

The Planck Distance

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Introduction

The Planck distance is traditionally defined as the smallest physically meaningful scale, below which classical notions of space and geometry cease to be valid. In directional geometry, this distance plays a fundamental role: it represents the minimal granularity of internal directions, meaning the smallest directional unit a domain can sustain.

In this framework, the Planck distance is not merely a theoretical limit arising from quantum physics; it becomes a **directional measure**, directly linked to a domain's ability to generate internal subdivisions. The central question is therefore:

Is the Planck distance truly the minimal granularity of the universe?

Directional geometry proposes a unique way to verify this hypothesis: **analyzing the directional saturation of a black hole**.

1. The Planck Distance as Minimal Directional Granularity

In directional theory, the minimal granularity δ represents the smallest internal distance between two distinct directions. If δ corresponds to the Planck distance, then:

$$\delta = l_p.$$

This granularity imposes an upper limit on directional density:

$$\rho_{\max} = \frac{1}{\delta}.$$

When this density is reached, no new internal direction can be added: the domain is saturated.

2. Verification Through Black Hole Saturation

A black hole is the geometric object with the highest density of internal directions. Its internal structure naturally reaches directional saturation:

$$\rho = \rho_{\max}.$$

If the Planck distance is truly the minimal granularity, then black hole saturation must occur **exactly** when directional density reaches:

$$\rho = \frac{1}{l_p}.$$

In other words:

The Planck distance is correct if the saturation of a black hole appears at the exact threshold where no new internal direction can be added.

If saturation appears before or after this threshold, then the Planck distance is not the correct directional granularity.

3. Why This Method Is Decisive

3.1. The Black Hole Pushes Geometry to Its Limit

It represents the domain where directional density is maximal.

3.2. Saturation Is a Measurable Directional Phenomenon

It manifests through:

- a minimal radius for a given mass,
- a maximal directional density,
- an impossibility of adding new internal directions.

3.3. The Planck Distance Becomes Testable

If saturation corresponds exactly to l_p , then l_p is the true granularity. If it does not, the real granularity is different.

4. Synthetic Formulation

A way to verify whether the Planck distance is the correct measure is to compute the saturation of a black hole. If saturation appears exactly at l_p , then l_p is the true granularity of the universe.

Chapter 1 — The Planck Distance as Minimal Directional Granularity

The Planck distance is traditionally defined as the scale at which classical descriptions of space cease to be valid. In directional geometry, this distance acquires a more fundamental interpretation: it represents the minimal directional granularity, meaning the smallest possible internal separation between two distinct directions within a geometric domain.

1.1. Directional Granularity

In a geometric domain S , the minimal directional granularity δ imposes a limit on internal subdivision. If two internal directions d and d' belong to the directional space $D(S)$, then:

$$\|d - d'\| \geq \delta.$$

This constraint means that there exists a directional distance below which no new direction can be defined. If δ corresponds to the Planck distance l_p , then:

$$\delta = l_p.$$

The Planck distance thus becomes the fundamental directional unit.

1.2. Maximum Directional Density

The minimal directional granularity imposes a maximum density:

$$\rho_{\max} = \frac{1}{\delta}.$$

When this density is reached, the domain is saturated: no new internal direction can be added, even if the domain attempts to increase its internal complexity.

If $\delta = l_p$, then:

$$\rho_{\max} = \frac{1}{l_p}.$$

The Planck distance becomes the absolute limit of directional density.

1.3. The Planck Distance as the Limit of Exponential Subdivision

In Exponential Division, each directional level is defined by:

$$|D_k| = |D_0|^k.$$

Directional density grows exponentially:

$$\rho_k = \frac{|D_k|}{\text{Vol}(S)}.$$

Saturation appears when:

$$\rho_k = \rho_{\max}.$$

If the Planck distance is the minimal granularity, then saturation must occur exactly when:

$$\frac{|D_0|^k}{\text{Vol}(S)} = \frac{1}{l_p}.$$

This point marks the ultimate limit of directional subdivision.

1.4. Why the Planck Distance Must Be Tested

The Planck distance is often presented as a fundamental constant, but no direct method exists to verify that it truly represents the smallest possible geometric unit. Directional geometry proposes a new approach:

Test the Planck distance by observing the directional saturation of a black hole.

If saturation appears exactly at l_p , then l_p is the real granularity of the universe. If saturation appears before or after, then the Planck distance is not the correct measure.

1.5. The Planck Distance as a Directional Hypothesis

In this framework, the Planck distance is not merely a theoretical limit from quantum physics; it becomes a **directional hypothesis**:

- it defines the minimal granularity,
- it sets the maximum directional density,
- it determines the saturation level,
- it influences the internal structure of black holes,
- it constrains directional growth in an expanding universe.

The remainder of the document will show how this hypothesis can be tested, validated, or refuted through the study of black hole directional saturation.

Chapter 2 — Directional Granularity and Quantum Physics

The Planck distance is generally presented as a limit arising from quantum physics, defined by the combination of fundamental constants: Planck's constant, the speed of light, and the gravitational constant. In directional geometry, this distance acquires a deeper meaning: it becomes the minimal directional granularity, the smallest internal unit that a domain's directional structure can distinguish.

This chapter establishes the link between directional granularity and the foundations of quantum physics, showing that the Planck distance can be interpreted as a limit of internal subdivision rather than a classical spatial limit.

2.1. The Planck Distance in Quantum Physics

The Planck distance is defined by:

$$l_p = \sqrt{\frac{\hbar G}{c^3}}.$$

It represents the scale at which quantum gravitational effects become significant. In standard physics, this distance is considered the smallest measurable length, below which classical notions of space lose their meaning.

However, this definition relies on external physical constants, not on an internal structure of space. Directional geometry proposes a complementary interpretation.

2.2. Directional Granularity as Internal Structure

In directional geometry, the minimal granularity δ is not a spatial length but an **internal directional distance**. It imposes a limit on the subdivision of internal directions:

$$\|d - d'\| \geq \delta.$$

If $\delta = l_p$, then the Planck distance becomes the smallest internal separation between two distinct directions.

This granularity is not imposed by matter or physical fields, but by the directional structure itself.

2.3. Exponential Subdivision and Quantum Limit

Exponential Division generates internal directions according to:

$$|D_k| = |D_0|^k.$$

Directional density grows exponentially:

$$\rho_k = \frac{|D_k|}{\text{Vol}(S)}.$$

Saturation appears when:

$$\rho_k = \frac{1}{\delta}.$$

If $\delta = l_p$, then the Planck distance becomes the ultimate limit of exponential subdivision. In other words:

The Planck distance is the limit at which internal geometry can no longer subdivide.

This interpretation directly links quantum physics to internal directional structure.

2.4. The Planck Distance as a Threshold of Directional Coherence

When directional granularity reaches the Planck distance, the internal structure becomes incompressible. No new direction can be added without violating directional coherence.

This phenomenon corresponds to a transition:

- before l_p , exponential subdivision is possible;
- at l_p , subdivision stops;
- beyond l_p , the internal structure is saturated.

The Planck distance thus becomes a **threshold of directional coherence**, analogous to an internal quantum limit.

2.5. Directional Interpretation of Quantum Physics

Quantum physics imposes limits of precision, localization, and measurement. Directional geometry offers a complementary interpretation:

- quantum limits emerge from minimal directional granularity;
- the Planck distance is the smallest directional unit;
- quantum phenomena reflect the internal structure of space rather than external fluctuations.

In this framework, the Planck distance is not merely a measurement limit: it is a structural property of directional space.

2.6. Toward a Directional Unification

By linking the Planck distance to directional granularity, directional geometry provides a conceptual bridge between:

- quantum physics,
- internal geometry,
- black hole structure,
- and exponential directional growth.

This unification allows the Planck distance to be reformulated as a fundamental geometric property, testable through black hole directional saturation.

Chapter 3 — The Planck Distance as the Limit of Exponential Subdivision

Exponential Division generates a hierarchy of internal directions whose cardinality grows exponentially. This growth cannot continue indefinitely: it is constrained by the minimal directional granularity δ . If this granularity corresponds to the Planck distance, then the Planck distance becomes the absolute limit of internal subdivision. This chapter demonstrates how this limit naturally emerges within directional structure.

3.1. Exponential Growth of Internal Directions

Exponential Division produces directional sets according to the relation:

$$|D_k| = |D_0|^k.$$

Each directional level D_k represents a higher order of internal complexity. The associated directional density is:

$$\rho_k = \frac{|D_k|}{\text{Vol}(S)}.$$

This density increases exponentially, independently of the geometric volume of the domain.

3.2. Emergence of the Directional Limit

The minimal directional granularity δ imposes a maximum density:

$$\rho_{\max} = \frac{1}{\delta}.$$

When directional density reaches this value, no new internal direction can be added. The directional hierarchy stops growing: the domain is saturated.

If $\delta = l_p$, then:

$$\rho_{\max} = \frac{1}{l_p}.$$

The Planck distance becomes the ultimate limit of exponential subdivision.

3.3. Saturation Condition and the Planck Distance

Saturation appears when:

$$\rho_k = \rho_{\max}.$$

Substituting the expressions for ρ_k and $\rho_{\max}$, we obtain:

$$\frac{|D_0|^k}{\text{Vol}(S)} = \frac{1}{l_p}.$$

This equation allows the determination of the maximal subdivision level:

$$k_{\max} = \left\lfloor \log_{|D_0|} \left(\frac{\text{Vol}(S)}{l_p} \right) \right\rfloor.$$

Thus, the Planck distance sets the maximal level of the directional hierarchy.

3.4. Geometric Interpretation

When exponential subdivision reaches the Planck distance:

- the internal directional space is completely filled,
- no new direction can be generated,
- the internal structure becomes incompressible,
- the directional hierarchy reaches its maximal level.

The Planck distance therefore marks the transition between:

- a phase of exponential growth,
- a phase of directional stability.

It constitutes the boundary between a subdivisible domain and a saturated domain.

3.5. The Planck Distance as a Threshold of Internal Coherence

At the Planck distance, directional coherence reaches its maximum:

- internal directions are separated by the smallest possible distance,
- the internal structure can no longer be refined,
- any attempt at further subdivision would violate minimal granularity.

The Planck distance thus becomes a threshold of directional coherence, analogous to an internal quantum limit.

3.6. Consequences for Directional Physics

If the Planck distance is truly the minimal granularity:

- exponential subdivision is bounded by l_p ,
- directional saturation is a real physical phenomenon,

- black holes reach their maximal density at l_p ,
- an expanding universe generates directional levels up to this threshold.

The Planck distance therefore becomes a structural property of space, not merely a constant derived from quantum physics.

Chapter 4 — Directional Evidence from Black Holes

Black holes represent the most extreme geometric objects in the universe. Their internal structure naturally reaches maximal directional density, making them ideal candidates for testing minimal directional granularity. If the Planck distance truly constitutes the smallest possible directional unit, then black hole saturation must occur exactly at this scale. This chapter demonstrates why black holes are the most direct means of verifying the validity of the Planck distance.

4.1. The Black Hole as a Saturated Domain

A black hole can be modeled as a compact geometric domain S whose internal directional density has reached its maximal value:

$$\rho_{\max} = \frac{1}{\delta}.$$

If $\delta = l_p$, then:

$$\rho_{\max} = \frac{1}{l_p}.$$

In this state, the internal directional set satisfies:

$$|D_{k_{\max}}| = |D_0|^{k_{\max}},$$

and no new direction can be added without violating minimal granularity. The black hole thus represents a saturated directional space, where the directional hierarchy has reached its maximal level.

4.2. Matter Absorption and Directional Desaturation

When a black hole absorbs matter or energy, its internal volume increases:

$$\text{Vol}(S) \rightarrow \text{Vol}(S) + \Delta V.$$

This increase causes a temporary decrease in directional density:

$$\rho = \frac{|D_{k_{\max}}|}{\text{Vol}(S) + \Delta V} < \rho_{\max}.$$

The black hole is no longer saturated. A directional margin appears, allowing new internal directions to be added.

4.3. Directional Reconstitution

To regain its saturated state, the black hole must generate new directions through Exponential Division:

$$D_{k_{\max}+1} = \bigcup_{d \in D_{k_{\max}}} \Delta(d).$$

The internal directional structure reorganizes to fill the newly available space. This process continues until:

$$\rho = \rho_{\max}.$$

Saturation is restored, but at a higher directional level.

4.4. Expansion of the Black Hole Radius

Internal directional reconstitution leads to an increase in the black hole's radius:

$$R \rightarrow R' > R.$$

This expansion is the direct consequence of the need to maintain maximal directional density in a domain whose volume has increased.

Thus, black hole growth can be interpreted as a **directional compensation mechanism**:

- matter absorption $\rightarrow$ increased volume,
- decreased directional density,
- generation of new directions,
- increased radius to restore saturation.

4.5. The Planck Distance as a Saturation Threshold

If the Planck distance is the minimal granularity, then black hole saturation must occur exactly when:

$$\rho = \frac{1}{l_p}.$$

In other words:

The Planck distance is correct if the directional saturation of a black hole appears at the exact threshold where no new internal direction can be added.

If saturation appears before or after this threshold, then the Planck distance is not the correct directional granularity.

4.6. Why Black Holes Are the Ultimate Test

Black holes are the only physical objects that:

- naturally reach maximal directional density,
- push internal geometry to its limit,
- reveal the minimal granularity of space,
- allow directional saturation to be measured.

They therefore constitute a cosmic instrument for verifying the Planck distance.

4.7. Theoretical Consequences

If the Planck distance is confirmed through black hole saturation:

- minimal directional granularity is validated,
- the internal structure of space is quantified,
- Exponential Division has a real physical limit,
- directional geometry becomes an experimental model,
- quantum physics and internal geometry converge.

If it is refuted, then the real granularity of the universe is different, and the Planck distance must be reevaluated.

Conclusion

The study of the Planck distance within the framework of directional geometry reveals an internal structure of space far richer than what classical models describe. The Planck distance no longer appears merely as an abstract quantum limit, but as the **minimal directional granularity**, meaning the smallest internal unit that a domain's directional structure can distinguish.

Exponential Division shows that the internal complexity of a domain grows exponentially, independently of its geometric volume. However, this growth is bounded by minimal granularity: when directional density reaches the maximal value imposed by δ , the internal structure becomes saturated. If $\delta = l_p$, then the Planck distance constitutes the ultimate limit of directional subdivision.

Black holes offer a unique way to test this hypothesis. Their internal structure naturally reaches directional saturation, and their growth results directly from the need to restore maximal density after an increase in volume. If saturation appears exactly at the threshold set by the Planck distance, then l_p is confirmed as the real granularity of the universe. If it appears before or after, directional granularity must be reevaluated.

In an expanding universe, directional desaturation occurs continuously, reactivating Exponential Division and generating new directional levels. The Planck distance then becomes the boundary between subdivisible domains and saturated domains, playing a central role in the universe's internal dynamics.

Taken together, these results show that the Planck distance is a fundamental geometric concept, directly linked to the internal directional structure of space. It makes it possible to formalize the relationship between granularity, saturation, exponential growth, and extreme phenomena such as black holes. This approach opens the way to a profound reformulation of fundamental physics, in which directional geometry becomes a conceptual framework capable of describing the internal structure of the universe at all scales.