

**How far has so far the Spin-Charge-Family  
theory succeeded to offer the explanation  
for the observed phenomena in elementary  
particle physics and cosmology :**  
**Short overview of the spin-charge-family  
theory and its achievements so far**

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## Some publications:

- ▶ *Phys. Lett.* **B 292**, 25-29 (1992), *J. Math. Phys.* **34**, 3731-3745 (1993), *Mod. Phys. Lett.* **A 10**, 587-595 (1995), *Int. J. Theor. Phys.* **40**, 315-337 (2001),
- ▶ *Phys. Rev.* **D 62** (04010-14) (2000), *Phys. Lett.* **B 633** (2006) 771-775, **B 644** (2007) 198-202, **B** (2008) 110.1016, *JHEP* **04** (2014) 165, *Fortschritte Der Physik-Progress in Physics*, (2017) with H.B.Nielsen,
- ▶ *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,
- ▶ *New J. of Phys.* (2011) 103027, *J. Phys. A: Math. Theor.* **45** (2012) 465401, *J. Phys. A: Math. Theor.* **45** (2012) 465401, *J. of Mod. Phys.* **4** (2013) 823-847, arxiv:1409.4981, **6** (2015) 2244-2247, *Phys. Rev.* **D 91** (2015) 6, 065004, . *J. Phys.: Conf. Ser.* **845 01 IARD 2017**, *Eur. Phys. J.C.* **77** (2017) 231, Rev. Article in **Progress in Particle and Nuclear Physics**, <http://doi.org/10.1016.j.ppnp.2021.103890>

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**:

**A.**

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

$\alpha$ name	hand- edness $-4iS^{03}S^{12}$	weak charge $\tau^{13}$	hyper charge $Y$	colour charge	elm charge $Q$
$u_L^i$	-1	$\frac{1}{2}$	$\frac{1}{6}$	colour triplet	$\frac{2}{3}$
$d_L^i$	-1	$-\frac{1}{2}$	$\frac{1}{6}$	colour triplet	$-\frac{1}{3}$
$\nu_L^i$	-1	$\frac{1}{2}$	$-\frac{1}{2}$	colourless	0
$e_L^i$	-1	$-\frac{1}{2}$	$-\frac{1}{2}$	colourless	-1
$u_R^i$	1	weakless	$\frac{2}{3}$	colour triplet	$\frac{2}{3}$
$d_R^i$	1	weakless	$-\frac{1}{3}$	colour triplet	$-\frac{1}{3}$
$\nu_R^i$	1	weakless	0	colourless	0
$e_R^i$	1	weakless	-1	colourless	-1

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.

**B.**

- ▶ **The existence of massless vector gauge fields to the observed charges of the family members, carrying charges in the adjoint representation of the charge groups.**

**Masslessness needed for gauge invariance.**

## Gauge fields before the electroweak break

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

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

They all are vectors in  $d = (3 + 1)$ , in the adjoint representations with respect to the weak, colour and hyper charges.

## C.

- ▶ The **existence of a massive scalar field - the higgs**,
  - carrying the weak charge  $\pm\frac{1}{2}$  and the hyper charge  $\mp\frac{1}{2}$ .
  - gaining at some step the **imaginary mass** and consequently the **constant value** , 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.

name	hand- edness	weak charge	hyper charge	colour charge	elm charge
0. $Higgs_u$	0	$\frac{1}{2}$	$\frac{1}{2}$	colourless	1
$\langle Higgs_d \rangle$	0	$-\frac{1}{2}$	$\frac{1}{2}$	colourless	0

name	hand- edness	weak charge	hyper charge	colour charge	elm charge
$\langle Higgs_u \rangle$	0	$\frac{1}{2}$	$-\frac{1}{2}$	colourless	0
0. $Higgs_d$	0	$-\frac{1}{2}$	$-\frac{1}{2}$	colourless	-1

D.

- ▶ 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 **assumptions** of the *standard model* **remain unexplained**.

- ▶ There are several cosmological observations which do not look to be explainable within the *standard model*, like
  - The existence of the *dark matter*
  - The *matter/antimatter asymmetry* in the universe
  - The need for the *dark energy*
- ▶ the **observed dimension of space time**,
- ▶ the **quantization of the gravitational field**,
- ▶ ...

- ▶ The **Standard model** assumptions have in the literature several explanations, but with **many new not explained assumptions**.
- ▶ **It is obviously the time to make the new step beyond the *standard model*.**

- ▶ **The Spin-Charge-Family** theory offers the explanation for
  - i. all the assumptions of the *standard model*,
  - ii. for many observed phenomena:
    - ii.a. the **dark matter**,
    - ii.b. the **matter-antimatter** asymmetry,
    - ii.c. **others observed phenomena**,
  - iii. explaining the Dirac's postulates for the **second quantized fermion** and **second quantized boson** fields,
  - iv. Explaining the offer of the **Fadeev-Popov ghosts**.
  - v. **making several predictions**.

**Is the Spin-Charge-Family theory the right next step beyond both standard models?**

- ▶ Work done so far on the **spin-charge-family theory** is promising.

## We try to understand:

- ▶ What are **elementary constituents** and **interactions** among **constituents** in our Universe, in any universe?
- ▶ Are the elementary constituents of only one kind?
- ▶ Are the four observed interactions — **gravitational, electromagnetic, weak and colour** — of the common origin?
- ▶ Are the **laws of “nature”** simple and “elegant”?
- ▶ Are all the **fermion** and **boson** fields second quantized?

- ▶ Can the postulates **for the second quantized fermions** and **for the second quantized bosons** be understood in equivalent way?
- ▶ Can the description of the internal space of **fermions with the Clifford odd** and of the internal space of **bosons with the Clifford even** algebra explain/replace the second quantization postulates?
- ▶ Is the space-time  $(3 + 1)$ ? If yes, 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 are 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 open questions in elementary particle physics and cosmology, explaining:
  - o The **origin of the family members and the charges.**
  - o The **origin of the families and their properties.**
  - o The **origin of the scalar fields and their properties.**
  - o The **origin of the vector fields and their properties.**
  - o The **origin of the internal space of fermions and bosons and of their properties.**
  - o The **origin of the dark matter.**
  - o The **origin of the "ordinary" matter-antimatter asymmetry.**

## My proposition:

Assuming:

- ▶ That the space-time is  $d \geq (13 + 1)$ ,
- ▶ that the internal space of fermions is describable by the superposition of the Clifford odd products of  $\gamma^a$ ,
- ▶ that the internal space of bosons is describable by the superposition of the Clifford even products of  $\gamma^a$ ,
- ▶ that the second kind of the Clifford objects,  $\tilde{\gamma}^a$ , are used to denote the family quantum numbers of fermions,
- ▶ that the starting action for massless fermions and bosons assumes only one kind of fields, spin connections of two kinds, or, may be even better, the bosons with the internal space described by the Clifford even algebra,

then one has a chance to get answers on all the above questions.

o 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!

o 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.

- o I shall first make a short introduction into the **Spin-Charge-Family** theory.
- o I shall report on **how does the odd Clifford algebra explain the second quantization postulates of Dirac.**  
Rev. article in **JPPNP –2021** Progress in Particle and Nuclear Physics <http://doi.org/10.1016.j.pnpn.2021.103890>
- o I shall report on **how does the even Clifford algebra explain the second quantization of boson fields.** [arXiv:2108.05718]
  - o I shall make an overview of achievements so far of the **Spin-Charge-Family** theory.

- ▶ A brief introduction into the **spin-charge-family theory**.

- ▶ There are **two kinds of the Clifford algebra objects** in any  $d$  . I recognized that in Grassmann space.

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$$\theta^a\text{'s and } p_a^\theta\text{'s, } p_a^\theta = \frac{\partial}{\partial \theta_a}$$

with the property

$$(\theta^a)^\dagger = \eta^{aa} \frac{\partial}{\partial \theta_a}.$$

- The **Dirac**  $\gamma^a$  (recognized 90 years ago in  $d = (3 + 1)$ ).
- The **second one**:  $\tilde{\gamma}^a$ ,

$$\gamma^a = (\theta^a - i p^{\theta a}), \quad \tilde{\gamma}^a = i(\theta^a + i p^{\theta a}),$$

References can be found in  
**Progress in Particle and Nuclear Physics**,  
<http://doi.org/10.1016.j.pnnp.2021.103890> .

- ▶ The two kinds of the **Clifford algebra objects** anti-commute in the sense

$$\begin{aligned} \{\gamma^a, \gamma^b\}_+ &= 2\eta^{ab} = \{\tilde{\gamma}^a, \tilde{\gamma}^b\}_+, \\ \{\gamma^a, \tilde{\gamma}^b\}_+ &= 0, \end{aligned}$$

- ▶ the **postulate**

$$(\tilde{\gamma}^a \mathbf{B} = \mathbf{i}(-)^{n_B} \mathbf{B} \gamma^a) |\psi_0 \rangle,$$

$$(\mathbf{B} = a_0 + a_a \gamma^a + a_{ab} \gamma^a \gamma^b + \dots + a_{a_1 \dots a_d} \gamma^{a_1} \dots \gamma^{a_d}) |\psi_0 \rangle$$

with  $(-)^{n_B} = +1, -1$ , if  $B$  has a Clifford even or odd character, respectively,  $|\psi_0 \rangle$  is a vacuum state on which the operators  $\gamma^a$  **apply**, **reduces the Clifford space for fermions for the factor of two**, while the operators  $\tilde{\gamma}^a \tilde{\gamma}^b = -2i\tilde{S}^{ab}$  define the **family quantum numbers**.

- ▶ It is convenient to write all the **"basis vectors"** describing the internal space of either **fermion fields** or **boson fields** as products of **nilpotents** and **projectors**, which are eigenvectors of the chosen Cartan subalgebra

$$\begin{aligned}
 S^{03}, S^{12}, S^{56}, \dots, S^{d-1 d}, \\
 \tilde{S}^{03}, \tilde{S}^{12}, \tilde{S}^{56}, \dots, \tilde{S}^{d-1 d}, \\
 \mathbf{S}^{ab} = S^{ab} + \tilde{S}^{ab}.
 \end{aligned}$$

### nilpotents

$$S^{ab} \frac{1}{2} (\gamma^a + \frac{\eta^{aa}}{ik} \gamma^b) = \frac{k}{2} \frac{1}{2} (\gamma^a + \frac{\eta^{aa}}{ik} \gamma^b), \quad \mathbf{k}^{ab} := \frac{1}{2} (\gamma^a + \frac{\eta^{aa}}{ik} \gamma^b),$$

### projectors

$$S^{ab} \frac{1}{2} (1 + \frac{i}{k} \gamma^a \gamma^b) = \frac{k}{2} \frac{1}{2} (1 + \frac{i}{k} \gamma^a \gamma^b), \quad \mathbf{k}^{ab} := \frac{1}{2} (1 + \frac{i}{k} \gamma^a \gamma^b),$$

$$(\mathbf{k}^{ab})^2 = \mathbf{0}, \quad (\mathbf{k}^{ab})^2 = \mathbf{k}^{ab},$$

$$\mathbf{k}^{ab \dagger} = \eta^{aa} (-\mathbf{k}^{ab}), \quad \mathbf{k}^{ab \dagger} = \mathbf{k}^{ab}.$$

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

$$\tilde{S}^{ab}(\mathbf{k}) = \frac{k^{ab}}{2}, \quad \tilde{S}^{ab}[\mathbf{k}] = -\frac{k^{ab}}{2}.$$

$$\gamma^a(\mathbf{k}) = \eta^{aa}[-\mathbf{k}], \quad \gamma^b(\mathbf{k}) = -ik[-\mathbf{k}], \quad \gamma^a[\mathbf{k}] = (-\mathbf{k}), \quad \gamma^b[\mathbf{k}] = -ik\eta^{aa}(-\mathbf{k}),$$

$$\tilde{\gamma}^a(\mathbf{k}) = -i\eta^{aa}[\mathbf{k}], \quad \tilde{\gamma}^b(\mathbf{k}) = -k[\mathbf{k}], \quad \tilde{\gamma}^a[\mathbf{k}] = i(\mathbf{k}), \quad \tilde{\gamma}^b[\mathbf{k}] = -k\eta^{aa}(\mathbf{k}),$$

$$(\mathbf{k})(-\mathbf{k}) = \eta^{aa}[\mathbf{k}], \quad [\mathbf{k}](\mathbf{k}) = (\mathbf{k}), \quad (\mathbf{k})[-\mathbf{k}] = (\mathbf{k}),$$

$$(\mathbf{k})[\mathbf{k}] = 0, \quad [\mathbf{k}](-\mathbf{k}) = 0, \quad [\mathbf{k}][-\mathbf{k}] = 0,$$

$$\widetilde{(-\mathbf{k})}(\mathbf{k}) = -i\eta^{aa}[\mathbf{k}], \quad \widetilde{[\mathbf{k}]}(\mathbf{k}) = (\mathbf{k}), \quad \widetilde{(\mathbf{k})}[\mathbf{k}] = i(\mathbf{k}), \quad \widetilde{[-\mathbf{k}]}[\mathbf{k}] = [\mathbf{k}],$$

$$\widetilde{(\mathbf{k})}(\mathbf{k}) = 0, \quad \widetilde{[-\mathbf{k}]}(\mathbf{k}) = 0, \quad \widetilde{(\mathbf{k})}[-\mathbf{k}] = 0, \quad \widetilde{[\mathbf{k}]}[\mathbf{k}] = 0.$$

- ▶  $\gamma^a$  transforms  $\binom{ab}{k}$  into  $\begin{bmatrix} ab \\ -k \end{bmatrix}$ , **never** to  $\begin{bmatrix} ab \\ k \end{bmatrix}$ .
- ▶  $\tilde{\gamma}^a$  transforms  $\binom{ab}{k}$  into  $\begin{bmatrix} ab \\ k \end{bmatrix}$ , **never** to  $\begin{bmatrix} ab \\ -k \end{bmatrix}$ .
- ▶ There are the **Clifford odd "basis vector"**, that is the **"basis vector"** with an **odd number** of nilpotents, at least one, the rest are projectors, such **"basis vectors"** **anti-commute** among themselves.
- ▶ There are the **Clifford even "basis vector"**, that is the **"basis vector"** with an **even number** of nilpotents, the rest are projectors, such **"basis vectors"** **commute** among themselves.

- ▶ Let us see how does one family of the **Clifford odd "basis vector"** in  $d = (13 + 1)$  look like, if spins in  $d = (13 + 1)$  are analysed with respect to the **Standard Model groups**.
- ▶ **One irreducible representation** of one **family contains**  $2^{\frac{(13+1)}{2}-1} = 64$  members which include all the **family members, quarks and leptons with the right handed neutrinos included**, as well as all the **anti-members, antiquarks and antileptons**, reachable by either  $S^{ab}$  (or by  $\mathbb{C}_N \mathcal{P}_N$  on a **family member**).

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J. of Math. Phys. **44** 4817 (2003), hep-th/030322.

$S^{ab}$  generate **all the members of one family**. The **eightplet** (represent. of  $SO(7, 1)$ ) of quarks of a particular colour charge. **All are Clifford odd "basis vectors"** .

i		$ \psi_i\rangle$	$\Gamma^{(3,1)}$	$S^{12}$	$\Gamma^{(4)}$	$\tau^{13}$	$\tau^{23}$	$Y$	$\tau^4$
		Octet, $\Gamma^{(7,1)} = 1, \Gamma^{(6)} = -1$ , of quarks							
1	$u_R^{c1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ (+i)(+) &   & (+)(+) &    & (+)(-) & (-) & (-) \end{matrix}$	1	$\frac{1}{2}$	1	0	$\frac{1}{2}$	$\frac{2}{3}$	$\frac{1}{6}$
2	$u_R^{c1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ [-i][-] &   & (+)(+) &    & (+)(-) & (-) & (-) \end{matrix}$	1	$-\frac{1}{2}$	1	0	$\frac{1}{2}$	$\frac{2}{3}$	$\frac{1}{6}$
3	$d_R^{c1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ (+i)(+) &   & [-][-] &    & (+)(-) & (-) & (-) \end{matrix}$	1	$\frac{1}{2}$	1	0	$-\frac{1}{2}$	$-\frac{1}{3}$	$\frac{1}{6}$
4	$d_R^{c1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ [-i][-] &   & [-][-] &    & (+)(-) & (-) & (-) \end{matrix}$	1	$-\frac{1}{2}$	1	0	$-\frac{1}{2}$	$-\frac{1}{3}$	$\frac{1}{6}$
5	$d_L^{c1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ [-i](+) &   & [-](+) &    & (+)(-) & (-) & (-) \end{matrix}$	-1	$\frac{1}{2}$	-1	$-\frac{1}{2}$	0	$\frac{1}{6}$	$\frac{1}{6}$
6	$d_L^{c1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ (+i)[-] &   & [-](+) &    & (+)(-) & (-) & (-) \end{matrix}$	-1	$-\frac{1}{2}$	-1	$-\frac{1}{2}$	0	$\frac{1}{6}$	$\frac{1}{6}$
7	$u_L^{c1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ [-i](+) &   & (+)[-] &    & (+)(-) & (-) & (-) \end{matrix}$	-1	$\frac{1}{2}$	-1	$\frac{1}{2}$	0	$\frac{1}{6}$	$\frac{1}{6}$
8	$u_L^{c1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ (+i)[-] &   & (+)[-] &    & (+)(-) & (-) & (-) \end{matrix}$	-1	$-\frac{1}{2}$	-1	$\frac{1}{2}$	0	$\frac{1}{6}$	$\frac{1}{6}$

$\gamma^0 \gamma^7$  and  $\gamma^0 \gamma^8$  transform  $u_R$  of the 1<sup>st</sup> row into  $u_L$  of the 7<sup>th</sup> row, and  $d_R$  of the 4<sup>th</sup> row into  $d_L$  of the 6<sup>th</sup> row, doing what the Higgs scalars and  $\gamma^0$  do in the *standard model*.

$S^{ab}$  generate **all the members of one family with leptons included**. Here is The **eightplet** (represent. of  $SO(7,1)$ ) of **leptons colour chargeless. the  $SO(7,1)$  part is identical with the one of quarks.**

i		$ \psi_i\rangle$	$\Gamma^{(3,1)}$	$S^{12}$	$\Gamma^{(4)}$	$\tau^{13}$	$\tau^{23}$	$Y$	$Q$
		Octet, $\Gamma^{(7,1)} = 1$ , $\Gamma^{(6)} = -1$ , of leptons							
1	$\nu_R$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ (+i)(+) &   & (+)(+) &    & (+) & [+ ] & [+ ] \end{matrix}$	1	$\frac{1}{2}$	1	0	$\frac{1}{2}$	0	0
2	$\nu_R$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ [-i][- ] &   & (+)(+) &    & (+) & [+ ] & [+ ] \end{matrix}$	1	$-\frac{1}{2}$	1	0	$\frac{1}{2}$	0	0
3	$e_R$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ (+i)(+) &   & [-][- ] &    & (+) & [+ ] & [+ ] \end{matrix}$	1	$\frac{1}{2}$	1	0	$-\frac{1}{2}$	-1	-1
4	$e_R$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ [-i][- ] &   & [-][- ] &    & (+) & [+ ] & [+ ] \end{matrix}$	1	$-\frac{1}{2}$	1	0	$-\frac{1}{2}$	-1	-1
5	$e_L$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ [-i](+) &   & [-](+) &    & (+) & [+ ] & [+ ] \end{matrix}$	-1	$\frac{1}{2}$	-1	$-\frac{1}{2}$	0	$-\frac{1}{2}$	-1
6	$e_L$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ (+i)[- ] &   & [-](+) &    & (+) & [+ ] & [+ ] \end{matrix}$	-1	$-\frac{1}{2}$	-1	$-\frac{1}{2}$	0	$-\frac{1}{2}$	-1
7	$\nu_L$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ [-i](+) &   & (+)[- ] &    & (+) & [+ ] & [+ ] \end{matrix}$	-1	$\frac{1}{2}$	-1	$\frac{1}{2}$	0	$-\frac{1}{2}$	0
8	$\nu_L$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ (+i)[- ] &   & (+)[- ] &    & (+) & [+ ] & [+ ] \end{matrix}$	-1	$-\frac{1}{2}$	-1	$\frac{1}{2}$	0	$-\frac{1}{2}$	0

$\gamma^0\gamma^7$  and  $\gamma^0\gamma^8$  transform  $\nu_R$  of the 1<sup>st</sup> line into  $\nu_L$  of the 7<sup>th</sup> line, and  $e_R$  of the 4<sup>th</sup> line into  $e_L$  of the 6<sup>th</sup> line, doing what the Higgs scalars and  $\gamma^0$  do in the *standard model*.

$S^{ab}$  generate also all the **anti-eightplet** (repres. of  $SO(7,1)$ ) of **anti-quarks** of the anti-colour charge **belonging to the same family of the Clifford odd basis vectors** .

i		$ \psi_i\rangle$	$\Gamma^{(3,1)}$	$S^{12}$	$\Gamma^{(4)}$	$\tau^{13}$	$\tau^{23}$	$\Upsilon$	$\tau^4$
		Antioctet, $\Gamma^{(7,1)} = -1$ , $\Gamma^{(6)} = 1$ , of antiquarks							
33	$\bar{d}_L^{\bar{c}1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ [-i](+) &   & (+)(+) &    & [-] & [+ ] & [+ ] \end{matrix}$	-1	$\frac{1}{2}$	1	0	$\frac{1}{2}$	$\frac{1}{3}$	$-\frac{1}{6}$
34	$\bar{d}_L^{\bar{c}1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ (+i)[- ] &   & (+)(+) &    & [-] & [+ ] & [+ ] \end{matrix}$	-1	$-\frac{1}{2}$	1	0	$\frac{1}{2}$	$\frac{1}{3}$	$-\frac{1}{6}$
35	$\bar{u}_L^{\bar{c}1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ [-i](+) &   & [-](-) &    & [-] & [+ ] & [+ ] \end{matrix}$	-1	$\frac{1}{2}$	1	0	$-\frac{1}{2}$	$-\frac{2}{3}$	$-\frac{1}{6}$
36	$\bar{u}_L^{\bar{c}1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ (+i)[- ] &   & [-](-) &    & [-] & [+ ] & [+ ] \end{matrix}$	-1	$-\frac{1}{2}$	1	0	$-\frac{1}{2}$	$-\frac{2}{3}$	$-\frac{1}{6}$
37	$\bar{d}_R^{\bar{c}1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ (+i)(+) &   & (+)[- ] &    & [-] & [+ ] & [+ ] \end{matrix}$	1	$\frac{1}{2}$	-1	$\frac{1}{2}$	0	$-\frac{1}{6}$	$-\frac{1}{6}$
38	$\bar{d}_R^{\bar{c}1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ [-i](-) &   & (+)[- ] &    & [-] & [+ ] & [+ ] \end{matrix}$	1	$-\frac{1}{2}$	-1	$\frac{1}{2}$	0	$-\frac{1}{6}$	$-\frac{1}{6}$
39	$\bar{u}_R^{\bar{c}1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ (+i)(+) &   & (-)(+) &    & [-] & [+ ] & [+ ] \end{matrix}$	1	$\frac{1}{2}$	-1	$-\frac{1}{2}$	0	$-\frac{1}{6}$	$-\frac{1}{6}$
40	$\bar{u}_R^{\bar{c}1}$	$\begin{matrix} 03 & 12 & 56 & 78 & 9 & 1011 & 1213 & 14 \\ [-i](-) &   & (-)(+) &    & [-] & [+ ] & [+ ] \end{matrix}$	1	$-\frac{1}{2}$	-1	$-\frac{1}{2}$	0	$-\frac{1}{6}$	$-\frac{1}{6}$

$\gamma^0\gamma^7$  and  $\gamma^0\gamma^8$  transform  $\bar{d}_L$  of the 1<sup>st</sup> row into  $\bar{d}_R$  of the 5<sup>th</sup> row, and  $\bar{u}_L$  of the 4<sup>rd</sup> row into  $\bar{u}_R$  of the 8<sup>th</sup> row.

- ▶ We discuss so far the internal space of **fermions** describing their internal space with **Clifford odd "basis vectors"**.
- ▶ The detailed study of the **Clifford even "basis vectors"**, describing the internal space of **bosons**, together with the **Clifford odd "basis vectors"**, describing the internal space of **fermions** will be presented in a separate talk.

- ▶ Let us write down the **action**.
- ▶ **Fermions** and **bosons** can exist even if they do not **interact**, at least mathematically.
- ▶ Describing their internal spaces we do not pay attention on their interactions. We treat them as free fields.
- ▶ Describing the properties of **fermions** and **bosons** as we observe, the interaction should be included: A simple and elegant one (this is how I "see nature") demonstrating at low energies all the observed phenomena.

I use in the **spin-charge-family** theory a simple action.  
**Fermions** carry in  $d = (13 + 1)$  only **spins**, **two kinds** of **spins**  
 (no charges, no family charges “put by hand”)  
 and interact with the **gauge gravitational fields**.  
 $\gamma^a$ , in a superposition of odd products, determine **spins**,  
**charges and families of fermions**. (In a superposition of even  
 products, determine **spins and charges of bosons**).

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



$$\begin{aligned} \mathcal{L}_f &= \frac{1}{2}(\bar{\psi} \gamma^a p_{0a} \psi) + h.c. \\ p_{0a} &= f^\alpha{}_a p_{0\alpha} + \frac{1}{2E} \{p_\alpha, E f^\alpha{}_a\} - \\ \mathbf{p}_{0\alpha} &= \mathbf{p}_\alpha - \frac{1}{2} \mathbf{S}^{ab} \omega_{ab\alpha} - \frac{1}{2} \tilde{\mathbf{S}}^{ab} \tilde{\omega}_{ab\alpha} \end{aligned}$$

- ▶ The Einstein action for a free gravitational field is assumed to be linear in the curvature

$$\begin{aligned}
 \mathcal{L}_g &= E (\alpha \mathbf{R} + \tilde{\alpha} \tilde{\mathbf{R}}), \\
 \mathbf{R} &= f^{\alpha[a} f^{\beta b]} (\omega_{ab\alpha,\beta} - \omega_{ca\alpha} \omega^c_{b\beta}), \\
 \tilde{\mathbf{R}} &= f^{\alpha[a} f^{\beta b]} (\tilde{\omega}_{ab\alpha,\beta} - \tilde{\omega}_{ca\alpha} \tilde{\omega}^c_{b\beta}),
 \end{aligned}$$

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 "basis vectors" and correspondingly the creation operators for either the Clifford odd fermion fields or for the Clifford even boson fields in even and odd dimensional spaces will be presented in separate talks. These are the newest achievements of the spin-charge-family theory.
- ▶ The Clifford algebra objects, if used to describe the internal space — "basis vectors" — of fermion and boson fields, offer the explanation for the postulates of the usual second quantization procedure.
- ▶ The internal space offers a finite number of degrees of freedom for either fermion or boson fields.

It is the ordinary momentum or coordinate basis which offers the continuously infinite basis.

Progress in Particle and Nuclear Physics,  
<http://doi.org/10.1016.j.pnpn.2021.103890>

- ▶ The **spin-charge-family** explaining the observed properties of **quarks and leptons** and the **vector and scalar boson fields**, including the **cosmological observations**.

We have discussed so far **free fermion fields** and **boson fields** in any even dimensional space.

We describe the internal space of **fermion fields** and **boson fields** with the odd and even Clifford algebra elements, respectively.

The presentation of the internal spaces of **fermions** and **bosons** needs a separate talk.

- ▶ We (shall) learn that the **family members of fermions**, they are reachable by  $S^{ab}$ , distinguish in the eigenvalues of the Cartan subalgebra quantum numbers, and all the **families**, they are reachable by  $\tilde{S}^{ab}$ , are equivalent with respect to  $S^{ab}$ , they distinguish in the **family** quantum numbers.

We shall learn that the Hermitian conjugated partners of **fermion fields** form their own group.

- ▶ We shall learn that there are **two groups of boson fields**, each group has the Hermitian conjugated partners within the same group of **Clifford even members**, and that **there are NO families for bosons**.
- ▶ **Boson fields** carry in addition the space index, what will be discussed in an separate talk.

- ▶ The **spin-charge-family** theory assumes a simple starting action for fermions and bosons in  $d \geq (13 + 1)$ , with the **gravity** as the only gauge fields.
- ▶ It is the break of the starting symmetry which causes that **fermion fields** and **gravitational fields** manifest in  $d = (3 + 1)$  as all the observed **quarks and leptons** and the corresponding **vector** and **scalar** gauge fields.
- ▶ **C,P,T** symmetries in  $d = (3 + 1)$  follow from the **symmetry** in  $d \geq (13 + 1)$ .

*JHEP* 04 (2014) 165,  
*Phys. Rev. D* 91 065004 (2015),  
*J. of Mod. Physics* 6 (2015) 2244,  
 Rev. article in JPPNP <http://doi.org/10.1016.j.pppnp.2021.103890> .  
*J. of Math. Phys.* 34 (1993), 3731,  
*J. of Math. Phys.* 43, 5782 (2002) [hep-th/0111257].

- ▶ Is the **spin-charge-family** theory following what **“nature”** does while breaking starting symmetries?

## In the **spin-charge-family** theory:

- ▶ 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 assumed, *Eur. Phys. J. C* **77** (2017) 231.
  - **Vector** and **scalar gauge fields** **origin in two spin connection fields**, the **gauge fields** of  $\gamma^a\gamma^b$  and  $\tilde{\gamma}^a\tilde{\gamma}^b$ , and in
  - **vielbeins**, the gauge fields of momenta *Eur. Phys. J. C* **77** (2017) 231, [arXiv:1604.00675].
- ▶ If there are **no spinor sources present**, then either vector ( $\vec{A}_m^A$ ,  $m = 0, 1, 2, 3$ ) or scalar ( $\vec{A}_s^A$ ,  $s = 5, 6, \dots, d$ ) gauge fields are determined by **vielbeins** uniquely.

- ▶ **Spinors (fermions)** interact correspondingly with
  - the **vielbeins** and
  - the **two kinds of the spin connection fields**,  
*Eur. Phys. J. C* **77** (2017) 231.
- ▶ 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 field**.

There are two kinds of **scalar fields** with respect to the space index  $s$  — manifesting in  $d = (3 + 1)$ :

- ▶ **A.** 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**.

Phys. Rev. **D 91** (2015) 6, 065004

- ▶ **B.** Those with the "spinor charge" of a quark and ( $s = 9, 10, ..d$ ) 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

## Breaking symmetry from $M^{13+1}$ into $M^{7+1} \times M^6$

- ▶ We start with the massless solutions of the Weyl equation in  $d = (13 + 1)$  with the "basis vectors", described by the odd Clifford algebra objects, determining the internal space of fermions.
- ▶ With the spin (or the total angular momentum) in extra dimensions,  $d > (7 + 1)$ , determining the charge in  $d = (7 + 1)$ .
- ▶ Also all the boson fields, vector and scalar gauge fields, are in  $d = (13 + 1)$  massless free fields (with the "basis vectors", described by the even Clifford algebra objects, determining the internal space of bosons, as we shall learn in special talk.)

- ▶ We then let the  $\mathcal{M}^{13+1}$  manifold to break into  $\mathcal{M}^{7+1} \times$  an almost  $S^6$  sphere.
- ▶ The Weyl equation,  $m = (0, 1, 2, 3, 5, 6, 7, 8)$  and  $s = 9, 10, \dots 13, 14$  is

$$(\gamma^m p_m + \gamma^s p_{0s})\psi = 0,$$

$$p_{0s} = f_s^\sigma (p_\sigma - \frac{1}{2} S^{ab} \omega_{ab\sigma} - \frac{1}{2} \tilde{S}^{ab} \tilde{\omega}_{ab\sigma}) + \frac{1}{2E} \{p_\sigma, f_s^\sigma E\}_-.$$

- ▶ With the choice of the vielbein fields and the spin connection fields of both kinds,  $\omega_{ab\alpha}$  and  $\tilde{\omega}_{ab\alpha}$ , one can achieve that the infinite surface  $d = (9, 10, 11, \dots, 13, 14)$  curls into an almost  $S^6$  (with one hole with the substructure of  $SU(3) \times U(1)$ ) with massless fermions in  $d = (7 + 1)$ .
- ▶ This is the project, not yet done. The simpler problem with breaking  $\mathcal{M}^{5+1}$  manifold into  $\mathcal{M}^{3+1} \times$  an almost  $S^2$  sphere with one hole is done, without and with families taking into account.

*New J. Phys.* 13:103027, 2011.

*J. Phys. A: Math. Theor.* 45:465401, 2012.

## Condensate

- ▶ The (assumed so far, waiting to be derived how does this spontaneously appear) **scalar condensate** of **two right handed neutrinos** with the **family** quantum numbers of the upper four families (there are two four family groups in the theory), appearing  $\approx 10^{16}$  GeV or higher,
  - o **breaks the CP** symmetry, causing the **matter-antimatter asymmetry** and the proton decay,
  - o couples to all the **scalar fields**, making them massive,
  - o couples to all the phenomenologically **unobserved vector gauge fields**, making them massive.
  - o Before the electroweak break all the so far **observed vector gauge fields are massless**.

Phys. Rev. **D 91** (2015) 6, 065004,

J. of Mod. Phys. **6** (2015) 2244,

J. Phys.: Conf.Ser. 845 01, **IARD 2017**

▶ The **vector fields**, which do not couple to the condensate and remain massless, are:

o the **hyper charge vector field**.

o the **weak vector fields**,

o the **colour vector fields**,

o the **gravity fields**.

The  $SU(2)_{II}$  symmetry breaks due to the **condensate**, leaving the **hyper charge unbroken**.

## Nonzero vacuum expectation values of scalars

— waiting to be shown how does such an event, making the masses of the scalar gauge fields imaginary, appear in the *spin-charge-family* spontaneously.

- ▶ The scalar fields with the **space index (7, 8)**, gaining **nonzero vacuum expectation values**, a constant values, cause the **electroweak break**,
  - breaking the weak and the hyper charge,
  - changing their own masses,
  - bringing masses to the **weak bosons**,
  - bringing masses to the **families of quarks and leptons**.

Phys. Rev. **D 91** (2015) 6, 065004,

J. Phys.: Conf.Ser. 845 01 **IARD 2017**,

Eur. Phys. J.C. **77** (2017) 231 [arXiv:1604.00675],

J. of Mod. Phys. **6** (2015) 2244, [arXiv:1502.06786,

arXiv:1409.4981]

- ▶ The only gauge fields which do not couple to these scalars and remain massless are
  - electromagnetic,
  - colour vector gauge fields,
  - gravity.
- ▶ There are two times four decoupled massive **families** of **quarks and leptons** after the electroweak break:
  - There are the observed **three families** among the **lower four, the fourth to be observed**.
  - The stable among the **upper four families** form the **dark matter**.

Phys. Rev. **D 80**, 083534 (2009),

Phys. Rev. **D 91** (2015) 6, 065004,

J. Phys.: Conf.Ser. 845 01, **IARD 2017**

- ▶ 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 **break of manifold**  $M^{(13,1)}$  to  $M^{(7,1)} \times M^{(6)}$  is needed so that the manifold  $M^{(6)}$  makes an almost  $S^n$  sphere.
  - the **condensate** and
  - **constant values of all the scalar fields with  $s = (7, 8)$**  are needed that the **theory explains**
  - **all the assumptions** of the standard model, with the gauge fields, scalar fields, families of fermions, masses of fermions and of bosons included,
  - explaining also **the dark matter**,
  - **the matter/antimatter asymmetry**,
  - **the triangle anomalies cancellation** in the standard model

Forts. der Physik, Prog.of Phys.) (2017) 1700046  
and...

\*\*

Variation of the action brings for  $\omega_{ab\alpha}$

$$\begin{aligned}\omega_{ab\alpha} = & -\frac{1}{2E} \left\{ e_{e\alpha} e_{b\gamma} \partial_\beta (E f^{\gamma[e} f^{\beta]}_{a]}) + e_{e\alpha} e_{a\gamma} \partial_\beta (E f^{\gamma}_{[b} f^{\beta e]}) \right. \\ & \left. - e_{e\alpha} e^e{}_\gamma \partial_\beta (E f^{\gamma}_{[a} f^{\beta]}_{b]}) \right\} \\ & - \frac{e_{e\alpha}}{4} \left\{ \bar{\Psi} \left( \gamma_e S_{ab} + \frac{3i}{2} (\delta_b^e \gamma_a - \delta_a^e \gamma_b) \right) \Psi \right\} \\ & - \frac{1}{d-2} \left\{ e_{a\alpha} \left[ \frac{1}{E} e^d{}_\gamma \partial_\beta (E f^{\gamma}_{[d} f^{\beta]}_{b]}) + \frac{1}{2} \bar{\Psi} \gamma^d S_{db} \Psi \right] \right. \\ & \left. - e_{b\alpha} \left[ \frac{1}{E} e^d{}_\gamma \partial_\beta (E f^{\gamma}_{[d} f^{\beta]}_{a]}) + \frac{1}{2} \bar{\Psi} \gamma^d S_{da} \Psi \right] \right\}\end{aligned}$$

IARD, J. Phys.: Conf. Ser. 845 012017 and the Refs. therein

\*\*

and for  $\tilde{\omega}_{ab\alpha}$ ,

$$\begin{aligned}\tilde{\omega}_{ab\alpha} = & -\frac{1}{2E} \left\{ e_{e\alpha} e_{b\gamma} \partial_\beta (E f^{\gamma[e} f^{\beta]}_a) + e_{e\alpha} e_{a\gamma} \partial_\beta (E f^{\gamma}_{[b} f^{\beta e]}) \right. \\ & \left. - e_{e\alpha} e^e{}_\gamma \partial_\beta (E f^{\gamma}_{[a} f^{\beta]}_b) \right\} \\ & - \frac{e_{e\alpha}}{4} \left\{ \bar{\Psi} \left( \gamma_e \tilde{S}_{ab} + \frac{3i}{2} (\delta_b^e \gamma_a - \delta_a^e \gamma_b) \right) \Psi \right\} \\ & - \frac{1}{d-2} \left\{ e_{a\alpha} \left[ \frac{1}{E} e^d{}_\gamma \partial_\beta (E f^{\gamma}_{[d} f^{\beta]}_b) + \frac{1}{2} \bar{\Psi} \gamma^d \tilde{S}_{db} \Psi \right] \right. \\ & \left. - e_{b\alpha} \left[ \frac{1}{E} e^d{}_\gamma \partial_\beta (E f^{\gamma}_{[d} f^{\beta]}_a) + \frac{1}{2} \bar{\Psi} \gamma^d \tilde{S}_{da} \Psi \right] \right\}\end{aligned}$$

Eur. Phys. J. C, **77** (2017) 231 and the refs. therein.

**If there are no spinors present, the two spin connections are uniquely described by vielbeins  $f^\alpha_a$ .**

## Fermions

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

$$\begin{aligned}
 \mathcal{L}_f = & \bar{\psi} \gamma^m (p_m - \sum_{A,i} g^A \tau^{Ai} A_m^{Ai}) \psi + \\
 & \left\{ \sum_{s=[7],[8]} \bar{\psi} \gamma^s p_{0s} \psi \right\} + \\
 & \left\{ \sum_{s=[5],[6]} \bar{\psi} \gamma^s p_{0s} \psi + \right. \\
 & \left. \sum_{t=[9],\dots,[14]} \bar{\psi} \gamma^t p_{0t} \psi \right\} . \\
 & + \text{the rest , ,}
 \end{aligned}$$

## Covariant momenta

$$p_{0m} = \left\{ p_m - \sum_A g^A \vec{\tau}^A \vec{A}_m^A \right\}$$

$$\mathbf{m} \quad n \quad (0, 1, 2, 3),$$

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

$$\mathbf{s} \in (7, 8),$$

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

$$\mathbf{s} \in (5, 6),$$

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

$$\mathbf{t} \in (9, 10, 11, \dots, 14),$$

$$\mathbf{A}_s^{\text{Ai}} = \sum_{a,b} \mathbf{c}_{ab}^{\text{Ai}} \omega_{abs} ,$$

$$\mathbf{A}_t^{\text{Ai}} = \sum_{a,b} \mathbf{c}_{ab}^{\text{Ai}} \omega_{abt} ,$$

$$\tilde{\mathbf{A}}_s^{\text{Ai}} = \sum_{a,b} \tilde{\mathbf{c}}_{ab}^{\text{Ai}} \tilde{\omega}_{abs} ,$$

$$\tilde{\mathbf{A}}_t^{\text{Ai}} = \sum_{a,b} \tilde{\mathbf{c}}_{ab}^{\text{Ai}} \tilde{\omega}_{abt} .$$

$$\tau^{Ai} = \sum_{a,b} c^{Ai}_{ab} \mathbf{S}^{ab},$$

$$\tilde{\tau}^{Ai} = \sum_{a,b} \tilde{c}^{Ai}_{ab} \tilde{\mathbf{S}}^{ab},$$

$$\{\tau^{Ai}, \tau^{Bj}\}_- = i\delta^{AB} f^{Aijk} \tau^{Ak},$$

$$\{\tilde{\tau}^{Ai}, \tilde{\tau}^{Bj}\}_- = i\delta^{AB} f^{Aijk} \tilde{\tau}^{Ak},$$

$$\{\tau^{Ai}, \tilde{\tau}^{Bj}\}_- = 0.$$

- ▶ ○  $\tau^{Ai}$  represent the *standard model* charge groups  
 —  $SU(3)_c, SU(2)_w$  — the second  $SU(2)_{II}$ , the "spinor"  
 charge  $U(1)$ , taking care of the hyper charge  $Y$ ,
- ▶ ○  $\tilde{\tau}^{Ai}$  denote the family quantum numbers.

$$N_{(L,R)}^i := \frac{1}{2}(S^{23} \pm iS^{01}, S^{31} \pm iS^{02}, S^{12} \pm iS^{03}),$$

$$\tau_{(1,2)}^i := \frac{1}{2}(S^{58} \mp S^{67}, S^{57} \pm S^{68}, S^{56} \mp S^{78}),$$

$$\tau_3^i := \frac{1}{2}\{S^{9\ 12} - S^{10\ 11}, S^{9\ 11} + S^{10\ 12}, S^{9\ 10} - S^{11\ 12}, \\ S^{9\ 14} - S^{10\ 13}, S^{9\ 13} + S^{10\ 14}, S^{11\ 14} - S^{12\ 13}, \\ S^{11\ 13} + S^{12\ 14}, \frac{1}{\sqrt{3}}(S^{9\ 10} + S^{11\ 12} - 2S^{13\ 14})\},$$

$$\tau^4 := -\frac{1}{3}(S^{9\ 10} + S^{11\ 12} + S^{13\ 14}),$$

$$Y := \tau^4 + \tau^{23},$$

$$Y' := -\tau^4 \tan^2 \vartheta_2 + \tau^{23},$$

$$Q := \tau^{13} + Y,$$

$$Q' := -Y \tan^2 \vartheta_1 + \tau^{13},$$

and equivalently for family groups  $\tilde{S}^{ab}$ .

## Breaks of symmetries after starting with

- o massless spinors (fermions) ,
- o masses vielbeins and two kinds of the spin connection fields

**We prove for a toy model that breaking symmetry in  
Kaluza-Klein theories can lead to massless fermions.**

*New J. Phys.* 13, 103027, 2011.

*J. Phys. A. Math. Theor.* 45, 465401, 2012.

[arXiv:1205.1714], [arXiv:1312.541], [arXiv:hep-ph/0412208 p.64-84].

[arXiv:1302.4305], p. 157-166.



- ▶ The break from  $SO(13,1)$  to  $SO(7,1) \times SO(6)$ , caused by the appearance of the condensate, leaves **eight families** ( $2^{8/2-1} = 8$ , determined by the symmetry of  $\widetilde{SO}(1,7)$ ) massless. All the families are  $\widetilde{SU}(3)$  chargeless.

Phys. Rev. D, 80.083534 (2009)

- ▶ 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.

J. Phys.: Conf. Ser. 845 (2017) 012017

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

state	$\tau^{23}$	$\tau^4$	$Y$	$Q$	$\tilde{\tau}^{23}$	$\tilde{N}_R^3$	$\tilde{\tau}^4$
$ \nu_{1R}^{VIII} \rangle_1   \nu_{2R}^{VIII} \rangle_2$	1	-1	0	0	1	1	-1
$ \nu_{1R}^{VIII} \rangle_1   e_{2R}^{VIII} \rangle_2$	0	-1	-1	-1	1	1	-1
$  e_{1R}^{VIII} \rangle_1   e_{2R}^{VIII} \rangle_2$	-1	-1	-2	-2	1	1	-1

Let us look at boson "**basis vectors**" as will or was already presented in the figure, which analyses  ${}^1\hat{A}_f^{m\dagger}$  with respect to Cartan subalgebra members  $(\tau^3, \tau^8, \tau')$  in a toy model with  $d = (5 + 1)$ .

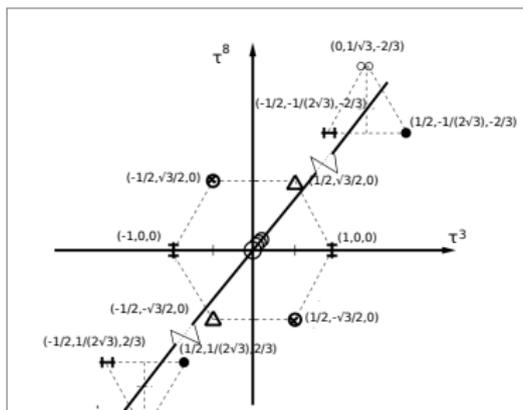
There are

**one sextet** with  $\tau' = 0$ ,

**four singlets** with  $(\tau^3 = 0, \tau^8 = 0, \tau' = 0)$ ,

one triplet with  $\tau' = \frac{2}{3}$  and one triplet with  $\tau' = -\frac{2}{3}$ .

The only  ${}^1\hat{A}_f^{m\dagger}$  which couple to condensate are the two triplets with non zero  $\tau' = \pm\frac{2}{3}$ , which **transform leptons** into **quarks**. **They become massive**.



- ▶ The **colour, elm, weak and hyper** vector gauge fields do **not interact with the condensate and remain massless.**  
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- ▶ **At the electroweak break** from  $SO(1, 3) \times SU(2)_I \times U(1)_I \times SU(3)$  to  $SO(1, 3) \times U(1) \times SU(3)$ 
  - o scalar fields with the space index  $s = (7, 8)$  obtain constant values and imaginary masses (nonzero vacuum expectation values),
  - o break correspondingly the weak and the hyper charge and change their own masses.
  - o They leave massless only the **colour, elm** and **gravity gauge fields**.
- ▶ All the eight massless families gain masses.

**Also these is so far just assumed, waiting to be proven that scalar fields, together with boundary conditions, are spontaneously causing also this last breaks.**

However, all the needed vector and scalar gauge fields, the fermion fields with all the observed properties, are already in the simple starting action, making the *spin-charge-family* theory (at least so far) very promising.

- ▶ To the **electroweak break** several scalar fields, the gauge fields of **two times  $\widetilde{SU}(2) \times \widetilde{SU}(2)$  and three times singlets  $U(1)$**  , 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  $\widetilde{SU}(2) \times \widetilde{SU}(2)$** .

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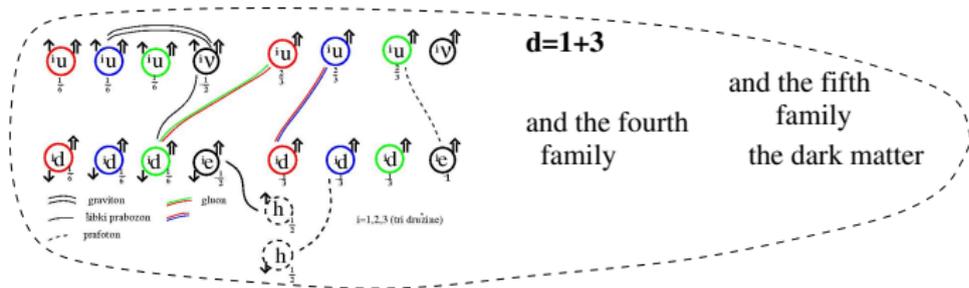
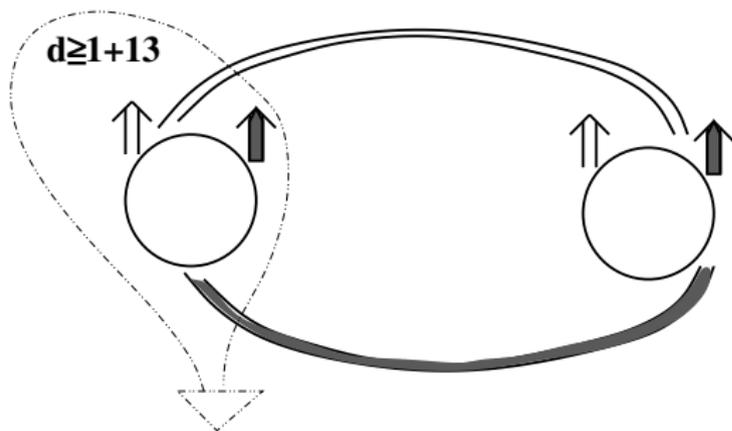
- ▶ The mass matrices of each family member manifest the  $\widetilde{SU}(2) \times \widetilde{SU}(2) \times U(1)$  symmetry, which remains unchanged in all loop corrections.

[arXiv:1902.02691, arXiv:1902.10628]

- ▶ 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,

Int. J Mod. Phys. **A 29**, 1450124 (2014), 21 pages.



\*\*

\*\*

- ▶ **All the vector gauge fields**,  $A_m^{Ai}$ ,  $(m, n) = (0, 1, 2, 3)$  of the observed charges  $\tau^{Ai} = \sum_{s,t} c^{Aist} S^{st}$ , 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 conection 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

$$S^{ab} \omega_{stm\dots g} = i(\delta_s^a \omega_{tm\dots g}^b - \delta_s^b \omega_{tm\dots g}^a).$$

\*\*

The action for vectors with respect to the space index  
 $m = (0, 1, 2, 3)$  origin in **gravity**

$$\int E d^4x d^{(d-4)}x_\alpha R^{(d)} = \int d^4x \left\{ -\frac{1}{4} F^{Ai}_{mn} F^{Aimn} \right\},$$
$$A^{Ai}_m = \sum_{s,t} c^{Aist} \omega_{stm}.$$

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,  
J. of Mod. Physics **6** (2015) 2244.

- ▶ 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  $\omega_{s'ts}$ :
  - Twice **two triplets**, the scalar gauge fields with the **family** quantum numbers  $(\tilde{T}^{Ai} = \sum_{a,b} \tilde{c}^{Ai}_{ab} \tilde{S}^{ab})$  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:

	state	$\tau^{13}$	$\tau^{23} = Y$	spin	$\tau^4$	Q
$A_{78}^{Ai}$ (-)	$A_7^{Ai} + iA_8^{Ai}$	$+\frac{1}{2}$	$-\frac{1}{2}$	0	0	0
$A_{56}^{Ai}$ (-)	$A_5^{Ai} + iA_6^{Ai}$	$-\frac{1}{2}$	$-\frac{1}{2}$	0	0	-1
$A_{78}^{Ai}$ (+)	$A_7^{Ai} - iA_8^{Ai}$	$-\frac{1}{2}$	$+\frac{1}{2}$	0	0	0
$A_{56}^{Ai}$ (+)	$A_5^{Ai} - iA_6^{Ai}$	$+\frac{1}{2}$	$+\frac{1}{2}$	0	0	+1

There are  $A_{78}^{Ai}$ <sub>(-)</sub> and  $A_{78}^{Ai}$ <sub>(+)</sub> 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  $s = (9, \dots, 14)$ .
- ▶ **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.
  - o **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  $\mathbf{s}=(7,8)$ , which gain **nonzero vacuum expectation values**, break the **weak and the hyper** symmetry, while conserving the **electromagnetic and colour** charge:

$$\begin{aligned} \mathbf{A}_s^{\mathbf{A}i} &\supset (\mathbf{A}_s^{\mathbf{Q}}, \mathbf{A}_s^{\mathbf{Q}'}, \mathbf{A}_s^{\mathbf{Y}'}, \tilde{\tilde{\mathbf{A}}}_s^{\tilde{\tilde{1}}}, \tilde{\tilde{\mathbf{A}}}_s^{\tilde{\tilde{N}}_L}, \tilde{\tilde{\mathbf{A}}}_s^{\tilde{\tilde{2}}}, \tilde{\tilde{\mathbf{A}}}_s^{\tilde{\tilde{N}}_R}), \\ \tau^{\mathbf{A}i} &\supset (\mathbf{Q}, \mathbf{Q}', \mathbf{Y}', \tilde{\tilde{\tau}}^1, \tilde{\tilde{\mathbf{N}}}_L, \tilde{\tilde{\tau}}^2, \tilde{\tilde{\mathbf{N}}}_R), \\ \mathbf{s} &= (7, 8). \end{aligned}$$

**Ai** denotes:

**o family** quantum numbers

$(\tilde{\tilde{\tau}}^1, \tilde{\tilde{\mathbf{N}}}_L)$  quantum numbers of the first group of four families

and

$(\tilde{\tilde{\tau}}^2, \tilde{\tilde{\mathbf{N}}}_R)$  quantum numbers of the second group of four families.

**o And family members** quantum numbers  $(\mathbf{Q}, \mathbf{Q}', \mathbf{Y}')$

$A_s^{Ai}$  are expressible with either  $\omega_{sts'}$  or  $\tilde{\omega}_{abs'}$ .

$$\vec{A}_s^1 = (\tilde{\omega}_{58s} - \tilde{\omega}_{67s}, \tilde{\omega}_{57s} + \tilde{\omega}_{68s}, \tilde{\omega}_{56s} - \tilde{\omega}_{78s}),$$

$$\vec{A}_s^2 = (\tilde{\omega}_{58s} + \tilde{\omega}_{67s}, \tilde{\omega}_{57s} - \tilde{\omega}_{68s}, \tilde{\omega}_{56s} + \tilde{\omega}_{78s}),$$

$$\vec{A}_{Ls}^N = (\tilde{\omega}_{23s} + i\tilde{\omega}_{01s}, \tilde{\omega}_{31s} + i\tilde{\omega}_{02s}, \tilde{\omega}_{12s} + \tilde{\omega}_{03s}),$$

$$\vec{A}_{Rs}^N = (\tilde{\omega}_{23s} - i\tilde{\omega}_{01s}, \tilde{\omega}_{31s} - i\tilde{\omega}_{02s}, \tilde{\omega}_{12s} - i\tilde{\omega}_{03s}),$$

$$A_s^Q = \omega_{56s} - (\omega_{910s} + \omega_{1112s} + \omega_{1314s}),$$

$$A_s^Y = (\omega_{56s} + \omega_{78s}) - (\omega_{910s} + \omega_{1112s} + \omega_{1314s})$$

$$A_s^4 = -(\omega_{910s} + \omega_{1112s} + \omega_{1314s}).$$

The **mass term**, appearing in the **starting action**,  
 is ( $p_s$ , when treating the lowest energy solutions, is left out)

$$\mathcal{L}_M = \sum_{s=(7,8), Ai} \bar{\psi} \gamma^s (-\tau^{Ai} A_s^{Ai}) \psi =$$

$$-\bar{\psi} \left\{ \overset{78}{(+)} \tau^{Ai} (A_7^{Ai} - i A_8^{Ai}) + \overset{78}{(-)} \tau^{Ai} (A_7^{Ai} + i A_8^{Ai}) \right\} \psi ,$$

$$\overset{78}{(\pm)} = \frac{1}{2} (\gamma^7 \pm i \gamma^8), \quad A_{\overset{78}{(\pm)}}^{Ai} := (A_7^{Ai} \mp i A_8^{Ai}).$$

Operators  $Y$ ,  $Q$  and  $\tau^{13}$ , applied on  $(A_7^{A_i} \mp i A_8^{A_i})$

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

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

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

manifest that **all**  $(A_7^{A_i} \mp i A_8^{A_i})$  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:

$(A_7^{A_i} + i A_8^{A_i})$  "dresses"  $u_R, \nu_R$  and  $(A_7^{A_i} - i A_8^{A_i})$  "dresses"  $d_R, e_R$ , with quantum numbers of their left handed partners, just as required by the "standard model".

**A<sub>i</sub>** determines:

either

o the **Q, Q', Y' charges** of the **family members**

or

o **family charges** ( $\vec{\tau}^{\vec{I}}, \vec{N}_L$ ), transforming a family member of one family into the same family member of another family,

manifesting in each group of four families the

$$\widetilde{SU}(2) \times \widetilde{SU}(2) \times U(1)$$

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  $\tilde{\tau}^{13} = 0$ ,  $\tilde{N}_L^3 = 0$ .

$\tilde{N}_R^3 = 0, \tilde{\tau}^{23} = 0$				$\tilde{N}_R^3 = 0, \tilde{\tau}^{23} = 0$				$\tilde{\tau}^{13}$	$\tilde{N}_L^3$
$u_{R1}^{c1}$	03 12 (+i) [+]	56 78   [+](+)	9 10 11 12 13 14    (+) [-] [-]	$\nu_{R1}$	03 12 (+i) [+]	56 78   [+](+)	9 10 11 12 13 14    (+) (+) (+)	$-\frac{1}{2}$	$-\frac{1}{2}$
$u_{R2}^{c1}$	03 12 [+i] (+)	56 78   [+](+)	9 10 11 12 13 14    (+) [-] [-]	$\nu_{R2}$	03 12 [+i] (+)	56 78   [+](+)	9 10 11 12 13 14    (+) (+) (+)	$-\frac{1}{2}$	$\frac{1}{2}$
$u_{R3}^{c1}$	03 12 (+i) [+]	56 78   (+)[+]	9 10 11 12 13 14    (+) [-] [-]	$\nu_{R3}$	03 12 (+i) [+]	56 78   (+)[+]	9 10 11 12 13 14    (+) (+) (+)	$\frac{1}{2}$	$-\frac{1}{2}$
$u_{R4}^{c1}$	03 12 [+i] (+)	56 78   (+)[+]	9 10 11 12 13 14    (+) [-] [-]	$\nu_{R4}$	03 12 [+i] (+)	56 78   (+)[+]	9 10 11 12 13 14    (+) (+) (+)	$\frac{1}{2}$	$\frac{1}{2}$
$\tilde{N}_L^3 = 0, \tilde{\tau}^{13} = 0$				$\tilde{N}_L^3 = 0, \tilde{\tau}^{13} = 0$				$\tilde{\tau}^{23}$	$\tilde{N}_R^3$
$u_{R5}^{c1}$	03 12 (+i) (+)	56 78   (+)(+)	9 10 11 12 13 14    (+) [-] [-]	$\nu_{R5}$	03 12 (+i) (+)	56 78   (+)(+)	9 10 11 12 13 14    (+) (+) (+)	$-\frac{1}{2}$	$-\frac{1}{2}$
$u_{R6}^{c1}$	03 12 (+i) (+)	56 78   [+][+]	9 10 11 12 13 14    (+) [-] [-]	$\nu_{R6}$	03 12 (+i) (+)	56 78   [+][+]	9 10 11 12 13 14    (+) (+) (+)	$-\frac{1}{2}$	$\frac{1}{2}$
$u_{R7}^{c1}$	03 12 [+i] [+]	56 78   (+)(+)	9 10 11 12 13 14    (+) [-] [-]	$\nu_{R7}$	03 12 [+i] [+]	56 78   (+)(+)	9 10 11 12 13 14    (+) (+) (+)	$\frac{1}{2}$	$-\frac{1}{2}$
$u_{R8}^{c1}$	03 12 [+i] [+]	56 78   [+][+]	9 10 11 12 13 14    (+) [-] [-]	$\nu_{R8}$	03 12 [+i] [+]	56 78   [+][+]	9 10 11 12 13 14    (+) (+) (+)	$\frac{1}{2}$	$\frac{1}{2}$

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  $Y' := -T^4 + \tau^{23}$  and interact with the scalar field  $(A_{(\pm)}^{Y'}, \vec{A}_{(\pm)}^{\tilde{I}}, \vec{A}_{(\pm)}^{\tilde{N}_L})$ .
- ▶ The group of the lower four families manifest the  $\widetilde{SU}(2)_{\widetilde{SO}(1,3)} \times \widetilde{SU}(2)_{\widetilde{SO}(4)} \times U(1)$  **symmetry** (also after all loop corrections).

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

[arXiv:1412.5866], [arXiv:1902.02691], [arXiv:1902.10628]

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  $m_{u_4} = m_{d_4}$ , [arxiv:1412.5866]:

- ▶ 1.  $m_{u_4} = 700$  GeV,  $m_{d_4} = 700$  GeV.....new<sub>1</sub>
- ▶ 2.  $m_{u_4} = 1200$  GeV,  $m_{d_4} = 1200$  GeV.....new<sub>2</sub>

$ V_{(ud)}  =$	$exp_n$	$0.97425 \pm 0.00022$	$0.2253 \pm 0.0008$	$0.00413 \pm 0.00049$	
	new <sub>1</sub>	0.97423(4)	0.22539(7)	0.00299	0.00776(1)
	new <sub>2</sub>	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 <sub>1</sub>	0.22534(3)	0.97335	0.04245(6)	0.00349(60)
	new <sub>2</sub>	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 <sub>1</sub>	0.00667(6)	0.04203(4)	0.99909	0.00038
	new <sub>2</sub>	0.00667	0.04206[5]	0.99909	0.00024[21]
	new <sub>1</sub>	0.00677(60)	0.00517(26)	0.00020	0.99996
	new <sub>2</sub>	0.00773	0.00178	0.00022	0.99997[9]

One can see what

B. Belfatto, R. Beradze, Z. Berezhiani, required in [arXiv:1906.02714v1], that

$V_{u_1 d_4} > V_{u_1 d_3}$ ,  $V_{u_2 d_4} < V_{u_1 d_4}$ , and  $V_{u_3 d_4} < V_{u_1 d_4}$ , ,  
**what is just happening in my theory.**

The newest experimental data, PDG, (P A Zyla at al, Prog. Theor. and Exp. Phys., Vol. 2020, Issue 8, Aug. 2020, 083C01) have not yet been used to fit mass matrix of Eq. (1).

- ▶ ○ The **matrix elements**  $V_{CKM}$  **depend strongly on the accuracy** of the experimental **3 x 3 submatrix**.
- Calculated **3 x 3 submatrix** of 4 x 4  $V_{CKM}$  depends on the  $m_{4th}$  **family masses**, but not much.
- $V_{u;d_4}$ ,  $V_{d;u_4}$  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 higher are the fourth family members masses, the better are conditions

$$V_{u_1 d_4} > V_{u_1 d_3} ,$$

$$V_{u_2 d_4} < V_{u_1 d_4} , \text{ and}$$

$$V_{u_3 d_4} < V_{u_1 d_4}$$

**fulfilled.**

- ▶ 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  $\widetilde{SU}(2)_{II\widetilde{SO}(3,1)} \times \widetilde{SU}(2)_{II\widetilde{SO}(4)}$  **scalar fields** with the corresponding family quantum numbers,
  - by the **scalars**  $(A_{78}^Q, A_{78}^{Q'}, A_{78}^{Y'})$ , 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,  $s = (9, \dots, d)$ :

	state	$\tau^{33}$	$\tau^{38}$	spin	$\tau^4$	Q
$A_{9\ 10}^{Ai}$ (+)	$A_9^{Ai} - iA_{10}^{Ai}$	$+\frac{1}{2}$	$\frac{1}{2\sqrt{3}}$	0	$-\frac{1}{3}$	$-\frac{1}{3}$
$A_{11\ 12}^{Ai}$ (+)	$A_{11}^{Ai} - iA_{12}^{Ai}$	$-\frac{1}{2}$	$\frac{1}{2\sqrt{3}}$	0	$-\frac{1}{3}$	$-\frac{1}{3}$
$A_{13\ 14}^{Ai}$ (+)	$A_{13}^{Ai} - iA_{14}^{Ai}$	0	$-\frac{1}{\sqrt{3}}$	0	$-\frac{1}{3}$	$-\frac{1}{3}$
$A_{9\ 10}^{Ai}$ (-)	$A_9^{Ai} + iA_{10}^{Ai}$	$-\frac{1}{2}$	$-\frac{1}{2\sqrt{3}}$	0	$+\frac{1}{3}$	$+\frac{1}{3}$
$A_{11\ 12}^{Ai}$ (-)	$A_{11}^{Ai} + iA_{12}^{Ai}$	$\frac{1}{2}$	$-\frac{1}{2\sqrt{3}}$	0	$+\frac{1}{3}$	$+\frac{1}{3}$
$A_{13\ 14}^{Ai}$ (-)	$A_{13}^{Ai} + iA_{14}^{Ai}$	0	$\frac{1}{\sqrt{3}}$	0	$+\frac{1}{3}$	$+\frac{1}{3}$

**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:

$$\tau^4 = \frac{1}{2}, \tau^{13} = 0, \tau^{23} = \frac{1}{2}$$

$$(\tau^{33}, \tau^{38}) = (0, 0)$$

$$Y = 1, Q = 1$$

$$\tau^4 = \frac{1}{6}, \tau^{13} = 0, \tau^{23} = -\frac{1}{2}$$

$$(\tau^{33}, \tau^{38}) = \left(\frac{1}{2}, \frac{1}{2\sqrt{3}}\right)$$

$$Y = -\frac{1}{3}, Q = -\frac{1}{3}$$



$$\tau^4 = 2 \times \left(-\frac{1}{6}\right), \tau^{13} = 0, \tau^{23} = -1$$

$$(\tau^{33}, \tau^{38}) = \left(\frac{1}{2}, \frac{1}{2\sqrt{3}}\right)$$

$$Y = -\frac{4}{3}, Q = -\frac{4}{3}$$

$$\tau^4 = -\frac{1}{6}, \tau^{13} = 0, \tau^{23} = -\frac{1}{2}$$

$$(\tau^{33}, \tau^{38}) = \left(\frac{1}{2}, -\frac{1}{2\sqrt{3}}\right)$$

$$Y = -\frac{2}{3}, Q = -\frac{2}{3}$$

$$\tau^4 = \frac{1}{6}, \tau^{13} = 0, \tau^{23} = \frac{1}{2}$$

$$(\tau^{33}, \tau^{38}) = \left(0, -\frac{1}{\sqrt{3}}\right)$$

$$Y = \frac{1}{6}, Q = \frac{2}{3}$$



$$\tau^4 = \frac{1}{6}, \tau^{13} = 0, \tau^{23} = \frac{1}{2}$$

$$(\tau^{33}, \tau^{38}) = \left(-\frac{1}{2}, \frac{1}{2\sqrt{3}}\right)$$

$$Y = \frac{2}{3}, Q = \frac{2}{3}$$

These two quarks,  $d_R^{c1}$  and  $u_R^{c3}$  can bind (at low enough energy) together with  $u_R^{c2}$  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.**

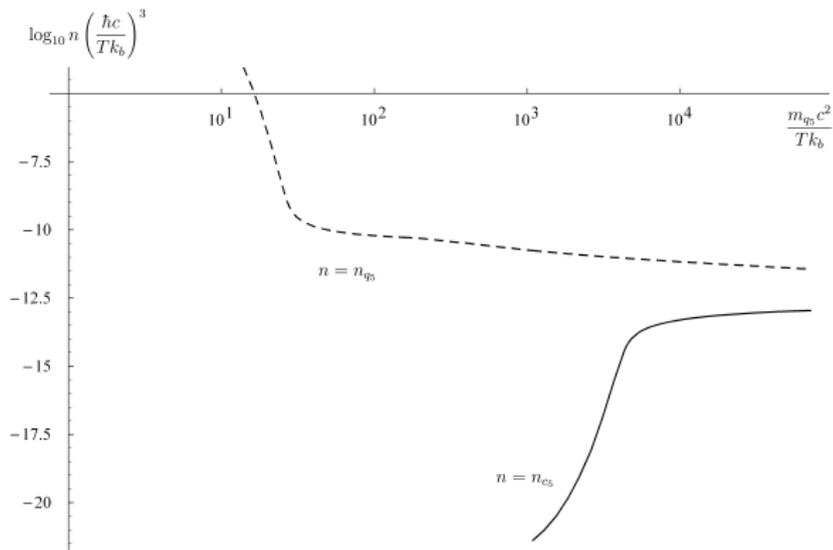
**These processes seem to explain the lepton number non conservation.**

## Dark matter

$d \rightarrow (d - 4) + (3 + 1)$  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**.

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**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** even offers the **creation and annihilation operators without postulation**.

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,  
Phys. Rev. D 91 (2015) 6, 065004.
- ▶ There is the **fourth family**, (weakly) coupled to the observed **three**, which will be observed at the LHC, New J. of Phys. 10 (2008) 093002.
- ▶ There is the **dark matter** with the predicted properties, Phys. Rev. D (2009) 80.083534.
- ▶ There is the ordinary **matter/antimatter asymmetry** explained and the **proton decay** predicted and explained, Phys. Rev. D 91 (2015) 6, 065004.

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.
- ▶ The **larger are masses of the fourth family the larger are  $V_{u_1 d_4}$  in comparison with  $V_{u_1 d_3}$  and the more is valid that  $V_{u_2 d_4} < V_{u_1 d_4}$ ,  $V_{u_3 d_4} < V_{u_1 d_4}$ .**  
The flavour changing neutral currents are correspondingly weaker.

- ▶ Masses of the **fifth family** lie **much above** the known three and the **predicted fourth family** masses.
- ▶ Although the upper four families carry the weak (of two kinds) and the colour charge, these group of four families are completely decoupled from the lower four families up to the  $< 10^{16}$  GeV, unless the breaks of symmetries recover.
- ▶ **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.
- ▶ Using **odd** and **even** Clifford algebra objects the **spin-charge-family** theory is offering an explanation for the **second quantization postulates** for **fermions** and **bosons**, while describing the internal space of **fermions** with the Clifford **odd anti-commuting "basis vectors"** and the internal space of **bosons** with the Clifford **even commuting "basis vectors"**.
- ▶ When all the properties of  $\hat{b}_f^{m\dagger}$ , and their **Hermitian conjugated partners**,  $\hat{b}_f^m$ , as well as of  $|\hat{A}_f^{m\dagger}|C_{f\alpha}^m$  will be understood we very probably will understand nature in  $d = (3 + 1)$  much better.

## To summarize:

- ▶ I hope that I managed to convince you that I can answer many open questions of particle physics and cosmology. The more work is put into this theory the more observed phenomenas I can explain and the predictions offer.
- ▶ **The collaborators are very welcome!**
- ▶ There are namely a lot of properties to derive.

## The theory explains:

- ▶ The appearance of the **finite** number of the **internal space "basis vectors"** of fermions,  $\hat{b}_f^{m\dagger}$ .  
The appearance of the **finite** number of the **internal space "basis vectors"** of bosons,  $\mathcal{A}_f^{m\dagger} \mathcal{C}_{f\alpha}^m$ .
- ▶ The **anticommutation relations** among the creation and annihilation operators, creating the **anticommuting single fermion states**.  
The **commutation relations** among the creation and annihilation operators, creating the **commuting single boson states**.
- ▶ The continuously **infinite** number of creation operators due to infinite dimensional ordinary space for **fermions** and **bosons**.
- ▶ The tensor products of the **Clifford odd creation operators** explain the **Hilbert space of the second quantized fermions**.

- ▶ 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 no **families** would appear.

**Vector gauge fields origin in gravity,**  
 in vielbeins  $f_{\alpha}^a$  and two kinds of the spin connection fields,  
 $\omega_{ab\alpha}, \tilde{\omega}_{ab\alpha}$ ,  
 the gauge fields of  $S^{ab}$  and  $\tilde{S}^{ab}$ . I showed above that both  
 are expressible by  $A_f^{m\dagger} C_{f\alpha}^m$  and  $\tilde{A}_f^{m\dagger} \tilde{C}_{f\alpha}^m$ .

- ▶ **Might it be that I could make consistent theory without fermions?**

That is: Could one relate  ${}^I\mathcal{A}_f^{m\dagger} {}^I\mathcal{C}_{f\alpha}^m$  and  $\omega^{ab}{}_{\alpha}$  without fermions?

Yes, I can relate  ${}^I\mathcal{A}_f^{m\dagger} {}^I\mathcal{C}_{f\alpha}^m$ , if I apply  $S^{ab}$  on  ${}^I\mathcal{A}_f^{m\dagger} {}^I\mathcal{C}_{f\alpha}^m$  and on  $(\alpha^{cd}\omega^{cd}{}_{\alpha} + \alpha^{ef}\omega^{ef}{}_{\alpha} + \alpha^{gh}\omega^{gh}{}_{\alpha} + \dots)$

- ▶ But **there are in Clifford algebra** Clifford **odd** and Clifford **even** "basis vectors". Then I should explain why nature uses only Clifford **even** "basis vectors". Why not Clifford **odd** "basis vectors"?
- ▶ **Nature uses obviously both, odd and even.**

\*\*29.06.2022 at 15:00

Let us compare the above **second quantization procedure**, describing **internal space of fermions with the odd Clifford algebra objects**, with the **second quantization procedure proposed by Dirac**, where the creation operators and correspondingly their Hermitian conjugate operators are **assumed**.

$$\psi_i(\mathbf{t}, \tilde{\mathbf{x}}) = \sum_{\mathbf{p}, i} \hat{a}^\dagger(\mathbf{p}, i) v(\tilde{\mathbf{p}}, i) e^{-\mathbf{p}_a \mathbf{x}^a}.$$

$v(\vec{p}, i)$  determine solutions of equations of motion for a particular  $e^{-\mathbf{p}_a \mathbf{x}^a}$ .

$\hat{a}^\dagger(p, i)$  is just assumed, together with the (assumed) Hermitian conjugate operator, to fill the anticommutation relation.

**In the spin-charge-family theory the creation operators appear from the odd Clifford objects, representing fermion states, applying on the vacuum state, in internal space.**

- ▶ The **anticommutation relations for creation operators and their Hermitian conjugated partners in the Dirac case in  $d = (3 + 1)$  for spin  $(\uparrow, \downarrow)$  and right and left handedness  $(\pm 1, \text{ respectively})$**

$$\begin{aligned} \{\hat{a}_i^\dagger(\vec{p}), \hat{a}_j^\dagger(\vec{p}')\}_+ &= 0 = \{\hat{a}_i(\vec{p}), \hat{a}_j(\vec{p}')\}_+, \\ \{\hat{a}_i(\vec{p}), \hat{a}_j^\dagger(\vec{p}')\}_+ &= \delta_{ij} \delta(\vec{p} - \vec{p}'), \end{aligned}$$

in the case of massless fermions.

- ▶ To be able to compare the spin-charge-family theory creation operators for this particular case of  $d = (3 + 1)$ , we make a choice of the creation operators representing spin  $\uparrow$  and right handedness,

$$\hat{b}_1^\dagger := \begin{matrix} 03 & 12 \\ [+i] \end{matrix} (+),$$

and spin  $\downarrow$  and right handedness,

$$\hat{b}_2^\dagger := \begin{matrix} 03 & 12 \\ (-i) \end{matrix} [-],$$

and shall not pay attention on charges (which in spin-charge-family theory originate in  $d \geq 5$ ) and families.

- ▶ In the spin-charge-family case the creation operators  $\hat{b}_i^\dagger, i = (1, 2)$  originate in "basis vectors" determining the internal space of fermions.
- ▶ Solutions of the Weyl equation – the Dirac equation for massless fermions – are superposition of both "basis vectors" for particular  $\vec{p}, p^0 = |\vec{p}|$   
 $\hat{\mathbf{b}}^{s\dagger}(\vec{p}) = \sum_i c^{is}(\vec{p}) \hat{b}_{\vec{p}}^{i\dagger} *_{\mathcal{T}} \hat{b}^{i\dagger} \quad i = (1, 2).$
- ▶ Let us write down both kinds of creation operators, the Dirac one and ours, both for the right handed case, leaving out therefore the index describing handedness  $h$  in the Dirac case and  $f$ , describing family, in our case

$$\hat{\mathbf{a}}^{s\dagger}(\vec{p}) \stackrel{\text{def}}{=} \sum_i \hat{\mathbf{a}}_i^{s\dagger}(\vec{p}) u_i^s(\vec{p}), \quad \hat{\mathbf{b}}^{s\dagger}(\vec{p}) = \sum_i c^{is}(\vec{p}) \hat{b}^{i\dagger} \hat{b}_{\vec{p}},$$

what is my redefinition of Dirac's operators.

- ▶ The creation operator of Dirac

$$\hat{\mathbf{a}}^{s\dagger}(\vec{p}) = \sum_i u_i^s(\vec{p}) \hat{a}_i^{s\dagger}(\vec{p}), \quad v^{si}(\vec{p}, \vec{x}) = u^{si}(\vec{p}) e^{i\vec{p}\cdot\vec{x}},$$

has to be related to

$$\hat{\mathbf{b}}^{s\dagger} = \sum_i c^{is}(\vec{p}) \hat{b}^i \hat{b}_{\vec{p}}.$$

$$\hat{\mathbf{a}}^{s\dagger}(\vec{p}) = \sum_i \hat{a}_i^{s\dagger}(\vec{p}) u_i^s(\vec{p}) \text{ to be related to } \hat{\mathbf{b}}^{s\dagger}(\vec{p}) = \sum_i c^{is}(\vec{p}) \hat{b}^i \hat{b}_{\vec{p}}.$$

Both creation operators,  $\hat{\mathbf{a}}^{s\dagger}(\vec{p})$  and  $\hat{\mathbf{b}}^{s\dagger}(\vec{p})$ , fulfill the same anticommutation relations,

$\hat{\mathbf{a}}^{s\dagger}(\vec{p})$  fulfill also the anticommutation relations of Dirac.

- ▶ Dirac equipped the creation operators (and correspondingly also the annihilation operators) with the quantum numbers  $(s, i)$  and with  $\vec{p}$ . He postulated for such creation and annihilation operators anticommutation relations.
- ▶ Our creation and annihilation operators,  $\hat{\mathbf{b}}^{s\dagger}(\vec{p})$  and  $\hat{\mathbf{b}}^s(\vec{p})$ , have anticommuting properties due to the anticommutativity of  $\hat{\mathbf{b}}^{i\dagger}$  and  $\hat{\mathbf{b}}^i$ , which are Clifford odd objects.

**The odd Clifford algebra offers the explanation for the Dirac's postulates for the second quantized fermions.**

►  $\psi^s(\vec{x}) = \int_{-\infty}^{+\infty} d^3p \hat{\mathbf{b}}^{s\dagger}(\vec{p}) e^{-i(p^0 x^0 - \vec{p}_k \cdot \vec{x})}$

**to be related to**

$$\psi^s(\vec{x}) = \int_{-\infty}^{+\infty} d^3p \hat{\mathbf{a}}^{s\dagger}(\vec{p}) e^{-i(p^0 x^0 - \vec{p}_k \cdot \vec{x})}.$$