A^{Ai}<em>{9} - iA^{Ai}</em>{10} ]</td>
<td>( + \frac{1}{2} )</td>
<td>( - \frac{1}{2} \sqrt{3} )</td>
<td>0</td>
<td>( - \frac{1}{3} )</td>
<td>( - \frac{1}{3} )</td>
</tr>
<tr>
<td>[ A^{Ai}_{11,12} ]</td>
<td>[ A^{Ai}<em>{11} - iA^{Ai}</em>{12} ]</td>
<td>( - \frac{1}{2} )</td>
<td>( + \frac{1}{2} \sqrt{3} )</td>
<td>0</td>
<td>( - \frac{1}{3} )</td>
<td>( - \frac{1}{3} )</td>
</tr>
<tr>
<td>[ A^{Ai}_{13,14} ]</td>
<td>[ A^{Ai}<em>{13} - iA^{Ai}</em>{14} ]</td>
<td>0</td>
<td>( - \frac{1}{\sqrt{3}} )</td>
<td>0</td>
<td>( - \frac{1}{3} )</td>
<td>( - \frac{1}{3} )</td>
</tr>
<tr>
<td>[ A^{Ai}_{9,10} ]</td>
<td>[ A^{Ai}<em>{9} + iA^{Ai}</em>{10} ]</td>
<td>( - \frac{1}{2} )</td>
<td>( + \frac{1}{2} \sqrt{3} )</td>
<td>0</td>
<td>( + \frac{1}{3} )</td>
<td>( + \frac{1}{3} )</td>
</tr>
<tr>
<td>[ A^{Ai}_{11,12} ]</td>
<td>[ A^{Ai}<em>{11} + iA^{Ai}</em>{12} ]</td>
<td>( + \frac{1}{2} )</td>
<td>( - \frac{1}{2} \sqrt{3} )</td>
<td>0</td>
<td>( + \frac{1}{3} )</td>
<td>( + \frac{1}{3} )</td>
</tr>
<tr>
<td>[ A^{Ai}_{13,14} ]</td>
<td>[ A^{Ai}<em>{13} + iA^{Ai}</em>{14} ]</td>
<td>0</td>
<td>( + \frac{1}{\sqrt{3}} )</td>
<td>0</td>
<td>( + \frac{1}{3} )</td>
<td>( + \frac{1}{3} )</td>
</tr>
</tbody>
</table>

They cause transitions from **anti-leptons** into **quarks** and **anti-quarks** into **quarks** and back, transforming matter into antimatter and back. The condensate breaks CP symmetry, offering the explanation for the matter-antimatter asymmetry in the universe.
Let us look at scalar triplets, causing the birth of a proton from the left handed positron, antiquark and quark:

\[ \tau^4 = \frac{1}{6}, \tau^{13} = 0, \tau^{23} = \frac{1}{2} \]
\[ (\tau^{33}, \tau^{38}) = (0, 0) \]
\[ Y = 1, Q = 1 \]

\[ \bar{e}_L^+ \rightarrow \bar{u}_L^{c2} \rightarrow \bar{d}_R^{c1} \]

\[ \tau^4 = 2 \times (-\frac{1}{6}), \tau^{13} = 0, \tau^{23} = -1 \]
\[ (\tau^{33}, \tau^{38}) = (\frac{1}{2}, -\frac{1}{2\sqrt{3}}) \]
\[ Y = -\frac{4}{3}, Q = -\frac{4}{3} \]

\[ \bar{u}_L^{c2} \rightarrow \bar{u}_R^{c3} \rightarrow \bar{u}_R^{c2} \]

\[ \tau^4 = \frac{1}{6}, \tau^{13} = 0, \tau^{23} = -\frac{1}{2} \]
\[ (\tau^{33}, \tau^{38}) = (\frac{1}{2}, -\frac{1}{2\sqrt{3}}) \]
\[ Y = -\frac{4}{3}, Q = -\frac{4}{3} \]
These two quarks, $d^c_1$ and $u^c_3$ can bind (at low enough energy) together with $u^c_2$ into the colour chargeless baryon - a proton.

After the appearance of the condensate the CP is broken.

In the expanding universe, fulfilling the Sakharov request for appropriate non-thermal equilibrium, these triplet scalars have a chance to explain the matter-antimatter asymmetry.

The opposite transition makes the proton decay.
Dark matter

\[ d \rightarrow (d - 4) + (3 + 1) \text{ before (or at least at) the electroweak break.} \]
We follow the evolution of the universe, in particular the abundance of the fifth family members - the candidates for the dark matter in the universe.

We estimate the behaviour of our stable heavy family quarks and anti-quarks in the expanding universe by solving the system of Boltzmann equations.

We follow the clustering of the fifth family quarks and antiquarks into the fifth family baryons through the colour phase transition.

The mass of the fifth family members is determined from the today dark matter density.

*Phys. Rev. D (2009) 80.083534*
Figure: The dependence of the two number densities \( n_{q_5} \) (of the fifth family quarks) and \( n_{c_5} \) (of the fifth family clusters) as the function of \( \frac{m_{q_5} c^2}{T_{k_b}} \) is presented for the values \( m_{q_5} c^2 = 71 \text{ TeV} \), \( \eta_{c_5} = \frac{1}{50} \) and \( \eta_{(q\bar{q})_b} = 1 \). We take \( g^* = 91.5 \).
We estimated from following the fifth family members in the expanding universe:

\[
10 \text{ TeV} < m_{q_5} c^2 < 4 \cdot 10^2 \text{TeV}.
\]

\[
10^{-8} \text{fm}^2 < \sigma_{c_5} < 10^{-6} \text{fm}^2.
\]

(It is at least $10^{-6} \times$ smaller than the cross section for the first family neutrons.)
We estimate from the scattering of the fifth family members on the ordinary matter on our Earth, on the direct measurements - DAMA, CDMS,..- ... 

\[ 200 \text{ TeV} < m_{q_5} c^2 < 10^5 \text{ TeV} \]
In the *standard model* the *family members* with all their properties, the *families*, the *gauge vector fields*, the *scalar Higgs*, the *Yukawa couplings*, exist by the *assumption*.

** In the *spin-charge-family theory* the appearance and all the properties of all these fields follow from the simple starting action with *two kinds of spins* and with the *gravity only*.

** The theory offers the explanation for the *dark matter*.

** The theory offers the explanation for the *matter-antimatter asymmetry*.

** All the *scalar* and all the *vector* gauge fields are *directly or indirectly observable*.
The spin-charge-family theory explains also many other properties, which are not explainable in the standard model, like "miraculous" non-anomalous triangle Feynman diagrams.

The more work is put into the spin-charge-family theory the more explanations for the phenomena follow.
Concrete predictions:

- There are several scalar fields:
  - two triplets,
  - three singlets,
  explaining higgs and Yukawa couplings,
  some of them will be observed at the LHC, JMP 6 (2015) 2244,

- There is the fourth family, (weakly) coupled to the observed three, which will be observed at the LHC,

- There is the dark matter with the predicted properties,

- There is the ordinary matter/antimatter asymmetry explained and the proton decay predicted and explained,
We recognize that:

- The last data for mixing matrix of quarks are in better agreement with our prediction for the $3 \times 3$ submatrix elements of the $4 \times 4$ mixing matrix than the previous ones.

- Our fit to the last data predicts how will the $3 \times 3$ submatrix elements change in the next more accurate measurements.

- Masses of the fourth family lie much above the known three, masses of quarks are close to each other.
Masses of the fifth family lie much above the known three and the predicted fourth family masses.

Baryons of the fifth family are heavy, forming small enough clusters with small enough scattering amplitude among themselves and with the ordinary matter to be the candidate for the dark matter.

The ”nuclear” force among them is different from the force among ordinary nucleons.
The spin-charge-family theory is offering an explanation for the hierarchy problem: The mass matrices of the two four families groups are almost democratic, causing spreading of the fermion masses from $10^{16}$ GeV to $10^{-8}$ MeV.
To summarize:

- I hope that I managed to convince you that I can answer many open questions of particle physics and cosmology.
- The collaborators are very welcome!