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Dark Energy and Dark Matter from Extra Dimensional Symmetry as Different Manifestations of Vacuum Energy

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Article

Dark Energy and Dark Matter from Extra Dimensional Symmetry as Different Manifestations of Vacuum Energy

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Abstract: Dark energy and dark matter are described as different manifestations of vacuum energy in the cyclic universe framework of Extra Dimensional Symmetry (EDS). Motivated by the cosmological constant problem, EDS doubles large spatial dimensions with microscopic partners of opposite chirality and dimension number (gravitational charge). In this framework, the bulk of vacuum energy, constrained by a Planck density constraint, exists in a gravitationally inert state where actual gravitational constant is zero G. This is in contrast with the gravitationally active state where actual gravitational constant is two Gs with each of these two states corresponding to opposite particle chirality. Dark energy is described as a small repulsive component of vacuum energy constrained to the active state by an asymptotically evolving asymmetry. Dark matter is described as the attractive component of vacuum energy, enabled by neutrino induced gravitational constant which also serves as neutrino mass generation mechanism. While ordinary neutrino interaction with dark energy yields light neutrino mass, chiraly inverted neutrino interaction with dense vacuum energy yields heavy neutrino mass. Transition to sterile neutrino phase can be activated by the gravitational effect of shear stress on the microscopic partners of the visible spatial dimensions. Observational and experimental tests are briefly discussed.

Keywords: chirality; dark energy; dark matter; extra dimension; gravity; neutrino; vacuum energy

1. Introduction

Dark energy is a mysterious energy component that has been observed to be driving the accelerated expansion of the universe, and have defied several explanations since its discovery in supernova observations [1]. Its existence has since been confirmed by several independent observations like the Planck measurements of the Cosmic Microwave Background (CMB), indicating that it accounts for about 68.3% of the gravitating energy content of the universe [2]. This is in addition to the older dark matter mystery [3] of a gravitationally attractive but invisible matter component constituting about 26.8% of the gravitating energy content of the universe. Only about 4.6% is in the form of visible baryonic matter.

The cosmological constant (Λ) earlier introduced into Einstein's Field Equations, which appears to be the simplest solution, results in a serious conflict between measured density of dark energy and the 120 orders of magnitude larger value predicted from quantum field theory [4]. The Λ problem has defied logical solution from supersymmetric cancellation approaches, relaxation of vacuum energy [5] and anthropic approach [6]. It also defies an approach that simply makes the spacetime metric insensitive to Λ [7].

Slowly evolving scalar field models like quintessence [8,9] is one of the many alternative approaches to solve the dark energy mystery without the Λ route. We also have modified gravity models [10] and unification of dark energy and dark matter [11]. See Ref. [12] for detailed review and Refs.[13,14] for recent review.

The amount of theoretical and observational efforts that has been applied to understand dark energy and dark matter indicates that they require new physics beyond the existing standard model of cosmology and particle physics.

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Attempts to resolve the dark matter mystery can be mainly classified as either a modification of gravity or introduction of new particles beyond the standard model of particle physics. However, both approaches of modified gravity and particle dark matter tends to fail in providing consistent explanations to the dark matter mystery as each approach tends to succeed in explaining some observations and fail at some others.

There is an approach that explains dark matter as gravitational polarization of vacuum energy by baryonic matter without invoking new particle or modifying gravity in the traditional sense [15]. It is based on the idea that matter and antimatter have opposite gravitational charges which requires a violation of the Weak Equivalence Principle. Preliminary findings from measurements of antiproton to proton charge to mass ratio imply that matter and antimatter gravitate the same way [16]. Furthermore, the recent result from the ALPHA collaboration has ruled out the possibility of gravitationally repulsive antimatter [17].

In this paper, the dark energy and dark matter puzzle are approached using the new framework of Extra Dimension Symmetry (EDS) that doubles the number of large extra dimensions with microscopic partners of opposite handedness. EDS provides a possible solution to the dark energy puzzle by placing vacuum energy (constrained by a Planck energy density constraint) in a gravitationally inert state where the actual gravitational constant is zero G. Due to a speed limit asymmetry between the two states and given the energy density constraint, a nonzero component of vacuum energy is constrained to the gravitationally active state, manifesting as dark energy. For dark matter, it relies on the background effect of neutrinos which induces nonzero gravitational constant in the inert state, enabling the gravitation of some dense component of vacuum energy which appears as dark matter and neutrino mass generation mechanism. See Ref [18] for a review on neutrino mass which is still an open question.

While neutrino interaction with dark energy produces light neutrino mass, chiraly inverted neutrino interaction with the bulk of vacuum energy produces heavy neutrino mass which manifests as cold dark matter. Transition to the heavy state can be enabled by the gravitational expansion of microscopic dimensions by shear stress or gravitational disturbance from sudden disappearance of negative pressure. This neutrino substrate approach for dark matter doesn't require the polarization of the quantum vacuum or opposite gravitational charges for particles and antiparticles like in [15].

This paper is organized as follows. Section 2 discusses the key dimensional symmetry in which spatial dimensions are grouped as a set of dimension(s) with dimensional partners having opposite dimension numbers (gravitational charge) that determines either a positive or negative response to the stress energy tensor. It also discusses the selective response of the extra dimensions to the components of the stress energy tensor. It further discusses the speed constraint, the two gravitationally inert and active states, their speed limit asymmetry and density constraint, which is then applied in section 4 to provide a possible solution to the Λ problem of dark energy. Section 3 discusses General Relativity in two set of these extra dimensions which determines the dynamics of expansion and contraction as well as chiral transition of neutrinos. Section 4 discusses the emergence of an asymptotically evolving Λ dark energy due to the speed limit asymmetry and energy density constraint discussed in section 2. It also briefly discusses dynamics of the resulting dark energy and the cyclic universe scenario that results from the reversal of a dimensionality parameter. Section 5 discusses the neutrino induced gravitation of virtual particles which appears as dark matter, neutrino mass and chiral transition. Section 6 discusses observational and experimental probe of this form of dark matter. Discussion and conclusion follows in Section 7.

2. Extra Dimensional Symmetry Framework

In this framework, the spatial dimensions are grouped, with the number of large spatial dimensions described by the dimension number S_n (analogous to baryon number) with a dimensionality parameter d that is an indication of handedness that can either be positive or negative (right handed or left handed) such that

$$S_n = (4n - 1)d. \tag{1}$$

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where $n = 0, 1, 2, 3, ...$ and with $d = +1$ (right handed) in the present universe, a dimension with $n = 0$, corresponds to $S_0 = -1$ which is a 1D time like spatial dimension that is invisible due to a speed constraint consistent with special relativity discussed later in Section 2.2. Dimensions with $n = 1$, corresponds to $S_1 = 3$ which is the visible 3D set of spatial dimensions. Ref [19] discusses right handedness of space time although in the context of the geometry of the Euclidean version of twistor space in understanding the symmetries of the standard model.

Gravitational interaction in S_1 is not diluted by a large S_0 as they are compartmentalized partly by their opposite dimension number and the entropic nature of S_0. While the positive dimension number (gravitational charge) of S_1 denotes positive response to the components of the stress energy tensor where mass energy is seen as positive and therefore attractive, the negative dimension number of S_0 denotes a negative response where mass energy appears negative and therefore repulsive.

The EDS framework further doubles these large set of right handed spatial dimensions ($S_1 = 3d$ and $S_0 = -1d$) with left handed microscopic partners that have opposite dimension numbers where $d = -1$, such that the total dimension number of the universe can be zero as illustrated in Table 1. While the dimensional partner of S_0, is a Planck size S_P dimension, the dimensional partner of S_1 is denoted S_α and the size of one of the component dimensions is constrained to 137 Planck units which determines the value of the fine structure constant. The $n = 0$ and $n = 1$ dimensions (S_0 and S_1 as well as their left handed partners S_P and S_α respectively) appears to be stable and gravitationally active except for the inert S_P dimension as discussed later in section 2.1.

Table 1. Periodic table of spatial dimensions indicating dimension number symmetry between the sets of right handed spatial and left handed spatial dimensions within the EDS framework. With positive dimensionality parameter d, the right handed spatial dimensions expanded in the early universe while their left handed partners of opposite dimensionality parameter, collapsed to their minimum length scales.

	Microscopic Spatial dimensions (Left Handed)	**Large Spatial dimensions (Right Handed)**
	$d = -1$	$d = +1$
n	$\mathbf{S_n} = (4n - 1)d$	$\mathbf{S_n} = (4n - 1)d$
1	$\mathbf{S_\alpha} = -3$	$\mathbf{S_1} = 3$
0	$\mathbf{S_P} = 1$	$\mathbf{S_0} = -1$

The opposite dimension numbers of right handed spatial and left handed spatial dimensions implies the inversion of the sign of the stress energy tensor in which expansion becomes contraction while contraction becomes expansion. As a result of this, the expansion of the large spatial dimensions S_1 and S_0 in the early universe is equivalent to the gravitational collapse of their dimensional partners. This is partly enabled by the selective response to the stress energy tensor discussed later in section 2.1.

In this attempt to resolve the mysteries of dark energy and dark matter, the focus is on the large spatial dimensions S_1 and S_0, their microscopic partners S_α and S_P illustrated in Figure 1 and how they interact with one another.

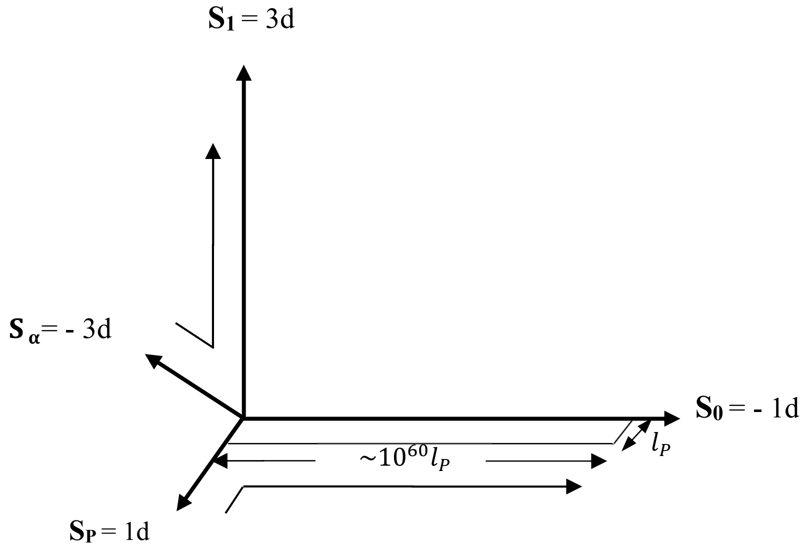

Figure 1. Large spatial dimensions S_1 and S_0 and their microscopic dimensional partners S_α and S_P. The opposite dimension numbers which inverts the sign of the stress energy tensor implies that S_P and S_α collapsed toward their minimum microscopic sizes during the inflation of S_1 and S_0 in the early universe.

2.1. Selective Response of Extra Dimensions to Components of the Stress Energy Tensor

As part of the symmetries in the EDS framework, every gravitational interaction in the visible spatial dimensions S_1 is mirrored in either of the extra spatial dimensions with negative dimension numbers such as S_0 and S_α. The S_P dimension is presently inert since has the same dimension number with the visible S_1 dimensions.

The S_0dimension is unable to respond to shear stress and negative pressure due to its one spatial dimensionality (shear stress requires at least two spatial dimensions) and its entropic nature. The size of S_0 associated with every cubic Planck volume of 3D space is a measure of its entropy$S$ such that, $S = l_0$ in Planck unit. It expands in response to energy density and positive pressure when $d = +1$, such as in the present universe, while the S_α dimension only responds to shear stress and negative pressure. The responses of S_0 and S_α to components of the stress energy tensor can serve as potential means of probing them alongside dark energy and dark matter which will be discussed later.

2.2. Speed Constraint and Invisibility of S_0 Dimension

Despite its cosmic size, the S_0 dimension is invisible due to its time like behavior from the speed constraint in the EDS framework. Consistent with Special Relativity, the speed constraint requires that a particle's velocity must always equal the maximum speed limit c in the $S_1 - S_0$ dimensions.

Massless particles like photons have zero velocity component along S_0, while massive particles and antiparticles travel in opposite directions along S_0 as illustrated in Figure 2. This motion along S_0 can be quantitatively equivalent to the passage of time such that,

$$c^2 = \mu^2 + \nu^2. \quad (2)$$

where μ is particle velocity along S_0, and ν is particle velocity along visible spatial dimensions S_1.

When $\nu \to 0$, for massive particles, $\mu \to c$ and conversely, when $\nu = c$, for massless particles, $\mu = 0$, to satisfy the speed constraint. This suggests that time can be an emergent temporal dimension driven by the velocity of particles along S_0 dimension. How fast time appears to pass for a massive particle can be equivalent to the ratio of its S_0 component of velocity μ to the speed limit c as,

$$\frac{1}{\gamma^0} = \frac{\mu}{c}. \tag{3}$$

where γ^0 is the equivalent Lorentz factor for the S_0 dimension. Since $\mu^2 = c^2 - v^2$,

$$\gamma^0 = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}. \tag{4}$$

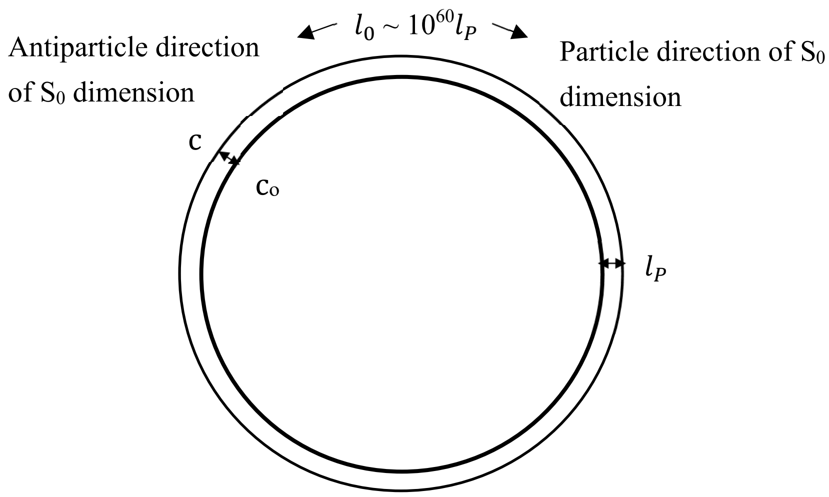

Figure 2. Ring structure of S_0- S_P dimensions with two slightly unequal speed limit states C and C_0 (which are of opposite chirality) at the two ends of S_P dimension that can be seen as two brane surfaces. Traveling in opposite directions of S_0 represents particle and antiparticle states.

2.3. Speed Limit Asymmetry

The asymmetry in speed limits c and c_0 is described by the asymmetry parameter Γ which is the ratio of the Planck size of S_P to the size of S_0 dimension, illustrated in Figure 2. $0 < \Gamma < 1$ such that,

$$\Gamma = \frac{2\pi}{l_o} \ . \tag{5}$$

where l_o ($\sim 10^{60}$) is the size of S_0 in Planck unit which expands with the gravitational contraction of S_1 as explained later in section 3, which implies a slightly larger value of l_o in deep gravitational potential wells and hence smaller value of Γ.

The asymmetry between the two speed limits c and c_0, as shown in Figure 2 can be expressed as,

$$C_o = C[1 - \Gamma\,]. \tag{6}$$

2.4. Gravitational State and Chirality Oscillation

In the EDS framework, the opposite speed limit states discussed in the previous subsection as illustrated in Figure 2, are also opposite gravitational on and off states and further corresponds to opposite chirality. Thus, for a Higgs interacting massive particle undergoing chirality oscillation, it also oscillates between the two G and zero G states with slightly different speed limits c and c_0 respectively. They still however experience an average gravitational constant value of 1G.

2.5. Planck Energy Density Constraint

The Planck energy density constraint essentially constrains the total energy density in a given volume of spacetime to always equal the upper limit of the Planck densityρ_P. This density constraint is analogous to the speed constraint in section 2.2 and can be expressed as,

$$\rho_P = \rho_m + \rho_{Vac}. \quad (7)$$

where ρ_{vac} is the vacuum energy density, and ρ_m is the total baryonic matter density.

However, Planck density is only obtainable in the gravitational active state where the speed limit is c while the bulk of the vacuum energy component exists in the inert state with lower speed limit and hence lower Planck density. The key significance of this, is in the emergence of non zero Λ dark energy in section 4. However, such energy density constraint implies a Planck density limit to the density of black holes like that suggested in [20], where Planck stars replace black hole singularities.

3. General Relativity in S_0 and S_α Dimensions

3.1. General Relativity in S_0 Dimension

In 1+1 dimensionality the curvature term in Einstein Field Equations is zero [21]. In S_0 dimension where the dimension number is negative, it can be expressed as,

$$\Lambda^0 g_{\mu\nu} = -\frac{8\pi G}{c^4} T_{\mu\nu}. \quad (8)$$

where Λ^0 is the equivalent cosmological constant in S_0 dimension, $g_{\mu\nu}$ is the metric tensor and $T_{\mu\nu}$ is the stress energy tensor. The negative dimension number of the S_0 dimension which inverts the sign of the stress energy tensor, confers on it some unique features such as:

i. Positive energy density in S_1 is equivalent to negative energy density everywhere in S_0.

An energy density associated with a given Planck volume of 3d space S_1 appears as an equivalent negative energy density everywhere along the corresponding S_0 dimension as illustrated in Figure 3.

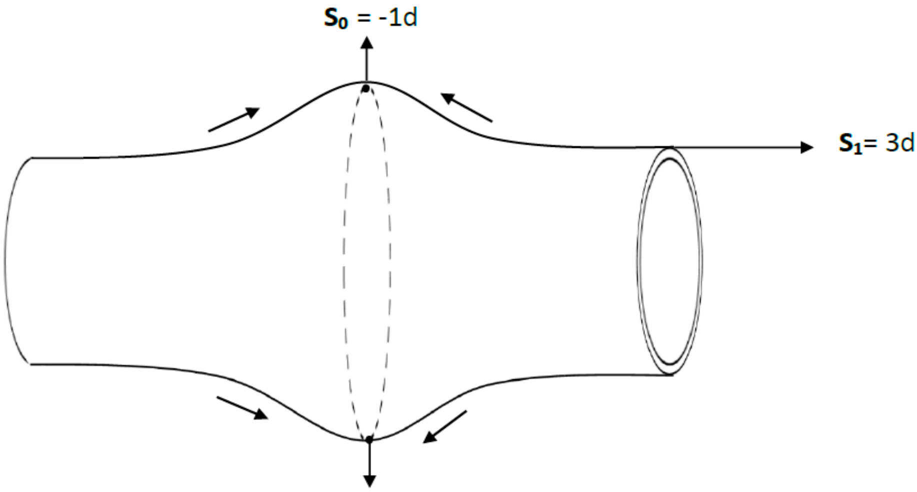

Figure 3. A gravitational well in S_1 is inverted into a gravitational hill with the expansion of S_0 by the gravitational interaction of a test particle. The test particle is replicated about 10^{60} times everywhere along S_0 dimension.

ii. Positive pressure in S_1 is equivalent to negative pressure in S_0

Any form of positive pressure in S_1 appears as negative pressure in S_0 for the same reason of negative dimensionality. The result is a positive cosmological constant expansion of S_0 that is equivalent to the curvature of S_1 ($G_{\mu\nu}$) as illustrated in Figure 4, such that,

$$G_{\mu\nu} + \Lambda^0 g_{\mu\nu} = 0, \quad (9)$$

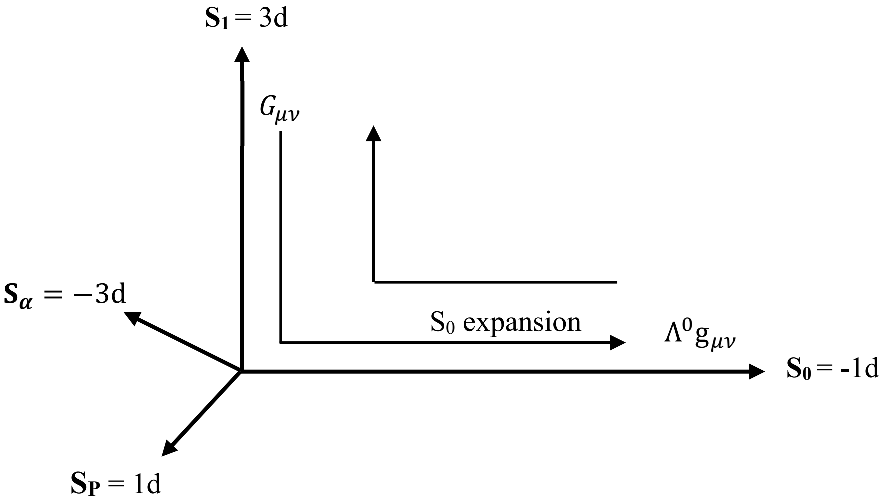

Figure 4. Gravitational inversion in S_1-S_0 dimensions. A positive cosmological constant expansion of S_0 is equivalent to the curvature of S_1 in the present universe with a positive dimensionality parameter. This is reversed in a cyclic universe when dimensionality parameter becomes negative.

3.2. General Relativity in S_α Dimensions

In 3D S_α dimensions, the Einstein tensor is not zero unlike in 1D S_0dimension. In addition, S_0 only responds to shear stress and negative pressure due to selective response to the stress energy tensor as discussed in section 2.1. The result is that the positive curvature effect ($G_{\mu\nu}$) of shear stress on S_1 dimensions is equivalent to the negative curvature effect ($-G^{\alpha}_{\mu\nu}$) of shear stress on the S_α dimensions. Therefore,

$$G_{\mu\nu} - G^{\alpha}_{\mu\nu} = 0. \tag{10}$$

Furthermore, the positive cosmological constant (Λ) expansion of S_1 due to negative pressure, is equivalent to the negative cosmological constant ($-\Lambda^{\alpha}$) contraction of S_α.

$$\Lambda g_{\mu\nu} - \Lambda^{\alpha} g_{\mu\nu} = 0. \tag{11}$$

The gravitational inversion of S_1- S_α dimensions as illustrated in Figure 5 results in the negative pressure driven collapse of S_α until all its component dimensions have completely collapsed to their minimum length scale.

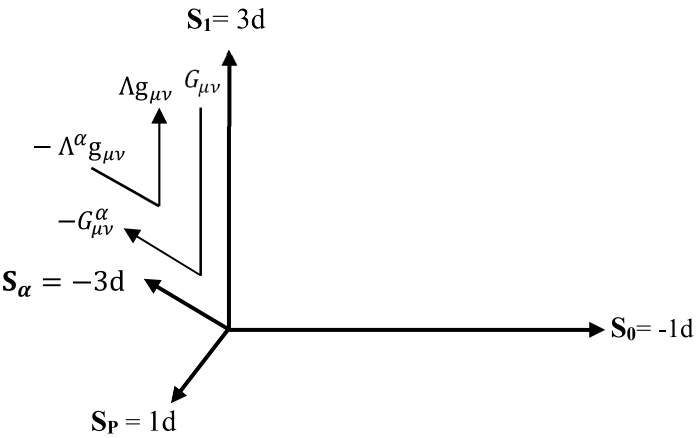

Figure 5. Gravitational inversion in S_1- S_α dimensions. Positive curvature of S_1 resulting from shear stress, is equivalent to the negative curvature of S_α due to the same shear stress component. Also, a positive cosmological constant expansion of S_1 is equivalent to a negative cosmological constant contraction of S_α.

4. Emergence of Asymptotically Evolving Cosmological Constant

The asymmetry in speed limit described in Equation (6) between the two gravitational states also reflects in the values of their Planck densities such that (Since $E = mc^2$),

$$\rho_{Vac} = \rho_P(1 - \Gamma^2) \quad (12)$$

Where ρ_{Vac} is the vacuum energy density and equals the lower Planck density in C_0 state. ρ_P is the Planck density in the C state. Γ is the asymmetry parameter that asymptotically approaches zero with the gravity driven growth of S_0 as discussed in the previous section.
In the presence of Baryons with energy density ρ_m, Eq. (12) can be expressed as,

$$\rho_P = \rho_m + \rho_{Vac} + \rho_P\Gamma^2. \quad (13)$$

Since the gravitationally inert (lower speed) state is unable to contain the total vacuum energy components, the small component $\rho_P\Gamma^2$ in Eq. (13) is therefore constrained to the gravitationally active state as a cosmological constant dark energy ρ_{DE} with an equation of state parameter $\omega = -1$ as illustrated in Figure 6. That is,

$$\rho_{DE} = \rho_P\Gamma^2. \quad (14)$$

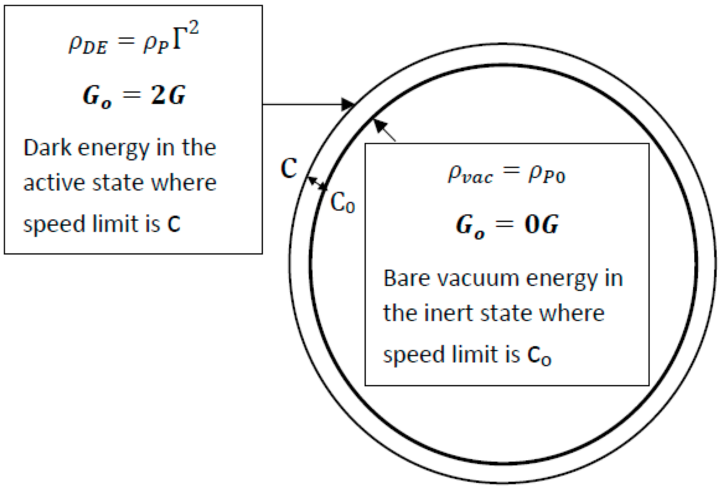

Figure 6. While the bulk of the vacuum energy components occupy the gravitationally inert state C_0 to its limit, there has to be a component ρ_{DE} in the gravitationally active state C to satisfy the energy density constraint. The lower Planck density ρ_{P0} is associated with the lower speed limit state C_0.

4.1. Dynamics of Λ Dark Energy in a Cyclic Universe

Despite maintaining a constant equation of state, this form of Λ dark energy varies spatially according to the suppression of Γ by gravitational potential wells (Eq. (5) and Figure (3)). The deeper the gravitational well the more the suppression and this can show up in the precision measurement of the Integrated Sachs Wolf effect. In addition, the density of this form of dark energy also tracks the gravity driven growth of l_o (as discussed in section 3.1) on cosmological time scale. A smaller l_o in the early universe can result in $\Gamma \lesssim 1$ with $\rho_{DE} \lesssim \rho_P$ capable of driving an inflationary universe before asymptotically falling close to its current value. The recent result from the DESI collaboration indicates a possible evolution of dark energy density [22].

Due to the gravitational symmetry in this framework, the positive Λ expansion of the visible spatial dimensions is equivalent to the negative Λ contraction of S_α until all its 3D components completely collapse to their characteristic minimum length scales.

The possible chiral oscillation of the dimensionality parameter in Eq. (1) on a cosmological time scale can result in a reverse cycle of the universe in which dimension number signs of the dimensions are reversed as well as their various responses to components of the stress energy tensor. In this scenario, in which the visible spatial dimensions S_1 illustrated in Table 1 as right handed, become

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left handed and their S_α partners become right handed, the dark energy equation of state still remains constant. Rather, it is the response of the visible spatial dimensions to positive energy density that becomes negative while its response to negative pressure becomes negative as well.

The result is that baryonic matter and dark matter becomes repulsive with black holes becoming white holes until complete evaporation, while dark energy becomes attractive, driving the collapse of the visible universe while expanding the S_α dimensions. Associated with an expanding S_α, is the fall in the value of the fine structure constant since it is coupled to the size of one of its 3 dimensions in this framework. The corresponding contraction of S_0 increases the density of dark energy in reverse towards the Planck density scale, while inert S_P dimension remains at the Planck scale, neither expanding nor contracting. This results in an accelerated collapse of the visible right handed spatial dimensions with the inflation of the left handed S_α dimensions in a cyclic scenario which gets reversed with chiral oscillation of the dimensionality parameter on cosmological time scale.

Since the size of S_0 is a measure of entropy, its contraction when the dimensionality parameter is negative implies reduction in entropy of the universe. This further implies possible loss of entropy to the Bulk in a Multiverse scenario.

5. Dark Matter from Neutrino Enabled Gravitation of Virtual Particles

In the EDS framework, the existence of most of the vacuum energy component in the gravitationally inert state ensures that virtual particles in such state are gravitationally inert. However, neutrinos can induce small component of the gravitational constant in this inert state. It enables virtual particles within a spatial volume determined by the size of neutrinos, to gravitate with positive pressure and appear as dark matter.

In the absence of neutrino coupling to the Higgs field, the mass generation mechanism for neutrinos in EDS, is this gravitational coupling to vacuum energy components either as dark energy in the active state or the bulk of vacuum energy in the inert state through the induced gravitational constant component. This neutrino induced gravitational constant G_ν is restricted to the internal structure of neutrinos without a radiative term and can be expressed as,

$$G_\nu = \beta\phi r G \tag{15}$$

where ϕ is the dimensionless phase parameter. It oscillates such that $0 \leq \phi \leq 1$. r is a dimensionless constant with a bound $0 < r < 1$ and may actually range from 0.1 to 0.9 for each of the neutrino flavours. β is a dimensionless energy scale parameter. It is the ratio of neutrino energy to Planck energy such that $0 < \beta < 1$.

$$\beta = \frac{E_\nu}{E_P} \tag{16}$$

where E_ν is neutrino energy and E_P is Planck energy.

5.1. Neutrino Mass Generation Mechanism

When neutrinos are in the gravitationally active state as left handed neutrinos and right handed antineutrinos, they interact with dark energy through their induced gravitational constant component G_ν from Eq. 15 such that,

$$\mu_\nu = G_\nu V_\nu \rho_{DE} \tag{17}$$

where μ_ν is the resulting neutrino gravitational parameter, ρ_{DE} is dark energy density and V_ν is the spatial volume under the influence of the neutrino gravitational constant component.

The generated mass m_ν from ordinary neutrino interaction with dark energy can therefore be expressed as,

$$m_\nu = \beta\phi r V_\nu \rho_{DE.} \tag{18}$$

It is therefore expected that maximum light neutrino masses obtainable when $\phi = 1$, should coincide and track the mass scale of dark energy at about 10^{-3} eV. Indeed an attempt was made in [23] to justify a possible coincidence between the mass scale of dark energy to what we expect of the neutrino mass.

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However, since light neutrino mass in this framework is coupled to dark energy, the maximum mass should be slightly lower in deep gravitational potential wells which also suppress dark energy density as discussed in Section 4.1.

When light neutrinos chiraly transition to right handed neutrinos and left handed antineutrinos, they interact with the bulk of vacuum energy in the otherwise gravitationally inert state. The mass of the resulting sterile neutrinos becomes increasingly heavy with the oscillation of ϕ and begins to behave as cold and ultra cold dark matter since Eq. (18) becomes,

$$m_{vs} = \beta\phi r V_v \rho_{Vac} \tag{19}$$

where m_{vs} is the mass of sterile neutrinos and ρ_{Vac} is the bulk of vacuum energy density which has a mass scale of 30 orders of magnitude greater than that of dark energy. It is therefore expected that the maximum mass scale of sterile neutrinos should be up to 10^{30} times greater than that for ordinary light neutrinos.

The value of r for the various neutrino flavours in Eq. (15) and by extension, Eq. (18) and Eq. (19) determines the neutrino mass hierarchy. For experimental determination of neutrino mass hierarchy, see Ref [24]

5.2. Neutrino Chiral transition

In this framework neutrino chiral oscillation depends on rotation with respect to the S_α dimensions which have collapsed to microscopic scales below the required transition threshold under the influence of negative pressure such as that from dark energy as discussed in section 3. However the gravitation effect shear stress expands these S_α dimensions as discussed in the same section 3. Once neutrinos pass through regions of spacetime with shear stress density (from baryons) above a certain threshold, S_α dimensions can expand beyond the transition threshold, allowing light neutrino chiral transition to heavy neutrinos which manifests as cold dark matter. The required transition threshold can also be achieved with high frequency gravitational oscillation in S_α that can be caused by sudden disappearance of high negative pressure.

6. Observational and Experimental Probe of Sterile Neutrino Dependent Dark Matter

6.1. Probe of Insensitivity to Baryonic Gravitational Potential Wells

Since sterile neutrinos and the associated cold dark matter exists in the zero G state in this framework, they should be insensitive to baryonic gravitational potential wells which exists in the two G state. However, baryonic matter and radiation can respond and there fore, fall into the gravitational potential well of cold dark matter and this should be observable in structure formation, gravitational lensing and even more discernible in the bullet cluster collision data [25].

6.2. Hierarchical Cold Dark Matter Halo Formation

When light neutrinos pass through shear stress generating baryonic structures such as planets and stars, their probability of chiral transition increases with the magnitude of shear stress and duration in such shallow gravitational potential. When chiral transition to sterile neutrinos eventualy occure, the phase parameter ϕ oscillates from zero to one over a transition period t_ϕ in the neutrino refrence frame. The transition distance therefore, will depend on relativistic time dilation and gravitational time dilation, resulting in a spectrum of transion distances that may range from a few kilometers for non relativistic cosmic neutrinos to several light years for ultra-relativistic neutrinos. While low energy neutrinos with short transition distances should have relatively short sterile life time, medium and high energy neutrinos, when they transition can have relativley long sterile life time on cosmological timescale.

The result is the formation of a herarchical halo profile around stress generating baryonic structures reflecting the spectrum of transition distances of the various neutrino energies and the stress profile of the baryons. It is also possible that diferent neutrino flavours have different transition

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period which can cause sterile neutrino flavour dispersion and contribute to the halo profile of this form of dark matter. See Ref [26] on Navaro-Frenk-White hierarchical halo profile.

6.3. Shear Activation and Indirect Detection of Sterile Cosmic Neutrinos

Since cosmic neutrinos have become non relativistic in the present universe their chiral transition probability should be relatively higher and should have shorter transition distance as justified in Section 5.4. For instance hundreds of meters of shear battery made of cells of tough alloys under shear stress of up to 2.4 Gpa (Maraging steel) can be installed vertically underground. Upward travelling cosmic neutrinos passing through such shear battery can chiraly transition to sterile neutrinos by the time they arrive the Earth surface. These sterile cosmic neutrinos can manifest as gravitational anomalies in the measurement of the gravitational constant.

6.4. Probe of Earth Quake Light from Possible Dent in the Fine Structure Constant

As earlier mentioned in section 2, the value of the fine structure constant is determined by the size (137 Planck units) of one of the component dimensions of S_α. Beyond a certain threshold in strength of gravity from shear stress, it is possible that the S_α dimensions can expand to the extent of causing a dent in the value of α. It conjectured here that there is a possible coupling of sterile neutrinos to such dent in α, making some sterile neutrinos observable in this regard.

There is a possibility that non relativistic cosmic neutrinos, on passing through regions of high tectonic stress, transition to sterile neutrinos that may show up above the surface not just as anomalies in measurements of the gravitational constant but as dent in α. Spatial variations in α have been reported in [27]. Such dent in α can be observed as slight drop in atomic energy levels and possible glow resulting from energy level transitions in atoms within the dent. Spectral analysis of Earth Quake Lights [28,29] can be of potential interest in this regard.

There is also the possibility of relativistic MeV neutrinos such as solar neutrinos and Geoneutrinos, transitioning over hundreds of thousands of kilometers forming halos of dark matter around the planet which can be the target of future probes.

6.5. Measurement of the Gravitational Constant during Solar Eclipse

There is the possibility of sterile transition of solar neutrinos after passing through regions of shear stress in the lunar interior, mostly from tidal forces and possible moon quakes which are usually stronger during solar eclipse. The resulting sterile neutrinos from coincident lunar quake and solar eclipse event on reaching Earth can be observed as anomalies in measurements of the gravitational constant. Moreover there have been various reports of anomalies in measurements of the gravitational constant during some solar eclipse events [30,31]. This is in addition to other reports of anomalies in measurements of the gravitational constant such as in [32] that appears to be correlated with length of day variation. Neutrino detectors can also be used to look out for expected deficit in the detection rate of light neutrino flavours under the moon's shadow during solar eclipse.

7. Discussion and Conclusions

EDS as a symmetry framework of spatial dimensions, doubles large spatial dimensions with microscopic partners of opposite handedness and dimension number which inverts the sign of gravitational interactions in these extra dimensions. It provides a framework for the possible resolution of the mysteries of dark energy, dark matter and neutrino mass. In doing so, it provides some potential insights into the dimensional structure of spacetime, gravity and the dynamics of a cyclic universe. It also implies that time could be an emergent property of a large extra spatial dimension S_0 with negative dimension number and size that is a measure of entropy.

Specifically, it places the bare vacuum energy component in a state where the gravitational field is switched off while real massive standard model particles chiraly oscillate between this gravitationally inert state and the active state.

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Due to a Planck energy density constraint and a speed limit asymmetry described by the asymptotically evolving asymmetry parameter Γ, a small component of vacuum energy is constrained to exist in the gravitationally active state and appear as dark energy. The density of this Λ form of dark energy with a constant equation of state parameter ω, asymptotically evolves towards zero with the gravity driven growth of S_0 dimension as explained in section 3. However, the chiral oscillation of the dimensionality parameter from Eq. (1) on a cosmological timescale can still result in a cyclic universe scenario as discussed in section 4.1.

Furthermore, EDS describes dark matter as resulting from neutrino enabled gravitation of virtual particles, in which neutrinos induce small component of the gravitational constant in the gravitationally inert state. The induced gravitational constant serves as a mass generation mechanism for neutrinos through this gravitational coupling to vacuum energy. While light neutrino mass arises from its interaction with dark energy heavy sterile neutrino mass arises from its interaction with the bulk of vacuum energy. However, chiral transition to sterile neutrino phase is suppressed by negative pressure driven collapse of the S_α dimension, but can be activated with the extra degree of freedom from shear stress driven expansion of S_α.

Due to various transition distances which depends on time dilations, the resulting sterile neutrinos and cold dark matter readily form hierarchical halos, exhibiting hybrid particle and modified gravity behaviour like the gravitational polarization of vacuum energy approach [15] and superfluid dark matter [33]. Experimental and observational probes for this sterile neutrino dependent form of cold dark matter were briefly discussed in section 6.

Expected results from the trio of the JWST, Euclid and upcoming Nancy Grace Roman Telescope and Vera Rubin Observatory, are expected to provide precision measurements of dark energy density as well as the dynamics of dark matter. Such precision measurements should glean out the predicted suppression of dark energy density in the deep gravitational potential wells of baryonic matter.

EDS also provides a potential insight on baryon asymmetry which may arise if the universe has a net spin with respect to the S_0 dimension in a Multiverse scenario. Since spin in opposite directions of S_0 as illustrated in Figure 2 represents particle and antiparticle states, a net spin may result in baryon asymmetry particularly in the early universe. Such form of baryon asymmetry would have reduced in the present universe by a factor of Γ^{-1} with the expansion of the S_0 dimension.

In conclusion, the EDS framework offers new physics explanations for dark energy and dark matter as different manifestations of vacuum energy. While dark energy is the small repulsive component of vacuum energy in the active state, dark matter is simply virtual particles in the inert state that are enabled to gravitationally attract with neutrino induced gravitational constant and also serves as mass generation mechanism for neutrinos. The predicted dynamics of dark energy as well as the shear stress activation of sterile neutrinos provides observational and experiment probes with potential insights into a number of other unsolved problems.

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