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Neutrino Masses, Custodial Symmetry and the Planck Energy

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Abstract

A framework is analyzed where the Standard Model physics emerges as a low-energy effective field theory on a $(7+1)$D spacetime and Minkowski space is a monolayer composed of unresolvable tetrahedral unit cells at the Planck scale. We demonstrate that the SSB of the isospin cells into a chiral all-out configuration naturally generates a local $O(4)$ isospin symmetry which governs the dynamics of the Higgs doublet and the mass hierarchy of the electroweak sector. By identifying the axial generators of the broken symmetry with massive vector bosons, we recover the electroweak phenomenology. The inherent handedness of the isospin vacuum provides a 7D origin for parity violation, establishing a direct link between the topology of the unresolvable spatial lattice and the observed chiral nature of weak interactions. The role of the $O(4)$ symmetry of the Higgs potential is elucidated, and how the SM custodial symmetry is associated to neutrino masses, the latter being obtained from isospin-orbit coupling between isospins and the Planck lattice.

Introduction

In this paper, the fundamental degrees of freedom are $SO(7, 1)$ fermions localized at the vertices of a 3D 'monolayer', to be interpreted as the physical universe. Within each unit cell, the internal degrees of freedom span a 4D isospin space, characterized by an $O(4) \cong SU(2)_L \times SU(2)_R$ symmetry as part of the full $SO(7, 1)$ group.

The core of the theory lies in the induced order of the vacuum. Through a quadratic Dzyaloshinskii-Moriya-type interaction (DMI)[4, 6], the system undergoes spontaneous symmetry breaking, transitioning from a symmetric state to a chiral all-out tetrahedral configuration. This transition is identified with the electroweak phase transition. We define the primary energy scales: E_p (the Planck binding energy among the fundamental fermions) and D_{LL} (their isospin exchange energy, corresponding to the Fermi scale E_F).

A key feature of the model is the emergence of the Higgs doublet as a collective excitation of the isospin vectors. Unlike the Standard Model, where the Higgs is an elementary field, here it represents the radial and angular fluctuations of the tetrahedrally ordered isospin cells. Furthermore, we explore the custodial symmetry[9] inherent in the $O(4)$ structure, which protects the W/Z mass ratio, and the role of broken axial generators in defining the massive sector of the theory.

We examine the origin of parity violation. We argue that the all-out configuration selects a discrete handedness in the internal isospin space. When excitations in the form of quarks, leptons or gauge bosons propagate through the monolayer, their interaction with the isospin background is governed by phase resonance. We demonstrate that only one chirality (left-handed) is compatible with the isospin vacuum's screw-sense, naturally leading to the maximal parity violation observed in weak interactions.

Finally, we address the question of neutrino masses. As a consequence of a SSB effect, we find the neutrinos to be massless modes of the isospin lattice, as long as the spatial Planck lattice structure is unresolvable, and that they obtain masses $O(1/E_p)$ when this assumption is given up.

The Details

Within the 7+1 dimensional spacetime there are fermions transforming under the fundamental 16D representation $8_L + 8_R$, where 8_L and 8_R are the two complex spinorial representations[7] of $SO(7,1)$, one with left handed and the other with right handed chirality. When decomposing $SO(7,1)$ into the Lorentz symmetry $SO(3,1)$ of a 'base' Minkowski spacetime and an 'internal' $SO(4)$, describing the symmetry group of the 4 extra dimensions, the representations decompose as

$$\begin{aligned} SO(7,1) &\rightarrow SO(3,1)\times SU(2)_L\times SU(2)_R \\ 8_L &\rightarrow ((1,2),(2_L,1))+((2,1),(1,2_R)) \\ 8_R &\rightarrow ((1,2),(1,2_R))+((2,1),(2_L,1)) \\ 8_L\oplus 8_R &\rightarrow ((1,2)+(2,1),(1,2_R)+(2_L,1)) \end{aligned} \tag{1}$$

where the covering group $SU(2)_L \times SU(2)_R$ of $SO(4)$ has been introduced. $(2,1)$ and $(1,2)$ denote left and right handed Weyl spinor representations of $SO(3,1)$ while the left and right handed $SO(4)$ spinors are denoted by $(2_L,1)$ and $(1,2_R)$. Note, the chiralities of all the doublets appearing in (1) are intertwined because they follow from the chiralities of the parent representations 8_L and 8_R.

These fermions are called tetrons Ψ, and it is assumed that the observed quarks and leptons arise as vibrations $\delta\vec{Q}$ ('iso-magnons') of isospin vectors in the 4 extra dimensions:

$$\vec{Q}_L = \frac{1}{4}\Psi^\dagger(1-\Gamma_5)\vec{\tau}\Psi = \frac{1}{2}\Psi_L^\dagger\vec{\tau}\Psi_L \qquad \vec{Q}_R = \frac{1}{4}\Psi^\dagger(1+\Gamma_5)\vec{\tau}\Psi = \frac{1}{2}\Psi_R^\dagger\vec{\tau}\Psi_R \tag{2}$$

In order to obtain the complete vibrational degrees of freedom, the decompositon of $8_L \oplus 8_R$ in the last line of (1) should be considered. The corresponding tetron field represents a Dirac field $(1,2)+(2,1)$ in the $SO(3,1)$ base part, with 2 $SO(4)$ doublets $\Psi_L = (U_L, D_L)$ and $\Psi_R = (U_R, D_R)$ on top.

Note that the indices L and R refer to the chiralities in the 4 extra dimensions. As well known, any rotation in $SO(4)$ can be described by a pair of 3D angular momentum vectors $\vec{Q}_L$ and $\vec{Q}_R$, corresponding to 2 simultaneous rotations of 2 planes in R^4. (The notion of a rotation axis is not meaningful in 4D.) In the special case $\vec{Q}_L = \vec{Q}_R$ this reduces to one rotation in just one plane. The conection with weak parity violation will be clarified in the section on chirality.

Description of the Ground State

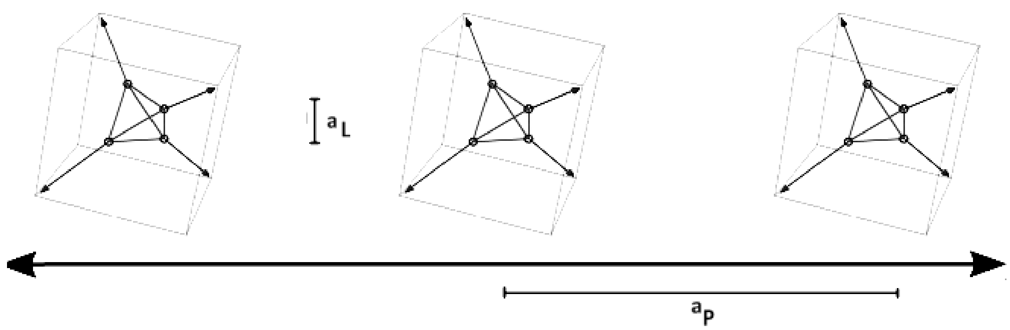

Figure 1: Depiction of 3 aligned tetrahedral unit cells. The big black double arrow represents physical space (the monolayer). a_L is the magnitude of one tetrahedron within the 3 extra dimensions and a_P the average distance between two neighboring tetrahedrons. The small arrows are the isospin vectors defined in (2), where actually each arrow stands for 2 vectors $\vec{Q}_L$ and $\vec{Q}_R$ which are aligned and equal in the ground state. The figure is a bit misleading, firstly because the tetrahedrons only extend into the extra dimensions but not into physical space, and secondly the relative magnitudes are not correctly drawn. Namely, while a_L and a_P are of the order of the Planck length L_p, the extension of the tetrahedrons formed by the isospin vectors is dictated by the Fermi scale. While gravity can be attributed to the elasticity of the coordinate bonds[3], the phenomena of particle physics arise from the interactions between isospin vectors.

The ground state of the system has been discussed at length in previous publications[1, 8]. According to this, at Planck scale distances our universe is a discrete structure consisting of aligned tetrahedrons extending into the 4 extra dimensions. More precisely, the ground state consists of unit cells where the isospin system of the tetrons forms an all-out configuration, as depicted in Fig. 1. This means, at each tetrahedral corner $i = 1-4$, vectors $Q_{L,i}$ und $Q_{R,i}$ are parallel and point in the tetrahedral easy axis direction.

Isospins Q_L and Q_R (2) form the generators of the group $SU(2)_L \times SU(2)_R$, which acts on the 4 extra dimensions. This 4D isospin space on which the tetrahedral unit cells are hosted is a subspace of the higher-dimensional 7D manifold. Adjacent unit cells are distributed exclusively in the dimensions orthogonal to the extra $\mathbb{R}^4$. Consequently, the all-out tetrahedral array forms a topological monolayer within the 7D bulk. This monolayer constitutes our physical universe; in the continuum limit, as the spatial lattice (but not the isospin structure) becomes unresolvable, it maps onto the familiar 3+1 dimensional Minkowski spacetime (for more details see the next section).

The expansion into a relativistic spacetime continuum introduces a significant constraint: the tetrahedral isospin symmetry is strictly defined only in the rest frame of the lattice. However, the quasiparticle excitations which make up for the ordinary matter and propagate along the monolayer exhibit different symmetry properties. Because these excitations are wave-like solutions within the 3+1 dimensional effective manifold, they manifest as Lorentz $SO(3,1)$ covariant objects. In this interpretation, while the fundamental vacuum is non-covariant and discrete, the observable physical sector - consisting of collective excitations - obeys the laws of special relativity. These particles 'glide' over the monolayer substrate, treating the underlying non-invariant isospin grid as a relativistic medium.

The Spatial Continuum Limit and the Discrete System of Isospins

In this work we are considering particle physics effects only, which amounts to switching off gravity (and the corresponding elasticity of the inter-tetrahedral spatial bonds) by considering the continuum limit with respect to physical space, while keeping the discrete tetrahedral isospin configuration intact. Actual calculations should be done in the rest system of the tetrahedral configurations, which on cosmic scales amounts to the so-called CMB rest system[15]. The expanding universe thus is not the expansion of an empty space, but of the increasing distance between the tetrahedral cells, corresponding to the uniform expansion of the monolayer grid.

It is well known that the fundamental spacetime constants c, $\hbar$ and G can be used to define the Planck length, time and mass L_p, T_p and M_p which describe the basic properties of space[m], time[s] and matter[kg]

$$c = \frac{L_p}{T_p} \qquad \hbar = E_p T_p \qquad \kappa = \frac{L_p}{E_p} \tag{3}$$

where $E_p = M_p c^2$ is the Planck energy and $\kappa = G/c^4$ the Einstein constant.

Our monolayer is a 'Planck lattice' in the sense that we identify the spacing between 2 unit cells as the Planck length L_p. More precisely, due to the elasticity of the spatial bonds between 2 cells, L_p corresponds to an average of these spacings. However, since we are not interested in gravitational but only in particle physics effects, we are allowed to take the limit $G \to 0$ while keeping c and h fixed. This removes the spatial elasticity, at the same time allowing to consider the continuum limit $L_p \to 0$ and arriving at a quantum field theory in flat spacetime.

According to (3) this limit implies $E_p \to \infty$ and corresponds to the observed large value of the Planck energy, which is interpreted as the binding energy of the 'lattice', while the DMI couplings (4) with magnitude $O(E_F)$ are the much smaller interaction energies among the isospins.

In other words, this limit sends G to zero while simultaneously allowing to use the continuum limit for the spatial coordinates and considering a system of discrete isospin vectors forming aligned tetrahedrons in the ground state.

As $E_p \to \infty$, the medium (which may be considered a kind of 'Lorentz ether') becomes infinitely stiff against gravitational deformations. What remains are the internal degrees of freedom of the symmetry group $SU(2)_L \times SU(2)_R$. If we consider E_p as the gigantic binding energy of the lattice (10^{19} GeV) and E_F as the gentle interaction energy of the isospins (10^2 GeV), we find ourselves in a regime where the lattice itself is rigid and indestructible, while the isospin degrees of freedom act upon it like a superfluid liquid.

Recovering Lorentz Invariance

Lorentz invariance is an emergent symmetry of the low-energy sector[10]. The preferred frame of the Planck-lattice exists, but it is hidden behind the energy barrier E_p. For the matter excitations, the geometry of the monolayer effectively behaves as a $3 + 1$ dimensional Minkowski space.

More in detail the vacuum of the present theory is a structured 'isospin crystal', with a lattice constant L_p being fixed up to the elasticity effects from gravitation. While this lattice constitutes a preferred frame, the observable excitations obey Lorentz invariance due to the following four principles:
-The continuum limit (non-resolvability): Since the lattice is unresolvable for wavelengths $\lambda \gg L_p$, the discrete differences between lattice sites smooth out into continuous fields. The underlying absolute grid disappears from the equations of motion, replaced by a smooth spacetime manifold where only the relative coordinates of the wave-packets matter.
-Universal limiting velocity: The 'speed of light' in the model is not an independent constant but an emergent property of the medium. It is determined by the ratio of the elasticity of the tetron interactions and their density. Since all excitations propagate through the same medium, they all share the same maximum propagation speed. This universal speed limit is the foundation of the Lorentz transformation.
-Hyperbolic dispersion relations: The excitations in the monolayer are not classical particles but collective modes which obey Lorentz-invariant wave equations like the Klein-Gordon or Dirac equation. Due to the restoration force of the ground state, these modes follow a relativistic dispersion relation: $E^2 = (pc)^2 + (mc^2)^2$.
-The internal nature of the observer: Since the observers (and their measuring devices) are themselves made of these same excitations, they are locked into the same wave dynamics. An observer moving through the monolayer cannot detect the static isospin cells because their own clocks and rulers change in unison. This is the Principle of Relativity realized within a medium.

Particle Physics Weak Isospin as Internal Pseudospin

In solid state physics, if there are 2 sublattices, this leads to left and right polarized magnons, and these are usually interpreted as 'pseudospin' $\pm\frac{1}{2}$ states, where the pseudospin behaves exactly like a spin-$\frac{1}{2}$ system[11].

In the present case the sublattices are formed by the $\vec{Q}_L$ and $\vec{Q}_R$ systems, respectively, and the transition between the 2 systems corresponds to the transition between weak isospin pairs. In this image, the choice between $\vec{Q}_L$ and $\vec{Q}_R$ is no longer a matter of location, but an internal quantum number. Later it wilI be described how the pseudospin symmetry is gauged and the electroweak vector bosons arise.

In order to define this more formally, one may introduce a doublet operator ψ that combines both systems $\psi = (\psi_L, \psi_R)$, where ψ_L stands for the $SO(4)$ fermionic excitations in the Q_L System und ψ_R for those in the Q_R System.

One may also consider triplets of pseudospin, and for example the axial Goldstone modes (ϕ_1, ϕ_2, ϕ_3) discussed below are such a triplet, which describes the entanglement or exchange between $\vec{Q}_L$ and $\vec{Q}_R$ of neighboring unit cells.

Dominance of DMI Interactions in Intra Cell Interactions

How obtain the above described ground state from a dynamics? When trying to adapt the isospin interactions to the observed quark and lepton spectrum, a dominance of DMI over Heisenberg interactions shows up[6, 1]:

$$\begin{aligned} H_{DMI} &= -D_{LL} \sum_{i \neq j=1}^{4} (\vec{Q}_{Li} \times \vec{Q}_{Lj})^2 - D_{LR} \sum_{i \neq j=1}^{4} (\vec{Q}_{Li} \times \vec{Q}_{Rj})^2 \\ &\quad -D_{RR} \sum_{i \neq j=1}^{4} (\vec{Q}_{Ri} \times \vec{Q}_{Rj})^2 \end{aligned} \tag{4}$$

where the top mass is essentially determined by D_{LL} (which turns out to be the driving force for the electroweak SSB) while D_{RR} mainly measures the mass of the b-quark and D_{LR} of the τ-lepton. There are also Heisenberg interactions in the system (related to the masses of the second family), but their couplings are all $\leq D_{LR}$.

Note that one has here a ‘quadratic’ type of DMI enforced by applying Moriya’s rules[5, 6] to the tetrahedral isospin configuration, and in contrast to the ‘linear DMI’ form $\vec{D}_{ij}(\vec{Q}_i \times \vec{Q}_j)$ usually encountered. In contrast to the linear DMI, the quadratic DMI effectively is $\sim (\vec{Q}_i\vec{Q}_j)^2 - (\vec{Q}_i)^2(\vec{Q}_j)^2$ and thus a non-chiral interaction, which means there is no apriori preference of the all-out configuration (which is left-handed) over the right-handed all-in configuration from the side of the Hamiltonian, but the choice of the all-out over the all-in configuration must be due to a SSB. For more details see the section on chirality below.

Another important point is that the sum excludes $i = j$, i.e. interactions of the tetron wave function with itself are not allowed. This is important, because otherwise the interaction $\sim (\vec{Q}_{Li} \times \vec{Q}_{Ri})^2$, which drives $\vec{Q}_{Li}$ and $\vec{Q}_{Ri}$ away from each other, would prevent the alignment of the $\vec{Q}_L$ and $\vec{Q}_R$ isospin structures.

As quantified in [1], the masses of the third family roughly correspond to the values of the DMI couplings

$$D_{LL} \approx m_t \qquad D_{LR} \approx m_\tau \qquad D_{RR} \approx m_b \tag{5}$$

Due to the 'induced ordering' described in the next section, D_{LL} is the driving force of the SSB in the system[1] and stabilizes the 2 aligned tetrahedrons in the unit cell more than a normal Heisenberg interaction could ever do. The point is that each corner of the tetrahedron has 3 neighboring edges. If $(\vec{Q}_i \times \vec{Q}_j)^2$ is maximized (i.e. H_{DMI} minimized), every spin tries to stand perpendicular to its 3 neighbors. The only configuation in the 3D spaces defined by Q_L and Q_R, that simultaneously optimzes this 'perpendicularity' condition, for all 4 corners of a tetrahedron, is the all-out ground state.

So the secret of the DMI alignment is, that it does not - like the Heisenberg interaction - favor parallel or anti-parallel configurations, but maximal orthogonality in all components, thus minimizing global frustration of the whole system of tetrahedrons. Since the DMI is quadratic (proportional to the sine squared of the angle between the 2 vectors), the restoring force for small deviations is particularly large making the ground state isospin tetrahedrons extremely rigid structures.

Induced Ordering

One might think that the SSB works in such a way that the $\vec{Q}_L$ lock into their tetrahedrons first, namely at temperatures D_{LL}, while the lock-in of the $\vec{Q}_R$ takes place at lower temperature D_{RR}, and the alignment between the $\vec{Q}_L$ and $\vec{Q}_R$ tetrahedron takes place only at temperatures D_{LR}. However due to the phenomenon of induced ordering[12] this is not the case, and in fact the whole process takes place at $D_{LL} = O(E_F)$.

The reason for that is that the large value of D_{LL} corresponds to a potential well so

[1]It is assumed that the intra-cell DMI coupling strengths are identical to next-neighbor inter-cell couplings.

steep that after formation of the $\vec{Q}_L$ tetrahedrons the secondary degrees of freedom are forced to align into this structure, even though by themselves they would freeze out only at much lower temperature.

Role of the $O(4)$ Symmetry Breaking in the Intracell Ordering Process

As before, we are assuming an unresolvable spatial lattice, defining a 3+1D Lorentz symmetry on the monolayer, and a system of isospin vectors pointing all-out into the 4 extra dimensions. These correspond to an $\mathbb{R}^4$ isospin space, which is spanned by vectors of the form $(\phi_1, \phi_2, \phi_3, \phi_4)$.

It may be noted that these 4 d.o.f. can be interpreted as 4 isospin excitations. It is true that in the ground state they look like static coordinates. However, in quantum field theory, they are fields, i.e. functions of space and time, each coordinate corresponding to a specific combination of isospin displacements at the vertices of the tetrahedron.

If these displacements oscillate in time, they describe excitations and in fact quasi particle fields in the physical base space (the monolayer), and since the isospin system as a whole is elastic with stiffness D_{LL}, these local oscillations propagate as a wave. In quantum mechanics, every such wave is a particle.

Any such local excitation means one is adding energy to the system. The ground state is given by

$$\langle(\phi_1, \phi_2, \phi_3, \phi_4)\rangle = (0, 0, 0, v) \tag{6}$$

and if one, for example, changes the value of the modulus

$$|\vec{\Phi}|^2 = \phi_1^2 + \phi_2^2 + \phi_3^2 + \phi_4^2 \tag{7}$$

of the vector, one creates a Higgs particle. On the other hand, if one displaces the field in the direction of $\phi_{1,2,3}$, i.e twists Q_L against Q_R, one creates angular fluctuations corresponding to a triplet particle.

In a more detailed manner, the complex Higgs doublet of the SM can be written as built up from these 4 fields according to

$$\Phi = \frac{1}{\sqrt{2}} \begin{pmatrix} \phi_1 + i\phi_2 \\ \phi_3 + i\phi_4 \end{pmatrix} \tag{8}$$

with its potential

$$V = -\frac{1}{2}\mu^2|\vec{\Phi}|^2 + \frac{\lambda}{4}|\vec{\Phi}|^4 \tag{9}$$

showing an obvious global O(4) symmetry.

Note that since the Higgs particle is a vibration of the $O(4)$ symmetric length (7), this oscillation is absolutely consistent with this symmetry. It is 'massive' because the system has an energetically preferred length v, the vacuum expectation value of $|\vec{\Phi}|$. Physically this expectation value can be traced back to the length of the isospins in their ground state $\langle\vec{Q}_L\rangle = \langle\vec{Q}_R\rangle$, and to the strength of the order inducing exchange coupling D_{LL} according to $v = D_{LL}|\langle\vec{Q}_L\rangle|$.

As elaborated in [1], the fields in the Higgs doublet as well as the gauge bosons are combined excitations of 2 neighboring unit cells. While the modes $\phi_{1,2,3}$ (and correspondingly the W bosons) describe angular excitations, the Higgs particle is an oscillation of the 'thickness' of the 4D 'wall' between adjacent cells. It changes the scalar value of the bond between cell A and cell B, and is blind to the direction in 4D space because it only modulates the intensity of the isospin transfer[2].

After the formation of the 2 rigid $\vec{Q}_L$ and $\vec{Q}_R$ tetrahedrons, the $O(4) = SO(3)_L \times SO(3)_R$ transformations emerge from their independent rotatabilites. Under this interpretation one can unravel the two $SO(3)$ groups in the following way:
-First, the 'axial' $SO(3)_A$ where the $\vec{Q}_{Li}$, i=1-4, of the Q_L tetrahedron are rotated opposite to the $\vec{Q}_{Ri}$. This is the symmetry broken by the electroweak interaction.
-And secondly, the diagonal or 'custodial' $SO(3)_V$ of joint identical rotations, i.e. where $\vec{Q}_{Li}$ and $\vec{Q}_{Ri}$ are rotated together by the same angle.

The former corresponds to the symmetry under rotations in the 14, 24, and 34 planes. This is broken when the 2 tetrahedrons lock in (both on the intra- and inter-cell level) and leads to the three would-be Goldstones ϕ_1, ϕ_2 and ϕ_3 in the Higgs doublet. The latter corresponds to rotations in the 12, 13, and 23 planes and is a true symmetry of each unit cell under rotations of isospin space and even remains a symmetry when one the considers the entirety of all unit cells after the SSB, i.e. after the all-out configurations of all unit cells have aligned.

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[2]The photon, for comparison, is the zero mode of the 4D rotation, in the sense that there is a specific combination of the $SU(2)_L$ and $SU(2)_R$ generators that leaves the isospin vector untouched and only shifts a global phase.

The dominance of the quadratic DMI has an important consequence for the ϕ fields. It means the potential does not have a linear term but a quadratic one - exactly what is needed for the SM Higgs potential: a potential that punishes any deviation from the all-out ground state $|\vec{\Phi}| = v$ regardless which of the 3 triplet directions $\phi_{1,2,3}$ the excitation takes.

In summary, rotations $\vec{Q}_{L,i}$ relative to $\vec{Q}_{R,i}$ have a chiral axial character, formally described by a Γ_5 factor, and correspond to rotations in the 14, 24, 34 planes. By twisting $\vec{Q}_{L,i}$ against $\vec{Q}_{R,i}$, one generates the three degrees of freedom ϕ_1, ϕ_2, ϕ_3 that appear as massless Goldstone bosons ('pions') in the $O(4)$ sigma model underlying the Higgs sector of the Standard Model. These modes are 'optical' inter cell excitation, i.e. they describe the relative displacement of the L and R subsystems. Since this displacement acts against the large D_{LL} coupling, these form a triplet to be identified as Fermi scale large mass particles (being 'eaten' by the corresponding gauge bosons).

On the other hand the joint isovectorial rotations of $\vec{Q}_{L,i}$ and $\vec{Q}_{R,i}$ form the custodial $SO(3)$ and correspond to rotations of the 12, 13 and 23 planes. Since they rotate $\vec{Q}_{L,i}$ and $\vec{Q}_{R,i}$ to the same extent, their relative orientation is preserved.
-For a single all-out cell (i.e. *locally*) this is an exact symmetry of the Hamiltonian. The cell does not notice if it is rigidly rotated as a whole.
-Even for the system of all aligned cells (i.e. *globally*) it remains an exact symmetry as long as the Planck spatial lattice is unresolvable. What happens when the Planck lattice structure is resolved, will be desribed in the section about neutrino masses.

Chirality of the Weak Interaction

Since they are angular momenta, the isospins $\vec{Q}_L$ and $\vec{Q}_R$ are pseudo-vectors and the symmetry of a tetrahedron formed by these vectors is described not by the ordinary tetrahedral point group T_d or A_4 but by a Shubnikov group[13, 14].

While T_d has no handedness, the Shubnikov point group for the all-out system under consideration possesses a fixed (let's say left) internal handedness, the state with opposite handedness being the all-in configuration. As discussed in the section on the quadratic DMI, the left-handed all-out configuration is a result of spontaneous breaking of parity. This handedness is on top of the chiralities of Q_L and Q_R and induces a preference for left chirality. As seen below, it provides a coherent environment for left-handed fermionic waves.

More in detail, one must take into account 3 levels of chirality:
-Internal isospin: The algebraic definition of $\vec{Q}_L$ and $\vec{Q}_R$ via the particle/antiparticle components of the $SO(7,1)$-Spinors.
-Vacuum structure: The geometric left-handedness of the all-out tetrahedron, chosen by the spontaneous symmetry breaking.
-Base-space propagation: The helicity of the excitation (e.g. the electron) as it moves through the 3D monolayer.

When a fermion wave propagates through the spatially irresolvable monolayer with its left-handed geometric structure, it provides a coherent environment for left-handed fermionic waves.

Conversely, a right-handed fermion attempts to induce an isospin flux that runs against the grain of the monolayer's spontaneously chosen chirality. It attempts to induce an isospin flux that opposes the spontaneously selected (all-out) handedness of the monolayer. In the effective field theory (continuum limit), this results in coupling constants g_R for right-handed fields vanishing due to destructive interference with the chiral isospin lattice structure and provides the explanation for maximal parity violation in the weak interactions. In the effective field theory of the monolayer, the coupling g_{eff} between the electron current and a W boson is determined by an integral over the internal geometry of the isospin cell. Since the mediator particles (the W bosons) are themselves only excitations of the left-handed vacuum structure, they do not change the vanishing of g_R.

One can decompose any fermionic excitation f = '$\delta\vec{Q}$' in the base space into its chiral components: $f = f_L + f_R$. Since the phase of the wavefunction in the base space is coupled to the rotation in isospin space, the wavefunctions contain phase factors that describe the rotation during propagation:
-Left-handed: $f_L \sim e^{i(kx-\omega t)} \cdot \chi_L(\xi)$
-Right-handed: $f_R \sim e^{i(kx-\omega t)} \cdot \chi_R(\xi)$
where x is the coordinate in physical space and ξ in the extra dimensions. The internal part $\chi(\xi)$ must reflect the tetrahedral symmetry. Since the all-out state has spontaneously chosen a left-handedness, the background contribution $\mathcal{M}_{ao}$ to the integral possesses a fixed winding number (helical structure) in the internal space:

$\mathcal{M}_{ao}(\xi) \sim e^{i\Phi_{ao}(\xi)}$.

Now consider the left-handed case (constructive interference): The coupling to the internal structure is defined such that its chiral phase θ_L runs in parallel with the phase of the vacuum Φ_{ao}:

$$g_L \sim \int d^4\xi \, e^{-i\theta_L(\xi)} \cdot e^{i\Phi_{ao}(\xi)} \approx \int d^4\xi \, e^{i(\Phi_{ao}-\theta_L)} \tag{10}$$

Since $\theta_L \approx \Phi_{ao}$ (resonance), the phase difference is close to zero. The integrand is nearly a constant 1, and the integral yields a large, finite value. The left-handed fermion 'locks' into the all-out structure.

On the other hand for the right-handed component f_R in the base space, the internal phase θ_R is inverted relative to the tetrahedral winding due to the opposite helicity in the base space:

$$g_R \sim \int d^4\xi \, e^{-i\theta_R(\xi)} \cdot e^{i\Phi_{ao}(\xi)} \tag{11}$$

Since θ_R runs 'against the grain' of Φ_{ao} (e.g. $\theta_R = -\Phi_{ao}$), the phases add up to a rapidly oscillating function:

$$g_R \sim \int d^4\xi \, e^{i(2\Phi_{ao})} \tag{12}$$

When averaged over the volume of the cell, these oscillations cancel each other out (destructive interference).

Neutrino Masses

In [1] neutrino masses have been parametrized in terms of (unknown) tiny isospin violating couplings. Here I want to describe in more physical terms how this violation can be traced back to the exchange of isospin between the system of isospin vectors and the underlying spatial Planck lattice. On the dynamical side this exchange ultimately is due to a (so far unspecified) isospin-orbit coupling between the isospins tetrahedron and the spatial Planck lattice. However, as shown below, the smallness of neutrino masses can be understood without specific assumptions on the dynamics, just from symmetry arguments, in terms of E_F and E_p, thus going beyond the mere parametrization given in [1].

Among the 24 excitations within the tetrahedral unit cell, neutrinos essentially correspond to the 'acoustic' modes ($\sim \vec{Q}_L + \vec{Q}_R$) where the isospin cell (and even the aggregate of all cells) rotationally vibrates as a whole. Within the continuum limit $L_p = 0$ considered so far, any acoustic isospin mode has vanishing mass, because in a perfectly continuous medium, the custodial $SO(3)$ symmetry (where $\vec{Q}_L$ and $\vec{Q}_R$ rotate together) is a global symmetry. Goldstone's theorem applies here: If one rotates the entire universe's isospin configuration by the same angle, the energy does not change. Result: The excitations corresponding to these rotations must be massless. They are pure Goldstone bosons.

We distinguish here between
-the *local* $SO(3)$ symmetry when $\vec{Q}_L$ and $\vec{Q}_R$ lock in to form an aligned inner- and intra-cell tetrahedral structure, corresponding to the pseudospin and axial transformations discussed above, and
-the *global* custodial $SO(3)$ which is vectorial and corresponds to a free rotatability of the full block structure of all aligned tetrahedrons.
While the former can be gauged with all the consequences we know from the SM (Higgs mechanism, generation of masses, appearance of gauge bosons etc), the latter remains unbroken as long as the Planck lattice remains unresolvable.

One may wonder how neutrinos can act as Goldstone bosons in isospin space, while remaining fermions in the physical base space. Well, regarding the isospin symmetry, a neutrino is a collective excitation of the vacuum's tetrahedral orientation - making it effectively a Goldstone boson of the broken isospin symmetry. On the other hand, since it is a discrete, quantized excitation of a single cell's internal degrees of freedom, it obeys Fermi-Dirac statistics in the $3 + 1$ dimensions of the monolayer base space (just as all the other quarks and leptons).

Only when resolving the spatial lattice and accounting for the discreteness and spatial orientation of the system, neutrinos get a mass. One then has to acknowledge that the isospins are not just floating in a vacuum; they are sitting on specific sites in a *spatially* discrete grid of tetrahedrons with defined spatial axes. In the all-out configuration, the isospins are pointing along these axes. If one now tries to rotate the Q_L/Q_R pair together, one is rotating them relative to those spatial axes, and because of the quadratic DMI, the spins want to point in the specific all-out directions defined by the Planck lattice.

This is a tiny explicit breaking of the custodial $SO(3)$ symmetry due to the lattice geometry providing an explicit preference for certain directions, and it gives the τ neutrino a mass

$$m(\nu_\tau) = D_{LL}\sqrt{\frac{D_{LL}}{E_p}} \tag{13}$$

with the DMI coupling D_{LL} to be identified with the Fermi scale E_F as explained in the previous sections.

Eq. (13) fits better to the phenomenological result[3] of $m_\nu \approx 0.05...0.4$ eV than the usual result from the seasaw[18] mechanism $m_\nu = E_F^2/E_p$ or $m_\nu = E_F^2/E_{GUT}$.

The square root in (13) acts as a dimensionless scaling factor (or 'attenuation factor') that describes how much of the SSB energy is felt by the long-wavelength acoustic mode. Essentially it corresponds to the square root of k over m which one encounters for the freqency of an harmonic oscillator where the restoring force k corresponds to the stiffness D_{LL} provided by the quadratic DMI. It wants to pull the spins back to the all-out orientation, while the inertia m of the field is related to the 'stiffness' E_p induced by the spatial lattice.

The masses of the other 2 neutrinos can be obtained by scaling down D_{LL} to the Heisenberg and torsional couplings responsible for the masses of the first and second family[1].

Remarks on Planck Scale Physics

It is often stated that at the Planck scale, physical processes can no longer be described by reasonable means due to quantum fluctuations. It is further argued that if the curvature of spacetime is concentrated at a scale as small as L_p, the energy becomes so intense that space dissolves into 'quantum foam'[19], causing causality and geometry to lose their meaning.

However, here we have a model where interactions down to the Planck scale are described using standard kind of laws. For example, the interaction of the isospin vectors obey the quantum mechanical laws of angular momentum and the gravitational force is a classical elastic interaction between the tetrahedral cells, even without need for quantization.

[3]There is an upper bound for the mass of the heaviest neutrino of 0.45 eV from the Katrin experiment[16], and a lower bound of 0.05 eV from neutrino oscillations[17].

This is possible, because in the present model the Planck scale is not the point of chaos but of highest order. In standard QFT, problems arise because space is assumed to be continuous. This leads to mathematical infinities (divergences) because wavelengths are allowed down to zero. In my model, the tetrahedral cell serves as a natural cut-off, protecting the system from singularities. Quantum fluctuations do not destroy geometry; they are merely vibrational modes of the lattice.

Attempts to quantize gravity are very awkward[20]. In my model, gravity is a classical elastic force between cells introducing curvature in the otherwise flat monolayer, similar to sound waves in a crystal. A sound field obeys classical wave equations, even if the individual atoms are quantum mechanical. Curvature thus is the mechanical stress among the cells. This explains why gravity is so difficult to reconcile with the quantum mechanics of particles: they operate on entirely different hierarchical levels.

Quantum mechanics is applied where it belongs: to the internal degrees of freedom (the isospin angular momenta). When two adjacent cells A and B interact, they exchange angular momentum. Since angular momentum is quantized in units of h, the standard laws of quantum mechanics emerge naturally from the discrete nature of the tetrahedral vertices. The quantum fluctuations at the Planck scale are nothing more than the zero-point oscillations of the isospin vectors. Instead of making the system indescribable, they merely define the vacuum noise of particle excitations.

Conclusions

In this work the emergence of the Standard Model symmetries from a discrete, unresolvable spacetime lattice was described where the physical $3+1$ dimensional world is an effective monolayer medium of tiny tetrahedrons with isospin energies E_F and spatial binding energies E_p.

In the model, the 24 fundamental fermions (leptons and quarks) emerge as localized vibrational modes of $SO(7,1)$ spinors within a single cell, while gauge bosons and the Higgs field are identified as collective excitations spanning adjacent cells. Spontaneous symmetry breaking of a quadratic Dzyaloshinskii-Moriya Interaction (DMI) induces an ‘all-out’ tetrahedral orientation, establishing a chiral vacuum. This geometry naturally explains the observed maximal parity violation of the weak interactions, as well as the mass hierarchy between quarks and leptons, and between the Fermi and Planck scales.

The monolayer model provides a micro-geometric origin to the Higgs mechanism of the Standard Model. By grounding electroweak phenomena in the discrete isospin geometry of an unresolvable Planck-scale lattice, the model offers intuitive solutions to long-standing problems:
-Mass generation: the Higgs doublet emerges as a bi-local excitation between adjacent cells, and fermion masses are determined by their coupling to the isospin tetrahedral order.
-Neutrino physics: neutrinos are identified as acoustic modes of the isospin lattice. Their infinitesimal masses follow a natural hierarchy scaling as $M_\nu \approx D_{LL}\sqrt{D_{LL}/E_p}$, explaining their suppression relative to the electroweak scale without requiring a traditional see-saw mechanism.
-Parity: the inherent handedness of the isospin lattice vacuum provides a geometric origin for parity violation, establishing a direct link between the topology of the unresolvable lattice and the observed chiral nature of weak interactions. More precisely, the all-out tetrahedral order acts as a chiral filter, providing a dynamical reason why right-handed fermions remain sterile to the isospin flux.

The framework suggests that the Standard Model is the effective continuum limit of a 'fluid crystal' of isospin vectors on an unresolvable Planckian grid. Future work will extend this geometric approach to reconcile the discrete tetrahedral symmetry with the continuous gauge groups of the strong interaction, potentially uncovering the dynamical origin of the strong interaction scale.

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