Knot physics: Neutrino helicity

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Abstract

We use the assumptions of knot physics to prove that a collection of interacting neutrinos and antineutrinos maximize their quantum probability when all neutrinos are of the same helicity and all antineutrinos are of the opposite helicity. In a previous paper we showed that the geometry of gravity spontaneously breaks symmetry. We show here that the geometry of gravity couples the neutrino linear momentum to its quantum phase. Likewise, the quantum phase of an interacting neutrino couples to its spin angular momentum. Therefore, the symmetry breaking of gravity couples the linear momentum of an interacting neutrino to its spin angular momentum, producing consistent helicity.

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This is a work in progress that requires updates for clarity and content.

I. INTRODUCTION

This paper will use many of the assumptions from the paper "Physics on a Branched Knotted Spacetime Manifold" [1] (available at **www.knotphysics.net**), which is necessary background reading. In particular, we show in that paper that gravity spontaneously breaks symmetry. We show in this paper how that spontaneous symmetry breaking produces the symmetry breaking of neutrino helicity.

Neutrinos have topology $\mathbb{R}^3\#(S^1 \times P^2)$. Their spin angular momentum comes from waves that travel in the direction of the S^1 fiber. For two neutrinos passing by each other, Lorentz transformations change the shape of the waves relative to the neutrino passing in the opposite direction. When neutrinos pass by each other, the geometry of their waves interacts either constructively or destructively. We show that the constructive interaction occurs when neutrino/neutrino and anti-neutrino/anti-neutrino interactions have the same helicity, and that the destructive interaction occurs when the neutrino/anti-neutrino interactions have the same helicity. Therefore, for a collection of interacting neutrinos and anti-neutrinos there are two stable states. Either all neutrinos have left-handed helicity and all anti-neutrinos are opposite or else all neutrinos have right-handed helicity and all anti-neutrinos are opposite.

II. NEUTRINO HELICITY

We first show that gravity couples the neutrino's linear momentum to its quantum phase. Then we show that neutrino interactions couple the spin angular momentum of the neutrino to its quantum phase. Because of those couplings, a fixed relationship between the neutrino linear momentum and spin angular momentum optimizes the quantum probability of a collection of interacting neutrinos.

In this paper we will assume that the A^ν field has the form $A^\nu = x^\nu + \varepsilon^\nu$ for small ε^ν. We also assume that the manifold geometry is of the form $(x^0, x^1, x^2, x^3, f^4, f^5)$ for functions f^4 and f^5 that depend on x^0, x^1, x^2, x^3, which is to say that the manifold is mostly flat with some displacement into the x^4 and x^5 directions.

A. Gravity couples linear momentum to quantum phase

Far from particles, the geometry of M is dominated by gravitational effects, and we will describe the geometry of M as $(x^0, x^1, x^2, x^3, b\sin(y), b\cos(y))$ for some scalars b and y that are functions of x^0, x^1, x^2, x^3. We will use y to show the relation between gravitational rotation, spin angular momentum, and quantum phase.

Gravity breaks parity. If there is no electromagnetic field, then we will set the gauge $A^\nu = x^\nu$ and gravitational rotation is of the form $(x^0, x^1, x^2, x^3, b\sin(k^\nu x_\nu), b\cos(k^\nu x_\nu))$ for a causal vector field k^ν. We showed in [1] that gravity spontaneously breaks symmetry such that the direction of rotation is the same everywhere. In other words, the sign of k^0 is the same everywhere. If there is an electromagnetic field, the A^ν field does not satisfy $A^\nu = x^\nu$. We recall from [1] that the manifold is constrained via the metric $g_{\mu\nu} = \rho^2 A_{\alpha,\mu} A^\alpha{}_{,\nu}$. We therefore use A^ν rather than x^ν to determine the form of the rotation, which we write $(x^0, x^1, x^2, x^3, b\sin(k^\nu A_\nu), b\cos(k^\nu A_\nu))$. Using the variable y to describe the rotation, we can therefore describe the gravitational rotation as $y = k^\nu A_\nu$.

We use a map from 3 dimensions to 5 dimensions to describe an elementary fermion $\mathbb{R}^3\#(S^1 \times P^2)$. The coordinates of the 3-space are toroidal coordinates (τ, σ, ϕ) and the coordinates of the 5-space are a mix of toroidal and Cartesian coordinates $(\tau, \sigma, \phi, x^4, x^5)$. If we denote by T the solid torus $\tau > 1$, then we can map from $\mathbb{R}^3 - T$ to $\mathbb{R}^5$,

$$X(\tau, \sigma, \phi) = \Big(\frac{\tau}{1-\tau}, \sigma, \phi, \tau\sin(2\sigma), \tau\cos(2\sigma)\Big) \tag{1}$$

Including the time coordinate and the quantum phase rotation of the particle we have

$$X(t, \tau, \sigma, \phi) = \Big(\frac{\tau}{1-\tau}, \sigma, \phi, \tau\sin(2\sigma + \omega t), \tau\cos(2\sigma + \omega t)\Big) \tag{2}$$

which means that $y = 2\sigma + \omega t$ close to the particle, ignoring the gravitational background. The knot can also have opposite σ orientation:

$$X(t, \tau, \sigma, \phi) = \Big(\frac{\tau}{1-\tau}, \sigma, \phi, \tau\sin(-2\sigma + \omega t), \tau\cos(-2\sigma + \omega t)\Big) \tag{3}$$

which means that $y = -2\sigma + \omega t$ close to the particle, ignoring the gravitational background.

Neutrinos are created by an interaction that involves a W boson and a charged lepton. The W boson, in this theory, is an intermediate geometry that produces one of two results.

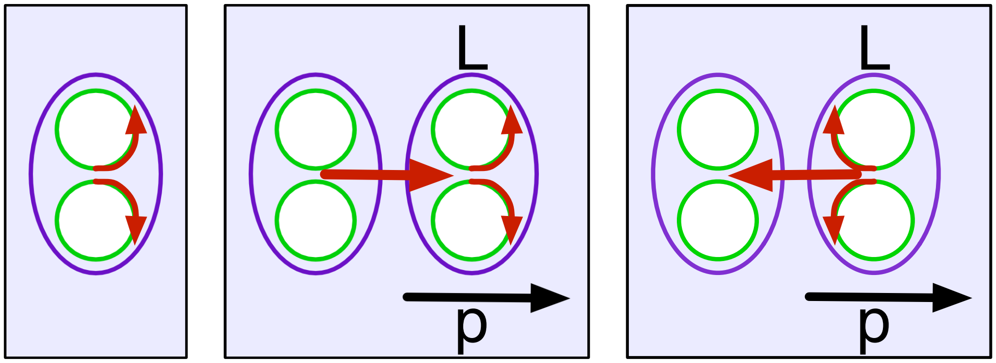

FIG. 1: The diagrams show constant ϕ slices of $\mathbb{R}^3\#(S^1 \times P^2)$. The red arrows are $\partial^\mu y$. The left diagram shows $\partial^\mu y$ on a $\mathbb{R}^3\#(S^1 \times P^2)$, in the $+\sigma$ direction. The other two diagrams show a lepton L becoming a neutrino. The lepton transfers charge to another $S^1 \times P^2$. The transfer of charge gives L momentum p in the opposite direction. Gravity produces a background rotation, with $\partial^\mu y = \partial^\mu(k_\nu A^\nu)$. The charges on each $S^1 \times P^2$ determine the direction of the spacelike components of $\partial^\mu(k_\nu A^\nu)$, which either point towards L (middle diagram) or away from L (right diagram). The vector field $\partial^\mu y$ must be consistent, therefore the direction of $\partial^\mu(k_\nu A^\nu)$ must match the direction of the $+\sigma$ (middle diagram) or $-\sigma$ (right diagram) arrows on L. The sign of the charge transfer determines whether the resulting particle is a neutrino or antineutrino. The sign of the charge transfer also determines the direction of the spacelike components of $\partial^\mu(k_\nu A^\nu)$. Therefore the relation between quantum phase σ and the linear momentum p for neutrinos is opposite to that of antineutrinos. Beginning with a neutrino L and producing a charged lepton would reverse the direction of p in the diagram.

The first possibility is that the W boson transfers charge away from a charged lepton to produce a neutrino. The second possibility is that the W boson produces a neutrino and a corresponding anti-lepton. In both cases, there is an electric field gradient at the creation of the neutrino, and we can treat both cases as equivalent for the purposes of this discussion. In Fig. 1 we see the relationship between the electric field and the neutrino geometry. At creation, $y = k_\nu A^\nu$ must be consistent with $y = +2\sigma + \omega t$ or $y = -2\sigma + \omega t$. At the neutrino creation, the $A^{0,\mu}$ field is lightlike, which determines whether the spacelike components of the vector $\partial^\mu y = \partial^\mu(k_\nu A^\nu)$ point towards the neutrino or away from it. Therefore, the sign of the charges determines whether the $\mathbb{R}^3\#(S^1 \times P^2)$ orientation is $+\sigma$ or $-\sigma$. The linear momentum of the neutrino is equal and opposite to the momentum that results from the interaction with W boson. Therefore the field at the neutrino creation determines the relationship between the neutrino's linear momentum and quantum phase. The charge that produces a neutrino is opposite to that of an antineutrino, therefore the relationship between linear momentum and quantum phase is also opposite.

B. Neutrino interaction couples spin angular momentum to quantum phase

Neutrinos have a large S^1 radius (see [1]) of about 10^{-6}m, are abundant, and travel at relativistic velocities. Therefore the neutrino/neutrino interactions are frequent, as in Fig. 2 where we see a pair of neutrinos interacting such that one neutrino passes through the center of the other. As the neutrinos pass by each other, their geometry interacts. The geometric interaction can either increase the quantum amplitude of the neutrinos or decrease it. The quantum amplitude determines the probability and we find that the neutrinos will tend towards the behavior that maximizes their quantum amplitude, and therefore maximizes probability. In the left diagram of Fig. 3 we see a neutrino and an antineutrino passing by each other. The red arrows again indicate the direction of increasing y corresponding to the term $+\sigma$ or $-\sigma$ in the eqns. (2) and (3). The red arrows have opposite direction, which implies that the neutrino and antineutrino contribute oppositely to $\partial^\mu y$, and therefore the geometric interaction reduces their quantum amplitudes as they pass by each other. In the right diagram of Fig. 3 we see a pair of neutrinos (or, equivalently, antineutrinos) passing by each other. We see that, in this case, the red arrows are aligned and contribute positively to each other in a way that increases the quantum amplitude of each of the neutrinos as they pass by each other. While this result is interesting, we will need an additional step to describe how the spin angular momentum of the interacting neutrinos influences the quantum amplitude.

First, we note the way that random contributions to the quantum amplitude affect probability. Suppose we have a map of the form

$$X(t,\tau,\sigma,\phi) = \Big(\frac{\tau}{1-\tau},\sigma,\phi,(1+f(\phi))\tau\sin(2\sigma+\omega t),(1+f(\phi))\tau\cos(2\sigma+\omega t)\Big) \tag{4}$$

with some random continuous function f that has $E[f]=0$ and small variance. Then we note that the quantum probability is of the form

$$P = \exp\Big(\int_0^{2\pi} \ln(1+f(\phi))^2)\,\mathrm{d}\phi\Big) \tag{5}$$

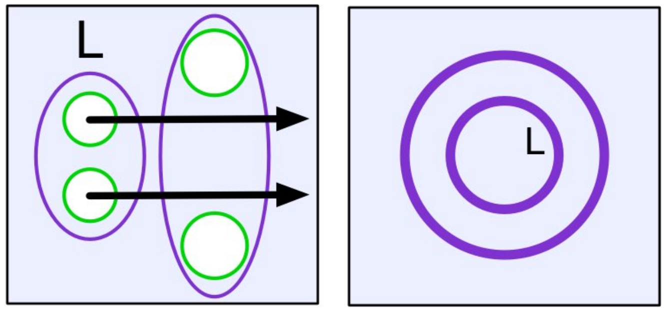

FIG. 2: The left diagram shows a constant ϕ slice of one neutrino passing through another one. The right diagram shows the same pass-through in a constant σ slice. Because of the large S^1 radius of neutrinos (see [1]) and the abundance of neutrinos, these pass-throughs are common.

The logarithm ln is a convex function, and therefore increasing the variance of $f(\phi)$ reduces the expected value of the integral. The spin angular momentum of a neutrino is the result of waves that circulate around the S^1 fiber of the particle. The map that includes spin angular momentum has the form

$$X(t,\tau,\sigma,\phi) = \Big(\frac{\tau}{1-\tau}, \sigma, \phi, (1+f(\phi-vt))\tau\sin(2\sigma+\omega t), (1+f(\phi-vt))\tau\cos(2\sigma+\omega t)\Big) \quad (6)$$

In this map, the random contribution to the particle amplitude is a wave of the form $1+f(\phi-vt)$ that circulates around the particle with velocity v. This is the geometry of the spin angular momentum in the rest frame of the particle. To describe the geometric interaction of two neutrinos that pass by each other, we shift to the center of mass frame. The corresponding Lorentz transformation changes the shape of the circulating waves. An equivalent way of saying this is that the Lorentz transformation is the result of the velocity of the neutrino as well as the velocity of the wave $f(\phi-vt)$ that produces its spin angular momentum.

In Fig. 4 we see two different cases of neutrinos passing by each other. In each case, we choose the directions of spin angular momenta that will maximize the quantum probability. In the left diagram, we see the case where a neutrino and antineutrino pass by each other. The red arrows are oppositely aligned and we can reduce the destructive interference by maximizing the random contribution from spin angular momentum. This is accomplished when the helicities of the neutrino and antineutrino are opposite. In the right diagram, we see the case where two neutrinos (or, equivalently, two antineutrinos) pass by each other. The red arrows are aligned and we maintain the constructive interference by minimizing the variance from the spin angular momentum contribution. This is accomplished when the helicities of the neutrinos are the same.

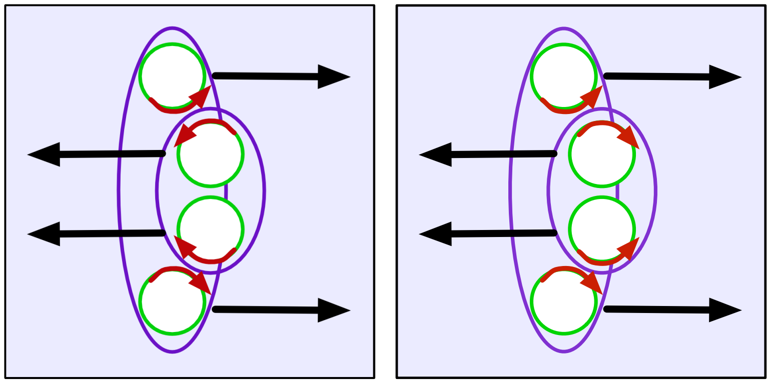

FIG. 3: The diagrams show constant ϕ slices of one neutrino passing through another neutrino. The red arrows are $\partial^\mu y$. As above, they indicate the σ orientation of the P^2. The quantum phase amplitude is maximized when the red arrows point in the same direction at the point where the P^2 slices are closest. That happens when both are neutrinos or both are antineutrinos.

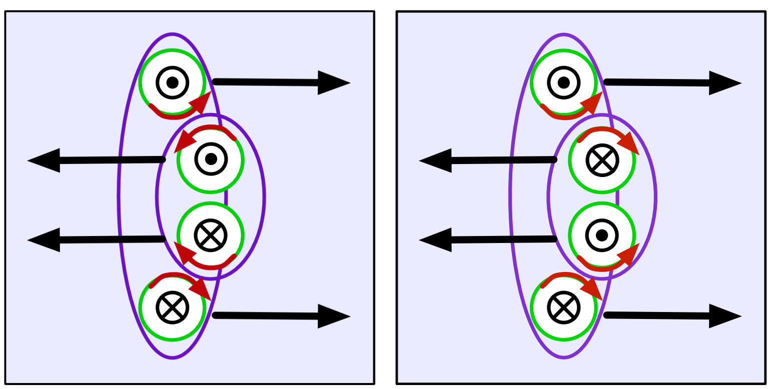

FIG. 4: The diagrams show constant ϕ slices of one neutrino passing through another neutrino with vectors indicating their spin angular momenta. The red arrows are $\partial^\mu y$. The spin angular momenta are those which make the red arrows $\partial^\mu y$ as consistent as possible after Lorentz transformation. On the left is a neutrino/antineutrino interaction; the spin angular momenta reduce the opposition of the vector $\partial^\mu y$. On the right is a neutrino/neutrino interaction; the spin angular momenta preserve the alignment of the vector $\partial^\mu y$ after Lorentz transformation. The helicity for neutrinos is the same. The helicity for antineutrinos is the same. The helicity of neutrinos is opposite to the helicity of antineutrinos.

III. BARYON ASYMMETRY

The distinction between neutrinos and antineutrinos is the consequence of two spontaneously broken symmetries. The first symmetry is the parity breaking of the gravitational background rotation. The second symmetry is the spin angular momenta of neutrinos and antineutrinos. If, in the early universe, these symmetries were unbroken, then the production of neutrinos and antineutrinos would have had random quantum phase and spin angular momenta. After symmetry breaking, there would be some number of neutrinos and antineutrinos but no reason to assume that those numbers would be exactly equal. It is reasonable to expect that one type would have a slight excess that would lead to excess matter in the universe.

IV. CONCLUSION

In knot physics, neutrinos are an uncharged $\mathbb{R}^3\#(S^1 \times P^2)$. The way in which neutrinos are produced creates a coupling between their quantum phase and their linear momentum. Interactions between neutrinos causes a coupling between their quantum phases and their spin angular momentum. The effect of these geometric relationships is that neutrinos are more likely to have one consistent helicity and antineutrinos are more likely to have the opposite helicity.

[1] C. Ellgen **www.knotphysics.net** Physics on a Branched Knotted Spacetime Manifold