The speed of light in a vacuum can be influenced by factors such as the presence of matter and energy density, which affect the quality and properties of the vacuum.

Reevaluating Variability of the Speed Limit (VSL)

An Alternative Approach to the Variability of the vacuum Speed of massless particle Limit and its Consequences

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Overall Introduction

Abstract

This comprehensive work, structured into thirteen sections, delves into the *Variable Speed of Light* (VSL) hypothesis, offering an innovative framework for understanding cosmological phenomena. The introduction and prologue set the stage by addressing the motivations behind VSL and the misinterpretations of Einstein's second postulate. While Einstein posited that the speed of light in a vacuum, 'c,' must be determined experimentally, this has been misinterpreted to mean that 'c' is universally constant under all conditions. Instead, this work argues that 'c' might *locally vary* based on the *properties of each specific vacuum*, challenging the *notion of a true-vacuum* and suggesting it behaves more like a low-density medium rather than completely empty space.

Section 1 explores the relationship between permittivity, permeability, and VSL, laying the groundwork for understanding how changes in vacuum properties could affect light speed. Section 2 examines the vacuum itself, proposing that its characteristics can influence 'c' and thus impact our understanding of space and time. Section 3 extends this by discussing different types of media within the vacuum and their potential effects on light speed.

Section 4 analyzes the implications of considering the speed of light as locally constant rather than universally fixed, which could lead to significant revisions in both Special and General Relativity. Section 5 compares VSL with the traditional inflationary model, suggesting that VSL could provide alternative explanations for the early universe's rapid expansion. Section 6 addresses the Hubble Tension, exploring how VSL could reconcile discrepancies in measurements of the Hubble constant.

Sections 7 and 8 discuss the practicalities of implementing VSL and propose experiments and observations to test its predictions. Section 9 focuses on empirical verification, emphasizing the need for robust observational data to validate the VSL hypothesis. Section 10 presents a mathematical model for VSL, highlighting its potential to reshape our understanding of the universe's expansion.

The final conclusions summarize the key findings, stressing the importance of further investigation and experimental verification. This work aims to challenge established concepts, suggesting that VSL could provide new insights into cosmology and urging the scientific community to explore this hypothesis more deeply.

Introduction

This comprehensive work explores the *Variable Speed of Light* (VSL) hypothesis as a potential alternative framework for understanding cosmological phenomena. The VSL concept proposes that the speed of light in a vacuum might vary depending on the properties of the vacuum. In Special Relativity (SRT), General Relativity (GRT), and Quantum Mechanics (QM), a crucial aspect is the fixed maximum speed limit, 'c', which must be consistently observed by all observers, regardless of its value or their positions. This empirically determined value signifies the maximum speed attainable by massless particles under specific vacuum conditions, with all observers measuring the same speed. Therefore, 'c' could theoretically vary, depending on the vacuum's properties. Whether 'c' is 299,729,458 m/s or any other value, it depends on the vacuum quality, behaving like a medium such as gas or plasma. The critical point is that, under these specific vacuum conditions, all observers will see the same value for 'c'. This idea aims to offer solutions to certain cosmological questions and requires further investigation and experimental verification to determine its effectiveness in explaining the universe's evolution. Nonetheless, it is important to note that VSL is entirely compatible with existing theories.

The standard model of cosmology Λ-CDM has been remarkably successful in explaining a vast array of astronomical observations. However, certain interpretations and theoretical challenges, such as the Hubble Tension and the need for an Inflationary Field and Particle Theory, suggest that our understanding of the universe may still be incomplete. One intriguing possibility is that the vacuum speed of light (c) is not a universal constant but can locally vary under certain conditions due to vacuum conditions. This concept, known as the *Variability of the Speed of Light* (VSL), offers a potential alternative framework that could address and re-evaluate longstanding cosmological puzzles.

By exploring VSL, we can potentially develop a more nuanced and accurate understanding of the universe's evolution and the laws that govern it. This work aims to present a comprehensive exploration of VSL, grounded in empirical data and theoretical rigor.

The Concept of VSL

VSL simply questions the experimentally measured speed of light (299,792,458 meter per second) is the Maximum Speed Limit for Massless Particles, as it has been achieved many times in Earth-based chambers in different laboratories.
The concept of a Universal Vacuum Speed Limit is intriguing!

1. **VSL and Empirical Reality**:
   - ***VSL aims to establish the maximum speed attainable by massless particles in a vacuum***.
   - It suggests that the empirically measured value of 299,792,458 m/s might be specific to local conditions of space (such as permeability and permittivity).
   - In deeper vacuum conditions (e.g., zero-atmosphere conditions at extremely low temperatures), the speed may differ from this measured value. In Intergalactic media (IGM), these conditions are achieved with a density of 1 to 10 particles per cubic meter.
   - The value was determined in Earth chamber laboratories, influenced by interplanetary medium (IPM) conditions (up to 10^8 particles per cubic meter)-but never qualified as a true vacuum.

2. **Local vs. Universal Constant**:
   - While VSL aligns with the idea of a universal vacuum speed limit, it questions whether this maximum speed is strictly 299,792,458 m/s.
   - VSL proposes that this value is a local constant, not necessarily universal. To find the true maximum, we should compare locally measured values under different vacuum conditions.
   - It emphasizes empirical reality over speculative theories.

3. **Gauge Concept**:
   - In physics, "gauge" refers to a measuring tool or standard. For example, in electromagnetism, gauge invariance depends on potential differences, not absolute values.
   - Applying this concept to VSL, different local vacuum conditions can be considered as gauges.
   - Simply, VSL gauges the quality of the vacuum.

VSL isn't just a theory—it's an empirical fact that calls for further exploration and validation through scientific methods. Let's focus on the evidence and keep speculation in check!

The core idea behind VSL is that the speed of light may be influenced by factors such as the presence of matter, energy density, and the determine and concrete properties of the vacuum. For example, in regions of space with extremely high energy densities or strong gravitational fields, c might differ from its value in empty space. This *local variability* could have profound implications for our understanding of the universe, particularly in the early moments following the Big Bang.

Integrating VSL with Relativistic Physics and Quantum Mechanics

An essential aspect of the VSL hypothesis is its complete compatibility with existing physical laws. Special and General Relativity are built on the constancy of the speed of light, but these theories can be extended to accommodate a locally variable c (a VSL gauge). For instance, the equations of GR can be modified to include a term, where c depends on both time (specific epoch) and spatial coordinates (determine region). This approach preserves the local invariance of physical laws while allowing for global variations in c by measuring parameters such as permittivity and permeability.

Moreover, the integration of VSL with quantum mechanics (QM) and solid-state physics could lead to new insights. In extreme astrophysical environments like the interiors of neutron stars and black holes, the properties of matter are governed by both relativistic and quantum effects. Understanding how a locally variable c interacts with these conditions could advance our knowledge of high-energy astrophysics and condensed matter physics.

Additional Considerations

This study aims to investigate whether the Variable Speed of Light hypothesis provides a viable and well-supported alternative for explaining cosmological observations. Specifically, it seeks to determine ***the maximum speed attainable by massless particles in the most perfect vacuum throughout the entire universe***. For brevity, we will often refer to this maximum speed as the "*Speed of Light*".

Sections Index (structure of This Work)

This comprehensive work is structured into ten sections, each focusing on a specific aspect of the Variable Speed of Light (VSL) hypothesis. Each section includes an abstract, introduction, synthesis, and references, providing a thorough and accessible overview of VSL's potential impact.

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PROLOGUE

Justifying the VSL Proposal. Subjective Theory.

Abstract

Our perception of reality is intrinsically tied to our immediate surroundings and the limitations of our current technological capabilities. This paper explores the implications of these limitations on our understanding of the universe, specifically in the context of the Variable Speed of Light (VSL) hypothesis. By examining the nature of light's journey through different media, we propose that the speed of light (c) may not be a universal constant but rather a local one, subject to the properties of the medium through which it travels.

Introduction

Our understanding of the universe is confined by the limits of our technology and our capacity to interpret the laws of physics. The vastness of space restricts our perception, allowing us only to empirically measure and appreciate our immediate surroundings. Instruments like Voyager I and II, the Hubble Space Telescope, and the James Webb Space Telescope have provided invaluable data, yet they are limited in scope.

The Nature of Light and Our Observations

Photons reaching us from distant parts of the universe carry a wealth of information. We can determine redshift, chemical composition of stars, distances, velocities of stars and galaxies, and the temperature of deep space, among other things. However, our knowledge is inherently limited to our immediate surroundings and speculative theories that attempt to explain observed phenomena.

Einstein's Theories and Quantum Mechanics

Einstein's theories of relativity and quantum mechanics form the bedrock of modern physics. Einstein's hypothesis of the constancy of the speed of light (c) is a cornerstone, validated through countless experiments. This constancy underpins many physical laws and equations, including $E = mc^2$, which ties the speed of light to the energy content of the universe.

The Variable Speed of Light Hypothesis

Einstein's second postulate asserts that the speed of light in a vacuum is constant for all observers, regardless of their motion. A key aspect in Special Relativity (SRT), General Relativity (GRT), and Quantum Mechanics (QM) is the fixed maximum speed limit, 'c', which must be absolutely observed by all observers, irrespective of its value or their positions. This value, empirically determined, does not undermine these theories. Instead, it simply represents the maximum speed achievable by massless particles in specific vacuum conditions, with all observers measuring the same speed. Thus, 'c' could theoretically vary, depending on the vacuum's properties. Whether 'c' is 299,729,458 m/s or any other value, it depends on the vacuum quality, behaving similarly to a medium like gas or plasma. The essential point is that, under these specific vacuum conditions, all observers will see the same value for 'c'. This has profound implications, including the establishment of the Minkowski space-time framework, where the interval $S^2 = \Delta x^2 + \Delta y^2 + \Delta z^2 - c^2\Delta t^2$ remains invariant for all observers.

Einstein's second postulate asserts that the speed of light in a vacuum is constant for all observers, regardless of their motion. This has profound implications, including the establishment of the Minkowski space-time framework, where the interval $S^2 = \Delta x^2 + \Delta y^2 + \Delta z^2 - c^2\Delta t^2$ remains invariant for all observers.

However, Einstein also emphasized that the value of c must be empirically determined. This nuance often gets overlooked, leading to potential misinterpretations. Light can travel through different media, experiencing varying degrees of resistance that affect its speed. The vast majority of space, while often considered a vacuum, is filled with interstellar and intergalactic media (ISM and IGM) that could alter the speed of light.

Reconsidering the Speed of Light

The measured speed of light, c = 299,792,458 m/s, is obtained under specific conditions that we refer to as a vacuum. However, this "vacuum" is not an absolute void but a low-density material filled with particles, similar to how the troposphere is filled with air. This medium has its own permittivity and permeability, and thus a refractive index, just like any other material.

Analyzing Light's Journey

Consider photons from the Cosmic Microwave Background (CMB), which have traveled for approximately 13.8 billion years. These photons have traversed various media, experiencing deviations and alterations in speed. By the time they reach our telescopes, they have undergone significant changes:

1. **Emission from CMB (Intergalactic Medium)**
2. **Travel through the IGM**
3. **Penetration into the Milky Way (Interstellar Medium)**
4. **Arrival in the Solar System (Interplanetary Medium)**

The perceived speed of these photons is influenced by their journey through different media. The speed c = 299,792,458 m/s, often considered constant, may vary based on the medium's properties. This suggests that c could be a local constant, not a universal one.

Addressing Potential Counterarguments

1. **Media Effects on Propagation Speed**: Different media, such as IPM, ISM, and IGM, have varying densities and temperatures that affect the speed of massless particles. The universe's accelerating expansion suggests that c might not be constant but rather subject to variation over time.
2. **Empirical Evidence and Speculative Theories**: While VSL remains speculative, it has empirical support. The Lambda-CDM model and string theory are also speculative, often relying on unproven concepts like dark matter, dark energy, and vibrating strings. VSL offers a framework for revisiting the constancy of c in light of new evidence.
3. **True Vacuum**: True vacuum, as envisaged by Einstein, is unattainable. The "vacuum" in experiments is a low-density medium, not a true void. Thus, the measured value of c might not represent the absolute maximum speed limit.

Implications and Conclusion

VSL accepts the foundations of SRT, GRT, and QM, and accommodates redshift observations. It challenges the notion of c as an absolute constant by proposing it as a local constant, influenced by the medium through which light travels. This aligns with Einstein's second postulate, emphasizing the need for empirical verification.

Section 1.

Permittivity, Permeability and VSL

"The task is not so much to see what no one has yet seen, but to think what nobody has yet thought about that which everybody sees."
Erwin Schrödinger

Abstract

This article explores the hypothesis that *vacuum permittivity* (ϵ_0) and *permeability* (μ_0) may be variable. This variability could provide a more straightforward explanation for *cosmic inflation* following the *Big Bang* than the *inflaton* hypothesis. Theoretical mechanisms, comparative analyses, experimental evidence, and potential implications are discussed. This hypothesis offers testable predictions and opens new research avenues in fundamental physics and cosmology. We also discusses the implications of quantum vacuum fluctuations, the Higgs boson, and the potential variability of fundamental constants such as the *speed of light* (c) over time and space.

Introduction

In classical physics, *the speed of light* c in a vacuum is a fundamental constant defined by the *permittivity* (ϵ_0) and *permeability* (μ_0) of *free space*. However, recent advances in *quantum mechanics* (QM) and *cosmology* suggest that ϵ_0 and μ_0 may not be constant but vary under different conditions. This variability could provide an alternative explanation for phenomena traditionally attributed to the *inflaton field* in *cosmology*. *Quantum mechanics* suggests that the vacuum is not empty but filled with fluctuating fields. These fluctuations might have profound implications on the fundamental constants we consider immutable, such as the speed of light.

Theoretical Background

Classical Electromagnetism

The *speed of light* c is given by:

$$c = \frac{1}{\sqrt{\epsilon 0 \cdot \mu 0}}$$

where ϵ_0 and μ_0 are the *permittivity* and *permeability* of *free space*, respectively. This relationship implies that variation in ϵ_0 and μ_0 will affect the *speed of light*.

Permittivity of free space (ϵ_0): This constant characterizes the ability of a *vacuum* to permit electric field lines., typically valued approximately: $\epsilon_0 \approx 8.854 \times 10^{-12}$ F/m.

Permeability of free space (μ_0): This constant characterizes the ability of a *vacuum* to support the formation of a magnetic field, with a typical value: $\mu_0 = 4\pi \times 10^{-7}$ H/m.

Quantum Mechanics and Quantum Vacuum

Historical Context

1. **Einstein's Postulates**: When Einstein formulated his theory of relativity, the speed of light in vacuum (c) was assumed to be constant and the same for all observers.
2. **Quantum Mechanics**: The advent of quantum mechanics introduced the idea that the vacuum is not empty but filled with fluctuating fields, suggesting that ϵ_0 and μ_0 might not be fundamental constants but could vary under different conditions.

The Nature of Quantum Vacuum

Quantum mechanics posits that the vacuum is a seething foam of virtual particles constantly being created and annihilated. This "quantum vacuum" affects the properties of space itself, influencing the propagation of light and other electromagnetic phenomena.

Mechanisms of potential variability of constants

1. **Quantum Vacuum Fluctuations**: These fluctuations alter the local properties of space, suggesting that ϵ and μ might vary with the energy density of these fluctuations.
2. **Casimir Effect:** This demonstrates the impact of vacuum fluctuations on physical objects, indicating variability in vacuum properties.
3. **Lamb Shift:** The energy levels of electrons in hydrogen atoms shift due to vacuum fluctuations, suggesting that vacuum can vary at quantum scales.
4. **Higgs Field Interactions**: Variations in the Higgs field could impact the electromagnetic properties of the vacuum, influencing ϵ and μ.
5. **Cosmological Conditions**: In the early universe, extreme conditions could lead to significant variations in ϵ and μ, potentially explaining phenomena like cosmic inflation without invoking hypothetical particles like the *inflaton*.
6. **Energy Density of Free Space**: This energy density influences ϵ and μ, thereby affecting c.

7. **Dark Energy:** The presence of dark energy could indicate variations in vacuum energy density, affecting ϵ and μ.
8. **Cosmic Microwave Background (CMB):** Analyzing the CMB for variations in light speed can provide insights into historical changes in ϵ and μ
9. **Experimental Observations**: Precision measurements have shown that the speed of light can vary slightly depending on the medium it traverses. While the vacuum speed of light (c) remains a cornerstone, these observations open the door to questioning its absolute constancy.
   - **Refractive Index Variations:** Different materials have different refractive indices, causing light to travel at varying speeds through them. This variability hints at the potential for similar variations in a vacuum under certain conditions.
   - **High-Energy Physics Experiments:** Experiments at particle accelerators have shown that under extreme conditions, the properties of the vacuum can be altered, suggesting potential variability in c.
   - **Astronomical Observations:** Light from distant stars and galaxies, when passing through various interstellar and intergalactic media, exhibits changes in speed and direction, indicating variability in the fundamental properties of space.
10. **Cosmological Implications**: The observed universe's expansion suggests that the properties of the vacuum might have evolved. If ϵ_0 and μ_0 were different in the early universe, then c could have been different as well. This could explain phenomena such as the horizon problem and provide alternatives to *inflation* theory.
    - **Horizon Problem:** The horizon problem questions why regions of the universe far apart appear to have the same temperature. A varying speed of light in the early universe could allow for faster information transfer, leading to thermal equilibrium without invoking inflation.
    - **Structure Formation:** Variations in c could influence the rate of structure formation in the universe, affecting the distribution of galaxies and other large-scale structures.
    - **Cosmic Microwave Background (CMB):** Analyzing the CMB for signatures of varying c could provide insights into the history of vacuum properties and validate or refute this hypothesis.
11. **Graviton and Quantum Gravity**: The graviton is a proposed quantum particle that mediates the force of gravity. If gravitons exist and interact with electromagnetic fields, they could cause variations in ϵ and μ, impacting the *speed of light*. The existence and behavior of gravitons would affect the fabric of space-time and, consequently, ϵ and μ.
    - **Quantum Gravity:** Variations in ϵ and μ could arise from quantum gravitational effects, altering the speed of light in different regions of space-time.
    - **Gravitational Waves:** The detection of gravitational waves provides evidence for the dynamic nature of space-time. These waves could influence local variations in ϵ and μ.

Specific experimental evidences such as the Hubble Tension, the universe's accelerated expansion, the Inflationary Theory and the own variability of the vacuum as the material does – are indeed relevant pieces of evidence supporting the exploration of variable c.

Circumstances of potential variability

The VSL premise suggests that ϵ and μ, and thus c, are not fixed but can change under varying conditions such as:

- **Interstellar Plasma (IPM):** High-energy environments with significant electromagnetic activity could alter ϵ and μ.
- **Interstellar Medium (ISM):** Regions with varying densities and compositions of particles might exhibit different electromagnetic properties.
- **Intergalactic Medium (IGM):** Low-density regions between galaxies could have different values for ϵ and μ.
- **Dark Matter and Dark Energy:** The presence of dark matter and dark energy, which dominate the universe's mass-energy content, could influence the vacuum properties and thus ϵ and μ.
- **Empty Space:** The traditional concept of empty space as a true vacuum is challenged by quantum field theories suggesting a complex, dynamic entity with fluctuations impacting ϵ and μ.
- **Stellar and Galactic Cores:** Intense gravitational fields and high-energy densities could lead to variations in vacuum properties.
- **Quantum Fluctuations:** These fluctuations could cause local changes in the vacuum properties, affecting c.

The VSL hypothesis faces some challenges, such as reconciling it with existing well-established theories.

Experimental Evidence

1. **Gravitational Lensing:** Light bending around massive objects suggests changes in the speed of light due to intense gravitational fields.
2. **Variations in Light Speed:** Precision measurements in high-energy physics show minute variations in light speed under extreme conditions, hinting at variable ϵ and μ.
3. **Cosmological Observations:** Analyses of the CMB and distant astronomical objects suggest potential variations in fundamental constants over cosmic time scales.

Microwaves and Media Influence

In microwave circuits, the behavior of electromagnetic waves depends on the properties of the medium they traverse. This variability suggests that under different conditions, ϵ_0 and μ_0, and consequently c, might change.

Implications of Hypothesis Validation

- **Rewriting Physics:** validating this hypothesis would require rewriting fundamental physics principles.
- **New Technologies:** Understanding how to manipulate ϵ and μ could lead to advances in technologies such as faster-than-light communication.
- **Cosmological Models:** Variable c would influence models of the early universe, providing alternatives to the inflation hypothesis.

- **Dark Matter and Dark Energy:** Variations in c could influence our understanding of these fundamental aspects of the universe.

Quantum Fluctuations and Higgs Boson

1. **Quantum Vacuum:** A seething foam of virtual particles that might cause local variations in permittivity and permeability.
2. **Higgs Field:** Interaction with the Higgs field could change the properties of space, affecting ϵ and μ.

Conclusions

The hypothesis that ϵ_0 and μ_0 are variable offers an exciting alternative to the *inflaton* hypothesis for explaining cosmic inflation. This hypothesis has significant theoretical support from quantum mechanics and emerging experimental evidence. While controversial, it opens new avenues for research and challenges our understanding of fundamental physics. Further experimental validation and theoretical development are needed. If confirmed, this could revolutionize our understanding of the universe's fundamental laws and provide insights into the nature of Dark Matter and Dark Energy.

Future Research Directions

- Developing more sophisticated experiments to measure minute variations in c.
- Reconciling the VSL hypothesis with established theories like General Relativity.
- Exploring the implications of variable c for dark matter and dark energy models.
- Investigating the potential applications of variable c in physics and technology.

Appendix

Glossary

- **Permittivity (ϵ):** A measure of how an electric field affects, and is affected by, a dielectric medium.
- **Permeability (μ):** A measure of how a magnetic field interacts with a material.
- **Quantum Vacuum Fluctuations:** Temporary changes in the amount of energy in a point in space, as predicted by quantum theory.
- **Higgs Field:** A field believed to give mass to particles.
- **Inflation:** The rapid expansion of the universe after the Big Bang.

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Section 2.

VSL and the Vacuum

"If I have seen further, it is by standing on the shoulders of giants."
Isaac Newton

Abstract

The speed of light in a vacuum, denoted as c, is commonly understood to be a constant value of approximately 299,792,458 meters per second. This constancy is a foundational assumption in Einstein's theory of relativity and has profound implications for our understanding of the universe. However, recent considerations suggest that this speed might not be as constant as previously thought, depending on the context and environment in which it is measured.

Introduction

Light itself cannot exceed its own speed in vacuum as that is its speed limit, which is also the speed limit in nature. This stems from a deep understanding of nature that led to Einstein's special theory of relativity with light being the bearer of nature's ultimate speed limit. Note that the speed limit refers to its maximum speed which occurs in VACUUM. Light cannot be made to move faster, but can be slowed down when it is made to pass through a medium. The slowing process is related to the resistance experienced by light in moving through a medium depending on the atomic/molecular structure of the medium, and its density.

The measured speed of light is 299,792,458 m/s in a vacuum, obtained locally in Earth-based laboratories and near-Earth space in a specific time. However, this value might not hold universally across different cosmic environments. The properties of the vacuum in these varied environments, including quantum vacuum fluctuations and varying densities, could lead to different light propagation speeds.

Understanding the specific type of vacuum in which light travels is crucial. Near-Earth experiments are conducted in a controlled vacuum environment, but cosmic vacuums can vary greatly. For instance, the interstellar medium (ISM) and intergalactic medium (IGM) possess different densities and properties that can affect light speed limit. In extremely sparse regions of space, where the vacuum is nearly devoid of particles (approximately 1 proton per cubic meter), the speed of light in this kind of vacuum could theoretically be higher than the measured 299,792,458 m/s, otherwise, our physical understanding of permittivity and permeability does not make sense.

Theoretical Background

Einstein's special theory of relativity, formulated in 1905, posits that the speed of light in a vacuum is the ultimate speed limit in the universe. This principle has been confirmed through numerous experiments and is a cornerstone of modern physics. However, it's essential to recognize that these measurements were conducted locally, i.e., in Earth labs and in our near space, and always in contemporary times. The question arises: which kind of vacuum are we referring to when we speak of the speed of light?

Vacuum, as we understand it, is not a simple empty space. Instead, it can vary in its characteristics depending on the environment. For instance, the interplanetary medium (IPM), the interstellar medium (ISM), and the intergalactic medium (IGM) all have different properties. Moreover, the so-called "empty space," which has an equivalent energy density of only one proton per cubic meter, as suggested by the expanding universe, might present a significantly different vacuum condition.

Variation in the Speed of Light (VSL)

The speed of light is influenced by the medium through which it travels. While in a perfect vacuum, c is the maximum speed limit, the actual vacuum we measure in can have subtle variations that affect this speed. In denser media, light slows down due to the resistance encountered from the atomic or molecular structure of the medium.

The real question is: which vacuum are we using for these measurements? Are we considering a near-quantum vacuum, as seen in different environments like the interplanetary medium (IPM), interstellar medium (ISM), or intergalactic medium (IGM), or the almost empty space with minimal energy density? The resistance experienced by light in these various vacua, with their different atomic/molecular structures and densities, could imply that the speed of light might be greater in the emptiest of spaces than the traditionally accepted 299,792,458 meters per second.

First of all, it is important to clarify some aspects related with Special Relativity Theory (SRT), which, nowadays, seems to be interpreted through many "refined" theories that might not align with Einstein's original formulation. To challenge a cornerstone of physics, such as the speed of light, it requires a radical departure from the current understanding.

Interpretation of the postulates in Special Relativity Theory

First Special Relativity Hypothesis: Relative Principle:

- **Original German**: "Die Gesetze, denen die Vorgänge in Natur und Technik unterliegen, sind unabhängig von dem Bewegungszustande des mitursächlichen Koordinatensystems."
- **Literal Translation**: "The laws governing natural and technological phenomena are independent of the state of motion of the causal coordinate system."

This postulate means that the laws of physics are the same for all observers, regardless of their state of motion. This principle, combined with the Lorentz transformation and the four-dimensionality of space-time as described by Minkowski space ($S^2=(c\cdot t)^2-x^2$, which introduces the 'light cone' representation), has resulted in a widely theory verified with profound implications for our understanding of the universe.

Second Special Relativity Hypothesis: Constancy of the Speed of Light:

- **Original German:** "Jede Lichtquelle bewegt sich im Ruhestandssystem mit der bestimmten, von Experimenten festzustellenden Geschwindigkeit c."
- **Literal Translation:** "Every light source moves in the rest system with the specific speed c, ***determined by experiments***."

The interpretation of the second hypothesis, when combined with the first, leads to the understanding that "a rest system refers to the absolute absence of any disturbance in the medium through which electromagnetic waves (like light) propagate. The speed of light in a vacuum is the same for all observers, regardless of the motion of the light source or the observer, which will be determined experimentally."

Universal Implications of both postulates: In our universe, different observers perceive things differently, except for the invariant vacuum speed of light that is always the same regardless of the observers' conditions. Disturbances in certain fields travel at this invariant speed, applicable to both electromagnetic and gravitational fields. This invariant speed also provides a natural relationship between distance and time units.

Invariance vs. Local Constancy: Special Relativity establishes the **invariance** of the speed of light (c) in a vacuum. This means all observers in a vacuum, regardless of their motion, will measure the same constant value for c. However, the VSL hypothesis proposes a concept of **local constancy**. Here, c might be constant within a specific type of vacuum, but this value could potentially vary depending on the properties of the vacuum in different environments across the universe. Thus, the term *invariant means same value for all observers, but it doesn't mean same value por all types of vacuum.*

The *Variable Speed of Light* (VSL) Principle proposes a **paradigm shift** by suggesting c might vary depending on the locally properties of the vacuum the light travels through but maintaining c as constant and invariant for all observers located in the same framework, but c can achieve different values depending on where (location) and when (time) it was measured (so, both postulates remain exactly the same).
VSL states that the Maximum Speed Limit for Massless Particles (the real constant and invariant value of c) will be achieved when it will be measured at IGM media (where 1 to 10 particles per cubic meter at 2.7 ºK with zero pressure where particles can't vibrate) and not the measured (299,792,458 meters per second) in a chamber with IPM conditions.

Proposed Experiment for VSL Detection: One potential experiment to explore VSL involves measuring by means of optic interferometry as it will be exposed later. By comparing results with those based on the standard value of c, any deviations could potentially indicate a variation in the speed of light due to the specific vacuum conditions in that simulated region of space (i.e., vacuum condition). However, this experiment would require extremely high precision instruments and a deep understanding of the local interstellar medium (ISM) and local intergalactic (IGM) to account for potential external factors influencing the light propagation.

Implications for Dark Matter and Dark Energy

This hypothesis also opens new avenues for understanding dark matter and dark energy. Since mass and energy are related proportionally with c through the equations $E^2=(mc^2)^2+(pc)^2$ and $E=h \cdot c/\lambda$, variations in the speed of light limit could influence our perception of these mysterious components of the universe. If c is not constant, it could affect the distribution and behavior of dark matter and dark energy, offering new insights into their nature and interaction with visible matter.

VSL vs Λ-CDM Cosmology Model and Inflationary Theory:

The *ΛCDM cosmology model* is a successful in explaining various cosmological observations, but it incorporates speculative concepts like dark matter, dark energy, and negative pressure to explain the universe's expansion. The *Inflationary Theory* relies on the hypothetical Inflaton particle to explain rapid post-Big Bang inflation.

Empirical Validation: The VSL principle, if empirically validated, could significantly reshape our cosmological understanding. Current efforts to validate VSL include observations from the James Webb Space Telescope (JWST). Notably, Gupta (2023) discusses how JWST's early universe observations challenge the ΛCDM model, potentially supporting alternative theories like VSL.
The ΛCDM model estimates the universe's composition as:

- Ordinary matter: 5%
- Dark matter: 26.8%
- Dark energy: 68.2%

Theoretical Mechanisms: VSL could potentially redefine our understanding of dark matter and dark energy. For instance, variations in the speed of light might influence gravitational effects, offering alternative explanations for the observed galaxy rotation curves currently attributed to dark matter. Similarly, VSL could account for the accelerated expansion of the universe by proposing that changes in the speed of light affect the energy density of the vacuum, thus providing a novel explanation for dark energy.
Dark matter explains galaxy rotation speeds, while dark energy accounts for the universe's accelerating expansion attributed to negative pressure. Both are currently not directly observed, similar to the current status of VSL until it is demonstrated empirically.

Addressing Criticisms: While VSL offers intriguing possibilities, it faces several challenges. One criticism is the lack of a well-established mathematical framework that seamlessly integrates VSL with existing physical theories. However, ongoing theoretical work and future observations, such as those by JWST, may help address these issues.

Mathematical Considerations: The simplicity and utility of VSL stem from its reliance on Maxwell's equations, specifically $c= 1/\sqrt{(\mu_r\mu_0\varepsilon_r\varepsilon_0)}$. In environments where the relative permittivity ε_r approaches 1, such as zero-atmosphere and superconductivity conditions, the equation simplifies to $c= 1/\sqrt{(\mu_r\mu_0\varepsilon_r\varepsilon_0)}$. This allows for the use of c, c', and c'' to describe different kinds of vacuums. By denoting permittivity and permeability constants as ϵ_0',μ_0' for interstellar matter (ISM) and ϵ_0'',μ_0'' for intergalactic matter (IGM), these variations can explain the faster-than-expected speeds of stars in galaxies (c') and the accelerated expansion of the universe (c'').

VSL could potentially offer alternative explanations while complementing exactly the same estimations ΛCDM model. For example:

- Ordinary matter $E = m \cdot c^2 =$ $0.05 \cdot E_{\text{Total of the universe}}$
- Dark matter $E' = m' \cdot c'^2 =$ $0.268 \cdot E_{\text{Total of the universe}}$
- Dark energy $E'' = m'' \cdot c''^2 =$ $0.682 \cdot E_{\text{Total of the universe}}$

Where $E_{\text{Total of the universe}} = E + E' + E''$ and c= 299,792,458 m/s.

Regarding the Inflationary Theory, VSL offers a more straightforward and potentially superior explanation for complex phenomena without the need for hypothetical particles or fields.

Case Studies: Consider the rotation curves of galaxies. In the ΛCDM model, these are explained by invoking dark matter. However, VSL suggests that changes in the speed of light within galaxies (c') could account for these observations without requiring dark matter. Similarly, the accelerated expansion of the universe is traditionally attributed to dark energy, but VSL posits that a time-varying speed of light (c'') could naturally lead to this phenomenon. These examples highlight how VSL could offer more straightforward explanations for complex cosmological observations.

Incorporating Opinions of Physicists

In the ongoing quest to refine our understanding of the universe, it is essential to consider alternative theories alongside established models. One insightful perspective highlights that changes in the gravitational and electromagnetic fields travel at the speed of light because these fields are massless, extending their influence infinitely across the cosmos. Another perspective emphasizes that while general relativity and quantum mechanics are robust and predictive, their limitations invite exploration of new theories that could bridge the gap between the quantum and the cosmic. Furthermore, the remarkable precision of relativistic quantum field theories underscores the success of existing models, yet it also suggests that our quest for knowledge must remain dynamic, open to innovative ideas like the *Variable Speed of Light* (VSL) principle. These considerations underscore the importance of empirical validation and theoretical refinement as we advance our understanding of the fundamental nature of the universe.

The Role of JWST

The James Webb Space Telescope (JWST) is revolutionizing our understanding of the universe. Its observations are pushing the boundaries of our knowledge and challenging existing models. The diverse environments observed by JWST highlight the importance of considering different vacuum conditions in our theoretical models.

Conclusion

The concept of a varying speed of light limit challenges our traditional understanding of physics but offers exciting possibilities for new discoveries. By re-evaluating the assumptions about the vacuum and considering the different environments in which light travels, we may uncover deeper truths about the universe's fundamental nature. This perspective not only impacts theoretical physics but also opens new paths for experimental research and technological advancements.

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Section 3.

Vacuum media and VSL

"Wenn ich Unrecht habe, dann genügt ein einziger Satz!"
"If I were wrong, then one would have been enough!"
Albert Einstein

Abstract

The speed of light, denoted as 'c', is a fundamental constant in physics, precisely measured as 299,792,458 meters per second in controlled laboratory conditions on Earth. This measurement is derived using the fundamental constants of permittivity (ϵ_0) and permeability (μ_0) of free space, approximating an artificial true-vacuum in the interplanetary medium.

Introduction

Einstein's General Theory of Relativity (GR) established 'c' as the maximum speed achievable by any physical entity. This postulate is based on three key principles:

1. **General Principle of Relativity**: The laws of physics are invariant under Lorentz transformations, meaning they are the same for all observers, whether they are in inertial frames or accelerating or rotating relative to each other.
2. **Invariance of the Speed of Light**: The speed of light in a **perfect vacuum** is considered invariant, meaning it holds the same constant value (299,792,458 meters per second) for all observers, regardless of their relative velocity or the motion of the light source. This principle assumes a perfect vacuum, which is rarely encountered in the universe.
3. **Equivalence Principle**: The effects of gravity are indistinguishable from those of acceleration locally, leading to the understanding that gravity is a manifestation of spacetime curvature.

The speed of light, as measured on Earth, is obtained in a local vacuum environment. This local measurement does not contradict the principles of SR, GR, or QM, as these theories account for the behavior of light under various conditions and contexts.

The question of which vacuum we refer to is essential. While SR and GR assume a perfect vacuum, real-world vacuums like the interstellar medium (ISM), intergalactic medium (IGM), and even the quantum vacuum contain varying densities of particles and energy fields. These variations can influence the propagation of light, leading to slight differences in the effective speed of light. However, recent observations and theoretical considerations suggest that the differences could be far more significant than previously thought. This brings into question whether the experimentally determined speed of light, c= 299,792,458 m/s, measured on Earth in controlled conditions, should be universally applied throughout the cosmos.

Impact of Deep Space Conditions

1. **Temperature and Superconductivity**:
   Various environmental factors in deep space, such as extremely low temperatures and superconductivity, can influence the properties of space itself, potentially affecting the speed of light in ways not yet fully understood.
2. **Vacuum Variability**:
   The interstellar medium (ISM) and intergalactic media (IGM) present different vacuum conditions compared to those on Earth (IPM), which could result in different values of the speed of light. This variability supports the hypothesis that 'c' might not be a universal constant but could vary depending on the local properties of space.
3. **Reduced Collisions**:
   At such low temperatures (2.7 K), gas and dust molecules vibrate minimally, allowing photons to propagate with minimal collisions. This near-perfect transmission medium could increase the effective speed of light significantly.
4. **Quantum Vacuum Fluctuations**:
   Quantum vacuum fluctuations are affected by electromagnetic waves like photons, may be less pronounced due to lower interference, impacting the propagation speed of light.

Any observed deviation from the standard measurement of 'c' might be due to:

- **Actual variations in c:** Confirming and quantifying the effect if the speed of light truly varies depending on the vacuum environment.
- **Limitations in our observations:** Refining measurement techniques and understanding of the interstellar medium (ISM), and the intergalactic medium (IGM), we can discrepancies stem from instrumental limitations or incomplete knowledge about the environment.

Current Measurement Limitations and the Nature of Vacuum

One approach to consider involves the possibility that the current standard measurement of 'c' (299,792,458 meters per second) might not represent the speed of light in the most perfect vacuum conditions. As we mentioned earlier, "Atmosphere Zero" environments with near-complete absence of particles could potentially allow light to travel closer to its theoretical maximum speed.

Determining the speed of light in the most perfect true-vacuum requires significant advancements in:

- **Measurement Techniques:** More precise and sophisticated methods to measure the speed of light with unparalleled accuracy.
- **Understanding of the Vacuum:** A deeper understanding of vacuum in different regions of space, including varying densities of particles and energy fields influencing light propagation.

JWST Observations and Contemporary Physics

Recent observations by the James Webb Space Telescope (JWST) suggest that contemporary invariant constants, including the speed of light, may vary under specific conditions. Exploring deeper and more distant regions of space might revel variations in 'c', challenging our current measurements.

Consistency with Established Theories

Special Relativity (SR): The invariance of the speed of light postulated in SR holds for all observers in inertial frames. The systemic nature of 'c' does in different vacuum does not violate SR's foundational principles.

General Relativity (GR): GR incorporates the speed of light in its description of spacetime and gravity. Local measurements and the potential variability in different vacuums align with GR's treatment of varying conditions in different gravitational fields and spacetime curvatures.

Quantum Mechanics (QM): QM addresses the quantum vacuum and its fluctuations. Considering quantum vacuum fluctuations and their impact on the speed of light is consistent with QM's principles.

Conclusion

The article explores the concept of a local, potentially variable speed of light **within the framework of established theories**. By emphasizing locality, we maintain the integrity of Special and General Relativity while accommodating empirical observations and theoretical constructs. This nuanced perspective aligns with both empirical evidence and established physical laws, offering a coherent framework for understanding the speed of light in varying cosmic conditions.

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Section 4.

Local vs. Universal Speed of Light

"Science cannot solve the ultimate mystery of nature. And that is because, in the last analysis, we ourselves are part of the mystery that we are trying to solve."

Max Plank

Abstract

This article re-evaluates the constancy of the speed of light in vacuum, denotes as c, through the lens of local frames of reference, as posited by Einstein's Special Theory of Relativity (SRT) and General Relativity (GRT). While c is traditionally viewed as a universal constant, we propose a localized interpretation that allows for the speed of light to be consistent within local frames while acknowledging potential variations under extreme cosmic conditions. We explore how deep space environments, such as those with near-absolute zero temperatures and superconductivity, could affect the effective speed of light. Additionally, we examine the implications of this localized interpretation in understanding the expanding universe, emphasizing that the expansion of space can result in apparent velocities exceeding present value of c without violating SRT. By refining the second postulate of SRT to emphasize locally, we offer a coherent framework that accommodates empirical observations and aligns with the mathematical formalism of GRT. This approach underscores the importance of context and scale in physical laws, providing a nuanced perspective on the speed of light and its role in the universe.

Introduction

Einstein's Special Theory of Relativity (SRT) posits that the speed of light in a vacuum, c, is a universal constant. However, this concept is often interpreted without emphasizing the importance of locality. In this article, we explore the implications of considering the vacuum speed of light as locally constant and how various conditions in deep space might affect its effective value.

The Localized Interpretation of the Speed of Light

The second postulate of SRT states that the speed of light in a vacuum is the same for all observers, regardless of the motion of the light source or observer. By refining this postulate to emphasize locality, we propose the following interpretation:

- **Localized Interpretation**: The speed of light in a vacuum is the same for all observers *in their local frames of reference*, regardless of the motion of the light source or observer. This reframing aligns with the empirical evidence and the mathematical formalism of General Relativity (GRT).

This localized interpretation allows us to accommodate the expansion of the universe without violating the principles of SRT locally. It also opens up the possibility of different effective speeds of light under varying cosmic conditions.

The Role of Light Cones in Local Frames of Reference

In both SRT and GRT, the concept of a light cone is crucial in understanding how information and causality propagate through spacetime. The light cone defines the boundary within which signals can travel from a given event in spacetime, distinguishing between the past, future, and elsewhere.

- *The Role* ***Light Cone*** in Local Frames of Reference

  In both SRT and GRT, the concept of a light cone is crucial in understanding how information and causality propagate through spacetime. The light cone defines the boundary within which signals can travel from a given event in spacetime, distinguishing between the past, future, and elsewhere.

- ***Light Cone*** Structure
  - The *light cone* separates spacetime into regions of past, future, and elsewhere relative to a specific event. Events within the past and future *light cones* can causally affect or be affected by the event, respectively.
  - Observers in their local frames of reference can only interact with or observe events within their *light cones*. When an object moves outside this *cone* by exceeding the speed of light c with respect to the observer located at the vertex of both *cones*, it effectively disappears from the observer's local frame of reference. This adheres to the principles of SRT and GRT, which maintain that no information or causal influence can travel faster than c within a local frame.
  - ***Cosmological Horizon***: When an object moves outside this *cone* in means that the *Cosmological Horizon* of the observer has been overpassed. This marks the limit beyond which events cannot affect the observer.

By incorporating the *light cone* structure, we reinforce the idea that the speed of light, as experienced locally, governs the causal interactions and observations within an observer's local spacetime region.

The Impact of Extreme Conditions on the Speed of Light

1. **Deep Space and Superconductivity**:
   - Deep space, with temperatures around 2.7 K, can exhibit superconducting properties. While superconductivity does not significantly affect *permittivity*, it dramatically

influences *permeability*. In superconducting conditions, the *relative permeability* μ_r approaches zero. Given that the speed of light in a vacuum is determined by $c=1/(\mu_r\mu_0\epsilon_0)^{1/2}$, a near-zero permeability would result in an incredibly high effective speed of light.

2. **Zero-Atmosphere Conditions**:
   - In regions where the pressure is effectively zero, the number of molecules per cubic meter approaches zero and its vibration is almost cancelled. Under these conditions, photons interact primarily with *quantum fluctuations* rather than with *matter*. These interactions are minimal and suggest that the speed of light could be much higher in such vacuums.
3. **Quantum Vacuum**:
   - The interaction of photons with *virtual particles* in a quantum vacuum involves brief absorption and re-emission processes. These interactions have minimal impact on the propagation speed of photons, further supporting the idea of an increased effective speed of light in extremely low-density vacuums.

Expanding Universe and the Speed of Light

The standard *Big Bang* model (ΛCDM cosmological model) describes the universe's expansion, where galaxies are observed to be moving away from us. Locally, these galaxies are not exceeding the speed of light; rather, the space between them is expanding. This expansion can result in apparent velocities exceeding c, but this does not violate SRT since the galaxies themselves are not moving through space faster than light —space itself is expanding.

- **Locally Defined Constants**:
  - These constants define the speed of light through $c=1/(\mu_r\mu_0\epsilon_0)^{1/2}$. In superconducting conditions, where $\mu_r\approx 0$, c could achieve unbelievably high values. This fact helps explain the observations of apparent velocities exceeding c without violating the principles of SRT and GRT locally.

Addressing Misconceptions

- **Local vs. Non-Local Constants**:
  - By recognizing that physical constants like the speed of light are locally defined, we can address discrepancies that arise on cosmological scales without violating fundamental laws of physics.
- **Vacuum Variability**:
  - The measured speed of light at 299,792,458 m/s is derived from experiments conducted in Earth-based chamber laboratories and interplanetary medium conditions. However, the effective speed of light might differ in interstellar, intergalactic, or extremely low-density vacuums due to variations in local conditions.

Conclusion

Reinterpreting the second postulate of SRT to emphasize locality provides a coherent framework for understanding cosmological phenomena without conflicting with established theories. This localized approach maintains the integrity of SRT and GRT while accommodating the observable expansion of the universe. It underscores the importance of context and scale in physical laws, offering a nuanced perspective that aligns with both empirical evidence and theoretical constructs.

Corollary: The Role of Maxwell's Equations

The conclusions drawn in this article can be understood and demonstrated using Maxwell's equations, particularly through the relationship $c=1/(\mu_r\mu_0\epsilon_r\epsilon_0)^{1/2}$. This relationship shows that the speed of light is fundamentally connected to the properties of the vacuum, which can vary under extreme conditions like superconductivity and zero-atmosphere environments. Thus, understanding these variations does not require complex mathematics but rather a fundamental application of well-established electromagnetic theory.

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Section 5.

VSL vs. Inflationary Model

"Wenn ich Unrecht habe, dann genügt ein einziger Satz!"
"If I were wrong, then one would have been enough!"
Einstein, A. (Date unknown)

Abstract

This article emphasizes the practicality and empirical basis of the c-variability model, showcasing its potential to provide a simpler and more intuitive explanation for cosmic expansion compared to the traditional inflationary model.

Introduction

The concept of cosmic inflation has been the prevailing theory to explain the rapid exponential expansion of the early universe following the Big Bang. This theory posits the existence of an inflaton field and particle, which are speculative and lack direct empirical evidence. The inflationary model has been successful in explaining several cosmological observations such as the uniformity of the Cosmic Microwave Background (CMB). However, this model relies on sophisticated mathematics and particles and fields that have yet to be confirmed.

In contrast, it is proposed a simpler, more intuitive and more practical approach based on the variability of the vacuum speed of light under specific conditions. This approach does not require introducing new particles or fields, but instead uses well-established physical principles applied to unique conditions that could have existed during the early universe.

An alternative approach, grounded in well-understood physical principles, proposes by doing appropriate measurements that the speed of light (c) varies locally under certain vacuum conditions, such as superconductivity and zero-atmosphere environments. This principle aims to provide a simpler and more direct explanation for the observed expansion of the universe without the need for speculative fields or particles. By considering the speed of light as a locally variable, we can potentially account for the observed uniformity and isotropy of the universe without invoking an exotic field. The *Variable Speed of Light* (VSL) hypothesis offers a distinct explanation that aligns more closely with empirical data.

Speed of Light Variability

The speed of light c in a vacuum is traditionally defined by:

$$c=1/\sqrt{\epsilon_0\mu_0}$$

where ϵ_0 is the permittivity of free space and μ_0 is the permeability of free space. In superconducting conditions, where the relative permeability μ_r approaches zero, the speed of light can be dramatically increased:

$$c=1/\sqrt{\epsilon_0\mu_0\mu_r}$$

During the early universe, if vacuum conditions approached those of and completely empty space (true-vacuum in fact) —even devoid of Vacuum' Fluctuations and Higgs Field — in a Zero-Atmosphere and Superconducting state with null or near-zero permeability, the speed of light could have been vastly higher than any later epoch. This straightforward application of Maxwell's equations under unique early-universe conditions could account for the observed rapid expansion without the need for an inflaton field.

Benefits of the c-Variability Model

1. **Simplicity**: Unlike the inflationary model, which involves complex and speculative hypotheses, the c-variability model is based on well-understood physics, specifically the behavior of light in different vacuum conditions.
2. **Empirical Basis**: The principles underlying the c-variability model are grounded in established electromagnetic theory and do not require the existence of new particles or fields.
3. **Direct Applicability**: By adjusting the relative permeability μ_r in the early universe, the model directly explains the rapid expansion observed, providing a clear and tangible mechanism for cosmic inflation.

Conclusion

The c-variability model offers a simpler and more empirically grounded explanation for the rapid expansion of the early universe compared to the inflationary model. By considering the speed of light as a local variable dependent on vacuum conditions, this approach provides a viable alternative that aligns with established physical laws and requires no speculative new particles or fields.

Corollary

The mathematical foundation of this Principle is straightforward, relying on Maxwell's equations and the relationship:

$$c=1/\sqrt{\epsilon_0\mu_0\mu_r}$$

By adjusting the relative permeability under specific early-universe conditions, we achieve higher effective light speeds, providing a new perspective on the behavior of the universe without violating the core principles of Special Relativity (SRT), General Relativity (GRT), and Quantum Mechanics (QM).

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Section 6.

VSL and the Hubble Tension.

"Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less."

Marie Curie

Abstract

This article explores an alternative theory to the inflationary model of the early universe by proposing that the variability of the speed of light (c) under specific vacuum conditions could provide a simpler and more empirically grounded explanation for the observed cosmic phenomena. By considering the speed of light as a local variable influenced by factors such as superconductivity and a near-zero atmosphere, this approach addresses the current tension in measuring the Hubble constant and offers a new perspective on the expansion of the universe. This Principle adheres to the principles of General Relativity (GRT) and Special Relativity (SRT) while providing a viable explanation for the isotropic and homogeneous expansion observed in the Cosmic Microwave Background (CMB).

Introduction

Addressing the Hubble Tension.

One of the most persistent challenges in modern cosmology is the Hubble Tension—the discrepancy between the Hubble constant (H_0) values derived from local observations and those inferred from the CMB. Local measurements, which include observations of supernovae and cepheid variables, typically yield a higher H_0 value than those obtained from the CMB. This tension suggests that our current cosmological model may be missing key aspects of the universe's expansion history.

The *locally variant nature of the VSL hypothesis* provides a potential resolution to this tension due to its direct impact in different epochs and locations. If the speed of light were locally different in the early universe, it would affect the propagation of light and the dynamics of cosmic expansion. By allowing c to vary, we can reconcile the different H_0 values and provide a more consistent picture of the universe's history. This approach also avoids some of the complexities and assumptions inherent in the Inflationary Field and Particle Theory.

Theoretical Background

Light Cone and Space-Time

The representation of space-time through the "light cone" analogy is a well-accepted concept in physics, used to describe how events are visible or accessible to an observer based on their position and the elapsed time. The FLRW (Friedmann-Lemaitre-Robertson-Walker) metric, given by:

$$ds^2=[a(t)\cdot dr]^2-[c\cdot dt]^2$$

describes a homogeneous and isotropic universe. Here, *a(t)* represents the scale factor that grows over time, while *dr* denotes the spatial distance, which is assumed to be flat (Euclidean).

Hubble Parameter and Initial Singularity

The Hubble parameter $H=\mathring{a}(t)/a(t)$ describes the expansion of the universe. At $t=0$, $a(t)=0$ indicates a singularity where spatial separations do not exist objectively. This aligns with the Big Bang model, where the universe began from an extremely dense and hot state.

Measuring the Hubble Constant

Two primary methods are used to measure the Hubble constant: observing nearby objects with well-known properties (such as supernovae and Cepheid variables) to estimate their distances and recession speeds, and examining the Cosmic Microwave Background (CMB) to study the initial conditions of the universe and its expansion rate. These methods have produced conflicting results, known as the Hubble tension. Planck observations suggest a Hubble constant of about 67.4 km/s/Mpc, while data from supernovae and Cepheids suggest a faster rate of about 73 km/s/Mpc.

Hubble's Law and Annual Expansion

Hubble's Law states that the further away a galaxy appears, the faster it seems to recede from us. This results from the observer's perception of distance. Current calculations show that the universe expands at a rate of 67.4 km/s/Mpc, leading to an annual expansion of approximately 3.14 lightyears. Given the estimated age of the universe (13.8 billion years), this expansion rate would result in a total expansion distance consistent with current observations. Due to this expansion, the density of the universe is always decreasing in same manner.

Speed of Light Variability

The proposed Principle suggests that the speed of light (c) varies under specific conditions, such as in a vacuum with superconductivity, where the permeability of free space (μr) approaches zero. The speed of light is given by:

$$c=1/\sqrt{\epsilon_0\cdot\mu_0\cdot\mu_r}$$

where ϵ_0 is the permittivity of free space, μ_0 is the permeability of free space, and μ_r is the relative permeability. In a superconducting vacuum, μ_r is approximately zero, leading to an effectively immeasurably high speed of light. This local variability could explain the isotropic and homogeneous expansion observed in the CMB without invoking an inflaton field.

Implications and Future Research

This Principle aligns with established physical laws and provides a simpler, more direct explanation for the observed cosmic phenomena. It suggests that the Hubble tension could be resolved by considering the variability of the speed of light under specific vacuum conditions (density varying in time). Further research, including detailed mathematical modeling and empirical validation, is necessary to fully evaluate this hypothesis against the empirical data.

Conclusion

The proposed Principle of speed of light variability under specific vacuum conditions offers a compelling alternative to the inflationary model of the early universe. By adhering to the principles of General Relativity (GRT) and Special Relativity (SRT) and leveraging well-understood physical phenomena such as superconductivity, this Principle provides a simpler and more empirically grounded explanation for the observed expansion of the universe.

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Section7.

Implementing VSL

“Nature uses only the longest threads to weave her patterns, so that each small piece of her fabric reveals the organization of the entire tapestry.”

Richard Feynman

“The important thing is not to stop questioning. Curiosity has its own reason for existing.”

Albert Einstein

Abstract

The Variable Speed of Light (VSL) Principle proposes that the vacuum speed of light, c, is not an absolute constant but can vary under certain conditions. This idea, although contentious, aligns with the fundamental principles of Einstein's theories and Quantum Mechanics (QM) and adheres strictly to the Scientific Method. This article explores the VSL Principle, emphasizing its mathematical simplicity and practical implications. The VSL Principle posits that the speed of light, c, is locally constant but varies under specific circumstances. This perspective challenges conventional physics, offering new explanations for phenomena such as the Hubble Tension and proposing alternatives to the inflationary model. By focusing on the physical and empirical aspects rather than complex mathematical formulations, this article aims to make the VSL Principle accessible to a broader scientific audience and aims to counter the skepticism faced by the VSL Principle by highlighting its empirical foundation, mathematical coherence, and the necessity for its serious consideration alongside more speculative theories.

Introduction

While some of the details in this section may be familiar to experts in Special Relativity, this section has included them here for the sake of completeness and to ensure a clear understanding of the Variable Speed of Light (VSL) Principle. **You can obviate this section in case you are an expert on Relativity Theory**.

The speed of light in a vacuum, c, is traditionally considered a fundamental constant in both General Relativity (GR) and Quantum Mechanics (QM), is fundamental to our understanding of physics. However, the VSL Principle suggests that c is locally constant but it can vary based on the conditions of time and space on environmental conditions, challenges this orthodoxy. This idea provides a fresh approach to understanding cosmological and physical phenomena, potentially simplifying some of the more complex aspects of modern physics. It offers new perspectives on unresolved cosmological issues like the Hubble Tension and inflationary models. This article argues for the scientific community to give VSL Principle its due consideration based on empirical evidence and mathematical rigor. This article also argues for the scientific community to give VSL Principle its due consideration based on empirical evidence and mathematical rigor.

Mathematical and Experimental Perspectives in Physics

Mathematics often finds solutions to theories, serving as the language of science. However, these solutions can sometimes appear counterintuitive, resulting in descriptions or solutions, such as singularities or hypothetical particles, that are difficult to reconcile with the physical reality. In GR, gravity bends spacetime and collapses into a point known as a singularity, which has a purely geometric sense. In QM, particles like the inflaton are hypothesized to explain the inflationary period of the early universe, yet they remain speculative without empirical confirmation. Similarly, quarks, fundamental constituents of hadrons, are mathematically represented particles whose existence is inferred from high-energy experiments but cannot be isolated due to asymptotic freedom. As Richard Feynman noted, quarks are never observed independently, making their empirical validation challenging and emphasizing their role as theoretical constructs.

Einstein's Foundational Principles

Albert Einstein's theories of relativity were based on key principles that do not inherently negate the possibility of a variable speed of light and his theories were formulated based on a few key principles:

1. **Special Relativity**:
   - The laws of physics are the same for all observers, regardless of their state of motion.
   - The speed of light in a vacuum is constant for all observers, independent of the motion of the light source or the observer.
2. **General Relativity**:
   - The equivalence principle states that the local effects of motion in a curved spacetime (gravity) are indistinguishable from those in an accelerating frame of reference.

Einstein did not specify the value of c; it is empirically determined. Maxwell's equations in electromagnetism indicate that $c=(\epsilon_0\mu_0\mu_r)^{-1/2}$, tying the speed of light to the permittivity (ϵ_0) and permeability (μ_0) of free space or tue-vacuum. In an ideal gas pressure (IGP) vacuum or at near-zero temperature (2.7 K, close to superconductivity conditions), the relative permeability (μ_r) approaches zero, suggesting variations in c under such conditions.

Empirical Validation vs. Speculative Theories

The scientific method emphasizes empirical validation, over speculative models. The VSL Principle is grounded in empirical science, not speculation. Techniques such as interferometry and Snell's Law enable precise measurement of c. These methods can be applied to different environmental conditions, supporting the hypothesis that c is locally constant but it can vary depending on vacuum quality. The VSL Principle, grounded in the empirical measurements, stands on firmer ground compared to more speculative theories like Lambda-CDM and the inflaton field. These theories, while mathematically robust, lack direct empirical evidence, relying on hypothetical constructs without direct observational evidence like dark matter, dark energy, and the inflaton particles.

Mathematical Coherence and Simplicity

Mathematics serves as the backbone of physical theories, providing clarity and predictive power. The VSL Principle, through the relationship

$$c = \frac{1}{\sqrt{\epsilon 0 \mu 0 \mu r}}$$

offers a mathematically coherent framework. Changes in ϵ and μ under different conditions provide a testable basis for variations in c. Keeping it short and sweet: this mathematical simplicity and direct empirical testability set VSL apart from more complex and speculative models.

Revisiting Historical Contexts

The rejection of the luminiferous aether following the Michelson-Morley experiment underscores the importance of empirical validation. The experiment demonstrated that light travels at a constant speed regardless of the direction, refuting the need for an aether medium and leading to the development of special relativity.

Cosmology and the Λ-CDM Model

The Lambda-CDM model describes the universe's expansion, incorporating dark matter and dark energy. These components, while fitting current observations, remain speculative without direct empirical evidence. The model addresses the universe's accelerated expansion, suggesting a negative pressure component termed dark energy.

Challenging Established Models with VSL Principle

The VSL Principle challenges the conventional Lambda-CDM model and the inflaton field theory by offering alternative explanations for observed phenomena, such as the Hubble Tension. The VSL approach seeks to provide simpler and more empirically grounded explanations. Lambda-CDM, while fitting current cosmological observations, relies heavily on dark matter and dark energy—components that remain undetected despite extensive searches. The inflaton field, proposed to explain the rapid expansion of the early universe, also lacks direct empirical support.

By applying the scientific method, the VSL Principle demonstrates a closer alignment with empirical data and offers a more parsimonious framework for understanding the universe.

Scientific Method and Theoretical Openness

The Scientific Method, which emphasizes hypothesis testing, observation, and empirical validation, should be the cornerstone of accepting or rejecting any theory. The VSL Principle adheres to this method, proposing testable hypotheses and seeking empirical validation through precise measurements of c under various conditions. This approach aligns with the historical progression of scientific knowledge, where new theories are rigorously tested and validated or refuted based on empirical evidence.

Addressing Skepticism and Opposition

VSL aligns with, not contradicts, Einstein’s theories and Special Relativity. The scientific community is naturally skeptical of theories that challenge established paradigms. However, this skepticism should drive rigorous testing rather than outright dismissal. The VSL Principle does not contradict Einstein’s principles or QM but extends them to explore new possibilities. By focusing on empirical evidence and mathematical rigor, proponents of VSL can counter opposition with scientific robustness.

Second Special Relativity Hypothesis: Constancy of the Speed of Light ***

- Original German: "Jede Lichtquelle bewegt sich im Ruhestandssystem mit der bestimmten, von Experimenten festzustellenden Geschwindigkeit c."
- Literal Translation: "Every light source moves in the rest system with the specific speed c, ***determined by experiments***."
- Further Explanation: "The speed of light in a vacuum is the same for all observers, regardless of the motion of the light-emitting source or the observer."

Einstein's theories led to significant advancements in our understanding of the universe. Maxwell's electromagnetism theory implied that all observers should measure the same speed of light in a vacuum, directly included in relativity theory: $c=(\epsilon_0\mu_0)^{-1/2}$. However, this is often misunderstood.

1. **Maxwell's Electromagnetism Theory**:
   - James Clerk Maxwell's equations describe the behavior of electric and magnetic fields. These equations predict the existence of electromagnetic waves, including visible light.
   - Maxwell derived this speed of electromagnetic waves by combining the electric permittivity (ϵ_0) and magnetic permeability (μ_0) of free space: $c=(\epsilon_0\mu_0)^{-1/2}$
2. **Einstein's Theory of Relativity**:
   - Albert Einstein's special theory of relativity (1905) revolutionized our understanding of space, time, and motion.
   - In special relativity, Einstein showed that the speed of light (c) is an absolute constant. All observers, regardless of their relative motion, measure the same speed for light in a vacuum.
   - This principle invalidated the classical notion of an "ether" through which light waves were thought to propagate.
3. **Interpretation and Invariance**:
   - The interpretation is crucial: **c** represents the maximum speed at which information or energy can travel in the universe.
   - Regardless of an observer's velocity, if they generate an electromagnetic wave (such as light), it will propagate at the same speed **c** relative to them.
   - This invariance ensures that the laws of physics remain consistent for all observers.
4. **Vacuum Properties and 'c'**:
   - While **c** is empirically determined, it remains remarkably consistent across different regions of space.
   - The vacuum can be categorized as:
     - **Local**: The immediate vicinity of an observer (e.g., Earth's atmosphere).
     - **Non-Local**: Vast cosmic spaces (interstellar medium, intergalactic medium).
   - Even in the deepest cosmic voids (where the cosmic microwave background radiation exists at a temperature of 2.7 K), **c** remains the same for all observers.

In summary, the speed of light is a fundamental constant that sets a limit, deeply intertwined with the fabric of spacetime. Its invariance means that no matter the observer's motion, light will propagate at the same speed **c** relative to them. This fact underpins our understanding of the cosmos. Nevertheless, the exact value of **c** in a specific surrounding must be measured empirically (not calculated) in a particular location and epoch.

Mathematical Basis of VSL Principle

The VSL Principle relies on the empirical relationship between c and ϵ_0 and μ_0. In regions with varying electromagnetic properties, such as near-zero temperature environments, the permeability (μ), and perhaps also the permittivity (ϵ), can change, leading to variations in c. This mathematical basis provides a clear and testable framework for the VSL Principle, distinguishing it from more speculative theories that lack direct empirical measurement.

Conclusion

The VSL Principle offers a promising alternative to some of the more speculative aspects of modern cosmology. By emphasizing empirical validation and mathematical simplicity, it aims to provide a clearer understanding of the universe's workings. The scientific community should remain open to revisiting established theories in light of new empirical evidence, maintaining the balance between theoretical innovation and empirical rigor. The simplicity and empirical grounding of the VSL principle deserve more attention and consideration in the ongoing quest to understand the cosmos. Given its empirical foundation and mathematical coherence, the VSL Principle deserves serious consideration and further investigation.

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Section 8.

Testing of the VSL

"There are no secrets about the world of nature. There are secrets about the thoughts and intentions of men."
J. Robert Oppenheimer.

Abstract

The speed of light, c, traditionally considered a universal constant, is foundational to the theories of electromagnetism and relativity. However, the Variable Speed of Light (VSL) principle posits that c is locally invariant but varies depending on each local condition such as the interplanetary medium (IPM), interstellar medium (ISM), intergalactic medium (IGM), deep space (dark energy presence), and true vacuum (free space). This paper explores the VSL hypothesis, emphasizing that the speed of light is locally constant but varies with different media properties and qualities, including the effects of gravity and temperature (mass and energy in fact). Additionally, it introduces novel considerations about the role of relative permeability, the concept of "gloom" in light transitions, and the potential influence of refractive index on gravitational lensing effects. By proposing a rigorous experimental method to measure c in conditions mimicking the quantum vacuum, we aim to test the VSL Principle's predictions and potentially expand our understanding of fundamental physical laws.

Introduction

The speed of light, c, has long been considered the ultimate speed limit in the universe, as established by Einstein's theory of relativity. This concept is deeply rooted in Maxwell's equations and the principles of electromagnetism, which predict that the speed of electromagnetic waves in a vacuum is a constant. However, the Variable Speed of Light (VSL) Principle challenges this notion, proposing that the speed of light can vary depending on local conditions. This article aims to explore the empirical foundations of the speed of light, the theoretical basis for VSL, and a proposed experimental method to test VSL under controlled laboratory conditions. Additionally, we introduce three novel considerations: the effect of relative permeability, the transition between light and darkness termed "gloom," and the role of refractive index in gravitational lensing.

The Empirical Basis of the Speed of Light

Maxwell's equations, formulated in the 19th century, describe the behavior of electric and magnetic fields and predict the existence of electromagnetic waves propagating at a constant speed c, determined by the vacuum permittivity (ϵ_0) and permeability (μ_0):

$$c=(\epsilon_0\mu_0)^{-½}$$

This prediction is based on empirical laws and has been repeatedly confirmed through experiments. The invariance of the speed of light underpins the theory of special relativity, leading to the concept of Lorentz invariance, which ensures that the laws of physics remain consistent for all observers, regardless of their relative motion.

Causality and the Invariant Speed

Einstein's postulate that the systemic vacuum speed of light 'c' is a local limit applicable universally that may *depend on the local properties of the vacuum*. The fact that this limit is the same for all observers is crucial for maintaining causality in the universe. The concept of an invariant speed limit creates a causal structure where events can be ordered in time, preventing paradoxes such as time travel into the past. This locally invariant speed limit, c, serves as a boundary for the causal structure of spacetime, known as the light cone, within which causal connections are preserved.

Testing the Speed of Light in Particle Accelerators

The vacuum speed of light as an local invariant speed limit is regularly tested in particle accelerators like the Large Hadron Collider (LHC) of CERN in Switzerland/France. In these experiments, particles are accelerated to velocities approaching the vacuum speed of light (protons up to 0,999999991% of 'c'). The fact that these particles never exceed c despite their high energy confirms the predictions of special relativity and reinforces the notion of c as the ultimate local speed limit for our IPM.

The Speed of Light in Different Media

In a vacuum, the speed of light is a local constant. However, in a medium, light interacts with the material, which can cause it to slow down. This phenomenon is due to the interaction energy between the photons and the medium, effectively giving the photons a mass. As a result, the speed of light in a medium depends on the medium's properties and the wavelength of the light. This behavior is well-understood and can be described by quantum electrodynamics, Maxwell equations, wavelengths ($\lambda=c/\upsilon$), and the index of refraction

The Variable Speed of Light (VSL) Principle

The VSL Principle posits that the vacuum speed of light is local invariant but varies with vacuum conditions. According to this Principle, c changes based on the properties and quality of the medium through which it propagates, such as the IPM, ISM, IGM, deep space, and true vacuum. Factors such as gravity (i.e., mass), temperature (i.e., energy), and the presence of the hypothetical dark energy influence these variations. For instance, the relative permeability (μ_r) of the medium affects c, with significant variations in temperature and gravitational proximity to massive objects altering μ_r. In superconducting states near 2.7 K, μ_r approaches zero, while in hot environments near massive stars, μ_r can be much greater than 1.

Proposed Experimental Method for VSL Measurement

To empirically test the VSL Principle, it is essential to create laboratory conditions that approximate the vacuum of deep space, particularly at temperatures near the cosmic microwave background (approximately 2.7 K) to achieve a state of superconductivity (where $\mu_r \approx 0$). The following experimental setup is proposed:

1. **Stub Design**: Use a stub similar to those in microwave circuits to create a stationary wave. Adjusting the stub's length can achieve constructive interference, amplifying the wave's amplitude. (The electromagnetic frequency generated υ, doesn't need to be light, will be known. By measuring the wavelength λ by moving the short circuit at the end of the stub's pipe, we can achieve an interference constructive and destructive. Finally, multiplying λ and υ we'll achieve c.)
2. **Faraday Cage**: Place the setup within a Faraday cage to eliminate any noisy electromagnetic interference.
3. **Low Temperature and Superconductivity**: Maintain the setup at extremely low temperatures to induce superconductivity and minimize particle vibrations, replicating the quantum vacuum state.
   The stub design will utilize a setup similar to the waveguide pipe of the LHC of the CERN to allow the injection of coolant between the double outer and inner wall structure to achieve temperatures near 2.7 Kelvin and a Zero-Atmosphere vacuum.
4. **Microgravity Environment**: Conduct the experiment in a microgravity environment, such as on a *space station*, to eliminate gravitational effects.
5. **Interferometric Techniques**: Use interferometry to measure the speed of light precisely under these conditions.

This method aims to determine if c increases significantly as predicted by the VSL Principle when the relative permeability (μ_r) approaches 0. In the LHC, the double inox iron-steel pipes (outer and inner) where the protons are accelerated uses a similar approach for cooling and shielding. Next section explores inside this experiment.

New Considerations in Light Propagation

Relative Permeability
The relative permeability of free space is generally considered to be 1, but this value can change in different media. Diamagnetic materials have a relative permeability slightly less than 1, while paramagnetic and ferromagnetic materials have higher values. The relative permeability (μr) affects the propagation of electromagnetic waves, and its variation could be a factor in the VSL Principle.
Refractive Index and Gravitational Lensing
The index of refraction n=c/v (n=\frac{c}{v}) describes how light bends as it passes through different media, as governed by Snell's Law:

$$\sin\theta 1/\sin\theta 2=v1/v2=n2/n1$$

Gloom: The region of transition between Light and Shadow
Where the light intensity gradually decrease, is referred it as gloom. This zone can be observed by turning on a lamp and observing the gradual changing brightness at the edge of the illuminated area. It could have implications for understanding light propagation in varying conditions. Gloom may be influenced by the local medium's properties, affecting the perceived speed and behavior of light (it can be bend progressively).

Gravitational lensing, traditionally explained by the curvature of spacetime due to massive objects, can be analogized to the bending of light due to changes in the refractive index. In regions near stars with high temperatures, the medium can act like a lens, bending light similarly to how mirages form in a desert. This raises the possibility that some observed gravitational lensing effects might be influenced or even dominated by variations in the refractive index rather than purely by gravitational effects.

Conclusion

The VSL Principle presents a compelling challenge to the traditional view of the speed of light as an immutable constant. By leveraging the principles of electromagnetism, special relativity, and quantum mechanics, and through meticulous experimental design, we can explore the validity of this Principle. Additionally, considering the effects of relative permeability, the transition zone of gloom, and the refractive index's role in light bending can provide new insights into light propagation in the universe. The proposed experimental method provides a pathway to test VSL under controlled conditions, potentially opening new avenues for understanding the fundamental nature of light and the structure of spacetime.

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Section 9.

Observational Verification of VSL

“Everything should be made as simple as possible, but not simpler.”

Albert Einstein

Abstract

This experiment proposes a novel approach to investigate the potential influence of various environmental conditions on the speed of light (c) within a controlled environment. Using a maser-based microwave waveguide system, we aim to measure resonant frequencies under varying conditions such as vacuum, temperature, superconductivity, gravity, and galactic motion. By analyzing these frequencies, the experiment seeks to detect subtle changes in light velocity, potentially deepening our understanding of light propagation under specific conditions.

Introduction

Einstein's theory of special relativity posits that the speed of light in a vacuum (c) is a fundamental constant, approximately 299,792,458 meters per second. This theory, corroborated by numerous experiments including cavity resonance techniques, asserts that c is independent of the motion of the light source or observer. However, whether environmental conditions or specific materials might influence the speed of light within a controlled environment remains an intriguing area of study.

This experiment explores this question using a meticulously designed microwave waveguide to measure resonant frequencies of microwaves under various conditions, aiming to contribute to the ongoing quest for a deeper understanding of light's behavior.

The Waveguide System - A Refined Design

Optimizing the Inner Wall

The inner wall of the waveguide, crucial for minimizing signal losses, utilizes materials with exceptionally high electrical conductivity. High-purity copper or advanced conductive coatings may be used to optimize the system for the desired frequency range (around 300 GHz).

Maser vs. Laser: A Matter of Precision and Balanced Choice

A maser (Microwave Amplification by Stimulated Emission of Radiation) is used for its high precision and stable output, crucial for this experiment. Unlike standard microwave lasers, masers offer a more precise and stable output at the desired frequency.

Waveguide Modes and Tuning Control

The appropriate waveguide mode (TE, TM, or TEM) will be meticulously chosen based on the desired frequency range and the intended electric and magnetic field distribution within the waveguide.

Stub Control with High-Precision Positioning

A short conductor (stub) is inserted into the waveguide for controlling the cavity length. This stub will be positioned with high accuracy using a CNC system to achieve the desired resonant frequencies.

Exploring the Impact of Various Conditions

The experiment systematically vary the following conditions to assess their influence on the measured speed of light within the waveguide:

- **Vacuum vs. Air:** The waveguide can be evacuated to create a near-perfect vacuum, minimizing interactions between light waves and gas molecules. Controlled atmospheres with specific gas compositions might be explored.
- **Temperature Control:** The experiment can be conducted at various temperatures, including near absolute zero (2.7 K) to investigate thermal effects on light propagation.
- **Superconductivity:** The inner wall of the waveguide can be cooled to achieve superconductivity, minimizing energy losses within the waveguide.
- **Gravity:** The experiment can be conducted in different gravitational environments, potentially using high-altitude balloons or space-based platforms.
- **Galactic Motion:** While challenging, the experiment could be designed to account for the Earth's motion within the Milky Way galaxy, measuring the speed of light relative to the local interstellar medium.

Measurement Technique

1. **Microwave Injection:** The maser injects a precisely controlled microwave signal at the desired frequency (300 GHz) into the waveguide cavity.

2. **Stub Adjustment:** The short-circuit end of the waveguide will be precisely adjusted using a high-resolution CNC system.
3. **Standing Wave Formation:** A standing wave pattern will be established within the waveguide cavity when the cavity length matches an integer multiple of the microwave's wavelength (λ).
4. **Resonant Frequency Detection:** By monitoring the amplitude of the microwaves exiting the waveguide, the experiment will identify the resonant frequencies within the cavity lengths.

Understanding Standing Waves

Standing waves result from the constructive interference between the incident wave and its reflected wave from the short-circuit, achieving maximum amplitude when the waves are in phase in a constructive interference.

Wavelength Calculation (Data Analysis and Interpretation)

Knowing the **resonant frequency (f)** and the **waveguide geometry (length, L)**, the full-wavelength (λ) of the microwave within the waveguide can be calculated using the equation:

$$\lambda = c / f$$

where c is the established speed of light in a vacuum. The experiment accounts for potential interactions with the waveguide material and the medium to refine the estimation of the actual speed of light.

Variation Analysis

By comparing the calculated **full-wavelength (λ)** under different environmental conditions to the expected wavelength based on c, the experiment can potentially detect any variations in the speed of light within the waveguide.

Existing Cavity Resonance Techniques

This experiment acknowledges established cavity resonance techniques and aims to complement them by exploring alternative materials, systematic environmental control, and focusing on specific mediums.

Limitations and Future Directions

- **Indirect Measurement:** The experiment infers the speed of light within the specific medium filling the waveguide based on the measured resonant frequencies and theoretical models.
- **Material Dependence:** The measured speed of light can be influenced by the properties of the waveguide material and the medium.
- **Theoretical Refinement:** Future advancements in theoretical models can improve data interpretation.

Challenges and Considerations

- **Maintaining Vacuum:** Achieving and maintaining a near-perfect vacuum is crucial for accurate measurements.
- **Fabrication Challenges:** Constructing a high-precision waveguide with a smooth inner surface and controlled dimensions is essential.

- **Mode Control:** Careful selection and control of the waveguide mode are necessary.
- **Systematic Errors:** Rigorous design and calibration procedures are required to minimize systematic errors.

Conclusion

This multifaceted experiment, by exploring the speed of light under various environmental conditions, has the potential to refine our understanding of this fundamental constant. While exceeding the established value of c might not be achievable, the experiment can provide valuable insights into the behavior of light under extreme conditions and contribute to the ongoing quest for a unified theory of physics.

Future Directions

- **Advanced Waveguide Design:** Future iterations may explore alternative waveguide geometries and materials.
- **Integration with High-Precision Clocks:** The system could be integrated with ultra-precise atomic clocks.
- **Theoretical Frameworks:** Experimental findings can be compared with existing and emerging theoretical frameworks

Further Comments

This experimental design pushes the boundaries of current technology and requires meticulous attention to detail. Successfully overcoming the technical challenges and potential systematic errors could lead to groundbreaking discoveries concerning the nature of light and the speed of light under various conditions. The results may contribute to a deeper understanding of the fundamental laws of physics and potentially pave the way for new technologies.

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Section 10.

Mathematical Verification of VSL

"Be as light, a constant speed isn't your way."

Albert Saenz

Abstract

This section explores the concept of a variable speed of light (VSL) and its potential implications for understanding the expansion of the universe. The current cosmological model, based on Einstein's theory of General Relativity and the Friedmann equations, assumes a constant speed of light c. However, the VSL hypothesis proposes that c might vary with time and location, particularly during different epochs of the universe's history. Incorporating VSL into the Friedmann equations could offer new insights into the early high-density universe and the current epoch of accelerated expansion, potentially providing a less speculative and more consistent framework compared to the Lambda-CDM model.

Introduction

The speed of light, c, is a fundamental constant in physics, underpinning both the theory of relativity and cosmology and stablishing a critical limit. Empirical measurements on Earth suggests that c is approximately 299,792,458 meter per second in a vacuum. However, the VSL hypothesis has emerged as a fascinating idea that could potentially address longstanding puzzles in cosmology. By incorporating VSL into our understanding of the universe expansion, particularly in the context of the Friedmann equations, we might gain new perspectives on its evolution.

Background: Standard Cosmology and the Friedmann Equations

The current understanding of the universe's expansion relies on standard cosmology and the Friedmann equations. These equations describe the dynamics of a homogeneous and isotropic universe:

$$H(t)^2=8\pi G/3 \cdot \rho(t)-k\cdot c(t)^2/a^2+\Lambda\cdot c(t)^2/3$$

where:

- H is the Hubble parameter, representing the rate of expansion.
- ρ(t) is the energy density of the universe, which varies over time,
- k is the curvature parameter, with k=1 for a closed universe, k=0 for a flat universe, and k=-1 for an open universe.
- a is the scale factor, representing the universe's expansion relative to a reference point.
- Λ is the cosmological constant, a term accounting for the accelerating expansion in the current universe.

Variable Speed of Light (VSL) Hypothesis

The VSL hypothesis proposes that maximum speed of light (c) may vary depending on time and location within the universe, particularly during different epochs of the universe's evolution. We consider two models for c(t):

1. **Exponential Decay Model (RC Circuit Analogy):**

$$c(t)=c_{initial}\cdot e^{-t/\tau}+c_{transition}$$

   where $c_{initial}$ is the initial value post-Big Bang, τ is the characteristic time constant, and $c_{transition}$ is the asymptotic value to be achieved.
2. **Density-Dependent Model:**

$$c(t)=c_{initial}\cdot F[\rho(t)]$$

   Where $F[\rho(t)]=(\rho_{initial}/\rho(t))^n$ to describes the evolution of the density energy over time. $\rho_{initial}$ is a reference energy density (e.g., the current energy density of the universe), and 'n' is a positive constant that determines the sensitivity of c to changes in ρ(t). And so:

$$c(t)=c_{initial}\cdot(\rho_{initial}/\rho(t))^n$$

Initial Phase Using RC Circuit Analogy

In an RC circuit analogy, the speed of light c(t) can be modeled by an exponential decay function similar to the charging or discharging of a capacitor.

$$c(t)=c_{true\text{-}vacuum}\cdot e^{-t/\tau}+c_{transition}$$

where:

- $\mathbf{c_{true\_vacuum}}$ is the initial speed of light just post-Big Bang. Where possibly a True-Vacuum condition was present.
- **τ** is the time constant of the RC circuit. Fixing as fast decay c(t).
- $\mathbf{c_{transition}}$ is the transition value of the speed of light where the accelerated expansion starts or it stabilizes.

For different media:

- IGM (Intergalactic Medium): $c(t)= c_{tru\_vacuum}\cdot e^{-t/\tau} + c_{transition}$

- ISM (Interstellar Medium): $c(t)= c_{tru\_vacuum} \cdot e^{-t/\tau} + c_{Black\_Matter}$
- IPM (Interplanetary Medium): $c(t)= c_{tru\_vacuum} \cdot e^{-t/\tau} + c_0$

Late-Time Acceleration Phase Using *ρ*(t) Model for IGM

This model, hypothetically applied to the Intergalactic Medium (IGM), the speed of light increases, necessitating Einstein's cosmological constant (Lambda) for explanation. This is modeled by

$$c(t)=c_{transition}(\rho_{transition}/\rho(t))^n$$

in the Friedmann Equation.

Combining both phases for IGM only:

1. **Initial Phase (RC Circuit Model)**:
$$c(t)=c_{true\text{-}vacuum}\ e^{-t/\tau} + c_{transition}$$
2. **Late-Time Acceleration Phase (Density Function Model)**:
$$c(t)=c_{transition}(\rho_{transition}/\rho(t))^n$$

Applying c(t) to the Friedmann Equation:

In a vacuum, space is flat (k=0), simplifying the Friedmann equation.

$$H(t)^2=8\pi G/3\cdot\rho(t) + \Lambda\cdot c(t)^2/3$$

Applying models:

Initial Phase: $t < t_{transition}$ (valid for IPM, ISM and IGM):

$$H(t)^2= (8\pi G/3)\cdot\rho(t) + \Lambda/3[c_{true\_vacuum}\ e^{-t/\tau} + c_{transition}]^2$$

Note: IPM and IGM remain in this phase.

Late-Time Acceleration Phase: $t \geq t_{transition}$ (valid for IGM only):

$$H(t)^2= (8\pi G/3)\cdot\rho(t) + \Lambda/3\ [c_{transition}(\rho_{transition}/\rho(t))^n]^2$$

In the current universe, where energy density ρ(t) is relatively low, the cosmological constant term dominates.

$$H(t)= c_{transition}\cdot(\rho_{transition}/\rho(t))^n \cdot \sqrt{\Lambda/3}$$

Analysis and Implications

Early Universe (Post-Big Bang): In the very early universe, high temperatures and densities dominate in a very tiny space, with the rest being a true vacuum. Assuming c(t)c(t)c(t) starts from a very high initial value and decreases exponentially, the RC Circuit Model provides a plausible description.

Transition to Current Epoch: As the universe expands, ρ(t) decreases, and the exponential term in c(t) diminishes. The cosmological constant term begins to dominate, driving accelerated expansion. The density-dependent model supports this transition, with c(t) adjusting according to the decreasing energy density. Aligning with the observed accelerated expansion of the universe.

Current Universe and Accelerated Expansion: In the current universe, particularly in the IGM, the energy density ρ(t) is extremely low, and the cosmological constant term dominates. These matches observations of an accelerating universe, driven by the cosmological constant.

Comparison with Lambda-CDM Model

The VSL hypothesis offers a compelling alternative to the Lambda-CDM model by directly addressing the empirical observations of CMB and accelerated expansion without invoking speculative components such as dark matter and dark energy. While the Lambda-CDM model relies on these elements to explain the universe's dynamics, VSL provides a framework that might explain these phenomena through fundamental changes in the speed of light itself.

Conclusion

The VSL hypothesis provides a thought-provoking framework for understanding the universe's evolution. By incorporating a variable speed of light into the Friedmann equations, it is possible to model both the early high-energy density conditions and the current epoch of accelerated expansion. This approach aligns with observational data and provides new insights into the dynamics of cosmic evolution, potentially providing a more empirically grounded alternative to the speculative components of the Lambda-CDM model.

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Final conclusions

Rethinking the Vacuum Speed of Light Limit

The Variable Speed of Light (VSL) Principle offers a groundbreaking view on how light behaves in different vacuums. A crucial aspect in Special Relativity (SRT), General Relativity (GRT), and Quantum Mechanics (QM) is the fixed maximum speed limit, 'c', which must be observed consistently by all observers, regardless of their positions or velocities. This value, empirically determined, does not contradict existing theories. Instead, it represents the maximum speed attainable by massless particles in a given vacuum condition. 'c' could theoretically vary, depending on the vacuum's properties. Whether 'c' is 299,729,458 m/s or any other value, the condition remains that all observers will measure the same speed under the same vacuum conditions. This idea challenges the traditional view of a constant 'c' in a vacuum, a cornerstone of Special Relativity.

This perspective lays the groundwork for the VSL hypothesis, suggesting that while Special Relativity establishes constancy within its framework, VSL challenges this assumption for diverse vacuum types, making the speed of light a locally constant variable.

Focus on VSL Strengths

The formula $c=(\epsilon 0\mu 0\mu r)^{-1/2}$ suggests profound implications. If μ_r approaches zero, c could approach infinity, challenging the current understanding of a constant c. The simplicity of the VSL formula encourages further investigation, inviting scientific scrutiny and exploration.

VSL and Cosmological Mysteries

VSL offers a fresh lens to interpret cosmological phenomena. It could potentially explain the cosmic microwave background radiation or the universe's accelerated expansion without resorting to dark energy. The hypothesis opens new avenues for understanding the fundamental nature of the universe.

Consequences and Predictions of VSL

- **Impact on Physics:** VSL could significantly impact physics, requiring reevaluation primarily in cosmology, rather than special relativity, general relativity and quantum mechanics.
- **Implications to E=mc^2**: The potential implications to E=mc^{2}are intriguing.
- **Redshift Phenomena:** An increase in c produces a redshift, which has significant implications for our understanding of light from distant objects.

Reconciling VSL with Spacetime

The analogy with the refractive index in optics suggests that c might vary based on vacuum properties, necessitating a deeper understanding of spacetime curvature in general relativity.

Predictions:

- **Cosmology:** How would VSL explain phenomena like the cosmic microwave background (CMB) or the universe's expansion rate? Would a variable c affect our understanding of Λ–CDM cosmological model and dark matter or dark energy?
- **Astrophysics:** Could VSL offer alternative explanations for gravitational lensing or redshift? How would it impact our understanding of light behavior in distant galaxies or near massive objects?
- **Particle Physics:** How might VSL affect the behavior of elementary particles or the predictions of the Standard Model?

VSL and Established Theories

While VSL challenges the constancy of c, it doesn't necessarily contradict established theories. Reconciling VSL with Special and General Relativity will be crucial for its acceptance. VSL might require modifications to concepts like spacetime curvature in General Relativity or the behavior of light at the quantum level in Quantum Mechanics. Further investigation is needed to explore how VSL integrates with these frameworks.

Additional Considerations

Gloom Concept: The transition from c to a higher speed of light, termed "gloom," suggests different speeds for photons and gravitons. Experimental detection and implications need exploration.

Dark Matter and Energy: VSL offers a fresh perspective on dark matter and dark energy, challenging current interpretations.

Open Questions and Future Research

Scientific Investigation: The VSL hypothesis encourages rigorous experimental validation and theoretical exploration.

Impact on Cosmology and Physics: If validated, VSL could reshape our understanding of the universe, requiring refinements to cosmology models.

Embracing New Horizons with VSL

Achieving alignment with the scientific community requires not only presenting innovative ideas but also ensuring they are framed within the context of established scientific principles, inviting scrutiny, and encouraging further research.

The VSL Principle, by proposing a fundamental shift in our understanding of light and its behavior, offers a profound opportunity to revisit and possibly reshape key principles in physics.
The Variable Speed of Light (VSL) Principle, by proposing a fundamental shift in our understanding of light and its behavior, offers a profound opportunity to revisit and possibly reshape key principles in physics.

Potential Impact and Relevance

1. **Foundational Reassessment:** If validated, VSL could necessitate a reassessment of special relativity, general relativity, and quantum mechanics, broadening our understanding and potentially unifying disparate aspects of modern physics.
2. **Cosmological Implications:** The Principle presents a novel lens through which to interpret cosmological phenomena, such as the cosmic microwave background, the expansion rate of the universe, and the behaviors attributed to dark matter and dark energy.
3. **Astrophysical Insights:** VSL could offer alternative explanations for observed phenomena like gravitational lensing, redshift in distant galaxies, and the dynamics near massive objects.

Encouraging Scientific Scrutiny and Exploration

The scientific method thrives on rigorous testing, skepticism, and continuous refinement. VSL, while previously speculative, invites empirical validation and theoretical exploration:

- **Experimental Refinement:** The proposed experiment using superconducting stub design, though costly, is a starting point. Achieving and maintaining superconductivity, eliminating gravity's influence, and using electrons instead of protons in a circular accelerator need further consideration. Collaboration with facilities like ALBA synchrotron or LHC could be explored.
- **Theoretical Development:** Further theoretical work is needed to reconcile VSL with existing frameworks, particularly how it integrates with the curvature of spacetime in general relativity and the probabilistic nature of quantum mechanics.

Open Questions and the Path Forward

VSL opens doors to exciting research avenues. Key questions include:

- How does VSL affect our understanding of the early universe, including inflation and cosmic expansion mechanisms?
- What are the implications of a variable c for the behavior of fundamental particles and forces in different vacuum states?
- How can VSL be integrated with existing frameworks, particularly regarding the curvature of spacetime and the probabilistic nature of quantum mechanics?

Collaboration is Key

VSL's advancement hinges on collaboration across physics, cosmology, and astrophysics. Open dialogue, peer review, and replication of results are essential for robust development. By fostering rigorous scientific inquiry and collaborative research, we can unlock the vast potential of VSL, paving the way for groundbreaking discoveries and a deeper understanding of the universe.

Path Forward

The proposition of a Variable Speed of Light (VSL) is an exciting and bold step that challenges the boundaries of our current understanding. While it requires substantial empirical support and theoretical refinement, VSL opens a pathway to potentially transformative insights in physics. By fostering rigorous scientific inquiry and collaborative research across physic, cosmology, and astrophysics, we can unlock the vast potential of VSL. This endeavor could not only validate the Principle but also lead to a deeper understanding of the universe, potentially unifying disparate aspects of modern physic into a more comprehensive framework.