# The Spin-Charge-Family theory offers the explanation for the assumptions of the Standard model, for the Dark matter, for the Matter-antimatter asymmetry..., making several predictions

N.S. Mankoč Borštnik, University of Ljubljana, Bled 2014

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- *Phys. Lett.* **B 292**, 25-29 (1992), *J. Math. Phys.* **34**, 3731-3745 (1993), *Modern Phys. Lett.* **A 10**, 587-595 (1995),
- *Int. J. Theor. Phys.* **40**, 315-337 (2001),
- *Phys. Rev.* **D 62** (04010-14) (2000), with H. B. Nielsen,
- *Phys. Lett.* **B 633** (2006) 771-775, **B 644** (2007) 198-202, **B** (2008) 110.1016, (2006), with H.B.N.
- *Phys. Rev.* , **D 74** 073013-16 (2006), with A.Borštnik.Bračič,
- *New Jour. of Phys.* **10** (2008) 093002, hep-ph/0606159, with G.Bregar,M.Breskvar, D.Lukman,
- *Phys. Rev.* **D** (2009) 80.083534, astro-ph/arXiv: 0907.0196, with G.B.,
- *New Jour. of Phys.* (2011) 103027,
- *J. Phys. A: Math. Theor.* **45** (2012) 465401,
- *J. of Modern Physics* **4** (2013) 823-847,
- *JHEP* **04** (2014)165, with H.B. N.

More than **30 years ago** the **standard model** offered an elegant new step in understanding the origin of fermions and bosons.
It postulated:

- The existence of the **massless family members**; **coloured quarks and colourless leptons**, **both left and right handed**, the **left handed members** distinguishing from the **right handed ones** in the **weak** and **hyper charges**.
- The existence of **massless families to each of a family member.**

- The existence of the **massless** **gauge fields** to the observed **charges** of the family **members**.

## 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**.

**Elm. charge = weak charge + hyper charge.**

- The existence of the **scalar field**, the **Higgs**, which takes care of masses of **weak gauge fields** and **fermions**, **and is chosen** to be a **weak doublet**, just like **fermions**, in order to "dress right handed" family members with the weak and the appropriate hyper charge and to assure the appropriate mass ratios of weak bosons.
- **The existence** of the **Yukawa couplings**,

$$\mathbf{Y}^{\alpha} \frac{\mathbf{v}}{\sqrt{\mathbf{2}}}$$

taking care of the masses of **fermions**, together with the **Higgs**.

- **The Higgs field**, **the scalar in** $d = (3+1)$, **a doublet with respect to the weak charge**. $P_R = (-1)^{2s+3B+L} = 1$.

- 

| name | hand-edness | weak charge | hyper charge | colour charge | elm charge |
|---|---|---|---|---|---|
| $0\cdot$ **Higgs**$_u$ | 0 | $\frac{1}{2}$ | $\frac{1}{2}$ | colourless | 1 |
| $< Higgs_d >$ | 0 | $-\frac{1}{2}$ | $\frac{1}{2}$ | colourless | 0 |

- 

| name | hand-edness | weak charge | hyper charge | colour charge | elm charge |
|---|---|---|---|---|---|
| $< Higgs_u >$ | 0 | $\frac{1}{2}$ | $-\frac{1}{2}$ | colourless | 0 |
| $0\cdot$ **Higgs**$_d$ | 0 | $-\frac{1}{2}$ | $-\frac{1}{2}$ | colourless | $-1$ |

**The *standard model* assumptions have been confirmed without offering surprizes.**

**The last unobserved field, the scalar Higgs, detected in June 2012, was confirmed in March 2013.**

What questions should one ask to see the next step beyond the standard model?

- Where do families originate? Why there exist families at all? How many families are there?
- Why there are left and right handed family members, distinguishing so much in charges and why quarks and leptons manifest so different properties if they all start as massless?
- How is the origin of the scalar field (the Higgs) 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? Why is the higgs, or are all the scalar fields, if there are several, doublets with respect to the weak and the hyper charge?



The Spin-Charge-Family theory offers the explanation

- **Why there are no scalar fields with the colour charge in the fundamental representation?**
- **Where** does the **dark matter originate?**
- **Where** does the **"ordinary" matter-antimatter asymmetry originate?**
- Where do the **charges and correspondingly the so far (and others possibly be) observed gauge fields originate?**
- What is the dimension of the space? $(3+1)$?, $((d-1)+1)$? What is $d$?
- **What** is the role of the **symmetries**– discrete, continuous, global and gauge – in Nature?
- And many others.



**The Spin-Charge-Family theory offers the explanation**

**My statements:**

- **Next trustable step beyond the standard model must offer answers to several open questions. It must explain:**
  **o The origin of charges.**
  **o The origin of families.**
  **o The origin of scalar fields.**
  **o The properties of families.**
  **o The properties of scalar fields.**
  **o The origin of "ordinary" matter-antimatter asymmetry.**
  **Inventing a next step which covers only one of the open questions**, leaving the rest untouched, **can hardly be the right step**.
- **There exist not yet observed families, gauge fields, scalar fields.**
- **Dimension of space is larger than 4** (very probably infinite).

In the literature NO explanation for the existence of the families can be found. Several extensions of the standard model are, however, proposed, like:

- A tiny extension: The inclusion of the right handed neutrinos into the family.
- The $SU(3)$ group is assumed to describe – not explain – the existence of three families.
  Like higgs has the charge in the fundamental representation of the group, also Yukawas are assumed to be scalar fields, in the bi-fundamental representation of the $SU(3)$ group.

- **SU(5), SU(8), SO(10) grand unified theories are proposed, unifying all the charges.** But the **spin** (the handedness) **is** obviously connected with the charges (the weak and the hyper, which goes only in Kaluza-Klein-like theories).
- **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, are not, to my understanding, the right step beyond the *standard model*.**

The **Spin-Charge-Family Theory** is offering **the explanation for:**

- The **existence of the families**.
- The **existence of the family members** and therefore for the **origin of the charges**.
- The **origin of the gauge fields**.
- The **origin of several scalar fields** which offer the explanation for the **origin of mass matrices of fermions and masses of gauge fields**, explaining why they are doublets with respect to the weak and the hyper charge.
- The **origin of the dark matter**.
- The **explanation for the "ordinary" matter-antimatter asymmetry**.
- **And...**

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

- **Spinors carry in** $d \geq (13+1)$ **TWO kinds of SPIN**.
  **o NO CHARGES**.
  **o** The **Dirac spin** $(\gamma^a)$ **in** $d = (13+1)$ **describes in** $d = (3+1)$ **the spin and ALL the charges of quarks and leptons**.
  **o** The **SECOND kind of the spin** $(\tilde{\gamma}^a)$ **generates FAMILIES**.

- **Spinors couple in $d=(13+1)$ to the vielbeins and the two kinds of the spin connection fields.**
- **There are therefore in $d=(13+1)$ only**
  **o spinors with the two kinds of spins and**
  **o the gravitational field .**
- **In $d=(3+1)$ the spin-connection fields of both kinds, together with the vielbeins, manifest either as the**
  **o gauge vector fields or as**
  **o the scalar fields.**
- **There are in $d=(3+1)$ scalar fields with the weak and the hyper charge in the fundamental representations, the vacuum expectation values of which determine on the tree level masses of fermions.**

- **There are in $d = (3+1)$ also the scalar fields with the twice "spinor" charge and the triplet colour charge, which transform antileptons into quarks, and antiquarks into quarks and back.**
- **These scalars are in the presence of the scalar condensate of the two right handed neutrinos responsible for the "ordinary" matter-antimatter asymmetry.**
- **These scalar fields are responsible also for the proton decay.**

1. **A** simple **action in $d = (13+1)$ for** spinors and spin connections and vielbeins manifests effectively in $d = (3+1)$, after appropriate breaks of the starting symmetry, the **standard model action**:
2. **For fermions – predicting the fourth family coupled to the so far observed three ones,** and the **dark matter family**.
3. **For** gauge vector fields, predicting **new fields**.
4. **For** scalar fields, which take care of **mass matrices of fermions** and **masses of weak bosons**, predicting several scalars, explaining the higgs and Yukawas.
5. **For** scalars**, which are colour triplets**, taking care of the **"ordinary" matter-antimatter asymmetry**, predicting **proton decay**.

**There are two kinds of the Clifford algebra objects** (**only two**):

- The **Dirac $\gamma^a$ operators** (used by Dirac 80 years ago).
- The **second one:** $\tilde{\gamma}^a$, which I recognized in the Grassmann space.

$$
\begin{aligned}
\{\gamma^a, \gamma^b\}_+ &= 2\eta^{ab} = \{\tilde{\gamma}^a, \tilde{\gamma}^b\}_+ ,\\
\{\gamma^a, \tilde{\gamma}^b\}_+ &= 0,\\
(\tilde{\gamma}^a B : &= i(-)^{n_B} B \gamma^a \,)\, |\psi_0>,\\
(B &= a_0 + a_a\gamma^a + a_{ab}\gamma^a\gamma^b + \cdots + a_{a_1\cdots a_d}\gamma^{a_1}\ldots\gamma^{a_d})|\psi_0>
\end{aligned}
$$

$(-)^{n_B} = +1, -1$, 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**.

$$\mathbf{S}^{ab} := (i/4)(\gamma^a \gamma^b - \gamma^b \gamma^a),$$

$$\tilde{\mathbf{S}}^{ab} := (i/4)(\tilde{\gamma}^a \tilde{\gamma}^b - \tilde{\gamma}^b \tilde{\gamma}^a),$$

$$\{\mathbf{S}^{ab}, \tilde{\mathbf{S}}^{cd}\}_- = 0.$$

- $\tilde{\mathbf{S}}^{ab}$ define the equivalent representations with respect to $\mathbf{S}^{ab}$.

My recognition:

- If $\gamma^a$ **are used to describe the spin and the charges of spinors,**
  $\tilde{\gamma}^a$ **can be used to describe families of spinors**.

**Must be used!!**

A simple action for **a spinor which carries in** $d = (13+1)$ **only two kinds of a spin** (no charges) and for **the gauge fields**

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

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

$$p_{0a} = f^{\alpha}{}_a p_{0\alpha} + \frac{1}{2E}\,\{p_\alpha, Ef^{\alpha}{}_a\}_-$$

$$\mathbf{p_{0\alpha} = p_\alpha} \quad -\frac{\mathbf{1}}{\mathbf{2}}\mathbf{S^{ab}}\,\omega_{\mathbf{ab}\alpha} - \frac{\mathbf{1}}{\mathbf{2}}\mathbf{\tilde{S}^{ab}}\,\tilde{\omega}_{\mathbf{ab}\alpha}$$

- **The only internal degrees of freedom of spinors (fermions) are the two kinds of the spin.**
- **The only gauge fields are the gravitational ones – vielbeins and two kinds of spin connections.**

- The action for spinors seen from d=(3+1), analysed with respect to the standard model groups. :

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

The action

$$
\begin{aligned}
p_{0m} &= \{p_m - \sum_A g^A \vec{\tau}^A \vec{A}^A_m\} - g^B \vec{\tau}^B \vec{A}^B_m - \sum_A \tilde{g}^A \vec{\tilde{\tau}}^A \vec{\tilde{A}}^A_m \\
m &\in (0,1,2,3)\,, \\
p_{0s} &= f^{\sigma}_{s}[p_\sigma - \sum_A g^A \vec{\tau}^A \vec{A}^A_\sigma - \sum_A \tilde{g}^A \vec{\tilde{\tau}}^A \vec{\tilde{A}}^A_\sigma]\,, \\
s &\in (7,8)\,, \\
p_{0s} &= f^{\sigma}_{s}[p_\sigma - \sum_A g^A \vec{\tau}^A \vec{A}^A_\sigma - \sum_A \tilde{g}^A \vec{\tilde{\tau}}^A \vec{\tilde{A}}^A_\sigma]\,, \\
s &\in (5,6)\,, \\
p_{0t} &= f^{\sigma'}_{t}(p_{\sigma'} - \sum_A g^A \vec{\tau}^A \vec{A}^A_{\sigma'} - \sum_A \tilde{g}^A \vec{\tilde{\tau}}^A \vec{\tilde{A}}^A_{\sigma'})\,, \\
t &\in (9,10,11,\ldots,14)\,,
\end{aligned}
$$

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

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

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

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

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

**o** $\tau^{Ai}$ stay for the standard model charge groups,
for the second $SU(2)_{II}$,
for the "spinor" charge,
$\tilde{\tau}^{Ai}$ stay for the family quantum numbers.

Breaks of symmetries when starting with **massless spinors** (fermions) and **vielbeins and the two kinds of spin connections**

**SO(1, 13)**

**BREAK I**

↓

**SO(1, 7)**× **U(1)**× **SU(3)**

↙ ↘

eight massless families

**SO(1, 3)** × **SO(4)** × **U(1)**× (devided into two groups) **SU(3)**

**BREAK II**

↓

The Standard Model type of breaking

↓

**SO(1, 3)** × **U(1)** × **SU(3)**

- Breaking the symmetry from $SO(13,1)$ to $SO(7,1) \times U(1) \times SU(3)$ occurs at very high energy scale (E $> 10^{16}$ GeV). It is followed by the break of $SO(7,1) \times U(1) \times SU(3)$ into $SO(3,1) \times SU(2) \times SU(2) \times U(1) \times SU(3)$. Both breaks leave eight families ($2^{8/2-1} = 8$, determined by the symmetry of $SO(7,1)$) massless.

- We are studying (with H.B. Nielsen, D. Lukman) on a toy model of $d = 5+1$ how to obtain after breaking symmetries massless spinors chirally coupled to the Kaluza-Klein-like gauge fields. Boundaries and the "effective two dimensionalities" seems to be very promising.

- Within $SO(7,1)$ $\times U(1) \times SU(3)$ the **weak ($SU(2)_I$) charge** and the **second ($SU(2)_{II}$) charge**, determining the **hypercharge**, both belonging to $SO(4)$ **of** $SO(7,1)$, **"see" spin-handedness**.
- There are **two groups of four families** - $2^{d/2-1}$ -, belonging to $\tilde{SO}(7,1)$, due to $\tilde{SU}(2)_L \times \tilde{SU}(2)_1$ and $\tilde{SU}(2)_R \times \tilde{SU}(2)_2$.

I shall show that:

- The **scalar condensate of the two right handed neutrinos carrying the family charge of the upper four families**, the "spinor" charge $-1$ and the $SU(2)_{II}$ charge equal to $1$ - consequently $Y = 0$ and $Q = 0$ - makes massive all the so far nonobserved gauge vector fields, making massive also the scalar fields.
  The only massless gauge fields are before the electroweak break the gauge fields of $Y$**, of the weak charge and of the colour charge**.
- The nonzero vacuum expectation values of the scalar fields with the **scalar index** $(7, 8)$, which all appear to be **weak doublets** with the by the *standard model* **required hypercharge**, take care at the **electroweak break of masses of the quarks and leptons and of the weak bosons**,

- **Vector boson gauge fields have the charges** in the **adjoint representations**.
- The **scalar fields with** $s \in (7, 8)$ have the **family charges** in the **adjoint representations,**
  **while they are doublets with respect to the weak charge**, and with respect to the $SU(2)_{II}$ **charge**, which manifests as the **hyper charge** (together with $\tau^4$ from $SO(6)$).
- The **scalar fields** with $t \in (9, 10, \ldots, 14)$ are **triplets** with respect to the **colour charge**.
  They have **family charges** in the **adjoint representations**.

- **Scalars** with the **weak, $SU(2)_{II}$, or colour charges in the fundamental representations do not have all the charges of the quarks and leptons.**
- All **the family members of all families** have **all the charges** in the **fundamental representations of the corresponding groups.**
- **Although the scalar fields carry some of the charges in the fundamental representations NO supersymmetry is predicted**, at least **NOT** at the low energy regime.

## Our technique to represent spinors works elegantly.

- *J. of Math. Phys.* **43**, 5782-5803 (2002), hep-th/0111257,
- *J. of Math. Phys.* **44** 4817-4827 (2003), hep-th/0303224,

both with H.B. Nielsen.

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

$$\text{for } \eta^{aa}\eta^{bb} = -1,$$

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

$$\text{for } \eta^{aa}\eta^{bb} = 1$$

with $\gamma^a$ which are the usual **Dirac operators**

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

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

$\gamma^a$ **transforms** $\overset{ab}{(k)}$ **into** $\overset{ab}{[-k]}$**, never to** $\overset{ab}{[k]}$**.**

$\tilde{\gamma}^a$ transforms $\overset{ab}{(k)}$ **into** $\overset{ab}{[k]}$**, never to** $\overset{ab}{[-k]}$**.**

- One Weyl representation of one family contains all the **family members** with the **right handed neutrinos included**. It includes also **antimembers**, which are reachable also by $\mathbb{C}_{\mathcal{N}}$ $\mathcal{P}_{\mathcal{N}}$ **on a family member**.
- There are $2^{(7+1)/2-1} = 8$ **families**, which decouple into twice four families, with the quantum numbers **($\tilde{\tau}^{2i}$, $\tilde{N}^{i}_{R}$)** and **($\tilde{\tau}^{1i}$, $\tilde{N}^{i}_{L}$)**, respectively.

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

| i | | $\vert^a\psi_i>$ | $\Gamma^{(3,1)}$ | $S^{12}$ | $\Gamma^{(4)}$ | $\tau^{13}$ | $\tau^{23}$ | $Y$ | $\tau^4$ |
|---|---|---|---|---|---|---|---|---|---|
| | | Octet, $\Gamma^{(7,1)}=1$, $\Gamma^{(6)}=-1$, of quarks | | | | | | | |
| 1 | $\mathbf{u_R^{c1}}$ | $\stackrel{03}{(+i)}\stackrel{12}{(+)} \vert \stackrel{56}{(+)}\stackrel{78}{(+)} \Vert \stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | 1 | $\frac{1}{2}$ | 1 | 0 | $\frac{1}{2}$ | $\frac{2}{3}$ | $\frac{1}{6}$ |
| 2 | $u_R^{c1}$ | $\stackrel{03}{[-i]}\stackrel{12}{[-]} \vert \stackrel{56}{(+)}\stackrel{78}{(+)} \Vert \stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | 1 | $-\frac{1}{2}$ | 1 | 0 | $\frac{1}{2}$ | $\frac{2}{3}$ | $\frac{1}{6}$ |
| 3 | $d_R^{c1}$ | $\stackrel{03}{(+i)}\stackrel{12}{(+)} \vert \stackrel{56}{[-]}\stackrel{78}{[-]} \Vert \stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | 1 | $\frac{1}{2}$ | 1 | 0 | $-\frac{1}{2}$ | $-\frac{1}{3}$ | $\frac{1}{6}$ |
| 4 | $\mathbf{d_R^{c1}}$ | $\stackrel{03}{[-i]}\stackrel{12}{[-]} \vert \stackrel{56}{[-]}\stackrel{78}{[-]} \Vert \stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | 1 | $-\frac{1}{2}$ | 1 | 0 | $-\frac{1}{2}$ | $-\frac{1}{3}$ | $\frac{1}{6}$ |
| 5 | $d_L^{c1}$ | $\stackrel{03}{[-i]}\stackrel{12}{(+)} \vert \stackrel{56}{[-]}\stackrel{78}{(+)} \Vert \stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | -1 | $\frac{1}{2}$ | -1 | $-\frac{1}{2}$ | 0 | $\frac{1}{6}$ | $\frac{1}{6}$ |
| 6 | $\mathbf{d_L^{c1}}$ | $\stackrel{03}{(+i)}\stackrel{12}{[-]} \vert \stackrel{56}{[-]}\stackrel{78}{(+)} \Vert \stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | -1 | $-\frac{1}{2}$ | -1 | $-\frac{1}{2}$ | 0 | $\frac{1}{6}$ | $\frac{1}{6}$ |
| 7 | $\mathbf{u_L^{c1}}$ | $\stackrel{03}{[-i]}\stackrel{12}{(+)} \vert \stackrel{56}{(+)}\stackrel{78}{[-]} \Vert \stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | -1 | $\frac{1}{2}$ | -1 | $\frac{1}{2}$ | 0 | $\frac{1}{6}$ | $\frac{1}{6}$ |
| 8 | $u_L^{c1}$ | $\stackrel{03}{(+i)}\stackrel{12}{[-]} \vert \stackrel{56}{(+)}\stackrel{78}{[-]} \Vert \stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | -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 $\mathbf{u_R}$ of the $1^{st}$ row into $\mathbf{u_L}$ of the $7^{th}$ row, and $\mathbf{d_R}$ of the $4^{rd}$ row into $\mathbf{d_L}$ of the $6^{th}$ row, doing what the Higgs and $\gamma^0$ do in the Stan. model.



The Spin-Charge-Family theory offers the explanation

# The eightplet of leptons .

| i | | $\vert^a\psi_i>$ | $\Gamma^{(3,1)}$ | $S^{12}$ | $\Gamma^{(4)}$ | $\tau^{13}$ | $\tau^{23}$ | $Y$ | $\tau^4$ |
|---|---|---|---|---|---|---|---|---|---|
| | | Octet, $\Gamma^{(7,1)}=1,\ \Gamma^{(6)}=-1$, of leptons | | | | | | | |
| 1 | $\nu_R$ | $\overset{03}{(+i)}\overset{12}{(+)} \vert \overset{56}{(+)}\overset{78}{(+)} \vert\vert \overset{9\,10}{(+)}\ \overset{11\,12}{[+]}\ \overset{13\,14}{[+]}$ | 1 | $\frac{1}{2}$ | 1 | 0 | $\frac{1}{2}$ | 0 | $-\frac{1}{2}$ |
| 2 | $\nu_R$ | $\overset{03}{[-i]}\overset{12}{[-]} \vert \overset{56}{(+)}\overset{78}{(+)} \vert\vert \overset{9\,10}{(+)}\ \overset{11\,12}{[+]}\ \overset{13\,14}{[+]}$ | 1 | $-\frac{1}{2}$ | 1 | 0 | $\frac{1}{2}$ | 0 | $-\frac{1}{2}$ |
| 3 | $e_R$ | $\overset{03}{(+i)}\overset{12}{(+)} \vert \overset{56}{[-]}\overset{78}{[-]} \vert\vert \overset{9\,10}{(+)}\ \overset{11\,12}{[+]}\ \overset{13\,14}{[+]}$ | 1 | $\frac{1}{2}$ | 1 | 0 | $-\frac{1}{2}$ | $-1$ | $-\frac{1}{2}$ |
| 4 | $e_R$ | $\overset{03}{[-i]}\overset{12}{[-]} \vert \overset{56}{[-]}\overset{78}{[-]} \vert\vert \overset{9\,10}{(+)}\ \overset{11\,12}{[+]}\ \overset{13\,14}{[+]}$ | 1 | $-\frac{1}{2}$ | 1 | 0 | $-\frac{1}{2}$ | $-1$ | $-\frac{1}{2}$ |
| 5 | $e_L$ | $\overset{03}{[-i]}\overset{12}{(+)} \vert \overset{56}{[-]}\overset{78}{(+)} \vert\vert \overset{9\,10}{(+)}\ \overset{11\,12}{[+]}\ \overset{13\,14}{[+]}$ | -1 | $\frac{1}{2}$ | -1 | $-\frac{1}{2}$ | 0 | -$\frac{1}{2}$ | $-\frac{1}{2}$ |
| 6 | $e_L$ | $\overset{03}{(+i)}\overset{12}{[-]} \vert \overset{56}{[-]}\overset{78}{(+)} \vert\vert \overset{9\,10}{(+)}\ \overset{11\,12}{[+]}\ \overset{13\,14}{[+]}$ | -1 | $-\frac{1}{2}$ | -1 | $-\frac{1}{2}$ | 0 | $-1$ | $-\frac{1}{2}$ |
| 7 | $\nu_L$ | $\overset{03}{[-i]}\overset{12}{(+)} \vert \overset{56}{(+)}\overset{78}{[-]} \vert\vert \overset{9\,10}{(+)}\ \overset{11\,12}{[+]}\ \overset{13\,14}{[+]}$ | -1 | $\frac{1}{2}$ | -1 | $\frac{1}{2}$ | 0 | -$\frac{1}{2}$ | $-\frac{1}{2}$ |
| 8 | $\nu_L$ | $\overset{03}{(+i)}\overset{12}{[-]} \vert \overset{56}{(+)}\overset{78}{[-]} \vert\vert \overset{9\,10}{(+)}\ \overset{11\,12}{[+]}\ \overset{13\,14}{[+]}$ | -1 | $-\frac{1}{2}$ | -1 | $\frac{1}{2}$ | 0 | -$\frac{1}{2}$ | $-\frac{1}{2}$ |

**In the standard model** the families exist by the assumption.
In the **spin-charge-family theory the families are created.**

- $\gamma^a$ **transforms** $\overset{ab}{(k)}$ **into** $\overset{ab}{[-k]}$**, never to** $\overset{ab}{[k]}$**.**
  $S^{ab}$ **transform one family member into another one.**
- $\tilde{\gamma}^a$ transforms $\overset{ab}{(k)}$ **into** $\overset{ab}{[k]}$**, never to** $\overset{ab}{[-k]}$**.**
  $\tilde{S}^{ab}$ **transform a family member into the same family member of another family.**

**Eight families** of $u_R$ (spin 1/2, colour $(\frac{1}{2}, \frac{1}{2\sqrt{3}})$) and of $\nu_R$ (spin 1/2). All have the weak charge $\tau^{13} = 0$, $\tau^{23} = \frac{1}{2}$, $\tilde{\tau}^4 = -\frac{1}{2}$. Quarks have "spinor" q.no. $\tau^4 = \frac{1}{6}$ and leptons $\tau^4 = -\frac{1}{2}$. The first four families have $\tilde{\tau}^{23} = 0$, $\tilde{N}^3_R = 0$, the second four families have $\tilde{\tau}^{13} = 0$, $\tilde{N}^3_L = 0$.

| | | | | $\tilde{\tau}^{13}$ | $\tilde{N}^3_L$ |
|---|---|---|---|---|---|
| $u^{c1}_{R\,1}$ | $\stackrel{03}{(+i)}\stackrel{12}{[+]}\mid\stackrel{56}{[+]}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{[-]}\;\stackrel{13\,14}{[-]}$ | $\nu_{R\,1}$ | $\stackrel{03}{(+i)}\stackrel{12}{[+]}\mid\stackrel{56}{[+]}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{(+)}\;\stackrel{13\,14}{(+)}$ | $\frac{1}{2}$ | $-\frac{1}{2}$ |
| $u^{c1}_{R\,2}$ | $\stackrel{03}{[+i]}\stackrel{12}{(+)}\mid\stackrel{56}{[+]}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{[-]}\;\stackrel{13\,14}{[-]}$ | $\nu_{R\,2}$ | $\stackrel{03}{[+i]}\stackrel{12}{(+)}\mid\stackrel{56}{[+]}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{(+)}\;\stackrel{13\,14}{(+)}$ | $\frac{1}{2}$ | $\frac{1}{2}$ |
| $u^{c1}_{R\,3}$ | $\stackrel{03}{(+i)}\stackrel{12}{[+]}\mid\stackrel{56}{(+)}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{[-]}\;\stackrel{13\,14}{[-]}$ | $\nu_{R\,3}$ | $\stackrel{03}{(+i)}\stackrel{12}{[+]}\mid\stackrel{56}{(+)}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{(+)}\;\stackrel{13\,14}{(+)}$ | $-\frac{1}{2}$ | $-\frac{1}{2}$ |
| $u^{c1}_{R\,4}$ | $\stackrel{03}{[+i]}\stackrel{12}{(+)}\mid\stackrel{56}{(+)}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{[-]}\;\stackrel{13\,14}{[-]}$ | $\nu_{R\,4}$ | $\stackrel{03}{[+i]}\stackrel{12}{(+)}\mid\stackrel{56}{(+)}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{(+)}\;\stackrel{13\,14}{(+)}$ | $-\frac{1}{2}$ | $\frac{1}{2}$ |
| | | | | $\tilde{\tau}^{23}$ | $\tilde{N}^3_R$ |
| $u^{c1}_{R\,5}$ | $\stackrel{03}{(+i)}\stackrel{12}{(+)}\mid\stackrel{56}{(+)}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{[-]}\;\stackrel{13\,14}{[-]}$ | $\nu_{R\,5}$ | $\stackrel{03}{(+i)}\stackrel{12}{(+)}\mid\stackrel{56}{(+)}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{(+)}\;\stackrel{13\,14}{(+)}$ | $-\frac{1}{2}$ | $-\frac{1}{2}$ |
| $u^{c1}_{R\,6}$ | $\stackrel{03}{(+i)}\stackrel{12}{(+)}\mid\stackrel{56}{[+]}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{[-]}\;\stackrel{13\,14}{[-]}$ | $\nu_{R\,6}$ | $\stackrel{03}{(+i)}\stackrel{12}{(+)}\mid\stackrel{56}{[+]}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{(+)}\;\stackrel{13\,14}{(+)}$ | $-\frac{1}{2}$ | $\frac{1}{2}$ |
| $u^{c1}_{R\,7}$ | $\stackrel{03}{[+i]}\stackrel{12}{[+]}\mid\stackrel{56}{(+)}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{[-]}\;\stackrel{13\,14}{[-]}$ | $\nu_{R\,7}$ | $\stackrel{03}{[+i]}\stackrel{12}{[+]}\mid\stackrel{56}{(+)}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{(+)}\;\stackrel{13\,14}{(+)}$ | $\frac{1}{2}$ | $-\frac{1}{2}$ |
| $u^{c1}_{R\,8}$ | $\stackrel{03}{[+i]}\stackrel{12}{[+]}\mid\stackrel{56}{[+]}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{[-]}\;\stackrel{13\,14}{[-]}$ | $\nu_{R\,8}$ | $\stackrel{03}{[+i]}\stackrel{12}{[+]}\mid\stackrel{56}{[+]}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\stackrel{11\,12}{(+)}\;\stackrel{13\,14}{(+)}$ | $\frac{1}{2}$ | $\frac{1}{2}$ |

Before the electroweak break all the families are mass protected and correspondingly massless.

- **The part of the action, responsible for masses of quarks and leptons and the weak vector bosons.**

$$\mathcal{L}_M = \{ \sum_{\mathbf{s}=[\mathbf{7}],[\mathbf{8}]} \bar{\psi}\gamma^{\mathbf{s}} \mathbf{p}_{\mathbf{0s}}\, \psi\} + \text{the rest}\ ,$$

I shall show that the rest get **masses** due to interaction with the **condensate.**

- The scalar fields $A^{Ai}_{7}$ and $A^{Ai}_{8}$ do carry the **weak charge** $\pm\frac{1}{2}$ and the **hypercharge** $\mp\frac{1}{2}$, where the fields $A^{Ai}_{s}$ , $s \in (7,8)$ stay for either $A^{Q}_{s}$, $A^{Q'}_{s}$ and $A^{Y'}_{s}$, or for the scalar gauge fields carrying the family quantum numbers: $\tilde{A}^{4}_{s}$, $\tilde{A}^{Q}_{s}$, $\vec{\tilde{A}}^{1}_{s}$, $\vec{\tilde{A}}^{2}_{s}$, $\vec{\tilde{A}}^{N_R}_{s}$, $\vec{\tilde{A}}^{1}_{s}$ **and** $\vec{\tilde{A}}^{N_L}_{s}$.
  To see this let us rewrite the mass term $\sum_{s=7,8} \bar{\psi}\,\gamma^{s}\,p_{0s}\,\psi$ as follows

$$\sum_{s=7,8} \bar{\psi}\,\gamma^{s}\,p_{0s}\,\psi = \bar{\psi}\{\stackrel{78}{(+)}\,(p_{07} - i p_{07}) + \stackrel{78}{(-)}\,(p_{07} + i p_{07})\,\psi\,\}\,,$$

  and then apply the operator $Y$ and $\tau^{13}$ on the fields $(A^{Ai}_{7} \mp i\,A^{Ai}_{8})$.

- To do that one must take into account the application of $S^{ab}$ on a vector fields

$$(S^{ab})^{c}{}_{d} A^{d \dots e \dots g} = i(\eta^{ac} \delta^{b}_{e} - \eta^{bc} \delta^{a}_{e}) \, A^{d \dots e \dots g} \,,$$

for each index $(e \in (d \dots g))$ of a bosonic field $A^{d \cdots g}$ separately.

Namely, by using for $S^{ab}$ in expressions for $\tau^{13}$ and $Y$ we find

$$\tau^{13}\,(A^{Ai}_7 \mp i\,A^{Ai}_8) \;=\; \pm\frac{1}{2}\,(A^{Ai}_7 \mp i\,A^{Ai}_8)\,,$$
$$Y\,(A^{Ai}_7 \mp i\,A^{Ai}_8) \;=\; \mp\frac{1}{2}\,(A^{Ai}_7 \mp i\,A^{Ai}_8)\,,$$

provided that $Ai$ do not concern the weak or the $SU(2)_{II}$.

These scalar fields, those which are involved in $\gamma^0 \stackrel{78}{(-)} A^{Ai}_{\pm}$, are causing transformation of $u^{c1}_R$ into $u^{c1}_L$ or $\nu_R$ into the $\nu_L$. **This prooves that all the scalar fields with the scalar index $s \in (7,8)$** have the **weak charge** and the **hyper charge** $(\tau^{23}+\tau^4)$ in the **fundamental representations of the groups.**

## Scalar fields at the electroweak break taking care of masses of the lower four families and the weak bosons

- Two triplets and three singlets $\phi^{\mathbf{Ai}} = [\tilde{\mathbf{A}}^{\tilde{\mathbf{N}}_{\mathbf{L}}\mathbf{i}}_{\pm}, \tilde{\tilde{\mathbf{A}}}^{\mathbf{1i}}_{\pm}, \mathbf{A}^{\mathbf{Q}}_{\pm}, \mathbf{A}^{\mathbf{Q}'}_{\pm}, \mathbf{A}^{\mathbf{Y}'}_{\pm}]$
- The (assumed, not derrived yet) Lagrange density for **scalars**

$$
\begin{aligned}
\mathcal{L}_{\mathbf{sb}} &= \frac{1}{2}\,(p_{0m}\,\mathbf{\Phi}^{\mathbf{Ai}})^{\dagger}(p_0^m\,\mathbf{\Phi}^{\mathbf{Ai}}) - V(\mathbf{\Phi}^{\mathbf{Ai}})\,,\\
V(\mathbf{\Phi}^{\mathbf{Ai}}) &= \sum_{A,i}\{-\frac{1}{2}\,(m_{Ai})^2\,(\mathbf{\Phi}^{\mathbf{Ai}})^2 + \frac{1}{4}\sum_{B,j}\lambda^{Ai\,Bj}\,(\mathbf{\Phi}^{\mathbf{Ai}})^2\,(\mathbf{\Phi}^{\mathbf{Bj}})^2\}\,,\\
p_{0m} &= p_m - g^{Ai}\,\tau^{Ai}\,A^{Ai}_m\,.
\end{aligned}
$$

- The mass eigenstates $\Phi^{\beta}$:
in the representation of which the potential is on the tree level diagonal.

$$V(\mathbf{\Phi}^{\beta}) = \sum_{\beta}\{-\frac{1}{2}(m_{\beta})^{2}(\mathbf{\Phi}^{\beta})^{2}+\frac{1}{4}\lambda^{\beta}(\mathbf{\Phi}^{\beta})^{4}\},$$

$$\frac{\partial V}{\partial \mathbf{\Phi}^{\beta}}|_{v_{Ai}} = 0,$$

- The **scalar fields** $\gamma^{0}\stackrel{78}{(\mp)}\tau^{Ai}\Phi^{Ai}_{\mp}$ transform the **right handed family members** into the corresponding **left handed partners**.

$$\gamma^{0}\stackrel{78}{(-)}\tau^{Ai}\Phi^{Ai}_{-}\psi^{k}_{(u,\nu)R} \to \tau^{Ai}\Phi^{Ai}_{-}\psi^{k}_{(u,\nu)L},$$
$$\gamma^{0}\stackrel{78}{(+)}\tau^{Ai}\Phi^{Ai}_{+}\psi^{k}_{(d,e)R} \to \tau^{Ai}\Phi^{Ai}_{+}\psi^{k}_{(d,e)L}.$$

Let $(\psi^{\alpha}_{(\mathbf{L},\mathbf{R})}\;,\;\mathbf{\Psi}^{\alpha}_{(\mathbf{L},\mathbf{R})})$
$\alpha = (u_{L,R}, d_{L,R}, \nu_{L,R}, e_{L,R})$, be the massless and the final (after all the loop corrections taken into account) massive four vector of the lower group of families with the family member q.n. equal to $\alpha$, respectively.
Then

$$\psi^{\alpha}_{(\mathbf{L},\mathbf{R})} = S^{\alpha}\,\mathbf{\Psi}^{\alpha}_{(\mathbf{L},\mathbf{R})}$$

$$\begin{aligned} \overline{\mathbf{\Psi}}^{\alpha}\, S^{\alpha\dagger}\, \mathcal{M}^{\alpha}\, S^{\alpha}\, \mathbf{\Psi}^{\alpha} &= \overline{\mathbf{\Psi}}^{\alpha}\, \mathrm{diag}(m^{\alpha}_{1}, \cdots, m^{\alpha}_{4})\, \mathbf{\Psi}^{\alpha}\,, \\ S^{\alpha\dagger}\, \mathcal{M}^{\alpha}\, S^{\alpha} &= \mathbf{\Phi}^{\alpha}_{\mathbf{f}}\,. \end{aligned}$$

The (**Yukawa**) couplings of the scalar fields to the $\alpha$ member of the $k^{th}$ family

$$(\mathbf{\Phi}^{\alpha}_{\mathbf{\Psi}})_{\mathbf{k}\,\mathbf{k'}}\,\mathbf{\Psi}^{\alpha\,\mathbf{k'}} \;=\; \delta_{k\,k'}\,m^{\alpha}_{k}\,\mathbf{\Psi}^{\alpha\,\mathbf{k}}\,.$$

The superposition of scalar fields which couple to fermions in the mass eigenstates basis

$$\mathbf{\Phi}^{\alpha}_{\mathbf{fk}} \;=\; \sum_{\beta} D^{\alpha\,\beta}_{k}\,\mathbf{\Phi}^{\beta}\,.$$

- Due to

$$\begin{aligned} \tau^{1+}\tau^{1-}\,\mathbf{\Phi^{Ai}}_{+} &= \mathbf{\Phi^{Ai}}_{+}\,, \\ \tau^{1-}\tau^{1+}\,\mathbf{\Phi^{Ai}}_{-} &= \mathbf{\Phi^{Ai}}_{-}\,, \\ Q\,\mathbf{\Phi^{Ai}}_{\pm} &= 0\,, \\ Q'\,\mathbf{\Phi^{Ai}}_{\pm} &= \pm\frac{1}{2\cos^2\theta_1}\,\mathbf{\Phi^{Ai}}_{\pm}.\,, \end{aligned}$$

the **vector gauge fields** $A^{1\pm}_m (= W^{\pm}_m)$ and $A^{Q'}_m\ (= Z_m)$ $= \cos\theta_1 A^{13}_m - \sin\theta_1 A^{Y}_m$ become massive, while $A^{Q}_m\ (= A_m)$ $= \sin\theta_2 A^{13}_m + \cos\theta_1 A^{Y}_m$ stays massless, if $\frac{g^1}{g^Y}\tan\theta_1 = 1\,.$

- Correspondingly the mass term of the **vector gauge bosons** is

$$(p_{0m}\,\hat{\Phi}^{I}_{\mp})^{\dagger}\,(p_0{}^{m}\,\hat{\Phi}^{I}_{\mp}) \rightarrow$$
$$(\frac{1}{2})^2\,(g^1)^2\,v_I^2(\frac{1}{(\cos\theta_1)^2}\,Z^{Q'}_{m}\,Z^{Q'\,m} + 2\,W^{+}_{m}\,W^{-\,m})\,,$$

$$Tr(\Phi^{vI\dagger}_{\mp}\,\Phi^{vI}_{\mp}) = \frac{v^2}{2}\,.$$

- These scalars with the weak and the hyper charge in the fundamental representations determines masses of all the members of the four families of quarks and leptons.

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

- We take the diagonal matrix elements $\mathcal{M}^{\alpha}_{d}$, $\alpha = \{u, d, \nu, e\}$ and the mixing matrices $V_{\alpha\beta}$ for the quark pair and the lepton pair from the experimental data, assuming that there is $4 \times 4$ mixing matrix which is unitary.

  **The unitary conditions for the $n \times n$ matrix when applied on the $(n-1) \times (n-1)$ submatrix, determine for $n \geq 4$ the $n \times n$ matrix uniquely.**

  For an orthogonal matrix this is the case for any $n$.

  If assuming that $(n-1) \times (n-1)$ submatrix is unitary, we lose $(2n-1)$ informations, when the free choice of phases are taken into account $(2n-1)$ goes into $(2n-3)$.
  For an orthogonal matrix we lose in this case $(n-1)$ informations.

- Taking into account the invariants

$$\sum_{i=1,4} m_i^\alpha \,, \quad \sum_{i>j=1,4} m_i^\alpha \, m_j^\alpha \,, \quad \sum_{i>j>k=1,4} m_i^\alpha \, m_j^\alpha \, m_k^\alpha \,,$$
$$m_1^\alpha \, m_2^\alpha \, m_3^\alpha \, m_4^\alpha \,,$$

determined by the masses of the three families and depending on the fourth family mass, we reduce the number of free parameters of each mass matrix from 6 to 3.

- The orthogonal mixing matrix, if known for three families exactly, determines all $6 = 3 + 3$ free parameters of the two family members.

- This would determine in the **spin-charge-family** theory the masses and the mixing matrices of the **four families of quarks and leptons** uniquely in the case that all the experimental data would be measured accurately and that orthogonality and reality of mixing matrices would be a good approximation.

- The measured values within the experimental accuracy enable to determine **intervals** of the fourth family members masses.
- **The accurate enough experiments can exclude the fourth family**.

**Together with G. Bregar and in the last time also with D. Lukman, we treat quarks and leptons in an equivalent way**. We have now very preliminary results, not yet the intervals for the fourth family members, since the results are very sensitive to the accuracy of the experimental data. The more carefully we are considering the calculations, the more massive are the fourth family members, and closer are the mass matrices to the **democratic matrices** for either quarks or leptons, which is undersandable.

- **Quarks** very preliminary, where the fourth family masses are not at all the right one yet:

$$\mathbf{M}^u_d/MeV/c^2 = (1.24703, 620.141, 172\,000., 650\,000.?))\,,$$
$$\mathbf{M}^d_d/MeV/c^2 = (2.92494, 54.793, 2\,899., 700\,000.?)\,,$$

$$|V_{ud}|_{ij} = \begin{pmatrix} 0.9740 & -0.2243 & -0.0041 & \mathbf{0.0306} \\ 0.2242 & 0.9737 & -0.0409 & \mathbf{-0.0049} \\ 0.0084 & 0.0403 & 0.986 & \mathbf{0.1616} \\ \mathbf{-0.031} & \mathbf{-0.0052} & \mathbf{-0.162} & \mathbf{0.9864} \end{pmatrix}_{ij}\,,$$

# Mass matrices of quarks:

- $$M^u = \begin{pmatrix} 351427. & 256907. & 257179. & 342730. \\ 256907. & 342353. & 342730. & 257179. \\ 257179. & 342730. & 343958. & 256907. \\ 342730. & 257179. & 256907. & 334884. \end{pmatrix},$$

- $$M^d = \begin{pmatrix} 175762. & 174263. & 174289. & 175708. \\ 174263. & 175581. & 175708. & 174289. \\ 174289. & 175708. & 175898. & 174263. \\ 175708. & 174289. & 174263. & 175717. \end{pmatrix},$$

- **Leptons** very preliminary (not with the right fourth family masses):

$$\mathbf{M}^{\nu}_{d}/MeV/c^2 = (5\cdot 10^{-9}?\,, 1\cdot 10^{-8}?\,, 5.\cdot 10^{-8}?\,, 60?\,000\,,$$
$$\mathbf{M}^{e}_{d}/MeV/c^2 = (0.510998928?\,, 105.6583715?\,, 1776.82?\,120\,000)$$

$$|V_{\nu e}|_{ij} = \begin{pmatrix} 0.9740 & -0.2243 & -0.0041 & \mathbf{0.0306} \\ 0.2242 & 0.9737 & -0.0409 & \mathbf{-0.0049} \\ 0.0084 & 0.0403 & 0.986 & \mathbf{0.1616} \\ \mathbf{-0.031} & \mathbf{-0.0052} & \mathbf{-0.162} & \mathbf{0.9864} \end{pmatrix}_{ij},$$

- $$\mathcal{M}^{\nu} = \begin{pmatrix} 14\,021 & 14\,968 & 14\,968 & -14\,021 \\ 14\,968 & 15\,979 & 15\,979 & -14\,968 \\ 14\,968 & 15\,979 & 15\,979 & -14\,968 \\ -14\,021 & -14\,968 & -14\,968 & 14\,021 \end{pmatrix},$$
- $$\mathcal{M}^{e} = \begin{pmatrix} 28\,933 & 30\,057 & 29\,762 & -27\,207 \\ 30\,057 & 32\,009 & 31\,958 & -29\,762 \\ 29\,762 & 31\,958 & 32\,009 & -30\,057 \\ -27\,207 & -29\,762 & -30\,057 & 28\,933 \end{pmatrix},$$

**Let me conclude on properties of quarks and leptons** as suggested by the **spin-charge-family** theory:

- Taking symmetries for the lowest four families as suggested by the **spin-charge-family** theory and the experimental data we treat **quarks and leptons in equivalent way**. Differences in the properties of quarks and leptons are due to different couplings of family members to the scalars $A^{Q}_{\pm}$, $A^{Q'}_{\pm}$ **and** $A^{Y'}_{\pm}$, which in loop corrections inflence all the off matrix elements of the mass matrices.
- **The theory predicts**, so far very preliminary, **masses of the fourth family members within some intervals, not yet succesfully found - due to the inaccuracy of the experimental data and the calculations, very sensitive to the experimental data - and suggests new measurements.**

The **spin-charge-family** theory is explaining the **dark matter**

- There are **four families**, decoupled from the lower four families, of quarks and leptons, the baryons of the lowest (the satble one) of which contribute to the **dark matter.**
- With G. Bregar we investigate this possibility.

- Since the masses of the fifth family lie much above the known three and the predicted fourth family masses, the baryons made out 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 candidat for the dark matter.
- We make a rough estimation of properties of clusters of the members of the fifth family $(u_5, d_5, \nu_5, e_5)$, which have, due to the splin-charge-family theory, the properties of the lower four families:
  the same family members and
  interacting with the same gauge fields.

- We use a simple (the Bohr like) model to estimate the size and the binding energy of the fifth family baryon, assuming that the fifth family quarks are heavy enough to interact with one gluon exchange only.
- We estimate the behavior of such clusters in the evolution of the Universe.
- We estimate the behavior of such clusters when hitting our Earth, and in particular the DAMA/NaI and DAMA-LIBRA experiments and other experiments measuring the dark matter, in dependence of the mass of the fifth family.

- **The elm. neutral fifth family baryons (neutrinos also contribute) form the dark matter.**
- **Direct measurements and cosmological evolution limit my fifth family mass** to $10\,TeV < m_{q_5} c^2 < 10^4\,TeV$.
- The dark matter baryons are opening an interesting new "fifth family nuclear" dynamics.

hep-ph/0711.4681,p.189-194; *Phys. Rev.* **D 80**, 083534 (2009).

**Matter-antimatter asymmetry** in the **spin-charge-family theory**.

- Scalars with the scalar (space) index $t \in (9, 10, \ldots, 13, 14)$ **are colour triplet scalar fields. I shall show that they cause transitions from positrons to quarks and from antiquarks into quarks, and back, transforming antimatter into matter and matter into antimatter.**
- **These scalar fields cause the birth and the decay of a proton.**

- The **condensate** of the two right handed neutrinos coupled to spin zero, which carries the $\tau^{23} = 1$ ($SU(2)_{II}$) charge and $\tau^4 = -1$ (the "spinor " charge $-\frac{1}{3}(S^{9\,10}, S^{11\,12}, S^{13\,14})$) and correspondingly $Q = 0$, $Y = 0$, breaks this matter-antimatter symmetry, by breaking $\mathbb{C}_{\mathcal{N}}\mathcal{P}_{\mathcal{N}}$ symmetry - offering the explanation for the **"ordinary" matter-antimatter asymmetry**.
- The condensate brings masses to all the scalar gauge fields and to the vector gauge fields $\vec{A}^2_m$, to $\vec{\tilde{A}}^2_m$, to $\vec{\tilde{A}}^{N_R}_m$, leaving massless the vector gauge colour $\vec{A}^3_m$, weak $\vec{A}^1_m$ and hypercharge $A^Y_m$ fields.
- The scalar fields with the scalar index $s \in 7, 8$ bring masses, when gaining nonzero vacuum expectation values, to the fermions and also to the weak bosons, changing their own masses.

- The action for spinors seen from d=(3+1), analysed with respect to the standard model groups.

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

Let us see what does, for example, the term $\gamma^0 \overset{9\,10}{(+)} \tau^{2-} A^{2-}_{\overset{9\,10}{(+)}}$ do on the positron $\mathbf{\bar{e}_L}$! (line 59)

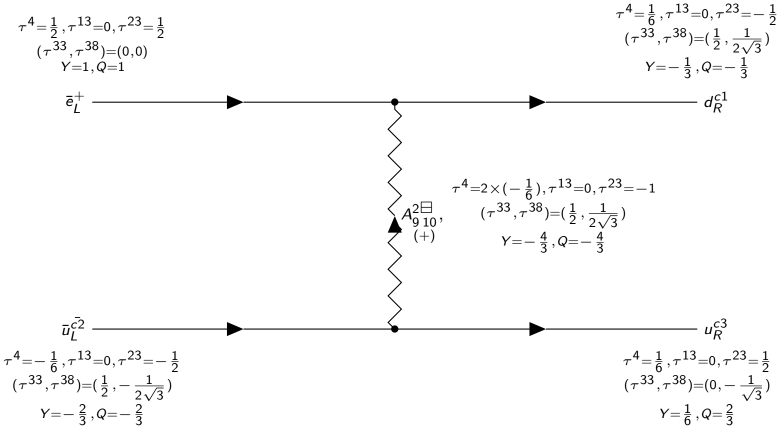
$\overset{9\,10}{(+)} \tau^{2-} A^{2-}_{\overset{9\,10}{(+)}} \overset{03}{[-\mathbf{i}]}\overset{12}{(+)} \mid \overset{56}{(+)}\overset{78}{(+)} \mid\mid \overset{9\,10}{[-]}\overset{11\,12}{(-)}\overset{13\,14}{(-)}$!

To evaluate this one must know that

$$\overset{ab}{(k)}\overset{ab}{(k)} = 0\,, \qquad \overset{ab}{(k)}\overset{ab}{(-k)} = \eta^{aa}\,\overset{ab}{[k]}\,,$$
$$\overset{ab}{(k)}\overset{ab}{[k]} = 0\,, \qquad \overset{ab}{(-k)}\overset{ab}{[k]} = \overset{ab}{(-k)}\,,$$
$$\tau^{1\pm} = (\mp)\ \overset{56}{(\pm)}\overset{78}{(\mp)}\,, \quad \tau^{2\mp} = (\mp)\ \overset{56}{(\mp)}\overset{78}{(\mp)}\,,$$

It follows $\rightarrow$ $\overset{03}{(+\mathbf{1})}\overset{12}{(+)} \mid \overset{56}{[-]}\overset{78}{[-]} \mid\mid \overset{9\,10}{(+)}\overset{11\,12}{(-)}\overset{13\,14}{(-)} = \mathbf{d^{c1}_R}$ (line 3).

The birth of a proton from the left handed positron, antiquark and quark:



If the antiquark $\bar{u}_L^{\bar{c}2}$, from the line 43, with the "spinor" charge $\tau^4 = -\frac{1}{6}$, the weak charge $\tau^{13} = 0$, the second $SU(2)_{II}$ charge $\tau^{23} = -\frac{1}{2}$, the colour charge $(\tau^{33}, \tau^{38}) = (\frac{1}{2}, -\frac{1}{2\sqrt{3}})$, the hyper charge $Y(= \tau^4 + \tau^{23} =) -\frac{2}{3}$ and the electromagnetic charge $Q(= Y + \tau^{13} =) -\frac{2}{3}$ submits the $A^{2\boxminus}_{\substack{9\,10 \\ (+)}}$ scalar field, it transforms into $u_R^{c3}$ from the line 17, carrying the quantum numbers $\tau^4 = \frac{1}{6}$, $\tau^{13} = 0$, $\tau^{23} = \frac{1}{2}$, $(\tau^{33}, \tau^{38}) = (0, -\frac{1}{\sqrt{3}})$, $Y = \frac{2}{3}$ and $Q = \frac{2}{3}$ .

These two quarks, $d_R^{c1}$ and $u_R^{c3}$ can bind (at low enough energy) together with $u_R^{c2}$ from the $9^{th}$ line, the colour chargeless baryon - a proton. This transition is presented in the figure.
The opposite transition would make the proton decay.

Let us now calculate **properties of the scalar and vector gauge fields** appearing in that part of the action, which is responsible for the birth or decay of a proton and possibly for the matter-antimatter asymmetry.

We need the expression for the transformation of the vector index

$$(S^{ab})^{c}{}_{d} A^{d\dots e\dots g} \;=\; i(\eta^{ac}\delta^{b}_{e} - \eta^{bc}\delta^{a}_{e})\, A^{d\dots e\dots g}\,,$$

for each index $(e \in (d \dots g))$ of a bosonic field $A^{d \cdots g}$ separately, and the expressions for the group generators in terms of $S^{ab}$ or $\tilde{S}^{ab}$, which is the same for spinors and vectors.

| field | prop. | $\tau^4$ | $\tau^{13}$ | $\tau^{23}$ | $(\tau^{33}, \tau^{38})$ | $Y$ | $Q$ | $\tilde{\tau}^4$ | $\tilde{\tau}^{13}$ | $\tilde{\tau}^{23}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| $A^{1\pm}_{9\,10\,(\pm)}$ | scalar | $\mp\frac{1}{3}$ | $\pm\mathbf{1}$ | 0 | $(\pm\frac{1}{2}, \pm\frac{1}{2\sqrt{3}})$ | $\mp\frac{1}{3}$ | $\mp\frac{1}{3} + \mp\mathbf{1}$ | 0 | 0 | 0 |
| $A^{13}_{9\,10\,(\pm)}$ | scalar | $\mp\frac{1}{3}$ | 0 | 0 | $(\pm\frac{1}{2}, \pm\frac{1}{2\sqrt{3}})$ | $\mp\frac{1}{3}$ | $\mp\frac{1}{3}$ | 0 | 0 | 0 |
| $A^{1\pm}_{11\,12\,(\pm)}$ | scalar | $\mp\frac{1}{3}$ | $\mp\mathbf{1}$ | 0 | $(\mp\frac{1}{2}, \pm\frac{1}{2\sqrt{3}})$ | $\mp\frac{1}{3}$ | $\mp\frac{1}{3} + \mp\mathbf{1}$ | 0 | 0 | 0 |
| $A^{13}_{11\,12\,(\pm)}$ | scalar | $\mp\frac{1}{3}$ | 0 | 0 | $(\mp\frac{1}{2}, \pm\frac{1}{2\sqrt{3}})$ | $\mp\frac{1}{3}$ | $\mp\frac{1}{3}$ | 0 | 0 | 0 |
| $A^{1\pm}_{13\,14\,(\pm)}$ | scalar | $\mp\frac{1}{3}$ | $\mp\mathbf{1}$ | 0 | $(0, \mp\frac{1}{\sqrt{3}})$ | $\mp\frac{1}{3}$ | $\mp\frac{1}{3} + \mp\mathbf{1}$ | 0 | 0 | 0 |
| $A^{13}_{13\,14\,(\pm)}$ | scalar | $\mp\frac{1}{3}$ | 0 | 0 | $(0, \mp\frac{1}{\sqrt{3}})$ | $\mp\frac{1}{3}$ | $\mp\frac{1}{3}$ | 0 | 0 | 0 |
| $A^{2\pm}_{9\,10\,(\pm)}$ | scalar | $\mp\frac{1}{3}$ | 0 | $\pm\mathbf{1}$ | $(\pm\frac{1}{2}, \pm\frac{1}{2\sqrt{3}})$ | $\mp\frac{1}{3} + \mp\mathbf{1}$ | $\mp\frac{1}{3} + \mp\mathbf{1}$ | 0 | 0 | 0 |
| $A^{23}_{9\,10\,(\pm)}$ | scalar | $\mp\frac{1}{3}$ | 0 | 0 | $(\pm\frac{1}{2}, \pm\frac{1}{2\sqrt{3}})$ | $\mp\frac{1}{3}$ | $\mp\frac{1}{3}$ | 0 | 0 | 0 |
| ... | | | | | | | | | | |
| $\tilde{A}^{1\pm}_{910\,(\pm)}$ | scalar | $\mp\frac{1}{3}$ | 0 | 0 | $(\pm\frac{1}{2}, \pm\frac{1}{2\sqrt{3}})$ | $\mp\frac{1}{3}$ | $\mp\frac{1}{3}$ | 0 | $\pm\mathbf{1}$ | 0 |
| $\tilde{A}^{13}_{910\,(\pm)}$ | scalar | $\mp\frac{1}{3}$ | 0 | 0 | $(\pm\frac{1}{2}, \pm\frac{1}{2\sqrt{3}})$ | $\mp\frac{1}{3}$ | $\mp\frac{1}{3}$ | 0 | 0 | 0 |
| ... | | | | | | | | | | |
| $\tilde{A}^{2\pm}_{910\,(\pm)}$ | scalar | $\mp\frac{1}{3}$ | 0 | 0 | $(\pm\frac{1}{2}, \pm\frac{1}{2\sqrt{3}})$ | $\mp\frac{1}{3}$ | $\mp\frac{1}{3}$ | 0 | 0 | $\pm\mathbf{1}$ |
| $\tilde{A}^{13}_{910}$ | scalar | $\mp\frac{1}{3}$ | 0 | 0 | $(\pm\frac{1}{2}, \pm\frac{1}{\ldots})$ | $\mp\frac{1}{3}$ | $\mp\frac{1}{3}$ | 0 | 0 | 0 |

**A condensate of two right handed neutrinos $|\nu_R^{VIII}>_1\,|\nu_R^{VIII}>_2$** carrying the family quantum numbers of the upper four families, **makes these fields verry massive, breaking the $\mathbb{C}_{\mathcal{N}}\cdot\mathcal{P}_{\mathcal{N}}^{(d-1)}$ symmetry and also the matter-antimatter symmetry**

## Properties of the condensate:

The condensate of the two right handed neutrinos $\nu_R$, with the $VIII^{th}$ family quantum number, coupled to spin $S^{12} = 0$ and belonging to a triplet with respect to the generators $\tau^{2i}$, is presented together with its two partners. The right handed neutrino has $Q = 0 = Y$. The triplet carries $\tilde{\tau}^4 = -1$, $\tilde{\tau}^{23} = 1$ and $\tilde{N}^3_R = 1$, $\tilde{N}^3_L = 0$, $\tilde{Y} = 0$, $\tilde{Q} = 0$.

| state | $S^{03}$ | $\tau^{13}$ | $\tau^{23}$ | $\tau^4$ | $Y$ | $Q$ | $\tilde{\tau}^{13}$ | $\tilde{\tau}^{23}$ | $\tilde{\tau}^4$ | $\tilde{Y}$ | $\tilde{Q}$ | $\tilde{N}^3_L$ | $\tilde{N}^3_R$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $(\lvert\nu^{\mathbf{VIII}}_{\mathbf{1R}} >_{\mathbf{1}}\ \lvert\nu^{\mathbf{VIII}}_{\mathbf{2R}} >_{\mathbf{2}})$ | 0 | 0 | 1 | −1 | 0 | 0 | 0 | 1 | −1 | 0 | 0 | 0 | 1 |
| $(\lvert\nu^{VIII}_{1R} >_1\ \lvert e^{VIII}_{2R} >_2)$ | 0 | 0 | 0 | −1 | −1 | −1 | 0 | 1 | −1 | 0 | 0 | 0 | 1 |
| $(\lvert e^{VIII}_{1R} >_1\ \lvert e^{VIII}_{2R} >_2)$ | 0 | 0 | −1 | −1 | −2 | −2 | 0 | 1 | −1 | 0 | 0 | 0 | 1 |

- **It stays an open question what does make the right handed neutrinos to form such a condensate.**
- **It stays an open question also whether or not the masses of all these scalar and vector gauge fields agree with the experimental data**.

**To summarise**:

- The scalar fields, contributing to the birth of baryons, get masses through couplings to the scalar condensate of the two right handed neutrinos, carrying the hypercharge and the electromagnetic charge equal to zero.
- Neutrinos of the condensate belong to the upper four families.
- The condensate breaks $\mathbb{C}_{\mathcal{N}}\ \mathcal{P}_{\mathcal{N}}$ causing the difference among baryons and antibaryons.
- Also the vector gauge fields which couple to the condensate get masses.

- The vector gauge fields which stay **massless up to the electroweak phase transitions** are the **colour charge octet**, the **weak charge triplet** and the **hypercharge singlet**.
- All the **families are mass protected**, since the **right handed** members carry the $\tau^{23}$ **charge and no weak charge**, while the **left handed** members are **weak charged**, with $\tau^{23} = 0$ , until the **electromagnetic chargeless weak and hyper charged scalar fields** with the space index $s \in (7,8)$, get nonzero vacuum expectation values and **break** therefore the **protection**.
- $A^{Ai}_{s}$ , $s \in (5,6)$ couple to the condensate and become massive, not influencing the properties of the lower four families. Also two more, together therefore 4 out of 14, dimensions do not manifest at low energies due to the heavy masses of the gauge fields of $-\frac{1}{3}(S^{9\,10} + S^{11\,12} + S^{13\,14})$.

- **The scalar fields, causing the birth of baryons, have the colour charges** in the **fundamental representations of the colour groups**, resembling the **supersymmetric partners of the quarks**, **but they are not**.
- **Similarly as the scalar fields, gaining non zero vacuum expectation values**, carry the **weak and** the **hyper charge** in the **fundamental representations of the weak and the $U(1)$ group.**

**The spin-charge-family theory offers**

- **The next trustable step beyond the standard model**, **offering answers to several open questions**. It explains:
  - **o The origin of charges.**
  - **o The origin of families.**
  - **o The origin of scalar fields.**
  - **o The origin of vector fields.**
  - **o The properties of families.**
  - **o The properties of scalar fields.**
  - **o The properties of vector fields.**
  - **o The origin of "ordinary" matter-antimatter asymmetry.**
  - **o The origin of the dark matter.**



**The Spin-Charge-Family theory offers the explanation**

- **The spin-charge-family theory predicts:**
  **o Not yet observed families**;
  **the fourth and the fifth will be or are observed**.
  **o New vector and scalar gauge fields.**
  **o New "nuclear" matter made out of heavy stable family members**.
  **o Proton decay.**
- **Dimension of space is larger than** 4 (very probably infinite).