Giving mass to the mediating boson of HyperSymmetry by a field transformation applying Higgs mechanism beyond the Standard Model

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Abstract. According to gauge theories, interaction mediating spin-0 bosons must be massless. Theory of hypersymmetry (HySy) predicted massive intermediate bosons. Hypersymmetry field rotation, to be described in this paper, gives mass to the HySy mediating boson. Hysy rotation is performed in the velocity dependent $D$ field – a gauge field defined beyond the Standard Model (SM). Its angle is something similar to the weak mixing Weinberg angle that explains the surplus mass to the neutral weak vector boson; as well as it is similar to the fermion flavour mixing Cabibbo-Kobayashi-Maskawa angles that justify the mass change under weakly interacting quarks’ mixing, respectively. Mass of intermediate bosons must arise from dynamical spontaneous breaking of the group of HySy. The mass of the discussed (fictitious) Goldstone bosons can be removed by the unitarity gauge condition through the Higgs (BEH) mechanism. According to the simultaneous presence of a SM interaction’s symmetry group and the HySy group, their bosons should be transformed together. Spontaneous breakdown of HySy may allow to perform a transformation that does not influence the SM physical state of the investigated system. The paper describes a field transformation that eliminates the mass of the intermediate bosons by the application of the BEH mechanism, rotates the SM and HySy bosons’ masses together, while leaves the SM bosons intact. The result is an angle of precession inclination that characterises the HySy mechanism. In contrast to the known SM intermediate bosons, the HySy intermediate bosons have no fix mass. The mass of the HySy intermediate bosons (that appear as quanta of a velocity dependent gauge field $D$) depends on the relative velocity of the particles whose interaction they mediate, therefore the derived transformation angle is a function of that velocity.

1. Introduction

A general form of the Lorentz transformation’s matrix can be written as follows:

$$
\Lambda = 
\begin{bmatrix}
1 + (\kappa - 1) \frac{v_1^2}{v^2} & (\kappa - 1) \frac{v_1 v_2}{v^2} & (\kappa - 1) \frac{v_1 v_3}{v^2} & i \kappa \frac{v_1}{v} \frac{v}{c} \\
(\kappa - 1) \frac{v_2 v_1}{v^2} & 1 + (\kappa - 1) \frac{v_2^2}{v^2} & (\kappa - 1) \frac{v_2 v_3}{v^2} & i \kappa \frac{v_2}{v} \frac{v}{c} \\
(\kappa - 1) \frac{v_3 v_1}{v^2} & (\kappa - 1) \frac{v_3 v_2}{v^2} & 1 + (\kappa - 1) \frac{v_3^2}{v^2} & i \kappa \frac{v_3}{v} \frac{v}{c} \\
-i \kappa \frac{v_1}{v} \frac{v}{c} & -i \kappa \frac{v_2}{v} \frac{v}{c} & -i \kappa \frac{v_3}{v} \frac{v}{c} & \kappa 
\end{bmatrix}
$$

(1)
where \( \mathbf{v} \) is the velocity of the interacting particles relative to each other; \( v_i \) are the components of \( \mathbf{v} \); \( v_1^2 + v_2^2 + v_3^2 = v^2 \) and \( \kappa = 1/\sqrt{1 - (v/c)^2} \). We will compare this transformation matrix with the matrix of a general rotation. Lorentz transformation was discussed at the previous PIRT-2017 conference by R. Kerner [17] in several aspects. This paper extends the topic from another, special aspect, in the light of field rotation.

Theories are generally considered relativistic if they meet the condition to be invariant under Lorentz transformation. E.g., GTR and QED both meet this condition. However, derivations of all the Einstein equations and their solutions, as well as the Dirac equation (and related other discussions of QED) are performed with assuming preliminary approximations to “not too high velocities”. In fact, invariance under the Lorentz transformation is a necessary condition for a theory to be relativistic, but that condition is not (always) sufficient [7,10]. High energy experiments reach velocities very near to that of the light. In the interpretation of their results one can no more disregard effects of those high velocities. The absence of such precise high velocity considerations led to anomalies that formulated the demand to extend the Standard Model (SM) in the nineties. In contrast to other models proposed for the extension of the SM, hypersymmetry (HySy) \(^1\) offered an alternative by the application of a strongly relativistic model [2-6, 8-10]. This model includes (among others) a velocity dependent field \( \mathbf{D} \), which then proved to be a gauge field, and should be added to the SM fields. The assumption of \( \mathbf{D} \) is no more surprising than the introduction of the Higgs (BEH) field was in the mid-sixties. Accepting this assumption, prediction of intermediate bosons of the \( \mathbf{D} \) field could already have indicated less surprise.

According to gauge theories, interaction mediating bosons must be massless. Theory of HySy predicted spin-0, but massive intermediate bosons \( (\delta) \). Mass of intermediate bosons in spin-0 fields must arise from dynamical symmetry breaking [12-14,19]. Mass of \( \delta \) should arise from spontaneous breaking of the group of HySy. The group of HySy [7,10] has two free parameters. Its spontaneous breakdown may eliminate one of them: it allows to perform a transformation that does not influence the physical state of the investigated system. The other free parameter can be discussed in terms of the BEH mechanism [11,15]. The intermediate bosons of the SM belong to one of the three Goldstone boson types defined by Weinberg \(^2\), respectively. The simultaneously appearing HySy \( \delta \) boson belongs to the fictitious Goldstone bosons, whose mass is removed by the Higgs mechanism. The mass of the fictitious Goldstone bosons is eliminated by the unitarity gauge condition. (HySy meets that condition.) According to the simultaneous presence of a SM interaction’s symmetry group and the HySy, their bosons should be rotated simultaneously \( (G_{SM} \otimes G_D) \) \(^3\).

In the course of interactions between two fermions, the bosons of the \( \mathbf{D} \) field are expected

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\(^1\) The term hypersymmetry was interpreted in physics last time in the mid-nineties, although in a quite another meaning. Its appearance was related to the childhood of supersymmetry in the meaning of an extension, while in other publications as generalisation of that (first of all by R. Kerner et al., [16]). That meaning was abandoned in a few years and the proposed algebra was not used for long. We applied this term in a new meaning for an alternative, competing model of the supersymmetry.

\(^2\) Originally, there was assumed that the spontaneous symmetry breakdown responsible for the intermediate vector-boson masses was due only to the vacuum expectation values of a set of spin-0 fields. Later this approach became more sophisticated, and it assumed that the concerned symmetry breaking was of a purely dynamical nature. Weingberg [20] distinguished three types (fictitious, true and pseudo-) of Goldstone bosons, and, accordingly, three dynamical symmetry breaking mechanisms. We remark, that Weingberg’s classification allowed the existence of other, that time unknown gauge fields and intermediate bosons, what encouraged the elaboration of the here discussed HySy field rotation mechanism. In respect of the latter, cf., also the remarks Sec. IV. (3)(B) in [14].

\(^3\) Comparison of the rotation of the \( \delta \) in combination with a respective SM boson, and the mixing of the also massive neutral weak vector boson with \( \gamma \) needs further investigation. Note, the latter are rotated (by \( \theta_B \)) in field \( \mathbf{B} \), while the former are rotated in field \( \mathbf{D} \) (characterised indirectly by \( \theta_D \)), simultaneously, as we will see below.
to be exchanged (anti/)parallel with the exchange of a SM boson [3], since the D field appears always as an extension to a SM interaction field. The HySy theory must demand avoiding to affect the respective SM bosons. For this reason, when the HySy theory assumes that the dions obtain their mass by a transformation of the non-SM D field via a BEH-mechanism, it should guarantee that the respective SM boson be left intact. The latter condition demands the existence of a transformation matrix that includes a particular transformation angle (like the fermion flavour mixing $\theta_C$ Cabibbo angle [1]). This rotation – that can be characterised by an inner precession inclination angle $\theta_D$ – can guarantee that an expected 0 mass (Goldstone) boson would transform into the predicted mass HySy $\delta$ boson (or back), while the (anti/)parallel SM boson does not change its properties, similar to the mechanism of the electro-weak theory’s weak (Weinberg) mixing angle (cf., footnote 2) that does not affect the 0 mass of the photon. The existence of such a HySy field rotation mechanism is discussed below.

2. Mass of the $\delta$ boson
The interaction between two isotopes of any field-charge is mediated by a massive non-SM gauge boson [2,3]. According to the isotopic field-charge (IFC) theory, the mass of this boson (called dion, $\delta$) is the difference between the boosted (dressed) and the rest (bare or invariant) masses. The mass of this gauge boson is independent of the type (gravitational, electromagnetic, weak, strong) of the interaction:

$$m(\delta) = m_T - m_V = (\kappa - 1)m_V$$

where $\kappa = 1/\sqrt{1 - (v/c)^2}$, $m_T$ is the Lorentz boosted mass and $m_V$ denotes the mass that appears in the potential (scalar) part of the Hamiltonian, which is equal to the rest mass of the concerned field-charge.

Spontaneous symmetry breaking rotates the massless Goldston boson plane, producing as a result the massive $\delta$ boson and the respective SM mass bosons (here denoted by $\xi$). In the opposite direction, the same rotation transforms (in its gauge field) the massive HySy $\delta$ boson’s and the respective SM $\xi$ boson’s plane into a massless Goldston boson ($\delta'$), while leaving the SM $\xi$ boson intact [cf., Eqs. (11)+]. In the instance of the isotopic field-charge field (marked D) the quanta of this field ($\delta$) are associated with the conservation of the isotopic field-charge spin (IFCS or $\Delta$) introduced in physical terms in [3]. The (inverse) transformation that eliminates “unwanted” masses produced by the spontaneous symmetry breaking is expected to depend on the velocity of the interacting isotopic field-charges relative to each other, and assumes the presence of a velocity dependent (kinetic) field (D) instead of a simple configuration space.

This paper defines the transformation of the fields, whose quanta are the $\delta$ bosons. Note that the $\delta$ bosons never appear alone. They act simultaneously (parallel or antiparallel) with one of the Standard Model (SM) bosons. Therefore, one requires the transformation of the D field together with one of the SM fields (denoted here by $X_{SM}$). Note also that the derivation of the field equations of the interactions and their solutions included approximations (cf. Sec. 1 above): although all field theories required invariance under the Lorentz transformation, they included restrictions to “not too high” velocities. Those approximations cannot be applied at the high kinetic energies (and the respective high velocities) for the interpretation of data collected in experiments producing large accelerations.

3. Transformation in a coupled SM field and the D field
Conservation of the $\Delta$ quantity first requires invariance under hypersymmetry (HySy, cf., Darvas, 2018b). At the same time, the interaction between two particles requires invariance under the Lorentz transformation. As it was shown several times (among others, in [10]), invariance of physical theories under the Lorentz transformation is a necessary condition, but it is not always sufficient. In certain instances the transformation needs to be complemented with others.

The formula demonstrated in Eq. (1) holds when the origin of the reference frame is fixed to one of the interacting field-charges and is restricted to the situation when the velocity vector
arrows from one of the field-charges towards the other (at least, while the velocity is not too high, as we will demonstrate it following Eq. (18)). At this stage, we do not require any prescription for the direction of the co-ordinate axes. In short, let’s interpret the velocities that define the Lorentz transformation in the configuration space, transformed into the above mentioned velocity dependent field.

Let’s introduce the following notations:

\[
\frac{v}{c} = \sin \vartheta; \quad \kappa = \frac{1}{\cos \vartheta}; \quad (\kappa - 1) = \frac{1 - \cos \vartheta}{\cos \vartheta}; \quad \text{and} \quad u_i = \frac{v_i}{v} \quad (i = 1, 2, 3).
\]

The \( u_i \) are unitary length \((u_1^2 + u_2^2 + u_3^2 = 1)\) vector components, arrowing in the direction of the axes of the co-ordinate system. So, the Lorentz transformation can be rewritten in the following forms:

\[
\Lambda = \kappa \begin{pmatrix}
\cos \vartheta + (1 - \cos \vartheta)u_1^2 & (1 - \cos \vartheta)u_1u_2 & (1 - \cos \vartheta)u_1u_3 & iu_1 \sin \vartheta \\
(1 - \cos \vartheta)u_2u_1 & \cos \vartheta + (1 - \cos \vartheta)u_2^2 & (1 - \cos \vartheta)u_2u_3 & iu_2 \sin \vartheta \\
(1 - \cos \vartheta)u_3u_1 & (1 - \cos \vartheta)u_3u_2 & \cos \vartheta + (1 - \cos \vartheta)u_3^2 & iu_3 \sin \vartheta \\
-iu_1 \sin \vartheta & -iu_2 \sin \vartheta & -iu_3 \sin \vartheta & 1
\end{pmatrix}
\]

(3)

Let’s take a general \( \vartheta \) angle rotation matrix in a 3D space stretched by unit axis vectors \( u_i \):

\[
R = \begin{pmatrix}
\cos \vartheta + (1 - \cos \vartheta)u_1^2 & (1 - \cos \vartheta)u_1u_2 - u_3 \sin \vartheta & (1 - \cos \vartheta)u_1u_3 + u_2 \sin \vartheta & 0 \\
(1 - \cos \vartheta)u_2u_1 + u_3 \sin \vartheta & \cos \vartheta + (1 - \cos \vartheta)u_2^2 & (1 - \cos \vartheta)u_2u_3 - u_1 \sin \vartheta & 0 \\
(1 - \cos \vartheta)u_3u_1 - u_2 \sin \vartheta & (1 - \cos \vartheta)u_3u_2 + u_1 \sin \vartheta & \cos \vartheta + (1 - \cos \vartheta)u_3^2 & 0 \\
0 & 0 & 0 & 1
\end{pmatrix}
\]

(4)

However, one can interpret the \( R \) transformation of the velocity vector components projected in the velocity dependent field as well. Note, while \( \vartheta \) is a symbolic notation in the Lorentz transformation, it denotes a real rotation angle in \( R \).  

Let’s compare this transformation matrix \( R \) with the formula for the Lorentz transformation. In this order, let’s decompose \( R \) to the following two matrices:

\[\text{The method to be applied shows certain partial similarity to the derivation of Wigner-Thomas rotation, which applies that a boost (here by } v \text{) and a rotation are equivalent with the combination of two coupled boosts. In the inverse, they correspond to transformations whose combination produces a (Thomas-) precession. As we will show, one of the coupled boost vectors will precess around the other’s arrow, or vice versa. However, while the Wigner-Thomas rotation is interpreted in the configuration space, we apply it for transformations projected in abstract gauge fields.} \]
Now, we see that transformation matrices: $E$ can be represented by the so-called tau ($\tau$) transformation and the HySy of the IFC transformation. One can check in [7,10] that the transformation $R$ functions of the relative velocity of the interacting agents. In the instance of low velocity, the transformation (8) is expressed in terms of a real rotation minus a precession, and both are of the axis defined by the vector $v$. The unitary velocity components in the precession matrix can be interpreted as spatial projections of the velocity dependent IFCS vectors from a velocity dependent field. The matrices in the second terms in (7) and (8) are rotation-like too. They suggest precession of the axis defined by the vector $v$ around the $u_i$ velocity components. Thus, the Lorentz transformation (8) is expressed in terms of a real rotation minus a precession, and both are functions of the relative velocity of the interacting agents. In the instance of low velocity, the transformation $R$ turns into the traditionally known Lorentz transformation. In the presence of a velocity dependent field, the transformation $\Lambda$ must be extended according to the rule expressed in (8). The unitary velocity components in the precession matrix can be interpreted also like spatial projections of the velocity dependent IFCS vectors from a velocity dependent field ($D$) to the configuration space.

We remind that the IFC theory requires invariance under the combination of the Lorentz transformation and the HySy of the IFC transformation. One can check in [7,10] that the HySy can be represented by the so-called tau ($\tau$) algebra that (in $\tau_3$ representation) led to two transformation matrices: $E$ and $\tau_3$. Remember:

$$E = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} I_L & 0 \\ 0 & 1 \end{bmatrix} \quad \text{and} \quad \tau_3 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix} = \begin{bmatrix} I_L & 0 \\ 0 & -1 \end{bmatrix}$$
where $I_L$ is a $[3x3]$ minor matrix, introduced in [7]. ($E$ is the unit element of the HySy group.) According to the above derivations, in the presence of a velocity dependent field, one should apply the extended $R$ transformation matrix [cf., (4), (7)] for the matrix of the Lorentz transformation. Let’s introduce a $[3x3]$ minor matrix in $R$, to get $R$ in the form

$$R = \begin{bmatrix} R^{(M3)} & 0 \\ 0 & 1 \end{bmatrix}$$

where [cf., (6)]:

$$R^{(M3)} = \begin{bmatrix} \cos \vartheta + (1 - \cos \vartheta)u_1^2 & (1 - \cos \vartheta)u_1u_2 - u_3 \sin \vartheta & (1 - \cos \vartheta)u_1u_3 + u_2 \sin \vartheta \\ (1 - \cos \vartheta)u_2u_1 + u_2 \sin \vartheta & \cos \vartheta + (1 - \cos \vartheta)u_2^2 & (1 - \cos \vartheta)u_2u_3 - u_1 \sin \vartheta \\ (1 - \cos \vartheta)u_3u_1 - u_2 \sin \vartheta & (1 - \cos \vartheta)u_3u_2 + u_1 \sin \vartheta & \cos \vartheta + (1 - \cos \vartheta)u_3^2 \end{bmatrix}$$

(9)

Transformations $T^{(D)}$ in a velocity dependent (D) field under the combination of the extended Lorentz transformation and the transformation matrices of the HySy take the following forms:

$$T^{(D)}_+ = E \cdot R = \begin{bmatrix} I_L \\ 0 \end{bmatrix} \begin{bmatrix} R^{(M3)} \\ 0 \end{bmatrix} = \begin{bmatrix} I_L \cdot R^{(M3)} \\ 0 \end{bmatrix}$$

and

$$T^{(D)}_- = \tau_3 \cdot R = \begin{bmatrix} I_L \\ 0 \end{bmatrix} \begin{bmatrix} R^{(M3)} \\ 0 \end{bmatrix} = \begin{bmatrix} I_L \cdot R^{(M3)} \\ 0 \end{bmatrix}$$

(10)

Now, we can formulate the sought transformation of the field (convolution of a traditional SM field $X_{SM}$ and the associated non-SM D field) that is expected to eliminate “unwanted” masses of the quanta ($\delta$) of the D field. Note, that in contrast to the fix mass of all SM bosons, the mass of $\delta$ depends on the relative velocity between the two interacting isotopes of the concerned field-charges. Therefore, we are expecting a transformation formula depending on velocity.

There are two bosons mediating interaction in these fields. There appears one of the SM (plus gravity) bosons, depending on the kind of the interaction that we denote by a general character $\xi$. ($\xi$ may denote either the graviton or the photon, one of the weak vector bosons, or one of the strong gluons.) There appear also the bosons of the D field, $\delta$.

Thus, the transformation of their fields may take the following two forms in each of the respective interactions:

$$\begin{bmatrix} D' \\ X'_{SM} \end{bmatrix} = T^{(D)}_+ \begin{bmatrix} D \\ X_{SM} \end{bmatrix} = \begin{bmatrix} I_L \cdot R^{(M3)} \\ 0 \end{bmatrix} \begin{bmatrix} D \\ X_{SM} \end{bmatrix}$$

(11)

and

$$\begin{bmatrix} D' \\ X'_{SM} \end{bmatrix} = T^{(D)}_- \begin{bmatrix} D \\ X_{SM} \end{bmatrix} = \begin{bmatrix} I_L \cdot R^{(M3)} \\ 0 \end{bmatrix} \begin{bmatrix} D \\ X_{SM} \end{bmatrix}$$

(12)

We can read that these transformations do not affect any of the SM bosons ($X_{SM}$ coincide with $X'_{SM}$, $\xi'$ are equal to $\xi$). The latter are not subjects to any transformation in the D field.

This is reassuring that the isotopic field-charge model does not destroy the SM, it only extends it at very high velocities of the interacting agents. Eqs. (11) and (12) rotate the non-SM D field

5. The Weinberg angle mixes two bosons appearing both in a SM interaction field. The CKM angles mix quark flavours in another, but also SM field. The HySy rotation angle does not mix the $\delta$ bosons of the D field with any of the SM bosons (denoted by $\xi$), what latter appear simultaneously in one of the SM interaction fields ($X_{SM}$). Therefore HySy does not mix them, instead it is expected to rotate the $\delta$ boson’s field while to leave the respective $\xi$ SM boson’s field unchanged. The rotation formula to be derived in the following part of the paper corresponds to this expectation.
of the massive intermediate bosons and one of the $X_{SM}$ SM fields to produce Goldstone bosons consisting of massless IFC bosons in $D'$, and the respective SM bosons in $X'_{SM}$ (cf., footnote 2).

The transformation of the $D$ section of the combined field is the same both in (11) and (12)

$$D' = I_L \cdot R^{(M3)} \cdot D.$$  

Since $I_L \cdot R^{(M3)}$ is a [3x3] matrix, this can be written also as

$$
\begin{bmatrix}
D'_1 \\
D'_2 \\
D'_3
\end{bmatrix} = I_L \cdot R^{(M3)}
\begin{bmatrix}
D_1 \\
D_2 \\
D_3
\end{bmatrix}
$$

Let’s write the transformation of this section of the field in detail. First, investigate the $I_L \cdot R^{(M3)}$ product:

$$I_L \cdot R^{(M3)} =$$

$$
\begin{bmatrix}
1 & 0 & 0 \\
1 & 0 & 0 \\
1 & 0 & 0
\end{bmatrix}
\begin{bmatrix}
\cos \vartheta + (1 - \cos \vartheta)u_1^2 & (1 - \cos \vartheta)u_1u_2 - u_3 \sin \vartheta & (1 - \cos \vartheta)u_1u_3 - u_2 \sin \vartheta \\
(1 - \cos \vartheta)u_2u_1 + u_3 \sin \vartheta & \cos \vartheta + (1 - \cos \vartheta)u_2^2 & (1 - \cos \vartheta)u_2u_3 - u_1 \sin \vartheta \\
(1 - \cos \vartheta)u_3u_1 - u_2 \sin \vartheta & (1 - \cos \vartheta)u_3u_2 + u_1 \sin \vartheta & \cos \vartheta + (1 - \cos \vartheta)u_3^2
\end{bmatrix}
$$

$$= \begin{bmatrix}
\cos \vartheta + (1 - \cos \vartheta)u_1^2 & (1 - \cos \vartheta)u_1u_2 - u_3 \sin \vartheta & (1 - \cos \vartheta)u_1u_3 + u_2 \sin \vartheta \\
(1 - \cos \vartheta)u_2u_1 + u_3 \sin \vartheta & \cos \vartheta + (1 - \cos \vartheta)u_2^2 & (1 - \cos \vartheta)u_2u_3 + u_1 \sin \vartheta \\
(1 - \cos \vartheta)u_3u_1 - u_2 \sin \vartheta & (1 - \cos \vartheta)u_3u_2 + u_1 \sin \vartheta & \cos \vartheta + (1 - \cos \vartheta)u_3^2
\end{bmatrix}$$

(13)

One sees that the three rows of the resulted matrix coincide ($D'_1 = D'_2 = D'_3 = D'$), as expected.

Thus:

$$D' = \begin{bmatrix}
\cos \vartheta + (1 - \cos \vartheta)u_1^2 + (1 - \cos \vartheta)u_1u_2 - u_3 \sin \vartheta + (1 - \cos \vartheta)u_1u_3 + u_2 \sin \vartheta \end{bmatrix} D \quad \text{or} \quad D' = \begin{bmatrix}
\cos \vartheta + (1 - \cos \vartheta)u_1u_2 + (1 - \cos \vartheta)u_1u_3 + u_2 \sin \vartheta + (u_2 - u_3)
\end{bmatrix} D$$

(14)

In order to discuss this value, let’s introduce polar co-ordinates for the $u_i$ unitary projected velocity components of the IFCS. We remind that we still have prescribed no constraint for the axes in the configuration space, where the $u_i$ velocity component projections arrow. We were free to orient those axes arbitrary. Now, let us define the axes so that the inclination angle of $v$ in respect of $u_3$ be $\Theta_D$, and, let $\psi$ denote rotation angle around $u_3$ in the $u_1 - u_2$ plane, what is perpendicular to $u_3$.

![Figure 1. Representation of the inclination (precession) angle $\Theta_D$ of the vector $v$ in respect of the axis $u_3$.](image)

Since $u_i$ are components of a unitary vector,

$$u_1 = \sin \Theta_D \cos \psi,$$

$$u_2 = \sin \Theta_D \sin \psi,$$

$$u_3 = \cos \Theta_D.$$  

As it can be read from Figure 1, $\Theta_D$ is the angle of a precession of $v$ in a fixed reference frame. $\Theta_D$ characterises the velocity dependence of the transformation of the field $D$. Now:

$$D' = \begin{bmatrix} \cos \vartheta + (1 - \cos \vartheta)(\sin^2 \Theta_D \cos^2 \psi + \sin^2 \Theta_D \cos \psi \sin \psi + \sin \Theta_D \cos \psi \cos \Theta_D) + \\ + \sin \vartheta (\sin \Theta_D \sin \psi - \cos \Theta_D) \end{bmatrix} D$$

One can fix the reference frame, considering that the precession of $v$ around the axis $u_3$ cannot depend on the phase angle (of a rotation by $\psi$) in the $u_1 - u_2$ plane. One can interpret $\psi$ as a phase parameter of the spontaneous symmetry breaking in the $D$ field. So, we are free to fix $\psi$ (by an arbitrary choice) as $\psi = \pi/2$. In this case $\cos \psi = 0$, $\sin \psi = 1$. With the above assumptions on the orientation of the reference frame of the velocity components:

$$D' = [\cos \vartheta + \sin \vartheta (\sin \Theta_D - \cos \Theta_D)] D$$

Considering the identity $\cos \Theta_D - \sin \Theta_D \equiv \sqrt{2} \cos \left( \Theta_D + \frac{\pi}{4} \right)$:

$$D' = \left[ \cos \vartheta - \sin \vartheta \sqrt{2} \cos \left( \Theta_D + \frac{\pi}{4} \right) \right] D$$

The transformation of $D$ is a function of the symbolic angles $\vartheta$ and $\Theta_D$. Both can be expressed with the relative velocity of the interacting field-charges. $\vartheta$ is defined by the Lorentz transformation, $\Theta_D$ by the transformation in the HySy field $D$. In simpler form:

$$D' = \sqrt{1 - \left( \frac{v}{c} \right)^2} - \sqrt{2} \frac{v}{c} \cos \left( \Theta_D + \frac{\pi}{4} \right) D$$

Inserting this in (11) [and in (12), respectively]:

$$\begin{bmatrix} D' \\ X'_{SM} \end{bmatrix} = \begin{bmatrix} \sqrt{1 - \left( \frac{v}{c} \right)^2} - \sqrt{2} \frac{v}{c} \cos \left( \Theta_D + \frac{\pi}{4} \right) & 0 \\ 0 & \pm 1 \end{bmatrix} \begin{bmatrix} D \\ X_{SM} \end{bmatrix}$$

According to (16), $\vartheta$ and $\Theta_D$ define together the transformation that eliminates unwanted masses produced by the spontaneous symmetry breakdown in the $D$ field, and justify the mass of the $\delta$ boson. This formula complies with the transformation of the electro-weak field by the Weinberg mixing angle. However, there are differences as well.

Once, (16) transforms two coupled fields together, one of which is not a SM field.

Secondly, while there are fixed mass bosons in the weak interaction, the mass of the HySy field’s boson depends on the relative velocity of the interacting field-charges. This is in accordance with the velocity dependence of the $D$ field, and this is reflected in the field’s transformation formula for the elimination of unwanted masses produced by the spontaneous symmetry breakdown.

Thirdly, we must remark that the assumption of isotopic field-charges originates in the asymmetry expressed in the Möller scattering matrix [3, 18]. That assumption involved the mass difference between the IFC siblings. A later formula obtained in the SM for the Möller scattering asymmetry for electrons includes the (weak mixing) Weinberg angle. The value of the Weinberg angle varies depending on the momentum transfer. The momenta affect the fixed masses of the concerned weak bosons. In contrast to that, although the transformation formula in the $D$ field affects also the mass of the quanta of the field, but it leads to a boson mass depending on the relative velocity of the particles between which it mediates. Moreover, the appearance of the velocity dependent angle in the formula for the transformation of the $D$ field is simpler than in the Möller scattering asymmetry. At the same time the angle in (16) runs over a wider scale than the Weinberg angle does.
In short, Eq. (16) is the formula by which spontaneous symmetry breaking transforms the respective quanta of the original SM field and of the D field.

We can expect the (11)-(12) rotation matrices in the D-X_{SM} field couple (as expressed in (16)) in the rotation matrix form

$$\begin{bmatrix} \sqrt{1 - \left(\frac{v}{c}\right)^2} - \sqrt{\frac{2}{c}} \cos \left(\Theta_D + \frac{\pi}{4}\right) & 0 \\ 0 & \pm 1 \end{bmatrix} = \begin{bmatrix} \cos \varphi(v, \Theta_D) & \sin \varphi(v, \Theta_D) \\ -\sin \varphi(v, \Theta_D) & \cos \varphi(v, \Theta_D) \end{bmatrix}$$

where \(\varphi(v, \Theta_D)\) denotes an angle that mixes the D and the respective X_{SM} fields. However, the inclination angle \(\Theta_D\) appears to be more characteristic for the rotation of the D field.

### 4. Discussion of the resulted field transformation

According to (17) \(\sin \varphi(v, \Theta_D) = 0\), meaning stable values for \(\varphi(v, \Theta_D)\), while \(v\) and \(\Theta_D\) may vary. Since \(\sin \varphi(v, \Theta_D) = 0\)

(a) \(\varphi = 0\) and \(\cos \varphi = 1\); or

(b) \(\varphi = \pi\) and \(\cos \varphi = -1\).

In case (a): \(\varphi = 0\), there occurs no transformation in the field D. In this case [cf., (11)] \(T_{\Theta}^{(D)}\) turns into the identity transformation: \(T_{\Theta}^{(D)} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}\).

The case (b): \(\varphi = \pi\) corresponds to a real transformation, by the matrix \(\tau_3\). According to Eqs. (12) and (17)

$$\cos \left(\Theta_D + \frac{\pi}{4}\right) = \sqrt{1 - \left(\frac{v}{c}\right)^2} + \frac{1}{\sqrt{2}v/c}.$$  (18)

The formula in Eq. (18) provides limits for the domain of interpretation of \(v/c\), and respectively, for \(\Theta_D\). One must avoid the right side to grow higher than allowed by a cosine function. Discussion of these limits allows us to define the limits where HySy is broken.

The negative value of the square root in the numerator in (18) provides either – excluded – precession angles less than \(-\pi/2\) or positive precession angles. Since \(\varphi = \pi\) rotation of the D - X_{SM} fields causes a sign inversion in the \(v - \Theta_D\) plane [flips the (velocity) vectors in these fields over in the opposite direction], only negative \(\Theta_D\) precession angles can be interpreted. Therefore, we can limit the domain of \(\Theta_D\) further: \(-\pi/2 \leq \Theta_D \leq 0\). Thus, all precession angles provided by negative square roots in the numerator should be excluded.

Considering positive values of the numerator, expression (18) is meaningless when \(\frac{v}{c} < \sqrt{8/9} \approx 0.943\). This is the minimal velocity where HySy prevails. Under this limit velocity \(v < \sqrt{8/9}c\) the HySy is broken. At \(v = \sqrt{8/9}c\), \(\Theta_D = -\pi/4\). Starting from this spontaneous symmetry breaking angle value, while the velocity (kinetic energy) accelerates further, the value of the \(\Theta_D\) precession angle spontaneously bifurcates. It either increases, reaching \(\Theta_D = 0\) at \(v = c\); or decreases, reaching \(\Theta_D = -\pi/2\) at \(v = c\). The observable domain of \(\Theta_D\) varies between \(-\pi/2 < \Theta_D < 0\) (cf., Figures 2 and 3).

In other words, according to Eq. (17) the HySy rotation angle is \(\varphi = \varphi(v, \Theta_D)\), as learned in the SM. The identity transformation [case (a)] indicates no transformation of the field D in SM terms. This case says, field D is present at the range \(0 < v \leq c\), but its presence does not guarantee that HySy phenomena, like a HySy boson (dion), can be observed.

There may show up domains where HySy is broken. The real transformation [case (b)] indicates a \(\pi\) angle rotation of the plane of the fields D-X_{SM}, i.e., vectors flip over in opposite direction. This justifies negative precession angles around velocity vectors in the D field.
Figure 2. According to the discussion of the Eq. (18), the vectors are flipped over in opposite direction under a real transformation and this is resulted in negative precession angle $-\pi/2 < \theta_D < 0$. $v$ rotates around the axis $v_3$ along a cone.

The fix value of the $\varphi$ rotation angle in the SM hides the essence of the rotation of a field beyond the SM, like $D$. Since $D$ exists beyond the SM, new rules may prevail in it. The essential characteristic angle is hidden in the velocity dependence of $\varphi(v, \Theta_D)$. The spontaneous symmetry breaking in HySy is characterised by that $\Theta_D$ precession angle. The curve of $v/c$ in the function of the available values for $\Theta_D$ shows a sombrero-like graph (cf. Figure 3). This complies with similar shapes for SM spontaneous symmetry breakings. According to the discussion of the set of values for the Eq. (18), $\Theta_D$ is interpreted between $-\pi/2$ and 0 (marked in bold line), and the respective values of velocity between $\sqrt{8/9} \leq v/c < 1$, at least, considering the positive value of the square root in the numerator in (18). The $\sqrt{8/9} \leq v/c$ limit for $v/c$ means the limit under which velocity the HySy is broken.

Figure 3. The dependence of $\Theta_D$ on $v/c$. $\Theta_D$ can be interpreted in the range $-\pi/2 < \theta_D < 0$ (bold line). Below the spontaneous breaking point at $\varphi(v, \Theta_D) = \left(\sqrt{\frac{8}{9}}, -\pi/4\right)$, no HySy can be observed. At velocity $\sqrt{\frac{8}{9}}c$, $\Theta_D$ spontaneously bifurcates when the velocity (kinetic energy) accelerates further. It either increases, reaching $\Theta_D = 0$ at $v = c$; or decreases, reaching $\Theta_D = -\pi/2$ at $v = c$. Under the breaking velocity no HySy can be observed.

In point of fact, HySy is effective between velocities $\sqrt{8/9} \leq v/c < 1$ with a domain of the precession angle $-\pi/2 < \Theta_D < 0$. (We exclude the boundaries of the domain, because no massive particle can appear at velocity $c$).

The trigonometric formula demonstrates spectacularly the precession of the $D$ field depending on the velocity [cf., Eq. (15)]. The angle of the precession expresses the relation of $v$ to $v_3$. It can be formulated in word-paint that the $v$ vector of the velocity of one of the interacting
isotopic field-charges in respect to the other precesses around the straight, marked out by \( v_3 \), arrowing between the two interacting field-charges (cf., Figure 1). In another view, the \( v \) velocity vector precesses around the projection of the third component of the unitary length IFCS from the \( D \) field to the configuration space. The angle of this precession varies with the change of the respective velocity \( v \). It can be formulated also that the vector of velocity is always tangential to the line connecting the interacting agents, but that line is curved in the gauge field \( D \) induced by their own velocity. The latter can be expressed by the inverse of the matrix in Eq. (16).

5. The mass of the mediating boson \( \delta \) in light of the transformation of the \( D \) field

The obtained set of the \( \Theta_D \) angle values determines the rotation of the \( D \) field that eliminates unwanted masses produced by the spontaneous symmetry breaking, what is responsible for the mass of the field’s \( \delta \) boson. There is easy to see that the velocity dependence of \( \Theta_D \) (18) is in close relation with the velocity dependent coefficient \( (\kappa) \) of the mass of the \( \delta \) boson.

As we saw, \( m(\delta) = m_T - m_V = (\kappa - 1)m_V \) where the value of \( m_V \) is equal to the rest mass. At the minimum energy of the appearance of the HySy \( \frac{m(\delta)}{m_V} = \kappa - 1 = \frac{1+\sqrt{1-(v/c)^2}}{\sqrt{1-(v/c)^2}} = 2 \). This energy value corresponds to the middle apex in the sombrero curve at \(-\pi/4\) (cf., Figure 3). What is the same, the \( m_T \) mass of the Lorentz boosted isotopic field-charge at the lower limit of HySy should be \( \frac{m_T}{m_V} = \kappa = 3 \). In other words, HySy is broken until the mass of the respective mediating boson does not reach the double of the mass in rest of the emitting particle, or, what is the same, the Lorentz boosted mass does not reach the triple of the mass in rest of the emitting particle. This expresses the lower limit of the observability of a boson \( \delta \) that appears first at velocity \( v = \sqrt{8/9}c \).

When \( v \) approaches to zero, the mass of \( \delta \) approaches to 0. However, \( \delta \) cannot be observed near to such low velocity, due to the spontaneous symmetry breaking of the IFCS field. This was expected, since low velocity means to return to the full domination of the SM. There is not allowed to appear a measurable strength value for the \( D \) field, and transformation of a boson in the \( D \) field within the limits of the SM. That means, the calculation confirms that one can observe no \( \delta \) bosons when a \( D \) field vanishes. \(^{6}\) Moreover, we showed in the previous paragraphs that there exists a stronger exact limit for \( v \) in order to eliminate the observation of a massive \( \delta \). This fact confirms that the IFC theory extends the SM so that the SM is left intact and holds at the range of its validity, i.e., at not extremely high energies.

We were seeking to find a transformation of the \( D \) field that may eliminate the mass of the \( \delta \) boson. \(^{6}\) This is equivalent with a rotation of the field demanded by the spontaneous symmetry breaking and a precession of the velocity \( v \) around its third projection in the \( D \) field (that produced the mass of the field’s bosons).

6. Conclusions

We have derived the transformation formula that eliminates “unwanted” masses produced by the spontaneous symmetry breaking of the \( D \) field and justifies the mass of the quantum of the \( D \) field. The derivation justifies that \( D \) must be a gauge field, i.e., velocity dependence cannot be considered a simple rotation in the configuration space defined in the matter field. Earlier publications by the author (e.g., [10]) showed that this \( D \) field is subject of an invariance under rotations of an SU(2) isomorphic group that characterises hypersymmetry. We demonstrated that the (isotopic field-charge spin) transformation in the \( D \) field must be coupled with a SM interaction field, and also that the transformation leaves the mediating bosons of the respective SM field intact [3]. The derived formula confirms that the \( D \) field causes no observable effects.

\(^{6}\) Let’s avoid confusing the identity transformation of the boson \( \delta \) at zero velocity with the field rotation transforming its mass into 0.
at low velocities, but it should be taken into account at relativistic high velocities: it extends
the SM so that it does not influence the latter in the range of its validity.

We derived a limit velocity \( \frac{v}{c} = 2\sqrt{2}/3 \), below which HySy is definitely broken. The Lorentz
invariance is extended over this limit velocity (energy) by an invariance under HySy. A non-SM
transformation of the \( D \) field interpreted by the BEH mechanism and discussed in section 4
justifies the mass of the quanta of the field. This transformation is characterized by a mixing
angle \( \pi \) and a precession inclination angle \( \Theta_D(v) \). This inclination angle of precession of vectors,
interpreted in the velocity dependent field, rotates the field that is responsible for eliminating
the mass of the field’s intermediate boson. The latter angle is interpreted by HySy, beyond the
SM. The mass of the quanta of the \( D \) field \( (\delta) \) depends on \( \Theta_D(v) \).

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References
[1] Cabibbo N 1963 Unitary symmetry and leptonic decays Phys. Rev. Lett. 10 531
[2] Darvas G 2009 Conserved Noether currents, Utiyama’s theory of invariant variation, and velocity dependence
in local gauge invariance Concepts of Physics VI 1 pp 3-16 (Preprint 0811.3189v1)
[3] Darvas G 2011 The Isotopic Field Charge Spin Assumption International Journal of Theoretical Physics 50
10 pp 2961-91 (Preprint 1809.03843)
[4] Darvas G 2013 A symmetric adventure beyond the Standard Model - Isotopic field-charge spin conservation
in the electromagnetic interaction Symmetry: Culture and Science 24 1-4 pp 17-40
[5] Darvas G 2013 The isotopic field-charge assumption applied to the electromagnetic interaction Int. J. Theor.
Phys. 52 11 pp 3853-69
[6] Darvas G 2014 Electromagnetic Interaction in the Presence of Isotopic Field-Charges and a Kinetic Field
Int. J. Theor. Phys. 53 1 pp 39-51 (Preprint 1809.03880)
[7] Darvas G 2015 Quaternion-vector dual space algebras applied to the Dirac equation and its extensions
Bulletin of the Transilvania University of Brasov, Series III: Mathematics, Informatics, Physics 8(57) 1
pp 27-42
[8] Darvas G 2017 Hypersymmetry of gravitational and inertial masses in relativistic field theories paper
submitted to XX International Conference Physical Interpretrations of Relativity Theory Moscow 3-6 July
2017 (Preprint 1809.0694)
[9] Darvas G 2018 Hypersymmetry as a New Paradigm in Contemporary Physical World-View 11th International
Symposium honouring noted mathematical physicist Jean-Pierre Vigier “Advances in Fundamental Physics,
Prelude to Paradigm Shift” 6-9 August 2018 Liege Belgium
[10] Darvas G 2018 Algebra of hypersymmetry (extended version) applied to state transformations in strongly
relativistic interactions illustrated on an extended form of the Dirac equation Preprint 1809.05396
[11] Englert F and Brout R 1964 Phys. Rev. Lett. 13 321
[12] Glashow S L 1961 Nucl. Phys. 22 579
[13] Goldstone J 1961 Nuovo Cimento 19 154
[14] Goldstone J, Salam A and Weinberg S 1962 Broken symmetries Phys. Rev. 127 3 p 965
[15] Higgs P W 1964 Phys. Rev. Lett. 12 132; 13 508
[16] Abramov V, Kerner R and Le Roy B 1997 Hypersymmetry: A Z3-graded generalization of supersymmetry
Journal of Mathematical Physics 38 1650
[17] Kerner R 2018 Quantum Physical Origin of Lorentz Transformations Journal of Physics: Conf. Series 1051
012018
[18] Møller, C. 1931 Über den Stoß zweier Teilchen unter Berücksichtigung der Retardation der Kräfte Zeitschrift
für Physik 70 11-12 pp 786–95
[19] Weinberg S 1967 A model of leptons Phys. Rev. Lett. 19 21 p 1264
[20] Weinberg S 1976 Implications of dynamical symmetry breaking Phys. Rev. D 13 4 p 974