The Boundaries of the Physical Realm: On the Universality of Observability, Utilizability, and the Light-Speed Limit

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Abstract:  
This paper aims to define and explore the fundamental boundaries of the “physical realm.” The core thesis is that all phenomena and entities accessible to human cognition, observation, and utilization are strictly confined within a realm defined collectively by the particles of the Standard Model and General Relativity. The upper speed limit within this realm is the vacuum speed of light , and its energy carriers are the 61 known elementary particles (and their field composites). We demonstrate that any purported “particle” or “energon” claiming to transcend this realm, if it does not participate in the four known fundamental interactions (or couples to them with strictly zero strength), is—in principle—undetectable and unusable for observers within the “physical realm.” Its velocity limit also cannot be defined by . Such entities are essentially meta-physical. We further propose that the essence of the “observable universe” is the manifestation of the “physical realm” in spacetime. Any superluminal entity, if it exists, would necessarily lie beyond our event horizon, thus being eternally excluded from our physical reality. This paper ultimately delineates a clear operational boundary for physics and explores the possibility of investigating beyond this boundary.

Keywords: Physical realm; Observability; Light-speed limit; Standard Model; Superluminal motion; Dark matter; Dark energy; Meta-universe

1. Introduction: What is the “Physical Realm”?

The “physical realm” is not an a priori concept but an operational definition grounded in empirical observation and experimental verification. It is defined by the following elements:

1.1.Material basis: The 61 elementary particles of the Standard Model (quarks, leptons, gauge bosons, Higgs boson).

1.2.Interactions: The four fundamental forces: gravitation, electromagnetism, the strong force, and the weak force.

1.3.Spacetime background: The spacetime geometry described by General Relativity, whose local invariant speed is .

1.4.Quantum rules: The fundamental principles of quantum mechanics.

Any phenomenon, to be deemed “physical,” must be describable, predictable, and ultimately detectable and verifiable through experiments utilizing combinations of the above elements.

1. The Physical Attributes of Utilizable Energy

For a form of energy to be utilizable, it must satisfy two fundamental conditions, both of which anchor it firmly within the “physical realm”:

2.1Detectability (Interaction): It must be capable of exchanging energy-momentum with our detectors (composed of atoms and electrons) through non-gravitational means (as gravity is too weak). This implies it must have a non-zero coupling constant with the electromagnetic field, nuclear forces, or the weak force.

* + Examples: Photons (electromagnetic force), neutrons (strong force), neutrinos (weak force).
  + Counterexample: Dark Matter. We postulate its existence solely through its gravitational effects. However, its coupling to photons may be exceedingly weak or zero, rendering it impossible for us to “capture” a dark matter particle to perform work. For us within the “physical realm,” it is nearly unusable.

2.2.Localizability and Convertibility (Field Composites): Energy must be able to form localized field composites (particles), and these composites must be able to reconfigure (undergo reactions) to transform their energy into forms we require (e.g., thermal energy, electrical energy).

* + Dark Energy is a perfect counterexample: it does not form any localized field composites; it is diffuse and homogeneous, incapable of being focused, collected, or triggering any form of “dark energy reaction.” It is physically non-operable.

3. The Universality of the Light-Speed Limit and Its Boundaries

The limiting nature of the speed of light is not an isolated postulate but a cornerstone of the spacetime structure of the physical realm. It is a manifestation of Lorentz invariance, which is deeply woven into the mathematical frameworks of both the Standard Model and General Relativity.

* For any entity within the “physical realm”: Regardless of whether its rest mass is zero, the speed of propagation of its information, energy, or causal influence cannot exceed . This is an iron law of modern physics.

Now, consider the “non-physical realm particles or energons” you proposed. Let us assume its existence and assign it a property :

3.1.If has any non-gravitational coupling with the physical realm (even extremely weak): Then it becomes detectable. Once detected, it must be incorporated into our physical models, and its behavior (including speed) must obey Lorentz invariance, meaning its speed cannot exceed . Otherwise, it would lead to causality paradoxes, undermining the entire foundation of physics.

3.2.If the coupling between and the physical realm is strictly zero (i.e., completely decoupled): Then:

* + It is undetectable: We have no experimental means to perceive its existence.
  + It is unusable: It cannot transfer energy to our world.
  + Its speed is not defined by : Since it does not participate in our spacetime interactions, our spacetime rules (including ) do not constrain it. It could be considered superluminal, but this assertion is meaningless because “speed” itself is a concept relative to our reference frame, and a completely decoupled entity cannot be measured or defined by our reference frame.

Therefore, we conclude:

* All utilizable energy necessarily has a speed
* All entities with speed are necessarily unusable and likely undetectable.
* “Superluminal motion” and “usability within the physical realm” are mutually exclusive.

1. The “Observable Universe” as a Manifestation of the Physical Realm

The radius of the observable universe (approximately 46.5 billion light-years) is determined by the speed of light and the age of the universe. This means all information we can receive has propagated at speeds

* If a superluminal entity exists, it could, within the age of the universe, reach us from farther away. However, because it is superluminal, it cannot send information to us (information propagates at Thus, while it might exist within our “past light cone,” it would forever lie beyond our “event horizon.” We cannot perceive it; it has no causal connection to our physical reality.
* Consequently, the boundary of the observable universe is, in essence, the spacetime boundary of the “physical realm.” Beyond this boundary, existence may occur, but for us, it is equivalent to non-existence.

1. Theoretical and Philosophical Implications

5.1.The Self-Limitation of Physics: Physics is a science based on interaction. An entity completely devoid of interaction with our world is unspeakable in physical terms. Its existence or non-existence is physically indistinguishable.

5.2. The Implication of Dark Matter and Dark Energy: They reside precisely at the edge of the “physical realm.” Dark matter interacts weakly via gravity, and dark energy influences spacetime geometry through gravity. However, their non-gravitational couplings to the Standard Model are likely exceedingly weak. This makes them, while existent, nearly unusable, revealing the resource boundaries of the physical realm.

5.3. The Metaphor of the Meta-Universe: This concept is philosophically analogous to a “world” completely decoupled from our physical universe. Without information exchange between them, for the inhabitants of one world, the other does not exist (or is merely an object of philosophical speculation).

1. Conclusion

You have raised a profound argument concerning the fundamental nature of physics. We conclude that:

* Utilizability Detectability Physical Realm.
* The physical realm is defined collectively by the speed of light , the particles of the Standard Model, and their interactions.
* An entity whose speed exceeds must necessarily be decoupled from our physical realm, rendering it undetectable and unusable.
* The “observable universe” is the cosmological manifestation of the “physical realm.” Beyond its boundary lies, for physics, true nothingness.

Ultimately, physics is the science of what we can do and what we can know, not the science of all that might exist. The “universe” we discuss is always, necessarily, “our physical universe.”

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