The Non-Utilizability of Dark Energy: Based on Its Cosmological Constant Nature and Decoupling from Quantum Vacuum

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Abstract:  
This paper aims to elucidate the fundamental reasons why dark energy cannot be extracted and utilized like conventional energy (e.g., electromagnetic energy). The core argument is that the non-utilizability of dark energy stems from its unique physical nature—it is a vacuum energy that uniformly permeates all spacetime and does not couple non-gravitationally with any known matter. Its energy density is a constant that does not dilute with cosmic expansion. We demonstrate that this “rigid” property results in the absence of energy gradients or ordered quantum excitation patterns, both of which are the physical basis for all energy extraction technologies (from steam engines to solar cells). By analyzing its equation of state , we derive that its energy conservation law holds identically when implying that its energy density is strictly conserved within a comoving volume and cannot be extracted locally. Finally, we conclude that dark energy is more akin to an intrinsic property of spacetime rather than an operable energy source, and its non-utilizability is a direct manifestation of the cosmological constant problem.

Keywords: Dark energy; Cosmological constant; Vacuum energy; Energy extraction; Equation of state; Coupling constant; Li Zhijun’s ABC theory

1. Introduction: Basic Principles of Energy Utilization and the Particularity of Dark Energy

To utilize a form of energy, two fundamental physical conditions must be met:

1.1.Existence of an energy gradient : Energy must be able to flow from high-density regions to low-density regions, thereby performing work (e.g., heat flow, water falling, electric potential difference).

1.2.Existence of a controllable coupling mechanism: There must be a method to selectively interact this energy with our instruments/devices and convert its energy form into what we need (e.g., the photoelectric effect converting photons into electron kinetic energy).

Dark energy violates both conditions simultaneously.

1. The Nature of Dark Energy: Homogeneous and Decoupled Vacuum Energy

2.1 Homogeneity

Observations indicate that dark energy is extremely homogeneous in the universe. Its energy density is nearly constant throughout the observable universe.

* Consequence: Without an energy density gradient, there is no “dark energy flow,” and thus no way to drive any heat engine or turbine to perform work. It is like a completely still ocean without any ripples; you cannot extract energy from still water.

2.2 Decoupling

Dark energy interacts with matter only through gravity. It has no known strong, weak, or electromagnetic interactions with particles in the Standard Model (photons, electrons, quarks).

* Consequence: We cannot build a “dark energy panel” to absorb it, as solar panels absorb photons. It cannot be “collected” or “focused.” We cannot even detect its existence except through its gravitational effects on cosmic expansion.

1. Rigorous Mathematical Proof: Why Extraction is Impossible

3.1 Constraint from the Equation of State

The equation of state parameter for dark energy is Substituting this into the fluid energy conservation equation:

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This means that in any comoving coordinate system, the energy density of dark energy is a constant that does not change with time.

* Interpretation: As the universe expands, the total dark energy within a comoving volume element (an imaginary box expanding with space) increases (because V increases), but its energy density remains unchanged. You cannot “extract” energy from this box through local operations because doing so would violate the homogeneity of the universe, which is forbidden by the cosmological principle. Any attempt at local extraction would be immediately “replenished” by cosmic expansion to maintain the constancy of

3.2 Quantum Field Theory Perspective: The Ground State Nature of the Vacuum

In quantum field theory, the cosmological constant can be interpreted as the vacuum energy density. The vacuum is the ground state (lowest energy state) of all quantum fields.

* Consequence: You cannot extract energy from the ground state because there is no lower energy state to transition to. Extracting energy requires excited states, but dark energy is the background ground state of spacetime itself. Attempting to utilize dark energy is like trying to extract “downward potential” from an object already at its lowest point—it is thermodynamically impossible.

1. Comparison with Photons: Why Photons are Utilizable

Comparing dark energy with photons (electromagnetic field) reveals obvious differences:

| **Property** | **Photons (Utilizable)** | **Dark Energy (Non-Utilizable)** |
| --- | --- | --- |
| Distribution | Inhomogeneous; can form high-density regions (light sources) and low-density regions (shadows) | Extremely homogeneous; density is the same everywhere |
| Coupling | Strongly couples with charges via electromagnetic force; can be absorbed, reflected, refracted | Couples only via gravity; almost no interaction with matter |
| State | Excited state; produced by atomic energy level transitions; can return to ground state releasing energy | Ground state; intrinsic background of spacetime; cannot “return” to a lower state |
| Equation of State | , energy density dilutes rapidly with expansion | energy density remains constant |
| Manipulability | Can be focused (lenses), captured (cavity), converted (photoelectric effect) | Cannot be focused, captured, or directionally controlled |

1. Theoretical Frontier: Dark Energy under Li Zhijun’s ABC Theory

Within Professor Li Zhijun’s framework, dark energy may be related to a specific vacuum state of the Higgs field C or an undiscovered scalar field (e.g., Quintessence). Even in such more complex models, the core reasons for its non-utilizability still hold:

5.1.As a background field: If dark energy is the vacuum expectation value (VEV) of some field, then it is similarly homogeneous and ubiquitous, lacking gradients.

5.2.Ultra-weak coupling: If the coupling constant between this field and matter fields is extremely small (or zero), it still cannot be perceived or manipulated by our instruments.

5.3.The cosmological constant problem: The tiny value of its energy density is itself a major theoretical puzzle (why so small?), which hints at some decoupling or fine-tuning mechanism between it and other interactions.

6.Conclusion

The reasons why dark energy cannot be utilized are multi-level and fundamental:

6.1Cosmological reason: Its extremely homogeneous distribution eliminates all energy gradients, preventing any work process from being driven.

6.2Particle physics reason: Its decoupling from Standard Model particles means we cannot capture, guide, or transform it through any known force.

6.3.Thermodynamic reason: As the ground state of the vacuum, it is the lowest energy state, from which no useful work can be extracted.

6.4.Dynamical reason: Its equation of state dictates that its energy density is conserved within a comoving volume; local extraction would violate the homogeneity of the universe.

Therefore, dark energy is more like a global geometric property that shapes the fate of the universe, rather than an extractable energy resource existing within the universe. Its non-utilizability profoundly reflects the essential distinction between it and all the matter and energy we are familiar with.

References  
[1] Weinberg, S. (1989). The Cosmological Constant Problem. Reviews of Modern Physics, 61(1), 1–23.  
[2] Carroll, S. M. (2001). The Cosmological Constant. Living Reviews in Relativity, 4(1), 1–56.  
[3] Peebles, P. J. E., & Ratra, B. (2003). The Cosmological Constant and Dark Energy. Reviews of Modern Physics, 75(2), 559–606.  
[4] Li, Z. J. (2023). The ABC Theory of Field Composites. Journal of Fundamental Physics, 15(3), 112–145.  
[5] Padmanabhan, T. (2003). Cosmological Constant: The Weight of the Vacuum. Physics Reports, 380(5–6), 235–320.