# Do we have the explanation for the families and their properties, for the scalar Higgs and Yukawa couplings and for the gauge vector fields?

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**Collaborators** on this project, which **S**usana **N**orma **M**ankoč **B**orštnik has started almost 15 years ago:
Anamarija **Borštnik Bračič**, Gregor **Bregar**, Matjaž **Breskvar**, Albino **Hernandez Galeana**, Dragan **Lukman**, Holger Bech **Nielsen** (first of all so far), others.

- *Phys. Lett.* **B 292**, 25-29 (1992),
- *Modern 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, (2006), with H.B.N.
- *Phys. Rev.* , **D 74** 073013-16 (2006), with A.B.B..
- *New Jour. of Phys.* **10** (2008) 093002, hep-ph/0606159, with G.B.,M.B., D.L.
- *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.

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.**

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

**Members of each of the $i = 1, 2, 3$ massless families before the electroweak break. Each family contains the left handed weak charged quarks and the right handed weak chargeless quarks, belonging to the colour triplet**
$(1/2, 1/(2\sqrt{3}))$, $(-1/2, 1/(2\sqrt{3}))$, $(0, -1/(\sqrt{3}))$.

**And the anti-fermions** to each family and family member.

- The existence of the **massless** **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** $d = (1+3)$, **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**,

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

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

- **The Higgs field**, **the scalar** **in** $d = (1+3)$, **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** | $-1$ |

**Let us summarize the standard model assumptions, suggested by the observations**

- **All fermions have all the charges, which are not singlets, in the fundamental representations of the charge groups**.
- **All gauge bosons have all the charges, which are not singlets, in the adjoint representations of the corresponding groups. The singlet values are all zero for all the gauge fields.**
- **Higgs scalars** are **doublets** with respect to the **weak charge**.

**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?**

- **Why there exist families at all?**
  **How many families are there?**
  **Why family members – quarks and leptons – manifest so different properties if they all start as massless?**
- **How is the origin of the scalar field (the Higgs) 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 bosons?**
  **Why are all the scalar fields doublets with respect to the weak charge?**
- **Where** does the **dark matter 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? $(1+3)$?, $(1+(d-1))$? What is $d$?
- What is the role of the **symmetries**– discrete, continues, global and gauge – in Nature?
  What is the origin of **fermion-antifermion asymmetry**?
- And many others.

**My statement:**

- **Next trustable step beyond the standard model must offer answers to several open questions not only to one.**
- **There exist not yet observed families, gauge fields, scalar fields.**
- Dimension of the space is large than 4.

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 representaion of the $SU(3)$ group.
- Supersymmetric theories assuming the existence of partners to the existing fermions and bosons, with charges in the opposite representations.

**The spin-charge-family-theory does offer**
**a possible explanation for the existence of families,**
**offering answers besides to the "urgent" open questions**
**also to many of the "not so urgent" open**
**questions, presented above.**

## Content of the talk

- A brief introduction into the **spin-charge-family-theory**.
- Achievements of the **spin-charge-family-theory** so far.
- Some new predictions for the measurements.
- **Problems in this theory to be solved**.

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

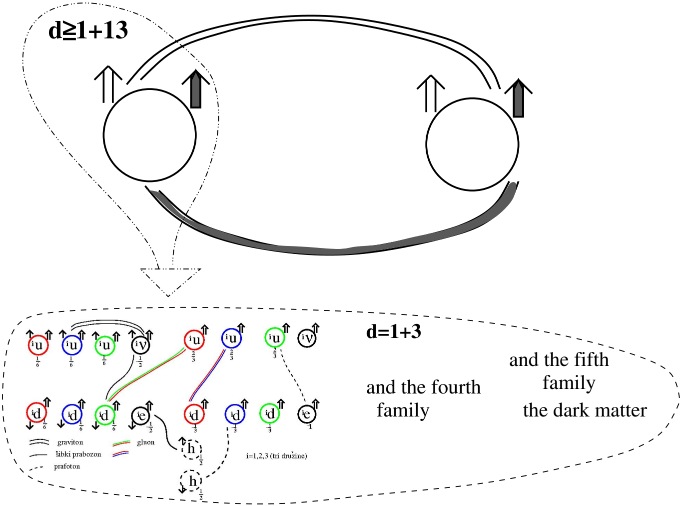
- The **existence of families**.
- The **existence of family members**.
- The **origin of charges**.
- The **origin of gauge fields**.
- The **origin of several scalar fields**. which offer the (hopefully right) explanation for the **origin of mass matrices of fermions and masses of gauge fields**.
- The **origin of dark matter**.
- **And...**

**Is the spin-charge-family theory the right way at least as a first step beyond the standard model?**

- **Spinors carry in $d \geq (1+13)$ two kinds of the spin. No charges.**
  **In $d = (1+3)$** the **Dirac spin ($\gamma^a$) takes care of the spin and the charges of quarks and leptons**.
  The **second kind of the spin ($\tilde{\gamma}^a$) generates families**.
- **Spinors couple correspondingly to vielbeins and to two kinds of spin connection fields**.
  **In $d = (1+3)$** the **spin-connection fields together with the vielbeins manifest as the gauge vector fields and the scalar fields**. **The vacuum expectation values of the scalar fields determine on the tree level masses of fermions**.

- The **scalar fields and the vector boson fields are a part of vielbeins** and **spin connections of both kinds**. **All couple to fermions**.
- **A simple action in $d = (1 + 13)$ for spinors and spin connections and vielbeins manifests in $d = (1 + 3)$,** after appropriate breaks of the starting symmetry, the **standard model action**
  1. **for fermions – predicting the fourth family coupled to the so far observed three** and the **dark matter family**,
  2. **for gauge fields**, predicting new ones,
  3. **for scalar fields**, which take care of **mass matrices** of **fermions** and **masses of weak bosons**, predicting several ones.

- All **vector boson fields have all the charges** in the **adjoint representations**.
- The **scalar fields** have the **family charges** in the **adjoint representations, while they are doublets with respect to the weak charge**.
- All **family members of all families** have all the charges in the **fundamental representations of the corresponding groups.**
- **No supersymmetry is predicted at low energy regime**.


d≧1+13
d=1+3
and the fourth family
and the fifth family
the dark matter
graviton
šibki prabozon
prafoton
gluon
i=1,2,3 (tri družine)

**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.

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

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

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

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

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

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

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** $d = (1+13)$ **only two kinds of a spin** (no charges) and for **the gauge fields**

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

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

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

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

- **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.**

# Breaks of symmetries when starting with **massless spinors**

$\mathbf{SO(1,13)}$

**BREAK I**

$\downarrow$

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

$\swarrow$ eight massless families $\searrow$

$\mathbf{SO(1,3)} \times \mathbf{SU(2)_{II}} \times \mathbf{SU(2)_{I}} \times \mathbf{U(1)_{II}} \times$ (eight massless families)

**BREAK II**

$\mathbf{SO(1,3)} \times \mathbf{SU(2)_{I}} \times \mathbf{U(1)_{I}} \times$ (four families stay massless,) (four families obtain masses

$\downarrow$

**BREAK I**

The Standard Model type of breaking

$\downarrow$

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

- The action for spinors at the low energy regime

$$
\begin{aligned}
\mathcal{L}_f &= \bar{\psi}\gamma^m(p_m - \sum_{A,i} g^A \tau^{Ai} A^{Ai}_m)\psi + \\
& \{ \sum_{s=[7],[8]} \bar{\psi}\gamma^s p_{0s}\, \psi\} + \\
& \text{the rest}\ , \\
p_{0m} &= f^\mu_m (p_\mu - \sum_A g^A\, \vec{\tau}^A\, \vec{A}^A_\mu)\,, \\
p_{0s} &= f^\sigma_s (p_\sigma - \sum_B g^B\, \vec{\tau}^B\, \vec{A}^B_\sigma - \sum_B \tilde{g}^B\, \vec{\tilde{\tau}}^B\, \vec{\tilde{A}}^B_\sigma)\,.
\end{aligned}
$$

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

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

**Before the last two breaks, BREAK II and Break I, of symmetries there are eight massless families of fermions.**

- It is the term $\bar{\psi}\gamma^s p_{0s}\psi\,, s \in \{[7],[8]\}$ which determines massess of fermions on the tree level.
- Before the electroweak break ( BREAK I) the four out of eight families remain massless. Four of the eight gain masses.
- The lowest among the **decoupled** upper, massive after the $SU(2)_{II} \times U(1)_{II}$ break, four families is the **candidate** for forming the **dark matter** clusters.

## 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.

$$\begin{aligned}
\overset{ab}{(\pm i)}: &= \frac{1}{2}(\gamma^a \mp \gamma^b),\ \overset{ab}{[\pm i]} := \frac{1}{2}(1 \pm \gamma^a \gamma^b) \\
&\text{for } \eta^{aa}\eta^{bb} = -1, \\
\overset{ab}{(\pm)}: &= \frac{1}{2}(\gamma^a \pm i\gamma^b),\ \overset{ab}{[\pm]} := \frac{1}{2}(1 \pm i\gamma^a \gamma^b), \\
&\text{for } \eta^{aa}\eta^{bb} = 1
\end{aligned}$$

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** $\overset{ab}{[-k]}$**.**

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

| i | | $\vert^a\psi_i>$ | $\Gamma^{(1,3)}$ | $S^{12}$ | $\Gamma^{(4)}$ | $\tau^{13}$ | $\tau^{23}$ | $Y$ | $\tau^4$ |
|---|---|---|---|---|---|---|---|---|---|
| | | Octet, $\Gamma^{(1,7)}=1,\ \Gamma^{(6)}=-1,$ of quarks | | | | | | | |
| 1 | $\mathbf{u_R^{c1}}$ | $\stackrel{03}{(+i)}\stackrel{12}{(+)}\mid\stackrel{56}{(+)}\stackrel{78}{(+)}\mid\mid\stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | 1 | $\frac{1}{2}$ | 1 | 0 | $\frac{1}{2}$ | $\frac{2}{3}$ | $\frac{1}{6}$ |
| 2 | $u_R^{c1}$ | $\stackrel{03}{[-i]}\stackrel{12}{[-]}\mid\stackrel{56}{(+)}\stackrel{78}{(+)}\mid\mid\stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | 1 | $-\frac{1}{2}$ | 1 | 0 | $\frac{1}{2}$ | $\frac{2}{3}$ | $\frac{1}{6}$ |
| 3 | $d_R^{c1}$ | $\stackrel{03}{(+i)}\stackrel{12}{(+)}\mid\stackrel{56}{[-]}\stackrel{78}{[-]}\mid\mid\stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | 1 | $\frac{1}{2}$ | 1 | 0 | $-\frac{1}{2}$ | $-\frac{1}{3}$ | $\frac{1}{6}$ |
| 4 | $\mathbf{d_R^{c1}}$ | $\stackrel{03}{[-i]}\stackrel{12}{[-]}\mid\stackrel{56}{[-]}\stackrel{78}{[-]}\mid\mid\stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | 1 | $-\frac{1}{2}$ | 1 | 0 | $-\frac{1}{2}$ | $-\frac{1}{3}$ | $\frac{1}{6}$ |
| 5 | $d_L^{c1}$ | $\stackrel{03}{[-i]}\stackrel{12}{(+)}\mid\stackrel{56}{[-]}\stackrel{78}{(+)}\mid\mid\stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | -1 | $\frac{1}{2}$ | -1 | $-\frac{1}{2}$ | 0 | $\frac{1}{6}$ | $\frac{1}{6}$ |
| 6 | $\mathbf{d_L^{c1}}$ | $\stackrel{03}{(+i)}\stackrel{12}{[-]}\mid\stackrel{56}{[-]}\stackrel{78}{(+)}\mid\mid\stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | -1 | $-\frac{1}{2}$ | -1 | $-\frac{1}{2}$ | 0 | $\frac{1}{6}$ | $\frac{1}{6}$ |
| 7 | $\mathbf{u_L^{c1}}$ | $\stackrel{03}{[-i]}\stackrel{12}{(+)}\mid\stackrel{56}{(+)}\stackrel{78}{[-]}\mid\mid\stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | -1 | $\frac{1}{2}$ | -1 | $\frac{1}{2}$ | 0 | $\frac{1}{6}$ | $\frac{1}{6}$ |
| 8 | $u_L^{c1}$ | $\stackrel{03}{(+i)}\stackrel{12}{[-]}\mid\stackrel{56}{(+)}\stackrel{78}{[-]}\mid\mid\stackrel{9\,10}{(+)}\stackrel{11\,12}{(-)}\stackrel{13\,14}{(-)}$ | -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.

**In the standard model** the families exist by 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 $u_R$ with the spin 1/2 of a particular colour and of a **colourless** $\nu_R$ :

| | | | | |
|---|---|---|---|---|
| $I_R$ | $u_R^{c1}$ | $\stackrel{03}{(+i)}\stackrel{12}{[+]}\vert\stackrel{56}{[+]}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{[-]}\;\;\stackrel{13\,14}{[-]}$ | $\nu_R$ | $\stackrel{03}{(+i)}\stackrel{12}{[+]}\vert\stackrel{56}{[+]}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{(+)}\;\;\stackrel{13\,14}{(+)}$ |
| $II_R$ | $u_R^{c1}$ | $\stackrel{03}{[+i]}\stackrel{12}{(+)}\vert\stackrel{56}{[+]}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{[-]}\;\;\stackrel{13\,14}{[-]}$ | $\nu_R$ | $\stackrel{03}{[+i]}\stackrel{12}{(+)}\vert\stackrel{56}{[+]}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{(+)}\;\;\stackrel{13\,14}{(+)}$ |
| $III_R$ | $u_R^{c1}$ | $\stackrel{03}{(+i)}\stackrel{12}{[+]}\vert\stackrel{56}{(+)}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{[-]}\;\;\stackrel{13\,14}{[-]}$ | $\nu_R$ | $\stackrel{03}{(+i)}\stackrel{12}{[+]}\vert\stackrel{56}{(+)}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{(+)}\;\;\stackrel{13\,14}{(+)}$ |
| $IV_R$ | $u_R^{c1}$ | $\stackrel{03}{[+i]}\stackrel{12}{(+)}\vert\stackrel{56}{(+)}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{[-]}\;\;\stackrel{13\,14}{[-]}$ | $\nu_R$ | $\stackrel{03}{[+i]}\stackrel{12}{(+)}\vert\stackrel{56}{(+)}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{(+)}\;\;\stackrel{13\,14}{(+)}$ |
| $V_R$ | $u_R^{c1}$ | $\stackrel{03}{(+i)}\stackrel{12}{(+)}\vert\stackrel{56}{(+)}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{[-]}\;\;\stackrel{13\,14}{[-]}$ | $\nu_R$ | $\stackrel{03}{(+i)}\stackrel{12}{(+)}\vert\stackrel{56}{(+)}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{(+)}\;\;\stackrel{13\,14}{(+)}$ |
| $VI_R$ | $u_R^{c1}$ | $\stackrel{03}{(+i)}\stackrel{12}{(+)}\vert\stackrel{56}{[+]}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{[-]}\;\;\stackrel{13\,14}{[-]}$ | $\nu_R$ | $\stackrel{03}{(+i)}\stackrel{12}{(+)}\vert\stackrel{56}{[+]}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{(+)}\;\;\stackrel{13\,14}{(+)}$ |
| $VII_R$ | $u_R^{c1}$ | $\stackrel{03}{[+i]}\stackrel{12}{[+]}\vert\stackrel{56}{(+)}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{[-]}\;\;\stackrel{13\,14}{[-]}$ | $\nu_R$ | $\stackrel{03}{[+i]}\stackrel{12}{[+]}\vert\stackrel{56}{(+)}\stackrel{78}{(+)}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{(+)}\;\;\stackrel{13\,14}{(+)}$ |
| $VIII_R$ | $u_R^{c1}$ | $\stackrel{03}{[+i]}\stackrel{12}{[+]}\vert\stackrel{56}{[+]}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{[-]}\;\;\stackrel{13\,14}{[-]}$ | $\nu_R$ | $\stackrel{03}{[+i]}\stackrel{12}{[+]}\vert\stackrel{56}{[+]}\stackrel{78}{[+]}\Vert\stackrel{9\,10}{(+)}\;\;\stackrel{11\,12}{(+)}\;\;\stackrel{13\,14}{(+)}$ |

Before the break of
$SO(1,3)\times$ $\mathbf{SU(2)_I}$ $\times$ $\mathbf{SU(2)_{II}}$ $\times\mathbf{U(1)_{II}}$ $\times$ $SU(3)$ into
$SO(1,3)\times$ $\mathbf{SU(2)_I}$ $\times$ $\mathbf{U(1)_I}$ $\times$ $SU(3)$
all the eight families are massless.

**The** symmetry **breaks are caused by the two kinds of** the **spin connection fields with the scalar index, the gauge fields of** (particular superposition of) $\tilde{\mathbf{S}}^{\mathbf{ab}}$ together with (particular superposition of) $\mathbf{S}^{\mathbf{ab}}$.

At the symmetry $SO(1,7) \times U(1)_{II} \times SU(3)$ there are $2^{(1+7)/2-1}(= 8)$ massless families of **fermions**

which stay massless also after the break
$SO(1,7) \times U(1)_{II} \times SU(3)$ into
$SO(1,3) \times SU(2)_{I} \times SU(2)_{II} \times U(1)_{II} \times SU(3)$.

- The **scalar fields** $\tilde{A}_s^{\tilde{A}i}$ **and** $A_s^{Bj}$**, in adjoint representations with respect to the family groups, are obviously doublets with respect to the weak charge group.** The mass term

$$\sum_{s=[7],[8]} \bar{\psi}_L \gamma^s (p_s - \sum_{\tilde{A},i} \tilde{g}^{\tilde{A}} \tilde{\tau}^{\tilde{A}i} \tilde{A}_s^{\tilde{A}i} - \sum_{B,j} g^B \tau^{Bj}, A_s^{Bj}) \psi_R$$

**namely does what the** *standard model* **Higgs does: Transforms the right handed quarks and leptons into the left handed partners, generating the mass matrices.**

- To the break of symmetries from $SU(2)_{I} \times SU(2)_{II} \times U(1)_{II}$ to $SU(2)_{I} \times U(1)_{I}$ only scalar fields which are triplets with respect to $\vec{\tilde{\tau}}^{2}$ and $\vec{\tilde{N}}_{R}$ are assumed to contribute.
  $\mathbf{\tilde{A}_{s}^{2i}}$, $\mathbf{\tilde{A}_{s}^{\tilde{N}_{R} i}}$.
- To the break of symmetries from $SU(2)_{I} \times U(1)_{I}$ to $U(1)$ both kinds of scalar fields are assumed to contribute, those which are triplets with respect to $\vec{\tilde{\tau}}^{1}$ and $\vec{\tilde{N}}_{L}$
  $\mathbf{\tilde{A}_{s}^{1i}}$, $\mathbf{\tilde{A}_{s}^{\tilde{N}_{L} i}}$
  and singlets
  $\mathbf{A_{s}^{Y'}}$, $\mathbf{A_{s}^{Q'}}$, $\mathbf{A_{s}^{Q}}$.

Before the BREAK II the vielbeins (together with the spin connection fields of $S^{ab}$) manifest the **massless gauge vector fields** in (1+3)

$$g^4\,\tau^{\mathbf{4}}\,\mathbf{A}^{\mathbf{4}}_{\mathbf{m}}\,,\quad g^2\,\tau^{\mathbf{2i}}\,\mathbf{A}^{\mathbf{2i}}_{\mathbf{m}}\,,$$
$$g^1\,\tau^{\mathbf{1i}}\,\mathbf{A}^{\mathbf{1i}}_{\mathbf{m}}\,,\quad g^3\,\tau^{\mathbf{3i}}\,\mathbf{A}^{\mathbf{3i}}_{\mathbf{m}}\,,$$

and the vielbeins together with the spin connection fields of $\tilde{S}^{ab}$ and $S^{st}$ manifest in $d=(1+3)$ the **scalar gauge fields** of $\tau^{Ai}$ and $\tilde{\tau}^{\tilde{A}i}$

$$g^1_1\,\tau^{\mathbf{1i}}\,\mathbf{A}^{\mathbf{1i}}_{\mathbf{s}}\,,\quad g^1_1\,\tau^{\mathbf{2i}}\,\mathbf{A}^{\mathbf{2i}}_{\mathbf{s}}\,,$$

$$\tilde{g}^2\,\tilde{\tau}^{\mathbf{2i}}\,\tilde{\mathbf{A}}^{\mathbf{2i}}_{\mathbf{s}},\quad \tilde{g}^1\,\tilde{\tau}^{\mathbf{1i}}\,\tilde{\mathbf{A}}^{\mathbf{1i}}_{\mathbf{s}},\,,$$
$$\tilde{g}^{\tilde{N}_R}\,\tilde{\mathbf{N}}^{\mathbf{i}}_{\mathbf{R}}\,\tilde{\mathbf{A}}^{\tilde{\mathbf{N}}_{\mathbf{R}}\mathbf{i}}_{\mathbf{s}}\,,\quad \tilde{g}^{\tilde{N}_L}\,\tilde{\mathbf{N}}^{\mathbf{i}}_{\mathbf{L}}\,\tilde{\mathbf{A}}^{\tilde{\mathbf{N}}_{\mathbf{L}}\mathbf{i}}_{\mathbf{s}}\,.$$

Correspondingly it follows (so far by the assumption) after the BREAK II and I the effective actions:

For the **gauge vector bosons** $A^{Ai}_{m}$

$$S_{vb} = \int d^{(1+3)}x \, \{-\frac{\varepsilon^{A}}{4} \mathbf{F}^{\mathbf{Aimn}} \mathbf{F}^{\mathbf{Ai}}{}_{\mathbf{mn}} + \frac{1}{2} (m_{A_V i})^2 \mathbf{A}^{\mathbf{Ai}}_{\mathbf{m}} \mathbf{A}^{\mathbf{Ai\, m}} + \text{contributions of scalar massive fields.}\}$$

And for the **gauge scalar fields** $\phi^{Ii}$

$$\mathcal{L}_{sb} = \frac{1}{2}(p_{0m}\, \mathbf{\Phi^{Ai}})^{\dagger}(p_0^m\, \mathbf{\Phi^{Ai}}) - V(\mathbf{\Phi^{Ai}}),$$

$$V(\mathbf{\Phi^{Ai}}) = \sum_{A,i}\{-\frac{1}{2}(m_{Ai})^2(\mathbf{\Phi^{Ai}})^2 + \frac{1}{4}\sum_{B,j}\lambda^{Ai\,Bj}(\mathbf{\Phi^{Ai}})^2(\mathbf{\Phi^{Bj}})^2\},$$

$$p_{0m} = p_m - g^{Ai}\,\tau^{Ai}\,A^{Ai}_m.$$

Here $\phi^{\mathbf{Ai}}$ stays for all the scalar fields

$(\phi^{\mathbf{Ai}} = [\tilde{\mathbf{A}}^{\tilde{\mathbf{N}}_{\mathbf{R}}\mathbf{i}}_{\pm}, \tilde{\mathbf{A}}^{\tilde{\mathbf{N}}_{\mathbf{L}}\mathbf{i}}_{\pm}, \tilde{\mathbf{A}}^{\mathbf{2i}}_{\pm}, \tilde{\mathbf{A}}^{\mathbf{1i}}_{\pm}, \mathbf{A}^{\mathbf{Y}'}_{\pm}, \mathbf{A}^{\mathbf{Q}'}_{\pm}, \mathbf{A}^{\mathbf{Q}}_{\pm}])$,

**so far assumed so that the theory is renormalizable.**

Let me present the notation after the electroweak break

$$\mathbf{A} = 1 \quad \mathbf{U(1)} \text{ elm charge} \quad i = \{1\} \qquad \cdots\cdots \text{usually } \mathbf{Q},$$
$$\mathbf{A} = 2 \text{ broken } \mathbf{SU(2)} \text{ charge} \quad i = \{+,-,3\} \quad \cdots \text{usually } \tau^{\pm}, \mathbf{Q}',$$
$$\mathbf{A} = 3 \quad \mathbf{SU(3)} \text{ colour charge} \quad i = \{1,\cdots,8\} \quad \cdots \text{usually } \lambda^{\mathbf{i}}/\mathbf{2},$$

**family quantum numbers** :

**two groups of four families** $\mathbf{\Sigma} = \mathbf{II}, \mathbf{I}$,

**in each group the family index i** $=\in (\mathbf{1}, \mathbf{2}, \mathbf{3}, \mathbf{4})$, The **spin-charge-family theory action** resembles after the first of the two breaks **the standard model action before the electroweak break**

**There are also many differences, like:**

- **There are several scalar fields**, with the family **charges** in the **adjoint representations**, **but they all are doublets with respect to the weak charge**.
- **There is the operator** $\frac{1}{2}(\gamma^7 \mp \gamma^8) = \stackrel{78}{(\pm)}$, which does the **"dressing" job of the Higgs in an ussual way**.
- **There are twice four families predicted at the low energy regime, four of them forming families out of which there are the measured ones. There is the dark matter family as well**.

Achievements of the **spin-charge-family-theory** so far concerning:

- **Families:** **Two decoupled groups of four families, three of the lowest four observed, the lowest of the upper four are expected to form the dark matter.**
- **Scalar fields:** **Two decoupled groups of scalar fields: contributing to the mass matrices of the twice four families.**
- **Massive vector boson fields:** **The** $SU(II)$ **and the** $SU(I)$ **(the weak) bosons.**

- **The fifth family is stable. Its elm neutral baryons (neutrinos also contribute) form the dark matter.**
- **Direct measurements and cosmological evolution limit my fifth family mass** to $10\,TeV < m_{q_5} c^2 < 10^3\,TeV$.
- 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);

## The lowest four families

The mass matrix of any family member, of any **quark** and any **lepton**, **obeys the same symmetry** – the symmetry required by the **spin-charge-family** **theory** on the tree level and (almost) proven to be kept in all loop corrections.
We simplify the present study by assuming:

- The mass matrices are Hermitian and real.
- The mixing matrices are real unitary $4 \times 4$ matrices.

The effective Lagrange density for spinors is **after the electroweak break** close to what the **standard model** assumes

$$
\begin{aligned}
\mathcal{L}_{\mathbf{f}} &= \bar{\psi}(\gamma^{\mathbf{m}}\, \mathbf{p_{0m}} - \mathbf{M})\psi\,, \\
p_{0m} &= \mathbf{p_m} - \{\mathbf{e\, Q\, A_m} + \mathbf{g^1} \cos\theta\, \mathbf{Q'\, Z^{Q'}_m} + \frac{\mathbf{g^1}}{\sqrt{\mathbf{2}}}(\tau^{\mathbf{1+}}\mathbf{W^{1+}_m} + \tau^{\mathbf{1-}}\mathbf{W^{1-}_m} \\
&+ g^2 \cos\theta_2\, Y'\, A^{Y'}_m\}\,, \\
\bar{\psi}\, \mathbf{M}\, \psi &= \bar{\psi}\, \gamma^{\mathbf{s}}\, \mathbf{p_{0s}}\psi \\
p_{0s} &= p_s - \{\tilde{g}^{\tilde{N}_L}\, \vec{\tilde{N}}_L \vec{\tilde{A}}^{\tilde{N}_L}_s + \tilde{g}^{\tilde{Q}'}\, \tilde{Q}'\, \tilde{A}^{\tilde{Q}'}_s + \frac{\tilde{g}^1}{\sqrt{2}}(\tilde{\tau}^{1+}\, \tilde{A}^{1+}_s + \tilde{\tau}^{1-}\, \tilde{A}^{1-}_s) \\
&+ e\, Q\, A_s + g^1 \cos\vartheta_1\, Q'\, Z^{Q'}_s + g^2 \cos\vartheta_2\, Y'\, A^{Y'}_s\}\,.
\end{aligned}
$$

**Mass matrices** of **quarks and leptons** have after the **electroweak break** **after taking into account loop corrections in all orders a very determined symmetry**

$$\mathcal{M}^{\alpha} = \begin{pmatrix} -a_1 - a & e & d & b_1 \\ e & -a_2 - a & b_2 & d \\ d & b_2 & a_2 - a & e \\ b_1 & d & e & a_1 - a \end{pmatrix} .$$

- 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 (7) to 3 (4).

- 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 $b_1 = b_2$, 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**.

**We follow the procedure**:

- The diagonalizing matrices $S^\alpha$ and $S^\beta$, each depending on 3 (for $b_1 = b_2$ otherwise 4) free parameters, are for real and symmetric mass matrices orthogonal. They follow from the procedure

$$M^\alpha = S^\alpha \,\mathbf{M}^\alpha_d \,T^{\alpha\,\dagger}\,, \quad T^\alpha = S^\alpha \,F^{\alpha\,S} F^{\alpha\,T\,\dagger}\,,$$
$$\mathbf{M}^\alpha_d = (m^\alpha_1, m^\alpha_2, m^\alpha_3, m^\alpha_4)\,,$$

in two ways

$$A.:\; S^\beta = V^\dagger_{\alpha\beta} S^\alpha\,, \qquad B.:\; S^\alpha = V_{\alpha\beta} S^\beta\,,$$
$$A.:\; V^\dagger_{\alpha\beta}\, S^\alpha \,\mathbf{M}^\beta_d \,S^{\alpha\dagger}\, V_{\alpha\beta} = M^\beta\,, \qquad B.:\; V_{\alpha\beta}\, S^\beta \,\mathbf{M}^\alpha_d \,S^{\beta\dagger}\, V^\dagger_{\alpha\beta} = M^\alpha\,.$$

We use both ways iteratively.

**We, coll. with Gregor Bregar treat quarks and leptons in an equivalent way**:

- **Quarks** very preliminary:

$$
\begin{aligned}
\mathbf{M}^{u}_{d}/MeV/c^2 &= (1.24703, 620.141, 172\,000., 650\,000.?))\,,\\
\mathbf{M}^{d}_{d}/MeV/c^2 &= (2.92494, 54.793, 2\,899., 700\,000.?)\,,
\end{aligned}
$$

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

$$
\mathcal{M}^{u} = \begin{pmatrix} 101\,630 & -46\,077 & -46\,154 & -94\,733 \\ -46\,077 & 321\,824 & 315\,685 & -46\,154 \\ -46\,154 & 315\,685 & 309\,681 & -46\,077 \\ -94\,733 & -46\,154 & -46\,077 & 98\,4880 \end{pmatrix}
\mathcal{M}^{d} = \begin{pmatrix} 36\,244 & 104\,497 & 104\,484 & -36\,223 \\ 104\,497 & 315\,176 & 315\,198 & -104\,48 \\ 104\,484 & 315\,198 & 315\,235 & -104\,49 \\ -36\,223 & -104\,481 & -104\,497 & 36\,304
$$

- **Leptons** very preliminary:

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

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

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

**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 coupling of family members to the scalars $A^{Q}_{s}$, $A^{Q'}_{s}$ **and** $A^{Y'}_{s}$.
- **The theory predicts**, so far very preliminary, **masses of the fourth family members within some intervals, due to the inaccuracy of the experimental data and suggests new measurements.**

## Scalar fields at the electroweak break

- 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 Lagrange density

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

- The mass eigenstates $\Phi^{\beta}$: $\quad \mathbf{\Phi^{Ai}} = \sum_{\beta} \mathcal{C}^{Ai}_{\beta}\, \mathbf{\Phi}^{\beta}$ , in the representation of which the potential is on the tree level diagonal.

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

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

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

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

$$(\psi^{\alpha\,\mathbf{k}}_{\mathbf{(L,R)}}\,,\,\boldsymbol{\Psi}^{\alpha\,\mathbf{k}}_{\mathbf{(L,R)}})\,,\quad \alpha \;=\; (u_{L,R}, d_{L,R}, \nu_{L,R}, e_{L,R})\,,$$

massless and massive $k^{th}$ component of the four vectors,
$\psi^{\alpha}_{\mathbf{(L,R)}} = V^{\alpha}_{(L,R)}\,\boldsymbol{\Psi}^{\alpha}_{\mathbf{(L,R)}}$, respectively.
We have

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

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

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

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

- The **scalar fields** change, when gaining a nonzero vacuum expectation values, properties of the vacuum. At the electroweak BREAK I in the vacuum the new terms appear. In our technique it is

$$\begin{aligned}\stackrel{78}{(-)} \ominus_I : &= \stackrel{78}{(-)}\; Ts_{\tilde{N}_L} |(\stackrel{56}{[+]}\stackrel{78}{(+)})\; Td_{(-)\tilde{\tau}^1} ||\; \stackrel{9\,10}{[+]}\,\stackrel{11\,12}{[+]}\;\stackrel{13\,14}{[+]}\,, \\ \stackrel{78}{(+)} \oplus_I : &= \stackrel{78}{(+)}\; Ts_{\tilde{N}_L} |(\stackrel{56}{[-]}\stackrel{78}{(-)})\; Td_{(+)\tilde{\tau}^1} ||\; \stackrel{9\,10}{[-]}\,\stackrel{11\,12}{[-]}\;\stackrel{13\,14}{[-]}\;.\end{aligned}$$

Here $Ts_{\tilde{N}_L}$ denotes a triplet with respect to the operators $\vec{\tilde{N}}_L$ and a singlet with respect to $\vec{N}_L$, while $(\stackrel{56}{[+]}\stackrel{78}{(+)})\; Td_{(\mp)\tilde{\tau}^1}$ are the two triplets with respect to $\vec{\tilde{\tau}}^1$ and doublets with respect to $\vec{\tau}^1$.

- Due to

$$\tau^{1+}\tau^{1-} \stackrel{78}{(+)} \oplus_I = \stackrel{78}{(+)} \oplus_I \,, \qquad \tau^{1-}\tau^{1+} \stackrel{78}{(-)} \ominus_I = \stackrel{78}{(-)} \ominus_I \,,$$

$$Q \stackrel{78}{(+)} \oplus_I = \quad 0 \quad = Q \stackrel{78}{(-)} \ominus_I \,,$$

$$Q' \stackrel{78}{(+)} \oplus_I = -\frac{1}{2\cos^2\theta_1}\,, \qquad Q' \stackrel{78}{(-)} \ominus_I = \frac{1}{2\cos^2\theta_1}\,,$$

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 $A^{Q}_m \; (= \mathbf{A_m})$ $= \sin\theta_2 A^{13}_m + \cos\theta_1 A^{Y}_m$ stays massless, if $\frac{g^1}{g^Y} \tan\theta_1 = 1$.

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

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

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

**What predictions does the spin-charge-family theory offer?**
**What are not yet solved problems?**

- There are **four** in the low energy regime, rather than **three**, coupled families of **quarks and leptons. Careful measurments of the mixing matrices will show this up.**
- **Quarks and leptons** manifest the **same symmetries of mass matrices**.
- The existence of **four families** explains the properties of **neutrinos**.
- The theory **predicts the intervals** for the masses of the fourth families, the more accurate are the measured properties of quarks and leptons, the narrower will be intervals.
- There are **several scalar fields** which will be observed at the LHC.

- The **dark matter** origin in the **fifth family**.
- There are more than so far observed vector gauge fields.
- There is no supersymmetric partners, at least not to the observed ones.

- From $Tr(\Phi^{vI\dagger}_{\mp}\,\Phi^{vI}_{\mp}) = \frac{v^2}{2}$ we extract from the masses of gauge bosons one information about the vacuum expectation values of the scalar fields, their coupling constants and their masses.
- Mass matrices of quarks and leptons offer additional information about the scalar fields of the *spin-charge-family* theory.
- Measuring charged and neutral currents, decay rates of hadrons, the scalar fields productions in the fermion scattering events and their decay properties provides us with additional in formations.

**The spin-charge-family theory offers the explanation for the assumptions of the standard model and several predictions.** Yet there are several **proofs** needed and **calculations to be made**.

- Although I see formally that $SO(4) \times U(1)_{II}$ must break into $SU(2)_I \times U(1)_I$ leading to the $SU(2)_{II}$ **massive vector gauge fields and the massless weak** $SU(2)_I$ **vector gauge field**, this must be **proven**.
- Although I see that the symmetry is conserved whatever diagram I look at to see whether or not the symmetry of mass matrices on the tree level is conserved in all orders in loop corrections, this is **not yet a proof**.

- Although we have seen that the **loop corrections** of all the contributions **manifest coherence**, this is **not yet a proof** that this coherence really leads to mass matrices, which manifest then the measured properties of quarks and leptons.
- Also the **properties of scalar fields** wait to be **formally derived**.
- Additional numerical evaluation of the mass matrices of the four families of quarks and leptons are needed.
- Carefull study of predictions of the properties of scalar fields, possibly measured at the LHC, are needed.
- And many additional problems to be solved and measurements to be predicted.