**Sousa–Ether Theory: A Cosmological Model of Oscillating Dark Energy**

Sousa–Ether Theory

**Abstract**

The Sousa–Ether Theory is a new cosmological framework that treats dark energy as a time-varying, oscillating field rather than a true constant. In this model, the “cosmological constant” $\Lambda$ becomes $\Lambda(t)$, an oscillating term that gradually decays over cosmic time. We propose that this dynamic dark energy arises from fundamental matter–antimatter interactions in the quantum vacuum, modeled via a tachyonic field (a field with negative mass-squared) that permeates space. The theoretical foundation intertwines philosophical ideas of a pervasive ether-like medium with modern physics, yielding a set of modified Friedmann equations that incorporate an oscillatory $\Lambda(t) = \eta \cos^2(\omega t) e^{-\alpha t}$. We derive the key equations of the model, including the integration of $\Lambda(t)$ into the Friedmann–Lemaître framework and an expression for the “sustaining constant” $\eta$ that anchors the dark energy amplitude. The physical and observational implications of an oscillating dark energy component are discussed, including potential effects on cosmic expansion history and consistency with current observations. Finally, we outline how future experiments and observations might validate the Sousa–Ether Theory’s predictions. This work is presented in an open and collaborative spirit, offered as a contribution to humanity without proprietary claims.

**Introduction**

Figure 1: Artist’s impression of the evolution of the Universe from the Big Bang (left) to the formation of galaxies (right). In the early universe, matter and antimatter were created in pairs and mostly annihilated each other, while in recent epochs (right side) dark energy drives an accelerated expansion of space. The discovery of the accelerated expansion of the Universe in the late 1990s – through observations of distant Type Ia supernovae – revealed the presence of a mysterious form of energy, termed dark energy, that permeates all of space . In the standard $\Lambda$CDM model of cosmology, this dark energy is mathematically equivalent to a cosmological constant $\Lambda$, a uniform energy density filling space that remains constant in time. Einstein famously introduced $\Lambda$ in 1917 to allow for a static universe, then later called it his “biggest blunder” after the expansion of the universe was confirmed . Ironically, Einstein’s once-discarded term was resurrected to explain the accelerating universe, and the cosmological constant has since been a cornerstone of the standard model of cosmology . Yet, despite its success in fitting observations, this simple constant is conceptually puzzling – its nature and origin remain deeply mysterious.

One major mystery is the apparent matter–antimatter asymmetry of the universe. According to both theory and philosophical expectation, the Big Bang should have created equal amounts of matter and antimatter . If every particle of matter had an antimatter counterpart, they would eventually annihilate into pure energy, leaving almost no matter behind . In reality, however, the observable universe is made almost entirely of matter, with antimatter exceedingly rare . Some physical mechanism – still not fully understood – must have tipped the balance to produce the slight excess of matter that survived annihilation . During the first fractions of a second after the Big Bang, the hot dense universe was a seething plasma of particle–antiparticle pairs popping in and out of existence . As it expanded and cooled, most matter–antimatter pairs annihilated each other into radiation, and only a tiny residue of matter (on the order of one particle in a billion) remained to form the atoms, stars, and galaxies we see today . This asymmetry suggests that the laws of physics subtly distinguish matter from antimatter – for example, through CP-violation in particle decays – but the exact cause of the imbalance is still an open problem in cosmology and particle physics .

Another profound puzzle is the magnitude of the cosmological constant itself. Simple estimates of the vacuum energy arising from quantum fluctuations (virtual particle–antiparticle pairs momentarily appearing and disappearing) yield a value for $\Lambda$ that is up to $10^{120}$ times larger than what is observed . This huge discrepancy between theory and observation – often called the cosmological constant problem – suggests that something is missing in our understanding of how vacuum energy contributes to the universe . Many physicists suspect that a dynamical mechanism or yet-unknown cancellation effect is at work to yield the tiny but nonzero dark energy that we detect.

Faced with these enigmas, it is natural to seek new theoretical approaches. The Sousa–Ether Theory arises from a philosophical re-examination of these cosmological problems. The term “Ether” in the name harkens back to the 19th-century idea of a luminiferous aether – a ubiquitous medium filling space – but recasts it in modern terms. In our context, the “ether” is not a rigid substance or preferred reference frame, but rather a dynamic field permeating the cosmos, akin to the quantum fields of particle physics. Notably, Einstein himself contemplated the need for a “new ether” in general relativity (the gravitational field of spacetime) while preserving relativistic invariance, indicating that the concept of an all-pervading medium can be made consistent with modern physics. Here we extend that notion: we posit that dark energy behaves as an oscillating ether-like field, one that interacts with matter and antimatter and evolves over time instead of remaining constant.

In this theory, matter–antimatter interactions – possibly through quantum vacuum fluctuations or other mechanisms – play a key role in driving oscillations of the dark energy field. Instead of a fixed $\Lambda$, we have $\Lambda(t)$ whose value changes as the universe ages. This approach has the potential to alleviate the aforementioned puzzles: a time-variable vacuum energy might naturally be much smaller on average than naive quantum estimates (solving the vacuum energy discrepancy), and an oscillating dark energy could make the coincidence of matter and dark energy densities less puzzling by causing the ratio to vary over time rather than being a one-off coincidence . Indeed, a purely static $\Lambda$ faces the so-called “coincidence problem”: why are we living at the epoch when dark energy is just becoming dominant, rather than far in the future or past? A dynamic $\Lambda(t)$ that was larger in the past and will vary in the future could mean that dark energy and matter densities cross paths multiple times in cosmic history, reducing the improbability of the current epoch .

The purpose of this paper is to present the complete formulation of the Sousa–Ether Theory in a rigorous yet accessible manner. We begin with the theoretical foundations, describing the physical rationale for an oscillating dark energy field and its connection to matter–antimatter dynamics. Next, we formulate the mathematical model: we introduce a specific functional form for $\Lambda(t)$ and incorporate it into the Friedmann equations of cosmic expansion, alongside a tachyonic field ($m^2 < 0$) representation that provides the underlying mechanism for the oscillation. We derive the relevant equations, including the calculation of the constant $\eta$ that defines the initial amplitude of dark energy. We then discuss the physical implications of this model and what observable consequences it might entail, from the early universe (inflation and primordial conditions) to the present and future cosmic acceleration. Finally, we conclude with a vision for future work and how the Sousa–Ether Theory might be tested or validated, and we offer an ethical note on the open contribution of this work. Throughout, we use clear, technical language intended for physicists and cosmologists, while also making the content understandable to researchers in related fields by explaining key terms and concepts.

**Theoretical Foundation**

**Matter–Antimatter Interaction and Vacuum Energy**

A central premise of the Sousa–Ether Theory is that the quantum vacuum is not inert, but a lively stage where matter and antimatter continually interact. In quantum field theory, even “empty” space is teeming with fluctuations: particles and their antiparticles are spontaneously created as virtual pairs and then annihilate each other almost instantaneously. This constant emergence and disappearance of particle–antiparticle pairs – electrons with positrons, quarks with antiquarks, and so on – gives rise to what is called vacuum energy or zero-point energy . Many researchers have hypothesized that dark energy is an expression of this vacuum energy . In a vivid description, the vacuum can be imagined as being filled with these pairs “popping” in and out of existence, a dynamic churn that, despite averaging out on small scales, might have a cumulative effect on cosmic scales . Indeed, in general relativity, any energy density – even that of empty space – contributes to the curvature (and thus expansion) of the universe. Einstein’s cosmological constant $\Lambda$ can be interpreted as the energy density of the vacuum .

However, as noted earlier, if one naively sums the contributions of all possible quantum fluctuations, the vacuum energy comes out enormously too large . This suggests that some cancellations or oscillations occur that drastically reduce the effective vacuum energy. The Sousa–Ether Theory proposes that oscillatory interactions between matter and antimatter in the vacuum could lead to such cancellations on large scales. In particular, if the vacuum energy is not static but oscillates between positive and negative phases or between higher and lower values, the net effect over time could be a much smaller average value, potentially matching the tiny dark energy density we observe. Conceptually, one can imagine a field (the “ether” field) whose oscillations are driven by the continuous creation and annihilation of particle-antiparticle pairs. When a particle and antiparticle form and then annihilate, they release energy (often as photons or other particles) . If this process is happening uniformly throughout space and time, it might act like a kind of zero-point oscillation of the fabric of spacetime itself.

Furthermore, matter–antimatter interactions might not be perfectly symmetric. We know from laboratory experiments that certain decays of subatomic particles (like kaons and $B$-mesons) prefer matter over antimatter by a tiny amount (violating CP symmetry). In the early universe, such slight biases could have led to the matter excess we see today . In the context of our theory, any small asymmetry in how matter and antimatter behave in the vacuum could induce oscillations in the vacuum energy. One could speculate, for example, that virtual matter–antimatter fluctuations create an oscillating pressure: as pairs form, they momentarily contribute positive energy (pressure), and as they annihilate, they create a perturbation that could be modeled as a negative pressure or a reduction in vacuum energy, and this cycle repeats. While this description is qualitative, it provides an intuitive picture for why dark energy might naturally vary instead of remaining fixed. The key idea is that dark energy is an emergent, time-dependent phenomenon resulting from underlying quantum processes, rather than a fundamental constant of nature.

It is worth noting that the idea of an all-pervading field is not foreign to modern physics. The Higgs field, for instance, is a scalar field filling space that gives particles mass. Similarly, the concept of an inflaton field in early universe cosmology is a scalar field responsible for a rapid early expansion (inflation) and then decaying. In a sense, the Sousa–Ether Theory extends these ideas to the present-day acceleration: it suggests an analogous field that remains active (though slowly dying out) throughout cosmic history. This “ether” field is the medium of the vacuum, and its excitations or oscillations manifest as dark energy. Crucially, this does not conflict with relativity – the field is Lorentz-invariant and homogeneous on large scales, so it doesn’t single out a special frame any more than the Higgs field does. Instead, it provides a dynamic underpinning for what would otherwise be an inexplicable constant.

**Dark Energy as an Oscillating Field**

In the standard model of cosmology, dark energy is characterized by an equation of state $w \approx -1$, meaning its pressure $p$ is approximately the negative of its energy density $\rho$ ($p \approx -\rho$). This is what one expects for a cosmological constant or vacuum energy – it has tension but no dissipative pressure, leading to a repulsive gravitational effect (accelerating expansion). The Sousa–Ether Theory retains the essential feature $w \approx -1$ on average, but allows $\rho$ (and thus $p$) to change with time. We envisage dark energy as a field oscillating in value, much like a pendulum or a vibrating system, but one that loses energy slowly over time (a damped oscillator).

Mathematically, we represent the dark energy density (or equivalently the $\Lambda$ term in Einstein’s equations) as a function of cosmic time $t$. The proposed form is:

\Lambda(t) = \eta \, \cos^2(\omega t) \, e^{-\alpha t},

where $\eta$ is a constant amplitude (the sustaining constant of the vacuum energy, setting the initial strength of dark energy), $\omega$ is the angular frequency of oscillation, and $\alpha$ is a small positive constant that governs the exponential decay (damping) of the oscillation. This functional form encapsulates the core idea of the theory: at $t=0$ (very early times), $\Lambda(0) = \eta$ is at its maximum value, but as $t$ increases, the $\cos^2(\omega t)$ factor causes $\Lambda$ to periodically vary between 0 and $\eta e^{-\alpha t}$, while the $e^{-\alpha t}$ factor ensures that these oscillations decrease in amplitude over time. In other words, dark energy starts off large (possibly dominating the early dynamics), then diminishes, oscillating around lower and lower values, approaching zero in the very far future. By using $\cos^2(\omega t)$ (which ranges from 0 to 1), we ensure $\Lambda(t)$ is always non-negative, consistent with it being an energy density. The use of $\cos^2$ (as opposed to a simple cosine) means the oscillation has a period of $\pi/\omega$ (since $\cos^2(\theta)$ has a period of $\pi$, half that of $\cos\theta$), and avoids negative values of $\Lambda$ which would be difficult to interpret physically in this context.

Physically, $\omega$ and $\alpha$ are parameters that would determine how fast and how long the dark energy oscillations persist. If $\omega$ is very large (rapid oscillations) compared to the Hubble expansion rate, then on timescales of cosmological observations, the dark energy might effectively appear as a smooth average (with an average equation of state slightly different from $-1$). If $\omega$ is small (slow oscillations), the dark energy density could undergo noticeable changes over the history of the universe – potentially even causing alternating periods of acceleration and deceleration. Meanwhile, $\alpha$ controls how quickly the oscillation’s amplitude decays. A small $\alpha$ means the oscillations continue for a long time with almost undiminished amplitude, whereas a larger $\alpha$ damps the oscillation more rapidly. In principle, $\omega$ and $\alpha$ would be determined by the underlying physics (for example, by the mass scale and coupling of the field driving the oscillation), but in this phenomenological model they are free parameters to be constrained by observations.

The notion of a dynamic dark energy is not without precedent. Theories of quintessence have long hypothesized a scalar field that slowly rolls down a potential, causing a time-varying dark energy equation-of-state. What distinguishes the Sousa–Ether approach is the explicit oscillatory behavior superimposed with a decay. Interestingly, some observational studies have looked for signs of oscillating dark energy in the astronomical data . There are hints that the assumption of a perfectly constant dark energy may not hold; for instance, recent results from the Dark Energy Survey (DES) have been interpreted as possibly hinting that dark energy evolves over time, instead of being truly constant . If this is validated, it would imply that the cosmological constant is not constant after all, but a dynamic phenomenon requiring new theoretical explanations . The Sousa–Ether Theory provides one such possible explanation by explicitly constructing a model of dynamic dark energy.

In summary, the theoretical foundation of our model is the idea that the vacuum is a dynamic medium where matter-antimatter processes induce an oscillating dark energy component. This oscillation is built into the model via the $\cos^2(\omega t)$ factor, and the eventual dying-out of dark energy is encoded in the exponential $e^{-\alpha t}$. The next section will translate this conceptual model into the language of modern cosmology by incorporating $\Lambda(t)$ into the standard equations governing the universe’s expansion.

**Mathematical Formulation of the Model**

In this section, we develop the mathematical equations that define the Sousa–Ether cosmological model. We modify the standard Friedmann equations of general relativity to include a time-dependent dark energy term $\Lambda(t)$, and we introduce a tachyonic field to represent the dynamic vacuum. We also derive an expression for the constant $\eta$ (the sustaining constant) in terms of measurable parameters. Throughout, we assume a homogeneous and isotropic universe (the Friedmann–Lemaître–Robertson–Walker metric), consistent with the cosmological principle.

**Time-Dependent Dark Energy Term $\Lambda(t)$**

We begin by formalizing the ansatz for the dark energy term. As stated, we propose:

\Lambda(t) = \eta \cos^2(\omega t) e^{-\alpha t},

where $\eta$, $\omega$, and $\alpha$ are constants characterizing the model. Here $\Lambda(t)$ has units of [time$^{-2}$] in geometric units (the same units as the cosmological constant in Einstein’s field equations, since normally $\Lambda$ enters as $\Lambda c^2$ in SI units or simply $\Lambda$ in $1/\text{length}^2$ units in cosmology). The sustaining constant $\eta$ sets the scale of dark energy at $t=0$. In many cosmological models, $t=0$ corresponds to the Big Bang. It might seem counter-intuitive to talk about dark energy at the very beginning of the universe – after all, we usually think radiation dominated then matter dominated, with dark energy only becoming important late. However, in our scenario, it is conceivable that $\Lambda(0)$ was extremely large, possibly driving a brief early era of inflation-like expansion, and then it decayed very rapidly (due to the $e^{-\alpha t}$ factor). By the time of Big Bang Nucleosynthesis or the Cosmic Microwave Background (CMB) formation, $\Lambda(t)$ could have dropped to negligible values, preserving the successes of the standard early universe model. It then would have re-emerged to a significant (but much smaller) value at late times, as the $\cos^2$ oscillation allowed $\Lambda(t)$ to periodically increase even as the envelope $e^{-\alpha t}$ was slowly declining. Thus, our model can in principle be consistent with the observed timeline: negligible dark energy at recombination (as supported by CMB data) and dominant dark energy today. The specific choice of $\omega$ and $\alpha$ would determine this history quantitatively.

It is useful to appreciate the behavior of $\cos^2(\omega t)$. We can rewrite $\cos^2(\omega t)$ using a trigonometric identity: $\cos^2(\omega t) = \frac{1 + \cos(2 \omega t)}{2}$. This means the dark energy term can be expressed as

\Lambda(t) = \frac{\eta}{2} e^{-\alpha t} \Big[ 1 + \cos(2\omega t) \Big].

So it consists of a decaying constant piece $\frac{\eta}{2} e^{-\alpha t}$ plus an oscillatory piece $\frac{\eta}{2} e^{-\alpha t} \cos(2\omega t)$. At early times, the oscillatory term might cause rapid variations, but if $\omega$ is high, these would average out. At late times, as $e^{-\alpha t}$ becomes very small, $\Lambda(t)$ tends toward zero, essentially eliminating dark energy in the far future. This contrasts with $\Lambda$CDM where dark energy remains constant and would dominate forever; in our model, dark energy is a transient phenomenon on the longest timescales (albeit one that lasts for a substantial fraction of the universe’s lifespan). Interestingly, this scenario would predict that the current accelerated expansion is not a perpetual state but will eventually slow down and perhaps even reverse to deceleration when $\Lambda(t)$ becomes sufficiently small compared to matter (or if $\cos^2$ hits a node). This is a striking difference that could have observational consequences for the fate of the universe.

**Incorporation into Friedmann Equations**

The Friedmann equations describe how the scale factor $a(t)$ of the universe evolves under the influence of various energy components (matter, radiation, curvature, and $\Lambda$). In a flat universe (spatial curvature $k=0$) with a cosmological constant, the standard Friedmann equations are:

* First Friedmann equation (Hubble equation):

H^2(t) \equiv \left(\frac{\dot a}{a}\right)^2 = \frac{8\pi G}{3}\,\rho(t) + \frac{\Lambda}{3},

where $H(t)$ is the Hubble parameter, $\rho(t)$ is the total energy density of matter and radiation, and $\Lambda$ is the cosmological constant (we use units with $c=1$).

* Second Friedmann equation (acceleration equation):

\frac{\ddot a}{a} = \frac{\Lambda}{3} - \frac{4\pi G}{3}\big(\rho + 3p\big),

where $p(t)$ is the total pressure of matter and radiation . This equation shows how $\Lambda$ (with $p\_\Lambda = -\rho\_\Lambda$) gives a positive contribution to $\ddot a$ (accelerating expansion), whereas normal matter and radiation (with $p \ge 0$ or $p = \rho/3$ for radiation) cause deceleration.

In our model, $\Lambda$ is replaced by $\Lambda(t)$. The Friedmann equations become time-dependent in a way that cannot be trivially absorbed into $\rho$ and $p$ because $\Lambda(t)$ does not obey the same equation of state at all times (except that its instantaneous $w(t) = -1$ if we treat it as a vacuum component at a given $t$). We can proceed by treating the $\Lambda(t)$ term as a part of the energy content of the universe – a time-varying vacuum energy density $\rho\_\Lambda(t) = \frac{\Lambda(t)}{8\pi G}$ – and include it in the energy conservation and Friedmann equations.

The modified first Friedmann equation is:

H^2(t) = \frac{8\pi G}{3}\big[\rho\_m(t) + \rho\_r(t) + \rho\_\Lambda(t)\big],

for a flat universe ($k=0$), where $\rho\_m \propto a^{-3}$ is the matter density (including dark matter and baryons) and $\rho\_r \propto a^{-4}$ is the radiation density (photons and neutrinos), evolving in the standard way with expansion, and $\rho\_\Lambda(t) = \frac{\Lambda(t)}{8\pi G}$ is specified by our oscillating $\Lambda(t)$. The second Friedmann (acceleration) equation similarly becomes:

\frac{\ddot a}{a} = \frac{\Lambda(t)}{3} - \frac{4\pi G}{3}\Big[\rho\_m(t) + \rho\_r(t) + 3p\_m(t) + 3p\_r(t)\Big].

Since matter has $p\_m \approx 0$ (pressureless dust) and radiation has $p\_r = \frac{1}{3}\rho\_r$, this simplifies to:

\frac{\ddot a}{a} = \frac{\Lambda(t)}{3} - \frac{4\pi G}{3}\Big[\rho\_m(t) + \rho\_r(t) + 3\cdot 0 + 3 \cdot \frac{1}{3}\rho\_r(t)\Big] = \frac{\Lambda(t)}{3} - \frac{4\pi G}{3}\Big[\rho\_m(t) + 2\rho\_r(t)\Big].

One immediate observation is that a time-varying $\Lambda(t)$ means that the usual conservation equation $\dot{\rho}\_\Lambda = 0$ (for constant $\Lambda$) no longer holds. Instead, the vacuum energy density is changing, which raises the question: where is the energy flowing to or from? In general, if $\Lambda(t)$ is truly fundamental and not interacting with other components, one would modify the conservation equation to:

\dot{\rho}\Lambda + \dot{\rho}{m+r} + 3H(\rho\_{m+r} + p\_{m+r}) = 0,

where an exchange term could be included between $\rho\_\Lambda$ and $\rho\_{m+r}$ (matter+radiation) if energy is transferred. For simplicity, one might assume that $\Lambda(t)$ is a prescribed function (as we have) and allow violation of separate energy conservation for the vacuum component, as long as total energy is conserved when including the vacuum as a component of the stress-energy tensor. An alternative approach is to imagine that the oscillating vacuum field decays into or draws energy from matter or some other reservoir (like a scalar field kinetic energy). This is beyond our current scope, but it is a point to be considered in detailed implementations of the model. Many interacting dark energy models have been studied where dark energy exchanges energy with dark matter to alleviate the coincidence problem . In spirit, our model could be analogous if the decrease in $\rho\_\Lambda$ feeds into an increase in matter or radiation energy (though in practice, a decaying vacuum energy would probably heat the cosmic plasma slightly or produce additional relativistic particles).

For the present development, we proceed by treating $\Lambda(t)$ as an external function in the Friedmann equations. To solve these equations, one would typically specify initial conditions $a(t\_i)$, $\dot{a}(t\_i)$ at some early time $t\_i$ (e.g. the end of inflation or at nucleosynthesis) and then integrate forward. While an exact analytic solution with arbitrary $\omega$ and $\alpha$ is not obtainable in closed form, we can reason about regimes:

* Early times ($t$ small): $\Lambda(t) \approx \eta \cos^2(\omega t)$ (since $e^{-\alpha t} \approx 1$ for very small $t$). If $\eta$ is very large, $\Lambda$ may dominate $H^2$ initially. This would effectively drive $a(t)$ exponential (inflationary expansion) if $\rho\_m$ and $\rho\_r$ are negligible. However, $\cos^2(\omega t)$ oscillates on timescale $\sim \frac{\pi}{\omega}$. If $\omega$ is high, there could be many oscillations in a tiny fraction of a second. Rapid oscillations of vacuum energy in the early universe could lead to particle production or resonant effects (somewhat analogous to preheating after inflation, where an oscillating inflaton field decays into particles). If $\omega$ is low, then $\cos^2(\omega t)$ stays near 1 for a while, and the universe undergoes a quasi-de Sitter expansion with $\Lambda \approx \eta$ until $\cos^2$ significantly drops. In either case, because $\alpha$ might not yet have had time to act, $\Lambda$ remains near its initial amplitude for some oscillations.
* Intermediate times: As the universe expands and $\Lambda(t)$ decays, there comes a point where $\rho\_m$ (which is dropping as $a^{-3}$) and $\rho\_\Lambda(t)$ become comparable. If $\Lambda(t)$ decays fast enough, matter (or radiation) will overtake it and dominate the expansion for a long period (the usual matter-dominated era essential for structure formation). During this era, $a(t)$ would evolve approximately as in the standard model (e.g. $a(t) \propto t^{2/3}$ in matter domination) except perhaps for small perturbations when $\cos^2(\omega t)$ modulates $\Lambda(t)$. If $\omega$ is extremely low, one could even have scenarios where $\Lambda(t)$ drops to near zero (allowing matter domination), then later $\cos^2(\omega t)$ brings $\Lambda(t)$ up again to cause late acceleration.
* Late times (near present): $\Lambda(t)$ has become relatively small in absolute terms but might again be comparable to the matter density as matter dilutes. Suppose at some redshift $z \sim \mathcal{O}(1)$ (not long ago in cosmic terms), $\Lambda(t)$ rises (due to the oscillation) while matter density falls, leading to the current acceleration. Observationally, we know dark energy is about ~70% of the energy today . This can be matched in our model by choosing parameters such that $\Lambda(t\_0)$ (at the current age $t\_0 \approx 13.8$ Gyr) yields $\rho\_\Lambda(t\_0) \approx 2.3 \times 10^{-27}\text{kg/m}^3$ (the equivalent density for dark energy today) or $\Lambda(t\_0) \approx 1.1 \times 10^{-35}\text{s}^{-2}$ in geometric units. We will show how $\eta$ can be determined to satisfy this. After the present, in our model, $\Lambda(t)$ will continue to oscillate but the envelope will keep decaying, so eventually dark energy’s influence will wane. In the very far future, the matter density will be extremely low as well (since it keeps diluting), so the universe might enter a diluted phase with almost no significant energy content – essentially coasting with whatever curvature or tiny $\Lambda$ remains.

The above qualitative analysis indicates that the model can replicate the broad sequence of cosmic history (inflation -> radiation domination -> matter domination -> dark energy domination -> eventual decline) if parameters are appropriately chosen. A full numerical integration would be needed to explore the detailed behavior and constraints (which is beyond the scope of this manuscript), but the key equations are in place.

**Tachyonic Field Component**

To provide a microphysical backbone for the oscillating $\Lambda(t)$, we introduce a tachyonic field in the model. In field theory, a tachyon is a hypothetical field with negative squared mass ($m^2 < 0$). This does not imply particles traveling faster than light in a physical sense; rather, it indicates an instability of the vacuum state. The most famous example is the Higgs field before electroweak symmetry breaking – one can think of it as a “tachyon” sitting at the top of a potential hill and rolling down to a stable minimum (tachyonic fields often roll toward a true vacuum and shed their instability). In string theory, tachyonic fields arise naturally (for instance, the open string tachyon), and their condensation can drive dramatic physical processes. It has been proposed that a tachyonic scalar field could be a candidate for dark energy . When such a field evolves, it can have an equation of state that starts near $w = -1$ (cosmological constant–like) and potentially changes over time. In particular, a rolling tachyon can have negative pressure needed for accelerated expansion .

We incorporate a tachyonic field $\phi(t)$ by envisioning that the oscillations in $\Lambda(t)$ are driven by $\phi$ moving in a potential. A simple way to model this is to consider an effective potential $V(\phi)$ for the field which has an unstable maximum (the top of a hill). At early times, $\phi$ might be near this maximum (like how inflation often starts with a field high up its potential). The negative $m^2$ means $\phi$ will not stay there; it will spontaneously roll off. As $\phi$ rolls, its potential energy $V(\phi)$ can play the role of a transient $\Lambda(t)$. If $V(\phi)$ oscillates (for example, imagine a potential shaped in such a way that $\phi$ oscillates around a minimum after rolling down), then $V(\phi(t))$ would contribute an oscillating vacuum energy.

A concrete example: suppose $V(\phi)$ has a form that near the minimum behaves like $V(\phi) \approx \frac{1}{2} m\_{\rm eff}^2 (\phi - \phi\_0)^2$ (a normal positive-mass excitation around $\phi\_0$) but $\phi$ initially was at a higher value and rolled down. The initial roll (when $\phi$ was effectively tachyonic) could correspond to the rapid decay of $\Lambda$ after the Big Bang (inflationary epoch). After settling near the minimum, $\phi$ might oscillate around $\phi\_0$ with frequency determined by $m\_{\rm eff}$, and these small oscillations would cause $V(\phi)$ to oscillate. If those oscillations are underdamped, $\phi$ can oscillate for a long time (much like a scalar field oscillating and behaving like matter or dark energy depending on the equation of state). In fact, a coherently oscillating scalar field can act like a fluid with an oscillating equation of state. Some studies have shown that an oscillating scalar could mimic an oscillating dark energy or even dark matter under certain conditions .

Rather than delve into a specific potential, we treat the tachyonic field in a phenomenological way. The presence of a tachyonic field ensures that the equation of state for the vacuum component remains $p\_\Lambda \approx -\rho\_\Lambda$, as is required for acceleration , but also that $\rho\_\Lambda$ is dynamic. One can imagine writing an action for the field such that the effective $\Lambda(t)$ arises from $V(\phi(t))$. The details of the field’s oscillation could be complex – in particular, a tachyonic field might damp in part by particle production or other effects. However, in many models, if the coupling to other fields is weak, the scalar oscillations can persist (this is similar to how an axion field oscillation can act as dark matter). We assume here that the $\phi$ field is predominantly influencing the gravitational dynamics and not rapidly decaying into radiation (or if it does, that energy is somehow fed back into the effective $\Lambda$ oscillation in a cycle).

The benefit of introducing $\phi$ is that it provides a concrete realization of how $\Lambda(t)$ might arise. It shifts the description from a mysterious time-dependent $\Lambda$ to a dynamical system with a Lagrangian. For instance, one could consider a Lagrangian for the tachyonic field of the form:

L = -\,V(\phi) \sqrt{1 - \dot{\phi}^2},

which is a form often used for tachyon condensates (note the non-standard kinetic term under the square root). In a homogeneous configuration, this leads to a pressure $p\_\phi = -V(\phi)\sqrt{1-\dot{\phi}^2}$ and energy density $\rho\_\phi = \frac{V(\phi)}{\sqrt{1-\dot{\phi}^2}}$. If $\dot{\phi}^2$ is small (slow roll), then $p\_\phi \approx -\rho\_\phi \approx -V(\phi)$, acting like a $\Lambda$ term. As $\phi$ evolves, the effective $w\_\phi$ can change. With appropriate $V(\phi)$, one can achieve $w\_\phi$ oscillating around $-1$. In fact, one finds that a tachyonic field naturally has $p = -\rho$ if it doesn’t interact, mimicking a cosmological constant , but when it is dynamical and perhaps interacting, it can solve the coincidence and fine-tuning issues by evolving over time .

To summarize this component: we posit an underlying tachyonic scalar field $\phi(t)$ whose dynamics yield the $\Lambda(t)$ given above. In doing so, we tie our model to known physics frameworks and ensure that the oscillating dark energy has a consistent theoretical origin. The negative mass-squared of the field drives the initial rapid change (like the release of vacuum energy early on), and the later oscillations of the field manifest as the oscillations of $\Lambda(t)$. This approach sits at the intersection of dark energy and inflation theories, essentially bridging early universe dynamics with late-time acceleration in one unified picture.

**Calculation of the Sustaining Constant $\eta$**

A crucial parameter in the model is $\eta$, the sustaining constant, which represents the initial amplitude of the oscillating dark energy term. We call it the “sustaining” constant because it effectively sustains the cosmic acceleration over time – it is the reservoir from which the dark energy draws. Here we discuss how $\eta$ can be determined or constrained by requiring consistency with current observations and possibly with conditions in the early universe.

At the present time $t\_0$ (around 13.8 billion years after the Big Bang), cosmological measurements indicate a dark energy density $\rho\_{\Lambda,0}$ that is approximately $70%$ of the total energy density of the universe . In terms of $\Lambda$, this corresponds to $\Lambda(t\_0) \approx 1.1 \times 10^{-35},\text{s}^{-2}$ (using $H\_0 \approx 2.2\times 10^{-18},\text{s}^{-1}$ and $\Omega\_\Lambda \approx 0.70$) . Let us denote $\Lambda\_0 = \Lambda(t\_0)$ for brevity. Our model must produce this value at the current epoch. From $\Lambda(t) = \eta \cos^2(\omega t) e^{-\alpha t}$, we have:

\eta = \Lambda(t) \, e^{\alpha t} / \cos^2(\omega t).

Evaluating at $t = t\_0$ gives:

\eta = \Lambda\_0 \, e^{\alpha t\_0} / \cos^2(\omega t\_0).

This formula expresses $\eta$ in terms of known or assumed quantities. If we know $\alpha$, $t\_0$, and if we have some idea of $\cos^2(\omega t\_0)$, we can solve for $\eta$. In the simplest case, consider that at the current epoch the oscillation is near a peak, so $\cos^2(\omega t\_0) \approx 1$. (This is something we could assume for an order-of-magnitude estimate – if we happen to be near a moment when dark energy is at a local maximum of its oscillatory cycle. Even if not exactly true, since $\cos^2$ ranges between 0 and 1, this assumption gives a lower bound on $\eta$ because any other phase would require a larger $\eta$ to get the same $\Lambda\_0$.) Also, for a rough estimate, let’s suppose $\alpha t\_0$ is not extremely large. The current Hubble timescale is $\sim 1/H\_0 \sim 4.35 \times 10^{17}$ s. If $\alpha$ is of order the Hubble rate (just as a trial number, say $\alpha \sim 10^{-18},\text{s}^{-1}$), then $\alpha t\_0 \sim 0.4$ (dimensionless). If $\alpha$ is smaller, $\alpha t\_0$ could be $\ll 1$. We don’t expect $\alpha t\_0$ to be huge; if it were, $\Lambda$ would have decayed by many e-folds since the Big Bang, making it negligible now unless $\eta$ was astronomically large to begin with (which might conflict with early universe conditions). So it’s reasonable that $e^{\alpha t\_0}$ is a factor of order unity to perhaps a few.

Taking $\cos^2(\omega t\_0) \approx 1$ and, for example, $\alpha t\_0 \approx 1$, we get $\eta \approx \Lambda\_0 e^{1} \approx 2.7 \Lambda\_0$. Using $\Lambda\_0 \approx 1.1 \times 10^{-35},\text{s}^{-2}$, this yields $\eta \sim 3 \times 10^{-35},\text{s}^{-2}$. If $\alpha$ is much smaller (say $\alpha t\_0 \approx 0.1$), then $\eta \approx 1.1 \Lambda\_0 \approx 1.2 \times 10^{-35},\text{s}^{-2}$. If $\cos^2(\omega t\_0)$ were, say, 0.5 (meaning we are at half maximum of the oscillation), then $\eta$ would need to be twice as large to compensate. Thus, $\eta$ is likely on the order of $10^{-35}$ to $10^{-34},\text{s}^{-2}$ in units of $\Lambda$. Converting that to an energy density: $\rho\_\eta = \eta/(8\pi G)$. Using $8\pi G \approx 1.67 \times 10^{-26},\text{m}^{-2}$ (since $G \approx 6.67 \times 10^{-11},\text{SI}$ units, and converting to the same units as $\Lambda$ which is $m^{-2}$ in geometric units), we get $\rho\_\eta \sim \frac{10^{-35}}{1.67 \times 10^{-26}} \text{m}^{-2}$ in units of $c^2/G$ – numerically, that’s about $6\times 10^{-10},\text{m}^{-2}$ in these units, which converting to J/m³ yields $\sim 5 \times 10^{-27},\text{kg/m}^3$ (which is roughly the current dark energy density order of magnitude). The details aside, the important point is that $\eta$ comes out to be on the order of the current dark energy level or a bit higher, which is sensible.

Another way to determine $\eta$ is to consider the early universe. If we desire that inflation (or an inflation-like early accelerated phase) was driven by this $\Lambda(t)$, then $\eta$ must have been extremely large to start with – potentially on the order of the grand unified theory (GUT) scale in energy density ($\sim 10^{-9},\text{kg/m}^3$) or even Planck scale, depending on how much inflation. However, it could be that inflation proper was a separate event and our $\Lambda(t)$ was subdominant until later. In that case, $\eta$ need not correspond to the inflationary scale; it could be tuned just to produce late-time acceleration and minor effects earlier. For now, we use observational calibration at $t\_0$ to fix $\eta$. The result can be stated generally: the sustaining constant $\eta$ is chosen such that $\Lambda(t)$ matches the observed dark energy density at present. Any viable set of parameters $(\eta, \omega, \alpha)$ must satisfy that condition (along with not spoiling other epochs). This effectively “calculates” $\eta$ once $\omega$ and $\alpha$ are specified.

To illustrate with a concrete example, suppose $\omega$ is such that one oscillation period is on the order of the age of the universe (so $\omega t\_0 \sim \mathcal{O}(1)$ radian, meaning $\omega \sim 10^{-18},\text{s}^{-1}$). If we also take $\alpha$ of similar order $10^{-18},\text{s}^{-1}$, then $\eta$ might be a few times $\Lambda\_0$ as above. If instead $\omega$ is much larger (say oscillation period of a billion years, which is small compared to $t\_0$, i.e. $\omega \sim 2\pi/(10^9 \text{yr}) \approx 2\times 10^{-17},\text{s}^{-1}$), then there have been many oscillations by now. Unless we are accidentally at a trough, $\cos^2(\omega t\_0)$ will average to 0.5 over many oscillations, so we’d set $\eta \approx 2\Lambda\_0 e^{\alpha t\_0}$. If $\alpha$ is very small, $\eta \approx 2 \Lambda\_0$. These differences are not huge in magnitude, reinforcing that $\eta$ will be of the same order as $\Lambda\_0$ (within perhaps one or two orders of magnitude at most) when calibrated to today’s universe.

In conclusion, by inputting the known value of dark energy today into our $\Lambda(t)$ expression, we can determine the sustaining constant $\eta$. This constant essentially encodes the “amount” of dark energy the universe started with. The fact that it is not enormously larger than $\Lambda\_0$ (for reasonable $\alpha$) is encouraging, because it means the model doesn’t require an implausibly fine-tuned huge cancellation (beyond the usual tuning that any dark energy model requires to match the small observed value). Instead, $\eta$ is on the same order as $\Lambda\_0$ times a factor accounting for decay and phase, making it a sensible, if empirically determined, parameter of the model.

Figure 2: Graphical illustration of the oscillating dark energy term $\Lambda(t)$ (vertical axis) as a function of time (horizontal axis) in the Sousa–Ether Theory. In this example, $\Lambda(t)$ starts at $\Lambda(0)=\eta$ and undergoes damped oscillations (with angular frequency $\omega$ and decay rate $\alpha$). The amplitude of $\Lambda(t)$ diminishes over time (envelope decays exponentially), and the value oscillates between zero and the decaying maximum. Such behavior is designed to fit a large initial $\Lambda$ that decreases to the small value observed today, while causing periodic accelerations in the expansion of the universe. This plot qualitatively demonstrates how dark energy in this model is initially significant, then nearly vanishes, and then has recurring boosts (though progressively smaller) at later times. The real universe’s parameters would be chosen such that one of these boosts corresponds to the current epoch of acceleration.

**Discussion: Physical and Observational Implications**

The Sousa–Ether Theory presents a distinctive cosmic narrative that differs from the standard $\Lambda$CDM in testable ways. In this section, we discuss the physical implications of an oscillating, decaying dark energy and how one might detect or constrain such behavior with observations.

Cosmic History and Inflation: One attractive aspect of the model is the possibility that it provides a unified picture of accelerated expansion episodes in the universe. The early inflationary period required in the Big Bang model could, in principle, be driven by the initial large value of $\Lambda(t)$ (when $t$ is near 0 and $\Lambda \approx \eta$). If $\eta$ is set appropriately high, $\Lambda(t)$ would act like a cosmological constant of that magnitude, driving exponential expansion. However, because $\Lambda(t)$ in our model oscillates and decays, it would not remain stuck in that inflationary state forever – it would naturally decay (possibly rapidly if $\alpha$ is large in the early universe or if the oscillation leads to efficient conversion into radiation/matter). This could provide a graceful exit from inflation without invoking an ad hoc inflaton field, though in practice our tachyonic field $\phi$ essentially plays the role of an inflaton in that scenario. After inflation, as $\Lambda(t)$ became small, the universe would enter the radiation- and matter-dominated eras, allowing structures to form and the classical Big Bang nucleosynthesis and CMB history to proceed unaltered. One needs to ensure that by the era of nucleosynthesis (within the first few minutes of the universe) $\Lambda(t)$ had decayed to a value much smaller than the radiation density, otherwise it could interfere with element formation. This requirement can be satisfied by choosing $\alpha$ and $\omega$ such that $\Lambda(t)$ was negligible by, say, $t \sim 10^2$–$10^3$ seconds. Since $\Lambda(t)$ decays exponentially, even a modest $\alpha$ (on the order of $10^{-2},\text{s}^{-1}$, just to illustrate) would reduce $\Lambda$ by many orders of magnitude in a few hundred seconds. Thus, our model can be made consistent with early universe constraints.

Present Acceleration and Oscillation Signatures: During the current epoch, dark energy is measured primarily through its influence on the expansion rate as a function of redshift (e.g., via supernova distance-redshift relations, baryon acoustic oscillations, and the growth of large-scale structure). If dark energy oscillates with a period comparable to or shorter than the Hubble time, its equation of state $w(z)$ (as a function of redshift) would deviate from $-1$. One signature might be a slightly oscillatory behavior in the effective equation of state or in the deceleration parameter $q(z)$. Some phenomenological studies have searched for oscillatory features in the expansion history by fitting cosmological data to models where $w(z)$ has sinusoidal variations. So far, $\Lambda$CDM (constant $w=-1$) fits the data extremely well, but the data permits small deviations. The Dark Energy Survey (and other surveys like Planck, BOSS, etc.) have hinted that $w$ might be around $-1$ but not exactly, and even that it could vary . If future observations show a trend where, for example, the effective dark energy density was lower at intermediate redshifts ($z \sim 1$) and higher today (or vice versa), that could be evidence of oscillation. The Sousa–Ether model could accommodate such behavior. In particular, if $\omega$ is such that half a period ago (a few billion years ago) $\cos^2(\omega t)$ was smaller, then dark energy would have been less dominant at that time, potentially addressing the coincidence problem (making it more natural that only recently did dark energy become significant).

Additionally, an oscillating $\Lambda(t)$ could imprint subtle effects on structure formation. The growth of cosmic structures (galaxies, clusters) is governed by the competition between gravitational attraction of matter and the repulsive effect of dark energy. If dark energy was oscillating in strength, the growth rate of perturbations might speed up during epochs of low $\Lambda$ and slow down during epochs of high $\Lambda$. This could lead to features in the matter power spectrum or cluster abundance as a function of redshift. Some studies of oscillating dark energy models have found that they can slightly alter the matter power spectrum in ways that future galaxy surveys might detect . At present, the data is not sufficient to confirm such effects, but upcoming surveys (for instance, the Vera Rubin Observatory’s LSST, ESA’s Euclid mission, or NASA’s Nancy Grace Roman Space Telescope) will greatly tighten constraints on any time-variation of dark energy.

Coincidence Problem and Multiple Epochs of Acceleration: A striking consequence of an oscillatory dark energy is the possibility of multiple acceleration phases. In $\Lambda$CDM, we have essentially one accelerated phase (now and the future) and one decelerated phase (the past, after inflation). In our model, if the oscillations were slow enough, there could have been a brief acceleration even during the matter era if $\cos^2(\omega t)$ peaked at some time. For example, one could imagine that a few billion years after the Big Bang, $\Lambda(t)$ had a local maximum that temporarily increased $q = \ddot{a}a/\dot{a}^2$ above zero (accelerating), and then it subsided. The current acceleration would then be a second occurrence. Such behavior would be very intriguing – it would point to an underlying dynamical cycle. Observationally, finding evidence of a past acceleration earlier than expected would be revolutionary. Right now, the data is consistent with a single onset of acceleration around $z \approx 0.5$–$1$. The model could be tuned so that earlier oscillations either were too mild to cause acceleration or happened when radiation domination made them irrelevant. In any case, the general prediction remains: the future will not be a simple de Sitter expansion, but rather a damping oscillatory approach to a new state. This means, for instance, that the far future fate of the universe in this model is not an exponential blow-up (Big Rip or eternally accelerating de Sitter), but likely a slower expansion or even cyclic behavior. Given $\Lambda(t) \to 0$ as $t \to \infty$, eventually matter (whatever remains) or curvature could dominate and slow the expansion. There is even a speculative scenario where if the oscillation continued and $\Lambda$ became negative for a period (though our $\cos^2$ form disallows negative values, a slightly modified oscillation could allow it), the universe could recollapse. We have not incorporated negative $\Lambda$ in our primary model, but it’s an interesting extension: an oscillating $\cos$ (not squared) would yield alternating sign dark energy, which could lead to a cyclic universe (bang, crunch, bang, etc.). Our current model does not go that far – $\cos^2$ keeps it always expansionary (or at least never strongly contracting).

Consistency with Local Physics: On smaller scales like the solar system or galaxies, the presence of an oscillating dark energy field is unlikely to be directly noticeable, as dark energy is extremely dilute and homogeneous. The tachyonic field $\phi$ would couple gravitationally to everything, but since it has no charge or significant interactions (by assumption, as we haven’t introduced any), it would not affect laboratory physics except possibly through a very tiny time-dependence of the gravitational “constant” or other subtle effects. We assume here that any such effects are below current detection thresholds, which is plausible. The oscillation period, if of cosmological scale, is far too long to affect laboratory timescales. If it were shorter, there could be potentially detectable oscillations in the expansion rate even on scales of years or decades (e.g., anomalies in pulsar timing or orbital dynamics). However, those would be incredibly tiny – because $\Lambda(t)$ is so small in absolute terms that any variation on short timescales would be negligible compared to local gravitational influences. Thus, the best hope to detect this theory’s effects lies in cosmological observations of the expansion history and structure.

Relation to Experiments and Existing Work: The Sousa–Ether Theory intersects with several areas of current experimental research:

* Dark Energy Surveys: As mentioned, large imaging and spectroscopic surveys of galaxies (DES, Euclid, LSST, DESI, etc.) are measuring the expansion history and growth of structure with high precision. They will either detect deviations from $\Lambda$CDM or push the limit on how much $w$ can vary. If these surveys find evidence that $w \neq -1$ or $\dot{w} \neq 0$, especially if they see an oscillatory pattern in the data (even one slow oscillation), it would strongly support models like ours . Conversely, if $w$ is constrained to be exactly -1 to within, say, $\pm 0.01$ at all probed redshifts, our model would need $\omega$ so high or $\alpha$ so large that effectively it mimics $\Lambda$CDM very closely.
* Cosmic Microwave Background (CMB): The CMB is mostly sensitive to early-universe physics and the integrated effect of dark energy via the late Integrated Sachs-Wolfe (ISW) effect. If dark energy was dynamically significant at high redshift (which in our model it isn’t really after early times if we set parameters right), it could affect CMB. We ensure $\Lambda(t)$ decayed early so CMB should be mostly standard. The ISW effect (changes in CMB photon energies as they pass through time-evolving gravitational potentials at late times) could be different if dark energy oscillates. A rising then falling dark energy could produce a non-monotonic ISW contribution. Some studies have looked for signs of this in the large-angle CMB correlations with large-scale structure. So far, $\Lambda$CDM is fine, but again, data is improving.
* Gravitational Waves: Interestingly, if the dark energy field oscillates, one might wonder if it can emit gravitational waves or cause oscillations in the gravitational wave background. A homogeneous oscillating field does not source gravitational waves (because it’s the same everywhere, there’s no quadrupole), but if there were spatial perturbations in the field, those could lead to waves. It’s a stretch to detect, but worth noting as a theoretical point.
* Laboratory Tests of Fundamental Constants: If $\Lambda(t)$ comes from a scalar field, one could imagine that field might couple to other sectors (like changing particle masses or couplings slightly over time). Some experiments (atomic clocks, resonant mass detectors, etc.) search for periodic variations in constants or forces. If $\omega$ corresponded to, say, an oscillation period of a year or so, those could show up. However, it is more plausible $\omega$ is extremely low frequency (cosmological timescale) or very high (damped out quickly). We don’t expect any such lab signals given our parameter choices, but it’s good to remain open to cross-disciplinary checks.

Philosophical Implications: On a conceptual level, the Sousa–Ether Theory resurrects the notion of an ether in a modern guise. This is philosophically intriguing because for a long time the idea of an ether was considered obsolete. Here we see that what was dismissed (a pervading substance) reappears as something else (a dynamic field). This mirrors the way Einstein’s “blunder” of a cosmological constant was later vindicated . It suggests a historical lesson: ideas in physics can transform and find new life in different theoretical contexts. Our theory offers a vision of the vacuum as a living, time-evolving entity rather than a fixed backdrop. If true, it means the universe has additional layers of dynamism even in what we call “empty space.”

**Conclusion**

The Sousa–Ether Theory provides a comprehensive framework that addresses some of the most profound open questions in cosmology by introducing a time-oscillating, decaying dark energy component. We have presented the theory in the form of a scientific manuscript, laying out its philosophical motivation, theoretical foundations, mathematical formulation, and potential implications. In this model, dark energy is no longer an immutable cosmological constant but a manifestation of an underlying ether-like field that interacts with matter and antimatter and evolves over time. The key equation $\Lambda(t) = \eta \cos^2(\omega t) e^{-\alpha t}$ captures the essence of this evolution: oscillations that gradually fade, reconciling a large initial vacuum energy with the tiny value observed today. By embedding this $\Lambda(t)$ into the Friedmann equations, supplemented by a tachyonic field to drive the oscillations, we obtain a self-consistent cosmological model.

This theory offers potential solutions or at least alleviations for the cosmological constant problem (through dynamical cancellation of vacuum energy) and the coincidence problem (through oscillatory timing of dark energy dominance) . It is consistent with known physics if parameters are chosen carefully, and it remains within observational bounds while being testable by upcoming precise cosmological measurements. If dark energy is indeed found to vary with time , it will be a revolutionary discovery, and models like Sousa–Ether will become crucial in explaining the phenomenon. Conversely, if $\Lambda$ is confirmed to be absolutely constant, the oscillating aspect of the theory would be tightly constrained (perhaps forcing $\omega \to 0$ and $\alpha \to 0$, reducing Sousa–Ether to $\Lambda$CDM itself in the limit).

Looking ahead, much work can be done to further develop and test this theory. On the theoretical side, a deeper analysis of the tachyonic field dynamics and its coupling to other fields would firm up the microphysical picture. One could explore, for example, particle production during oscillations, or whether the tachyonic field could also play the role of dark matter (as some scalar field models attempt to unify dark sectors). On the observational side, one should derive detailed predictions for cosmological surveys: for instance, the expected shift in the distance–redshift relation or the pattern of cosmic microwave background anisotropies under different oscillation parameters, and then compare with data. It will also be important to ensure that the model does not conflict with any high-precision observational pillars of cosmology, like big bang nucleosynthesis light element abundances or the observed angular acoustic peaks of the CMB, which put tight limits on any extra dynamics in those eras.

From a philosophical and methodological standpoint, the Sousa–Ether Theory exemplifies how scientific progress often revisits old ideas in new light. The concept of an ether has been reborn here not as an invisible mechanical medium for light, but as a dynamic cosmological field – showing the evolution of scientific ideas over time. In embracing this term, we acknowledge that our understanding of the vacuum and spacetime is still incomplete and open to imaginative new constructs.

In conclusion, we find the Sousa–Ether Theory to be a promising and rich approach to cosmology. It maintains agreement with established observations while opening new avenues for explaining why our universe is the way it is. The true test of any such theory will be its agreement with empirical evidence. As new data arrives, we will either find encouraging signs that dark energy has subtle time-dependence – in which case the ideas presented here will gain traction – or we will learn that dark energy is truly a cosmological constant, in which case portions of this theory would need revision or simplification. Either outcome will deepen our understanding.

Ethical Note: This work is offered as an open contribution to the scientific community and to humanity at large. We have not sought any patents or proprietary claims on the ideas presented herein. Instead, in the spirit of open scientific inquiry, we invite researchers worldwide to examine, challenge, and build upon the Sousa–Ether Theory. Our aim is to advance knowledge and understanding of the cosmos, and we believe that collaborative verification and exploration of these concepts will be the surest path to truth.

– Sousa–Ether Theory