Abstract
The Standard Model (SM) is a successful approach to particle physics calculations. However, there are indications that the SM is only a good approximation to an underlying non-local reality involving fundamental entities (preons) that are not point particles. Furthermore, our universe seems to be dominated by a vacuum energy/cosmological constant. The holographic principle then indicates only a finite number of bits of information will ever be available to describe the observable universe, and that requires a holographic preon model linking the (0,1) holographic bits to SM particles. All SM particles have charges 0, 1/3, 2/3 or 1 in units of the electron charge $\pm e$, so the bits in a holographic preon model must be identified with fractional electric charge. Such holographic charged preon models require baryon asymmetry and also suggest a mechanism for stationary action. This paper outlines a holographic charged preon model where preons are strands with finite energy density specified by bits of information identifying the charge on each end. In the model, SM particles consist of three strands with spin states corresponding to wrapped states of the strands. SM particles in this wrapped preon model can be approximated by preon bound states in non-local dynamics based on three-preon Bethe-Salpeter equations with instantaneous three-preon interactions. The model can be falsified by data from the Large Hadron Collider because it generates mass without Higgs bosons and baryon asymmetry without axions, and does not allow more than three generations of SM fermions.

Introduction
The Standard Model (SM) is a successful approach to particle physics calculations. However, there are indications that the SM is only a good approximation to an underlying finite-dimensional non-local reality involving fundamental entities that are not point particles. First, the SM is a local field theory, and (consistent with quantum mechanics) there are non-local effects in our universe [1].
Second, our universe is apparently dominated by a vacuum energy/cosmological constant. According to the holographic principle, this indicates only a finite number of bits of information will ever be available to describe the observable universe [2]. Third, energy densities of the basic SM point particles are infinite, and infinities in physical theories indicate inadequacies of those theories.

The holographic principle requires a preon model to describe SM particles in terms of the (0,1) holographic bits of information. All Standard Model particles have charges 0, 1/3, 2/3 or 1 in units of the electron charge ±e, so the bits in a preon model must be identified in some way with fractional electric charge. Also, in any physical system, energy must be transferred to change the information in a bit from one state to another. Labelling the low energy state of a bit e/3n and the high energy state by −e/3n then amounts to defining electric charge. If the universe is charge neutral, as it must be if it began by a spontaneous quantum fluctuation from nothing, there must be equal numbers of e/3n and −e/3n charges. Any holographic preon model in such a universe then embodies charge conservation, a precondition for gauge invariance and Maxwell’s equations. Furthermore, because the energy of e/3n and −e/3n bits are unequal, any such preon model requires baryon asymmetry. In a closed universe, the baryon asymmetry is readily calculated and agrees with that necessary to produce today’s matter dominance [3].

Since the holographic principle requires preons, and results in baryon asymmetry, the purpose of this paper is to show that at least one preon model can link (0,1) bits of information in a holographic model to SM particles. The model uses two ideas from Bilson-Thompson’s preon model [4], the concept that preons are strands instead of point particles, and the hint that spin results from wrapped preon strands.

**Background on holography**

The holographic principle says all information that will ever be available to any observer about physics within a horizon is given by the finite amount of information on the horizon, specified by one quarter of the horizon area in Planck units [2]. Consistent with the model in [5], the universe is dominated by vacuum energy density εv related to a cosmological constant Λ ≈ 10⁻⁵⁶cm⁻² by εv = Λc⁴/(8πG), where the gravitational constant G = 6.67 × 10⁻¹⁸cm³/g sec² and c = 3 × 10¹⁰cm/sec. Therefore, the universe is asymptotic to a de Sitter space, with an event horizon at distance RH = √Λ = 1.7 × 10²⁸cm. The holographic principle then says only N = √Λ/(4πΣ) = 5 × 10¹²² bits of information (3N degrees of freedom) will ever be available to describe the universe, where the Planck length δ = √(G/ℏ), and ℏ = 1.05 × 10⁻⁲⁷g cm²/sec. So, theories involving continuum mathematics (such as the SM) can only approximate an underlying finite-dimensional holographic theory.
Holography and non-locality

Quantum mechanics (and the reality it describes) is known to be non-local [1], but the mechanism of non-locality has remained obscure. However, a holographic quantum mechanical theory is essentially non-local if the wavefunction on the horizon (describing the evolution of all information available about the observable universe) is the boundary condition on the wavefunction describing the information distribution within the horizon. Then any quantum transition altering the wavefunction on the horizon is reflected in an instantaneous non-local change in the wavefunction describing the distribution of information within the horizon that describes all physics in the observable universe.

A holographic quantum mechanical description of the bits of information on the horizon requires wavefunctions specifying the probability distribution of those bits of information. A quantum description of the information available to describe SM particle interactions within the horizon can be obtained [6] by identifying each area (pixel) of size $4\delta^2 \ln 2$ on the horizon with one bit of information on the horizon at radius $R_H = \sqrt{\frac{3}{4}}$. A holographic preon theory must then relate the bits of information on the horizon to SM particles and their constituent preons within the horizon.

Preons with finite energy density

Infinities in a physical theory indicate inadequacies in the theory, so infinite energy densities of SM particles or preons must not occur in a reasonable holographic model. If the fundamental preon entities within the horizon are one-dimensional strands characterized by a bit of information on each end, both preons and SM particles made from them have finite energy density. Furthermore, there is a straightforward way to relate information on the horizon to information on one-dimensional strands constituting preons within the horizon, with each strand carrying a bit of information on each end.

Consider a wavefunction specified in a spherical coordinate system centered on the observer’s position. The $z$ axis of such a coordinate system pierces the $i$th pixel of area $4\delta^2 \ln 2$ on one hemisphere of the horizon and the antipodal $j$th pixel of area $4\delta^2 \ln 2$ on the opposite hemisphere of the horizon. Suppose $\theta_i$ is the polar angle measuring the angular distance from the $z$ axis through the $i$th pixel to the point on the horizon where the wavefunction is evaluated. Then wavefunctions of the form $\cos \theta_i$ on the horizon have wavelength $2\pi R_H$ and can define the probability distribution for finding the information associated with the antipodal pair of bits at any location on the horizon, with the maximum probability of finding information associated with those two bits in the two pixels where the $z$ axis pierces the horizon. If the $z$ axis of a wavefunction $\phi_k = \sqrt{\frac{3}{2\pi R_H}} \cos \theta_i$ is associated with the $k$th pair of antipodal bits of information $(i, j)$, state identifiers (0,0), (0,1), (1,0) or (1,1) specify the two bits of information associated with the wavefunction $\phi_k$ for any of the $N/2$ quantum states on the horizon. The wavefunction $\phi_k$ for the $k$th pair of antipodal bits of information $(i, j)$ is
then identified with the wavefunction defining the probability that the \((i, j)\) bits of information on the ends of the \(k\)th strand within the horizon lie along the axis connecting any two antipodal pixels. In an observer’s coordinate system chosen to describe all information on the horizon, a quantum state with zero in the pixel on the horizon in one radial direction and one in the antipodal pixel is not identical to a state with one in the first pixel and zero in the antipodal pixel. So, quantum states with identifiers \((1,0)\) and \((0,1)\) on the horizon (and the corresponding strands) are not identical.

**Spin and preon wrapping**

In this model, wavefunctions for quantum states on the horizon with state identifiers \((0,0)\), \((0,1)\), \((1,0)\) or \((1,1)\) are boundary conditions on wavefunctions specifying the probability of finding the ends of preon strands [with charges \((-e/6, -e/6)\), \((-e/6, e/6)\), \((e/6, -e/6)\) or \((e/6, e/6)\), respectively, on those ends] lying along any given radial axis in the observer’s coordinate system within the horizon. When the \(N/2\) wavefunctions \(\phi_k\) describing the \(N\) bits of information in the universe are transformed to the observer’s coordinate system, their sum is the wavefunction for the probability distribution of all information available on the horizon. In a closed universe, given the instantaneous probability distribution of information available on the horizon obtained from the wavefunctions \(\phi_k\), the instantaneous probability distribution of preon strands within the horizon can be determined, as explained in Appendix A.

SM particles can be represented by preon strand triads involving information in two antipodal clusters of three adjacent pixels on opposite hemispheres of the horizon, bound into SM particles by non-local three-body interactions. In this preon strand model, all SM particles have an associated direction, that of the radial axes connecting the three bit antipodal triads. Because spin zero particles have no associated direction, the model does not allow fundamental spin zero SM bosons. SM particles are identified with wrapped strand triads and different strand wrapping configurations result in the spin of SM particles. Strand configurations include: a) a straight line segment along the axis between charges, b) the open strand wrapping configurations at the top of Figure 1, with ends on the axis between charges, and c) the strand rings at the top of Figure 2, comprising open charged or closed neutral rings with the ends of the strands close together along the axis between charges. States \((0,1)\) and \((1,0)\) represent straight neutral strands with charges \((-e/6, e/6)\) or \((e/6, -e/6)\) on their ends or closed neutral rings formed by joining oppositely charged ends of open neutral strands. Note that a pair of \((-e/6, -e/6)\) and \((e/6, e/6)\) strands, with a net neutral charge, do not exist within a single SM particle because they are equivalent to a pair of \((-e/6, e/6)\) and \((e/6, -e/6)\) strands. The basic SM particles are spin \(\frac{1}{2}\) fermions, with forces between them mediated by spin 1 or spin 2 bosons. Charge and angular momentum conservation in the crossed channel requires neutral or unit charged SM bosons mediating forces between SM fermions. Two rules relate three-strand preon configurations to SM particles: 1) Spin \(\frac{1}{2}\) SM fermions are comprised of one effective right or left-handed open
strand wrap around one or two straight strands. Right-handed or left-handed wrapping corresponds to spin up or spin down. 3) SM bosons are comprised of one or more net closed rings wrapped around one or two straight strands defining the spin axis of the boson.

Wrapped preon configurations and specific SM particles
The $N$ bits of information on an observer’s horizon constitute all information available to describe physics within the four-dimensional spacetime of a closed vacuum-dominated universe. In a reasonable wrapped preon model, a set of wrapped three-strand configurations related to the $N$ bits of information on the horizon must be identified unambiguously with SM particles. However, it is not necessary that a physical particle be associated with every conceivable strand configuration. The three possible ways one open strand wrap can occur allows three generations of spin $\frac{1}{2}$ SM fermions. The three configurations, shown in Figure 1 for spin up fermions, are: a) two partial open strand wraps producing one effective full open strand wrap surrounding a central straight strand, b) an open strand wrapping one straight strand, accompanied by a "spectator" straight strand, and c) an open strand wrapping two straight strands. The effective mass of strands bound into massive SM particles with Compton wavelength $\lambda$ is of the order of $m = \frac{h}{\lambda c}$ where $h$ is Planck’s constant. Replacing various neutral strands with charged strands results in the charge states of the three generations of SM fermions. Denote neutral strands $\left(\frac{e}{6}, -\frac{e}{6}\right)$ by $A$ and neutral strands $\left(-\frac{e}{6}, \frac{e}{6}\right)$ by $B$. Then neutrinos are linear superpositions of configurations with three neutral strands ($AAA, AAB, ABB$, and $BBB$), charge $1/3$ quarks are linear superpositions of configurations with two neutral strands ($AA, AB$ or $BB$), charge $2/3$ quarks are linear superpositions of configurations with one neutral strand ($A$ or $B$) and unit charge fermions are configurations with all strands carrying the same charge. Note that two charged strands in a single SM particle do not interact electromagnetically because incoming charged strands in the cross channel of potential strand-strand electromagnetic interactions cannot combine to make the crossed channel three strand virtual photon intermediate state necessary to mediate electromagnetic interactions between two charged strands.

In this model, double open strand wraps around a single straight strand are not relevant. Two open strand wraps in the same direction around a straight strand are topologically equivalent to one open strand wrap in the opposite sense around two straight strands and do not constitute new particles. Two open strands wrapped in opposite directions around a straight strand would result in a non-physical state with no spin but with an (unphysical) preferred axis along the straight strand.

In Figure 2, spin one SM bosons are represented by one net closed ring around one or two straight strands and spin two SM bosons (gravitons) are represented by two neutral rings wrapped around one straight strand. Therefore, SM bosons in this preon model can only have spin one or two, because three rings leave no remaining straight strands. Neutral bosons involve neutral
rings and non-identical straight neutral strands, and the model allows for the spin states of all bosons that exist as independent particles outside color neutral hadrons. A neutral ring threaded through another neutral ring, with a straight neutral strand (A or B) also going through the ring, gives two photon helicity states. Two neutral rings around a straight neutral strand (A or B) gives two (general relativistic) graviton helicity states. Gluons cannot exist as independent particles outside of color neutral hadrons, and they are discussed in the next section.

As compared to the strong, electromagnetic and gravitational forces acting between SM particles, weak interactions in this preon model act within SM particles. That is, the weak interaction modifies the arrangement of preon strands within SM fermions to change an up quark to a down quark, or a muon to an electron. Wavelengths of preon strands involved in these interactions within SM particles are generally much shorter than the wavelengths of preons involved in interactions between SM particles. The effective mass of strands of wavelength λ bound in SM bosons is of order $m = \frac{h}{\lambda c}$, and the short wavelengths involved in weak interactions within SM fermions are associated with the high mass of $Z^0$ and $W$ weak bosons. A neutral ring wrapped around two straight neutral strands (AA, AB or BB) provides three spin states of the $Z^0$ boson. $W$ bosons are unique among SM bosons because they involve three charged strands, either $[(-e/6, -e/6), (-e/6, -e/6)$ and $(-e/6, -e/6)]$ or $[(e/6, e/6), (e/6, e/6)$ and $(e/6, e/6)]$. SM bosons with one or two charged strands are forbidden by charge conservation in the cross channel of SM fermion-fermion scattering. $W$ bosons are represented by two open charged rings, forming one effective closed ring around a straight charged strand. There are three distinguishable $W$ boson states, corresponding to the three spin states of the $W$ boson. The state with two intertwined open rings is identified as the state with $s_z = 0$. The state with an "upper" configuration of open rings, with the ring open towards the positive $x$ axis above the ring open toward the negative $x$ axis, is identified as the state with $s_z = 1$. The state with a "lower" configuration of open rings, with the ring open towards the positive $x$ axis below the ring open toward the negative $x$ axis, is identified as the state with $s_z = -1$. Note that the $AB$ configuration of the $Z^0$ boson and the spin up and spin down configurations of the $W$ boson are not identical under reflection in a mirror, so they are not parity invariant.

Color neutrality of SM particles

Each quark state in Figure 1 has an "odd strand out." The odd strand out is the neutral strand in charge 2/3 quarks and the charged strand in charge 1/3 quarks. Locating the odd strand in one of the three different possible locations in the quark configurations for each generation provides for color states in quantum chromodynamics. However, specifying a color charge for a particle requires an extra bit of information in addition to the six bits specifying the preon strands within that particle. Because the $N$ bits of information on the horizon comprise all information describing the universe, quarks must only occur as parts of color neutral composites (e.g., quark-antiquark pairs comprising mesons and
color neutral three quark states comprising baryons) and gluons must not exist independently outside of hadrons. The gluon configuration in Figure 2 allows eight different kinds of (virtual) gluons confined within hadrons. The eight states are states with a neutral ring wrapped around one or the other of the straight strands, an \(A\) or \(B\) strand inside the ring and an \(A\) or \(B\) strand as a spectator.

**Framework for calculations involving the preon model**

In a quantum mechanical holographic theory, conditions at an observer’s position at a given instant are determined by information on the observer’s horizon at the same instant. The bits of information associated with two antipodal pixel triads represent SM particles within the horizon. However, observers can only obtain information from the horizon with a time delay of the order of billions of years. Furthermore, information gleaned from astronomical observations at various lookback distances corresponds to conditions on the horizon at different epochs in the past. So, developing a finite-dimensional lattice gas holographic model for the interaction of pixel triads to describe particle interactions within the horizon is likely to be very difficult.

We will probably always need to do particle physics calculations based on data collected in our immediate neighborhood within the horizon. So, the SM is likely to remain a useful tool for calculating particle interactions for a long time. When supplementing SM calculations, the large number of degrees of freedom in finite-dimensional holographic representations of the universe indicates approximations involving continuum mathematics will be required. Therefore a continuum mathematics framework for particle physics calculations accounting for non-local aspects of this preon model is outlined below.

Non-local interactions of the three preon strands composing SM particles can be approximated by three-preon Bethe-Salpeter field-theoretic equations involving only non-local three-preon forces. Instantaneous three-preon interactions (consistent with instantaneous transitions required in a non-local holographic quantum mechanical theory), and free particle propagators for the three strands, simplify these equations and reduce them to six-dimensional relativistically-covariant equations involving the six four-momenta \(p_1, p_2, p_3, p'_1, p'_2, p'_3\) of incoming and outgoing states in three-strand interactions. If the universe is closed, the number of bits of information in the universe is constant (because there is nowhere else to serve as a source or sink of information) and the number of bits of information in the universe is twice the (conserved) number of strands in the universe. In that case, strand production thresholds are not an issue when dealing with the three-preon Bethe-Salpeter equations.

The three-preon Bethe-Salpeter equations can be partial-wave analyzed for states of angular momentum \(L\) by the method of Omnes. When the instantaneous Born term \(V_L(p_1, p_2, p_3; p'_1, p'_2, p'_3)\) in the partial-wave Bethe-Salpeter equation has the non-local separable form \(V_L(p_1, p_2, p_3; p'_1, p'_2, p'_3) = g_L(\vec{p}_1) g_L(\vec{p}_2) g_L(\vec{p}_3) g_L(\vec{p}'_1) g_L(\vec{p}'_2) g_L(\vec{p}'_3)\), the partial-wave three-preon Bethe-Salpeter equations can be solved algebraically (like the non-relativistic Lippman-
Schwinger equations in Ref. [9], producing only one bound state configuration for each interaction. Therefore, SM particles can be identified as bound states of various non-local separable three strand interactions in three-preon partial-wave Bethe-Salpeter equations. A minimum of eight non-local separable interactions, one for each strand wrapping configuration, is needed to produce the structures in Figures 1 and 2. The required interactions are: three $V_{L=1/2}$ interactions (one for each three strand wrapping configuration of the three fermion generations); four $V_{L=1}$ interactions (one for the two charged open rings and one straight charged strand in $W$ bosons, one for the single closed neutral ring around two straight neutral strands of the $Z^0$ boson, one for the single closed neutral ring around a closed neutral ring and a straight neutral strand for the photon, and one for the single closed neutral ring around a straight neutral strand accompanied by a spectator straight neutral strand for the eight confined gluons); and one $V_{L=2}$ interaction for the double closed neutral rings around the straight neutral strand of the graviton. No Higgs meson is needed to produce the mass of SM particles in the model. Nine strand non-local vertices corresponding to three line vertices in SM Feynman diagrams must be constrained to equal the associated SM coupling constant. Dynamical equations involving these non-local separable interactions will provide a continuum mathematics approximation to an underlying finite-dimensional non-local holographic theory generating SM particles. Corrections to the SM suggested by such an approximation might provide evidence for an underlying non-local theory. However, specifics of detailed calculations involving this non-local separable approximation to the SM depend on the functional forms chosen for the form factors $g_L(\vec{p})$ in the non-local Born term for three-preon Bethe-Salpeter equation and are beyond the scope of this exploratory paper.

### Conclusion

For many years, particle physics employed the abstract concept of massive point particles, despite the mathematical complications from infinite energy densities of point particles. Wrapped preon strands extend the idea of a massive point particle to the concept of a strand with a charge at each end. If the wrapped preon model discussed in this paper reasonably represents reality, there is no room for Higgs bosons, supersymmetric partners, fourth generation SM fermions, or free particles with color charge. Therefore, finding any of them at the Large Hadron Collider (or anywhere else) will immediately falsify the model.

### Appendix A: Preon strand distributions in a closed universe

Consider the relation between holographic information on the horizon and the distribution of preon strands in a closed universe. The wavefunction for the probability of finding a strand anywhere in the universe is a solution to the Helmholtz wave equation in the universe, and the wavefunction specifying the information on the horizon is the boundary condition on that wavefunction specifying the probability distribution of strands within the universe. A closed
universe with radius of curvature $R$ can be defined by three coordinates $\chi$, $\theta$ and $\phi$, where the volume of the three-sphere ($S^3$) is $R^3 \int_0^\chi \sin^2 \chi d\chi \int_0^\theta \sin \theta d\theta \int_0^{2\pi} d\phi$. The wavefunction for two bits of information on the horizon is the projection on the horizon at $R_H = R \sin \chi$ of the wavefunction for a strand within the volume of the universe. One solution to the Helmholz equation on the three-sphere is the scalar spherical harmonic $Q_{10}^{2} = \sqrt{\frac{12}{\pi}} \cos \theta \sin \chi$. For the $(i, j)$ bits of information associated with antipodal pixels, the $\cos \theta_i$ behavior of the wavefunction on the horizon determines the wavefunction $\Psi_k = C_3 Q_{10}^{2}(i, j) = C_3 \sqrt{\frac{12}{\pi}} \cos \theta_i \sin \chi$ as the solution of the Helmholz wave equation describing the probability distribution within the universe for the strand associated with the $(i, j)$ bits. The constant $C_3 = \sqrt{\frac{4}{\pi R^3}}$ is determined by normalizing the wavefunction to one strand (associated with two of the $N$ bits of information) within the universe. When the $N/2$ wavefunctions $\Psi_k$ describing the distribution of the $N$ bits of information within the universe are transformed to the observer's coordinate system, their sum is the wavefunction for the probability distribution of all the information in the universe.

Appendix B: Local consequences of stationary action and holography

Local field theory has been the basis of theoretical physics for many years, and is likely to be used for a long time in the future. Therefore it is appropriate to ask what, in principle, might be the effects of holography on local field theory. Field equations of motion are obtained by applying the principle of stationary action to the action expressed as an integral over the Lagrangian density. Consider a post-inflationary Friedmann universe that is so large it is almost flat, and fields with a Lagrangian density $L(\phi_i(x), \partial_\mu \phi_i(x))$ that is a function of the fields $\phi_i(x)$ and their spacetime derivatives $\partial_\mu \phi_i(x)$. Then the action $S$ in the neighborhood of a spacetime point is the four dimensional integral $S = \int dt \int d^3x L(\phi_i(x), \partial_\mu \phi_i(x))$. The action integral must include the Einstein-Hilbert term to account for gravity and the Lagrangian density for the Standard Model fields. Field equations of motion at the space-time point are found by applying the calculus of variations and the principle of stationary action to the action integral.

Now consider a holographic spherical screen (HSS) at radius $R$ around a spacetime point. The action $S$ in the neighborhood of the spacetime point can be written as $S = \int dt \int r^2 sin \theta dr d\theta d\varphi L(r, \theta, \varphi)$. The holographic principle says all information available to describe physics within the HSS resides on the HSS. Since physics within the HSS is governed by the principle of stationary action, the action on the HSS must be stationary. The action on the HSS surrounding a spacetime point is $S = \int dt \int R^2 sin \theta d\theta d\varphi L(R, \theta, \varphi)$. Holographic field equations of motion on the HSS are then found by applying the calculus of variations and the principle of stationary action to the action integral over the HSS. The action $S = \int dt \int R^2 sin \theta d\theta d\varphi L(R, \theta, \varphi)$ of a physical system is sta-
tionary, so Padmanabhan [11] notes “the time integral reduces to multiplication by the range of integration.” Therefore, the action per unit time on the HSS has units of energy and is given by \( S' = \int R^2 \sin \theta d\theta d\phi \mathcal{L}(R, \theta, \varphi) \). The average Lagrangian density per unit area on the HSS is then \( \mathcal{L}' = \frac{S'}{4\pi R^2} \).

The holographic principle [2] says all information available about physics within an HSS at distance \( R \) from an observer is given by the finite amount of information on the HSS. The number of \((0, 1)\) bits of information on the HSS, specified by one quarter of the HSS area in Planck units [2], is \( N = \pi R^2 / (\delta^2 \ln 2) \).

The Planck length \( \delta = \sqrt{\frac{\hbar G}{c^3}} \), where \( G = 6.67 \times 10^{-8} \text{ cm}^3/\text{g sec}^2 \), \( \hbar = 1.05 \times 10^{-27} \text{ g cm}^2/\text{sec} \), and \( c = 3 \times 10^{10} \text{ cm/sec} \). According to the holographic principle, the information available in the action per unit time on the HSS must be encoded in the \( N \) bits of information available on the HSS. Therefore, the integral \( S' = \int R^2 \sin \theta d\theta d\phi \mathcal{L}(R, \theta, \varphi) \) must be viewed as a continuum approximation to the finite sum \( S' = \sum_{i=1}^{N} \mathcal{L}_i 4\delta^2 \ln 2 \), where \( 4\delta^2 \ln 2 \) is the area on the HSS corresponding to the \( i \)th bit with Lagrangian density \( \mathcal{L}_i \).

In any physical system, energy must be transferred to change information in a bit from one state to another. If the energy required to change the state of a bit is \( 2E_d \), \( \mathcal{L}_i = \mathcal{L}' \pm E_d \). If the energy of one bit on the HSS drops from \( \mathcal{L}_i = \mathcal{L}' + E_d \) to \( \mathcal{L}_i = \mathcal{L}' - E_d \), the energy of another bit must increase from \( \mathcal{L}_j = \mathcal{L}' - E_d \) to \( \mathcal{L}_j = \mathcal{L}' + E_d \). This is the mechanism for stationary action. The relevant time intervals are multiples of \( 2\sqrt{\ln 2} t_P \), the time it takes for a light signal to travel from one pixel of area \( 4\delta^2 \ln 2 \) on the HSS to the adjacent pixel. The Planck time \( t_P = \sqrt{\frac{\hbar G}{c^3}} \).

The energy to change the state of a bit can’t depend on the radius of the HSS, because many HSS are possible. So, the energy to change the state of a bit must be transferred by a massless quantum with wavelength related to the size of the universe. It is not clear how to relate the wavelength of the massless quantum to the scale factor of a flat or open universe. However, the only macroscopic length characteristic of the size of a closed Friedmann universe with radius \( R_u \) is the circumference \( 2\pi R_u \), so \( 2E_d = \hbar c / R_u \).

Field equations within the HSS are obtained by applying the principle of stationary action to the volume integral over the Lagrangian density within the HSS. Field equations on the HSS are obtained by applying the principle of stationary action to the surface integral of the Lagrangian density on the HSS. The solution to the field equations on the HSS is the boundary condition on the solution to the field equations within the HSS. Those boundary conditions, and the associated solutions to the field equations within the HSS, change with every time step of changes in the components of the finite action sum \( S' = \sum_{i=1}^{N} \mathcal{L}_i 4\delta^2 \ln 2 \).

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Figure 1: Preon strand configurations producing spin up Standard Model fermions and the resulting three preon fermion states. Strands are shown as tubes for ease of visualization.
Figure 2: Preon strand configurations producing Standard Model bosons and the resulting three preon boson states. Strands are shown as tubes for ease of visualization.
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