Chapter 13

The Origin of Intrinsic Spin and the Pauli Exclusion Principle in the Evans Unified Field Theory

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Abstract

The tetrad of the Evans unified field theory is shown to be the wavefunction for electromagnetism, the Dirac equation, strong force theory and the Majorana/Weinberg spin equations for any particle and field in physics. The origin of intrinsic spin in physics is shown to be a basis set of elements in the tangent spacetime to a base manifold at point P. The tangent spacetime is a Minkowski spacetime and the base manifold an Evans spacetime. The origin of the Pauli exclusion principle is the half integral intrinsic spin described by an appropriate basis set of elements. Right and left intrinsic spin in electrodynamics are the two states of circular polarization which are again described by an appropriate basis set. Similar reasoning applies for the origin of quark color and for general spin in the Majorana Weinberg equations. In the Evans unified field theory there is therefore a self-consistent description of intrinsic spin in physics and gravitational theory.

Key words: Evans field theory; intrinsic spin; right and left circular polarization; Pauli exclusion principle; quark color; Majorana Weinberg equations.

13.1 Introduction

A true unified field theory must be able to trace the origin of intrinsic spin in physics, and describe the various manifestation of spin in all radiated and matter fields. Furthermore it must be able to integrate this type of theory with gravitational theory and also with quantum mechanics. This is a formidable problem which appears to have been given one plausible solution lately [1]– [17] in the Evans unified field theory. In this paper the origin of intrinsic spin is discussed in terms of the tetrad, which is the fundamental field in the Evans theory for all material matter and radiation. It is shown in Section 13.2 that there exists a basis set of elements in tangent spacetime at a point P in the base manifold, a basis set which defines the existence of intrinsic spin. In electrodynamics the basis set defines left and right circular polarization and the intrinsic spin field of generally covariant electrodynamics. In Section 13.3 the intrinsic left and right spin of a fermionic field in the Dirac equation is defined in terms of the appropriate basis set, and the origin of the Pauli exclusion principle revealed. In Section 13.4 the origin of quark color in strong field theory is defined by a color basis set in the tangent spacetime, and this is related to quark flavor in the base manifold by the tetrad field of strong force theory. This is the matter field of the six quarks currently postulated to exist and the tetrad in this case is a transformation matrix linking quark color and flavor. Finally in Section 13.5 the Majorana Weinberg equations for arbitrary spin are set up using the same principles of differential geometry which underpin the Evans unified field theory. In each case the wavefunction is the tetrad $q^a{}_\mu$, and the tangent spacetime label a is the index of the elements of the basis set. The index a is the index of intrinsic spin.

13.2 Electrodynamics

The existence of intrinsic spin in electrodynamics was discovered experimentally by Arago in 1811 and is referred to as left and right circular polarization. The existence of the Evans spin field, observed in the inverse Faraday effect is indicated conclusively by general relativity [1]– [17]. The vector potentials for left and right circular polarization are:

$$\mathbf{A}_R{}^{(1)} = \frac{A^{(0)}}{\sqrt{2}} \left(\mathbf{i} - i\mathbf{j} \right) e^{i\phi} \tag{13.1}$$

$$\mathbf{A}_L{}^{(1)} = \frac{A^{(0)}}{\sqrt{2}} \left(\mathbf{i} + i\mathbf{j} \right) e^{i\phi}, \tag{13.2}$$

where ϕ is the electromagnetic phase and where the (1) index denotes complex conjugation as follows:

$$\mathbf{A}_R{}^{(1)} = \mathbf{A}_R{}^{(2)*} \tag{13.3}$$

$$\mathbf{A}_L{}^{(1)} = \mathbf{A}_L{}^{(2)*}. \tag{13.4}$$

The left and right spin field is then:

$$\mathbf{A}^R = \frac{A^{(0)}}{\sqrt{2}} (\mathbf{i} - i\mathbf{j})\, e^{i\phi} \tag{13.5}$$

$$\mathbf{A}^L = \frac{A^{(0)}}{\sqrt{2}} (\mathbf{i} + i\mathbf{j})\, e^{i\phi}. \tag{13.6}$$

For our present purposes we may simplify the argument by writing:

$$\mathbf{A}_R{}^{(1)} = \mathbf{A}^R \tag{13.7}$$

$$\mathbf{A}_L{}^{(1)} = \mathbf{A}^L. \tag{13.8}$$

The basis vectors for the complex circular basis are defined by:

$$\mathbf{e}^{(1)} = \frac{1}{\sqrt{2}} (\mathbf{i} - i\mathbf{j}) \tag{13.9}$$

$$\mathbf{e}^{(2)} = \frac{1}{\sqrt{2}} (\mathbf{i} + i\mathbf{j}) \tag{13.10}$$

$$\mathbf{e}^{(3)} = \mathbf{k} \tag{13.11}$$

where **i**, **j**, and **k** are Cartesian unit vectors. Therefore:

$$\mathbf{A}^R = A^{(0)} e^{i\phi} \mathbf{e}^{(1)} \tag{13.12}$$

$$\mathbf{A}^L = A^{(0)} e^{i\phi} \mathbf{e}^{(2)}. \tag{13.13}$$

It follows that the right and left basis vectors may be defined as:

$$\mathbf{e}^R = e^{i\phi} \mathbf{e}^{(1)} \tag{13.14}$$

$$\mathbf{e}^L = e^{i\phi} \mathbf{e}^{(2)}. \tag{13.15}$$

Within the phase factor $\mathbf{e}^{i\phi}$ these are the $\mathbf{e}^{(1)}$ and $\mathbf{e}^{(2)}$ basis vectors of the complex circular basis. The components of the right and left basis vectors define a tetrad matrix:

$$q^a{}_\mu = \begin{bmatrix} e^R{}_x & e^R{}_y \\ e^L{}_x & e^L{}_y \end{bmatrix} \tag{13.16}$$

where

$$\begin{aligned} e^R{}_x &= \frac{e^{i\phi}}{\sqrt{2}} \quad , \quad e^R{}_y = \frac{-ie^{i\phi}}{\sqrt{2}} \\ e^L{}_x &= \frac{e^{i\phi}}{\sqrt{2}} \quad , \quad e^L{}_y = \frac{ie^{i\phi}}{\sqrt{2}}. \end{aligned} \tag{13.17}$$

The tetrad in Eq.(13.16) obeys the Evans wave equation in the limit of zero photon mass:

$$kT = \left(\frac{mc}{\hbar}\right)^2 \longrightarrow 0 \tag{13.18}$$

so that:

$$\Box q^a{}_\mu = 0. \tag{13.19}$$

With the Evans Ansatz:

$$A^a{}_\mu = A^{(0)} q^a{}_\mu \tag{13.20}$$

Eq.(13.19) is the d'Alembert wave equation in free space:

$$\Box A^a{}_\mu = 0. \tag{13.21}$$

The tetrad $q^a{}_\mu$ is always defined geometrically [18] by:

$$V^a = q^a{}_\mu V^\mu \tag{13.22}$$

where V^a is a vector in the tangent spacetime and V^μ is a vector in the base manifold.

Define

$$V^\mu = \begin{bmatrix} e_x \\ e_y \end{bmatrix} = e^{-i\phi} \begin{bmatrix} 1 \\ 1 \end{bmatrix} \tag{13.23}$$

and

$$V^a = \begin{bmatrix} e^R \\ e^L \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1-i \\ 1+i \end{bmatrix} \tag{13.24}$$

and it follows from Eqs.(13.16) and (13.22) to (13.24) that:

$$\frac{1}{\sqrt{2}} \begin{bmatrix} 1-i \\ 1+i \end{bmatrix} = \frac{e^{i\phi}}{\sqrt{2}} \begin{bmatrix} 1 & -i \\ 1 & i \end{bmatrix} \begin{bmatrix} e^{-i\phi} \\ e^{-i\phi} \end{bmatrix} \tag{13.25}$$

i.e.

$$V^a = q^a{}_\mu V^\mu \tag{13.26}$$

Q.E.D.

From Eq.(13.25) it is seen that the basis set for the intrinsic spin of electromagnetism is:

$$\mathbf{e}^{(1)} \times \mathbf{e}^{(2)} = i\mathbf{e}^{(3)*} \tag{13.27}$$

$$\mathbf{e}^{(2)} \times \mathbf{e}^{(3)} = i\mathbf{e}^{(1)*} \tag{13.28}$$

$$\mathbf{e}^{(3)} \times \mathbf{e}^{(1)} = i\mathbf{e}^{(2)*} \tag{13.29}$$

i.e. the basis set is made up of the complex circular unit vectors. Eq.(13.27) to (13.29) have $O(3)$ symmetry. This reasoning may be extended to find the origin and meaning of intrinsic spin in other contexts.

13.3 Fermionic Matter Field And The Dirac Equation

The tetrad field for the Dirac equation is

$$q^a{}_\mu = \begin{bmatrix} q^R{}_1 & q^R{}_2 \\ q^L{}_1 & q^L{}_2 \end{bmatrix} \tag{13.30}$$

where the Pauli spinors are defined by:

$$\phi^R = \begin{bmatrix} q^R{}_1 \\ q^R{}_2 \end{bmatrix}, \quad \phi^L = \begin{bmatrix} q^L{}_1 \\ q^L{}_2 \end{bmatrix}. \tag{13.31}$$

The tetrad field is defined by:

$$V^a = q^a{}_\mu V^\mu \tag{13.32}$$

where

$$V^a = \begin{bmatrix} e^R \\ e^L \end{bmatrix}, \quad V^\mu = \begin{bmatrix} e^1 \\ e^2 \end{bmatrix}. \tag{13.33}$$

The column vector V^μ is a two dimensional column vector in the base manifold and transforms under $SU(2)$ symmetry [19]. Similarly the column vector V^a is a two dimensional column vector in the tangent spacetime.

The tetrad field $q^a{}_\mu$ is defined by Eq.(13.30) and obeys the Evans wave equation [1]– [17]:

$$(\Box + kT)\, q^a{}_\mu = 0. \tag{13.34}$$

The Dirac equation is recovered in the limit:

$$kT \longrightarrow \left(\frac{mc}{\hbar}\right)^2, T \longrightarrow \frac{m}{V} \tag{13.35}$$

where m is the mass of the fermion, $\hbar$ is the reduced Planck constant, c is the velocity of light and V is the rest volume of the fermion:

$$V = \frac{\hbar^2 k}{mc^2}. \tag{13.36}$$

In the limit (13.35) the Dirac spinor is defined [1]– [17] by:

$$\psi = \begin{bmatrix} q^R{}_1 \\ q^R{}_2 \\ q^L{}_1 \\ q^L{}_2 \end{bmatrix} \tag{13.37}$$

and the Dirac equation is:

$$\left(\Box + \left(\frac{mc}{\hbar}\right)^2\right)\psi = 0. \tag{13.38}$$

This is a free particle equation, and in this limit no gravitational attraction exists between fermions in Eq.(13.38). To describe gravitational attraction between fermions we need the Evans wave equation (13.34), in general without approximation.

13.4 Strong Field Theory

In contemporary strong field theory [19] there are thought to exist six quark flavors and three quark colors. If we accept this view uncritically the Evans unified field theory can be applied to the n-quark models, where $n = 2, \ldots, 6$. These models transform under $SU(n)$ symmetry [19]. In the 2-quark model there are two flavors, u and d, and three colors, R, W and B. Define the following column two-vector (a two-spinor) in the base manifold:

$$V^{\mu} = \begin{bmatrix} u \\ d \end{bmatrix} = \begin{bmatrix} e^1 \\ e^2 \end{bmatrix} \tag{13.39}$$

and the following column three-vector (a three-spinor) in the tangent spacetime to the base manifold at point P:

$$V^{a} = \begin{bmatrix} e^R \\ e^W \\ e^B \end{bmatrix}. \tag{13.40}$$

The flavors u and d represent two physically distinct quarks, each of which has color R, W and B. The u and d particles are analogous to the two distinct electrons of Dirac theory. The electrons are distinct because they are left and right handed, with half integral spin. Similarly, R, W and B in strong field theory plays the role of half integral spin in electron theory. It is seen that strong field theory is built up by direct analogy with Dirac theory, and quarks also have half integral spin [19].

Now define the tetrad matrix linking quark color and quark flavor. This must be a 2×3 matrix:

$$\begin{bmatrix} e^R \\ e^W \\ e^B \end{bmatrix} = \begin{bmatrix} q^R{}_1 & q^R{}_2 \\ q^W{}_1 & q^W{}_2 \\ q^B{}_1 & q^B{}_2 \end{bmatrix} \begin{bmatrix} e^1 \\ e^2 \end{bmatrix}. \tag{13.41}$$

Therefore the color-flavor tetrad for the two-quark model is:

$$q^a{}_{\mu} = \begin{bmatrix} q^R{}_1 & q^R{}_2 \\ q^W{}_1 & q^W{}_2 \\ q^B{}_1 & q^B{}_2 \end{bmatrix} \tag{13.42}$$

and is the eigenfunction of the Evans wave equation [1]– [17]:

$$(\Box + kT)\, q^a{}_{\mu} = 0. \tag{13.43}$$

This means that $q^a{}_{\mu}$ is the quark matter field. The quarks interact through gluons, which are the radiated fields [19] of strong field theory.

Similarly, in the three-quark model the tetrad is defined by:

$$\begin{bmatrix} e^R \\ e^W \\ e^B \end{bmatrix} = \begin{bmatrix} q^R{}_1 & q^R{}_2 & q^R{}_3 \\ q^W{}_1 & q^W{}_2 & q^W{}_3 \\ q^B{}_1 & q^B{}_2 & q^B{}_3 \end{bmatrix} \begin{bmatrix} e^1 \\ e^2 \\ e^3 \end{bmatrix} \tag{13.44}$$

and is a 3×3 matrix. The name "tetrad" is used generically [18]. As a final example the tetrad of the four-quark model is a 4×3 matrix defined by:

$$\begin{bmatrix} e^R \\ e^W \\ e^B \end{bmatrix} = \begin{bmatrix} q^R{}_1 & q^R{}_2 & q^R{}_3 & q^R{}_4 \\ q^W{}_1 & q^W{}_2 & q^W{}_3 & q^W{}_4 \\ q^B{}_1 & q^B{}_2 & q^B{}_3 & q^B{}_4 \end{bmatrix} \begin{bmatrix} e^1 \\ e^2 \\ e^3 \\ e^4 \end{bmatrix} \tag{13.45}$$

and it is possible to proceed in this way up to the six-quark model, where the tetrad is a 6×3 matrix.

13.5 Majorana And Weinberg Equations

The Majorana equation [20, 21] represents the free space equations of electromagnetism as Weyl equations, i.e. a Dirac equation with no mass term. The equations of electromagnetism used originally by Majorana in the nineteen twenties were the Maxwell Heaviside equations. In order to derive the generally covariant Majorana equation the unified field theory is needed. The Weinberg equation [22] for any spin is a generalization of the Majorana equation for any half-integral or integral spin. All these spin equations are special cases of the Evans unified field theory. In order to illustrate this consider the Maxwell Heaviside field equations in free space. In S.I. units:

$$\nabla \times \mathbf{E} + \frac{\partial \mathbf{B}}{\partial t} = \mathbf{0} \tag{13.46}$$

$$\nabla \times \mathbf{B} - \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t} = \mathbf{0} \tag{13.47}$$

where $\mathbf{B}$ is magnetic flux density and $\mathbf{E}$ is electric field strength. These equations are used simply for the sake of illustration. The generally covariant equations of electrodynamics from the Evans unified field theory [1]– [17] include the fundamental Evans spin field - which is absent from the Maxwell Heaviside field theory but which is observed experimentally in the inverse Faraday effect. Eqs.(13.46) and (13.47) can be written as:

$$\nabla \times (\mathbf{E} - ic\mathbf{B}) + \frac{i}{c}\frac{\partial}{\partial t}(\mathbf{E} - ic\mathbf{B}) = \mathbf{0}. \tag{13.48}$$

Now consider the right and left circularly polarized solutions of Eq.(13.48):

$$\mathbf{E}^R = \frac{E^{(0)}}{\sqrt{2}}(\mathbf{i} - i\mathbf{j})\, e^{i\phi} \tag{13.49}$$

$$\mathbf{B}^R = \frac{B^{(0)}}{\sqrt{2}}(i\mathbf{i} + \mathbf{j})\, e^{i\phi} \tag{13.50}$$

and

$$\mathbf{E}^L = \frac{E^{(0)}}{\sqrt{2}}(\mathbf{i} + i\mathbf{j})\, e^{i\phi} \tag{13.51}$$

$$\mathbf{B}^L = \frac{B^{(0)}}{\sqrt{2}} \left(-i\mathbf{i} + \mathbf{j}\right) e^{i\phi}. \tag{13.52}$$

Use

$$E^{(0)} = cB^{(0)} = \omega A^{(0)} \tag{13.53}$$

to obtain

$$\mathbf{E}^R - ic\mathbf{B}^R = 2\omega \frac{A^{(0)}}{\sqrt{2}} \left(\mathbf{i} - i\mathbf{j}\right) e^{i\phi}. \tag{13.54}$$

Define the potential field as:

$$\mathbf{A}^R = \frac{A^{(0)}}{\sqrt{2}} i \left(\mathbf{i} - i\mathbf{j}\right) e^{i\phi} \tag{13.55}$$

so that

$$\mathbf{E}^R - ic\mathbf{B}^R = 2\frac{\omega}{i}\mathbf{A}^R. \tag{13.56}$$

Similarly:

$$\mathbf{E}^L + ic\mathbf{B}^L = 2\frac{\omega}{i}\mathbf{A}^L \tag{13.57}$$

where

$$\mathbf{A}^L = \frac{A^{(0)}}{\sqrt{2}} i \left(\mathbf{i} + i\mathbf{j}\right) e^{i\phi}. \tag{13.58}$$

Eqs.(13.56) and (13.57) define the right and left handed potential fields. These obey the equations:

$$\left(\nabla \times + \frac{i}{c}\frac{\partial}{\partial t}\right) \mathbf{A}^R = \mathbf{0} \tag{13.59}$$

$$\left(\nabla \times - \frac{i}{c}\frac{\partial}{\partial t}\right) \mathbf{A}^L = \mathbf{0}. \tag{13.60}$$

The components of Eq.(13.59) are:

$$\frac{\partial {A^R}_z}{\partial y} - \frac{\partial {A^R}_y}{\partial z} + \frac{i}{c}\frac{\partial {A^R}_x}{\partial t} = 0 \tag{13.61}$$

$$\frac{\partial {A^R}_x}{\partial z} - \frac{\partial {A^R}_z}{\partial x} + \frac{i}{c}\frac{\partial {A^R}_y}{\partial t} = 0 \tag{13.62}$$

$$\frac{\partial {A^R}_y}{\partial x} - \frac{\partial {A^R}_x}{\partial y} + \frac{i}{c}\frac{\partial {A^R}_z}{\partial t} = 0. \tag{13.63}$$

Now use the quantum condition [19]:

$$p^\mu = i\hbar\partial^\mu \tag{13.64}$$

where

$$p^\mu = \left(\frac{En}{c}, \mathbf{p}\right), \quad \partial^\mu = \left(\frac{1}{c}\frac{\partial}{\partial t}, -\nabla\right). \tag{13.65}$$

Thus:

$$En = i\hbar\frac{\partial}{\partial t}, \quad \mathbf{p} = -i\hbar\nabla. \tag{13.66}$$

Eqs.(13.61) to (13.63) therefore become:

$$EnA^R{}_x + ic\left(p_y A^R{}_z - p_z A^R{}_y\right) = 0 \tag{13.67}$$

$$EnA^R{}_y + ic\left(p_z A^R{}_x - p_x A^R{}_z\right) = 0 \tag{13.68}$$

$$EnA^R{}_z + ic\left(p_x A^R{}_y - p_y A^R{}_x\right) = 0. \tag{13.69}$$

Define the three-spinor:

$$\phi^R = \begin{bmatrix} A^R{}_x \\ A^R{}_y \\ A^R{}_z \end{bmatrix} \tag{13.70}$$

and:

$$\begin{aligned} \alpha\cdot\mathbf{p} &= \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & -i \\ 0 & i & 0 \end{bmatrix} p_x + \begin{bmatrix} 0 & 0 & i \\ 0 & 0 & 0 \\ -i & 0 & 0 \end{bmatrix} p_y + \begin{bmatrix} 0 & -i & 0 \\ i & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} p_z \\ &= i\begin{bmatrix} 0 & -p_z & p_y \\ p_z & 0 & -p_x \\ -p_y & p_x & 0 \end{bmatrix}. \end{aligned} \tag{13.71}$$

Then Eqs.(13.67) to (13.63) are:

$$\left(\frac{En}{c}\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} + i\begin{bmatrix} 0 & -p_z & p_y \\ p_z & 0 & -p_x \\ -p_y & p_x & 0 \end{bmatrix}\right)\begin{bmatrix} A^R{}_x \\ A^R{}_y \\ A^R{}_z \end{bmatrix} = 0 \tag{13.72}$$

or

$$\left(\frac{En}{c} + \alpha\cdot\mathbf{p}\right)\phi^R = 0. \tag{13.73}$$

Similarly:

$$\left(\frac{En}{c} - \alpha\cdot\mathbf{p}\right)\phi^L = 0 \tag{13.74}$$

where the three-spinors are defined as:

$$\phi^R = \begin{bmatrix} A^R{}_x \\ A^R{}_y \\ A^R{}_z \end{bmatrix}, \quad \phi^L = \begin{bmatrix} A^L{}_x \\ A^L{}_y \\ A^L{}_z \end{bmatrix}. \tag{13.75}$$

Eqs.(13.73) and (13.74) are the Majorana equations [20, 21]. They are Weyl-type equations, i.e. a Dirac equation with no mass term. Instead of Pauli matrices however, the $O(3)$ symmetry rotation matrices of Eq.(13.71) are used. Eqs.(13.73) and (13.74) are limits of

$$\left(\Box + \left(\frac{mc}{\hbar}\right)^2\right)\psi = 0. \tag{13.76}$$

when $m \longrightarrow 0$. Here

$$\psi = \begin{bmatrix} \phi^R \\ \phi^L \end{bmatrix} \tag{13.77}$$

is a six-spinor analogous to the Dirac four-spinor of Eq.(13.37). Eq.(13.76) is a limit of the Evans wave equation:

$$(\Box + kT)\,\psi = 0. \tag{13.78}$$

The spinor ψ is obtained from the tetrad:

$$q^a{}_\mu = \begin{bmatrix} A^R{}_1 & A^R{}_2 & A^R{}_3 \\ A^L{}_1 & A^L{}_2 & A^L{}_3 \end{bmatrix} \tag{13.79}$$

defined by:

$$A^{(0)} \begin{bmatrix} e^R \\ e^L \end{bmatrix} = \begin{bmatrix} A^R{}_1 & A^R{}_2 & A^R{}_3 \\ A^L{}_1 & A^L{}_2 & A^L{}_3 \end{bmatrix} \begin{bmatrix} e^1 \\ e^2 \\ e^3 \end{bmatrix}. \tag{13.80}$$

This illustration shows that the Maxwell-Heaviside electromagnetism of the standard model is an example of a spin equation which is the massless special relativistic limit of the Evans wave equation. The symmetry in this case can be either $O(3)$ or $SU(3)$. Finally the Weinberg equation [22] is the spin equation for any integral or half integral spin, and the Weinberg equation is also a limit of the generally covariant Evans wave equation.

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